JOINT PROCEEDINGS

TROPICAL REGION

21st Annual Meeting of the Caribbean Food Crops Society and 32nd Annual Meeting of the American Society for Horticultural Science — Tropical Region

technology for agricultural development

Hilton Hotel, Port of Spain, Trinidad
8 - 13 September 1985

Host Institutions

— Caribbean Agricultural Research and Development Institute

— Ministry of Agriculture, Lands and Food Production, Trinidad & Tobago

— Faculty of Agriculture, University of the West Indies

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PREFACE

St Clair Forde
President, CFCS

The 21st Annual Meeting of the Caribbean Food Crops Society which was held jointly with the 32nd Annual Meeting of the American Society of Horticultural Science (Tropical Region) attracted around 230 participants, mainly from North and South America and the Caribbean.

The Keynote Address given by Dr Martín Piñeiro, who at that time was Research Co-ordinator at the Centro de Investigactiones Sociales Sobre El Estado y la Administration in Argentina and is now Director General of the Inter-American Institute for Cooperation in Agriculture (IICA). His informative paper on "Innovation and Agricultural Development: Some Issues on Research Policy" is recorded in these Proceedings.

The technical sessions began with a panel discussion on "Appropriate Technology for Agricultural Development in the Caribbean Region" Members of the head table were: Dr Tom Henderson (Caribbean Agricultural Extension Project), Dr Collin Weir (Lincoln University, USA), Mr Ronald Baynes (Barclays Bank International, Barbados) and Dr H. K. Wutscher (US Department of Agriculture) and Dr Darshan Padda (College of the Virgin Islands).

Over 60 papers were presented covering such topics as vegetable crops, root crops, fruits, ornamentals, cereals and grains, post-harvest techniques, soil fertility and plant nutrition, farming systems, agricultural development and pest and disease control. These papers form the main part of these Proceedings. Most of the papers are in English with a Spanish Abstract; the few that are in Spanish or French carry an English Abstract. Since these are Joint Proceedings, papers are not uniform in presentation; they follow the two different formats required by the two Societies.

On Wednesday there was an all-day excursion when participants visited the Caroni (1975) Ltd Research Station, the Sugarcane Feed Centre, the Ministry of Agriculture's Experimental Station and two farmers at the Waller Field area in northwest Trinidad. There were also special-interest field trips to see The University of the West Indies Field Station; the Commonwealth Institute of Biological Control; and modern under-cover vegetable production technology in the Santa Cruz Valley.

The preparation and organization of a meeting of such dimensions obviously took a good deal of time and effort. I wish to express my sincere thanks especially to the Organizing Committees but also to other groups, firms and organizations who contributed in making this 21st Meeting the success it undoubtedly turned out to be.

INNOVATION AND AGRICULTURAL DEVELOPMENT: SOME ISSUES ON RESEARCH POLICY

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I. INTRODUCTION

Science and technology became, after World War II, a major force behind economic and social change. More than any other element such as natural resources or economic policy, technological innovation determines the capacity to produce, the productivity of resources and the competitiveness in international markets. This last element is of fundamental importance in the case of smaller countries that must develop with relatively open economies and consequently depend upon their competitiveness for their economic survival.

The profound changes that have taken place both in the institutional setting in which technology is produced and diffused into the production system, and the economic transformations brought about by the resulting agricultural modernization, have also brought new situations and new issues in the discussion of research policy.

This paper attempts to discuss some of these issues and their significance for the definition of a research policy.

The paper has three parts in addition to this introduction. The second part presents an overview of recent institutional and technological developments that have taken place in the region. The third section discusses some major issues that emerge from these developments and suggests their main implications in relation ot an effective research policy. Finally, the fourth and last section attempts to draw some general conclusions.

II. AN OVERVIEW OF RECENT DEVELOPMENTS IN LATIN AMERICA AND THE CARIBBEAN COUNTRIES

During the last two decades the Latin American and Caribbean regions have experienced significant changes in agricultural production and institutions. The creation, and in many cases rapid growth, of research institutions were accompanied by an heterogeneous but rapid and significant process of agricultural modernization that changed quite substantially the structure of production and trade.

The intensity of this process, as well as its qualitative characteristics, must be carefully taken into consideration in the definition of an effective research policy. In particular, there are three main elements that I would like to emphasize because of their special importance.

1. The development of research institutions

Two well-defined stages mark the institutional development of agricultural technology generation and transfer in Latin America, particularly in South American countries: the extent of research efforts and the degree and forms of public research institutions. The first stage lasted from the early 19th century, when research was just beginning, until the middle 1950s; during this period research activity was both erratic and unsophisticated.

The first experimental stations aimed at the generation and/or transfer of new technological knowledge were established in the early 1930s and were more clearly defined in the following decade. The situation however, remained unstable due to frequent changes in their administrative affiliation and, hence, in their financing. The universities and agricultural schools, which played an important role in the early part of this century, progressively lost power to the institutes or departments that depended directly on the agricultural ministries. Eventually, research activities were almost entirely centralized in the ministries.

This institutional model was plagued by deficiencies resulting from the ministries' organizational characteristics. The most important deficiencies were: the lack of stable financial support; poor linkage to the problems and priorities of producers; undirected efforts; inadequate communication between researchers, on the one hand, and technical assistance and extension agents, on the other; and finally, the lack of coordination between technology-generating institutions and those that determine agricultural policy for the effective development of the productive process (prices, credits, services and others) (Trigo *et al.*, Chap. 7, Samper, A., 1979).

The second stage started in the mid-fifties when a set of new elements substantially changed the situation: decentralized institutes with autonomous administrations based on the experience in the United States (The Experiment Station System) were created.

The new institutional model was based on two central ideas: a) the realization that the main element in agricultural development was the adoption of technology; and b) the conviction that a wide range of technology, useful to the Latin American producer, was available internationally. Accordingly, the main goal was to ensure the transfer of technology from developed to under-developed countries. To make this possible, infrastructures geared to adaptive research linking receiver countries with research centers

were needed; research offices of the agricultural ministries were not up to the task. This objective had solid financial and technical support from international sources which made possible the building of facilities and the training of research personnel for the new institutes.

From this process emerged: the National Institute of Agricultural Technology (INTA) of Argentina in 1957; the National Institute of Agricultural Research (INIAP) of Ecuador in 1959; the complex made up by the National Council of Agricultural Research and the National Fund for Agricultural Research (CONIA–FONAIAP) in Venezuela between 1959 and 1961; the National Institute of Agriucltural Research (INIA) in Mexico in 1960; the Agricultural Research and Promotion Service (SIPA) in Peru; the Colombian Agricultural Institute (ICA) in 1963; and the Agricultural Research Institute (INIA) in Chile in 1964. All followed the same general model in which the legal administrative nature is a decentralized, autonomous, public entity that carries out research and transfer activities.1/

The institutional model, though decentralized and autonomous, covers a wide range of products, regions and producer types. They also responded to the view that agricultural technology is a public responsibility implying that public institutions must play an important role.

The technological infrastructure's trend toward modernization can also be seen in other situations where no new organisms were created. In Uruguay's Alberto Boerger Agricultural Research Center (CIAAB), though direct affiliation to the Ministry was maintained, profound operational modifications were introduced which affected technology generation and transfer as well as training, when postgraduate study was included in the Center for Temperate Zone Research and Study, created through the sponsorship of the Interamerican Institute of Cooperation in Agriculture (IICA) in the early 1960s.

Brazil's is an atypical situation. The 1960s brought only slight changes but, in 1973, the Brazilian Corporation for Agricultural Research (EMBRAPA) was created. This organism has certain characteristics that differentiate it from the other institutes mentioned, such as that it does not carry out extension, an activity which was assigned to a twin organism, the Brazilian Corporation for Technical Assistance and Rural Extension (EMBRATER). Most important is the explicit acknowledgement of the need for a multi-organizational institutional model, which includes various public sector administrative levels (national and state) as well as the private sector; priorities and objectives are coordinated by EMBRAPA. For this reason EMBRAPA can be considered an extension of the 1960 institutional model, or a new model which modifies the role of the State and the relationship between the public and private sectors.

From 1960 on, there was a vigorous expansion of research and technology transfer activities based on this institutional model and on growing financial support by international and national sources. The expansion process consisted of field work (the creation of new experiment stations and extension agency networks) and the initiation of extensive training programs for the personnel of the institutes, which led to the development of national infrastructures for postgraduate training in Argentina, Brazil, Colombia, Mexico, Peru and Uruguay.

Other exceptions to the organizational model exist in El Salvador, Honduras and Paraguay, and in the English-speaking countries of the Caribbean. In the first three countries, research has remained a relatively centralized activity under the Ministry of Agriculture. A similar situation exists in the Caribbean countries, though their special relationship to Great Britian and the strong ties that some have developed among themselves make for an important difference. Caribbean countries rely on the University of the West Indies and a regional organization (CARDI) which, together, carry out the vast majority of the area's research activities.

2. Technological cycles in agriculture

Technical change in the agricultural sector requires a rather complex process by which knowledge, human behavior and improved inputs merge in a productive way, resulting in an increase in the productivity of natural resources and human labor.

The first two have been to a great extent assumed to be the responsibility of the public sector which, through research organizations and extension activities, has tried to promote technical change. It is probably obvious that in the case of agronomic practices specially adapted to relatively simple agriculture these two elements are the basis for achieving increases in factor productivity. However, as agriculture becomes more sophisticated, a large proportion of the new technological innovations will be embodied in industrial inputs which require a progressively more sophisticated industrial base as well as distribution and financing mechanisms. Thus in market economies where the state in general does not participate directly in the production of goods, technical change progressively depends on the development of the industrial and services sectors.

Recent works1/ suggest that at least in Latin America technical change in agriculture shows innovative cycles where each cycle is characterized by a dominant technology. In addition, the emergence and sequential nature of some of these cycles seem to be partially explained by the development of industrial sectors which follow a certain logic within the process of capital accumulation in the overall economy. This process has special characteristics in each country and consequently the sequence of some of the cycles and their length will not necessarily be always the same. For example in Argentina and Brazil, although a similar pattern can be observed, fertilizers become important at different moments of the modernization process.

1/ Similar institutions were later created in Panama, Bolivia and Guatemala.

1/ Piñeiro, M.; Da Silva, J.G.

In spite of these differences and for the purpose of this paper it is possible to present a description of the general characteristics and sequential order of technical cycles in Latin America.

Figure 1 presents the sequential nature of the cycles and the dominant technology in each one of them. The general timing corresponds, in a general way, to the more developed agriculture in Latin America generally coincident with the temperate regions.

The first stage is characterized by the diffusion of improved agronomic practices, many of them introduced from abroad, while others were developed by local research institutions and the farmers themselves. It is important to note that, because of the disembodied nature of these technologies, it is virtually impossible for those who create and diffuse these technologies to capture the benefits derived from them. Consequently, the public sector was the main source for the development and adaptation of these innovations. The weakness of public research institutions before the sixties probably explains the modest impact of these technologies and consequently the relative stagnation of agriculture production before the sixties.

The second stage is characterized by the diffusion of a number of powerful technologies that share the main characteristics of being of the embodied type. They are mechanization, improved seeds and agrochemicals. The order in which these technologies are incorporated into production depends on a number of factors. Mechanization and fertilization will be strongly affected by factor endowment and relative prices. For this reason they were rapidly adopted only under certain production conditions. On the other hand improved seeds, which require substantial research work for their adaptation to each specific ecological condition, required for their development the existence of a minimum research infrastructure in the country. Finally, the diffusion of pesticides and herbicides was closely associated to the previous diffusion of highly productive varieties and to some extent to the late development of the more specific and effective agrochemicals in the developed world and to the development of a minmum industrial and distribution infrastructure in the developing countries.1/

The dominant element in this sequence of technical change is the growing importance of technologies of the embodied type. Their diffusion will bring, in market economies, the development of the private sector willing and able to capture the benefits obtainable from the production and distribution of these technologies.

Finally, it is also important to note that, as indicated in Figure 1, the more recent scientific discoveries in the general area of biotechnology could suggest the possible emergence of a third technological stage or cycle characterized by the utilization of research techniques that could radically alter the way in which research is done and in the productivity of agricultural technologies. This third cycle will also intensify the need for more sophisticated and complex research.

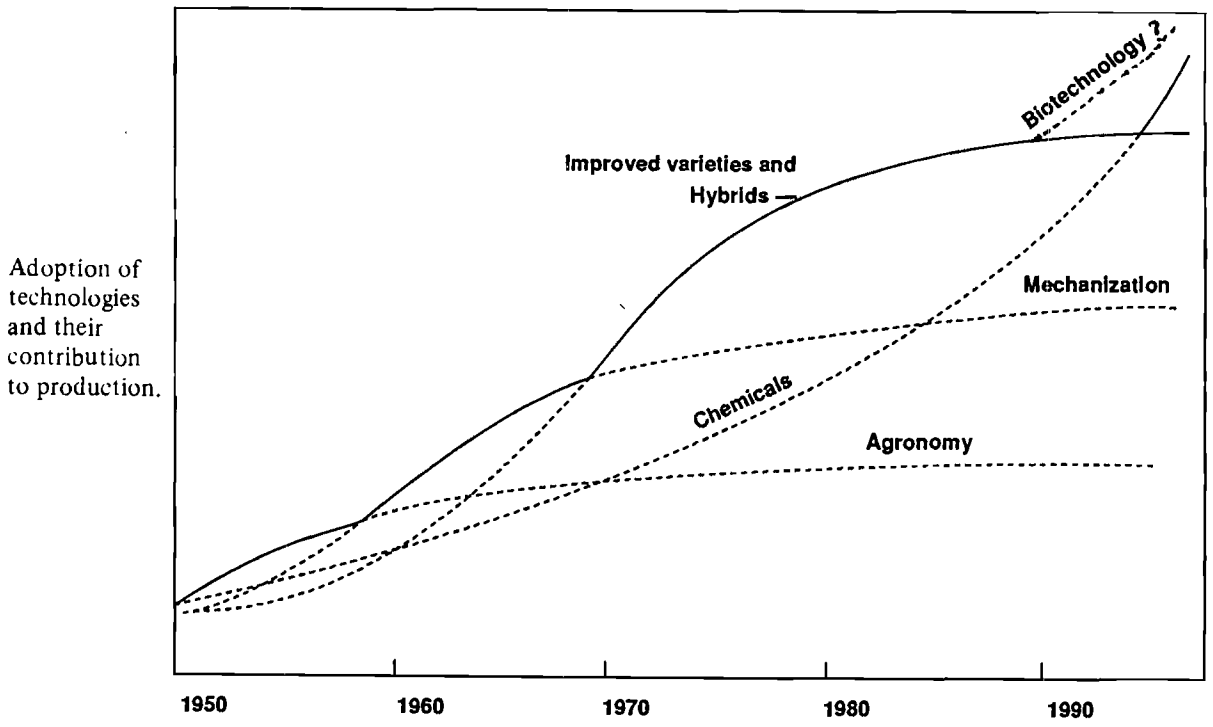

Fig. 1 Technological Cycles

1/ For a more detailed description of cycles see Piñeiro, May 1984.

3. The nature of the modernization

Although the modernization process experienced during the last two decades was significant and had an important effect in total food production and regional trade flows, it was quite uneven between regions, crops and to some extent types of farming.

A major part of modernization was associated either with cereals cultivated in temperate regions under similar ecological conditions to those in the industrialized countries or to tropical crops like sugarcane where international transfer of technology has been strong and effective. A large number of food crops of relatively less importance on a worldwide scale, but important to special regions in Latin America, has not experienced substantive productivity changes.

Modernization has not been exclusively a large farm phenomenon. There are a number of cases where small farms were able to adopt new technology and initiate processes of capital accumulation. However, in general small farming has benefited less from technical changes which had the overall effect of increasing land concentration and vertical integration and a negative impact on income distribution.1/

This is an important theme because technological innovation is a major economic force and our countries must utilize it at its full potential. However, at the same time it is necessary to take additional measures to insure that the costs of modernization are shared in an equitable manner by society as a whole and not by those social groups that have the least capacity to protect themselves.

These actions are mainly related to two things. First, the type of research that receives high priority: which regions, crops and major problems are given the highest research priority determine, to a certain extent, who benefits from them. Secondly development projects, retraining of labor and other similar measures are important policy actions that can be taken to alleviate and socialize the costs associated with agricultural modernization.

III. SOME ISSUES FOR THE EIGHTIES

Agricultural modernization has implied a number of important changes in the general research environment and the emergence of new and important issues in research policy. I would like to present and discuss a few of them that I consider of particular importance. Although the discussion is strongly based on the past experience of some of the larger Latin American countries I have tried, when possible, to make special reference to the specific conditons of the Caribbean region.

1. The growing complexity of technology and the need for basic science

One consequence of the modernization process is the growing importance of basic research as the source of information for creating new technologies. This affects the organization of national research programs.

The national institutes were created with the main purpose of developing technology that has been adapted to the particular conditions of their own countries. This process was to be based on industrialized countries' technology and on basic research available in their public sectors (mainly in the universities). One result of this objective was that the institutes were, at least in the spirit of the law of their creation, restricted as to basic research activities. At the same time, the autonomous nature of the institutes, their affiliation to the ministries of agriculture, and their great size compared to other research institutions, resulted in their developing quite independently from the rest of the national scientific and technical system.

While the institutes were in their growing and expansion stage and their dominant activity was the adaptation of existing technology, this situation did not alter their effectiveness. As technology has become more complex and more dependent on scientific knowledge, the isolation of the national scientific system and its weaknesses have limited the institution's efficiency in its specific task of generating technology.

On the other hand, the growing pre-eminence of complex technologies and their strong dependence on basic science have created conditions for the accelerated development of the private transnational sector; access to technological information in industrialized countries and in certain economies of scale is a basic factor in the ability to compete in the technological input market.

These conditions create new problems for less developed countries. The risk is no longer just the importation of technology that cannot be adapted to their needs. The central problem is the possibility (not immediate but nevertheless real) that, because of commercial practices or international conflicts, a country might not have access to the basic information necessary for developing its own technology. This vulnerability points up the need for a basic science infrastructure that can interact with and replace the international scientific system should the need arise. The infrastructure should be part of the institutes or closely linked to them.

2. New roles for the public sector: the production and distribution of technological inputs

The growing importance of embodied technologies in the innovative process creates the need for the development of an industrial and services sector capable of producing, and/or importing and distributing, the wide array of technological inputs associated with agricultural modernization.

1/ For a discussion of this topic see Piñeiro and Trigo.

It is usually argued that in market economies the private sector will invest in those areas where new needs generate opportunities for private profits. This view is specially congruent with ideas now quite popular in Latin America regarding the existence of an overgrown government bureaucracy and the convenience of relying on the private sector for the provision of all goods and services which are socially needed.

While analyzing this view it is important to review the historical evidence regarding the overwhelming role that the public sector has played in most or all successful cases of economic development in Latin America. The point is that underdevelopment is characterized by a weak private sector, dominated by small business firms with low production technology and limited capacity to enter into high technology production areas. In many cases government is the only organization with sufficient economic and human resources and organizational dimension to be able to start the production and distribution of technological inputs.

For this reason it is likely that in many cases, specially in small countries and/or small markets, a sustained modernization process will require an active role of government organizations in the production and distribution of technological inputs. This role might be temporary and complementary to the activities developed by the private sector, which in the end may become the main or only source for these inputs.

In most cases if the government is to play this role it will be necessary to create new organizations and institutional mechanisms specially adapted for these activities and with special linkages with public research institutions for which they will depend for the provision of the necessary knowledge. It is through these linkages that the whole innovative process will be integrated into one institutional system.

3. Organizational implications for public research

We have argued that as agricultural modernization progresses, and specially as a consequence of the emergence of the private sector as a major source of agricultural technology, the roles of public research institutions must evolve. The general direction of this evolution is to move towards more upstream research activities and more specialized and selective research topics which have a natural complementarity with the applied research emphasized by the private sector.

This likely and desirable evolution of public research has a number of important organizational consequences derived from the fact that different research activities have some very distinct organizational requirements. Some of the more important are discussed below.

Adaptative research characteristic of the early stages of agricultural moderization is dominated by very practical research in agronomy and related fields. This research is best adapted to the work of individual researchers or at best small groups of researchers. It must be highly decentralized and close to real production problems and does not require elaborate and sophisticated programming mechanisms neither to select research priorities nor to organize the allocation of resources. As the focus of research institutions moves to applied research including the development of technologies and products (seeds), the organization of research becomes more complex. Here the concept of multidisciplinary teams organized around well defined projects or programs and with a minimum critical mass becomes of fundamental importance. 1/ Similarly, the selection of competitive research objectives makes it necessary to develop more sophisticated programming mechanisms to allow a rational and orderly allocation of resources.

Upstream research is more removed from the productive system and consequently not always it is possible to relate it to clearly enunciated objectives. It cannot be rigidly planned because results will tend to be less predictable and the very nature of the activity requires a flexible and loose organization that permits the continual redirection of research, adjusting it to results and the intuition and hunches of the researcher. For this same reason research results are more related to the imagination and perception of individual researchers than to the integrated and persistent work of interdisciplinary teams. For this reason upstream research will require an organization that follows more closely disciplinary lines that do not require large and solidly structured teams or departments, but it does require an intellectual environment that provides for permanent and flexible mechanisms for consultation and discussion of ideas and hypotheses with colleagues.

These and other organizational elements will have to be adapted and changed as research institutions move from adaptative research to applied research and finally towards upstream reasearch. Similarly, the structure of newly created organizations should be fine-tuned to the level of development of the country in question and the type of research that the institutions should concentrate on given that level of development.

4. The role of the university and its linkages to research institutions

The institutional model developed in Latin America for agricultural research relied almost exclusively in the creation of national research institutions which, for the most, were not directly involved in teaching.2/

1/ The concept of large interdisciplinary teams with clearly defined research objectives was initiated with what later was called big science, the best known example being the Manhattan project that resulted in the development of the atomic bomb. Close and well known examples are the crop improvement programs of the international centers of the CGIAR System.

2/ There are a number of exceptions to this general statement. Peru, specially until the early seventies, and Costa Rica are notable examples.

This separation of research and teaching activities was justified on two basic elements: a) the need to have institutions able to respond with agility to the priorities and needs of the development process; the universities, with their academic independence, were seen to follow their own priorities which sometimes respond to a different perception of what is important and necessary; and b) Latin American universities have an excessive level of political activity, which implies uncertainty and discontinuity in research.

Although there is considerable truth in these perceptions, it is also correct that the separation of research from teaching activities has also created a number of problems. First, the absence of students with their natural intellectual curiosity and the stimulating effect of classroom preparation have eliminated one of the main elements of dynamism in research institutions and a major force against institutional obsolescence. Secondly, the lack of integration between research and university teaching made more difficult the development of postgraduate programs as a natural institutional development. I think this is one of the important reasons that explain the notable absence of strong postgraduate teaching in most Latin American universities. Thirdly, the usual organization of universities along disciplinary departments, their traditional independence from political pressures interested in short run problems and the recognition for academic standards usually imply that research in universities has a tendency to move rapidly into basic research. This tendency, which could be considered as a disadvantage at early levels of development, can become a source of strength as the country develops and technological needs become more sophisticated.

It is important to note that the institutional development in the Caribbean region was quite different and that the University of the West Indies is the major research institution in the region. The advantages and weaknesses of this organizational framework under the special conditions of the region should be studied and understood.

5. Critical mass, research teams and the role of regional efforts

We have already mentioned the growing complexity of agricutlural technology and its dependence on relatively complex and sophisticated research. This process has increased the need and importance of interdisciplinary teams of well qualified scientists, and, in some fields, with access to expensive equipment. These requirements imply not only a increasing cost of research activities but also a higher investment in human resources and physical facilities with a longer period of matureness.

As an illustration of the relatively high cost of agricultural research it has been calculated that a well integrated crop improvement program for one of the major species requires an annual expense in the order of US $500,000. It is quite obvious that small countries cannot sustain, economically, a research infrastructure covering the majority of crops and problems needed for a productive and internationally competitive agricultural sector. It is in this perspective that regional research efforts must be seen as an important and probably unavoidable solution for the development of research efforts with sufficient critical mass.

Central America and the Caribbean region, both with a large number of relatively small countries, have made important efforts in the direction of developing regional organizations. It is an important idea and one that offers a viable alternative for productive and economically feasible research activities. For this to happen countries must be willing to provide stable financing and to establish binding coordination mechanisms with their own national research activities in order to pool resources, avoid duplication of efforts and effectively develop a regional network for research and technology diffusion.

6. Linkages to international public research

One of the consequences of the growing importance of basic research is the increasing need for the development of close and effective linkages of national research programs with public research institutions in the developed world. These linkages are necessary in order to have access to scientific knowledge that developing countries cannot produce in all the fields that are needed and important for the development of agricultural technology.

The establishment of these linkages implies the existence in the national programs of at least small groups, sufficiently advanced and specialized, to be able to have effective professional relationships with their scientific counterparts in the developed world. They must be capable of formulating the appropriate questions and of using the answers related to available scientific information in the resolution of problems of applied research. In this function, regional organizations can play an important role both because of their size and the resulting economies of scale, and because of the mobility and flexibility that these organizations enjoy in relation to international travel and access to information.

7. Research priorities and their linkage to production needs

We have argued that universities and regional research organizations are extremely valuable parts of an overall research system, specially as technologies become more complex and more dependent on basic research. On the other hand, both types of organizations are prone to aggravate a basic problem of most research institutions: the selection of research priorities closely related to the solution of production problems in the real world.

This problem is related to a number of organizational and functional characteristics of research institutions. First, it is related to the existence of a well structured and methodologically sound system of diagnosis of production problems and the determination of their relative importance as a basis for assigning research priorities. Secondly, it is also related to the governance of the organization. Technically sound research priorities will be implemented only if the decision making process has the adequate participation of the potential users of the technology and of researchers themselves.

These two elements related to technical and political considerations are more easily met by national research organizations than by universities, which have a higher degree of academic autonomy, or by regional organizations more removed from the farmers or producers level. However, this does not imply that these organizations cannot develop the appropriate organizational and management mechanisms to ensure the necessary linkages between research priorities and real production problems. Each institution must find its own way to ensure these conditions in an appropriate manner, but there are a number of general principles that inform on the alternative solutions to this problem.

8. Technological cycles and the concept of appropriate technology

The discussion of previous sections points to the evolution of agricultural modernization towards more sophisticated and complex innovations of the embodied type. This pattern of agricultural development is closely identified with the experience of the more developed and commercialized agriculture found in temperate Latin America and some regions of the continent.

In many other regions small farming, associated in some cases with a peasant type economic structure, is still important both numerically and in terms of its contribution to total food production. It is obvious that in those countries where this type of production is still important public research institutions must dedicate a substantial part of their research effort to develop technologies appropriate for these conditions, which are characterized by being very site specific, having low capital use and high concentration of labor, and usually associated with small size farms.

Under these conditions agronomic research of the most pure type is still the most important element that may lead to agricultural modernization. It is in this line of thought that the concept of appropriate technology has a new and positive meaning. Following the ideas of one of its main originators (Suchumaker), appropriate technology is usually associated with small size and opposed to modernizing technology. But if one recognizes the evolutionary perspective implied by the existence of interrelated technological cycles which are determined not only by technical elements but also by the level of development of agriculture and the general economy, then the concept of appropriate technology may be redefined to mean that a technology is appropriate if it is congruent with the level of development achieved in each particular case. The argument can be illustrated by saying that hybrid seeds are not appropriate until the country has a research and seed multiplication capacity for the production and distribution of seeds or that sophisticated farm machinery cannot be effectively utilized if a distribution and services infrastructure has not been developed previously.

It is important to note that public research institutions, that must dedicate a substantial part of their effort to the development of agronomic technologies in the early phases of the technological cycle, will also need some specific organizational characteristics. The main point here is the capacity to work under multicrop rotations with strict restrictions in relation to capital and labor availability. Under these conditions the capacity to identify the real production constraints and the interactive relationships between different crops and farming practices is of particular importance. Consequently the organizational structure will have to give particular attention to interdisciplinary teams with regional responsibilities and relatively less attention to either more specialized crop improvement programs or disciplinary departments.

IV. CONCLUDING COMMENTS

In the last few years technological change in agricultural production has rapidly increased, becoming a major element in the modernization of agriculture in a number of countries of the world. These processes were made possible by dramatic changes in the availability of technological innovations in a number of crops of great importance, specially for the temperate regions of the world. In Latin America and the Caribbean region modernization, although important, has been uneven and concentrated in a few crops and regions. The challenge of the decade is to extend this process to a wider range of crops and ecological regions.

The modernization process also implies important changes in the research environment, raising important new issues, problems and challenges. Probably the most important one refers to the organization of public research institutions (including the universities), which have been -and still are- the main source of scientific and technological know-how. How they adapt to the circumstances, define new roles for themselves and organize to remain productive and flexible will be a major determinant of viable agricultural production in the region.

BIBLIOGRAPHY

Da Silva, José G., "A Relação Setor Público-Privado na Geração de Tecnologia Agrícola no Brasil". UNICAMP/ Instituto de Economía, Campinas, Relatório de Pesquisa Nº 13, May 1985.

Piñeiro, Martín, "Technological cycles in Latin American agriculture", PROAGRO-Project; Doc. Nº 12, CISEA, Buenos Aires, October 1984.

Piñeiro, Martín & Trigo, Eduardo, "La investigación agropecuaria en el sector público de América Latina: problemas y perspectivas", PROAGRO Project, Doc. Nº 11, CISEA, Buenos Aires, September 1984.

Piñeiro, Martín & Trigo, Eduardo (ed.) "Technical change and social conflict in agriculture. Latin American perspectives", Westview Press, Boulder, Colorado, 1983.

Trigo, Eduardo; Piñeiro, Martín & Ardila, Jorge, "Organización de la investigación agropecuaria en América Latina", IICA, San José, Costa Rica, 1982.

BREEDING TOMATOES FOR THE CARIBBEAN

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ABSTRACT

For over 15 years the INRA Antilles Guyane Plant Breeding Station in Guadeloupe and IRAT Antilles in Martinique have been working in cooperation on breeding tomato varieties adapted to the Caribbean.

The main problems encountered were heat tolerance and disease resistance, especially to Bacterial Wilt caused by *Pseudomonas solanacearum* which prohibits growing of susceptible tomato lines in infested areas.

The first step of this work was the introduction and screening of an extensive world collection. This resulted in the identification of some tropical and subtropical varieties suited for cultivation in certain situations in the French Antilles.

The second step was to breed varieties better adapted to our conditions. This resulted in the release of lines resistant to *P. solanacearum* and/or heat tolerant. The last variety released, "Caraibe," which is both heat tolerant and resistant to *P. solanacearum,* also carries resistance to *Stemphylium solanae* (Gray Leaf Spot) and *Fusarium oxysporum* (Races 0 and 1).

Further breeding is needed to add root knot nematode resistance, *Cladosporium fulvum* (Leaf Mould) resistance, to improve fruit quality and to diversify varietal types.

RESUMEN

Por mas de quince años la Estación Guyana del Mejoramiento Genético, INRA Antilles, en Martinica, ha estado trabajando cooperativamente, con miras hacia un mejoramiento genético de variedades de tomate adaptadas para el Caribe. Los principales problemas encontrados fueron: tolerancia al calor y resistencia a enfermedades, especialmente al Añublo Bacterial, causadas por *Pseudomonas solanacearum,* lo cual no permite el creciminento de tomate de lineas susceptibles, en areas infestadas. La primera etapa del mencionado trabajo fué, la introducción de y la selección de una colleccion mundial muy extensa. Esto dío como resultado, la identificación de algunas variedases tropicales y sub-tropicales aptas para el cultivo, en ciertas situaciones, en las Antillas Francesas.

La segunda etapa fué, de mejorar genéticamente, variedades las cuales son mejor adaptadas a nuestro medio. Esto dío como resultado el relevo de lineas resistentes a *P. solanacearum,* y con o sin tolerancia al calor. La ultima variedad relevada, 'Caraibe', la cual es tolerante al calor y resistente a *P. solanacearum,* tambien es resistente a *Stemphylium solanae* (Mancha gris) y *Fusarium oxysporum* (Raza 0 y I). Se necesita llevar a cabo un mejoramiento genético adicional para, poder obtener resistencia al Nodulador, al *Cladosporium fulvum* (Moho), mejorar la calidad del fruto y diversificar los tipos varietales.

Keywords: Tomato, *Lycopersicon esculentum,* heat tolerance, disease resistance, breeding, French Antilles, hot humid tropics.

Tomatoes are the most popular vegetable worldwide. Over 45 million tonnes are produced on more than 2 million hectares. Out of this total, only about 15% are produced in the tropics. This limitation is due to many different causes, prime among which are lack of appropriate varieties adapted to the tropical climate, thus leading to very low yields, extreme susceptibility to diseases and parasites, poor organization of marketing and severe post harvest losses. The situation in the Caribbean is that of the hot, humid tropics with added difficulties due to land limitation and steepness. For more than twenty years two French research institutes IRAT (Institut de Recherches Agronomiques Tropicales et de Cultures Vivrieres) and INRA (Institut National de la Reacherche Agronomique) have been conducting research in Guadeloupe and Martinique to solve problems of tomato production in the Caribbean. These studies concern cultural practices, plant protection and plant breeding. This paper is the summary of work done on breeding tomatoes for adaptation to the climate of the West Indies and for resistance which are now grown on a commercial scale in our area as well as in many other tropical countries.

Climate and its Effects on Growth, Flowering and Fruiting

Climate

The climate of Guadeloupe and Martinique is that of the hot, humid tropics. Average yearly temperature is 25°C at sea level (–0.5°C at 100m altitude). Daily variations are small (4 to 7°C) and there is little year to year difference (about 1°C). There are two main seasons, the dry season (December to May) and the rainy season (June to September). During the latter, day temperatures are high though not excessive; maximum seldom reaches 32°C, but night temperatures often average 25°C. Atmospheric numidity is always high 80 – 90% (Table 1).

Table 1: Climatic data, Saint François, 1965–1984

Month	Temperature Minimum °C	Temperature Maximum °C	Day/Night Variation °C	Rain mm	Radiation m/m²	Insolation 1/10 hour
January	21.73	27.74	6.01	61.88	16.99	73.67
February	21.51	27.77	6.26	38.56	19.08	77.78
March	21.78	28.11	6.33	43.09	21.27	77.15
April	22.52	28.74	6.22	83.21	21.76	77.74
May	23.59	29.32	5.73	109.17	20.69	71.95
June	24.38	29.95	5.57	78.08	20.83	73.01
July	24.51	30.12	5.61	114.08	21.05	74.84
August	24.41	30.24	5.83	112.36	21.31	77.37
September	23.91	29.98	6.07	146.41	19.96	70.16
October	23.64	29.82	6.18	157.35	18.33	69.79
November	22.99	29.87	6.08	153.07	16.52	72.05
December	22.11	28.14	6.03	117.05	15.27	67.58

Average winds, which are the trade winds, blow regularly from the East (NE, E, SE). Rains are very irregular in quantity and distribution and day length varies from 11 to 13 hours. Tomato production is mostly a problem during the rainy season, due to high night temperatures, relative humidity, rainfall and poor light conditions resulting from overcast skies.

Effects on growth, flowering and fruiting

Temperature affects growth, flowering, fruitset and fruit growth (1, 4, 11, 12). Bad light conditions affect pollination and fruitset (9). High relative humidity is unfavorable for pollen liberation and germination (9, 13)

In our case, during the cool dry season tomato production is almost normal, whereas during the warm rainy season we observe serious disorders etiolation, poor flowering, small clusters, small fruits, fruit cracking, blossom end rot - all of which lead to low yields and poor fruit quality.

Over a five year period, with Florida commercial varieties, yields averaged 16 to 20 tonnes/ha in August/September and 35 to 40 tonnes/ha in January/February (Fig. 1) with European varieties yields were under 5 tonnes/ha.

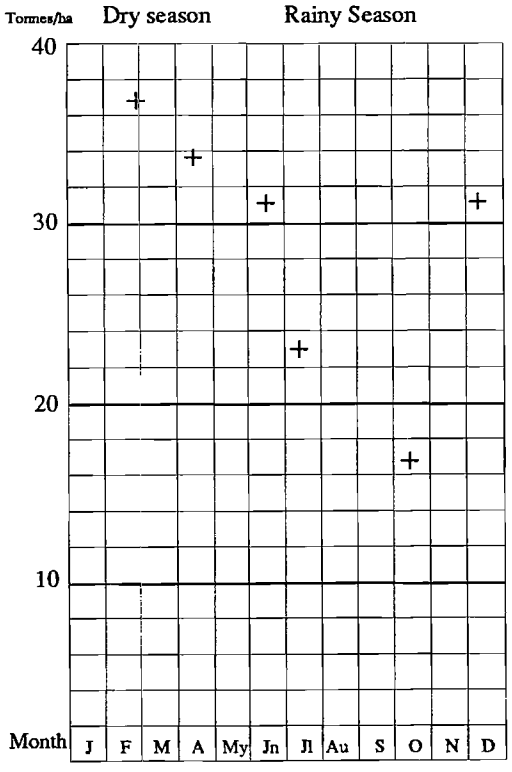

Fig.1. Average yield of four tomato varieties in 14 trials over 5 years at IRAT, 1963–1968

Breeding for Heat Tolerance

Screening for heat tolerant material

We screened local and introduced material. The first introductions that we made in 1969 were very extensive and included genotypes described for setting fruit under adverse conditions (4) and commercial varieties from various countries of temperate and subtropical and tropical climates. Observations on fruitset and yield enabled us to confirm the good level of tropical genotypes and of those released for resistance to cold sterility. In this group the most outstanding was Summertime, which surpassed cultivars such as Swift, Coldset, Porter, Nagcarlang and Fireball. The temperate varieties had poor fruitset, the worse being the European greenhouse varieties.

Further introductions were based solely on heat tolerant material from plant breeders working on that subject – Cueto (Cuba), T.P. Hernandez (Louisiana), P.W. Leeper (Texas), M.A. Stevens (California) and R. L. Villarfal (Philippines, then AVRDC, Taiwan). Some included parthenocarpic gene pat 2, from the Russian variety, Severianin.

Breeding

In the first part of our breeding programme we used the pedigree method from crosses between small-fruited, heat-tolerant material and Florida commercial varieties chosen for fruit quality and disease resistance.

After a few years we adopted a recurrent selection method followed by a modified single seed descent, from multiple crosses, between improved heat tolerant material. Resulting lines were assessed in the Antilles (Guadeloupe, Martinique), then in Louisiana in the summer of 1982 and 1983 at Louisiana State University (LSU, Baton Rouge).

Results and discussion

In Guadeloupe, best results were obtained from crosses including Summertime, Saladette and BL 6807. According to studies made by M.A. Stevens and co-workers, this is due to greater dehiscible pollen production (Saladette) and better translocation (BL 6807). We never got outstanding results with Malinkta 101 and/or Nacarlang, compared to, or in combination with, other varieties. This seems to indicate that we do not have problems with gamete viability. We also have no obvious advantage with parthenocarpy.

In Louisiana, where night temperatures (23 to 26°C) are comparable to those of Guadeloupe, but day temperatures are higher, we had some differences. During periods with days under 32°C almost all of the heat tolerant lines did well. But as soon as the day temperatures exceeded 32°C, the advantage of parthenocarpy became obvious.

Breeding for Disease Resistance

The major disease that threatens tomatoes in our region is Southern Bacterial Wilt caused by *Pseudomonas solanacearum* E.P. Smith that prevents cultivation of any susceptible variety in infested volcanic soil. Until recently coral soils or black vertisols, such as those encountered in the outer Caribbean Islands of Barbados, Grande-terre (Guadeloupe) and Antigua, were thought to be immune, but a case of *Pseudomonas* has been reported in Grande-terre, Guadeloupe.

Other diseases of less importance, but also of serious incidence, are caused by root knot nematodes, *Stemphylium solani, Alternaria solani, Xanthomonas vesicatoria, Fusarium oxysporum, Cladosporium fulvum* and *Phytophthora infestans* (Late Blight). Also of importance are spider mites and non parasitic

diseases, such a blossom end rot, fruit cracking, blotchy ripening, catface and sunscald.

Breeding for Pseudomonas resistance

Materials and methods

Several sources of resistance were available, viz., CRA 66 (Guadeloupe), UPR 199 (Puerto-Rico), PI 126 (Panama) and H 7996 (Hawai). A breeding program combining Back-Crossing, Pedigree then recurrent selection was under taken.

The most extensively used was CRA 66 in which resistance is multigenic (4, 5 genes) and semi dominant. It holds well in many tropical countries and also in Taiwan and Florida.

Results

Breeding results in the release of several lines – IRAT L3, Carette (Indeterminate types) and Caraibe (Determinate type) Caraibe, which also is heat tolerant, is now the most extensively grown on a commercial scale (Fig. 2).

Breeding for other diseases

In collaboration with INRA-Avignon (France) Vegetable Breeding Station, we also introduced resistance to *Fusarium oxysporum* (Races 0 and 1), *Stemphylium solanae* and root knot nematodes. We are now aiming to introduce combined resistance to root knot nematodes and *Cladosporium fulvum* from the linkage, MiCf2, Origin ONTARIO 7620 (KERR).

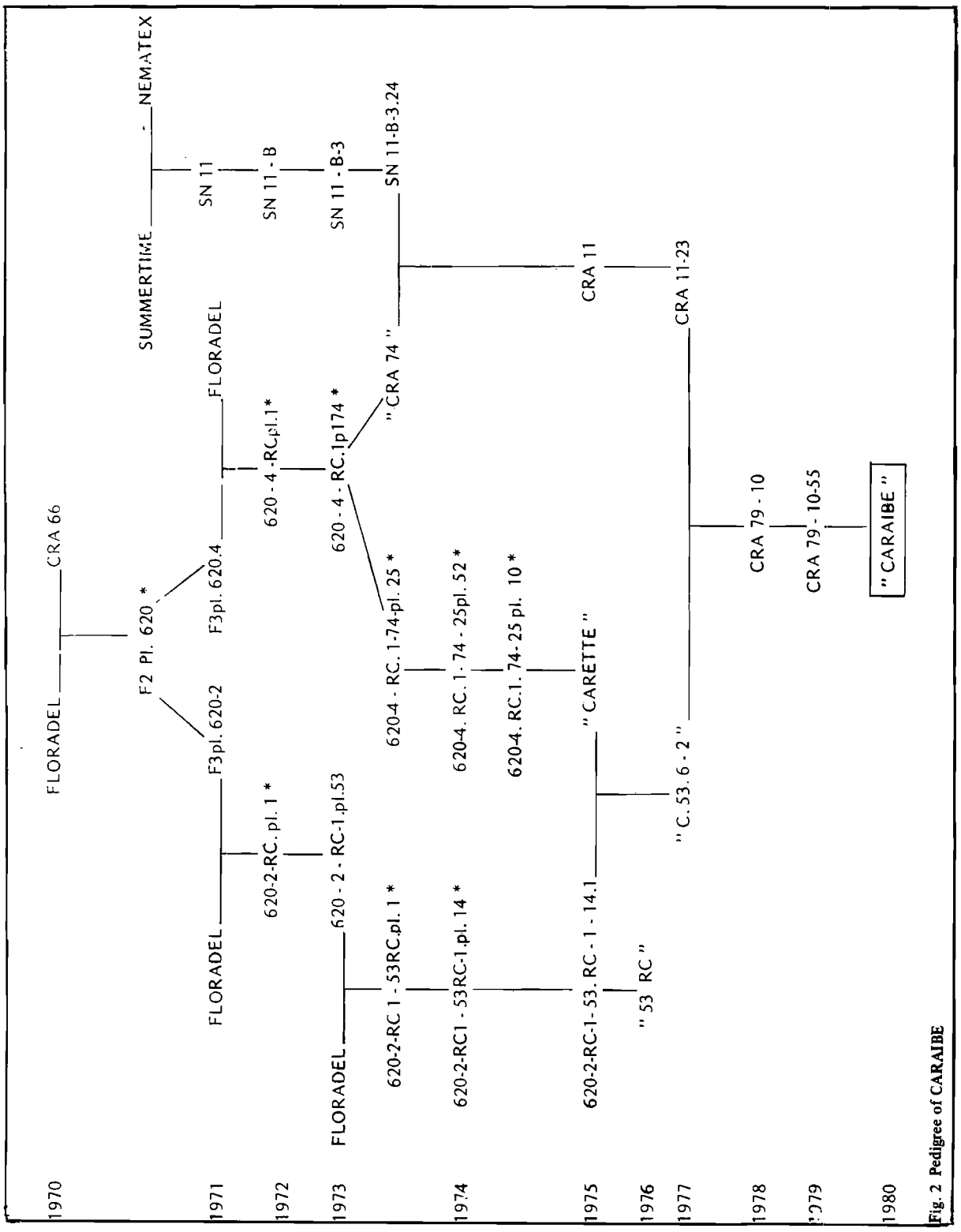

Fig. 2 Pedigree of CARAIBE

Conclusion

Breeding for heat tolerance enabled us to substantially increase tomato yields in the French Antilles, with the release in 1980 of the variety, "Caraibe," also resistant to Southern bacterial wilt *(Pseudomonas solanacearum)*. The observation of breeding material carrying different characters of heat tolerance lead us to the conclusion that heat stress in our region may be due mainly to carbohydrate starvation injury (10) resulting from high night temperatures, relative length of the nights and reduced daylight, all conditions that favour respiration to the detriment of photosynthesis. It might be interesting in these conditions to breed for reduced respiration rate and greater photosynthetic efficiency, leading to a higher level of net photosynthesis together with good translocation ability.

For *P. solanacearum* resistance we are aiming to combine different sources of resistance with the aim of obtaining high levels and stability in resistance. On a practical point of view we have to diversify the varieties to suit different types of cultivation.

References

1. Abdalla, A.A. and K. Verkerk. 1968 Growth, flowering and fruitset of the tomato at high temperature *Neth J. Agric. Sci.* 16 : 7176.

2. Anais G. 1978. Tomate amelioration pour l'adaptation au milieu. *Journées scientifiques* INRA Antillies Guyane 17.18.19 Octobre 1978.

3. Anais, G. 1984. Breeding tomatoes for heat tolerance in the French Antilles *9th Meeting of the Tomato Working Group of Eucarpia* - Wageningen 22 – 24 May 1984.

4. Beshir, A., E.L. Ahmadi, M. A. Stevens 1979. Reproductive responses of heat tolerant tomatoes to high temperatures. *J. Amer. Soc. Hort. Sci.* 104 (5) : 686 – 691.

5. Graham, T.O. 1966. Cold and heat sterility; New tomato types which help combat adverse floral set. TGC no. 16. p. 56 – 58.

6. Hernandez, T.P., G. Anais, S.M. Barineau and H.Y. Hanna 1983. Further studies on heat tolerance in tomatoes. Abstract of the Southern Region 43rd Ann. Meet. Amer. Soc. Hort. Sci. *Hort Science* 1, 18 (2) : 169.

7. Kaan, F. H. Laterrot and G. Anais 1975. A study of 100 tomato varieties in relation with climatic adaptation and resistance to 7 prevalent diseases in the West Indies. *Proc. XIIth Ann. meet. Carib. Food Crop Soc.* pp. 102 – 110.

8. Koot, Y. and W. Van Ravestijn 1962. The germination of tomato pollen on the stigma (as an aid to the study of fruit setting problems) *XVIth International. Hort. Cong.* 452 – 461.

9. Levitt, J. 1972. High temperature or heat stress., In *Response of plants of environmental stresses.* Academic Press N.Y. pp. 272 – 321.

10. Schaible, L.W. 1962. Fruit setting responses of tomato to high night temperature. *Proceedings plant science symposium.* Campbell Soup Co. pp. 89 – 98.

11. Stevens, M.A. 1981. Resistance to heat stress in crops. Campbell Institute for Agricul. Research pp. 458 – 487.

12. Villareal, R.L. Mercado F.C. Sen Hsiving Lai and Tai – Li Hu. Fruit setting ability of heat tolerant moisture tolerant and traditional tomato cultivars grown under field and greenhouse conditions. The *Philippine Journal of Crop Science* Vol. II (2) : 55 – 61.

GENETIC STRATEGIES FOR BREEDING LONG LASTING TOMATOES

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ABSTRACT

Tomatoes that will last for one month or more at tropical temperatures, without refrigeration, are now feasible. Attention has been given to major genes which drastically modify the ripening process. When these genes are homozygous, tomatoes do not develop full color and may not soften for months. In the heterozygous state, as would be found in hybrid tomatoes, these genes result in red tomatoes with extended shelf life. A search was made for genes that increase shelf life without drastic effects. Six sources of long-life were crossed to a conventional tomato cultivar and shelf life was measured in F_1, F_2, F_3 and BC generations. In each generation shelf lives were shorter than those of the long-lived parent, and usually as short or shorter than the mean of the two parents. A few segregants with exceptionally long shelf life were obtained. The results suggest that a relatively few genes are segragating and that these can be transferred to more suitable varieties to achieve long lasting tomatoes in pure lines.

RESUMEN

Ya es factible lograr tomates que puedon dura un mes o más a unas temperaturas tropicales, sin refrigeración. Se ha enfocados en algunos genes principales que modifican radicalmente el proceso de maduración. Cuando estos genes son homocigóticos, el color de los tombtes no se desarrolla plenamente y los frutos pueden tardar unos moses en ablandarse. En el estado heterocigótico, como el que puede observarso en los tomates híbridos, estos genes producen tomates rojos con una vida de almaconaje más extendida. Se buscó los genes que extiendon la vida de almacenajo sin producir otros efectas graves. Se cruzó seis especies duraderas con un cultivar de tomate tradicional y se calculó la vida de almacenaje para las generaciones F_1, F_2, F_3 y BC. Para cada generación, la vida de almacenaje era más corta que la de la planta madre más duradera; en la mayoría de los casos, era tan codta o más corta que la vida promedia de las dos plantas madres. Se obtuvo algunos elementos segregados con una vida de almacenaje excepcionalmente larga. Los resultados hacen creer que existen unos pocos genes segregantes y que éstos se pueden trasladar a unas especies más convenientes, afin de lograr tomates duraderas en las especies puras.

Keywords: Tomato, *Lycopersicum esculentum,* Breeding, Shelf life, Puerto Rico. Hot humid tropics.

The tomato, *Lycopersicum esculentum* Mill., is probably the most common and most highly acceptable fresh vegetable of the world. In addition to its many uses in processed form, it is part of the green salad that is considered essential in a balanced diet. The tomato production industry is enormous, with technology ranging from the primitive to the most advanced, complemented by systems of transportation and marketing, equally varied and complex. Yet the tomato is one of the most perishable vegetables. Its highest quality is seen when it is red-ripe, an ephimeral condition. Extensive refrigeration before or after ripening reduces quality.

It is desirable to have longer lasting tomatoes in the tropics. Tomatoes that reach a deep red color, and that retain their firmness and flavor for several weeks to a month, even without refrigeration, would result in greater flexibility in marketing and in convenience in the kitchen. Whether produced at home, in small farms, or in large commercial fields, such tomatoes would improve the conservation of the fruit and thus make usage more versatile.

The tomato fruit passes through a ripening process referred to as the climacteric (Khudairi, 1972). After a relatively long initial period of development as a green fruit, when physiological processes are fairly stable, the mature green fruit begins to ripen, a rapid process that will bring the tomato into an optimum state for consumption, and will then rapidly carry it beyond that stage to an unacceptable softness and off-flavor.

Some of the processes that occur before, during or after the climacteric include the following (Khudairi, 1972):

1. A synthesis of a series of carotenoids seen as progressive of yellow, orange and red color development, culminating in the production of lycopene. Meanwhile chorophyll degenerates.
2. The production of ethylene, which has hormonal effects on the process of ripening.
3. An increase in respiration, reaching a peak, the climateric, followed by a rapid decrease.
4. An increase in the action of certain enzymes, especially polygalacturonase, pectin esterase, and cellulase and the resultant softening of the fruit.
5. A decrease of acidity, dry matter, and sugars.
6. Other changes in flavor more difficult to define but of great importance.

An examination of fruits of the family Solanaceae shows that long-lasting fruits are not rare. The ornamental fruits of *Solanum mammosum* can last a year. Eggplant fruits are very slow in spoiling. The fruits of numerous red peppers may be stored for months. Even the common bell pepper fruit, when red ripe, can last a month or more. Thus, there is a suggestion that genes already exist in the family for long lived fruits. But can such genes be found in, or be incorporated in the tomato so that useful life is increased without loss of quality? In this paper I would like to stress that they can be found, and I would like to suggest a strategy for breeding long lasting tomatoes.

Major genes

Major genes with drastic effects on the ripening of the tomato have come from two sources, primitive varieties of tomatoes that were preserved in Europe because the fruits could be harvested and saved for the winter, and mutations that have been found by genetists and studied for their interesting characteristics. The major genes known are summarized in Table 1.

The five major genes have various aspects in common. First, they all have drastic effects. By drastic I mean to say that the homozygous plants produce fruits that ripen so poorly that they never become as good as normal tomatoes. Furthermore even if ethylene is used to stimulate ripening of mature green tomatoes, only slight improvements in ripening occur.

Table 1. Major genes affecting tomato fruit ripening

Gene Symbol and name	Source	Color of mature fruit	Shelf life of fruit*		Reference
			Homozygote	Heterozygote	
Nr (Neverripe)	Mutant	Yellow green	3	2	Tigchelaar, *et al.*, (1978).
rin (ripening inhibitor)	Mutant	Yellow	4	2	Tigchelaar, *et al.*, (1978).
nor (non-ripening)	Mutant	Yellow to orange	5	2–3	Ng & Tigchelaar, (1977).
alc (alcobaca)	Portugal France	Yellow to orange	5	2–3	Lobo, *et al.*, (1984).
Gr (Greenripe)	Mutant	Green to Yellow	5	4	Jarret, *et al.*, (1984).

* Rated from 1 (normal, 2 weeks) to 5 (4 – 6 months)

Various salt solutions in the soil can increase ripening, however, and indeed there appear to be other responses as well (Arad and Mizraki, 1983). Because these tomatoes do not ripen well, they are resistant to postharvest diseases.

The heterozygous condition of these five genes is about the same as the homozygous in the case of the dominant genes *Neverripe*, and *Greenripe* (Jarrett, *et al.*, 1984) but quite different for the other three genes. In the heterozygous condition of the latter, fruits ripen slowly to a normal level of color. They also remain firm longer, resist postharvest diseases, and have a longer storage life. These genes are, therefore, best used in the heterozygous form, in suitable F_1 hybrids. One commercial hybrid variety known as 'Long Keeper' is based on one such gene. Fruits of F_1 hybrids based on the gene *nor* ripened late, held longer in storage, but firmness varied, and appeared to depend more on the particular parents in the cross (McGlassen *et al.*, 1983). *Nor* did not affect fruit size, soluble solids, pH, titratable acids, or total ascorbic acid.

The mechanisms of physiological control of these major genes are not well known, but all lack the full polygalacturonase enzyme activity of normal tomato fruits. This is the chief enzyme responsible for softening of the fruit. There is currently great interest in working out the mechanisms of control.

In the mutant genes the climacteric tends to occur but later than normal and in a much reduced fashion. Ethylene gas is produced in lesser quantities. The respiration is lower. Chlorophyll may begin to break down, and carotenoid pigments may begin to form. Softening is delayed and may be reduced to a minimum (Ng and Tigchelaar, 1977).

It appears that other commercial hybrids will be developed from these genes, and these may change the entire pattern of production and marketing of tomatoes.

Minor genes

If genes are found with major effects on the ripening process, genes with lesser effects might also occur. These genes might make it possible to extend shelf life in normal varieties, that is, in pure lines that are homozygous for these genes. Such tomato cultivars might be more useful than hybrid varieties based on heterozygosity of a major shelf life gene.

With this in mind, we studied the shelf life of tomato fruits from 184 red fruited cultivars. These included *Lycopersicum esculentum, L. esculentum F. cerasiforme, L. pimpinellifolium,* and suspected hybrids. Five fruits that were just beginning to ripen, called in the trade "breakers" were harvested, from each plant, held at room temperature (26 – 28 °C) and observed for shelf life. The fruits were examined weekly and were discarded when diseased or excessively soft or shrivelled. Shelf life was noted as the number of weeks from harvest to discard.

The frequency distribution of varieties with shelf life from 0 to 23 weeks are given in Fig. 1. The majority of the varieties had shelf lives of 3 – 8 weeks. However, the fruits of a few varieties kept for double or even triple this time. Thirteen lines with exceptional shelf life are given in Table 2 with their identification by class of tomato. Only four of these lines were *L. esculentum.* The long shelf life of two of these was associated with a single previously known gene, *lutescens,* revealed here to have major effects on shelf life. The other two varieties were small

fruited primitive tomatoes. No modern, large fruited variety showed exceptional shelf life, but the best was the cultivar 'Pope', a plum-shaped tomato, with an average shelf life of 13 weeks. A line known as Burdick-038, collected in Morocco, had a shelf life of 15 weeks, but small fruits.

Table 2 Tomatoes with exceptional shelf life

TARS NO.	PI No.	Species	Shelf life (weeks)	Source
TA185	144955	*L. pimpinellifolium*	23.2	Peru
TA181	129097	f *cerasiforme*	22.0	Colombia
TA194	212409	*L. pimpinellifolium*	20.7	Venezuela
TA75	212429	*L. esculentum*	19.7	USA
TA162	118790	f. *cerasiforme*	18.5	Venezuela
TA273	205011	*L. esc.* × *L. pimp.*	18.2	USA
TA309	128277	*L. esculentum*	17.6	Argentina
TA326	204980	*L. esc.* × *L. pimp*	17.3	USA
TA276	205020	*L. esc.* × *L. pimp*	17.5	USA
TA285	286098	*L. esculentum*	17.5	Nigeria
TA325	204978	*L. esc.* × *L. pimp.*	17.1	USA
TA159	100697	f. *cerasiforme*	17.0	Peru
TA68	193399	*L. esculentum*	16.1	USA

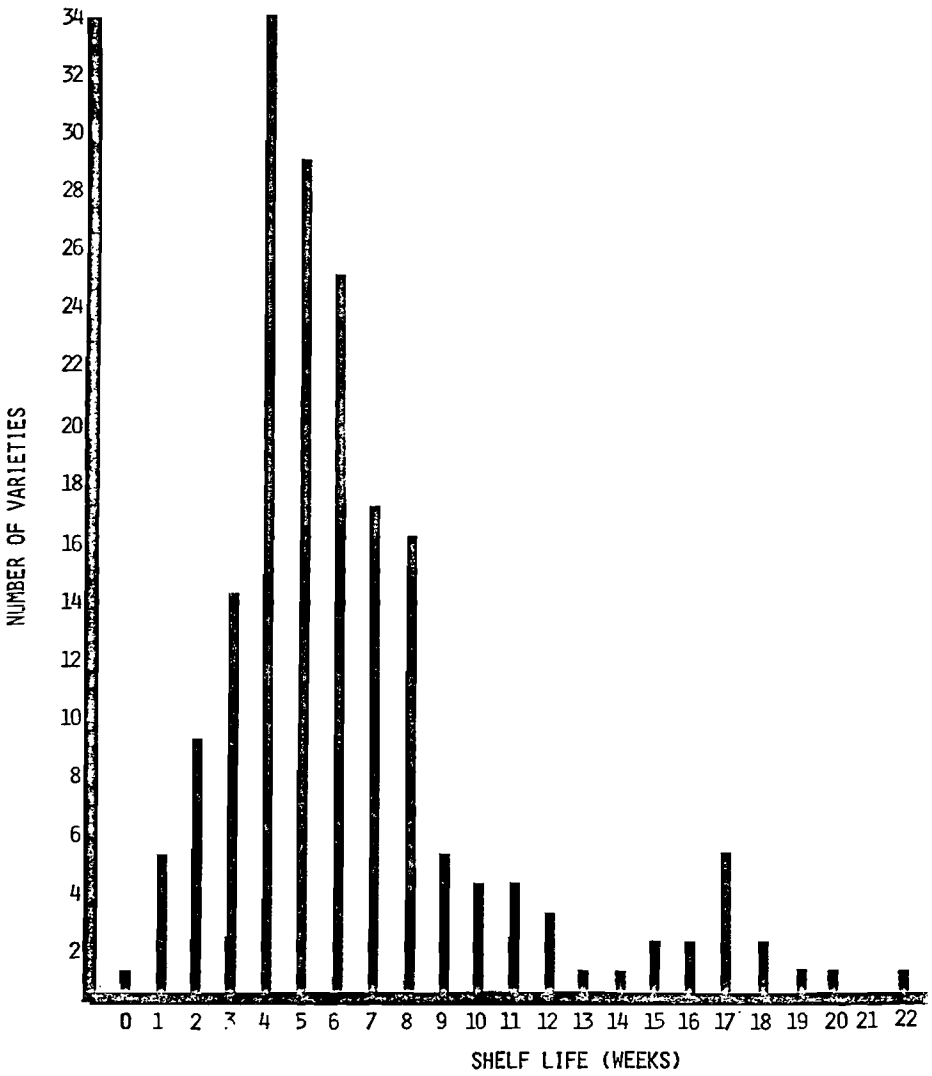

Fig. 1: Frequency distribution of tomato varieties with a shelf-life of 0 - 23 weeks.

Six of the lines were selected for further testing. Shelf life of each was measured three times from fruits produced in separate greenhouse plantings (Table 3). One tomato cultivar, 'Kewalo', bred in Hawaii and resistant to several diseases, with average shelf life of 75 weeks, was selected for crossing. The six lines were crossed as males to 'Kewalo', and the F_1 hybrids were backcrossed to 'Kewalo'. The shelf life of the F_1, F_2, and BC_1 hybrids and selected F_3's are given in Table 4, as compared to the shelf life of the original parents. In three F_1's the shelf life was longer and in the other three it was shorter than that of the male parent, but in all cases shelf life was equal to or greater than the mean of the shelf lives of the two parents.

Table 3 Shelf life in weeks of selected red fruited tomato cultivars as compared to that of a standard variety, in three trials.

Tomato line	Species or variety	Fruit size		Shelf life (weeks)		
		Length (mm)	Diameter (mm)	1981	1982	1983
TA 10	*L. esculentum* (Pope)	48	35	10.0	8.2	21.0
TA 162	f. *cerasiforme*	15	18	18.5	10.2	8.4
TA 181	f. *cerasiforme*	22	23	22.0	13.4	14.2
TA194	*L.pimpinellifolium*	10	10	20.7	11.8	14.6
TA 273	Hybrid, *L. esculentum* × *L. cerasiforme*	15	19	11.2	8.0	15.0
TA 277	*L. esculentum*	15	16	14.8	14.8	14.4
TA 8	*L. esculentum* (Kewalo)	51	62	7.1	8.0	7.4

Table 4 Shelf life of fruits (in weeks) of six tomato varieties as F_1, F_2, F_3, and BC hybrids, as compared to shelf life of parent lines.

Orginal parents and[1] shelf life	F_1	F_2			Selected F_3			BC	
		No of plants	Range	Mean	No of plants	Range	Mean	No of plants	Range
Kewalo, 7.5 x TA 110,13.1	18.6	18	7-13	8.1	17	8-13	11.1	11	4-6
Kewalo, 7.5 x TA 162,12.4	17.8	17	3-13	7.6	17	5-14	10.0	6	6-12
Kewalo, 7.5 x TA 181,16.6	13.4	17	6-15	11.2	24	5-17	10.4	16	6-13
Kewalo, 7.5 x TA 194,16.5	12.2	18	4-15	9.6	6	7-13	10.6	13	3-13
Kewalo, 7.5 x TA 273,12.5	10.8	14	3-12	9.0	16	7-13	10.5	22	2-13
Kewalo,7.5 x TA 277,14.7	18.8	16	9-14	11.0	13	6-15	12.1	18	5-12

[1]Shelf life of parents follows the name or number

From each of the six crosses, 14 – 18 plants of the F_2 were tested for shelf life. The shelf life values ranged widely in each cross from short (3 – 4 weeks) to moderately long (12 – 15 weeks). Almost all shelf lives in the F_2 were less than the shelf life of the original male parent (Table 4). The mean shelf lives of the F_2's were lower, (except in one case), than the mean of the parents. Mean shelf life of all F_2's was 9.4 weeks.

The frequency distributions of the F_2's are shown in Fig. 2. The mean of the original male parent is indicated on the bar graph by a single arrow. The average of the mean of the two parents is shown by a double arrow. The majority had shorter shelf lives than the average of the mean of the parents. In each F_2 population a few segregants demonstrated shelf lives almost as great as those of the original long-lived parent.

One outstanding F_2 plant was selected from each family and self pollinated. The shelf lives in F_3 families are given in Table 4. The F_3 families were small, six to 24 plants. The range in shelf lives were very similar to the ranges found in the F_2's. This signifies that there was considerable segregation in F_3's for the genes affecting shelf life. The mean shelf life of the F_3's was somewhat larger that the mean shelf life of the F_2's, which suggests progress due to selection.

In the BC (backcross generation) plants had been crossed to the original female 'Kewalo'. Small families of 6 to 22 plants were grown (Table 4). Shelf life of the BC hybrids ranged from 2 to 13 weeks, but mean shelf life was reduced in every family to less than the mean of the F_1, F_2, or F_3 generations. This suggests a continued segregation for genes affecting shelf life, and the presence of fewer genes that increase shelf life.

During the course of these investigations many individual plants were found with fruits of outstanding shelf lives. The fruits of these plants lasted for 4 months or more. During that time they remained red, did not soften, or shrivel excessively. The few fruits tasted had remained edible.

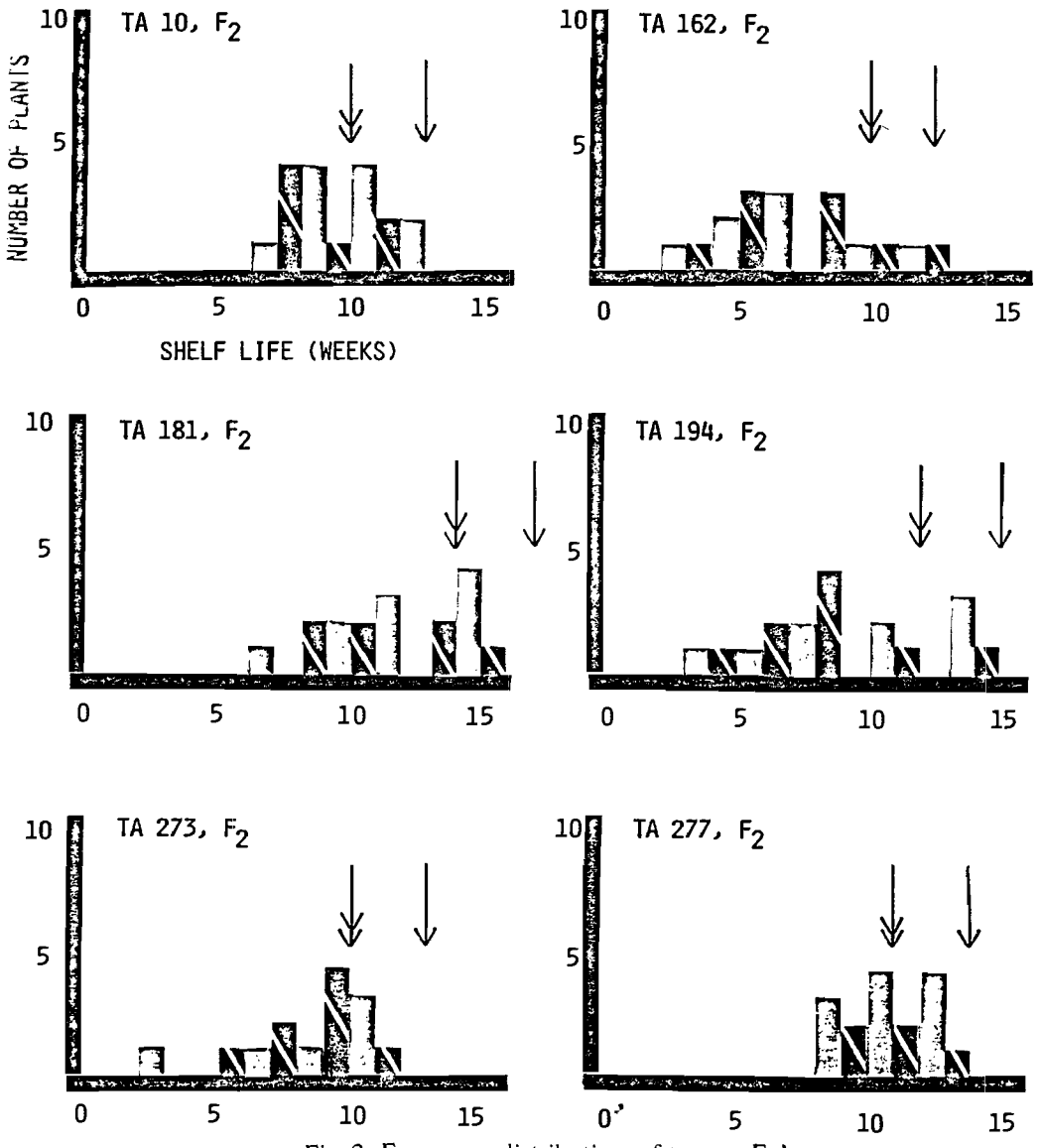

Fig. 2: Frequency distribution of tomato F_2's

Discussion

Current emphasis on major genes affecting fruit ripening has been useful in understanding the ripening process. Furthermore, some of these major genes may play a role in the development of long-lasting hybrid tomatoes. However, the effects of these genes are too drastic for use in commercial tomato varieties, which are pure lines (homozygous for all genes).

As revealed by our studies, long-lasting tomatoes from six cultivars appeared to be controlled by minor genes. In F_1 hybrids with a normal tomato, these genes are expressed, and thus at least some may be dominant in effect. In F_2, F_3, and BC generations considerable segregation occurred for shelf life suggesting that several genes control this characteristic. Although segregating populations were small, plants with outstanding shelf life were recovered from each population. Thus, the number of genes affecting shelf life appears to be small and manageable.

Therefore, it appears at the present time that the best strategy for the development of tomatoes with long shelf life is the use of the minor genes, transferred to suitable populations and combined with other characteristics of value. The varieties development in this fashion will have tomatoes that are normal in all respects but that have outstanding keeping quality.

References

Arad, S.M., and Mizrahi, Y. (1983) Stress induced ripening of the non ripening tomato mutant *nor*. *Physiologi plantarum.* 59 213 – 217.

Jarret, R.L., Tigchelaar, E.C. and Handa, A.K. (1984) Ripening behaviour of the green tomato mutant. *Jour. Amer. Soc. Hort. Sci.* 109 712 – 717.

Khudairi, A.K. (1972) The ripening tomatoes. *Amer. Scientist.* 60 696 – 707.

Lobo, M., Bassett, M.J. and Hannah, L.C. (1984) Inheritance and characterization of the fruit ripening mutation in "alcobaco" tomato. *Jour. Amer. Soc. Hort. Sci.* 109 741 – 745.

McGlassen, W.B., Sumeghy, J.B., Morris, L.L., McBride, R.L., Best, D.J. and Tigchelaar, E.C. (1983) Yield and evaluation of F_1 tomato hybrids incorporating the non ripening *nor* gene. *Australian Jour. of Exper. Agric. and Animal Husbandry.* 23 (120) 106 – 112.

Ng., T.H., and Tigchelaar, E.C., (1977) Action of the non ripening *nor* mutant on fruit ripening of the tomato. *Jour. Amer. Soc. Hort. Sci.* 102 504 – 509.

Tigchelaar, E.C., McGlassen, W.B., and Buescher, R.W. (1978) Genetic regulation of tomato fruit ripening. *Hort. Sci.* 13 508 – 513.

A REVIEW OF PEANUT CULTIVAR EVALUATION IN JAMAICA

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ABSTRACT

Work on peanut cultivar evaluation in Jamaica is reviewed. Over 100 introductions have been made in recent years and several have shown improved yield and kernel size compared to the local Valencia cultivar. Differences in season length (90 to 150 days) make comparison of cultivars based on kernel yield per unit area alone unsatisfactory for assessing the order of merit. The time factor must be taken into account to determine the economic rate of return on investment. Kernel yield in kg ha^{-1} per 5-day period of growth is suggested as the most suitable criterion for comparative performance.

Socio-economic factors suggest that cultivars of short season length and erect bunch habit as represented by Spanish/Valencia market types are suited to the rainfed conditions and low management input production system of small farmers.

Large seeded cultivars with spreading habit and requiring a long season length as represented by Viginia/Runner market types are suited to large farms equipped with machinery and irrigation facilities.

RESUMEN

Esta es una revisión del trabajo de evaluación de cultivares de maní llevados a cabo en Jamaica.

En años recientes más de 100 varidades fueron introducidas y muchas de ellas mostraron mejorias en cuanto se refiere a la producción y al tamaño del grano, comparadas con la variedad criolla, el cultivar Valencia. Variaciones estacionales (de 90 a 150 dias) hacen que la comparación de cultivares, basada solamente en la producción del grano/unidad de superficie, no sea satisfactoria para poder evaluar el orden de merito. El factor tiempo se debe considedar para poder determinar la tasa economica de rendimiento de inversión. El criterio mas adecuado para la comparación del desempeñamiento de las diferentes variedades es, el de la producción del grano por kg ha^{-1} per 5 dias de crecimiento.

Factodes sócio-económicos sugieren que las variedades precoces y con un habito de crecimiento arbustivo, como ser el de la variedad Spanish/Valencia, son adecuadas para condiciones pluviales y para el sistema de manejo de baja producción de los pequenos agricultores.

Las variedades de grano grande y de guia larga y de tipo de crecimento de dia largo representadas por la variedad Virginia/Runner, son adecuadas para plantaciones en fincas grandes equipadas con maquinarias y equipo de irrigación.

Keywords: Peanut, Cultivar evaluation, Jamaica.

Early research

Peanut varietal assessment in Jamaica attracted attention soon after the Second World War. Investigative Bulletins 1949/50 and 1950/51 of the Ministry of Agriculture report on a series of trials conducted under the various ecological conditions prevailing at four agricultural stations.

The seven cultivars under test were PL–118475, PL–148353, Virginia Bunch, Dixie Runner, Swaziland and Local Valencia. The low yields (685–970kg dried nuts ha^{-1} obtained may be attributed mainly to the wide spacing used – 30cm x 60cm.

The literature does not indicate any further research being done in Jamaica on variety testing until after an unfortunate attempt at large scale production at Hounslow. St. Elizabeth in the 1960s. The cultivar imported from the USA proved highly susceptible to the local disease complex and the disaster that resulted served as a deterrent to the development of the peanut industry for several years.

The incident, however, focused attention on the need for research and the Botany Department of the University of the West Indies (UWI), undertook a study of the reaction of local and imported peanut cultivars to infection by rust *(Puccinia arachidis)* and leaf spot *(Cercospora personatum)*

Of the 17 early maturing types tested, four were considered resistant to rust, three of these (PL–259747, PI–341879, (Tarapoto) and PI–350780) were also considered resistant to leaf spot.

The Local Spanish and Local Valencia, both early maturing, were classed as moderately resistant to rust but highly susceptible to leaf spot.

Among the 17 medium maturing varieties five were deemed resistant to rust and of these Florida 439–16 and NC–13 were also resistant to leaf spot.

Eight late maturing types were tested and of these only Virginia 56R was rated as being resistant to both rust and leaf spot. Unfortunately, there was no immediate follow-up of this work. To date, the UWI recommendation that large plots of Local Valencia should be grown and the most disease-resistant plants selected for bulking of their progeny has not been pursued. The possibility of upgrading the Local Valencia's performance by selection remains an area rich for research since it is known to contain a number of lines.

A preliminary evaluation of ICRISAT selections

In 1981, the International Groundnut Foliar Disease Nusery (IGFDN) in collaboration with the International Crop Research Institute for the Semi-arid Tropics (ICRISAT) provided CARDI (Jamaica Unit) with 43 selections for evaluation of disease resistance in different environments.

Comparison was made against the Local Valencia in a replicated trial on Maverley Loam at Mona. This investigation is presented in detail in the 1982 Annual Report of CARDI - Jamaica.

The cultivars were maintained using a high standard of husbandry except that fungicides were not used. For each plot, records were taken of the dates of first appearance of three diseases – rust, early leaf spot and late leaf spot. Guided by the ICRISAT 9-point field scale the severity of each of the three diseases was recorded, 70 and 94 days after planting.

It is reasonable to assume that the effect of disease on yield will vary according to:–

- The stage in the life cycle of the cultivar when infection occurred.
- The severity of the attack.

All cultivars in the trial were harvested within 122 days after planting and it was assumed that where slight or moderate disease severity occurred late in the life cycle of a cultivar (that is after 94 days) its yield potential would not have been altered appreciably. If however, the same level of severity occurred early, namely within 70 days (mid-crop) and this severity did not intensify with time, the yield potential was considered to be affected moderately. Using these assumptions Table 1 was drawn up.

Of the 19 selections where the disease complex was considered to either have had no effect or only a slight one, 14 were erect bunch, short season (15 – 110 days) types; the others were spreading bunch, medium season (111 – 125 days) types. The Local Valencia was also included in this group.

Six of the short season types, but none of the medium season type yielded better than the Local Valencia which produced the equivalent of 3770kg ha^{-1}. Of this group ICG–7886 gave the highest yield of 5020kg ha^{-1}; the others ICG–2716, 7893, 7896, 7897 and 7898 produced between 3865 and 4490kg ha^{-1}.

Table 1 The assumed relationship between levels of disease severity and the yield potential of peanut cultivars

Disease severity level at 70 days	Disease severity level at 94 days	Assumed disease effect on yield potential
Clean (Score 1 or 2)	Clean	None
Clean	Moderate (Score 3 or 4)	Slight
Clean	Severe (Score 5 or 6)	Moderate
Clean	Very severe (Score 7 or over)	Severe
Moderate (Score 3 or 4)	Moderate	Moderate
Moderate	Severe	Severe
Severe (Score 7 and over)	Severe	Very Severe

It is interesting to note that the highest yield of all was from ICG–1697 which gave 6160kg ha^{-1}, although this selection was severely affected by disease.

In fact, nine of the 15 selections with higher yields than the Local Valencia appeared to be more severely affected by disease. These findings suggest that the better performing introductions were capable of expressing their higher yield potential under conditions of high management inputs even without the use of fungicides.

The effect of management on yield of six high yielding ICRISAT selections

In the following season, (1982) six of the highest yielding ICRISAT selections were included in a series of six trials – two trials on each of the three major soil types used for peanut production in the parish of St. Elizabeth. The objective was to compare their performance with the indigenous Valencia under the low input management conditions of small farmers.

Mean yields at the six sites are presented in Table 2 along with the mean yield of the same selections grown in the same season but under high input management conditions (including the use of fungicides) at agricultural research stations.

The yield of the Local Valencia in these trials was consistent with its long term average under small farm conditions. The introductions with high potential yield under good management (Table 2) did not perform as well as the Valencia under the low input conditions on small farms.

Table 2 The effect of levels of management on yield (kg dried nuts per ha) of selected cultivars of peanut)

Cultivar	Management	
	Low	High
Local Valencia-Standard	1401	3320
ICG-1703	1334	3819
ICG-7882	1252	4587
ICG7898	1234	3468
ICG-1710	1149	3803
ICG-1712	1093	3921
ICG-7895	1025	3638

Recent cultivar evaluation

Since 1982 field and laboratory investigations have involved 111 cultivars:

43 ICRISAT selections

28 ICRISAT breeding lines and

40 U.S. selections

Field investigations have taken the form of observation plots (unreplicated) and replicated trials.

The better performing selections were included in six replicated trials. Randomised complete block designs with four replicates were used in all these trials. Plots consisted of four rows 3.6m long. Seeds were spaced 15cm apart with rows 60cm apart.

In establishment and maintenance a high standard of husbandry as set out in CARDI's Teck-pack (1982) for peanut production was maintained under the irrigated conditions at the two stations involved.

Records were take of:

- Stand count at 2 weeks and at harvest
- Dates of first appearance of leaf-spot and rust and levels of infection according to a 9-point scale, at mid-crop, at 75 per cent duration and finally at harvest.
- Season length as determined by lifting trials – maturity at 70 – 80 per cent of large nuts.
- Dried nut yield taken after 4 days of sun drying on a concrete barbecue.
- Shelling percentage and grading of kernels carried out on 0.45kg composite samples.

Variable seed viability caused much interplot variation within treatments. To reduce the effect of this variable, yields were adjusted to a constant population of 107,640 plants ha^{-1}. This adjustment gives an unfair advantage to cultivars which failed to produce many plants for harvest.

Ranking by yield

High yield variability in the trials prevented establishing with confidence the order of merit of the cultivars under test. However, under similar conditions of husbandry, several observations should allow establishing a consistent order for the cultivars relative to the Local Valencia.

In Table 3 mean yields of nuts from the indicated number of trials are rounded to the nearest 100kg and expressed as a percentage of the mean yield of the standard Local Valencia set at 100. The cultivars are grouped according to market types. The selection ICG–7898 had the highest ranking percentage yield. The Local Valencia was the highest ranked Valencia market type.

Productivity

Kernels are the most valuable part of the peanut. Hence, comparison of cultivars based on their kernel yield rather than their dried nut yield gives a better measure of their merit. The productivity of a cultivar can be expressed in terms of its kernel weight (kg) per ha per 5-day period of growth. (Table 3). The choice of a 5-day period recognises the difficulty in pinpointing maturity periods for optimum recovery of nuts at harvest.

On this criterion, Florunner was the highest ranking Runner market type and it also outranked the top performers of the Virginia market type. However, the selections ICG–7898 and ICG-7886 both of uncertain market type were superior to the Florunner (Table 3).

Ranking of kernel grades by market type

The size of the kernels and their uniformity are important qualities influencing the price paid for peanuts. The size fractions of seed samples of each cultivar were determined using a series of sieves with 14, 16, 18 and 21 mesh. The weight percentage of each fraction was established with their respective seed count per 100g. Only the two large fractions and their seed counts are reported in Table 4 by market type.

Considerable differences in seed count occur between cultivars both within and between market types but in general the large seed size of the Virginia market types is outstanding being almost twice that of the Spanish/Valencia market types. The weight percentages of the largest fraction retained on the 21 mesh sieve for both the Virginia and Runner market types are in general larger than those of the Spanish/Valencia types indicating greater seed uniformity. Excellent uniformity – 98 per cent by weight – occured in seed of cultivars ICG–6330, NC–7 and PI–315608. The indigenous cultivar, Local Valencia, possesses seed of wide size variability. Uniformity and size are both important.

Table 3 Ranking of peanut cultivars with Local (Jamaica) Valencia as standard

	No. of Expts.	* Approx. mean yield (kg/ha) nuts	** Percentage yield	Season length (no. of 5-day periods)	Approx. mean kernel yield (kg/ha)	Relative productivity (kernel yield) 5-day period of growth
		Virginia Market Types				
VA Bunch G2	2	4700	182	26	3440	132
NC-2	2	4600	159	25	3300	132
NC-7	6	4400	152	28	3150	112
Florigiant	3	3900	139	26	2740	105
Va 81B	2	3600	124	26	2540	88
Va 61R	2	3200	110	28	2440	87
NC-6	2	2900	100	26	2270	87
Va Runner G26	2	2600	90	26	1860	72
Early Bunch	2	1500	52	26	1130	43
		Runner Market Types				
Early Runner	2	4600	159	26	3540	136
Florunner	3	3700	128	26	3700	142
Dixie	2	2600	90	25	1780	71
Va Bunch 67	2	2500	86	25	1720	89
		Spanish Market Types				
Argentine	2	4000	138	26	3070	118
Comet	5	3900	139	23	2870	125
Pronto	2	2600	124	25	2820	105
lifspan	2	2900	100	23	2180	95
Starr	3	2800	86	23	1960	85
		Valencia Market Types				
Tennesse Red	3	2700	93			
Local Jamaica (Standard)	5	2900	100	20	2180	109
NM Val A	3	1600	55	23	1190	52
		Unspecified Market Types				
		ICRISAT Selections				
ICG-7898	4	5500	190	25	4010	160
ICG-7886	6	5300	183	25	3790	152
ICG-1697	6	4500	155	25	3270	131
ICG-6330	4	4300	148	25	3100	124
ICG-7900	2	3500	121	25	2500	100
		Other Cultivars				
Mat. 119	2	3400	117	23	2450	107
Altika	4	3100	107	26	2280	88
Dixie Anak	2	2700	93	25	1880	75
Norden Fla.	2	2400	83	22	1690	77
C-501	2	2400	83	25	1560	60
PI-315608	2	2100	72	25	1490	60

* Rounded to 100kg

** Local Valencia as standard, Yield of 2900kg per ha=100

Table 4. Ranking of peanut kernel grades by market types

Variety	Retained on 21 mesh sieve % by wt.	Seed count/100g	Retained 18-21 mesh sieve % by wt.	Seed count/100g
		ICRISAT Selections		
ICG-6330	98	180	2	266
ICG-7898	92	180	7	250
ICG-88	88	187	11	257
ICG-7900	84	137	13	247
ICG-1697	76	193	22	257
		Virginia Market Types		
NC-7	98	103	2	210
Va Runner G26	95	123	5	183
NC-2	92	110	4	200
Va 61R	91	123	7	220
Va Bunch G2	90	130	9	197
Va 81B	91	123	9	900
NC-6	90	143	9	263
Early Bunch	90	180	10	253
Florigiant	63	143	27	207
		Runner Market Types		
Florunner	92	157	7	263
Early Runner	90	163	8	240
Dixie Runner	90	130	7	203
Va Bunch 67	44	183	36	243
		Spanish Market Types		
Comet	80	193	16	293
Argentine	74	223	25	273
Starr	70	226	30	247
Tifspan	68	237	30	290
Pronto	68	200	30	253
		Valencia Market Types		
NM Val. 4	86	203	13	273
Local Valencia	73	210	24	267
Tennessee Red	60	233	38	257
		Other of uncertain Market Types		
PI-315608	98	76	1	320
Norden Fla.	96	113	3	390
Altika	92	120	6	237
Dixie Anak	91	153	7	207
Mat. 119	90	153	7	277
C-501	70	190	22	287

Disease suscepitibility of cultivars

An assessment of the effectiveness of the CARDI disease control recommendations was carried out on a Mona variety trial, planted 15 November 1984. Nine cultivars were involved: ICG–1697, ICG–6330, ICG–7886, ICG–7898, Va Bunch G2, Florunner, Comet, NC–7, Local Valencia. The spray programme involved low volume application at recommended rates of the cocktail mixtures set out below:

	Days after planting	Insecticide	Fungicide	Sticker
1st Application	15	Basudin 40 WP	Daconil 2787 WP 75	Citomel
2nd Application	85	Sevin(1kg/ha)	Dithane M45 (2 kg/ha)	Gaispray

Daily monitoring (excluding weekends) of the disease complex was rated on the 9-point field scale.

Leaf spot appeared simultaneously in most of the plots occupied by each of seven of the nine cultivars being compared on the 83rd day after planting. At this stage none of the plots of either ICG–7886 or Florunner showed symptoms of this disease which was the sole disease that had appeared. Infection of the latter cultivars occured on the 88th day after planting. Rust was identified in Comet plots on the 90th day after planting but none of the other culticars suffered from the disease.

At 115 days after planting ICG–6330 and ICG–7886 were only slightly affected (point 2 on the 9-point scale). All the others including the Local Valencia rated 3 except Comet which was severely affected (5).

At harvest disease severity was moderate (3) for ICG–6330, ICG–7886 and the Local Valencia. Severe symptoms were recorded for all the others with Comet and NC–7 being very severely affected.

The season length (a) of a cultivar may be divided into two periods as follows:

- A disease-tree period (b) extending from the date of planting to the date of first appearance of diseases.
- A disease-infected period (a-b) extending from the date of first appearance to the date of harvest

The rate of build up of disease is represented by dividing the level of infestation at harvest (c) by the length of the period of infection (a-b). The value obtained for Local Valencia was rated as 100 and the value of other cultivars determined by comparison with the standard (see Table 5).

Using these criteria Comet was the most disease susceptible cultivar and ICG–7886 the least.

The disease-free period of 83 days after planting was exceptionally long in comparison to the usual 60 day period. This may be attributed to weed-free conditions in combination with the early preventitive pesticide application.

With the exceptions of Comet and ICG–7886, the level of infection increased with the season lengths of the cultivars (Table 5). The high level of disease in the case of the short season Comet is in keeping with its known high susceptibility to rust. In the case of the long season cultivar ICG–7886, the low level of disease severity at harvest shows that the cultivar was even less susceptible than Florunner which exhibited a similar delay of infection.

Table 5. Relative rate and accumulated build up of diseases in peanut planted in November 1984 at Mona, Jamaica.

Cultivar	Season length (days) (a)	Disease-free period (days) (b)	Disease-infected period (days) (a-b)	Total score of disease severity* at harvest (c)	Index of rate of disease build up [(c)/(a-b]	Relative rate of disease build up (Valencia=100)
Local Valencia	121	83	38	3	0.07	100
ICG-6630	116	83	33	3	0.091	115
Comet	121	83	38	7	0.184	233
ICG-7898	134	83	51	5	0.098	124
ICG-7886	134	88	46	3	0.065	82
Florunner	134	88	46	5	0.109	138
VB-G2	134	83	51	5	0.098	124
ICG-1697	149	83	66	5	0.076	98
NC-7	149	83	66	7	0.106	134

* ICRISAT Scale (1-9)

The significance of season length on cultivar selection

The time interval from planting to maturity is an important characteristic in determining a cultivar's suitability to an ecological zone.

The season lengths for eight cultivars planted at two contrasting sites at different times are shown in Table 6. With one exception, ICG–6920, season lengths on the Caymanas Sandy Loam were earlier than those for the same cultivars on the Maverley Loam. Yields also indicate a trend for each cultivar to perform better on the Caymans Sandy Loam compared to the Marveley Loam. Insufficient meterological data are available to explain this behaviour.

Table 6. Season length (days) of selected cultivars grown in trials at Mona and Lawrencefield, Jamaica.

	Planted Mona November, 1984 Marverly Loam 270m above sea level	Planted at Lawrence-field, January, 1985 Caymanas Sandy Loam, 30 m above sea level	Difference in season length (days)
NC-7	149	119	30
ICG-1697	149	123	26
Florunner	134	119	15
ICG-7886	134	123	11
ICG-7898	134	126	8
Local Valencia	121	108	13
Comet	121	119	2
ICG-6330	116	123	(1)

However, factors such as time of planting and temperature, as a result of difference in elevation, are involved. The warmer environment of the low lying Caymanas Sandy Loam appeared to have favoured earliness. Photoperiodism of peanuts has previously been observed in Jamaica. Spring planted Valencia (April/May) experiences a period of increasing temperature and day length with advent of summer. This combination of conditions appears to hasten maturity which usually occurs within 105 days of planting. Fall planted Valencia (September/October) on the other hand, experiences a period of declining temperature and shortening of day-length with the approach of the winter months. These factors combine along with adequate rainfall in October/November to cause postponement of maturity to 115 days. Higher yields also characterise this period. Increased season length means that land is tied up for a longer period, and this is ususally accompanied by increased cultivation costs as a result of the need for added plant protection measures. In general the erect bunch types have a shorter duration than the spreading types.

Thus the indigenous Valencia cultivar has proven popular as a reliable cash crop for small farms in Jamaica for the following reasons:

- Short season length (110 days) and drought resistance allow the cultivar to fit conveniently with reduced risk into the rotational production systems dependent mainly on natural rainfall.
- Considerable tolerance to late leaf-spot and rust assures some returns with no or minimal investment in expensive imported fungicides.
- Compact fruiting habit combines with the strongly aggregated condition of the major soil types – Red Bauxite (St. Ann Clay Loam), Brown Bauxite, (Chudleigh Clay Loam) and Newel Clay Loam – to facilitate hand reaping. Indeed with the widely scattered patches of peanut cultivation, mechanized harvesting would be uneconomical.

Conclusions and recommendations

Low yields of 1000kg dried nuts ha^{-1} characterise small farm production systems in Jamaica. Confirmed investigations indicate that considerable improvement in productivity will be obtained from the indigenous cultivar known as Valencia with the adoption of the technological practices recommended by CARDI. The yield potential of the indigenous cultivar appears to be limited to about 3000kg ha^{-1}

but at this level it is still the best performing Valencia market type examined to date. Upgrading this performance by selection of progeny of the plants with the highest pod count and exhibiting the greatest resistance/tolerance to the challenge of the local disease complex is an area rich for research.

Preliminary examination on research stations of over 100 selections received from ICRISAT and CRSP have already revealed several genotypes of superior yield potential and seed quality than the Local Valencia. A long term evaluation programme is essential to establish the order or merit of the more promising selections in major ecological areas in which peanut production is already or potentially important.

The order of merit or the appropriateness of a selection depends on a number of factors which will optimise utilisation of local resources, both human and capital. The higher yield potential of a cultivar is the prime consideration as it reduces the unit cost of production. However, high yields of improved cultivars can only be realised through high management inputs which include an integrated plant production programme and it is in this regard that selections with resistance/tolerance to the challenge of the local disease complex gain importance in reducing the cost of fungicidal control. Disease resistance/tolerance and cultural measures for pest control are particularly valuable and appropriate to Jamaica's production system due to the high cost of foreign inputs. Nevertheless, selection for disease resistance is merely complementary to the prime objective of increased yield, as high yielding cultivars can well afford to pay for added plant protection measures and still give increased returns to the farmer. Much research therefore needs to be done on the frequency of application of the improved pesticides now available to maximise returns to the farmer.

Season length of a cultivar is another important consideration that determines its suitability for Jamaica with its seasonal rainfall distribution. Short rainy periods favour short season length cultivars as being more in keeping with natural resources. Satisfactory production from long season cultivars will only be feasible in areas with supplemental irrigation.

For assessing the order of merit of cultivars, the criterion of kernel yield in kg per ha per 5-day period of growth is suggested as being most suitable for ranking perforamnce.

Contrasting socio-economic conditions, existing between the two major ecological areas identified as being particularly suitable for peanut production, suggest separate strategies for peanut expansion. In the low lying limestone zone of St. Elizabeth in which Valencia production is traditionally important, development would be better based on expansion of Spanish/Valencia market types. The preponderance of small farms in this zone makes employment benefits, at the size of individual farm enterprise, a significant factor of resource utilization. Higher labour efficiency is facilitated in the cultivation of erect bunch types and in their subsequent harvest. Furthermore, sloping topography causing difficulties for mechanisation with high efficiency, combine with the wide adaptability of small seeded cultivars to give support to the zoning of market types.

On the other hand, the predominant plantation system of land tenure associated with the other major ecological zones on the Southern Plains with alluvial soils and irrigation facilities, will more readily accommodate the large seeded Virgina/Runner market type. Economies of scale will be possible, and capital intensive technology involving the use of digger-shakers and combine harvesting will be required for profitability as the cost of hired labour in Jamaica is high in terms of its productivity. Under these conditions, the higher productivity per plant of spreading cultivars might be advantageous. Indeed, it is on the potential of this ecological zone for peanut production that success of significant industrial development depends.

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THE EVALUATION OF TOMATO VARIETIES IN ST. LUCIA

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ABSTRACT

Two trials were conducted during the period October 1984 to May 1985, to identify AVRDC tomato varieties that can yield reasonably high when grown during the hot wet season (off-season) and/or cool season (in-season) of the tropical lowlands. A total of 30 varieties were evaluated. The results showed that four open pollinated varieties, i.e. CL5915 – 229D4 – 1 – 1 – 0, CL5915 - 229D4 – 1 – 5 – 0, CL5915 – 136D4 – 1 – 0 and CL5915 – 222D4 – 0 - 4 - 0; and two hybrids, i.e. PT913 and PT1600 out-yielded the Caraibe, the best of the currently grown varieties. The highest yield of 43.99 t ha^{-1} came from CL5915 – 229D4 – 1 – 5 – 0. This yield was more than double of the Caraibe (19.15 t ha^{-1}). Yield difference was due to differences in fruit size and number of fruit plant^{-1}.

RESUMEN

Durante el periódo entre Octubre de 1984 a Mayo de 1985, dos experimentos fueron llevados a cabo con el objeto de evaluar variedades de tomate del AVRDC, de alta producción, esto cuando estuviesen plantadas o, durante la estacion calurosa y humeda (fuera de estación) o, durante la estación templada (en estación) de las zonas bajas tropicales. Un total de 30 variedades fueron evaluadas. Los resultados mostraron que habian cuatro variedades de pollinacion de cruce, ejemplo: CL5915 – 229D4 – 1 – 1 – 0; CL5915 – 229D4 – 1 – 5 – 0, CL5915 – 136D4 – 1 – 0 y CL5915 – 222D4 – 0 – 4 – 0 y dos variedades híbridas ejemplo: PT913 y PT1600, las cuales produjeron mas que la variedad Caraibe, la cuál es considerada como la mejor entre las que se plantan actualmente. La producción mas alta de la variedad CL5915 – 229D4 –1 – 5 – 0, fue de 43.99 t ha^{-1}. Esta producción fue mas del doble que la de la variedad Caraibe (19.15 t ha^{-1}). Las diferencias de rendimiento fueron debidas a una variacion en el tamaño del fruto y al número de frutos planta^{-1} .

Keywords: Tomato varieties, St. Lucia. Hot humid tropics.

Tomato is one of the most important crops in the Eastern Caribbean. It is planted all year round in the region and demand for the crop is high. But, generally, yields are low, particularly during the hot summer season. One of the main reasons for this is that fruit setting of the crop is hindered when temperatures are high (over 24 °C). To improve the situation, high yielding varieties with heat tolerant traits are being sought.

At present, the CARDI's Farming Systems Research and Development Project, in co-operation with the Asian Vegetable Research and Development Centre (AVRDC), is evaluating some of the heat tolerant and high yielding varieties introduced from AVRDC in comparison with the local checks. The objective of this project was to identify tomato varieties that can yield reasonably high during the hot wet season (off-season) and/or cool season (in-season). The paper reported here includes two experiments, one conducted on the CARDI's Field Station and the other on farmer's field.

Experiment I

The experiment was conducted at the field station at La Resource which is about 19km south-east of Castries. A randomised complete block design with three replications was used. Thirteen tomato varieties, i.e. TK70, TN2, TM103, PT778, PT858, PT862, PT913, PT1017, PT1599, PT3027 and three commonly grown varieties – Calypso, Caraibe and Indian River, representing treatments, were evaluated.

Seedling preparation

Nursery soil, enough for 13 flats, (8.0cm x 32.0cm inside dimension), was prepared by thoroughly mixing (1: 2 ratio by volume) of Irish peat moss to moist soil with 23.4g ammonium sulphate, 39.0g of triple superphosphate and 23.4g of potassium chloride. The flats were then filled with the soil and dibbled to make 54 (6 x 9) planting holes per flat. Two seeds per hole of each variety were sown in the flats on 22 October, 1984. The flats were kept in the field and covered with nylon net. Water was given when necessary. Ten days after emergence, the seedlings were thinned to render one plant per hole. They were raised until most of them had five true leaves.

Field Planting

Since the field was rotavated long before the seedlings could be transplanted, it was heavily covered by grasses. About two weeks before transplanting, paraquat was applied to the field to take care of the grasses. Later, raised beds of 0.7m x 11m in area and 0.4m high were constructed manually. The beds were separated by furrows of 0.5m wide. Individual beds were divided into three plots each 3m long with two 1m walkways separating the plots.

Each plot received 180g ammonium sulphate, 115g triple superphosphate and 48g potassium chloride as basal fertilizer, which was mixed into the soil three days before transplanting. Twenty-eight – day-old seedlings were transplanted onto the plots on 19 November, 1984, forming one row per plot and spaced at 0.3m within row. The plants received two additional sidedressings each of 100g of ammonium sulphate and 33g of potassium chloride per plot. Diseases and insect pests were controlled by spraying Maneb and Basudin every ten days. Weeds were controlled manually and irrigation was supplied using tap water. The crop was harvested weekly from 11 January to 22 February, 1985.

Experiment II

This experiment was conducted on a farmer's field at Grande Riviere in the Northern part of the country. A total of 21 varieties were evaluated. This included the three highest yielders from the first experiment, i.e. PT858, PT862, and PT913 along with new heat tolerant material from AVRDC.

i.e. CL113–0–0–7–2–0–11
CL5915–371D4–1–2–0
CL5915–314D4–1–1–0
CL5915–153D4–3–6–0
CL5915–206D4–2–5–0
CL5915–206D4–2–1–0
CL5915–223D4–2–1–0
CL5915–229D4–1–5–0
CL5915– 39D4–1–4–0
CL5915–204D4–1–2–0
CL5915–229D4–1–1–0
CL5915–223D4–3–2–0
CL5915–136D4–1–0
CL5915–223D4–3–1–0
CL5915–223D4–2–2–0
CL5915–222D4–0–4–0
CL5916–214D4–1–4–0

and a recommended variety Caraibe, which was the highest yielder among the recommended varieties evaluated in the first trial. The experiment was carried out in a randomised complete block design with two replications.

Seedling preparation

Seedling preparation was the same as that of Experiment 1, except that Irish peat moss was not used. Seeds were sown in flats on 22 February 1985.

Field planting

Four raised beds, each of 1.5m x 24.2m in size, were used. The beds were separated by furrows 34cm wide and 45cm deep. One week before transplanting, each bed received 23kg of dolomitic lime and 900g of complete fertilizer 16:8:24 as a basal application. Individual beds were then divided into 11 small plots 1.5m x 1.6m in size. The plots were separated by walkways 60cm wide.

Twenty-four day-old seedlings were transplanted onto the plots on 17 March 1985, forming two rows per plot and spaced at 40cm within row and 100cm between rows. Each plot accommodated eight plants. On 29 April, each plant received 20g of complete fertilizer 16:8:24 as a sidedressing application. Fungicide (Maneb) and insecticides (Ambush and Kelthane) were applied twice on 29 March and 14 April. Weeding was done manually, and sprinkler irrigation was administered when necessary. The crops were harvested four times on 5, 11, 16, and 21 May.

Results and discussion

Experiment I

Percipitation during the period of the experiment was very minimal, therefore, the soil was very dry. Although irrigation (from tap water) was administered, the plants wilted most of the time, especially in the afternoon. This resulted in stunted and unhealthy plants. The temperature during the growing period ranged from 23.5 to 30.5°C, with an average mean monthly temperature of 27.1°C.

Table 1 shows some horticultural characteristics, i.e. plant height and days to 50% flowering, of the different tomato varieties. PT913 and PT1017 were the tallest at early growth (three weeks after transplanting; 3 WAT) and PT1599 and Calypso the shortest. Height differential pattern during the fourth week (4 WAT) was similar to that at 3 WAT. At 5 WAT, Caraibe was as tall as PT778 and PT1017, while TK70 and TN2 were the shortest. Varieties that reached 50% flowering earliest were TM103, TK70, PT778, PT858 and PT1017. TN2, Calypso, PT1599 and PT3027 reached 50% flowering the latest.

Table 1 Horticultural characteristics of tomato of different varieties grown during the dry season at La Ressource, St. Lucia.

	Plant height (cm)			Days to 50% flowering
	3WAT	4WAT	5WAT	(DAT)
Indian River	32.6	36.2	44.7	25
Calpyso	19.7	31.5	41.7	29
Caraibe	23.3	34.1	45.3	24
TK70	20.5	29.7	37.0	23
TN2	20.5	29.3	38.0	30
TM103	25.1	39.6	47.3	22
PT778	25.3	34.3	53.3	23
PT858	23.3	36.1	47.3	23
PT862	26.5	40.3	52.0	24
PT913	28.3	43.1	56.0	24
PT1017	28.0	42.4	52.7	23
PT1599	19.7	30.7	44.7	29
PT3027	21.0	30.7	42.7	29
L.S.D. (0.05)	3.2	6.9	9.7	1.6
(0.01)	4.3	9.3	13.1	2.2

WAT = Weeks after transplanting
DAT = Days after transplanting

Yield and yield attributes are shown in Table 2. Varieties which yielded higher than the best local check, Caraibe, were PT913 and PT1017. The highest yielder was PT913, which had a yield of 14.39 $t.ha^{-1}$. The lowest yields of 2.93 and 3.23 $t.ha^{-1}$ were from Indian River and Calypso, respectively.

Table 2 Yield and yield attributes of tomatoes of different varieties grown during the dry season at La Ressource

Varieties	Yield (t/ha)	Fruit size (g/fruit)	Fruit number /plant
TK70	6.33	39.7	5.3
TN2	4.25	34.4	4.6
Indian River	2.93	42.2	2.4
Calypso	3.28	42.3	2.8
Caraibe	7.02	43.7	5.7
TM103	7.29	34.5	8.1
PT778	8.61	38.5	8.1
PT858	9.28	50.1	6.8
PT862	10.41	44.5	8.5
PT913	14.39	27.0	19.1
PT1017	13.11	29.9	15.8
PT1599	8.44	35.1	8.7
PT3027	10.28	32.0	11.4
L.S.D. (0.05)	4.04	10.4	4.1
(0.01)	5.44	14.2	5.0

The two popular cultivars in Taiwan, TN2 and TK70, did not yield better than the local checks. Lack of a heat tolerant trait in the two cultivars may cause them to perform poorly in the tropical lowlands. Yield difference was due to differences in fruit size and number of fruits plant^{-1}. Although PT913 and PT1017 had the smallest fruit size, they had the highest number of fruits plant^{-1}, hence the highest yields. Large fruit sizes were from PT858, PY862, Caraibe, Calypso, and Indian River. PT858 had the largest fruit size of 50.1g fruit^{-1}.

The results showed that Caraibe yielded better than the other two local checks, although not significantly. This is due mainly to more fruits plant^{-1}. The results also indicated that those varieties which showed no apparent wilting like PT1017 and PT913, had the smallest fruit sizes and gave the highest yields. Based on yield performance, the following varieties were kept for further trial: PT913, PT1017, PT858, PT862 and PT3027.

Experiment II

The mean monthly maximum temperatures during the growing period ranged from 28.2 to 29.4 °C, whereas the mean monthly minimum temperatures ranged from 21.0 to 22.7 °C.

Unlike the first experiment, water was not a limiting factor of this trial, hence growth was very vigourous. The heights of the crop measured at 29 days after transplanting (DAT) are presented in Table 3. There was no statistical difference in plant height between Caraibe and most of the varieties under test. Varieties PT858, PT862, PT913, PT1600, CL5915–206D4–2–5–0, and CL5915–229D4–1–5–0, were statistically different from Caraibe in plant height. The tallest plant of 64.6cm was CL5915–206D4–2–5–0, which was the indeterminate type, and the shortest (43.8cm) was CL5915–341D4–1–1–0.

Late blight was a serious problem for this trial, although fungicide (Maneb) was applied. This may be due to the inadequate application of the fungicide (only two applications were made throughout the growing period). The disease incidence was first observed during the first week of May and its severity was rated on 7 May, as shown in Table 4. Obviously there were differential tolerant levels among the various varieties. Those rated zero were seriously affected by the disease and some of them were dying, such as CL5915–314D4–1–1–0, CL5915–39D4–1–4–0, PT858, and PT862. The best among the moderately tolerant group (rated 3) were PT913, CL5915–229D4–1–5–0, CL5915–136D4–1–0, and CL5915–222D4–0–4–0.

Table 3 Heights of tomatoes of different varieties at 29 days after transplanting, Grand Rivere, St. Lucia.

Variety	Height (cm)
PT858	60.8
PT628	65.8
PT913	55.5
PT1600	58.9
CL1131-0-0-7-2-0-11	52.0
CL5915-371D$_4$-1-2-0	53.8
CL5915-341D$_4$-1-1-0	43.8
CL5915-153D$_4$-3-6-0	50.0
CL5915-206D$_4$-2-5-0	64.6
CL5915-206D$_4$-2-1-0	54.6
CL5915-223D$_4$-2-1-0	54.8
CL5915-229D$_4$-1-5-0	56.8
CL5915-39D$_4$-1-4-0	46.7
CL5915-204D$_4$-1-2-0	49.3
CL5915-229D$_4$-1-1-0	50.8
CL5915-136D$_4$-1-0	54.6
CL5915-223D$_4$-3-1-0	50.8
CL5915-223D$_4$-2-2-0	48.4
CL5915-222D$_4$-0-4-0	47.5
CL5916-214D$_4$-1-4-0	51.5
Caraibe	46.5
L.S.D. (0.05)	8.9
(0.01)	12.2

Number of fruits from different harvests are presented in Table 5. All varieties, except PT913, CL5915–153D4–3–6–0, CL5915–223D4–3–1–0, CL5915–223D4–2–2–0, had their first harvest before the check – Caraibe. In general, more fruits were obtained from the third and fourth harvests than from the first two harvests. Most of the varieties gave higher numbers of fruits than Caraibe, except PT858, PT862, CL5915–371D4–1–2–0, CL5915–314D4–1–1–0, CL5915–206D4–2–5–0, CL5915–206D4–2–1–0, CL5915–223D4–2–1–0, and CL5916–214D4–1–4–0. The most prolific varieties in terms of fruit numbers were CL5915–222D4–0–4–0, CL5915–136D4–1–0, CL5915–229D4–1–5–0, CL5915–229D4–1–1–0, and PT913.

The size of the tomato fruits varied considerably with varieties and time of harvest (Table 6). Most of the varieties gave decreasing fruit sizes in succeeding harvests. The largest fruit came from the first harvest and the smallest from the fourth harvest. From every harvest, Caraibe gave the largest fruits i.e. 114.5, 125.2 and 73.8g fruit^{-1} for the second, third and fourth harvests, respectively.

Table 4 Rating of severity of late blight infestation on tomatoes of different varieties grown at Grand Riviere, St. Lucia.

Rating scale			
0	1	2	3
PT858	PT1600	CL1131-0-0-7-2-0-11	CL5915-153D_4-3-6-0
PT862	CL5915-204D_4-1-2-0	CL5915-206D_4-2-5-0	CL5915-229D_4-1-5-0
CL5915-371D_4-1-2-0	CL5915-223D_4-2-2-0	CL5915-223D_4-2-1-0	CL5915-229D_4-1-1-0
CL5915-314D_4-1-1-0	Caraibe	CL5915-223D_4-3-1-0	CL5915-136D_4-1-0
CL5815-206D_4-2-1-0			CL5915-222D_4-0-4-0
CL5915-39D_4-1-4-0			PT913
CL5915-214D_4-1-4-0			

0 - Severely affected

5 - not affected

Table 5 Number of fruits from various harvests of tomato of different varieties grown at Grand Riviere, St. Lucia.

Variety	Harvest (no/plant)				
	1st	2nd	3rd	4th	Total
PT868	14.5	18.5	27.5	3.5	64.0
PT628	20.0	32.0	31.0	22.5	105.5
PT913	N	12.0	60.5	169.0	241.5
PT1600	9.5	32.0	38.5	99.5	179.5
CL1131-0-0-7-2-0-11	12.0	36.5	50.0	110.5	209.0
CL5915-371D_4-1-2-0	17.0	9.0	22.0	60.0	108.0
CL5915-314D_4-1-1-0	14.6	58.0	54.0	N	126.6
CL5915-153D_4-3-6-0	N	21.3	60.6	121.3	203.2
CL5915-206D_4-2-5-0	1.0	12.5	20.5	62.5	96.5
CL5915-206D_4-2-1-0	3.5	15.5	28.0	40.0	87.0
CL5915-223D_4-2-1-0	0.5	19.5	38.0	64.5	122.5
CL5915-229D_4-1-5-0	3.0	36.0	79.5	121.0	239.5
CL5915-39D_4-1-4-0	18.5	42.0	60.0	16.0	136.5
CL5915-204D_4-1-2-0	14.5	23.5	54.5	96.0	187.5
CL5915-229D_4-1-1-0	8.5	53.5	97.5	75.5	235.0
CL5915-136D_4-1-0	18.0	56.0	78.0	131.0	283.0
CL5915-223D_4-3-1-0	N	12.0	54.0	99.0	165.0
CL5915-223D_4-2-2-0	N	19.4	44.0	85.4	148.8
CL5915-222D_4-0-4-0	29.0	55.5	96.5	120.5	301.5
CL5916-214D_4-1-4-0	16.5	22.0	36.0	20.0	94.5
Caraibe	N	3.0	20.0	36.0	59.0
L.S.D. (0.05)	8.0	15.0	30.0	57.1	72.8
L.S.D. (0.01)	11.0	20.4	42.0	77.8	99.2

N = No harvest

Table 6 Fruit sizes from various harvests of tomato of different varieties grown at Grande Riviere, St. Lucia.

Variety	Havest (g/fruit)			
	1st	2nd	3rd	4th
PT858	122.0	81.6	56.6	78.6
PT628	72.7	67.8	53.2	45.8
PT913	N	57.2	48.2	31.2
PT1600	84.1	81.8	62.0	42.8
CL1131-0-0-7-2-0-11	52.4	49.1	33.8	25.8
CL5915-371D_4-1-2-0	42.1	41.6	44.4	42.1
CL5915-314D_4-1-1-0	46.7	39.2	27.8	N
CL5915-153D_4-3-6-0	N	27.2	45.2	35.0
CL5915-206D_4-2-5-0	125.0	108.6	84.2	53.1
CL5915-206D_4-2-1-0	128.6	94.7	79.8	57.8
CL5915-223D_4-2-1-0	150.0	67.6	50.4	39.0
CL5915-229D_4-1-5-0	83.3	73.2	57.9	43.6
CL5915-39D_4-1-4-0	61.2	54.8	34.8	25.8
CL5915-204D_4-1-2-0	45.7	46.8	40.0	31.4
CL5915-229D_4-1-1-0	82.2	64.6	45.0	34.8
CL5915-136D_4-1-0	62.2	52.8	43.9	33.6
CL5915-223D_4-3-1-0	N	64.6	53.1	36.2
CL5915-223D_4-2-2-0	N	71.5	58.0	42.6
CL5915-222D_4-0-4-0	49.2	44.2	35.8	31.5
CL5916-214D_4-1-4-0	69.6	72.2	54.4	45.5
Caraibe	N	114.5	125.5	73.8
L.S.D. (0.05)	NS	33.9	17.5	28.9
L.S.D. (0.05)	NS	46.2	23.8	NS

No -No harvest

Yield and yield attributes are presented in Table 7. Yields were highly significantly different among the varieties evaluated. There were five varieties which out-yielded Caraibe statistically. These varieties were PT1600, CL5915–229D4–1–5–0, CL5915–229D4–1–1–0, CL5915–136D4–1–0, and CL5915–222D4–0–4–0, which gave the yields of 34.46, 43.99, 38.74, 40.83 and 38.92 t. ha^{-1}, respectively. Yield from Caraibe was only 19.15 t. ha^{-1}. PT858 and PT862, which were two of the best varieties in Experiment 1, did not yield better than Caraibe. In addition, they were susceptible to Fusarium wilt, (PT858) and Blossom end rot (PT762). The small fruit size tomato, PT913, yielded reasonably well (30.54 t. ha^{-1}), although not significantly better than Caraibe. Yield differences were due to differences in fruit size and number of fruits $plant^{-1}$. All of the five best yielders and PT913 had more fruits $plant^{-1}$ than Caraibe, although they had smaller fruit.

Based on yield performance and disease resistance, the following varieties will be kept for further evaluation: PT913, PT1600, CL5915–229D4–1–5–0, CL5915–229D4–1–1–0, CL5915–222D4–0–4–0 and CL5915–136D4–1–0. The differential responses of varieties during different planting times indicates that these new varieties will have to be tested for several seasons in order to arrive at firm recommendations for farmers.

Table 7 Yield and yield attributes of tomato of different varieties grown at Grand Riviere, St. Lucia

	Yield	Yield attributes	
		Fruit size	Number of fruits/
	(t/ha)	(g/fruit)	plant
PT858	18.34	81.5	8.0
PT628	21.56	59.1	13.2
PT913	30.54	36.6	30.2
PT1600	34.46	57.2	22.4
CL1131-0-0-7-2-0-11	24.04	33.5	26.1
CL5915-371D_4-1-2-0	15.72	42.4	13.5
CL5915-314D_4-1-1-0	15.29	35.1	11.9
CL5915-153D_4-3-6-0	27.16	38.7	19.1
CL5915-206D_4-2-5-0	22.21	67.8	12.1
CL5915-206D_4-2-1-0	22.44	73.3	10.9
CL5915-223D_4-2-1-0	20.12	42.9	15.3
CL5915-229D_4-1-5-0	43.99	53.5	29.9
CL5915-39D_4-1-4-0	20.48	43.6	17.1
CL5915-204D_4-1-2-0	23.67	37.1	23.4
CL5915-229D_4-1-1-0	38.74	47.9	29.4
CL5915-136D_4-1-0	40.83	41.8	35.4
CL5915-223D_4-3-1-0	25.18	44.2	20.6
CL5915-223D_4-2-2-0	26.00	50.9	13.9
CL5915-222D_4-0-4-0	38.92	37.0	37.7
CL5916-214D_4-1-4-0	19.06	58.8	11.8
Caraibe	19.15	94.9	7.4
L.S.D. (0.05)	13.75	11.4	9.1
L.S.D. (0.01)	18.76	15.5	12.4

THE EFFECT OF PLASTIC COVER ON TOMATO GROWTH IN THE RAINY SEASON

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ABSTRACT

Using tomatoes as the test crop, field experiments were conducted during the rainy season in 1981–84 to evaluate the usefulness of: (a) plastic bags placed individually over each plant, (b) black plastic mulch and (c) plastic covered sheds. It was found that the plastic bags over each plant increased vegetative growth but retarded fruiting, thus depressing yield. (b) and (c) either had no significant effect or they both equally increased yield. Wet season yields from the same field could be as low as 13% of the dry season yield.

RESUMEN

Experimentos de campo usando el tomate como el cultivo experimental, se llevarón a cabo durante la estación de lluvias en los años 1981–84, con el objeto de evaluar la utilidad de lo siguiente: (a) bolsas plásticas colocadas individualmente sobre cada una de las plantas, (b) plástico negro alrededor de las plantas, (c) cobertizos cubiertos de plástico. Se encontró que las bolsas plasticas colocadas sobre cada una de las plantas incremento el crecimiento vegetativo pero, retardo la fructificacion, por lo tanto el rendimiento fue menor. Los puntos b) y c) o no tuvieron un efecto significativo, o ambos de los usos incrementaron la producción, igualmente. Los rendimientos del mismo terreno, durante la estación de lluvias, fueron a veces menos en un 13% que el de los obtenidos durante la estación de sequia.

Keywords: Tomato, Wet season production, Plastic covers.

The large price increases of vegetables normally experienced during the wet season are an indicator of the low yields obtained. This is particularly true of tomato which is the most popular vegetable grown in the Caribbean.

The major factors limiting its growth in the wet season have been identified as: (i) high minimum temperature, usually 21 °C, which is too high for fruit set in most imported varieties; (ii) high humidity coupled with high temperature leading to greater incidence of pest and disease damage; (iii) adverse effects of temperature on metabolism; (iv) prolonged cloudy periods which reduce photosynthetic activity and (v) heavy rainfall which can cause damage to young shoots and flowers (Charles, 1981).

Of the five factors, probably the adverse effects of heavy rainfall are most amenable to control. Wilson (1979) showed that mulching and fertilization can significantly increase yield.

Increasing the yield of tomatoes in the wet season has become a major preoccupation in Trinidad. Farmers are constantly asking for advice on improving yields. Therefore, data on the simplest systems to the most sophisticated are needed.

The experiments reported here are the first in a series to be conducted to acquire such data. Only the simplest methods of controlling the effects of heavy rainfall were considered:

(a) covering each plant individually with plastic and

(b) covering the soil either with a plastic mulch or with a clear polythene covered shed.

Materials and methods

Between late 1981 and 1984 a total of five experiments were conducted. Experiments I, and III–V were conducted at El Carmen Experiment Station, Centeno. The soil is classified as an Aquatic Eutropept (USDA classification), and is a fine sandy clay with restricted drainage and shallow rooting depth. Experiment II was conducted at La Pastora Demonstration Station, Santa Cruz where the soil is classified as a Fluventic Eutropept (USDA classification); a fine sandy loam, free draining and having moderate rooting depth.

In Experiment I, clear plastic bags (120cm x 69cm) were used to cover each tomato plant. Three covering intervals were used: (a) at planting, (b) at first flowering and (c) at first fruiting. The control treatment had no cover. Six replicates were used in a completely randomised design.

Experiments II–V were all similar in that either a black plastic mulch or sheds covered with ordinary clear plastic were used to cover the whole plot. The plack plastic was laid over the plot and at suitable invervals, holes were made to plant the seedlings. The sheds were 3m x 1m and 2m high, two being used per plot. Only the top half of each shed was covered with plastic to allow for ventilation and comfort whilst working.

The treatments for Experiments II–V were (i) no cover, (ii) black plastic mulch and (iii) plastic sheds. These treatments were replicated three times.

Three-week old seedlings of tomato variety, Walter were used at a planting density of 32,000 plants ha^{-1} for all experiments. This variety is considered to be well suited to wet season conditions. All plants were staked. In all five experiments, basal fertiliser (13:13:20) was applied at the rate of 1200 kg ha^{-1} in three, split applications. Dymid (N–N, dimethyl–2–2–diphenyl acetamide) was applied at 5–10 kg ha^{-1} to the weed-free area and this was followed by Toxiphene EC45 (chlorinated camphene) at the rate of 7.4g l^{-1}.

Results and discussion

Experiment I

The rainfall during this experiment was 451mm.
Table I gives details of the yields of tomato obtained in Experiment I. No statistically significant differences, at the 5 per cent level, were found. The tomato plants were healthy throughout, only slight indications of bacterial wilt *(Pseudomonas solanacearum)* and blossom-end rot being found towards the end of the experiment.

Table 1 Mean yields of tomato plants covered individually with plastic bags at El Carmen. November 1981 - March 1982

Treatment	Yield per plant (g)	Estimated yield ha^{-1}
No cover	436	13,968
Covered at planting	231	7,398
Covered at flowering	450	14,390
Covered at fruiting	380	12,154
L.S.D. 0.05	346	

The lowest yield obtained was from plants covered at planting. This was due to retardation in fruit set and smaller fruit size. These plants grew very tall. There were two harvests. In the first harvest only one plot in this treatment had harvestable fruit; in the second, four out of the six plots had fruit.

The effect of temperature on fruit set and flowering is well known. Aung (1978) showed that temperatures of 26–30°C can increase vegetative growth and delay flowering.

An important factor in all the experiments was seedling survival after transplanting. A maximum of 50 per cent of the seedlings first planted survived to produce fruit.

It would seem from the results of this experiment that covering individual plants with a plastic bag has little or no advantage.

Experiment II

The rainfall recorded at La Pastora during the experiment was 354.8mm.

The yields obtained in this experiement are presented in Table 2. This field is well known to be infected with nematodes and the yields reflect this. There was wide variation not only between treatments but for plots of the same treatment.

Table 2 Mean yields of tomato plants grown on plastic mulch or under plastic shelters at La Pastora. November 1982-March 1983

Treatment	Yield per plant (g)	Estimated yield (kg/ha)
No cover	438	13910
Black Plastic mulch	1105	35376
Polythene sheds	716	22915
LSD 0.05	750	

Of the four replicates only one produced any fruit in the control treatment. This can be attributed in part of the adverse effects of heavy rainfall.

All the mulched plots produced fruit for three out of four harvests. In the fourth harvest only one plot had fruit. The plots covered with sheds had fruit in all four harvests. In this case, however, they were fewer and/or smaller than those in the mulch treatment.

Although the differences between the total yields for each treatment are large, they are not statistically significant at the 5 per cent level. It appears that the incidence of nematodes and/or other factors had a greater effect on yield than the treatments. It will require further investigation to elucidate the factors involved.

Experiments III–V

The yields obtained in Experiments III and IV were considerably depressed compared with those in Experiments I and V. In Experiment III this can be attributed to the much heavier rainfall since this soil is liable to waterlogging. Few plants produced fruits. There was little incidence of disease.

Analysis of the derived data to $\log_{10}$ from Experiment IV showed that the differences between the control and the two types of cover are significant at the 5 per cent level. Both mulching and covering with a shed increased yields to the same extent. This is the only experiment in which there was a statistically significant difference between yields. The yield in the control plot in Experiment IV was the lowest of the whole series of experiments.

Experiment V, is essentially, a dry season experiment conducted to give base data for all the other experiments conducted on this site. Comparison of the mean yields over all treatments in experiments III and V shows that the wet season yield can be as low as 13 per cent of the dry season yield. Therefore, there is considerable room for improvement.

Table 3 Rainfall and mean yields of tomato plants grown on plastic mulch or under plastic at El Carmen, 1983-1984

			Yield (kg/ha)			
Expt.	Period	Rainfall	Control	Mulch	Shed	LSD 0.05
III	6/83-10/83	1420.3	1868	1855	2554	1431
IV	11/83-1/84	684.0	756	3288	3726	3710
V	4/84-7/84	377.1	15271	15042	18292	8989

The evidence that black plastic mulch and clear polythene sheds as covers improve yield in the wet season is not conclusive. In one experiment only, out of four, did they increase yield significantly. Wilson (1978) and Horavitch and Churata-Masca (1982) showed that mulching with organic and plastic mulches, respectively, increased yield. It is not possible from the results of these experiments to say which type of cover, mulch or shed, would be the more beneficial.

Conclusions

1. Covering individual tomato plants with plastic bags had little or no effect on tomato yields.

2. Mulching with black plastic or polythene covered sheds only increased yields significantly in one experiment out of four.

3. Wide variation in yield obscured any differences due to the type of cover. The causes of these variations need further investigation, e.g., incidence of disease and the effect of temperature on flowering and fruit set.

References

Aung, L. H. (1978). Temperature regulation of growth and development of tomato during ontogeny. *1st International Symposium on Tropical Tomato.* AVRDC, Taiwan.

Charles, W. B. (1981) *Tomatoes.* Crop Bulletin **1 – 10,** Ministry of Agriculture, Lands & Food Production, Trinidad.

Horavitch, P. and Churata-Masca, M.G.C. (1982). Effects of support systems and mulches on tomatoes of determinate growth for fresh market. *Proc. Trop. Region, Am. Soc. Hort. Sci.* **25,** 457–459.

Wilson, G. F. (1978). The effects of *in-situ* mulch on tomato production. *1st International Symposium on Tropical Tomato.* AVRDC, Taiwan. 1978.

MECHANICAL PLANTING AND HARVESTING ON PLASTIC MULCHED BEDS

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ABSTRACT

Plastic mulches have many advantages for agriculture; however, their use was limited until compatible mechanized planting methods were developed for mulch. Mechanical methods for transplanting or seeding before or after mulch applications are discussed. Transplanting of containerized plants, including use of the water-wheel planter and sowing of ungerminated, pre-germinated, dry-coated, gel-coated or uncoated seeds using plug-mix, gel and gel-mix planters are described. Experimental mechanical and semi-harvesters were evaluated for market tomato harvests in Florida in the early 1970s; processing harvesters were modified to harvest market tomatoes from mulched beds in the mid-1970s and a few years later mechanical harvesters were used to harvest pineapples from mulched bed systems in Hawaii. Muletrain type and conveyor belt harvest aids were easily adapted to harvest from mulched beds.

RESUMEN

Los, abonos vegetales plásticos ofrecen muchas ventajas para la agricultura. Sin embargo, se utilizaron de manera manera limitado hasta que se desarrollaron unos métodos de plantación mecanizados que se podían utilizar con los abonos vegetales. Se examina los métodos mecánicos de transplantación o de siembra, tanto antes como después de la aplicación del abono vegetal. Se describe la transplantación de plantas en recipientes, incluídos el uso de la plantadora de tipo rueda hidráulica y la siembra de semillas no-germinadas, pre-germinadas, tratadas en seco, tratadas con gel o no-tratadas, utilizando las plantadoras de tipo plug-mix, gel y gel-mix. A principios de los años 70, se evaluó las segadoras mécanicas y semi-segadoras experimentales para la cosecha de tomates destinados a los mercados de Florida. A mediados de los años 70, so modificó las segadoras preparadoras existentes afin de poder tratar los tomatos procedentes de semilleros tratados con abono vegetal. Unos años más tarde, se utilizó segadoras mecánicas en Hawaii para cosochar piñas procedentes de semilleros tratados con abono vegetal. Se adaptó fácilmente los equipos auxilares de cosecha de tipo caravana y correa transportadora para cosechar los frutos procedantes de semilleros tratados con abono vegetal.

Keywords: Water-wheel; Punch planter; Plug-mix; Gel; Gel-mix.

Plastic mulch has been a sound investment for many horticultural enterprises in humid, tropical and temperate areas. After plastic film mulches were perfected for agriculture, commercial application was minimal until effective mechanized systems were developed to transplant or sow seeds through the film.

Transplanting

Convential types of transplanters were used to plant before mulch application and plant tops were pulled through holes cut in the film by hand, shortly after mulch was applied. This required extensive hand labour and plant heat stress occured during hot days when plant tops were under the film too long. Transplanters with cups to punch planting holes through plastic, developed by Holland Transplanters Company and Mechanical Transplanter Company improved efficiency and eliminated the probelm of heat stress. A grower designed water-wheel transplanter was a metal wheel, resembling a tire, with holes spaced around the circumference of the wheel, corresponding to the plant spacing desired. A wedge with open sides was attached outside the wheel over each hole. As the wedge rolled to a down position, a planting hole was punched through the plastic. At the same time, water, which was continually supplied to the inside of the wheel flooded the planting hole and settled the soil around roots of the transplant placed in the hole by hand by someone riding behind the planter wheel. This system is effective for transplanting as well as for planting seed-peat-lite mixtures.

A dibbling transplanter was designed and tested at the University of Florida Agricultural Engineering Department in 1984. It is a high speed automatic transplanter capable of working through plastic mulches, with wide plant spacing, using commercial containerized seedlings. This machine has a transplanting mechanism which should provide; high speed cycling (over 130 plants/minute); prolonged acceptance movement compatible with automatic feeding of the seedlings; extended deposition movement capable of placing the seedlings through plastic mulch while maintaining zero relative velocity; and gentle and precise handling of the seedlings. At present further work is required on the design of (1) an appropriate feeding device; (2) a synchronous drive system and (3) a method to vary plant spacing.

Seeding

A machine was designed by an Israeli Company (Teotechnic) in the late 1970s to sow seeds in clumps with a convential planter, followed by plastic mulch with holes burned in the plastic and synchronized to match the seed clumps just planted. This planter could not be used with fumigants because of the timing of the sowing and the holes placed in the film at the time of application.

A system was needed to sow seeds through plastic. After extensive research by hand planting methods a plug-mix system was developed that involves incorporation of crop seed and water into a mixture of peat moss and vermiculite with nutrients. A plug-mix planter was designed to mechanically plant the plug-mix through plastic mulch. The use of mulch for tomato production on the calcareous soils of South Florida expanded two fold each year after a demonstration in 1974 convinced L & D Farms to

use the new planter.

Pre-germinated seed has the potential to produce more uniform seedling emergence. Though fluid drill planters for sowing on soil without mulch were developed in the mid 1970s none were designed for mulch until 1979, when a Canadian firm developed the Skipper model K–1–G6 electronic gel seeder for mulched beds with equipment to deposit anticrustant over the gel-seed mixture. The electronic seeder mechanism caused problems unless certain engine rpm were maintained, thus the seeder was modified to function mechanically.

Fluid drilling Ltd. in England developed, the model 567 mulch planter with a stainless steel hole punch wheel which was effective on sandy soils. Mays Farms modified the 567 planter by adding a peat-lite dispenser, brushes to move media into plant holes and water to wet the peat-lite media. The hole punch was not effective on rock soil.

THE RESPONSE OF TWO SHORT-DAY ONION CULTIVARS TO CURING WITH SOLAR RADIATION IN PLASTIC TUNNELS

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ABSTRACT

Short-day onion *(Allium cepa L)* production in Florida is limited mainly by poor keeping quality associated with inadequate curing. Curing is a drying process which removes about 5% of the water. A plastic tunnel accumulated heat from solar radiation, which raised air temperatures, lowered relative humidity, promoted drying and protected the bulbs inside the tunnel from rain. Curing efficiency was determined by weight loss, shelf life and quality of bulbs of 'Yellow Granex 33' ('Granex') and 'Texas Grano 502' ('T.G. 502') grown in organic (muck) and mineral (sand) soils and cured in windrows and plastic tunnels. Both 'Granex' and 'T.G. 502' had good appearance and quality after curing, particularly when grown in sand. Weight loss of 'Granex' was 5.5% and 'T.G. 502' 7.5% after 25 days of curing. 'Granex' had 6.4% and 'T.G. 502' 24.3% decay after 51 days of room temperature storage. Muck and sand grown onions had the same weight loss during curing, but after 51 days of storage, onions grown in sand had less weight loss and decay than those grown in muck. Windrowed onions lost 9.2% weight and tunnel cured onions 3.8% in 25 days curing. Tunnel cured onions had significantly more decay than windrowed onions at the end of 51 days of storage. Interactions among cultivars x soils x methods of curing were found to be significant. Yield, keeping quality and appearance were maximized when 'Granex' was grown in sandy soil and cured in plastic tunnels or windrows when no rain occurred. Regression analysis indicated a relationship between weight loss and time. 'Granex' required 11 days and 'T.G. 502' six days of windrow curing to attain 5% weight loss. 'Granex' reached 5% weight loss in 22 days and 'T.G. 502' in 11 days when cured in the tunnel. This suggests that a monitoring process is needed to ascertain when 5% weight is attained.

RESUMEN

La produccion de cebolla *(A. cepa L.)* de corto día en Florida se limita mayormente por la corta vida poscosecha asosciada con curación inadequada. Curación es un proceso desecativo que elimina alrededor de 5% del agua. Un tunel. de polictileno acumuló calor de radiación solar, que subió las temperaturas del aire, bajó la humedad relativa, fomentó secamiento y protejó los bulbos dentro del tunel de la lluvia. Eficiencia de curación fue determinado por disminución de peso, duración de vida poscosecha y calidad de bulbos de 'Yellow Granex 33' ('Granex') y 'Texas Grano 502' ('T.G. 502') cultivados en suelos organicos (muck) y minerales (arena) y curados en amontonamientos a aire libre o en tuneles de plastico. 'Granex' y 'T.G. 502' tenían buena apariencia y calidad después de curación, particularmente cuando fueron cultivados en suelo arenoso. Después de 51 dias de curación la disminución de peso de 'Granex' era 5.5% y la de 'T.G. 502' era 7.5%. Después de 51 dias de almacenamiento a temperaturas medianas, 'Granex' sufrió 6.4% de pudrición, y 'T.G. 502' sufrió 24.3% de pudrición. Cebollas cultivadas en suelos orgánicos y suelos arenosos tenían la misma disminución de peso durante curación, pero después de 51 dias de almancenamiento, las cebollas de suelo arenoso sufrieron menos disminución de peso y pudrición que las de suelo orgánico. Cebollas en amontonamientos perdieron 9.2% del peso y cebollas en tuneles perdieron 3.8% del peso en 25 días de curación. Después de 51 días de almacenamiento, las cebollas curadas en tuneles sufrieron significativamente mas pudrición que las cebollas curadas en amontonamientos. Se encontró interacciones significantes entre variedades y suelos y métodos de curación. Rendimiento calidad en almacenamiento y apariencia fueron mayores cuando 'Granex' fue cultivado en suelo arenoso y curado en tuneles de plástico o en amontonamientos sin lluvia. Analisis de regresión indicó una relación entre disminución de peso y tiempo. 'Granex' exigió 11 días y 'T.G. 502' exigió 6 días de curación en amontonamientos para obtener un 5% disminución de peso cuando fueron curados in tuneles. Los datos sugieren que se precisa un método para determinar cuando se obtiene la disminución de 5% del peso.

Keywords: Onions, Yellow Granex 33, Texas Grano 502, Weight loss, Windrows, Storage, Decay.

In order to reverse cold induction and prevent premature bolting in celery, seedlings were enclosed in clear plastic tunnels. It was found that temperatures at midday were so high that top leaves of the seedlings were seriously scorched. Heat accumulation from solar radiation inside the tunnels could therefore apparently be used for drying or curing onions. Although cultivar testing and other research had been carried out extensively by the Florida Experiement Station system, large commercial onion production has not materialized. Poor keeping quality of the bulbs due in part to inadequate curing is one of the limiting factors. Curing is a drying process which removes water primarily from the external scales of the bulbs. Well cured bulbs have dried necks, outer scales which are paper thin and rustle to the touch, and improved keeping quality. Most onions in Florida are cured in the field by solar radiation. Some growers windrow onions in the field for several days and trim tops and roots before sorting and bagging them in the packing house. Other growers trim tops and roots, place the onions in mesh bags and leave them in the field for curing for several days before packing. A few trim and sort onions in the field in pallet boxes and send them to market in bulk as soon as possible. Depending on frequency and amount of rain field curing can be a failure (3). Other sources of energy have been tested for curing onions with promising results (2, 4, 5). However, there is no energy source less expensive than solar radiation. Beginning in the mid-seventies, the plastic tunnel concept was intensively studied, compared, improved upon, and

demonstrated in farmers' fields. Solar energy was selected instead of other sources for drying onions because of the need to reduce oil consumption. Also, the system is inexpensive, easy to handle, and adaptable for mechanization and use in remote areas. This paper presents some of the results obtained from curing onions by solar radiation. The objectives of these studies were: 1) to compare the response of two onion cultivars grown in histosols (Pahokee much) and a spodosol (Oldsmar fine sand) for quality before and after curing in windrows and plastic tunnels; 2) to assess the effect of all these components on keeping quality of bulbs during storage and 3) to test the feasibility of using the tunnel system in commercial production fields.

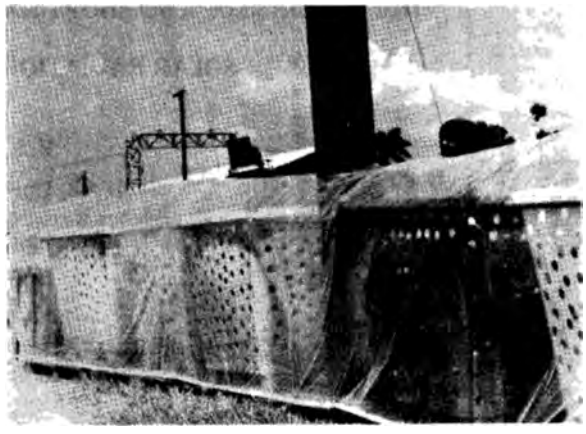

FIGURE 2

Materials and methods

'Yellow Granex 33' ('Granex') and 'Texas Grano 502' ('T.G. 502') were grown in raised beds following standard procedures (12). Seedings were planted with a narrow-row Planet Jr. planter during early fall. The narrow-row consisted of 3 closely spaced rows about 4cm apart, with 30cm between each set of 3 narrow-rows. Usually 3 sets per row/bed and 2 sets per row/bed were used for mineral and muck soil respectively. Seeding, harvesting and other procedures were conducted similarly on the same date in sand and muck grown onions, weather permitting. Maleic hydrazide (MH) was applied at a rate of 7 liter/ha 2 weeks before harvest. When approximately 20% of the tops fell over, the onion roots were undercut with an inclined sharp blade or a square rotating bar to hasten drying and maturity. This procedure was repeated after a rain or if the soil dried slowly. Onion bulbs of medium to large size were harvested (April and May depending on the year) by hand. After being cured in windrows the tops and roots were trimmed. Bulbs were trimmed when harvested for the tunnel curing treatments and placed in slotted pallet boxes.

The plastic tunnel was constructed over pallet boxes measuring 102 x 122 x 91cm, which held approximately 450kg of bulbs. Pallet boxes filled with onions were forklifted and placed side by side in a row. A 15 x 15cm welded wire mesh was stapled to the outside of the boxes, forming a semicircular roof of the tunnel which supported the plastic (Fig. 1). A 4 mil plastic sheet 3.75m wide was placed over the roof and sides of the boxes and held in place with nailed wood strips (Fig. 2). As the boxes were placed side by side, the welded wire and plastic were extended over the boxes forming a tunnel. The tunnel began with a heat-collecting section about 3m long that gradually extended over the tops and sides of the boxes. The tunnels were erected in the direction of the prevailing winds to increase air circulation. A chimney-like metal tube 5m long was suspended in the center of the tunnel to increase air movement. Crumpled paper over the bulbs prevented sunburn when clear plastic was used.

FIGURE 1

The experiment was analyzed as a randomized complete block design consisting of 6 replications. A treatment usually consisted of a pallet box or equivalent. Pallet boxes were divided with slotted partitions into 2 or 4 treatments when necessary with several boxes comprising the block or replication. The windrow cured onions were placed in boxes for storage by treatments. At the beginning, dry weights were compared to assess differences in curing. Later weight loss was expressed as a percentage of initial weight. A 5% weight loss was considered the threshold for adequate curing. The amount of decay and other disorders were expressed as a percentage of the last weight measured. Tunnel cured onions were stored in the same tunnels in the field or transferred in the same pallet boxes to a barn. Windrow cured onions were trimmed and transferred to a barn for storage in wooden boxes. Quality of the final product (appearance) was assessed by the experimenter and aides on a five point scale, from very poor to very good without sorting for size.

All weather parameters were measured. Temperatures were recorded with a multiple probe continuous Honeywell recorder at different depths inside the onion filled pallet boxes. Relative humidity was calculated from wet and dry bulb readings inside the tunnel. Solar radiation was obtained from integrated solar pyranometer in Langleys (gram calories per cm^2) at the Everglades Research and Education Center in Belle Glade. Rainfall was automatically recorded.

When curing in plastic tunnels with forced air, a high speed 45cm electric fan with 1472 liter/sec capacity was installed at the entrance of the heat collector. It was thermostatically activated when the air temperature reached 32.5 °C.

Results and discussion

Plastic tunnels raised the air temperature which in turn lowered the relative humidity and promoted drying of the bulbs. However, heat distribution was affected by position, i.e. depth, in the box (Table 1).

Table 1. Mean air temperatures (°C) in clear plastic tunnel at four depths and four time periods inside pallet boxes full of onions (Factorial 2 × 2 × 2 × 2).

Depth (cm)	Time 0800	1200	1600	2400
0	26.7	35.3	34.9	24.0
15	24.7	27.2	28.4	24.2
38	22.9	23.8	23.9	23.5
76	21.8	23.4	25.0	21.2
Relative Humidity	88	44	50	100

Mean — 523.35 Langleys/day and no rainfall during curing.

Temperatures at the top of the boxes rose rapidly as the day advanced and began to decrease after midafternoon. Air temperature changed more slowly at depths of 15, 38 and 76cm. Temperatures were dependent on the color of the plastic that was used. Temperatures were higher in clear plastic tunnels than in black, with mean differences of 3.0, 4.3, 3.1 and 0.2 °C at 0800, 1200, 1600 and 2400 hours, respectively. Some sunburing of the top layer of onions occurred with clear plastic. Straw or crumpled paper on top of the onions eliminated this disorder.

Temperatures decreased during the night, with the rate of heat loss being more rapid at the top of the onion layer. Temperatures near the bottom of the box underwent smaller changes from day to night. Variations in temperature inside the tunnel also occurred from day to day depending on cloud cover. Temperatures of 55 ° on top, 32 °, 30 ° and 24 °C at depths of 15, 61 and 76cm respectively were often recorded at midday under sunny skies. Variations in temperature caused by onion depth and relative humidity caused by time of day probably had different effects on the rate of curing.

Effect of curing method on dry weight.

Curing increased percent dry weight regardless of curing method (Table 2). Curing in windrows for 20 days with no rainfall appeared to be slightly better than tunnel curing. Tunnel curing was better than windrows curing after 22 days with rainfall. Under rainy conditions, windrowed onions actually showed an increase in water content (less dry weight). This indicates that with rainy weather tunnels are more efficient than windrows. Both windrowed and tunnel cured onions showed an increased percentage of dry matter regardless of the cultivar after 6 days of additional curing with no rainfall.

Table 2. Percentage dry weight of bulbs of two onion cultivars grown in organic soils after curing in windrows and in plastic tunnels with and without rainfall.

Curing Treatment	Days	Dry weight Granex 33 (%)	Texas Grano 502 (%)
No rain			
	0	7.20	—
Tunnel	20	7.38	—
Windrow	20	7 43	—
With rain[z]			
	0	6.96	6.79
Tunnel	22	7.38	6.78
Windrow	22	5.50	5.75
Tunnel	28	8.25	7.33
Windrow	28	7.03	6.86

[z]Seven rains fell (12 mm) during the 22-day curing period, and curing time was extended to 28 days.

Effect of curing methods on weight loss after curing and storage.

When bulb weight loss was measured after 14 days curing and 52 days storage 'T.G. 502' lost more weight than 'Granex' (Table 3). Windrowed onions lost more weight than tunnel cured onions after curing and storage. There were no losses due to decay or other disorders, indicating the excellent appearance and keeping quality of sand-grown onions. Onions with greater weight loss during curing continued to have greater weight loss in storage. It is not clear if a 5% weight loss is too much bulbs. 'T.G. 502' lost more weight than 'Granex'. 'T.G. 502' matures one or two weeks later than 'Granex', consequently, since they were harvested the same day, the bulbs of 'T.G. 502' may have contained more water and thus dried at a faster rate than did the more mature 'Granex'. This may indicate that greater water loss does not necessarily mean better curing if the bulbs are immature. The results also indicate that with no rainfall, windrow curing is more effective than tunnel curing.

Table 3. Bulb weight loss of two onion cultivars grown in mineral soils after 14 days of curing in windrows and in plastic tunnels and 52 days of storage at room temperature.

Treatments	Weight loss		Marketable	
	Curing (%)	Storage (%)	Yield (%)	Appearance
Cultivar (C)				
Granex 33	4.2	13.1	86.9	Good
T.G. 502	6.0	20.6	79.4	Good
Significance	**	**	**	
Curing method (M)				
Windrows	7.2	21.5	78.5	Good
Plastic Tunnel	3.1	12.3	87.7	Good
Significance	**	**	**	Good
C × M	NS	NS	NS	

NS — nonsignificant, ** — significant at 1% level.

Effect of clear and black plastic on tunnel curing and storage.

No differences were found in curing, storage, diseases and discolloration of the bulbs due to plastic color (Table 4). This indicates that the plastic tunnel is suitable for storage as well as for curing. However, it is advisable not to prolong storage in a tunnel unnecessarily because weight loss was more pronounced and decay increased as compared with bulbs stored in small wooden boxes inside a barn. 'T.G. 502' had more decayed and discolored bulbs than 'Granex' after 65 days of storage in tunnels. The black discoloration was produced by a saprophytic fungus of the *Aspergillus* family that thrives just below the outer dry scale of the onions. The fungus does not cause decay, but reduces the good appearance of the bulbs. The experimental bulbs were considered marketable since onions in the supermarket showed the same discoloration.

Table 4. Effect of plastic color on percentage of marketable weight, decayed and discoloration of bulbs of two onion cultivars grown in mineral soils after 11 days of curing in plastic tunnels plus 65 days of storage in the same tunnels

Treatments	Marketable onions		Defects after storage	
	Curing (%)	Storage (%)	Decayed (%)	Discoloration (%)
Plastic color (P)				
Clear	97.3	87.5	5.0	38.5
Black	96.8	88.3	6.0	36.5
Significance	NS	NS	NS	NS
Cultivar (C)				
Granex	97.8	91.0	3.5	25.3
T.G. 502	96.3	85.3	7.5	49.8
Significance	**	**	**	**
P × C	NS	NS	**	NS

NS — nonsignificant, ** — significant at 1% level.

Effect of forced air circulation inside the tunnel on weight loss.

Windrowed onions dried faster than those in tunnels with or without forced air (Table 5). Eight, 19 and 25 days were needed for curing in windrow, forced air and non-forced air, respectively, for the two cultivars. These differences is curing days were presumably caused by the small depth (20cm) of the onion mass over a large surface for the field windrowed onions, in contrast to 76cm depth in the tunnel. Air forced into the tunnel only slightly increased the drying rate from the non-forced air treatment, probably because most of the air took the path of least resistance, between the top layer of onions and the plastic roof. A different type of structure is needed if forced air circulation is to be used for curing - one which forces the air through the onion mass. The interactions were significant for final quality. Forced air tended to minimize the effect of cultivars, whereas in windrows and non-forced air, differences between cultivars were magnified. 'Granex' windrowed and 'Granex' in the tunnel had less decay and more marketable onions than 'T.G. 502' (1).

Table 5. Percentage weight loss of onion bulbs of two cultivars grown in organic soils when cured in plastic tunnels with and without forced air and in windrows in the field[z] from 5 to 25 days.

Curing method	Cultivar	Curing days 5 (%)	8 (%)	11 (%)	19 (%)	25 (%)	Mean weight loss (%)	Final quality: Sunburned and rots (%)	Marketable (%)
Windrowed	Granex	2.4	4.6	5.6	6.0	9.0		3	97
Windrowed	T.G. 502	3.2	6.5	8.3	9.0	12.5	10.8	10	90
Non-forced air	Granex	1.9	2.5	3.2	3.9	4.7		5	95
Non-forced air	T.G. 502	2.3	3.4	4.8	6.0	7.7	6.2	17	83
Forced air	Granex	1.6	2.8	3.7	4.7	6.1		12	88
Forced air	T.G. 502	2.5	3.5	4.6	5.6	7.5	6.8	13	87
Mean for cultivar									
Granex							6.6		
T.G. 502							9.2		
Significance									
Method		NS	NS	*	NS	**	**	*	*
Cultivar		NS	NS	NS	*	**	**	**	**
Interactions		NS	NS	NS	NS	NS	NS	*	*

[z]Windrowed onions were kept at room temperature after 11 days of curing.
NS — nonsignificant, * and ** significant at 5 and 1% level respectively.

Weight losses were measured 5 times during the 25 days of curing. Regression models for weight loss over time were calculated for 'Granex' and 'T.G. 502' cured in windrows and tunnels (Fig. 3). Weight loss was linearly correlated with curing days (R^2 = 0.87 to 0.95). When cured in windrows with no rainfall, 11 days were sufficient for 'Granex' to reach 5% weight loss, while 'T.G. 502' required 6 days. With tunnel curing, 22 days were needed for 'Granex' to reach 5% weight loss; 'T.G. 502' required 11. These results agree with the generalization that the longer the curing, the greater the weight loss (7). Tunnel curing requires more days than windrow curing if no rain falls. Cultivars differed in curing and storage characteristics as previously reported by others (10, 11). Bulb density and respiration rates were not different between bulbs of keepers and poor keepers (13). A high rate of water loss was characteristic of poor keepers. This agrees with the rate of water loss of 'T.G. 502' being faster than 'Granex'. 'T.G. 502' generally needed fewer days than 'Granex' to attain 5% weight loss, but it also decayed faster. Curing in onions can be defined as an accelerated rate of drying of the outer scales and necks to protect them from infection during storage. Well matured, disease-free bulbs eventually cure slowly (lose weight with time) without benefit of a specific curing period. If high

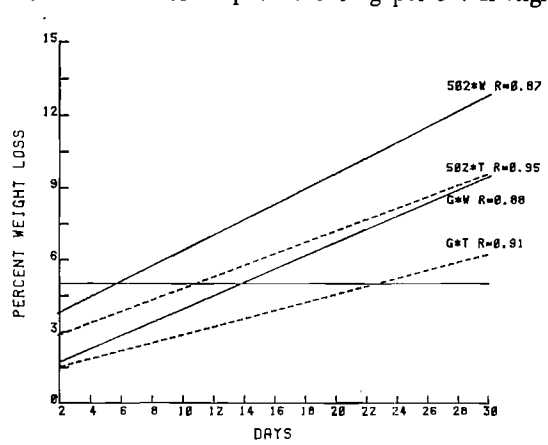

FIGURE 3

humidity and relatively high temperatures persist, however, even cured bulbs will decay in time (9). Well matured sand-grown onions, some cured and some uncured, were stored in several tomato boxes in a well ventilated barn. Neither cured nor uncured 'Granex' had any decay after 4 months, while only 7 bulbs decayed in the 'T.G. 502' uncured treatment.

Onions need to be cured to improve their keeping quality during storage and marketing (2, 5, 7, 8, 13); but no data exist as to how much curing is necessary and what criteria need to be met. This situation is confounded by reports of successful storage with uncured onions (6, 12) as well as with those cured for from 1 to several days. Amount of weight loss depends on the cultivar and perhaps on the degree of maturity. 'T.G. 502' consistently lost more weight and lost it faster than 'Granex'. This may have been because 'T.G. 502' was physiologically immature or because it was inherently more succulent, or both. The rate of weight loss is inversely correlated to keeping quality (13) and also appears to be a characteristic of the cultivar (10, 13). It is suggested that monitoring all components (cultivars, maturity, soil type, diseases, etc.) as well as weight loss could provide a better measure of the length of curing necessary. This is important both to expedite marketing and also because excessive curing appears to influence weight loss in storage. Excessive curing and long storage reduced final yields. A longer curing period does not seem to improve the keeping quality of cultivars which are inherently poor keepers such as 'T.G. 502'. Bulbs with dried necks and outer scales and weight loss approaching 5%, were considered cured.

Progress has been made to mechanize onion harvesting (3, 11). The various mechanical handling sequences are detrimental to keeping quality, especially for short-day onions. The tunnel method reduces handling to a minimum because onions could be cured and stored in the same pallet boxes.

Combined effect of varieties, soils and MH on curing and storage

Main effects and interactions are presented in Table 6. 'T.G. 502' lost more weight during curing and storage and had more decayed bulbs than 'Granex' after 51 days in storage. Muck grown onions lost more weight and had more decay than those grown in sand. Windrowed onions lost significantly more weight than those in tunnels, and the latter had significantly more decay. No effect was found due to MH in curing or storage.

Table 6. Percentage weight loss of onion bulbs after 25 days of curing plus 15 and 51 days of storage in two cultivars, grown in organic and sandy soils with and without malaic hydrazide and cured in windrows and in tunnels (A 2 × 2 × 2 × 2 factorial).

Treatments		Weight loss				
		Curing[z]	Storage			
		25 days (%)	40 days (%)	Decayed (%)	76 days (%)	Decayed (%)
Granex 33	(C)	5.48	8.13	1.00	13.04	6.44
T.G. 502		7.51	11.31	9.80	20.94	24.30
		**	**	**	**	**
Muck	(S)	6.47	10.45	10.62	18.71	25.92
Sand		6.51	8.81	0.27	15.26	4.82
		NS	NS	**	*	**
Windrow	(M)	9.19	11.01	4.63	18.04	8.71
Tunnel		3.80	8.25	6.26	15.94	22.03[y]
		**	**	NS	NS	**
No chemical	(Ch)	6.71	9.49	4.87	17.09	14.03
Maleic hydrazile		6.28	9.77	6.02	16.89	16.71
		NS	NS	NS	NS	NS
Significant interactions						
		C × M**	C × Ch*	C × S**	C × S**	C × S**
		C × Ch**			S × M**	C × M*
		S × Ch*				S × M*
		C × S × M**				C × S × M*

[z]No rain fell during curing (523.35 Langleys/day).
[y]Some of the decayed bulbs were due to accidental water damage.
NS — not significant, * and ** significant at 5 and 1% level respectively.

There was a significant interaction between cultivars and methods of curing and soils (Table 7). 'Granex' lost more weight than 'T.G. 502' in tunnels, whereas with windrows, 'Granex' lost less weight than 'T.G. 502'. This indicates that tunnel curing was more effective for 'Granex' and that windrow curing was more effective for 'T.G. 502'. Weight loss after 51 days of storage showed similar results as those for curing, except that 'T.G. 502' lost more weight than 'Granex' in the tunnel. 'T.G. 502' cured in windrows lost more weight than 'Granex' regardless of soil type; with tunnel curing 'Granex' grown in muck lost more weight than 'T.G. 502' grown in muck or sand (Table 8). 'T.G. 502' had more weight loss than 'Granex' after 51 days of storage, regardless of curing method and soil type except when grown in sand and cured in windrows. The longer the curing and storage period, the lower was the yield of salable onions (7).

Table 7. Percentage weight loss of bulbs of two onion cultivars during curing and storage in relation to curing methods.

Cultivars	Method: Windrow (%)	Method: Tunnel (%)	Mean (%)
	Curing for 25 days		
Granex	6.8	4.2	5.8
T.G. 502	11.6	3.4	7.1
Mean	9.2	3.8	
	Storage for 51 days		
Granex	14.9	11.1	13.0
T.G. 502	21.1	20.7	20.9
Mean	18.0	15.9	

Table 8. Percentage weight loss of bulbs of two onion cultivars due to methods of curing and soil type after 25 days of curing plus an additional 51 days of storage.

Cultivars	Soil	Method	Weight loss: Curing (%)	Weight loss: Storage (%)	Decayed (%)
Granex	Muck	Windrow	5.9	9.7	5.3
Granex	Muck	Tunnel	5.3	12.1	19.5
Granex	Sand	Windrow	7.7	20.2	0.0
Granex	Sand	Tunnel	3.1	10.2	1.1
T.G. 502	Muck	Windrow	11.8	26.2	20.7
T.G. 502	Muck	Tunnel	2.9	26.9	58.2[z]
T.G. 502	Sand	Windrow	11.4	16.1	8.8
T.G. 502	Sand	Tunnel	3.9	14.6	9.4

[z]Accidental water damage.

Performance of tunnel system in relatively large operations.

The tunnel method lends itself to mechanization (3, 11). Slotted pallet boxes full of trimmed bulbs were rapidly forklifted and put side by side in the field and the tunnel formed with wire and plastic as the harvest progressed. The amount of onions cured varied from 5 to 20 tons. In some trials rain fell during part of the curing period. Regardless of weather conditions, curing in a tunnel was equal to windrow curing or any method of field curing used by the farmer. However, keeping quality could not be determined because the onions were shipped as soon as the field cured onions were ready. These results were obtained with muck grown onions, which are more susceptible than sand grown onions to decay and present more keeping problems. The last commercial trial was conducted at Basore farm using 'T.G. 502' cured and stored in tunnels for about 25 days. No differences with the bag-cured system were detected.

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Literature cited

1. Anderson, G.R. 1984. Ambient air storage of short day onions. HortScience 19 (3) : 571 (Abstr.)

2. Buffington, D. F., S. K. Sastry, J. C. Gustashaw, Jr., D. S. Burgis. 1981. Artificial curing and storage of Florida onions. Transaction of the ASAE: 782 - 788.

3. Coble, C. G., W. H. Aldred, and R. C. Dillion. 1976. Mechanized harvesting system for fresh market onions. Amer. Soc. Agr. Eng. Paper No. 76 - 1532. 12 p.

4. Gull, D. D. 1960. Artificially curing Florida onions. Proc. Fla. State Hort. Soc. 73 : 153 - 156.

5. Guzman, V. L. and N. C. Hayslip. 1962. Effect of time of seeding and varieties on oinion production and quality when grown on two soil types. Proc. Fla. State Hort. Soc. 75 : 156 - 162.

6. Hoyle, B. J. 1948. Onion curing–A comparison of storage losses from artificial, field, and non-cured onions. Amer. Soc. Hort. Sci. Proc. 52 : 407 - 414.

7. Lorenz, O. A. and B. J. Hoyle. 1943. Effect of curing and time of topping weight loss and chemical composition of onion bulbs. Proc. Amer. Soc. Hort. Sci. 47 : 301 - 308.

8. Smittle, D. A. and R. E. Williamson. 1978. Onion production and curing in Georgia. Georgia Agr. Exp. Sta. Res. Report 284.

9. Stow, J. R. 1975. Effects of humidity on losses of bulb onions *(Allium cepa)* stored at high temperature. Expt. Agr. 11 : 81 - 87.

10. Toledo, J., M. Sherman and D. J. Huber. 1984. Some effects of cultivar bulb size and preharvest treatments on storage characteristics of north Florida onions. Proc. Fla. State Hort. Soc. 97 : 107 - 108.

11. Williams, L. G., D. L. Franklin. 1971. Harvesting, handling, and storing yellow sweet spanish onions. Idaho Agr. Exp. Sta. Bul. 526 : 31 p.

12. Williams, R. D. and J. Montelaro. 1977. Onion Production Guide. Florida Cooperative Extension Service. IFAS. Cir. 176D 12 p.

13. Woodman, R. M. and H. R. Barnell. 1937. The connection between the keeping quality of commercial varieties of onions and the rates of water loss during storage. Ann. Appl. Biol. 24 : 219 - 235.

POTENTIAL FOR HERBS AND SPICES PRODUCTION IN TRINIDAD & TOBAGO AND METHODS OF THEIR PROPAGATION

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ABSTRACT

The potential for herbs and spices production in Trinidad and Tobago is favourable on account of the climatic and soil conditions. At present there is a flourishing trade in manufactured packaged spices, but due to high cost of production and unavailability of suitable planting material, spice cultivation will be restricted to tumeric, ginger, peppers and now cardomoms. A review of the methods of propagation of a wide range of culinary, medicinal and perfumery herbs and spices is presented.

RESUMEN

Las posibilidades de producción de hierbas y especias en Trinidad y Tobago son favorables, debido a las condiciones del clima y del suelo. Existe actualmente un comercio floreciente de especias manufacturadas y envasadas, pero, debido a los altos costes de producción y la inasequibilidad de material de plantación adecubdo, el cultivo de especias se restdingirá a la curcuma longa, el jengibde, las pimientas y, últimamente, los cardamomos. Se resume los métodos de propagación de una serie de hierbas y especias usadas en la cocina, la medecina y la perfumeria.

The status of herbs and spices production in Trinidad and Tobago

A report on "The economic study on production and marketing of spices*, essential oils, and oleoresins in Trinidad and Tobago," (I.T.C.**, 1980), stated that this country has little tradition in the growing or cultivation of spices, with the exception of ginger and hot peppers, which are grown by small farmers as vegetables for the local market.

Market demands are satisfied by imported spices which show imports of 667,244kg. at a value of $2.75 million (T.T.$) in 1980, and T.T. $3.4 million in 1982. (C.S.O. Overseas Trade Reports 1976 – 1982). However, Trinidad and Tobago ranked fourth as the world's major exporter of nutmeg and mace for the period 1970 – 1974 (T.P.I.*** quarterly reports, 1973–1974). The decrease in spice production after 1975 has been part of the general decline in domestic agricultural production witnessed over the last ten years.

Potential for production of herbs and spices in Trinidad and Tobago

There appears to be a great potential for the exploitation of herbs and spices as economic crops in Trinidad and Tobago. This can be supported by the fact that much of the world's production is on tropical islands, e.g. Jamaica, Grenada, Zanzibar, Sri-Lanka, Sarawak, Seychelles etc.

Most spice crops thrive best at low altitudes in hot climates, without a prolonged dry season. The annual rainfall should be in the vicinity of 2,000 – 2,500mm., and average temperatures around 28 – 30 °C. When planted on well drained soils with adequate supplies of humus, and where the natural vegetation is tropical rain-forest, they grow well (Purseglove, 1973).

Advantages of herbs and spices cultivation

1. The final product is often high in value and small in volume.
2. Although they are labour intensive crops, particularly in harvesting and processing, they are ideal for small holdings, utilizing family labour.
3. Cultivation of spices would broaden the range of crops grown at present, and thus lower the dependency on the traditional export crops as foreign exchange earners.
4. There is an increasing international market for herbs of medicinal and cosmetological value, that are grown locally, and which are used in folklore remedies e.g. Aloes *(Aloe-vera)* and Khus Khus *(Vetiver zizanoides)*.
5. A number of spice crops also produce important essential oils and oleoresins that are important in the food, beverage, pharmaceutical, and perfumery and cosmetic industries eg. bay *(Pimento racemosa)*, nutmeg *(Myristica fragrans)* and pathchouly *(Pogostemon cablin)*.

There is a growing awareness today of the value of renewable natural resources, and this has led to an increasing consideration of certain wild plants as

* There is no standard definition of the term 'Herb', and the distinction between herb and spice is an imprecise one (Greenhalgh, 1980). The American Spice Trade Association defines spice as 'a product of plant origin which is used primarily for the purpose of seasoning food', while reference is made of it to include herbs and aromatic seeds. Heath (1973) and Rosengenten (1973) described spices as being more highly aromatic and often containing large percentages of essential oils than herbs.

** International Trade Centre.

*** Tropical Products Institute.

potentially important food sources (Zennie and Ogzewella, 1977). Seaforth (1983), in discussing the suitability of certain under-utilized plants for processing and marketing for the Caribbean Region, reported several herbs and spice plants which remain relatively under-utilized – whether as foods or as medicinal agents. Yet several herbal preparations from outside the Caribbean area are becoming quite important as beverages, food additives, food supplements or "Health foods" for the local people.

Problems associated with the development of the spice industry

Compared to other economic crops, little agronomic research has been devoted to spices, and at present the standards of cultivation are often lower than for other crops. Very little work, if any, has been done on the selection and breeding of many of them, and the numbers of recognised cultivars are often limited (Purseglove 1973). This may be due to the fact that commercial production of spices is a jealously guarded secret, and hence the reason for little published research findings.

Although serious pests and diseases are comparatively rare, the major problems in cultivation are the dioecous nature of most of the crops, the long and delayed period before they come into bearing, and the irregular bearing patterns with a bumper crop only every few years (Purseglove, 1973).

The major reason for the decline of the spice industry in Trinidad and Tobago is due to the fact that the most of the tree crop spices were assciated with cocoa and coffee plantations as shade or secondary crops. These include nutmeg, clove *(Syzygium aromaticum)* cinnamon *(Cinnamonum zeylanicum)*, and tonka bean *(Coumarouna odorata)*, as well as, rocou, anatou or ruku *(Bixa orellana L.)*, which is used as a natural food colouring. When most of the cocoa plantations were left abandoned due to falling prices and increased labour cost during the **'oil boom'**, so were the spice crops.

In the past, most of the tree crops were propagated by seeds, which normally have short viability and are heterogenous. In recent times, methods of vegetative propagation of some of the tree crops have been worked out with limited success.

This paper attempts to review the present method of propagation of most of the spice crops with the intention that the shortage of suitable planting material be corrected, and the production of high yielding clonal material of the desired sex, eg. in nutmeg and pimento, be realised. Further, the possible use of micro-propagation and plant tissue culture for certain crops eg. ginger and black pepper, as a means of improving the genetic variability and the mass production of planting material is investigated.

Review of methods of propagation of herbs and spices

The major spice crops showing the greatest economic potential are black pepper *(Piper nigrum)*, vanilla *(Vanilla fragrans (Salisb)* Ames. Syn; *V. plainflolia* Andrews), pimento *(Pimenta dioica* Mere.), clove *(Syzygium aromaticum* Syn. *Eugenia caryophyllus)*, nutmeg *(Myristica fragrans.* Hoult*)*, cinnamon *(Cinnamomium zeylanicum)*, bayleaf *(Pimenta racemosa)*, ginger *(Zingiber officinale* Rose*)*, tumeric *(Curcuma domestica* Syn; *C. longa.* Koenig non L.*)*, cardomoms *(Elettaria cardomomum* Maton) and curry leaf *(Murraya koenigi (L)* Spreng).

These particular spices are choosen as they are most commonly used, and are very well adapted to the local environment. Among the wide range of culinary herbs grown, chardon bene *(Eryngium foetidum)* has shown increasing acceptance and potential.

Propagation by seeds

Most of the major spices are propagated by seeds. However due to the problem of dioecism, as in nutmeg and pimento, it is difficult to distinguish between male and female trees until they come into bearing some 5 – 6 years or even later (Chapman 1965; Purseglove, 1981). As a result vegetative propagation has been developed.

Cloves are normally propagated from seeds of fully ripe fallen mother-of-cloves. Hulled seeds have been found to produce better seedlings than unhulled (Purseglove, 1981).

Cardomoms can be propagated by seeds. Seeds for sowing should be collected from ripe capsules, preferably from plants more than five years old (Purseglove, 1972). Seeds should be washed in water and sown immediately. Viability was found to last for not more than 9 days in storage (Purseglove, 1972). Germination is irregular and sprouting may continue even up to one year (Yegna Narayan Aiyer, 1944).

Seedling variability in black pepper has been reported to be wide and the plants may be dioecous (Purseglove, 1981). Vanilla is grown by seeds for breeding purposes using Knudson formula (1950), and hybirdization and production from seed has been reported in Puerto Rico and Malagassy Republic (Purseglove, 1972).

All of the seasoning or culinary herbs are grown by seeds, including hot and seasoning peppers. These include; coriander *(Coriandrum sativum L)*, thyme *(Thymus vulgaris)*, basil *(Ocimum basilicum)*, parsley *(Petroselium cripsum)*, cerlery *(Apium graveolens)*, dill *(Anethum graveolens)*, fennel *(Foeniculum vulgare)*, fenugreek *(Trigonella foenumgracecum)*, caraway *(Caruna carvi)*, chadon bene *(Eryngium foetidum)*, chives and shallots *(Allium schoenoprasum and A. cepa)*, wildmint *(Hyptis atrorubens)* and peppers *(Capsicum annum and C. frutescens)*.

In Trinidad only cloves and the seasoning herbs are propagated by seeds.

Budding and grafting

Vegetative propagation by budding and grafting has become more important where the problem of dioecism is prevalent as in pimento and nutmeg (Chapman, 1965).

Purseglove (1981) has referred to the work of Yegna Narayan Aiyer (1960) who has reported that temporary unions in cloves were achieved by grafting species of cloves *(Syzgium)* on to guava, *(Psidium guajava)*, but there is no indication that this technique has been successful.

The success of tongue-approach grafts of twigs of clove species on to *Syzyium cumini* (L) Skeels (syn: *Eugenia cumini* (L) Druce; *E. Jambolana* Lamk) by Duformet and Rodriguez (1972) has been referred to by Purseglove (1981).

Cuttings

Commercial vanilla is usually propagated by stem cuttings (Purseglove, 1981). For black pepper, cuttings should be taken from the terminal branches, as those from the lateral branches are found to produce infertile plants (Singh, 1974). Purseglove (1981) reported that it was found that single leaf bud cuttings were superior to stem cuttings for black pepper, in respect of the percentage rooting, the number and length of roots, and the development of shoots (Choudhary and Phadnis, 1971).

Purseglove (1981) has referred to the findings of Fernie (1974) who had some success with terminal leafy soft wood cuttings for clove, and the rooting of cinnamon cuttings by the Department of Agriculture, Seychelles (1970).

Nichols and Pryde (1958) working in Trinidad, reported that nutmegs could be propagated by cuttings using semi-hard wood, treated initially with 0.5 percent IBA solution followed by a second treatment 8 weeks after, with root induction occuring in 4 months. Similar work in Grenada by Nichols and Cruickshank (1958) using an initial hormone treatment of 0.6 percent IBA, followed by a second treatment of 0.5 percent indicated that basal callusing took about 8 weeks. Propagation by cutting for nutmeg was based on a similar technique developed by Cheeseman and Spencer (1936).

Cruickshank (1973) reported unsuccessful trials made in Grenada in 1956 to shieldbud young nutmeg seedlings, but Nichols and Cruickshank (1964) had fair results in approach grafting. However, with the latter technique, fears have been expressed about stock-scion incompatability. Also limited success has been obtained with side grafting.

Approach grafting will allow for the production of clonal material of known sex which are earlier bearing, especially for nutmeg and pimento.

Successful rooting of stem cuttings of pimento has been reported by Ward (1961), but the process is very labourious. Chapman (1965) reported a 30 percent success in budding, and 95 percent in approach grafting for pimento, although the latter method is more cumbersome. Pimento has been successful budded onto bay *(Pimento racemosa)* and vice versa (Purseglove 1981).

The Ministry of Agriculture and Forestry of Sarawak in 1969 bud-grafted cultivars of black pepper such as 'kuching' on to resistant stocks of Indian clones, especially 'Balacotta' which is relatively resistant to foot-rot but such grafts did not survive beyond the fruiting stage (Purseglove, 1981).

No propagation of spices by budding and grafting is done presently in Trinidad and Tobago.

Rhizomes

Cardomom, ginger and tumeric are propagated vegetatively by division of the rhizomes known as seed pieces or setts (Purseglove, 1972). For vegetative propagation of cardomoms, rhizomes from large clumps are divided into small units consisting of at least one old and one young shoot.

Vegetative propagation of tumeric requires that the rhizomes must have at least one or two buds. Purseglove (1981) reported that Aryadurai (1966) found that the mother rhizome performed better than daughter rhizomes for use as planting material.

Seeding rate for ginger was found to vary with the method of cultivation. Paulose (1973) reported that in India using setts weighing 28 – 56g., the rate of planting was 1.2 – 1.4 tonnes ha^{-1} Bendall and Daly (1966) and the Bureau of Agricultural Economics, Canberra (1971) using the same sett weight for ginger reported the rate of planting as 2.5 – 3.7 tonnes ha^{-1}.

Layering

The present method for vegetative propagation of nutmeg is marcotting or air-layering, a technique modified for marcotting *Theobroma cacao* by Nichols and Cruickshank (1964), using selected, healthy branches from mature bearing trees.

Purseglove (1981) reported successful vegetative propagation for black pepper and cinnamon through layering.

Root suckers/side shoots techniques

Curry leaf or kara pelay, which is normally propagated through seeds, extracted from fully ripe berries, can also be propagated by means of root suckers (Philip. 1981).

Similarly, chadon bene (Fitweed or culantro) multiplies by side shoots and seeds. Preliminary studies have shown that fresh seeds germinate between 21 – 30 days (Bridgemohan, 1983, unpublished).

Micro-propagation or tissue culture

The dormancy of buds in rhizomes of ginger and tumeric which limits propagation to once a year can be eliminated by clonal propagation *in-vitro*. Pillai (1982) reported that, using *in-vitro* culture, ginger plants could be raised without reference to seasons and dormancy period, and refers to success of rapid multiplication of tumeric plants using tissue culture by Nagauda *et al* (1978) and the clonal propagation of ginger through tissue culture by Hosoki *et al* (1977).

Vanilla can be grown by seeds, but is propagated by cuttings. Kononowicz and Janick (1984) reported that the multiplication of vanilla can be achieved by tissue culture, and successful establishment *ex-vitro* can be achieved. They have referred to the results of Cerra and Madizral (1981) who achieved shoot proliferation and rooting of vanilla, but establishment outside of the culture was not reported.

Research activities in spices at the Crop Research Division (Central Experiment Station) Centeno, Trinidad

The Central Experiment Station, guided by the I.T.C. report (1980) has initiated a programme for the development of spice cultivation in Trinidad and Tobago in three phases:

1. Establishment of a spice museum at C.E.S.
2. Implementation of a spice programme with the cocoa rehabilitation and re-afforestation programme.
3. Establishment of a commercial model spice farm.

With respect to phase 1 a spice museum was set up in 1982, and maintains a germplasm collection of black pepper, cardomom, ginger, bayleaf, tumeric, vanilla, clove, cinnamon, and other indigenious spices,

eg. curry leaf and chadon bene. Also a plot of capsicum pepper (hot peppers), of which there are over eight different types, and small amounts of condiments like chives, celery, parsely, aniseed and coriander are grown.

Work with the re-afforestation programme has been recently initiated using mainly black pepper and mauby. No commercial model spice farm has been established, but work on the systems of production for ginger and tumeric in soilless medium, intercropping and close spacing has been investigated. A cost of production for chadon bene has been worked out revealing a profit of TT$7,000 ha^{-1} (Bridgemohan, 1984).

Currently micro-propagation of black pepper is being studied at the University of the West Indies by Central Experimental Station personnel and the possibility of increasing the variability of ginger using tissue culture will be looked into. (Mohammed, 1985, personnel communication).

Conclusion

At present, climatic and soil conditions as well as level of technology in Trinidad and Tobago permit the cultivation of a number of herbs and spices in suitably selected regions. What is probably necessary is a definite strategy aimed at encouraging their production.

The demand for these commodities is increasing at about 6 – 10 percent per annum (Greenhalgh, 1979), with the demand coming from three areas, the food manufacturing sector, the institutional or food service sector, and the retail or household sector. It is projected that by 1990, this country may be importing close to TT$4.0 million in spices, (see appendix 1).

If the present consumption trend continues one can envisage that we will be net importers of most of the spices and curry ingredients. This is due to a shortage of labour and available lands, unwillingness of farmers to take the risk of cultivating the crops, the lack of suitable planting material and the major problem of the non-acceptance of locally produced materials by the local processors.

This presentation attempted to review the present methods of propagation, and the potential use of micro-propagation to make available suitable planting material, and to stimulate intensive production of black pepper, ginger, cardomom, tumeric, and curry leaf on small holdings to meet local requirements, and finally the possible development of an export market.

References

Blacklock J. G. (1954). A short study of pepper culture with special reference to Sarawak. *Trop. Agric. (Trinidad)* 31 40 – 56.

Bridgemohan, P. (1984). Spices in Trinidad. *Agri. News* 10 (1) Ministry of Agriculture Lands and Food Production, Trinidad.

Bridgemohan, P. (1984). Agronomic aspects of herbs and spices production. A paper presented at a Seminar at Central Expt. Station, Crop Research, Centeno. Trinidad, 25 July 1984.

Chapman, G. P. (1964). Some aspects of dioecism in pimento (Allspice). *Ann. Bot.* 28 451 – 8.

Cheeseman, E.E. and Spencer, G.E.L. (1936). The propagation of cuttings in tropical climates. *Trop. Agric. (Trinidad)*, 13 (8), 201 – 203.

Cruickshank, A.M. (1973). Some aspects of the nutmeg investigation programme in Grenada. *Proc. Conf. on Spices*, 10 – 14 April, 1972, Trop. Products Inst., London.

Ganpat, R. (1973). Cultivation of hot peppers. Crop Bulletin 26. Central Experiment Station, Crop Research, Ministry of Agriculture, Lands and Food Production, Trinidad.

Ganpat, R. *et al* (1975). Growing ginger. Crop Bulletin 26, Central Expt. Station, Crop Research, Min. of Agriculture Lands and Food Production, Trinidad.

Greenhalgh, P. (1979). Economic background to the exploitation of plant resources with particular references to spices and culinary herbs. *Trop. Science* 21 217 – 220.

Greenhalgh, P. (1980). Production, trade and markets for culinary herbs. *Trop. Science.* 22 159 – 188.

Harper, R.S. (1974). Pepper in Indonesia. *World Crops*, 26 130 – 3.

Heath, H. B. (1973). Herbs and spices for food manufacture. *Proc. Conf. on Spices.* 10 – 14 April, 1972. Trop. Products Inst., London.

Hosoki *et al* (1977). Clonal propagation of giner through tissue culture. *Hort. Sci.* 12 (5) 451 – 2.

International Trade Centre (1980). Report on the economic study and production of, and markets for spices, essential oils and oleoresins, UNCTAD, GATT. 120 – 155.

International Trade Centre, (1982). Spices – A survey of the world markets Vol. I and II. UNCTAD, GATT.

Kononowicz, H. and Janick, K. (1984) In-vitro propagation of *Vanilla plainfolia. Hort. Science* 19 (1) 58 – 59.

Nichols, R. and Cruickshank, A.M. (1964). Vegetative propagation of nutmeg *(Myristica fragans)* in Grenada, W.I. *Trop. Agric. (Trinidad).* 41 (2), 141 – 146.

Nichols, R. and Pryde, J.F.P. (1958). The vegetative propagation of nutmeg *(M. fragans)* by cuttings. *Trop. Agric. (Trinidad)* 35 (2) 119 – 129.

Paulose, T.T. (1973). Ginger cultivation in India, *Proc. Conf. on Spices*, 10 – 14 April, 1972, Trop. Products Inst., London.

Phadnis, N.A. and Choudhari, K.G. (1971). Sex determination in the seedlings stage of nutmeg *(M. fragans,* Houtt*) Trop. Science* 8 265 – 74.

Philip J. (1981). Curry leaf and its uses. *World Crops* 33 125 – 127.

Pillai, S.K. 91982). Note on the multiplication of ginger *in vitro. Indian Journal Agric. Sci.* 52 (6) 397 – 9.

Purseglove, J.W. (1968). *Tropical crops: Dicotyledons and Monocotyledons.* Vols. 1 and 2. London: Longmans, Green and Co. Ltd.

Purseglove (1973). General agronomic aspects of spice crops. *Proc. Conf. on Spices.* 10 – 14 April 1972. Trop. Products Institute, London.

Purseglove *el al* (1981). *Spices* Vol. 1 and 2. London: Longmans Group Ltd. (Tropical Agriculture Series).

Ridley, H.M. (1912) *Spices,* London: Macmillian.

Rosengarten, T. (1973). Spices then and now. *Proc. Conf. on Spices.* 10 – 14 April, 1972. Trop. Products Institute, London.

Seaforth, CE (1982). West Indian spices as biologically active agents. *Proc. Seminar on Spices,* 23 – 24 Nov., 1982 Port-of-Spain, Trinidad.

Seaforth *et al* (1983) *A guide to medicinal plants of Trinidad and Tobago,* London: Commonwealth Secretariat.

Singh, H.B. (1974). *Spices.* Handbook of plant introduction. F.A.O. No. 93.

Tibury, G.E. (1949). *The clove tree* London: Crosby Lockwood.

Ward, J. F. (1961) *Pimento.* Ministry of Agriculture and Lands, Jamaica.

Williams, R. O. (1950). The clove industry of Zanizibar. *World Crops* 2 143 – 5; 198 – 200.

Winters, H. F. and Muzik, T.J. (1963). Rooting and growth of fruiting branches of black pepper. 40 (3) 247 – 252.

Zennie, T. M. and Ogzewalla (1977). Asorbic acid and Vitamin A content of edible wild plants of Ohio and Kentucky. *Economic Botany.* 31 76 – 79.

Appendix I

Annual importation of spices into Trinidad and Tobago

Year	Total value of spices imported ($TT)
1976	1,352,632
1977	3,467,972
1978	2,279,641
1980	2,718,083
1981	2,993,010
1982	3,412,726

Value of spices imported ($TT), 1976-1982

Spice	1976	1977	1978	1980	1981	1982
Ginger	28,976	31,960	61,390	55,808	59,626	65,000
Turmeric	274,944	814,493	433,114	245,369	342,741	214,000
Cardomon	167	-	5,991	31,237	37,182	26,000

Source: C.S.O. – Overseas Trade Bi-monthly Report – 1976–82.

FIELD PERFORMANCE OF TISSUE-CULTURED GIANT CAVENDISH BANANA (MUSA AAA GROUP) UNDER DIFFERENT FERTILIZER, NEMATICIDE AND PLANTING TREATMENTS ON ST. CROIX, V.I.

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ABSTRACT

The feasibility of using imported propagules of Giant Cavendish Banana for field production is described. Best yield of 28.2 t ha^{-1} or 245, 070 fruits ha^{-1} in the plant were obtained with chicken manure at 3.5kg plant^{-1} without any nematicide. In the 1st Ratoon crop overall production was better with a maximum yield of 37.1 t ha^{-1} or 272,181 fruits ha^{-1} in plots treated with chicken manure and Temik 10%G at 84g plant^{-1}. Use of tissue culture material apparently did not increase crop production time with plants requiring 285 days from planting to flowering and an additional 75 days to harvesting. Both vegetative and fruiting characteristics of plants were very uniform with no apparent variability. Soil assays showed significant absence of the burrowing nematode and yield data indicated that nematicide application may not be required until the first ratoon crop. In comparison with plants produced from traditional suckers, tissue cultured paints had thicker pseudostems more leaves and produced heavier bunches (16kg vs. 12kg) with more fruits per bunch (127 vs. 101).

RESUMEN

Se describe la viabilidad de la utilización de propágulos importados de banano del tipo Giant Cavendish para la producción de campo. Se obtuvo el mejor rendimiento de 28,2 t/ha o 245 070 frutos/ha, usando la gallinaza en una relación de 3,5 kg/planta sin nematicida. En la primera cosecha de retoños, se obtuvo una producción global mejor - un rendimiento máximum de 37,1 t/ha o 272 818 frutos/ha en los semilleros tratados con gallinaza y Temik 10%G en una relación de 84 g/planta. El uso de culitvos de tejido no parecía mejorar la duración de producción del cultivo, puesto que las plantas necesitaron un período de 285 dias desde la plantación hasta la floración, y unos 75 días más hasta la cosecha. Las características vegetativas y fructíferas permanecieron uniformes sin variación aparente. Los ensayos del suelo presentaron una ausencia significante del nematodo horadador; y los datos sobre el rendimiento indicaron que la aplicación de la nematicida no sería necesaria hasta la primera cosecha de retoños. Comparadas con las plantas producidas de retoños tradicionales, les plantas producidas de cultivos de tejido tenían seudocabezas más gruesas y más hojas; y produjeron racimos más grandes (16 kg contra 12 kg), con más frutos por racimo (127 contra 101).

Although bananas are an important part of the diet of many Virgin Islanders, most of the bananas consumed are imported from the U.S. (via Florida) or other Caribbean islands (Table 1). Planting material used in the Virgin Islands is usually brought in from neighbouring Caribbean islands creating transportation and quarantine problems.

Propagation by tissue culture is a method of producing large numbers of pest-free material (Debergh and Maewe, 1983, Hughes *et al.*, 1978 and Murashige, 1974) that can be conveniently shipped between countries. Lui *et al* (1984) used meristem aspices of banana for rapid clonal multiplication and recovery of specific pathogen-free plants. Ramcharan (1983)

Table 1. Amount and value ($US) of banana and plantains imported into the US Virgin Islands for selective years.

Item	Quantity ('000kg)	Value $	Country of origin	Year
Plantain	1.5	594	Honduras	1980
Plantain	23.3	7,092	Costa Rica	1980
Plantain	34.0	12,288	Dom. Republic	1980
Plantain	1.9	577	St. Lucia	1980
Plantain & Banana	661.0	296,935	US (via Miami)	1980
Plantain & Banana	237.0	125,986	US (via Miami)	1983

Source: Bureau of Statistics, Dept. of Commerce, Charlotte Amalie St. Thomas, U.S. Virgin Islands.

developed a suitable method of transplanting and a container for use in hardening-off Giant Cavendish banana propagules shipped into St. Croix. Pool (1984) in Puerto Rico obtained excellent yields with tissue cultured clones of Ziv and Dwarf Cavendish cultivars introduced from Israel.

The Giant Cavendish banana is now a major commercial cultivar and like the rest of the Cavendish group is resistant to the Fusarium wilt but susceptible to nematodes (Rowe and Richardson, 1975). In St. Lucia (Holder and Gumbs, 1983), Giant Cavendish was found to have comparable yields to other Cavendish types, but was shorter and more wind resistant.

This paper describes an experiment to evaluate the feasibility of importing Giant Cavendish propagules and their subsequent field performance using different cultural treatments.

Materials and methods

The study was conducted at the Virgin Islands Agricultural Experiment Station on St. Croix, U.S. V.I. The climate is tropical with an annual average maximum and minimum temperature of 30 °C and 23 °C, respectively. The average annual rainfall is 1092mm. The soil is a Fredensborg clay loam characterized by an underlying layer of limestone or marl (Lugo-Lopez and Rivera, 1980). Soil chemical characteristics of the experimental plot are shown in Table 2.

Table 2. Soil chemical analysis of the experimental plot

C.E.C. meq/100g	pH	O.M. %	P ug/ml	K meq/100g	Ca meq/100g	Mg meq/100g	Fe ug./ml
35.6	7.9	2.9	14.6	0.36	38.9	2.7	1.8

The experiment was initiated on 1 December, 1982, using Stage III plantlets of Giant Cavendish bananas air-freighted into St. Croix from Oglesby Nursery of Holiday, Florida. The plantlets were hardened-off and established according to methods previously described (Ramcharan, 1984).

Plants were spaced at 2.4m x 2.1m (about 1945 plants ha^{-1} in a 2 x 2 x 3 factorial experiment using a completely randomized design with three replicate plots, each containing six plants. Treatments used were: method of planting – either tractor dug or hand dug holes; fertilizer – chicken manure or ammonium sulfate and nematicides – Temik (Aldicarb) 10%G, Furadan (Carbofuran) 5%G and a control without nematicide. Chicken manure was applied initially at 3.5kg. of well rotted manure in the planting holes but broadcast around the plants in the subsequent yearly applications. Ammonium sulphate was applied at a rate of 1.7kg. $plant^{-1}$ yr^{-1} divided into six applications. Potassium sulfate was applied at an overall rate of 800kg K_2O ha^{-1}. Temik 10%G at 84g $plant^{-1}$ and Furadan 5%G at 56g $plant^{-1}$ were incorporated at the time of planting and again at 6 and 4 months intervals respectively on the soil surface.

A trickle irrigation system consisting of 1.25cm black polyethylene tubes, one 3.8 1 hr^{-1} emitter $plant^{-1}$ and battery operated timers (Water Watch Corp, Seattle, Washington) was used to apply water and FE 138 sequestrene chelate (Ciba Geigy, Greensboro N.C.) at 60g ha^{-1} wk^{-1}.

Weed growth was controlled with post-emergent applications of Paraquat at 0.3kg a.i ha^{-1}.

The bunches were harvested when the fruit reached the light full or full ¾ stages.

Results and discussion

Of major significance in this study was the good uniformity both in the vegetative and fruiting phases of banana plants. Unlike a previous field study using tissue cultured plantain (Ramcharan and Gonzalez, 1984), the Giant Cavendish bananas showed no variability problems.

Yield data are represented in Tables 3 and 4. In the plant crop (Table 3) overall mean yield and fruits

Table 3. Yield (t/ha) and fruits/ha of the plant crop of tissue-cultured Gaint Cavendish banana

Nematicide	Mean yield (t/ha) [1] NH_4SO_4	Mean yield (t/ha) [1] Chicken manure	Fruits/ha NH_4SO_4	Fruits/ha Chicken manure
		Tractor-dug holes		
Without	22.2b[2]	24.9 ab	203,641 b	233,400 ab
Furadan 5%G	23.5 ab	24.5 ab	208,115 ab	232,816 ab
Temik 10%G	23.5 ab	26.4 ab	223,091 ab	232,030 ab
		Hand-dug holes		
Without	20.9 c	28.2 a	202,280 b	245,070 a
Furadan 5%G	24.5 ab	24.3 ab	221,146 ab	227,565 ab
Temik 10%G	23.0 b	23.1 ab	209,476 ab	227,954 ab
Mean	22.9	25.2*	211,291	233,139*

[1] Based on a plant population of 1945 plants/ha

[2] Mean separation within columns by Duncan's multiple range test, 5% level

*Significant at the 0.05 probability level

ha^{-1} of the chicken manure treatments were significantly higher than the ammonium sulphate treatment. In the 1st ratoon crop (Table 4) there were no significant differences although overall yields were higher than in the plant crop.

With respect of nematicides and method of planting treatments, no significant difference was found within the treatments. Although using a tractor for preparing planting holes did not improve yields, this method would certainly reduce labour costs for planting.

The average yield and fruits ha^{-1} between the treatments were 24.1 and 33.75t ha^{-1} with 222, 315 and 272, 818 for the plant crop and second crop respectively.

Table 4. Yield (t/ha) and fruits/ha of the 1st ratoon crop of tissue-cultured Gaint Cavendish banana

Nematicide	Mean yield (t/ha)[1] NH_4SO_4	Chicken manure	Fruits/ha NH_4SO_4	Chicken manure
		Tractor-dug holes		
Without	35.5[2]	30.4	258,685	275,412
Furadan 5%G	30.1	31.2	278,718	270,938
Temik 10%G	35.3	34.6	258,685	294,473
		Hand-dug holes		
Without	32.4	35.7	258,685	275,421
Furdan 5%G	36.5	35.2	278,718	270,938
Temik 10%G	31.0	37.1	258,685	294,477
Mean	33.5	34.0	265,362	230,274

[1] Based on a plant population of 1945 plants/ha.
[2] Means without a letter do not differ significantly (p=.05) according to Duncan's multiple range test.

The maximum yield in the plant crop was 28.2t ha^{-1} obtained with chicken manure and without nematicide. In the second crop the maximum yield was 37.1t ha^{-1} obtained with chicken manure and Temik 10%G. Chicken manure therefore appears to be superior to ammonium sulfate, particularly in the plant crop, when the plants are relatively free of nematode infestation. Soil OM content and CEC were low (Table 2) and better yields with chicken manure may have been mainly due to soil amelioration properties of the manure itself. It would therefore be interesting to observe effects of chicken manure used in combination with ammonium sulphate.

In the 1st ratoon crop, when soil nematode populations had built up, the use of Temik with chicken manure appeared to increase yields. This interaction between chicken manure and nematicide is therefore an important one that has so far not been reported.

In data not presented, it was shown that Giant Cavendish bananas originating from tissue culture took 285 days to shooting and an average of 75 days from shooting to harvesting.

Table 5 presents the total populations of major nematodes found in soil assays. These data corresponded to the second year of the experiment. Because the method of planting has no effect on the number of nematodes, this information was compiled to simplify data.

The F value in the analysis of variance showed no interaction between fertilizer and nematicides treatments. Also, the data in general showed that neither nematicide application nor fertilizer had any significant effect on the number of nematodes.

Of major significance was the total absence of the burrowing nematode *(Radopholus similis)* which is a common pest of the Giant Cavendish banana. Although high pH is known to suppress nematode population (pers. comm ., G. Goseco. United Fruits, Honduras), the use of tissue-cultured material may partly be responsible for this notable absence of *Radopholus*. Tissue culture may therefore afford a practical and effective means of excluding the burrowing nematodes from areas such as the Virgin Islands where this pest has so far not been extensively found.

Table 5. Total population of nematodes* extracted from 100cc of soil from rhizosphere on banana grown from explants and treated with different fertilizer and nematicides[1]

	No nematicide	Furadan 5%G	Temik 10%G
Chicken manure	291.2[2]	253.2	366.5
NH_4SO_4	276.0	277.0	306.5
Total	567.2	480.2	673.0

[1] Furadan applied at 4 month and Temik at 6 month intervals
[2] Means without a letter do not differ significantly (P.05) according to Duncan's multiple range test
*Including spiral, root-knot, and reniform types

Since the use of nematicides apparently had no effect on the number of nematodes at least in the plant crop, when using tissue-cultured plantlets, it may be possible to recommend that nematicides not be used locally until the 1st ratoon crop.

Table 6 shows comparative characteristics between Giant Cavendish grown from tissue culture and from suckers in the same soil type. The superiority of tissue-cultured Giant Cavendish is evident. The thicker pseudostem of the tissue-cultured plants is well suited to the windy conditions in the Virgin Islands. Also the apparent larger bunch and numbers of fruits produced from cloned plants could significantly increase total banana production in the islands.

Table 6. Comparative growth and yield characteristics of regular & tissue cultured Giant Cavendish banana.

	Planting material	
Parameter	Regular sword suckers	Tissue-cultured propagules
Height at shooting (m)	1.8	1.7
Pseudostem diameter * (cm)	13.2	16.5
Bunch weight (kg)	12.0	16.0
Fruit/bunch	101.0	127.0
Hands/bunch	7.0	7.6
Functional leaves	8.3	9.5

*measurement taken about 0.6 m above soil level.

In summary, the feasibility of using Giant Cavendish banana from tissue culture as planting material was established. The mature plants from tissue culture showed good uniformity in both the plant and succeeding crops and comparatively higher yields than traditionally grown plants. Tissue culture may therefore afford an effective means of excluding the burrowing nematode from the Virgin Islands, reduce the dependence on the use of chemical pesticides and generally increase production from the present acreage under banana cultivation.

References

Debergh, P.C. and Maewe, L.J. (1983) Contribution of tissue culture techniques to horticultural research and production. *Acta Horticulturae.* **131** 23 - 27.

Holder, G.D. and Gumbs, F.A. (1983) Agronomic assessment of the relative suitability of the banana cultivars 'Robusta' and 'Giant Cavendish' (Williams hybrid) to irrigation. *Trop. Agric (Trinidad)* **60** (1) 17 - 24.

Hughes, K., Henke, R., and Constantin, M. (eds). (1978). *Propagation of higher plants through tissue culture, a bridge between research and application.* Tech. Inf. Center, US Dept. Energy.

Liu, L.J., Gupta, P.P., Monllor, A.C., Rosa, E., Licha, M., Lizardi, E., Diaz, N., and Arocho, A. (1974) Tissue culture propagation of tania, banana, plantains, papaya, yam and sugar cane. *Proc. 20th Caribb. Food Crops. Soc. Mtg.* 21 - 26 Oct. 1984. St. Croix, V.I.

Lugo-Lopez, M.A., and Rivera L.H. (1980) Updated taxonomic classification of the soils of the U.S. Virgin Islands. *J. Agric. Univ. P. R.* **64** (2) 131 - 137.

Murashige, T. (1974) Plant propagation through tissue culture. *Ann. Rev. Plant Physiol.* **25** 135 - 136.

Pool, D.J. (1984) Evaluation of banana cultivars for fresh fruit market in Puerto Rico. *Fruits* 39 (2) 112 - 114.

Ramcharan, C. (1984) Studies on hardening-off method and starter container for Giant Cavendish banana explants shipped into St. Croix, V.I. Proc. 19th Caribb. Food Crops Soc. 89 - 96.

Ramcharan, C., and Gonzalez, A. (1984) Yield, agronomic characteristic and variability of Regular Maricongo and Dwarf Plantain (Musa AAB) using tissue-cultured plantlets in St. Croix, U.S. V.I. *Proc. 20th Caribb. Food Crops Soc. Mtg.* 21 - 26 Oct. 1984. St. Croix, V.I.

Rowe, P.R., and Richardson, D.L. (1975) Breeding banana for disease resistance, fruit quality and yield. Bull. **2** Dec. 1975. Tropical Agriculture Research Services, La Lima, Honduras, C.A.

EFFECTS OF SUPRAOPTIMAL ROOT TEMPERATURES ON BANANA, *IXORA, DRACAENA* AND CITRUS

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ABSTRACT

Thermostability of root cell membranes of excised roots of 'Grande Naine' banana, 'Carrizo' citrange, *Ixora coccinea* and *Dracaena marginata* 'Tricolor' were determined utilizing electrolyte leakage techniques. Mathematical models were developed to predict interaction of temperature (25° to 60°C) and exposure time (30 to 300 min.) on root membrance injury. Predicted critical exposure durations at 50°C were 45, 105, 221 and 221 min. for citrus, banana, *ixora* and *dracaena*, respectively. The physiological response to root temperature of 28°, 34° and 40°C for 6 hours daily differed with plant genera, although 34°C appeared to be the optimum or maximum allowable temperature in this study. Shoot to root ratio was highest at the 40°C root temperature for *ixora*, citrus and *dracaena* and was the lowest at 40°C for banana.

RESUMEN

La termostabilidad de membranas de celulas radiculares de raices cortados de banano 'Grande Naine', citrange 'Carrizo', *Ixora coccinea* y *Dracaena marginata* 'Tricolor' fue determinado usando tecinas de goteo electrolítico. Se desarrolló modelos mátematicos para predicar interacción de temperatura (25° a 60°C) y tiempo de exposicion (30 a 300 minutos) sobre daño a la membrana radicular. Duraciones predicados de exposición crítico a 50°C eran 45, 105, 221 y 221 minutos para cítrico, banano, *ixora* y *dracaena*, respectiveamente. La reacción fisiológica con temperaturas radiculares de 28°, 34° y 40°C por 6 horas diario varió entre genero, pero 34°C pareció ser la temperatura óptima o maxima permisible en este estudio. La relación del tallo a raíz era la mas alta con una temperatura radicular de 40°C para *ixora*, citrico y *dracaena* y era la mas baja a 40°C para banano.

Although many tropical plant species are tolerant of high soil temperatures in the field (19), the rapid temperature fluctuations and extremes that occur in container media under subtropical and tropical conditions (5, 9, 23) severely limit the nursery production phase of many fruits and ornamentals.

Higher evapotranspiration in containers as compared to field conditions can also lead to water stress which may be induced by high soil temperatures even under optimum soil moisture conditions (4, 18). Root temperatures have also been shown to influence several growth and physiological processes, including photosynthesis (7, 8), carbohydrate partitioning (1, 3, 6, 22), shoot to root ratios and whole plant weights (2, 3, 16).

Before effective measures can be taken to reduce supraoptimal root temperatures effects, it is important to identify the critical high temperature limits of tropical plant roots and to characterize some of the physiological responses induced by high root temperatures. This paper presents a review of preliminary results of a project on heat stress of plant roots funded by special Grants, USDA, Tropical Agriculture Section. The objective of this project was (a) to identify critical interactions of exposure duration and temperature on thermostability of excised roots of banana, ixora, dracaena, and citrus and (b) to study the influences of varying root temperatures on growth and physiology of container plants of the same species.

Critical exposure durations and temperatures for excised roots

Tissue-cultured plantlets of *Musa* spp. AAA 'Grande Naine', rooted cuttings of *Draceaena marginata* 'Tricolor' and *Ixora coccinea* and seedlings of 'Carrizo' citrange *(Citrus sinensis* x *Poncirus trifoliata)* were grown in 9 liter plastic containers. Osmocote 18–6–12, controlled release fertilizer was applied every 3 months at 24g per container. Plants were grown in 30 percent shade for 4 months before root thermostability determinations in August 1984.

Electrolyte leakage (L_e) procedures (10, 11, 12, 21) were used to measure themostability. Fifty 1g samples of carefully washed excised roots of each test plant were placed in test tubes and inserted into a temperature controlled circulating ethylene glycol bath for each of 12 temperature treatments (25 to 60°C) and 5 tubes were withdrawn at 30 min. intervals for up to 300 min. Twenty-five ml of deionized water were added to each sample tube before an ice bath incubation for 24 hrs. Conductivity of the incubation solution was then determined at room temperature and the samples were killed by autoclaving for 20 min at 120°C. Samples were incubated for another 24 hrs. before final conductivity measurements were taken. L_e of each sample was expressed as the ratio of the incubation solution conductivity before and after autoclaving. A sigmoidal response curve was fitted to L_e data across temperature treatments for each of the 10 exposures using a least-squares approach as described by Ingram (12). Mathematical models to describe temperature and exposure time interactions were derived (13, 14).

A sigmoidal response curve was the appropriate function to describe electrolyte leakage from roots of all test plants as influenced by temperature, T, at each exposure time, E. The temperature corresponding to the midpoint of the 10 sigmoidal curves decreased exponentially as E increased. The general equation describing the interactive effects of temperature and exposure time on root thermostability as measured by L_e was

$$L_e = z + (x-z)/1 + e^{-k(T-c-s(\ln E))}$$

where z was the baseline level of L_e, x was the maximum proportion of L_e, T was the treatment temperature, k was a function of the slope at the inflection point, c was the intercept of the temperature axis in

reference to critical temperatures, s was the slope of the fitted line of T across exposure times and E was the exposure time. The model has been described in detail for banana and dracaena and citrus and ixora. An equation was derived from the model for each test genera to predict cirtical exposure times, E_c, for given temperatures (13, 14).
These were:

Banana $E_c = e^{(62.168 - T)/2.615}$

Draceana $E_c = e^{(62.783 - T)/2.367}$

Citrus $E_c = e^{(65.073 - T)/3.964}$

Ixora $E_c = e^{(65.34 - T)/2.838}$

These equations were used to calculate E_c for selected temperatures presented in Table 1. The predicted E_c at 50 °C for example was twice as long for dracaena and ixora as for banana and 5 times as long for 'Carrizo' citrange. This would indicate a greater tolerance of dracaena and ixora roots to supraoptimal root temperatures as compared to roots of banana and citrus.

Table 1. Predicted critical exposure time for root cell membranes of 'Carrizo' citraize 'Grande Naine' banana *Ixora coccinea* and *Dracaena marginata* 'Tricolor' for selected temperatures.

Temperature (°C)	Predicted[y] critical exposure time, E_c (min)[z]			
	'Carrizo' citrange	*Ixora coccinea*	'Grande Naine' banana	*Dracaena marginata*
45	158 ± 25 [x]	- - -[w]	-- -- --	-- --
48	74 ± 23	-- -- --	225 ± 36	-- -- --
50	45 ± 10	221 ± 60	105 ± 14	221 ± 51
52	27 ± 8	110 ± 29	49 ± 6	95 ± 11
55	13 ± 5	38 ± 15	16 ± 5	27 ± 11
57	8 ± 4	19 ± 9	7 ± 4	11 ± 6

[z] Adapted from Ingram and Ramcharan (1986) *Trop. Agric. (Trinidad)* (In press) and Ingram and Ramcharan. (1986) J. Enuriron Hort. (In review)
[y] Calculated values derived from model describing temperature and exposure time interactions on membrane thermostability measured by electrolyte leakage.
[x] Confidence intervals calculated as $E_c + t_{.05}$ var (E_c).
[w] Predicted values were greater than 300 min. therefore, out of the range of the model.

Growth and physiological response to root zone temperatures

Dracaena, ixora, banana and citrus plants as described above were potted in 12 cm x 12.5 cm x 85 cm plastic containers. After 6 weeks, the containers were securely inserted into styrofoam-lined wooden 1m x 1m x 20cm air-bath boxes (15) in which the root systems were exposed to 28 ± 2, 34 ± 2, or 40 ± 2°C for 6 hrs. daily. Each box contained 9 plants. Four 100W aluminum foil-covered incandescent light bulbs provided convective heat, which was distributed by small 10cm x 10cm box fans. The bulbs were thermostatically controlled and temperatures in each box were characterized periodically with an Easterline Angus data logger using copper-constantan thermocouples. The boxes were located in a glasshouse with 800 μmol $m^{-2}s^{-1}$ maximum light intensity.

There were 4 replicate boxes for each treatment temperature and 2 or 3 plants per genera were randomly located in each box. Plants were drip irrigated with 300ml and fertilized weekly with a 20N-10P-17K solution at 150ppm N. The experiment was terminated after 90 days when shoot and root dry weights were determined and root and shoot samples taken for sugar and starch analysis using a previously described method (20).

Shoot to root ratio (S:R) was the major morphological feature affected by high root zone temperatures (Table 2). In the woody species ixora and citrus, S:R was increased by the 40°C treatment, as has been recorded for other woody plants (16). Increased lateral shoot growth and fewer flowers were evident also on ixora plants exposed to the higher temperatures. Increased S:R in dracaena was a consequence of reduced root growth. The 40 °C treatment also caused chlorosis and leaf drop with a consequent reduced quality of dracaena.

As has been reported for other herbaceous monocots (17, 3), morphological responses to high temperatures in banana were somewhat different. Shoot dry weight (leaf & pseudostem) increased linearly with increasing root temperatures. Since neither plant height nor leaf production were affected (data not shown) it may be deduced that the 40 °C treatment affected shoot size in banana mainly through its effect on reduced corm size.

Alterations in translocation and partitioning patterns of carbohydrates were apparently the major physiological effects of supraoptimal temperatures recorded in this experiment. Although absolute concentrations of sugar and starch did not differ with root temperature, partitioning or ratio between them differed (Table 2). Increased sugar: starch ratio (SU:ST) was found in the roots and decreased SU:ST in the shoots of ixora grown at 40 °C. This indicated increased translocation but not at the expense of shoot or root growth. In banana there was a decreased SU:ST in the roots and this appeared to be at the expense of shoot growth, particularly the corm. In dracaena, 40 °C caused considerable root growth reduction, and this was reflected in increased S:R ratio. This indicated increased translocation of photosynthates to the roots and probably high root respiration at the expense of root growth.

Table 2. Response of 'Grande Naine" banana, *Ixora coccinea, Dracaena marginata,* 'Tricolor' and 'Carrizo' citrange to three root zone temperatures. All data presented are means based on dry weight (g). (Adapted from Ingram *et al.* (1986). *HortScience*; In press)

Treatment Temperature (°C)	Shoot wt. (g)	Root wt. (g)	Shoot / root	Shoot sugar content (mg/g)	Shoot starch content (mg/g)	Shoot sugar/ starch	Root starch content (mg/g)	Root sugar content (mg/g)	Root sugar/ starch
				Ixora coccinea					
28	12.7	4.5	2.7	31.4	8.2	4.0	14.8	13.8	1.1
34	11.2	4.3	2.8	35.5	7.2	4.9	15.8	10.6	1.5
40	14.3	4.5	3.9	27.0	9.4	2.9	20.4	9.9	2.1
Linear[z]	NS	NS	NS	NS	NS	NS	NS	NS	0.05
Quadratic	NS	NS	0.06	NS	NS	0.05	NS	NS	NS
				'Grande Naine' Banana					
28	23.3	23.4	1.0	20.7	10.3	3.0	16.4	11.2	1.5
34	21.9	32.6	0.7	21.0	12.4	1.7	19.6	11.8	1.7
40	18.4	37.4	0.5	22.1	10.8	2.0	11.0	11.8	0.9
Linear	0.02	NS	0.02	NS	NS	NS	NS	NS	0.05
Quadratic	NS	NS	NS	NS	NS	NS	NS	NS	0.03
				'Carrizo citrange'					
28	2.4	2.6	1.0	19.0	26.4	0.7	16.0	20.4	0.8
34	3.0	3.3	0.9	21.3	24.2	0.9	11.1	19.2	0.6
40	3.2	2.6	1.3	31.9	25.4	1.3	11.0	21.9	0.5
Linear	NS	NS	0.05	NS	NS	NS	NS	NS	NS
Quadratic	NS	NS	NS	NS	NS	NS	NS	NS	NS
				Dracaena marginata 'Tricolor'					
28	31.8	23.8	1.3						
34	29.2	25.7	1.1						
40	26.8	13.6	2.0						
Linear	NS	0.05	NS						
Quadratic	NS	0.005	0.06						

[z] Regression analyses were used to test for significant linear and quadratic responses.

Summary

Plant roots in containers may be exposed briefly to temperatures approaching 50 °C several times per week during the summer months (11). Injury sustained in such a short period is called direct injury. Temperatures above 45 °C may be maintained for 3 to 6 hours daily and can result in indirect injury to plant roots (16). The temperatures causing direct injury of excised banana, citrus, dracaena and ixora roots were determined using electrolyte leakage procedures. Growth and physiological responses of the same species in containers exposed to 28, 34 or 40 °C for 6 hr daily were measured.

Excised dracaena and ixora roots withstood 50°C for up to 3 hr and were more thermotolerant than citrus and banana roots. However, data indicate that dracaena and ixora were less tolerant of prolonged daily exposures to supraoptimal yet sublethal temperatures. Dracaena root dry weight was reduced and leaf chlorosis and leaf drop increased by the 40 °C treatment. Ixora had more axillary growth, less flowering and reduced root sugar/starch ratio at 40 °C, implying a possible hormonal effect and alteration of translocation and/or root respiration.

Additional research has been initiated to more precisely determine the response of these plants to supraoptimal temperatures. Temperatures in container media in the tropics are also being characterized and methods of modifying these temperatures are being evaluated.

References

1. Barlow, F.W.R., L. Boersma, and J. L. Young. 1976. Root temperature and soil water potential effects on growth and soluble carbohydrate concentration of corn seedlings. Crop Sci. 16:59–62.

2. Barta, A.L. 1978. Effect of root temperature on dry matter distribution, carbohydrate accumulation, and acetylene reduction activity in alfalfa and birdsfoot trefoil. Crop Sci. 18:640–647.

3. Brown, R.H. and R.E. Blaser. 1970. Soil moisture and temperature effects on growth and soluble carbohydrates of orchard grass *(Dactylis glomerata)*. Crop Sci. 10:213–216.

4. Chen, H.-H., Z.-Y. Shen, and P.H. Li. 1982. Adaptability of crop plants to high temperature stress. Crop Sci. 22:719–725.

5. Fretz, T.A. 1971. Influence of physical conditions on summer temperatures in nursery containers. HortScience 6:400–401.

6. Guinn, G. and R.F. Hunter. 1968. Root temperature and carbohydrate status of young cotton plants. Crop Sci. 8:67–70.

7. Gur, A., B. Bravdo and Y. Mizirahi. 1972. Physiological response of apple trees to supraoptimal root temperatures. Physiol. Plant 27:130–138.

8. Gur, A., Y. Mizirahi, and R.M. Samish. 1976. The influence of root temperature on apple trees. II. Clonal differences in susceptibility to damage caused by supraoptimal root temeperature. J. Hort. Sci. 51:195–202.

9. Ingram, D.L. 1981. Characterization of temperature fluctuations and woody plant growth in white poly bags and conventional black containers. HortScience 16:762–763.

10. Ingram, D.L. 1985. Modeling high temperature and exposure time interactions on *Pittosporum tobira* Thunb. root cell membrane thermostability. J. Amer. Soc. Hort. Sci. 110:470–473.

11. Ingram, D.L. and D.W. Buchanan. 1984. Lethal high temperatures for roots of three citrus rootstocks. J. Amer. Soc. Hort. Sci. 109:189–193.

12. Ingram, D.L. and D.W. Buchanan. 1984. Lethal high temperatures for root of three citrus rootstocks. J. Amer. Soc. Hort. Sci. 109:189–192.

13. Ingram, D.L. and C. Ramcharan. 1985. Heat tolerance of 'Carrizo' citrange and *Ixora coccinea* root cell membranes. (In review).

14. Ingram, D.L. and C. Ramcharan. 1985. 'Grande Naine' banana and *Dracaena marginata* 'Tricolor' root cell membrane heat tolerance. Trop. Ag. (In press).

15. Ingram, D.L., C. Ramcharan and T.A. Nell. 1986. Responses of banana, ixora, citrus and dracaena to elevate root temperatures. HortScience 21: (In press).

16. Johnson, C.R. and D.L. Ingram. 1984. *Pittosporum tobira* response to container medium temperature. HortScience 19:524–525.

17. Ketellapper, H.J. 1960. The effect of soil temperature on the growth of *Phalxis tuberosa* L. Physiol. Plant. 13:641–649.

18. Levitt, J. 1980. Response of plants to environmental stresses. Vol. I. Chilling, freezing and high temperature stresses. Academic Press, New York.

19. Medcalf, J.C., 1985. Preliminary studies on mulching young coffee in Brazil. IBEC Res. Inst. Bull. No. 12.

20. Stamps, R.H. 1984. Production temperature effects on anatomy, morphology, physiology and postharvest longevity of leatherleaf fern *(Rumorhra adiantiforms* Forst. Ching). Dissertation Univ. of Florida. Gainesville, FL.

21. Sullivan, C.Y. 1972. Mechanisms of heat and drought resistance in grain sorghum and methods of measurement. p. 247–264. In: N.G.P. Rao and L.R. House (eds.) Sorghum in the seventies. Oxford & I.B.H. Publishing Co. New Delhi. India.

22. Turner, D.W. and E. Lahav. 1983. The growth of banana plants in relation of temperature. Aust. J. Plant Physiol. 19:43–53.

23. Young. K. and D.R.Q. Hammet. 1980. Temperature patterns in exposed black polyethylene plant containers. Agr. Meterol. 21:165 – 172.

ROOT AND SHOOT GROWTH OF *DRACAENA FRAGRANS* 'MASSANGEANA': CORRELATIONS WITH CANE CIRCUMFERENCE

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ABSTRACT

Root and shoot development of *Dracaena fragrans* 'Massangeana' was determined 51, 72, 93, and 114 days after fresh cut cane was planted. Basal circumference of canes varied from 13.5 to 19.5cm. At each sampling date, root: shoot ratio was affected by cane circumference. As cane circumference increased above 14.5cm, root length and root:shoot ratio decreased. Number of developing shoots was not affected by cane circumference at any sampling date. Leaf area was not affected until sampling day 114, when it increased as circumference increased.

RESUMEN

Se evaluaron los efectos de seis tratamientos sobre el desarrollo radicular en cañas de *Dracaena fragrans* "Massangeana". Los tratamientos fueron: (a) anillado a 12cm. de la base de la caña, (b) anillados a 6 y 12cm. de la base de la caña, (c) muescado usando un grupo de tres pequenos incisiones horizontales a 12cm. de la base de la cana, (d) muescado unsando dos grupos de tres pequenos incisiones horizontales a 6 y 12cm. de las base de la caña, (e) cortes longitudinales utilizando tres incisiones de 12cm. de largo distribuidas cada 120° alrededor de la caña y, (f) control. Aunque el desarrollo radicular fue afectado por los diferentes tratamientos, la circunferencia de las cañas también ejerció una fuerte influencia. Las cañas con las mayores y menores circunferencias desarrollaron un sistema radicular menos extenso que aquellas de tamaño medio, mientras que el óptimo desarrollo foliar ocurrió en aquellas cañas de circunferencia mayor.

Additional index words: Leaf area; Foliage plant.

Dracaena fragrans 'Massangeana' is a popular foliage plant in interiorscapes. When propagated by canes, a number of buds (usually 1 to 3) develop near the apcial end, forming whorls of leaves, commonly called 'heads' by tropical foliage plant growers. Because of this growth habit, 'Massangeana' are usually potted using 3 or 4 canes of different lengths per container to produce a larger visual mass (Fig. 1). During shipping, 1 or more of the canes frequently loses its vertical alignment in the container and leans against the side of the container. This problem was suspected to occur due to poor anchorage provided by the root system (2).

When purchasing cane for propagation, some growers perfer large circumference cane because they believe it produces larger 'heads' and a more salable plant. However, no known study has evaluated the root and shoot development of *D. fragrans* 'Massangeana' cane over time.

This study presents observations on root and shoot development of *D. fragrans* 'Massangeana' canes as affected by cane circumference.

Materials and methods

One hundred and twenty, 65-cm long cane pieces of *D. fragrans* 'Massangeana' were brought from Jamaica to Gainseville, FL. Upon arrival, a 1-cm slice was removed from the cane base and the lower portion of the canes (20cm) were soaked overnight in water. The canes were treated as follows: (a) girdling at 12 cm above cane base, (b) girdling at 6 and 12cm above cane base, (c) notching with 1 set of 3, 1cm incisions 12cm above cane base, (d) notching with 2 sets of 3, 1cm incisions 6 and 12cm above cane base, (e) wounding with 3 longitudinal 12cm cuts distributed 120° apart on the cane, and (f) untreated check. Each treatment was replicated 5 times per each of 4 planned sample dates. After treatment, the cane bases were dipped for 10 minutes in a Benomyl (600 ppm) + Streptomycin (300 ppm) solution, planted in standard black plastic 2-gallon containers filled with Canadian peat moss and placed in a greenhouse under light levels of 260 μmols s^{-1} m^{-2} (2000 ft.c.) in completely randomized blocks. Media was watered to keep it moist until rooting occurred, then fertigated with 100 ppm N as needed to keep it mosit. The 100 ppm N fertilizer solution was prepared from a 20–20–20 N–P_2O5–K_2O fertilizer. Greehouse heating and venting controls were set at 18 °C night and 25 °C day. Thirty canes were sampled every 3 weeks for 12 weeks, starting at day 51 after planting. On the last sample, plants needed 2 more weeks to meet the specifications of the Florida Foliage Industry for finished *D. Fragrans* 'Massangeana' cane (3).

At each sample date, the following data were taken: root length, fresh weight, dry weight; 'head' (shoot) length, fresh weight, dry weight; total leaf area for each 'head' and cane circumference. 'Head' length was measured from point of origin on the cane to the tip of the longest leaf in the whorl. Cane circumference was determined at each sampling date by measuring cane 2.5cm above the base. 'Head' size for each plant was approximated by the following formula:

$$\text{'Head' size} = \frac{\text{total leaf area}}{\text{number of 'heads'}} \times \frac{\text{total 'head' length}}{\text{number of 'heads'}}$$

The root:shoot ratio was computed in terms of root length to leaf area (1). Treatment effects have been previously reported and showed notching and girdling resulted in best root development (4). Analysis of the data revealed cane circumference influenced root and shoot development.

Results and discussion

At day 51, 72, and 93, cane circumference affected root length (Table 1). At day 114, the effect of cane circumference on root length was no longer evident

Table 1: Levels of statistical probability on the effect of cane circumference on different growth parameters of *Dracaena fragrans* 'Massangeana' at different days after propagation.*

Sample Day	Root Length	Leaf Area	Number of Heads	Root: Shoot Ratio	Head Size
51	0.0001	0.1711	0.3485	0.0006	0.0840
72	0.0003	0.8597	0.4582	0.0016	0.6172
93	0.0005	0.0942	0.7816	0.0001	0.3984
114	0.4008	0.0001	0.5575	0.0064	0.0688

*Values obtained from SAS Stepwise Regression Procedure, single variate model response reported.

if a single variate model was used to analyze the data. However, the SAS stepwise regression procedure showed that if leaf area effects were removed, cane circumference affected root length at p = 0.0002. As cane circumference increased above 14.5cm, root length decreased (Fig. 2). The effect of cane circumference on leaf area was not evident until day 114 when leaf area increased as cane circumference increased (Table 1, Fig. 3). The number of 'heads' produced per cane was not affected by the circumference at any harvest date. At day 114, an increased head size was associated with increased cane circumference (p = 0.0688). These results support the opinion of many *D. fragrans* 'Massangeana' growers that larger circumference canes produce shoots with more and/or larger leaves. However, these plants may not be the best plants to ship when the root:shoot ratios are considered. At each sampling date, cane circumference affected root:shoot ratio (Table 1) with decreasing ratios as cane circumference increased (Fig. 3). A cane circumference of 15.28cm was predicted by the SAS response surface regression procedure for optimum root and shoot development at day 114.

The results indicate that larger circumference cane (>17.0cm) takes longer than a smaller circumference cane to develop a balanced root:shoot system. Thus, root anchorage of large circumference cane would be less than small circumference can and the probability of leaning cane occurring during shipping and subsequent handling would be greater for large circumference cane. Consequently, producers of *D. fragrans* 'Massangeana' cane should harvest or cut cane before the basal circumference exceeds 17–18cm. If large circumference cane is used, growers should allow a longer time period for rooting. Other alternatives growers could use include girdling or notching cane for a better distribution of the root system as previously reported (4). Leaning cane can also be avoided by using a styrofoam plug in the center of multiple cane plantings and wrapping the outside of the canes with shipping tape (2). As previously reported (5), root and shoot development of thin cane (<13.5cm) is poor.

Literature Cited

1. Aung. L.H. 1974. Root-shoot relationships. *In* The Plant Root and Its Environment. Ed. E.W. Carson, pp. 29–61. University Press, Virginia.

2. Conover, C.A., A.R. Chase, and L.S. Osborne. 1984. Corn plant. A foliage plant research note RH–1984–J.

3. Gaines, R.L. 1978. Guidelines for foilage plant specifications for interior use. Florida Foliage 4(1): Special Supplements. 36 pp.

4. Melendro, D.Y., D.B. McConnell, T.J. Sheehan, and R.T. Poole. 1985. Root system distribution of containerized *Dracaena fragrans* 'Massangeana'. HortScience 20(3):57.

5. Poole, R.T., C.A. Conover, and W.E. Waters. 1974. Budbreak in canes of *Dracaena fragrans* Ker cv 'Massangeana'. HortScience (6):540–541.

Fig. 1. Multiple cane plantings of D. fragrans 'Massangeana.'

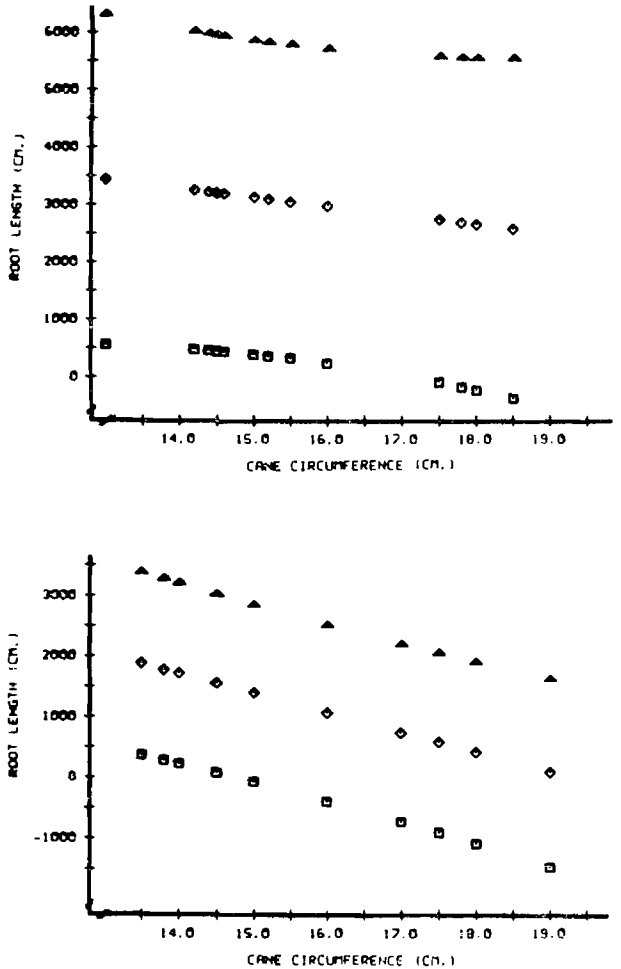

Fig. 2. Relationship between cane circumference and root length of D. fragrans 'Massangeana.' Upper graph day 114, lower graph day 93 after cut cane propagated. Data include all treatments.

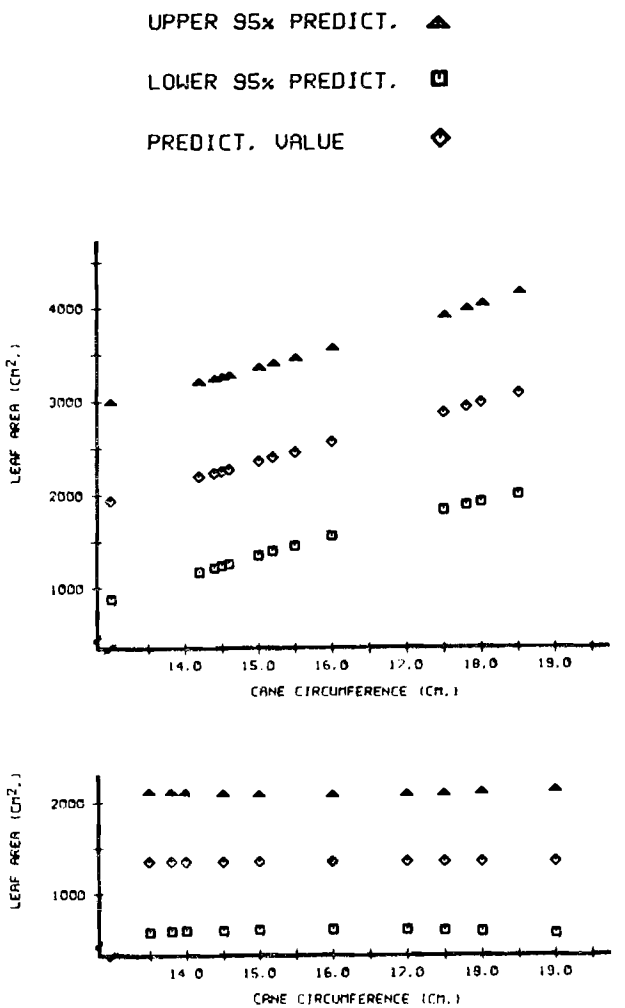

Fig. 3. Relationship between cane circumference and leaf area of D. fragrans 'Massangeana.' Upper graph day 114, lower graph day 93 after cut cane propagated. Data include all treatments.

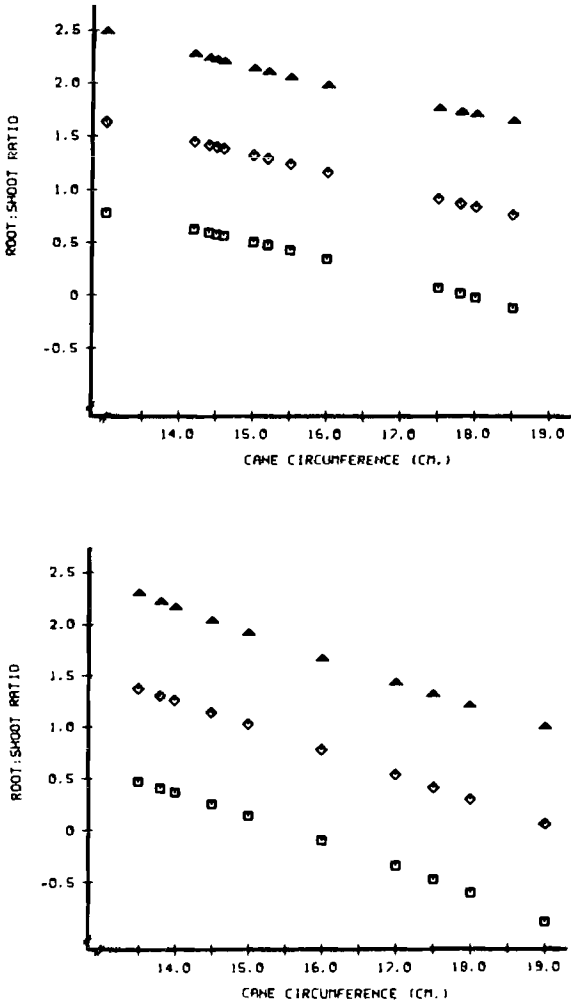

Fig. 4. Relationship between cane circumference and root:shoot ratio of D. fragrans 'Massangeana.' Upper graph day 114, lower graph day 93 after cut cane propagated.Data include all treatments.

THE VALUE OF CULTIVATING THE BAOBAB AND OTHER RARE EXOTIC TREES IN THE CARIBBEAN

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ABSTRACT

The baobab of Africa is one of the world's most unusual trees. In the literature it is described as 'rare' in the Caribbean, although it is far more common than is generally recognized. This paper examines the current uses of the baobab in the Caribbean and suggests several reasons why an effort should be made to encourage the cultivation of this and other rare exotic trees on a wider scale.

RESUMEN

El baobab de Africa es uno de los árboles más raros del mundo. En la literatura, se lo describe como siendo 'raro' en el Caribe, aunque en realidad, es mucho más corriente que se imagine. Este trabajo examina los usos corrientes del baobab en el Caribe. Además, sugiere varias razones porque se debe favorecer el cultivo de éste y de otros árboles exóticos en una escala más generalizada.

One of the world's most unusual trees is the African baobab. This spectacular tree never fails to attract attention wherever it grows because of the striking appearance of its very large, swollen, bottle-shaped trunk[1] topped by rapidly tapering branches that remain leafless for much of the year. Little has been written about the history and cultural significance of the baobab in the Caribbean.[2] This paper presents an initial exploration of the uses of the baobab in the region and suggests several reasons why this remarkable tree should be more widely cultivated. It is also written with the hope that it will stimulate those with a knowledge of the baobab in the Caribbean to share their interest through publication, presentation or personal communication.

The scientific name of the african baobab is *Adansonia digitata* and some nine species of the genus are only known to occur naturally in Madagascar and Australia. It is generally believed that the African baobab was taken to India, Sri Lanka and Java (Backer and Van Den Brink, 1963) in association with Arab trade and military activities. In 1874 Steward and Brandis (1874) reported baobabs were "cultivated in many places in the Peninsula, Bengal, and central India." Baobabs have been reported for Mauritius at least since 1816 (Armstrong, 1977) and more recently, occasional specimens have been reported for the Philippines (Maheshwari, 1971; Armstrong, 1977) and Hawaii (Neal, 1965).

The baobab has also been introduced into the tropics and subtropics of the New World. Owen (1970) reports their existence in South America and without great effort, I have identified over 20 trees in Florida and I suspect that there are many more.

In the literature the baobab is described as rare in the Caribbean region but it is far more common than is generally recognized. It has been reported for Cuba, Puerto Rico, Haiti, the U.S. Virgin Islands of St. Thomas and St. Croix, Antigua, St. Kitts–Nevis, Dominica, Barbados, Trinidad and Tobago, St. Vincent, and the Dutch West Indian Islands of Curacao, St. Eustatius, Saba and St. Martin.[2] Baobabs were also reported for Jamaica at the end of the eighteenth century and for the Bahamas within the past 30 years, but as far as I know they no longer exist in these places.

Arguments for a more widespread cultivation of baobabs in particular places and throughout the tropics generally are not new. In their 1874 study of the forest flora of northwest and central India, Stewart and Brandis (1874) described the baobab as a "useful tree' and suggested that "its cultivation should be encouraged." Dr. J.K. Maheshwari (1971) of the National Botanic Garden in Lucknow, India, went one step further suggesting that "an effort should surely be made towards the possible reintroduction and rehabilitation of baobabs over larger areas of the tropics." In his conclusion (p. 60) he wrote:

> "With its imposing place in the landscape and its usefulness to Man and wild animals, the Baobab Tree has some merits and deserves intensive study ... We have at present only sketchy information concerning the life–history of Baobabs from the time when their seeds germinate until they finally die. It would, therefore, be of considerable interest to launch a programme of sound conservation practices and build up Baobab National Monuments in suitable natural areas for the pursuit of basic scientific research and for preservation of this Goliath among trees."

While some scholars have not specifically called for the cultivation of the baobab on a wider scale, they have expressed concern for its survival. This is especially true for those who have studied the baobab in Africa. Until 1941, efforts were made in South Africa (as they were in Mozambique, Senegal, and elsewhere) to exploit the baobab commercially in

1. Baobabs come in several basic shapes of which the bottle-shaped baobabs and the baobab with three or four main trunks branching close to the ground are two common examples.

2. Work is now in progress to determine the distribution of baobabs in the Caribbean and to understand something about their history and cultural significance.

ways that could have proven disastrous for the species. Owen (1974) tells us that:

> "Fortunately, the authorities (in South Africa) concerned soon realized that the destruction of this most interesting tree for the production of a cheap product (paper, ceiling boards) which could readily have been made from other raw materials was not justified. Now, as a result of the Forest Act of 1941, the baobab has been declared a reserved tree in South Africa and is not allowed to be felled without the permission of the Minister. Its conservation has, therefore, been assured for posterity."[3]

This paper supports the point of view of those who would like to see the baobab more widely cultivated throughout the tropics. It also supports those who would like to ensure the preservation of the species although there is not at present any imminent threat to its survival. The suggestion that is being made here is that the Caribbean region should be (as Maheshwari (1971) has phrased it) an area of "Baobab National Monuments . . . for the pursuit of basic scientific research and for preservation of this Goliath among trees." Beyond scientific research and preservation, however, there are other reasons for cultivating the baobab in the region. Some of these reasons involve extending the current uses of the tree in the Caribbean and others relate to exploring potential uses that are worth considering.

Uses of the baobab in the Caribbean

In the Caribbean the baobab is useful as a garden curiosity, a garden specimen, a shade tree, a source of commercial products and a food tree.

Garden curiosity

It is quite clear that the baobab is of limited commercial value in the Caribbean and will probably remain so in the foreseeable future. This is not the plant that we ought to be considering if our only concerns were pressing "food problems" and problems of "foreign exchange." I am in full agreement with Hollis (1963), however, who wrote that she was "one of those who felt that this admirable tree justifies its existence by its mere appearance." If the only reasons for cultivating the baobab in the Caribbean was the fact that it is a rare exotic tree of intriguing appearance, I would still suggest that this tree be cultivated on a wider basis in the region. African legend tells us that the tree was planted "upside down." This points to the fact that its stumpy, irregularly shaped branches resemble roots thrusting into the air. The distinctly odd appearance of the baobab makes it an easily recognized feature of the landscape wherever it grows. Many writers have described this striking tree as "ludicrous," "monstrous," "bizarre," "grotesque" and "ugly" (Emboden, 1974). I would suggest, therefore, that it cultivation be extended in the Caribbean not as an "ornamental" but as a fascinating garden curiosity suitable for very dry places. It seems many of the baobabs planted in India, Hawaii, Florida and the Caribbean were planted as garden curiosities in yards, parks and public grounds of various types, and as garden specimens in experimental stations and botanic gardens (Everett, 1980). This is especially true of young trees planted in St. Croix. In Jamaica on the other hand there are no baobabs in the botanic gardens nor in any of the other public gardens or parks.

As a garden curiosity, a greater effort should be made to grow baobabs in school grounds, parks and along roadsides. This is very important, for I believe this impressive tree would awaken an interest in young people to seek a greater understanding of the world of plants and their importance in both economic and spiritual life.

Baobabs are already a factor to be considered in our efforts to understand Caribbean culture. The cotton tree *(Ceiba pentandra)* is a "spiritual" – some would say "sacred" – tree to the people of African descent throughout the Caribbean. One of the explanations offered for this fact is that the traditional ideas associated with the baobab in Africa were transferred to the cotton tree in the New World (Wilkinson, 1984). While there are many problems with this explanation it does point out the need to understand the baobab as an aspect of explaining cultural tradition in the Caribbean.

The baobab is also relevant to Caribbean people of East Indian background. The tree is now to be found in many parts of India where it provides useful products and is regarded as a "spiritual" or "sacred" tree (Hooker 1872; Stewart and Brandis, 1874; Cowen 1952; Prain, 1963; Burton-Page, 1969; Henry, 1973; Maheshwari, 1971).

Beyond the uses of the baobab in the cultures of Africa, India and the Caribbean, however, the tree is noteworthy for what it can tell us about the past. It seems reasonable to assume that this native of the African grassland has been closely associated with the human species over the long course of our evolutionary history. As Owen (1970) has pointed out, the baobab has been a "silent chronicler of events down the centuries" and we are beginning to realize that anthropologists (including archaeologists, physical anthropologists and cultural anthropologists), ecologists, historians and folklorists can learn a great deal from studying this tree (Hobley, 1922; Allison 1962; Harland, 1976; Shaw, 1976). The baobab has been mentioned in several discussions concerned with the origin of agriculture (Harlan, 1975; Rindos, 1984) and the tree is frequently mentioned in association with settlement patterns in Africa (Hobley, 1922; Allison, 1962; Shaw, 1976).

Shade

Although it does not produce heavy shade throughout the year as is typical of such evergreen tropical trees like the mango *(Mangifera indica)*, Cassia *(Cassia siamea)* and fig (*Ficus* spp.), the shade of baobab is welcomed in the hot, dry places where it is usually to be found growing (Everett, 1980). We can see excellent examples of this in St. Thomas, St. Croix (especially at Grove Place), Barbados, Antigua and elsewhere.

3. The continuation of Owen's (1974) comments are worth citing here. He writes: "One would like to see an extension of this legislative protection to other parts of Africa, for example, to the West Coast where commercial enterprises such as phosphate mining in Togo are destroying groves of mature baobabs."

Food

As a food tree, the baobab is primarily valued in Africa for its leaves and shoots, and for the seeds and pulp of the fruit. The fruit of the baobab is a woody, gourd-like capsule that is oblong in shape. It contains some 30 or more brown, kidneyshaped seeds embedded in a white or creamy acidic pulp laced together in a mass of tough, stringy fibers. The fruit is eaten as a fresh fruit. The dry pulp is eaten in Barbados, Trinidad and St. Croix where it is also used to make a drink. Both Dr. Martin at the Mayaguez Experimental Station in Puerto Rico and Dr. Campbell at the Tropical Research and Education Center told me that their families eat the fruit, although as far as I can tell the fruit is not generally eaten in Puerto Rico (where I believe there is only one tree) or in Florida.

People in the Caribbean should be encouraged to eat not only the pulp of the fruit but the seeds as well as the shoots and leaves. Anything that increases food supply in the Caribbean should be welcomed (especially tree crops), even if this source of food is considered suitable only for children or for use during "hard times" (i.e., times of "seasonal scarcity" or times of disaster). School children in Jamaica eat a wide variety of fruits during the school days that includes the tropical almond *(Terminalia catappa)* in some places, especially the coastal areas of the island, guinep *(Melicoccus bijugatus)*, tamarind *(Tamarindus indica)*, Chinese ackee *(Pithecolobium unguis-cati)*, mango *(Mangifera indica)*, June plum *(Spondias dulcis)* and jujube or Coolie plum *(Ziziphus mauritiana)*. There is no reason why the fruit of the baobab should not be added to this list. Charles Smith of the College of the Virgin Islands Extension Service said that as a child he ate the fruits of the baobab tree in Queens Park on his way to and from school. One of the advantages of the baobab as a food tree is that its fruits are available to be harvested during what is called "hard times" in Jamaica which is a period of seasonal scarcity associated with the winter dry season and much of the spring. At this time of year the pulp which is rich in ascorbic acid (Carr, 1955; Nicol, 1957) would be especially useful to people who live in the driest parts of the Caribbean where citruses are difficult to grow and expensive to buy.

Commercial products

I am aware of only two commercial uses of the baobab in the Caribbean although there are probably other commercial uses that have not yet been identified. In St. Croix the pulp of the fruit is used to make a refreshing drink as I have already mentioned, and this is sold in the Christiansted market. The other commercial value is the sale of the fruit which was reported in St. Croix, but this seems to be a very occasional practice.

In discussing the baobab with my colleagues they have argued that the baobab is not widespread throughout the Caribbean because of its limited commercial value. This seems to be a very simple point and yet it is not as simple as it would appear. I would argue that (with the exception of major export crops) there is no necessary relationship between the commercial value of a tree's product and the extent to which the tree is to be found in the environment. For example, if the commercial value of a tree's product was always the decisive factor determining its distribution in the environment, we would expect that "special mangos" in Jamaica like the varieties called East Indian, Julie, Bombay and Haydens would be the most commonly distributed. The same would be true of the litchi tree in Jamaica which produces a very valuable crop and yet the tree has spread very slowly. I would argue that the ease or difficulty of cultivation has a great deal to do with the trees we find growing in the Caribbean. The baobab like the litchi and special mangos is not rare because of the lack of commercial value but because it is not easily propagated.If the seeds discarded from the fruit of the baobab were as successful as those of the tamarind *(Tamarindus indica)*, ackee *(Blahia sapida)* or guinep *(Melicoccus bijugatus)*, I suspect they would be more widely known and used by Caribbean people. It seems, however, that the baobab like the litchi and other exotic plants will have to be deliberately cultivated in the Caribbean if a large number of people are ever to acquire a taste for its fruit and in that way improve the prospect of its commercial value.

When we think of "Caribbean food crops" or more specifically of plants cultivated for commercial reasons, there is a tendency for our thoughts to go immediately to production for export and this is as it should be. This does not mean, however, that we should neglect plants that have only a local commercial value or useful plants that have no commercial value. Many plants that have no export value are important to small farmers, local traders and consumers. Many examples could be cited.

Additional reasons for cultivating baobabs in the Caribbean

In arguing for the cultivation of the baobab in the Caribbean I would suggest that the usefulness of the tree is more than its value as a garden curiosity, a garden specimen, a shade tree, a source of commercial products and, a food tree. These uses of the baobab in the Caribbean are only some of the reasons why its cultivation should be extended, there are others that should be considered.

It is generally recognized that trees play a very important role in preventing erosion. The baobab is one of many trees that should be considered in an effort to establish sound conservation practices in the Caribbean. The tree would be especially valuable in areas which have been severly eroded, such as the Yallahs River Valley in southeastern Jamaica.

Pasture tree

The baobab should be considered as a pasture tree in the Caribbean for it provides several advantages. It is tolerant of dry conditions, it offers shade in places where there are usually few trees, the leaves can be used as feed in the spring and summer (as they have been in Nigeria), the dried pulp can be burnt as a fumigant to combat biting insects on animals as it is in parts of Africa (assuming this treatment is necessary or proves successful when tested) and the tree itself can be used as a live fence post tree. The baobab would be difficult to establish as a fence post tree (unlike the growstake, *Gliridiadia sepium*, which is common in Jamaica and is easily propagated from large cuttings). The fact that the bark of the mature tree can withstand great abuse, however, makes it worthy of being considered for this kind of use.

Habitat for other species

It is clear that human acitivity affects the survival of many species often resulting in the impoverishment of the biological environment in which it takes place. Planting baobabs would help to counteract this trend especially in the drier parts of the Caribbean which in many cases have been stripped of tree cover. In the arid and often treeless savannas of Africa the baobab is famous for the number of species it supports (Coe and Isaac, 1965; Owen, 1974). The baobab is rightly referred to as a tree that "teems with life." These include lizards and snakes; a wide variety of birds such as the pygmy falcon *(Poliohierax semitorquatus)*, buffalo weavers *(Babalornis albirostris)*, the greater honeyguides *(Indicator indicator)*, barn owls *(Tyto alba)*, Wahlberg eagles *(Aquila wahlbergi)*, starling *(Spreo superbus)*, and the orange-bellied parrots *(Poicephalus rufiventris)*; many insects, especially bees, ants and caterpillars which includes one kind eaten by the Venda of South Africa (Winter and Killick, 1966); and several mammals, primarily bats, rats, squirrels, lesser bush babies *(Galago Senegalensis)*, baboons and elephants.

In the drier parts of the Caribbean where many trees have been destroyed for firewood, charcoal, fence posts, yam sticks and so on, the baobab would provide an excellent habitat for many birds. There would be no reason for people to cut these trees down as they are virtually useless for timber and fuel. The wood is of poor quality being light, soft, spongy and water-logged.

To understand the role that baobab can play in the ecology of the Caribbean we need to study the trees that already exist in the region. For example, people in Africa frequently go to the baobab tree in search of honey (Stow, 1965) and in some cases they will hang artificial hives in the branches of the baobab (Aitken, 1951; Fleuret, 1980). While in St. Croix this summer I noted that the tree at Grove Place had a natural hive in one of its huge trunks. In Butler Bay St. Croix, I photographed a fruit on one of the trees with a hole at the top of it that was approximately one inch across. I also found fruits on the ground that had holes through their woody capsule. We need to learn a lot more about the ecology of the baobabs in the Caribbean.

Medicine

Among the many uses of the baobab is its value as a source of medicines for treating fevers, dysentery and other illnesses. Many writers have discussed the medicinal value of the tree, especially the bark, leaf and fruit which are the most frequently cited sources of health products. Given the long period of time over which this tree has been associated with human life, we should examine the medicinal claims that are made for the various remedies of which the baobab is a part. It is possible that when the medicinal uses of the baobab have been carefully examined, we will find something worthy of being added to the traditional folk medicine of the Caribbean.

Craft

In Africa the woody gourd-like capsule of the fruit is used as a water container and to make cups, bailers, floaters, and various kinds of vessels. While these uses have been displaced in many places by plastic and metal utensils the capsule, like that of the calabash, might still find a place in the toy chest of children and in the craft industries of the Caribbean islands whose importance to many people should not be overlooked. Although they are not as beautiful as the seeds from plants like the John crow bead *(Abrus precatorius)*, seaside bean *(Canavalia maritima)*, nickal or wari *(Caeralpinia bonduc)*, Job's tears *(Coix laeryma-jobi)*, horse eye *(Mucuna sloanei)*, red bead tree *(Adenanthera pavonina)*, woman tongue *(Albizia lebbeck)*, cocoon *(Entada gigas)*, and the flamboyant *(Delonix regia)*, they can still be used to string necklaces as they have been in Africa (Dalzier 1937).

Fiber and water storage

Two of the important traditional uses of the baobab in Africa were the fiber obtained from the inner bark (and used to make bags, strings for musical instruments and other purposes, tethering rope, matting, and door curtains), and the water that is natural or artificially stored in the tree (Blunt, 1923; Newbold, 1923; Owne, 1968; Fenner, 1980). It is doubtful whether the baobab will ever be useful in these ways in the contemporary Caribbean where industrial products have replaced many products derived from plants in the immediate environment and where water is available through an organized public works program or from rivers, wells, stand pipes and even water trucks.

Preservation of baobab

Over the years the baobab has been protected by traditional cultural values in many parts of Africa. More recently, however, Owen (1970) and others have pointed out that the development of urban Africa including the construction of roads, the opening up of mines and the extension of agricultural and pastoral activities has had a negative impact on the survival of the baobab. Restrictions imposed on elephant populations by human activities has also resulted in the increasing destruction of baobabs. Owen argued in 1970 (p. 35) that "the major threat to the species" at that time was "depredation by elephant". Robertson-Bullock's (1974) description of his 1960 visit to the Luambe Game Camp in what was then Northern Rhodesia is the most frequently cited report in this regard. Of a total of 38 trees, 36 were scarred by elephants over a period of two weeks. This was the first reported case of elephants destroying large numbers of trees in such a short period of time. The previous report was 1957 when only one tree was destroyed by elephants. Similar reports have come from East Africa concerning the Tsavo National Park in Kenya (Box and Sheldreck, 1963; Owen, 1974). While no one has argued that the baobab is on the verge of extinction, scholars like Owen (1970, 1974) and Maheshwari (1971) have expressed concern for its future. One important reason, therefore, for cultivating the baobab in the Caribbean is to insure its survival especially where this involves preserving the gentic diversity of the species.

Conclusion

It is quite clear that the mere cultivation of baobab trees in the Caribbean will not be the solution to major food problems now facing the region or the problem of "foreign exchange" which we hear so

much about today. It would not even seem relevant to those who believe that there is one simple, clear-cut, overall solution to all the problems of the region. I do not share this perspective. Given its actual and potential usefulness, the cultivation of the baobab and other useful exotic trees like the litchi *(litchi chinensis)*, and mangosteen, *(Gascinia mangostana)*, should be considered a necessary detail of any effort toward the overall development of Caribbean culture. The baobab excites curiosity, it has the potential to be of limited commercial value in the local market and it provides food, drink and shade. It touches on the history and folklore of Caribbean people and has potential uses, some of which I have described in this paper.

Bibliography

Aitken, Russell B. (1951) The tree that time forgot." *Natural History,* December 1951, pp. 456–63.

Allison, P.A. (1962) Historical inferences to be drawn from the effect of human settlement on the vergetation of Africa. *Journal of African History III*, (2) 241–9.

Armstrong, P. (1977) Baobabs: remnant of Gondwanaland *New Scientist,* January 27 212 – 3.

Backer, C.A., and Baklhuizen van den Brink, R.C. (1963) *Flora of Java,* 1. The Netherlands: N.V.P. Noordhoff-Groningen.

Blunt, H.S. (1923) Tebeldis. *Sidan Notes & Records,* 6 (1) 115 – 6.

Brandis, D. (1906/1971) *Indian Trees.* Dehra Dun, India: Bishen Singh Mahendra Pal Singh.

Burton–Page, J. (1969) The problem of the introduction of *Adansonia digitata* into India. *In* P.J. Ucko and G.W. Dimbleby (eds.) *The domestication and exploitation of plants and animals,* Chicago/New York: Aldine-Artherton Inc.

Carr, W.R. (1955) Ascorbic acid content of baobab fruit. *Nature* 176 (4496) 1273.

Coe, M.J. and Isaac, F.M. (1965) Research Notes. *East African Wildlife Journal,* **3** 123.

Cowan, D.V. (1952) *Flowering trees and shrubs of India.* Bombay, India: Thacker & Co., Ltd.

Dalziel, J.M. (1937) *The useful plants of West Tropical Africa.* London: Crown Agents for Overseas Governments and Administration.

Dassanayake, M.D. (Ed.) *A revised handbook to the flora of Ceylon* Washington, DC: Smithsonian Institution.

De Winter, B., de Winter, M. and Killick, D.J.B. (1966) *Sixty six Transvaal trees.* Transvaal: Botanical Research Institute.

Emboden, A. (1974) *Bizarre plants: Magical, monstrous, mythical.* New York: MacMillian Publishing Co., Inc.

Everett, H. (1980) *The New York Botanical Garden Illustrated Encyclopedia of Horticulture,* 1 48–50. New York & London: Garland Publishing, Inc.

Fairchild, D. (1931) *Exploring for plants.* New York: Mac Millian & Co.

Fenner, M. (1980) Some measurments on the water relations of baobab trees. *Biotropica* **12** (3) 205 – 9.

Fleuret, A. (1980) Nonfood uses of plants in Usambara *Economic Botany* **34** 320 – 33.

Guy, G.L. (1967) Notes on some histroic baobabs. *Rhodesiana* **16** 17–26.

Harlan, J.R., and de Wet, J.M.J., Stemler, A.B.L. (Eds.) *Origins of African Plant Domestication.* Paris, France: Mouton Publishers.

Hobley, C.W. (1922) on baobabs and ruins. *Journal of East African Natural History Society* 5 75–7.

Hollis, R. (1963) Reflections on baobabs. *The Nigerian Field* **28** (3) 134–8.

Hooker, J.D. (1872) *Flora of British India,* Vol. 1 Reprinted 1973 by: Ms. Bishen Singh Mahendra Pal Singh, New Connaught Place, Dehra Dun and M/S. Periodical Experts, Delhi, India.

Irvine, F.R. (1961) *Woody plants of Ghana (with special reference to their uses).* London: Oxford University Press.

Maheshwari, J.K. (1971) The baobab tree: Disjunctive distribution and conservation. *Biological Conservation,* 4((1) 57–60

Maheshwari, J.K. (1971) The baobab tree: Disjunctive distribution and conservation. *Biological Conservation,* 4 (1) 57–60.

Meek, C.K. (1971) *The northern tribes of Nigeria.* London: Frank Cass & Co., Ltd.

Neal, M.C. (1965) *In gardens of Hawaii.* Hawaii: Bishop Museum Press, pp. 568–71.

Newbold, D. (1924) More notes on Tebeldis. *Notes and Records,* 7 (1) 135–7.

Nicol, B.M. (1957) Ascorbic acid content of baobab fruit. *Nature,* **180** (4580) 287.

Owen, J. (1968) Water storage properties of *Adansonia digitata* (baobab). *The West African Archaeological Newsletter,* 9 95–6.

Owen, J. (1970) The medico-social and cultural significance of *Adansonia digitata* (Baobab) in African Communities. *African Notes* 6 (1) 24–36.

Owen, J. (1974) A contribution to the ecology of the African baobab. *Savanna,* **3** (1) 1–12.

Palmer, E. and Pitman, N. (1961) *Trees of South Africa.* Amsterdam: A.A. Bolkema.

Pardy, A.A. (1953) Notes on indigenous trees and shrubs of S. Rhodesia. *The Rhodesia Agricultural Journal* 50 (1) 5–6.

Prain, D. (1963) *Bengal plants,* Vol. 1. Botanical Survey of India. Calcutta, Government of India.

Rindos, D. (1984) *The origins of agriculture.* Orlando, Florida, U.S.A.: Academic Press.

Robertson-Bullock, W. (1974) Elephants eat baobab trees in Northern Rhodesia. *African Wild Life.* 14 (2) 1960 143–5.

Santapau, H., and Henry, A.N. (1973) *A Dictionary of the flowering plants in India.* New Delhi, India: Publications and Information Directorate.

Shaw, T. (1976) Early crops in Africa: A review of evidence. *In* J. Harlan et. al (eds.) *Origins of African Plant Domestication.* Paris, France: Mouton Publishers.

Stewart, J.L., and Brandis, D. (1874) *The forest flora of north-west and central India: A handbook of the indigenous trees and shrubs of those countries.* Prepared at The Herbarium of the Royal Gardens, Kew, England.

Stow, G.W. (1905) *The native races of South Africa.* New York: The MacMillan Co.

Ucko, P.J. and Dimbleby, G.W. (Eds.) (1969) The domestication and exploitation of plants and animals. *In Proceedings of meeting of the Research Seminar in Archaeology and Related Subjects.* Chicago/New York: Aldine-Atherton, Inc. pp. 331–5.

Watt, J.M. and Breyer-Brandwijk, M.G. (1962) *The medicinal and poisonous plants of Southern and Eastern Africa.* (2nd Edition). Edinburgh and London: E. & S. Livingstone, Ltd.

Weiss, E.A. (1979) Some indigenous plants used domestically by East African coastal fishermen. *Economic Botany.* **33** (1) 40.

Wilkinson, M.L. (1984) The tropics' crown of glory. *Americas* **64** 2–5.

Wright, I.M. and Kerfoot, O. (1966) The African baobab–Object of the awe. *The Journal of Natural History* 75 (5) 50–3.

CRITERIA FOR EVALUATING IMPORTANT FRUIT CHARACTERS IN MANGO *(Mangifera indica* L.) GERMPLASM

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ABSTRACT

Standardized criteria are needed to select seedlings of mango *(Mangifera indica* L.*)* that merit retention in a varietal improvement program, and to compare selections and cultivars evaluated. Such a slate lets seedlings and new or uncommon cultivars be compared with well-known standards. Preferences may vary in different regions, and performance of a given cultivar may vary; however, application of this system or clearly defined modifications of it can enhance the interchange of information and plant material worldwide among people working to improve mangos. Traits of importance are shape, size, colour, firmness, fiber content, disease resistance, flavor, and productivity. A tabular system for rating these characters like those already used for strawberry and blueberry was developed and is being used to advantage in a program of mango germplasm evaluation. Occasional defects such as fruit cracking, "jelly seed" or stem end breakdown are noted when necessary in a "Remarks" column. A "Score" column permits one or more checks to give an estimate of overall quality, and a tree slated for discard is also designated here by a special sign, "/x/".

RESUMEN

Seprecisan criterios para seleccionar plantas de mango *(Mangifera indica* L.) de semillero que merecen retención en programas de mejoramiento, y para comparar selecciones y variedades ya evaluados. Tal sistema permite la comparación de plantas de semillero y nuevas variedades con variedades establecidas. Preferencias pueden variar de región a región, y el comportamiento de una variedad puede variar; sin embargo, la aplicación, de este sistema o una clara modificación de ello podría aumentar el intercambio de inqormación y materia vegetal entre todos que trabajan para el mejoramiento del mango. Las caracteristicas mas importantes de la fruta son la forma, tamaño, color, firmeza, cantidad de fibra, resistencia a enfermedades, sabor, y productividad. Un sistema tabular para evaluar estas caracteristicas fue desarrollado y utilizado con ventaja en un programa de evaluacion de germoplasma del mango. Defectos de la fruta, tale como rajadura, pudrición interna, y pudrición por el tallo se notan en una columna para comentarios cuando sea necesario. Otra columna permite marcar una o mas veces para indicar la calidad general, y la marca "/x/" se usa para indicar la eliminación de una variedad o selección.

The most effective fruit varietal improvement programs entail the efficient exchange of information and also of germplasm which is evaluated for performance under a wide range of conditions. Cooperative work involving the U.S. Department of Agriculture and various State and private organizations resulted in an array of new blueberry and strawberry cultivars superior to those in use earlier (2, 7).

Specific criteria vital to a cultivar's success need to be applied to any possible selection to determine its varietal potential. Unless a specific genotype can produce acceptable fruit that is resistant to disease and shipping stresses, in sufficient quantities to supply market needs, it has no potential as a new cultivar despite any other superior attributes it may have. A great deal of time and expense can be saved by rigorous use of a rating system that can early pick out those few seedlings in a population that have varietal potential and compare them realistically with existing cultivars. Widespread application of such a system can enable one cooperator intelligently to select the most outstanding individuals from the working collections of others for trial under his or her own conditions. Limitations on land, water and labor increase the value of a system that enables such informed use of plant germplasm.

Careful laboratory analyses can obtain the precise data needed before final decisions on varietal release are made. Before that time, however, rapid practical means adapted to use on large numbers of individuals in the field are needed if adequate evaluation of seedling populations and first selections is to be carried forward. The application of a subjective rating system first used and described by Morrow *et al.* (6) affords such a means. Although each numerical rating is arrived at subjectively, the resulting figures can be analyzed objectively so that an idea of the character and potential usefulness of a given individual or group of individubls can be conveyed with a minimum of confusion to others familiar with the system. Long used by breeders of deciduous fruit, it has proved equally useful for evaluation of tropical and subtropical fruit in the Agricultural Research Service Clonal Repository at Miami — notably avacado, lychee and mango *(Mangifera indica* L.*)* (5). Because of wide current interest in mango improvement and the interest throughout the Caribbean Basin in producing fruit for North American markets, this system is now proposed in order to afford a uniform means of evaluating the performance and usefulness of specific mango cultivars and selections.

As a general rule, characters are rated on a scale of 1 to 10. (Fruit shape and yield, both special cases, are handled differently as discussed later.) A score of 1 indicates the least desirable, a score of 10 the most desirable rating for a particular character. A score of 5 or lower for any character except fruit shape is enough to bar that plant from consideration for introduction, although it may still be selected for use in breeding if it has other desired characters. Certain traits for which a given kind of fruit is rated may be critical in that fruit, such as fiber in the mango. Specific characters, however, are of general importance. These include fruit size, color, firmness, taste, disease resistance and productivity.

Characters for which mango germplasm is rated numerically are: fruit shape, size, firmness, color,

anthracnose disease resistance, taste, fiber content, and yield. A "Remarks" column also records any observation noted in one specific plant but not common enough to be regularly rated. Such remarked observations include a tendency to crack, to be soft near the seed ("jelly seed"), to show internal breakdown at the stem end, to exhibit aborted seeds under some conditions, or to be otherwise deficient. Total value is then summarized in a final column by assigning a 1 – to 4 – check rating of the plant as a whole, the greatest number of checks indicating the most valuable material, or assigning a rating of "/x/", "x-ing it off", if the plant is to be discarded. Character ratings, and how these are arrived at, are next discussed.

Shape

The numerical scale of 1 to 10 is not well adapted to describing mango fruit forms because the range of variation for this trait is narrower than such a range of figures would imply. Most fruit of a given mango cultivar consistently maintain a specific shape. Fruit shape in mango ranges among cultivars from one extreme of nearly spherical, assigned of value of 1, through a more-or-less kidney-shaped intermediate form, given a value of 3, to an elongate cylindrical, sausage or parenthesis shape assigned a value of 5. Variants on these generalized forms occur, such as the presence or absence of a beak at the fruit's distal end with or without a minute protuberance or nak above this, a sinus on the dorsal surface, or a depression at the peduncle's point of insertion. This last-named trait is a defect in a commercial cultivar because it affords rainwater a place to collect and promote fungal frowth. Any obvious eccentricity of form can be entered under "Remarks". The 1 to 5 scale affords a useful method of quantifying form in seedling populations or of describing it briefly in a new selection or cultivar, but no numerical rating is discarded.

Size

Mango cultivars from parts of the world where the fruit is a traditional crop show a wide range of size. For example, cultivars commonly grown in India range from the small Dashehari, which averages 172g wt to Banganpalli, which weighs approximately 625g (3). Four other Indian cultivars, Chowsa, Langra, Pairi and Suvarnarekha all weigh less than 300g, while Neelum at 364g approximates the smallest North American size accepted (3). The North American consumer's idea of proper mango size probably was influenced by Haden, the first important commercial cultivar, which ranges from 460–685g. Commercially successful cultivars grown in Florida now range in size from Van Dyke (280–400g) through Tommy Atkins (460–658g) to Keitt (570–860g) (4, 1). A fruit smaller than Van Dyke would have difficulty finding acceptance, whereas Keitt, larger than some markets prefer, encompasses the maximum acceptable size. Accordingly Keitt's numerical rating for size is 10, that of Tommy Atkins is 9, and that of Van Dyke is 6 or 7, depending on which end of its normal range the fruit under scrutiny approaches. The numerical rating thus reflects a mango fruit's absolute size instead of the degree it conforms to market preferences.

Firmness

Adequate firmness is essential to the success of any mango cultivar grown in one region and shipped to distant markets, as it is with any other fruit so handled. This trait varies widely within and between seedling populations. It can easily be described by the subjective, 1 to 10 rating system once the user has had enough practice to learn the skill by handling fruit. Van Dyke, for one example, is among the firmest of the well-known cultivars. Carrie, on the other hand, has one of the least firm fruits of any named cultivar grown in Florida, and would be rejected for serious consideration as a commercial cultivar even if it were otherwise acceptable. Firmness is unquestionably related to the amount and type of fiber in the fruit's pulp; too little fiber makes a fruit too soft to withstand packing and shipping stresses.

Colour

Preference for aspecific external appearance may vary more from one region ot another worldwide than for many other traits. Certainly Carabao, grown in the Philippines and exported from there to Japan, bears fruit of a yellow color that would not be accepted on North American markets when more attractive fruit are available, nor would that of Alphonso, one of India's most popular cultivars. Market preference in North America dictates a bright-colored fruit, blushed with red or purple. This probably results from Haden's long predominance as the market standard there. Such a fruit invariably has a competitive advantage over less colorful fruit of the same season. Accordingly color is rated from 1 to 10 based on the fruit's appearance, which is directly related to the amount of the fruit surface covered by a blush, and the brilliance of the orange to red or purple coloration of the blush.

Anthracnose Disease Resistance

Several fungus diseases impact on Florida mangos in the course of the fruit's development but one, anthracnose caused by *Colletotrichum gloeosporioides* Penz., is far and away the most important. Mango scab, *Sphaceloma mangiferae* Bit. and Jenk., seriously mars the fruit of a few cultivars imported for experimental use, but it is not usually important on commercial cultivars or seedlings related to them. Susceptibility to scab definitely appears to be of genetic origin because some accessions regularly show it. Where this is observed, it should be noted under "Remarks", but scab is not common enough to justify rating every accession for it. Powdery mildew, *Oidium mangiferae* Berthet is unfortunately more common than scab in Florida, particularly in years when the flowering season finds warm sunny daytime weather followed by foggy, humid nights. Susceptibility to *Oidium* varies among mango cultivars both in Florida and Africa. Severely affected cultivars can lose most of the flowers to a blight caused by the fungus, and less affected ones may keep fruit that set but is infected. This can then mature with scars of depressions on its surface. Despite occasional severity, powdery mildew is not sufficiently frequent in Florida to justify rating all plants for it. Those observed to be severely affected need to have the fact remarked.

Anthracnose caused by *Colletotrichum* fungus is the most important mango disease in Florida, and its control is critically important, necessitating an effective spray program (1). Mango cultivars vary in their field resistance to anthracnose disease, and some (Tommy Atkins and Keitt, for examples) appear to keep some resistance after harvest. This is reflected in their superior shelf life. Their commercial importance rests in part on their relative resistance to storage disease, however, no mango germplasm evaluated in Florida to date has shown immunity to anthracnose disease. All unsprayed fruit shows symptoms to a greater or lesser degree. Because high resistance can enhance the effectiveness of a well-conceived spray program in improving fruit quality and shelf life, all mango introductions are evaluated for resistance to anthracnose. A rating of 10 would indicate total freedom from infection, whereas a 1 rating is assigned to a fruit whose surface is entirely covered with anthracnose lesions. No mango introductions in the Miami repository are sprayed with fungicide during the season of flowering and fruiting, thus all can be compared for their relative resistance to anthracnose. Severity of infections can vary with the amount of early rainfall in a particular year, but relative differences among clones are reasonably consistent: those showing almost no infection in a "good" (dry) year continue to show less infection than more vulnerable cultivars in a "normal" or "bad" (wet) year.

Taste

Some mango seedling populations show remarkably wide variance in fruit flavor. Ratings of this attribute might be most influenced by personal preference. Undeniably it is more likely to be subjectively interpreted than most others. For this reason, it is important to keep in mind what would appeal to the widest audience and to avoid letting preference for a particular regional or local type influence one's choice. This does not suggest that monotony is a desirable goal. On the contrary, the taste specific to fine named mango cultivars needs to be kept as a criterion to avoid reducing all the selections made to a common level of blandness. In practice, rating mango seedlings and selections for taste is not difficult once experience is gained in the field. Furthermore, cultivars recognized as superior in one region are likely to be equally appreciated elsewhere. Certain well-known cultivars, such as Mulgoba, Edward, Keitt and the Cambodiana can be kept as standards with which to compare newly tested clones. In addition, certain unacceptable flavors that crop up in seedling populations are easily recognized. Metallic taste, excessive turpentine, excessive acid, and extremely bland, flavorless taste are examples of what is often enountered and discarded. Use of a taste panel made up of several knowledgeable individuals can reduce the subjectivity of this rating system.

Fiber Content

The first mangos grown in Florida were unimproved seedlings brought in from the Caribbean. The pulp of most contained abundant coarse fiber that tended to stick in the teeth and reduce the consumer's enjoyment of the fruit's eating quality. Improved germplasm imported later from India, the Phillipines and Vietnam showed that the fruit's fiber content need not be objectionable. Evaluation of seedling populations from parents of good quality showed that coarse, objectionable fiber is not the rule in such material (5). In evaluating fiber, two qualities need to be kept in mind: the fiber's, relative abundance and its fineness or coarseness. Abundant fine fiber, of a texture unobjectionable to the consumer, is a necessity to protect the interior of a commercial cultivar from bruising and internal collapse during handling and shipping. Thus, a "fiberless" mango is not the goal of any well-conceived improvement program. Both Keitt and Van Dyke cultivars, with an abundance of short, fine textured fiber, approach the ideal. Fruit of Tommy Atkins is more fibrous, but this attribute is unquestionably important for its shipping and storage abilities..

Yield.

It may be questioned how much can be learned of the potential prolificacy of a mature cultivar through observation of its initial cropping as a young seedling. Furthermore, many mango clones are notorious for alternate bearing. For this very reason, as much knowledge as possible about a potential variety's production needs to be gained from the start of the evaluation period. Observation of different seedling populations over a period of years suggests that their early yields actually portend subsequent cropping behavior. This vitally important trait obviously must continue under observation throughout the period of evaluation of a mango selection, before it can be named and released. There is no substitute for recorded kilograms and numbers-of-fruit data from replicated plantings to give a complete picture of a selection's potential vis-a-vis existing cultivars. However, because of the ease of applying the 1 to 10 rating system -- modified by the additional use of 0 -- as a field estimate of production, it deserves wide-scale use from the beginning of field observations. The ratings from 0 through 10 codify actual production compared to what it would be if a tree of a particular size were carrying a full crop, i.e. as much fruit as it could be expected to mature normally. Thus a tree with no fruit at all is scored 0; trees carrying a small number of fruit up to a crop about 10% of a full crop are scored 1; trees with greater crops up to 20% of normal are scored 2; and so on up the line, with a tree carrying 90% of a full crop scored 9 and one with a full crop scored 10.

Application of the Rating System

Ratings derived through use of the system described here have been given mango seedlings and cultivars in the Miami germplasm collection over a period of years, based on their observed performance here. (Modifications of the same system have also been applied to avacados, longans *[Euphoria longan* (Lour.) Steud.], and lychees *[Litchi chinensis* Sonn.]). More data are available on some accessions than others, depending on the length of time specific trees have been in the collection and the amount of attention devoted to them. Table 1 lists ratings of the most important Florida commercial mango cultivars and other local and foreign accessions. For 2 cultivars, Boribo and Gouveia, adequate yield performance information has not been accumulated, therefore no rating is given. As more data are collected,

some ratings may change from those presented here, particularly the yield ratings, but Table 1 reports the information presently available.

Literature Cited

1. Campbell, C.W. and Malo, S.E. 1972. The mango. Fruit Crops Fact Sheet # 2, Coop. Exten. Service, IFAS, Univ. of Fla., Gainesville. 4p.

2. Galletta, G.J. 1975. Blueberries and cranberries. In Advances in fruit breeding. J. Janick and J.N. Moore, Eds. Purdue Univ. Press, W. Lafayette, Indiana. 623 p.

3. Gangolly, S.R., Singh, R., Katyal, S.L. and Singh, D. 1957. The mango. Indian Council of Agric. Res., New Delhi. 530 p.

4. Knight, R.J., Jr. and Campbell, C.W. 1980. A industria de manga da Florida e seus cultivares. In Anais do I simposio brasileiro sobre a cultura de mangueira, L.C. Donadio, Ed. Fac. Ciencias Agrar. e Vet., UNESP, Jaboticabal, S.P. Brasil. 213 p.

5. Knight, R.J., Jr. and Manis, W.E. 1966. Mango germplasm evaluation. Proc. Fla. State Hort. Soc. 79: 415–419.

6. Morrow, E.B., Darrow, G.M. and Rigney, J.A. 1949. A rating system for the evaluation of horticultural material. Proc. Amer. Soc. Hort. Sci. 53: 276–280.

7. Scott, D.H. and Lawrence, F.J. 1975. Strawberries. In Advances in fruit breeding. J. Janick and J.N. Moore, Eds. Purdue Univ. Press, W. Lafayette, Indiana. 623 p.

Table 1 Ratings assigned mango accessions in the USDA collection at Miami

Clone	Shape[z]	Size[y]	Firmness	Color	Anthracnose	Fiber	Taste	Yield	Score[x]
Alphonso	3	5	7	2	3	7	9	1 [w]	/x/
Boribo	3	8	8	4	7	9	5	—	/x/
Carabao	5	6	7	3	5	9	8	6 [w]	/x/
Carrie	3	7	3	4	7	9	7	6	/x/
Gouveia	3	8	8	7	6	8	6	— √	
Haden	3	9	8	8	5	7	7	3 [w]	/x/
Kensington	3	8	7	7	7	8	7	6	√
Keitt	4	10	9	6	8	9	8	8	√√√
Langra	2	6	8	3	5	8	8	3 [w]	/x/
M–13269	3	8	9	5	7	7	7	8	/x/
Ono	4	7	5	6	7	7	7	6	/x/
Pope	3	9	5	7	2	8	8	1	/x/
Ruby	5	5	10	8	8	8	8	5 [w]	/x/
Tommy Atkins	3	9	9	9	9	6	6	7	√√√
Tyler	1	9	9	3	4	9	4	6	/x/
Van Dyke	3	7	10	9	7	8	7	6	√√√
Winters (M–20222)	4	7	7	8	7	7	7	7	√

[z] Ratings of 1 (round) to 5 (long) indicate fruit's shape, not its desirability.

[y] Ratings below 6 justify discard; those above 7 show size only, not merit.

[x] 1 or more checks indicates overall value; /x/ lacks commerical acceptability.

[w] Tends markedly towards alternate bearing.

EFFECTS OF GROWTH REGULATORS ON FLOWERING PATTERN, FLOWER SUPPRESSION AND FRUIT SET IN MANGO (*MANGIFERE INDICA* L. CV. JULIE).

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ABSTRACT

The effects of growth regulator treatments on flowering pattern, flower suppression and fruit set in mature mango trees were examined. Gibberellic acid (100 ppm) suppressed flowering for six weeks, this response being delayed in one trial. Potassium nitrate (20,000 ppm) greatly increased flowering whereas Ethrel (ethephon) at 2000 ppm was not as successful. Planofix (1-naphthylacetic acid, sodium salt) at 20 ppm appeared to increase initial fruit set when applied to inflorescences but this effect was not sustained in the trial. Planofix applied to fruit (1–2cm diameter) caused an 18% reduction in fruit drop which doubled final fruit yield.

RESUMEN

Se examina los efectos de los tratamientos con reguladores de crecimiento en el patrón de floración, la supresión de flores y el cuajado de frutos en los árboles maduros de mango. El ácido giberélico, 1000 ppm, suprimió la floración durante dos meses; sin embargo, hubo una reacción retardada en un ensayo. El nitrato de potasio, 20 000 ppm, aumentó considerablemente la floración, mientras que el Ethrel (etefón), 2 000 ppm, no fue tan exitoso. El Planofix (1-ácido naftilacético, sal de sodio 20 ppm) aumentó el cuajado inicial de los frutos, cuando se lo aplicó a las inflorescencias, pero este efecto no se mantuvo durante el ensayo. La aplicación del Planofix a los frutos (1 - 2 cm de diámetro) resultó en una reducción del 18% en la incidencia de la caída de frutos, lo que dobló el rendimiento final de frutos.

Keywords: Mango; Growth regulators; Flowering; Fruit-set.

The major commercial cultivar of mango in Trinidad is Julie. This cultivar is established in small orchards and is very popular for home planting because of its slow growth rate, good fruit quality and capacity to be quite prolific. However, average production is low at Centeno (150 fruit per tree or 12,552 kg ha^{-1} on 250 trees ha^{-1}) and may be almost nil in very wet areas of the island. Good producing trees average over 500 fruit per tree per year.

Low fruit production is thought to be due to two reasons:- low initial fruit-set taken at 2mm dia. and young fruit fall (< 2cm dia.). A major cause of low initial fruit-set is the ravaging effect of blossom blight (anthracnose disease) caused by *Colletotrichum gloeosporioides* which destorys most inflorescences especially in high rainfall areas.

Two approaches can be taken in solving the problem of low fruit production. The first is to limit flowering to the period of low relative humidity and rainfall when there is a reduced incidence of blossom blight and fruit drop due to anthracnose. Prevention of flowering may be accomplished by the use of growth regulators. The second approach involves the use of growth regulators to increase flowering and fruit-set and to reduce fruit fall.

Studies on mango in India have shown that NAA sprays have increased fruit-set (Singh *et al.*, 1965) and reduced fruit fall (Singh *et al.*, 1959). Both Ethrel (ethephon) (Chacko *et al.*, 1974; Vazquez and de los Santos de la Rosa, 1982) and KNO_3 (Bondad and Linsangan, 1979; Vazquez and de los Santos de la Rosa, 1982) have been used to induce flowering in mango whereas GA_3 has caused flowering suppression in citrus (Monselise and Halevy, 1964). Preliminary trials (unpublished) on mango shoots were done in 1982 by the authors using these three last named regulators with encouraging results.

In this study trials were conducted with growth regulators applied to whole trees. Flowering suppression, inflorescence production and fruit-set were examined in separate trials during the period March 1983 to May 1985.

Materials and methods

All trials were conducted on twenty-year old 'Julie' trees at Centeno. These had been cut back to a 2m height in October 1981. Spray treatments with one exception were all single applications which included a surfactant/sticker, Agral 90.

A system was devised for taking weekly data without counting the same inflorescences in two consecutive weeks. Young inflorescences which were characterized by small size, unopened flowers and absence of a purple tinge on the main stalk were not counted. Inflorescences that had many enlarged ovaries without petals and that had started drying were also excluded. The remainder were designated 'mature inflorescences' and counted. This 'mature inflorescence' stage did not last longer than one week.

Flower suppression

Trial 1. GA 1000 ppm was sprayed to drip on five non-flowering trees using a knapsack sprayer. Five control trees received no spray. Treatment date was 23 November 1983.

Trial 2. Four treatments (a control, GA 100 ppm, GA 500 ppm and GA 1000 ppm) were each applied to five non-flowering trees. Application was done with a mist-blower on 28 February 1985. The five control trees received no spray. Mature inflorescences were counted weekly in both trials. Fruit counts were taken for final vield in Trial 1 and for fruit-set in Trial 2.

Flower induction

Ethrel 2000 ppm and KNO_3 20,000 ppm were each sprayed onto ten non-flowering trees using a knapsack sprayer on 8 November 1983. Ten control trees received no spray. Mature inflorescences were counted weekly and a final fruit count for yield done at the mature green stage.

Fruit-set

Planofix (NAA) at the equivalent of 20 ppm NNA was sprayed on 15 'Julie' trees with a mist blower on 8 March 1983 and repeated after 17 days. Fifteen control trees received no spray. These trees were all carrying fruit of pea to marble size (1-2cm dia.). Three panicles, two with fruit and one not yet set, were selected on each tree at application. These panicles were monitored for data on fruit-set and loss.

Results and discussion

Flower suppression

'Julie' undergoes several flushes of flowering beginning around September. Flowering is light at first, becoming profuse from January onwards and ends around April.

A flowering flush occurred within two weeks from treatment date in both trials. GA_3 1000 ppm suppressed and delayed flowering for six weeks in Trial 1 (Fig. 1).

In contrast all GA_3 treatments including GA 1000 appeared not very effective initially in Trial 2 (Fig.2). However, the effect was significant by the third week after treatment (Fig.2). It is suspected that this delayed response occurred because treatment was applied late into the flowering period when the stimulus to flower had already taken effect.

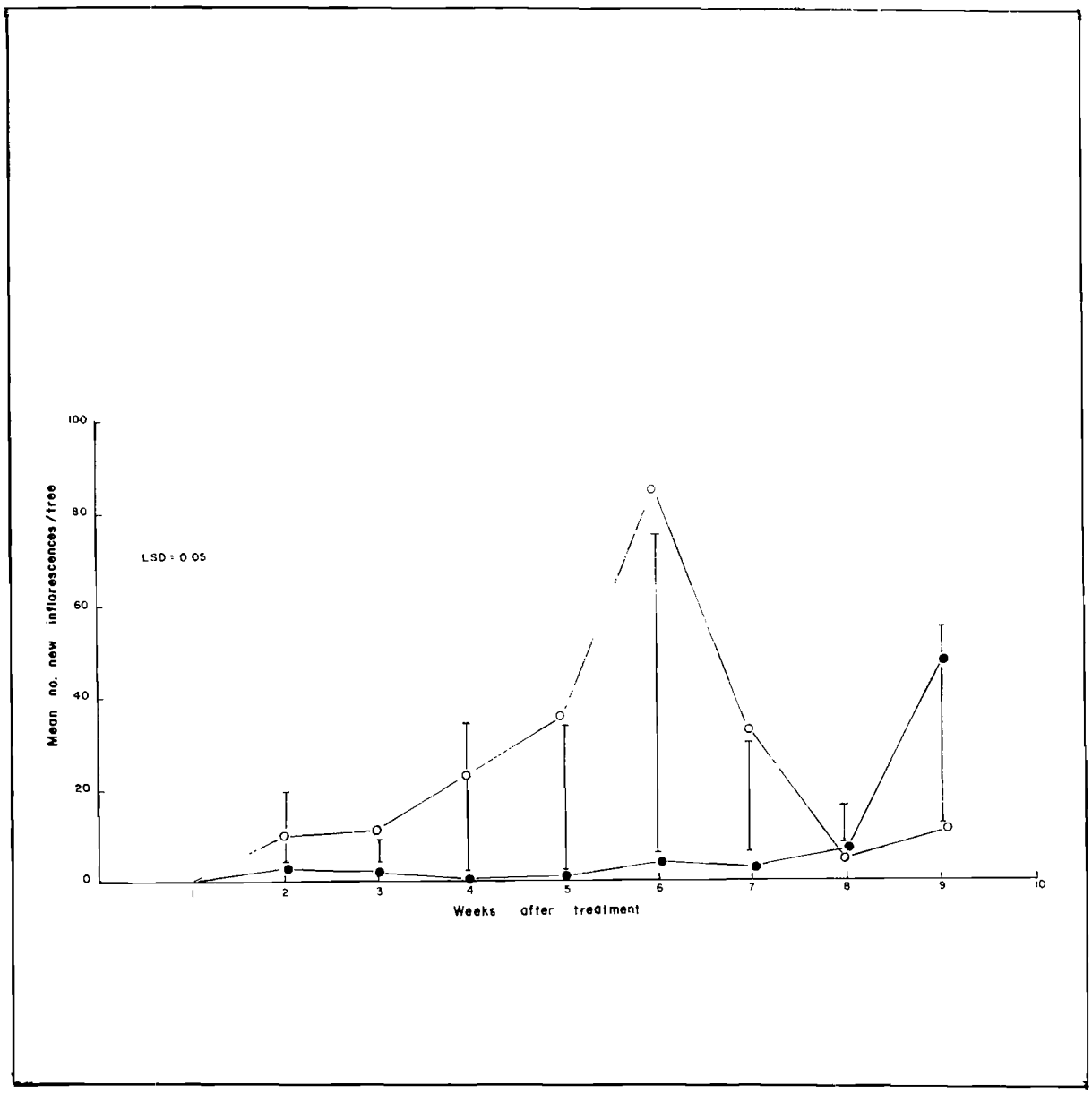

Figure 1: Flowering pattern of 'Julie' Mango in response to Gibberellic acid (GA) spray. ●, GA 1000 ppm; O, no spray. Treatment date 83. 11. 23.

The GA 100 ppm treatment was no longer effective by week 7 in contrast to the other GA treatments (Fig. 2). It may therefore be possible to control length of suppression period by varying GA concentration of the spray treatment. It appears that GA 100 ppm treatment must be used earlier than 28 February (Trial 2) for subsequent heavy flowering to occur naturally.

There was no statistical difference in final fruit yield between treatments in Trial 1. However, fruit-set data in Trial 2 (Fig. 2) shows better yielding in the control. This may be as a result of flowering suppression on the GA_3 treated trees. No subsequent flowering occurred for that production season in contrast with Trial 1 where treatment was applied early the season.

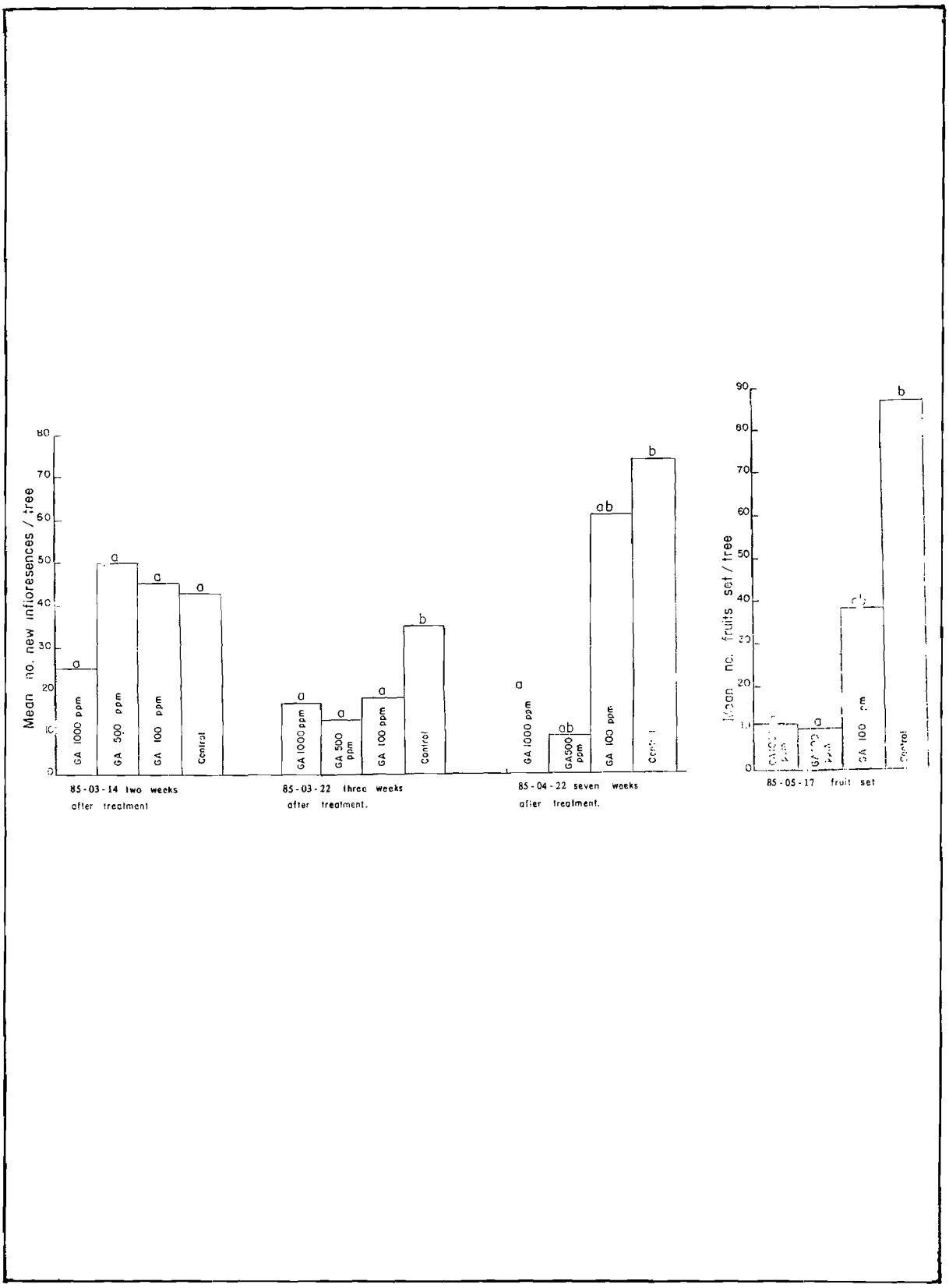

Figure 2: Flower production at intervals in 'Julie' Mango in response to treatment with Gibberellic acid (GA) and subsequent fruit set. Mean separation for flower production at each interval and for fruit set by Duncans mutiple range test, 5% level.

Flower induction

A significant increase in production of inflorescences was obtained with KNO_3 but not with Ethrel within two weeks of treatment (Fig. 3). This superior performance of KNO_3 supports the results on mango reported by Vazquez and de los Santos de la Rosa (1982) although repeated Ethrel treatment is known to give very good results in juvenile mango seedlings (Chacko *et al.*, 1974). Final fruit count showed no advantage of the increased flowering early in the season.

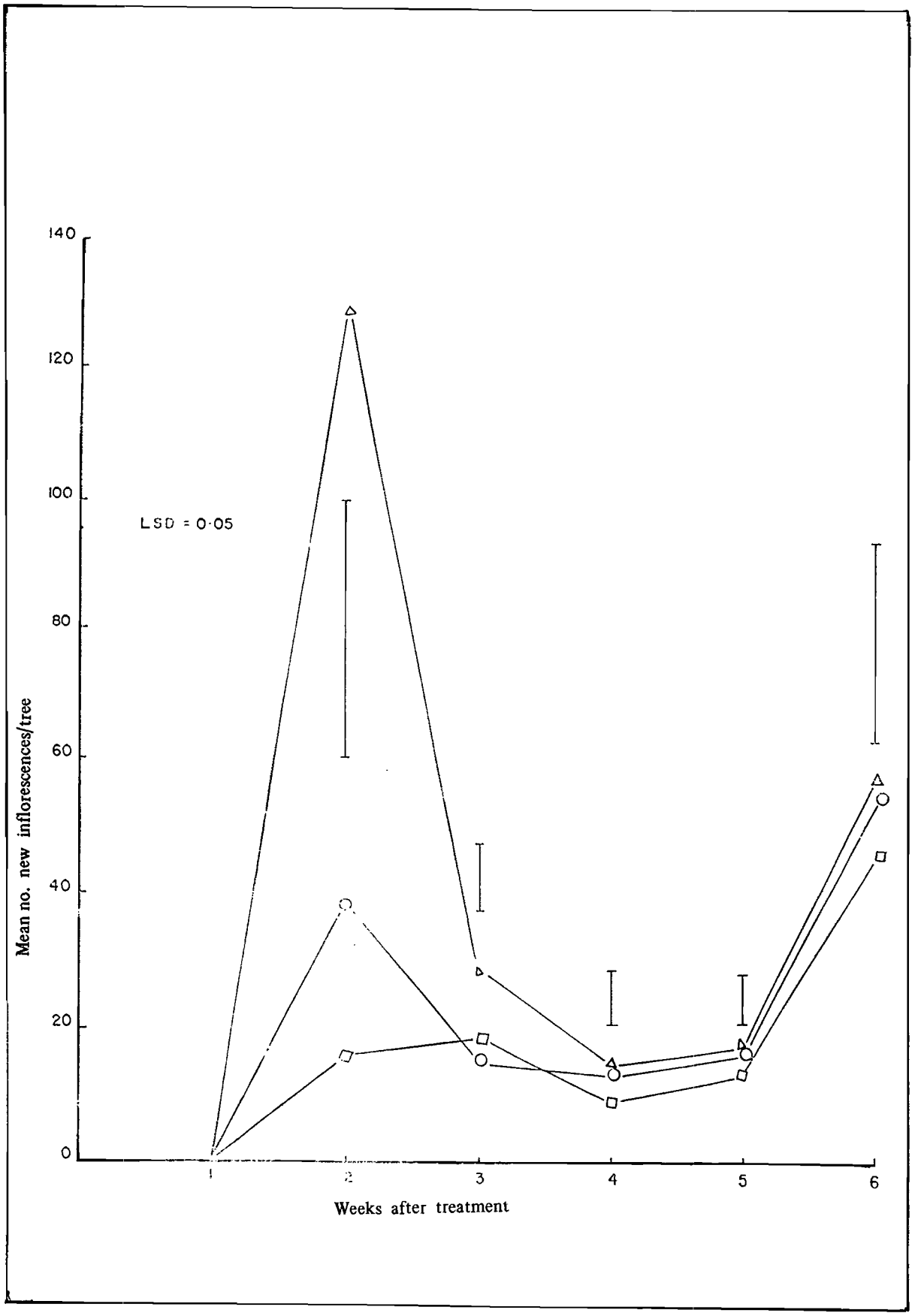

Figure 3: Flowering patternof 'Julie' Mango in response to growth regulator sprays. △, KNO_3 20,000 ppm; o, Ethrel 2,000 ppm; □, no spray. Treatment date 8. 11. 83.

Fruit-set

Initial fruit-set (just after petal loss) appeared to be increased by Planofix sprays on panicles that had been treated at the inflorescence stage. However, this effect was not significant (Table 1). Initial fruit-set is normally prone to fruit drop within six weeks after full bloom (Singh *et al.*, 1959). This fruit drop was 99% after six weeks in this study.

Treatment at the 1cm dia. stage, approximately one month after anthesis, resulted in an 18% reduction in fruit drop which doubled yield – 35% retention compared to 17% retention (Table 2). Singh *et al.*, (1959) obtained slightly higher results in their work on other cultivars using NAA at the same stage of fruit development.

Table 1 Effect of Planofix on initial fruit-set in 'Julie' mango.

No of weeks after treatment	Fruit-set		Panicles surviving	
	Treated	Untreated	Treated	Untreated
0	0	0	15	15
1	148	57 NS	13	11
2	47	10 NS	6	4
4	2	2	2	2
6	1	1	1	1

Table 2 Effects of Planofix on fruit drop in 'Julie' mango

	Treated	Untreated
Initial set before treatment (1cm. dia.)	82	103
Fruit drop after two months	53 (65%)	85 (83%)
Retained fruit	29 (35%)	18 (17%)*

* Significant at the 5% level.

Anthracnose was the major factor accounting for young fruit fall at Centeno (G. Persad, unpublished). The disease is expected to be least severe during April, the period of lowest rainfall and humidity. It may be advantageous to suppress early flowering and then later reinduce heavy flowering so that full bloom and fruit-set begins early April.

Conclusion

Data from individual trials demonstrate successful use of growth regulators on 'Julie' mango in controlling its reproductive phase in order to increase yield. Additional studies on continued suppression, subsequent reinduction of flowering and increasing fruit-set are required before the integrated use of growth regulators can be incorporated into the production system.

References

Bondad, N.D. and Linsangan, E. (1979) Flowering in mango induced with potassium nitrate, *Hort. Sci.* 14 527–528.

Chacko, E.K., Kohli, R.R., Dore Swamy, R. and Randhawa, G.D. (1979) Effect of (2–Chloroethyl) phosphoric acid on flower induction in juvenile *(Mangifera indica)* mango, *Physiol. plant.* 32 188–190.

Monselise, S.P. and Halevy, A.H. (1964) Chemical inhibition and promotion of citrus flower bud induction, *Proc. Amer. Hort. Sci.* 84 141–146.

Singh, K.K., Singh, S. and Chadha, K.L. (1959) Effect of some plant growth regulators on fruit drop in mango, *Ind. Jour. Hort.* 16 86–91.

Singh, R.N. Majumder, P.K. and Sharma, D.K. (1965) Studies on the bearing behaviour of some Indian varieties of mango *(Mangifera indica L)* under north Indian conditions, *Trop. Agriculture, Trin.* 42 171–174.

Vazquez, R.M. and de los Santos de la Rosa, R. (1982) Asparsiones de nitrato de potasio para adelantare e inducir la floracion del mango cv. Manila en Mexico, *Proc. Trop. Region. Amer. Soc. Hort. Sci.* 23 311–316.

FLORAL BIOLOGY OF *ANNONA SQUAMOSA* AND *ANNONA CHERIMOLA* IN RELATION TO THE SPONTANOUS APPEARANCE OF ATEMOYA IN ISRAEL

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ABSTRACT

During the 1930's numerous atemoya seedlings appeared in Isreal. At that period Annona seedlings were used for planting and seeds were often obtained from fruit tree collections where *A. cherimola* and *A. squamosa* were planted in close proximity. Both species have protogyneous flowers; however they differ greatly in their flowering pattern.*A. cherimola* flowers open in the morning, are fully receptive for about 24 hr and shed their pollen in the afternoon. *A. squamosa* (one tree and its offspring) flowers open during the day and shed their pollen around 2 a.m. During the first part of *A. cherimola* flowering season flowers were found to open only on alternate days, with full synchronization on all trees. These flowering patterns tend to promote cross pollination between *A. cherimola* and *A. squamosa*.

RESUMEN

Durante los años treinta, mucha plantas de semillero aparecieron en Israel. En aquél entonces, se utilizaba las plantas de semillero de Anona para la plataciónn y se obtenía frecuentemente las semillas en huertos donde se había plantado la *A. cherimola* y la *A. squamosa* a poca distancia entre los árboles. Ambas especies tienen flores protogineas; sin embargo, tienen patrones de floración muy diferentes. Las flores de la *A. cherimola* se abren por la mañana, son plenamente receptivas durante unas 24 horas y después dejan caer su polen por la tarde. Las flores de la *A. squamosa* (un árbol y su progenie) se abren durante el día y dejan caer su polen a eso de las dos de la tarde. Se notó que, durante la primnera parte de la florescencia de la *A. cherimola*, las flores sólo se abrían cada tercer día, con plena simcronización entre todos los árboles. Estos patrones de floracion tienden a favorecer la polinización cruzada entre la *A. cherimola* y la *A. squamosa*.

The sugar apple *Annona squamosa* L. and the cherimoya *Annona cherimola* Mill. are closely related; both belong to the section Atta Staff. of the genus (13). The two species originated in different geographical regions and under different ecological conditions: *A. squamosa* is native to the lowlands of tropical Central America, while *A. cherimola* originated in the Andean highlands of Ecuador and Peru (7, 9, 11).

Wester was the first to study the floral biology of *A. squamosa* and *A. cherimola* (17). Working in South Florida he found that both species are protogynous; no set was obtained when flowers were pollinated at the pollen dehiscence stage, while excellent set occurred if pollination took place about one day before pollen discharge. He found that good set occurred after reciprocal cross-pollinations between the two species, although most of the cherimoya fruitlets dropped before reaching maturity. Mature hybrid seeds were obtained on sugar apple mother trees and vigorous hybrid seedlings were produced in 1910 in Florida (18). Hybrid seeds from one sugar apple fruit were taken by Wester to the Philippines and sown in 1911 (18, 19, 20). The first hybrid plant fruited in 1913. Wester proposed the name "atemoya" for hybrids of *A. squamosa* and *A. cherimola* (19, 20). Hand pollination of *A. cherimola* flowers with *A. squamosa* pollen produced atemoya plants in Florida and India (2). Reciprocal crossing of of the two species was also performed successfully in Egypt (1).

Atemoya leaves are easily distinguishable from the leaves of either *A. cherimola* or *A. squamosa;* they are much larger than the leaves of *A. squamosa* and do not possess the velvety pubescence on the lower surface that is typical of *A. cherimola* (2, 6, 7, 20). The colour of the atemoya leaves is intermediate in intensity between the rather pale green of *A. squamosa* and the deep green of *A. cherimola* (7).

The atemoya, like *A. cherimola,* develops into a large, long-lived tree, in contrast to the small, short-lived *A. squamosa* tree. In warm climates the atemoya is much more productive than the cherimoya (2, 6, 7, 8, 9. 20). The best atemoyas are comparable in flavour to the best cherimoyas.

Spontaneous hybrids between *A. squamosa* and *A. cherimola* have been observed in Venezuela, Australia, Florida and Israel (6, 9, 10). We present here the known facts about the abundant appearance of atemoya in Israel, and describe the flowering behaviour of the two parents that gave rise to this large-scale spontaneous hybridization.

The history of Annonas in Israel

Both *A. squamosa* and *A. cherimola* were introduced into Palestine at the beginning of this century. The two species were frequently grown side by side, especially in experimental plots. In the 1930's and 1940's a considerable number of "productive cherimoya"seedlings were found. On close examination all of them were identified as atemoyas. Subsequent investigation indicated that similar hybrids had appeared even earlier (6,7,8,9).

During the first half of this century *A. squamosa* was a very popular fruit crop in Palestine. It was propagated exclusively by seeds, as its progeny came true to type. Off-type atemoya seedlings were observed in commercial *A. squamosa* nurseries and under bearing trees (6, 7, 8). It is not surprising that during this period hundreds of atemoya seedling trees appeared, mostly in backyard gardens. Outstanding trees were selected as hybrid annona cultivars ('Malali 1', 'Malali 2', 'Paldi', 'Kaller', 'Kaspi', 'Gefner' = 'Kabri', 'Bernitzki', 'Ubranitzki', 'Melamud', 'Kabarovski', Burshtein', 'Nordshtein', and others). These cultivars were vegetatively propagated by grafting and several of them now serve as the main

cultivars of the small (*ca.* 30 ha) *Annona* industry in Israel.

Floral biology of *A. squamosa* and *A. cherimola* in Israel

During the late 1970's and early 1980's the floral biology of the surviving trees of *A. squamosa* and *A. cherimola* in the Warbury Acclimatisation Garden, located at Rehovot, was studied, following a report by Oppenheimer of the frequent spontaneous appearance of atemoya seedlings under these trees (9).

The only surviving *A. squamosa* tree in the Warbury Garden was in severe decline and died in 1983. We studied its flowering and the flowering of four self-pollinated young seedlings of this tree. Flowers were found to open at various times during daylight, and all of them shed their pollen only during the night at about 2 A.M. Thus, at the time of pollen release there were no receptive flowers on the tree. Similar findings were reported by Nalawadi *et al.* in Dharwar, India (5). Other studies of the floral biology of *A. squamosa* are considerably at variance with our finding (1, 4, 14, 15). The discrepancies may be due to genetic variability (16), different climatic conditions, or both.

One healthy and vigorous *A. cherimola* tree was present in the Warbury Garden. Its flowering pattern was very similar to that of 'Jete' and 'Campa' cherimoya trees growing in the same region. Anthesis started in the morning (7 – 9 A.M.). The flowers were fully receptive for about 24 hours and shed their pollen in the early afternoon (3 – 4 P.M.). During the first part of the flowering season new flowers opened only on alternate days, and did not open on the day that the pollen was shed. These findings are at variance with those described in two reports from India (14, 15).

The flowering seasons of *A. squamosa* and *A. cherimola* on Israel's coastal plain coincide almost entirely, starting in the second half of May and ending in August. The synchrony of the flowering season together with the difference in their flowering patterns should promote cross-pollination whenever *A. squamosa* and *A. cherimola* are located in close proximity. We found in both species that at the time the flowers had shed their pollen their stigmata were no longer receptive, so that no self-fertilization could occur. Thus effective pollination depends on the transfer of pollen to receptive flowers.

Fruit beetles are the pollinating agents of both species in Israel (3, 12). The beetles are attracted by the freashly opened flowers and may spend many hours inside the flower during its female stage. Once the flower changes into the male stage the three petals spread out abruptly and the pollen is shed, the beetles, loaded with pollen, fly then to new receptive flowers of either species. From the time that *A. squamosa* pollen is shed, i.e., at 2 A.M., there is a period of about four hours during which only receptive flowers of *A. cherimola* are present. When *A. cherimola* pollen is shed, at 3 – 4 P.M., receptive flowers of *A. squamosa* are available for pollination, as are receptive *A. cherimola* flowers during the period when new flowers open every day. When *A. cherimola* flowers open only once every two days, i.e., early in the flowering season, no receptive flowers are present when pollen is shed.

To sum up: cross-pollination was greatly favoured when *A. squamosa* and *A. cherimola* trees were planted together in the coastal plain of Israel. Thus, the wide-spread natural hybridization and the abundant appearance of atemoyas was not accidental but inevitable.

Literature Cited

1. Ahmed, M.S. (1936) Pollination and Selection in *Anona quamosa* and *Anona cherimolia*. Bull. 157, Hort. Section, Technical and Scientific Service, Ministry of Agriculture, Egypt.
2. Gandhi, S. and Gopalkrishna, N. (1957) "The atemoya" a promising new Annona hybrid. Proc. Indian Acad. Sci., Section B 45:234–246.
3. Gazit, S., Galon, I. and Podoler, H. (1982) The role of Nitidulid beetles in natural pollination of Annona in Israel. J. Amer. Soc. Hort. Sci. 107:849–852.
4. Kumar, R., Hoda, M.N. and Singh, D.K. (1977) Studies on the floral biology of custard apple (*Annona squamosa* Linn.). Indian J. Hort. 34:252–256.
5. Nalawadi, U.G., Sulikeri, G.S. and Singh, C.D. (1975). Floral biological studies of *Annona squamosa* (L.) under Dharwar conditions. Prog. Hort. 7 (1):15–24.
6. Oppenheimer, C. (1942) Cultivation of New Subtropical and Tropical Fruit Trees in Eretz Israel. Hassadeh Press, Tel Aviv (Hebrew).
7. Oppenheimer, C. (1947) The Acclimatisation of New Tropical and Subtropical Fruit Trees in Palestine. Bull. 44, Agricultural Reseach Station, Rehovot.
8. Oppenheimer, C. (1955) Cultivation of New Subtropical Fruit Trees. Hassadeh Press, Tel Aviv (Hebrew).
9. Oppenheimer, C. (1978) Subtropical Fruit Trees and their Cultivation in Israel. Am Oved, Tel. Aviv (Hebrew)
10. Popenoe, J. (1974) Status of *Annona* culture in Florida. Proc. Fla. State Hort. Sco. 87:342–344.
11. Popenoe, W. (1921) The native home of the cherimoya. J. Hered. 12:331–336.
12. Podoler, H., Galon, I. and Gazit, S. (1984) The role of Nitidulid beetles in natural pollination of *Annona* in Israel; Attraction of Nitidulid beetles to *Annona* (atemoya) flowers in Israel. Acta Oecol. 5:369–381.
13. Safford, W.E. (1914) Classification of the genus *Annona*, with descriptions of new and imperfectly known species. Contrib. U.S. Nat. Herb. 18:1–68.
14. Thakur, D.R. and Singh, R.N. (1965) Studies on floral biology of Annonas. Indian J. Hort. 22:238–253.
15. Venkataratnam, L. (1959) Floral morphology and blossom biology studies on some Annonaceae. Indian. J. Agric. Sci. 29:69–76.
16. Venkataratnam, L. and Satyanaranayaswamy, G. (1958) Studies on the genetic variability in *Annona squamosa* L. Indian J. Hort. 15:228–238.
17. Wester, P.J. (1910) Pollination experiments with anonas. Torrey Bot. Club 37:529–539.
18. Wester, P.J. (1923) Annonaceous possibilities for the plant breeder. Philipp. Agric. 6:312–321.
19. Wester, P.J. (1914) The atemoya, a new fruit for the tropics. Philipp. Agric. Rev. 7:70–72.
20. Wester, P.J. (1915) Hybridization of Annonas. Philipp. Agric. Rev. 8:176–181.

CULTIVATION OF FRUITS OF THE ANNONACEAE IN FLORIDA

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ABSTRACT

Many species and cultivars of Annonaceae have been introduced anf tested in Florida. The atemoya *(Annona cherimola x A. squamosa)* and the sugar apple *(A. squamosa)* are now grown commercially and production is increasing. Cherimoya *(A. cherimola,* ilama *(A diversifolia),* soursop *(A. muricata),* custard apple *(A. reticulata)* and biriba *(Rollinia pulchrinervis)* are grown in home gardens for their edible fruits. The mountain soursop *(A. montana)* and pond apple *(A. glabra)* are grown as ornamental trees and as rootstocks.

The most important limiting factor to annona cultivation in Florida is freeze injury. Biriba, ilama and soursop are especially susceptible to cold injury. The cherimoya does not produce fruit well because the climate is too hot.

All of the annonas can be grown from seed, but superior selections can be reproduced true-to-type only by vegetative propagation. Veneer-grafting and chip-budding are the preferred methods. Superior selections of atemoya, sugar apple, ilama and soursop are propagated in this way, Custard apple and atemoya are used most commonly as rootstocks, but more research is needed because of problems with incompatibility.

Important pests and diseases include the annona seed borer, *Bephatelloides cubensis,* a fruit rot, caused by the fungus *Colletotrichum gloeosporioides,* and a leaf rust caused by the fungus *Phakopsora cherimoliae.* Research is needed on effective means of control.

RESUMEN

Se han introducido muchas especies y variedades de la familia Annonaceae el estado de Florida. Hay producción commercial de la atemoya *(Annona cherimola x A. squamosa)* y del anon *(A. squamosa)* y esta produccion esta incrementado. La chirimoya *(A. cherimola).* la ilama *(A diversifolia)* la guanábana *(A. muricata)* el corazón *(A. reticulata)* la biriba *(Rollinia pulchrinervis)* se cultivan para sus frutas comestibles en los huertos caseros. La guanábana cimarrona *(A.montana)* y el guanábana de corcho *(A. glabra)* se utilizan como portainjertos y como árboles ornamentales.

El factor que mas limita la produccion de las anonaceas en Florida son las heladas invernales. La biriba, la ilama y la guanábana son especialmente susceptibles al daño de temperaturas bajas. Por otro lado, la chirimoya no produce bien a causa del clima caliente.

Todas las annoaceas pueden ser propagadas por semilla, pero las plantas procedentes de semilla son variables. Selecciones superiores deben ser propagados vegetativamente. Los métodos preferidos en Florida son el injerto de chapa lateral y el injerto de yema de astilla. Las variedades que mas se usan para portainjertos son el corazón y la atemoya, pero debido a problemas de incompatibilidad se requiere mas investigación de portainjertos.

Las plagas y enfermedades importantes incluyen un insector perforador de la semilla *(Bephratelloides cubensis),* la anthracnosis de la fruta (causada por el hongo *Colletotrichum gloeosporioides)* y una roya de la hoja (causada por el hongo *Phakopsora cherimoliae.* Se precisan mas estudios sobre controles efectivos de estas problemas.

Additional index words: Annona, Rollinia, cold injury, propagation, grafting, rootstocks.

Two genera of the family Annonaceae are present in the native flora of southern Florida. *Asimina,* primarily a genus of the North Temperate Zone, is represented by *A. reticulata,* a shrubby plant which bears a small fruit not considered to be edible. The genus *Annona* is represented by *A. glabra,* the pond apple, a tropical tree at the northern limit of its range. It bears a fruit which is large and fleshy, but is not palatable because of undesirable flavor.

For a long time there has been interest in introduction and cultivation of tropical species of this family (3) in Florida. The most commonly cultivated species are listed in Table 1, along with their English common names and places of origin. Two species, the atemoya and the sugar apple, are now grown commercially (4, 6, 11). The others are grown in home gardens for their edible fruit, except for the mountain soursop and the pond apple, which are grown as ornamental trees and to a small extent as rootstocks for other species. This paper describes the current status of cultivation of the Annonaceae in Florida.

Climatic Adaptation

The most important limiting factor to survival of tropical annonas in Florida is the occasional freeze which can occur during the months of December, January or February. The soursop is especially susceptible to cold injury, often losing its leaves even when exposed to air temperatures a few degrees above freezing if they are accompanied by strong winds. Exposure to temperatures a few degrees below freezing can kill large trees. The biriba and the ilama are also very susceptible to injury by low temperature. These species can be grown only in the warmest areas and must be given good cold-protection when freezes occur.

The remaining species listed in Table 1 have sufficient cold tolerance to survive most of the cold periods which occur in the coastal areas of southern Florida. They, too, must be given some cold protection to survive freezes in the colder areas.

Table 1. Species of Anaonaceae commonly cultivated in Southern Florida.

Scientific name	Common name	Area of origin
Annona cherimola Mill.	cherimoya	South America
" *diversifolia* Saff.	ilama	Central America, Mexico
" *glabra* L.	pond apple	Tropical America, West Africa
" *montana* Macfady	mountain soursop	West Indies
" *muricata* L.	soursop	Tropical America
" *reticulata* L.	custard apple	Tropical America
" *squamosa* L.	sugar apple	Tropical America
A. cherimola × *A. squamosa*	atemoya	Australia, Israel, Florida, etc.
Rollinia pulchrinervis A.DC. (*R. deliciosa*)	biriba	South America

One species, the cherimoya, is poorly adapted to the Florida climate because the mean temperatures are too high. The plant originated in cool highland areas of the American tropics and it grows well in some cool subtropical regions also. In Florida it makes relatively poor vegetative growth and does not flower and fruit well, so it is not recommended for planting although it is grown by some home gardeners.

Variety Selection

All of the species cultivated in Florida can be grown from seed. The plants grow fast and usually begin to flower and bear fruit at 3 to 4 years of age. Some species can be grown from seed more successfully than others. Sugar apple seedlings come relatively true from seed and bear fruit at an early age, with a significant crop in the third year after planting. Nearly all of the commercial plantings of sugar apple in Florida are of seedling trees. There is variation within seedling populations of all the species, however, and the only way to reproduce superior selections dependably is by vegetative propagation.

The atemoya is the most variable of the Annonaceae grown in Florida, which is not surprising considering its hybrid origin. Many selections have been tested, including 'African Pride', 'Bernitski', 'Bradley', 'Chirimoriñon A'. 'Chirimoriñon B', 'Gefner', 'Guzman', 'Lindstrom', 'Malali', 'Page', 'Pink's Mannoth', 'Priestley' and 'Stermer'. Of these, the 'Gefner' is the most widely planted. It makes up nearly all the commercial plantings of atemoya.

A few selections of sugar apple have been made, including 'Lessard', 'Lincoln', 'Purple' and 'Seedless'. The 'Imery' ilama was introduced in 1961 from El Salvador. Selections of soursop include 'Cuban Fiberless' and 'Younghans'. Other selections have been made, but are not generally available.

Propagation

Species of Anonaceae are propagated commonly by seed. Seeds of most species will remain viable for a period of a few weeks to several months after removal from the fruit. Seeds of some tropical species remain dormant for a time after harvest and will not germinate until they pass an "after-ripening" period or, in some cases, are treated with chemical dormancy-breaking compounds like gibberellins (7).

Some method of vegetative propagation is required for true-to-type reproduction of superior selections. Rooting of cuttings or air layers have been tried in Florida for most species, but have not been successful.The most successful methods are veneer grafting and chip-budding (9). If the branches from which scions are to taken have leaves, it is well to remove the leaves 1- 2 weeks before the scions are cut. This causes the stumps of the leaf petioles to drop and the buds to swell, and in this way it can be determined whether or not the buds are alive. Grafting is used especially with atemoya, as noted above, but also for progagation of selections of ilama, soursop and sugar apple.

Rootstocks

The rootstock and scion combinations which have been used in Florida are listed in Table 2, with symbols inidicating the degree of success which has been obtained. More research is needed before we can be sure of the best rootstocks for use in Florida.

The main problem with interspecific grafting of the annonas is incompatibility. This has been recognized for a long time, but has become particularly evident during the past few years when large numbers of trees have been grown in orchard plantngs. In some cases the incompatibility seems to be simply between species. In others it is more complicated, with some cultivars compatible while others are not. For example, the atemoya cultivars 'Bradley' and 'Page' are compatible with rootstocks of custard apple, but the cultivar 'Gefner' is at least partially incompatible. This has caused considerable loss of plants in some commercial orchards.

Some areas in which annonas are grown are subject to occasional flooding. Pond apple is the only rootstock which is not injured by flooding; all of the others in common use are severely injured or killed if the root system is covered by water for more than about a day. It is recommended that planting sites in areas subject to flooding be mounded up or bedded to avoid the problem.

Economic Considerations

We are still in the process of determining the best cultivation methods in Florida. Growers use plant spacings between rows of 6 – 7m and spacings between plants in the row of 4 – 6m. Regular applications of NPK fertilizers are used, and sprinkler irrigation is used during dry periods.

Table 2. Rootstock-scion combination of annonas in Florida.

Rootstock	Scion			
	Atemoya	Ilama	Soursop	Sugar apple
Atemoya	+	?	0	?
Cherimoya	?	0	0	?
Custard apple	+	?	—	?
Ilama	0	+	0	0
Mountain soursop	0	0	?	0
Pond apple	+	—	?	—
Soursop	—	0	+	—
Sugar apple	?	?	—	+

+ Grafts successful in most cases
? Will form graft union; ultimate success not known
— Grafts not successful
0 No information available

The most important pest is an insect, *Bephratelloides cubensis,* which feeds as a larva and pupates inside the seeds and then bores through the fruit when it emerges as an adult (10). The life history of this insect was determined by Burner and Acuna (2). Work is in progress to determine suitable methods for its control.

Scale insects, particularly those of the genus *Philephedra,* can build up harmful populations on leaves, young stems and fruit of annona plants (10). Ambrosia bettles (possibly *Xyleborus* sp.) bore holes in young branches and reduce their vability (10). Work is in progress to determine the extent of damage done by pests and methods for their control (10).

A number of fungus diseases have been reported on annona plants in Florida (1). Two diseases cause serious damage. Anthracnose, caused by *Colletotrichum gloeosporioides* infection, damages fruit severely, causing it to drop from the tree or to remain on the tree and become mummified (1, 8). Spraying with fungicides during the early stages of fruit development gives some control, but work is needed to develop better methods. A rust fungus, *Phakopsora cherimoliae,* infects annona leaves and causes them to fall prematurely. This disease, which causes relatively little damage to isolated plants in home gardens, is becoming increasingly important in orchard plantings.

Diseases which cause relatively little damage at this time include root rots *(Armillariella, Phomopsis)* and leaf spots *(Alternaria, Cercospora, Gloeosporium, Helminthosporium, Phomopsis, Phyllosticta).*

The yield potential of annona plantings in Florida has not been determined with accuracy. Satisfactory crops are produced in Florida by natural pollination (5) although in some other places hand pollination is needed. With atemoya annual yields of 50 pounds or more of fruit per tree can be expected. Yields of sugar apple are less because the plants are smaller. Prices in the United States market have been good and growers have made good profits from their plantings. Presently there are around 20 acres of atemoya and 40 acres of sugar apple orchards in Florida, and plantings are increasing.

Possibilities for the Future

There are many possiblities for genetic improvement of the Annonaceae, particularly in the selection of better atemoya cultivars. The current interest in commercial production in Florida may provide impetus for more of this work to be done. In addition to the species which presently are valued for their fruit (atemoya, ilama, soursop and sugar apple) others may have promise for improvement by hybridization. These include the custard apple and the soncoya *(Annona purpurea).* It seems certain that improvement of fruits of the Annonaceae will continue in the future and that production in Florida will increase.

Literature Cited

1. Alfieri, S.A., K.R. Langdon, C. Wehlburg and J.W. Kimbrough. 1984. Index of plant diseases in Florida. Fla. Dept. Agr. and Cons. Services. Divn. of Plant Industry. Bul. 11:43.

2. Bruner, S.C., and J. Acuna. 1967. Sobre la biologia de *Bephrata cubensis* Ashm., el insecto perforado de las frutas anonaceas. Academia Ciencias Cuba. Inst. Agron. Ser. Agr. 1:14.

3. Campbell, C.W. 1970. Minor tropical fruit cultivars in Florida. Proc. Fla. State Hort. Soc. 83:353–356.

4. Campbell, C.W. 1971. Commercial production of minor tropical fruit crops in Florida. Proc. Fla. State Hort. Soc. 84:320–323.

5. Campbell, C.W. 1979. Effect of gibberellin and hand pollination on fruit-set of atemoya. Proc. Amer. Soc. Hort. Sci. Trop. Reg. 23:122–124.

6. Campbell, C.W. and R.L. Phillips. 1980. The atemoya. Fla. Coop. Ext. Serv. Fruit Crops Fact Sheet FC–64.

7. Campbell, C.W., and J. Popenoe. 1967. Effect of gibberellic acid on seed dormancy of *Annona diversifolia* Staff. Proc. Amer. Soc. Hort. Sci. Trop. Region 11:33–36.

8. Garcia, L.A. 1949. Anthracnose of the Annonaceae in Puerto Rico. J. Agr. Univ. Puerto Rico 33:27–43.

9. Ogden, M.H.A., C.W. Campbell and S. P. Lara. 1981. Grafting annonas in southern Florida. Proc. Fla. State Hort. Soc. 94:355–358.

10. Peña, J.E., H. Glenn and R.M. Baranowski. 1984. Important insect pests of *Annona* spp. in Florida. Proc. Fla. State Hort. Soc. 97:337–340.

11. Phillips, R.L., and C.W. Campbell. 1978. The sugar apple. Fla. Coop. Ext. Serv. Fruit Crops Fact Sheet FC–38.

COMPLEMENTOS A LA CLAVE PARA LA IDENTIFICACION DE LAS VARIEDADES COMERCIALES DE PINA

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RESUMEN

Previamente, Antoni y Leal diseñaron una clave para la identificación de las variedades comerciales de pina *(Ananas comosus)* basado en los caracteres. presencia de aguijones en las hojas; color de las hojas; peso del fruto; forma del fruto: color externo del fruto, color interno del fruto; profundidad de las bayas y orientación de las mismas. Se proponen añadidos a la misma a fin de incorporar otras variedades comerciales o semicomerciales.

ABSTRACT

Previously, Antoni and Leal developed a key to identifying commercial pineapple *(Ananas comosus)* varieties based on the following characteristics: presence of thorns in the leaf margins; leaf color, fruit weight; fruit shape; external and internal color of the fruit; locule depth and berry orientation. Now, some addenda are made to incorporate other commercial and semi-commercial varieties into the key.

La piña continúa siendo un frutal tropical de gran demanda en los mercados internacionales tanto en fruta fresca como en conserva.

Los datos de la F.A.O. (6) senalan que para 1983 se produjeron 8.665.000 toneladas métricas de piña; y al igual que en anteriores oportunidades (1), la producción correspondiente a una sola variedad fue de approximadamente 72,5% y que 5 variedades (Cayena lisa, Queen, Singapore Spanish, Espanola Roja y Pernambuco) constituyen más del 85% de esa producción.

El escaso número de variedades de piña utilizadas comercialmente implica un alto riesgo para la productividad, de presentarse algún competidor biótico.

Enmuchos países tropicales, especialmente de América Latina, existen gran cantidad de variedades y tipos de piña que se utilizan para satisfacer los mercados locales. Es imprescindible que ellas sean recolectadas en bancos de germoplasma, para ser evaluadas en programmas de mejoramiento, y evitar así, los riesgos de una erosión genética en esta especie.

Este trabajo al igual que los enteriores (1, 11) fue diseñado con el fin de facilitar la identificación de variedades comerciales de pina y otras consideradas con mucho potencial.

Revision de literatura

Otros trabajos (1, 11) llevaron a cabo una revisión exhaustiva de la literatura publicada al respecto, escapándose tal vez algunas descripciones de variedades locales en publicaciones de circulación restringida.

Algunas de estas publicaciones han sido posible revisarlas (4, 13, 17) lo que facilitó la reestructuración de esta clave.

Materiales y methods

Para elaboración de la clave se utilizó la metodología descrita con anterioridad, la cual *grosso modo* se basó en los siguientes caracteres:

a. Presencia de aguijones en los bordes de las hojas;
b. Color de las hojas;
c. Peso del fruto;
d. Forma del fruto;
e. Color externo del fruto;
f. Color interno del fruto;
g. Profundidad de las bayas (ojos) y
h. Orientación de las bayas

Resultados y discusion

En base a los datos de la FAO (6), se elaboró el Cuadro 1 donde se muestran los principales países productores de piña y las variedades más importantes en cada uno de ellos.

A la clave para la identificacion de las variedades comerciales de pina elaborada por Antoni y Leal (1), se le hicieron los añadidos y enmiendas que faciliten su uso.

Breve Description De Las Variedades De Piña Cultivadas Commercialmente En El Mundo

1. 'Española Roja' ('Spanish', 'Black Spanish', 'Key Largo', 'Habana', 'Cubana', 'Cowboy', 'Byll Head', 'Native Philippine Red' (2, 9). Plantas medianas, con hojas de aguijones pequeños, cortos. Fruto de tamaño mediano, de 0.8 a 2.25 kg, en forma de barril, color externo amarillo-anaranjado; con ojos muy definidos, rectangulares, planos, elevados hacia las esquinas; centro bien marcado; número de ojos variable entre 77 y 92, orientados en dos espirales; brácteas cubriendo cerca de 1/3 de la baya; pulpa blanca, jugosa de sa bor dulce y agradable.

2. 'Mauritius' ('Malacca Queen', 'Ceylon', 'Red Ceylon', 'Malacca', 'Red Malacca' (3, 9). Plantas pequeñas y compactas, de hojas largas y angostas, de color verde oscuro, con aguijones de color rojo en sus márgenes. Fruto de forma cónica a cilíndrica, peso de 0.5–1.5 kg; color externo amarillo brillante, color interno amarillo; ojos prominentes, angulares, con brácteas cubriendo 1/3 de la baya, en número de 130–170, orinetados en 3 espirales.

3. 'PR–1–67' (20). Plantas medianas, hojas con aguijones dobles o sencillos curvados hacia arriba; las hojas de color verde amarillento con tintes rojizos. Frutos de peso promedio alrededor de los 2.5 kg. en forma de barril; ojos dispuestos en 3 espirales; color externo amarillo-anaranjado; pulpa blanca; y en general may parecida 'Espanola Roja'.

4. 'Cabezona' ('Puerto Rico', 'Piña de Agua') (21). Planta de gran tamaño; hojas anchas, de bordes aserrados, con aguijones pequeños, y de color verde ceniza. Fruto de forma cónica, grande (más de 3.0 kg.), ojos anchos y rectangulares, orientados en dos espirales; color externo amarillo-anaranjado; pulpa blanca, agridulce, fibrosa. Es considerada un triploide natural.

5. 'Pernambuco' ('Eleuthera', 'Branco de Pernambuco', 'Perola') (7, 8, 9). Planta mediana, vigorosa, de hojas medianas, anchas, de color verde oscuro, provistas de aguijones grandes en sus márgenes. Fruto oblongo, de 0.9–1.8 kg de peso, de color externo amarillo, color interno amarillo, ojos redondeados en la parte superior y rectangulares en la base, profundos, con brácteas cubriendo 1/3–1/2 del ojo, orientados en 2 espirales.

6. 'Montufar' ('Sugar Slice') (17). Plantas medianas, de hojas cortas a medianas, de color werde a verde amarillento, con aguijones grandes en los bordes de las hojas. Fruto de forma cónica, peso de 0.8–1.4 kg de color externo verde amarillento, color interno amarillo.

7. 'Abacaxi' ('Abakka') (9, 18). Planta mediana, muy erecta, de hojas largas, de color verde oscuro, con manchas rojizas, de márgenes con aguijones medianos. Fruto piramidal a oblongo, peso de 1.8–2.5 kg, color externo amarillo profundo, color interno amarillo pálido a a blanquecino; ojos planos hexagonales, profundos orientados en 3 espirales. Produce gran cantidad de hijos en la base del fruto.

8. 'Ripley' ('Old Ripley', 'Montserrat') (14). Plantas de hojas anchas, bastante largas, de color verde con manchas marrón rojizo, de márgenes con aguijones poco fuertes e irregulares. Fruto redondeado oval con "cuello de botella", de 1.35 – 2.25 kg. de peso; color verde oscuro tornándose cobre pálido al madurar, con brácteas cubriendo ½ del ojo y gran cantidad de tricomas; pulpa amarillo pálido, muy dulce y suculenta, con poca fibra.

9. 'James Queen' ('Z') (15). Plantas vigorosas de tallo grueso, hojas largas, de color verde claro, con muchos aguijones fuertes. Frutos redondeados, de 1.12 a 1.4 kg. de peso, color externo amarillo dorado, color interno amarillo profundo, ojos pequenos prominentes, rectangulares, profundos. Esta variedad es un tetraploide natural.

10. 'Queen' ('Reina', 'Formosa') (4, 5, 14). Es una variedad muy vieja, con muchas subvariedades. Planta pequeña, de hojas cortas, de color verde claro, con presencia de muchos aguijones fuertes, espaciados. Frutos oblongos, reduciéndoes hacia el cuello, peso de 0.9–1.3 kg, color externo amarillo dorado, color interno amarillo profundo, ojos pequeños, prominentes, rectangulares, profundos, con brácteas cubriendo 1/3 del ojo, numero de bayas 130–140, los del tope del fruto minúsculos, dando la impresion de cuello de botella.

11. 'Spanish Jewel' (10). Plantas medianas, de hojas largas y anchas, color verde oscuro con manchas rjizas. Frutos de forma cilindricas, peso 2.25 kg; color externo anaranjado, color interno blanco; ojos planos rectangulares, profundos, en número de 95 a 100, orientados en 2 espirales.

12. 'Sugar Loaf' ('Pan de Azúcar', 'Andina', 'Papelón') (9). Plantas pequeñas a medianas, con hojas de color verde-morado, de márgenes con aguijones. Fruto oblongo-cónico, de 0.5 a 2.5 kg de peso; color externo amarillo produndo, color interno amarillo; ojos pequenos, ovales a redondeados, planos, profundos, de alrededor de 100 en número; brácteas cubriendo la buya.

13. 'Singapore Spanish' ('Singapore', 'Singapore Canning') (3, 9). Plantas medianas, hojas largas, angostas de color verde oscuro, con márgenes rojizos, con pocos aguijones frecuentemente cerca del ápice de la hoja. Fruto de forma cilíndrica, peso de 1.5–2.5 kg, color externo anaranjado, color interno amarillo pálido, ojos rectangulares, ligeramente prominentes en los bordes, profundos, en número de 110–115, orientados en 2 espirales.

14. 'Masmerah' (22). Plantas grandes, de hojas largas, angostas, de color verde oscuro, sin aguijones. Fruto de forma cilíndrica, peso de 1.5–3.0 kg, color externo anaranjado, color interno amarillo dorado, con corona grande (50 cm de largo o más), de ojos rectangulares, ligeramente profundos, en número de 110–115, orientados en 2 espirales.
La planta de 'Masmerah' es idéntica a una de 'Singapore Spanish', excepto que es más vigorosa y que las hojas carecen de aguijones.

15. 'Cayena Lisa' ('Sarawak', 'Kew', 'Giant Kew', 'Hilo', 'Claire', 'Esmeralda') (5, 9). Plantas medianas, de hojas largas y anchas, color verde oscuro con manchas rojizas, de bordes lisos con la excepción de algunos aguijones en la extremidad de la hoja. Fruto en forma cilíndrica, peso de 2.0 a 2.5 kg; color externo anaranjado rojizo, color interno amarillo pálido; ojos planos, hexagonales poco profundos, en número de 140–160, orientados en 3 espirales.

16. 'Champaka', Plantas grandes, de hojas largas y anchas, de color verde oscuro con manchas rojizas, de bordes lisos con la excepción de algunos aguijones en la extremidad de la hoja. Fruto cilíndrico, peso de 2.5–3.0 kg; color externo anaranjado rojizo, color interno amarillo, ojos planos, hexagonales, pocos profundos, en número de 160–180, orientados en 3 espirales. Selección de 'Cayena Lisa'.

17. 'Monte Lirio' ('Cambray', 'Milagrena') (5, 13, 16, 19). Planta pequeña, de pocas hojas; hojas medianas, de color verde intenso, sin aguijones, de bordes lisos y márgenes involutos ("piping"), con aguijón en la punta. Frutos globosos, de 1.0–1.8 kg de peso, color externo amarillo, color interno blanco.

18. 'Perolera' ('Tachirense', 'Capachera', 'Motilona', 'Lébrija') (12). Plantas grandes, hojas cortas a medianas, de color verde oscuro con manchas rojizas, de bordes lisos, y márgenes involutos ("piping"), con un aguijón en la punta. Fruto en forma de bloque, peso de 1.5 a 3.5 kg; color externo amarillo, color interno amarillo; ojos prominentes con brácteas sin aguijones, profundos, en número de 130–140, orientados en 3 espirales.

19. 'Barón de Rothschild' (9). Planta de tamaño pequeño a mediano; fruto de forma oblonga reduciéndose hacia la base de la corona; peso de 2.5 a 2.8 kg, color externo amarillo, color interno amarillo pálido; hojas con gran cantidad de espinas. Esta variedad es muy parecida a la 'Cayena Lisa'.

20. 'Brecheche' (11). Plantas pequeñas, hojas medianas, angostas, de color verde oliva, totalmente sin aguijones y sin márgenes involutos ("piping"). Fruto en forma cilíndrica, peso de 0.70–1.00 kg; color externo e interno amarillo; ojos hexagonale; planos, profundos, en número de 100–105, orientados en 3 espirales.

21. 'Bumanguesa' (11). Se piensa que sea una mutación de 'Perolera', de la cual se distingue por tener hojas de color verde claro. Fruto de color externo rojo a morado, color interno amarillo intenso, y ojos poco profundos, y orientados en 3 espirales.

22. 'Maipure' (11). Plantas grandes, hojas largas, color verde oscuro con manchas rojizas, de bordes lisos, con márgenes involutos ("piping") con aguijón en la punta. Fruto de forma cilíndrica, peso de 2.5–3.0 kg; color externo amarillo, color interno amarillo pálido; ojos planos, hexagonales, con bráctea sin aguijones, más grande que el ojo, en número de 170–190, orientados en 3 espirales.

23. 'Rondon' ('Abacaxi Rondón). Plantas medianas; de hojas medianas, de color verde oscuro con manchas rojizas, sin aguijones, de bordes lisos, y márgenes involutos ("piping"), con aguijón en la punta. Frutos cilíndricos-alargado de 1.5 a 1.8 kg de peso, de color externo amarillo-anaranjado, color interno blanco; ojos ligeramente planos, profundos, en número de 120–130, orientados en 3 espirales.

Clave De Las Variedades De Pina Cultivadas En El Mundo

A. Plantas con aguijones generalmente en toda la longitud de la hoja

B. Hojas de color verde (a veces con tintes rojizos)

C. Fruto en forma de barril.

D. "Ojos" del fruto orientados en 2 espirales

E. Color externo del fruto anaranjado, Color interno blanco-amarillento

F. Color interno del fruto blanco-amarillento ..... 'Española Roja'

FF. Color interno de fruto amarillo 'Mauritius'

DD. "Ojos" del fruto orientados en 3 espirales

E. Color externo del fruto anaranjado

F. Color interno del fruto blanco. 'PR-1-67'

CC. Fruto en forma oblonga-cónica

D. "Ojos" del fruto orientados en 2 espirales

E. Color externo del fruto amarillo-anaranjado

F. Color interno del fruto blanco

G. Peso del fruto 3.0 kg 'Cabezona'

GG. Peso del fruto 3.0 kg 'Pernambuco'

FF. Color interno del fruto amarillo 'Montufar'

DD. "Ojos" del fruto orientado en 3 espirales

E. Color externo del fruto amarillo-anaranjado

F. Color interno amarillo ..... 'Abakka'

CCC. Fruto en froma oblonga, con cuello de botella

D. Color interno del fruto amarillo pálido (Peso 1.35-2.25 kg) ..... 'Ripley'

DD. Color interno del fruto amarillo intenso ... (Peso 0.9-1.4 kg)

E. "Ojos" poco profundos ..... 'James Queen'

EE. "Ojos" profundos ..... 'Queen'

CCCC. Fruto en forma cilíndrica

D. "Ojos" del fruto orientados en 2 espirales ..... 'Spanish Jewel'

DD. "Ojos" del fruto orientados en 3 espirales ....'Barón de Rothschild'

BB. Hojas de color verde-morado a morado ..... 'Sugar Loaf'

AA. Plantas con aguijones en la extremidad (punta) de la hoja.

B. "Ojos" orientados en 2 espirales

C. Peso del fruto 1.0 kg ..... 'Singagore Spanish'

CC. Peso del fruto 1.5 - 3.0 kg ..... 'Masmerah'

BB. "Ojos" orientados en 3 espirales

C. Peso del fruto 2.0 - 2.5 kg ..... 'Cayens Lisa'

CC. Peso del fruto 2.5 -3.0 kg ..... 'Champaka'

AAA. Plantas con hojas totalmente sin aguijones

B. Frutos cilíndricos .....'Brecheche'

AAAA. Plantas con jojas totalmente sin aguijones (hojas de márgenes involutos-piping)

B. Frutos en froma del barril ..... 'Monte Lirio' (Cambray = Milagrena)

BB. Frutos cilíndricos

C. Color externo amarillo ..... 'Maipure'

CC. Color externo amarillo-anaranjado ..... 'Rondón'

BBB. Frutos en forma de bloque cilíndrico .....

C. Color externo amarillo ..... 'Perolera'

CC. Color externo rojo ..... 'Bumanguesa'

Literatura Citada

1. Antoni, M.G. y F. Leal. 1981. Clave para la identificación de las variedades comerciales de piña *(Ananas comosus).* Rev. Fac. Agron. (Maracay), Alcance. 29: 13-24.

2. Bondad, N.D. *et al.* 1979. The Philippines recommends for pineapple. Philippines Council for Agriculture Research. Los Baños. 66 p.

3. Brown, F.B. 1953. Pineapple varieties and selection in Malaya. Malay. Agric. J. 36:237-246.

4. Camargo, F.C. 1939. Ananas e Abacaxi. Revista de Agricultura Piracicaba. 14 (7-8): 321-338.

5. Collins, J.L. 1960. The pineapple. Leonard Hill, London, 249 p.

6. F.A.O. 1983. Anuario de Producción. Colección Estadística No. 55. 320 p.

7. Giacomelli, E.J. 1968. ABC de Abacaxicultura. O. Agrónomico, Campinas 20 (9-10): 11-22.

8. Giacomelli, E.J. 1969. Curso de Abacaxicultura. Universidade Federal de Pernambuco. Recife. 89 p. (Mimeografiado).

9. Hume, H.H. y H.K. Miller. 1904. Pineapple Culture II: Varieties. Florida. Agr. Expt. Sta. Bul. 70:36-62.

10. Kernes, K.R. and J.L. Collins. 1972. Pineapple varieties. In : Register of New fruit and Nut Varieties. Reid M. Brooks and H.P. Olmo. University of California Press. Berkeley. 708 p.

11. Leal, F. y M.G. Antoni. 1981. Descripción y clave de las variedades de piña cultivadas en Venezuela. Rev Fac. Agron. (Maracay), Alcance 29:51-79.

12. Leal, F.; M.G. Antoni y P. Rodriguez. 1979. Descripción de circo variedades de piña *(Ananas comosus)*9 en Venezuela. Rev Fac Agron. (Maracay). 10 (1-4): 21-30.

13. Montenegro, H.W.S. 1968. Cultivo de la piña en el Ecuador. Quito, Ecuador (Mimeografiado) 42 p.

14. Munro, D. 1835. Classification of pineapple varieties. Trans. London Hort. Soc. (Ser. 2) 1:1-34.

15. Nyenhuis, F.M. 1964. 'James Queen'. A new pineapple variety. Farm. South Afr. 40 (8) :54-56.

16. Pareja-Cobo, J.M.A. 1968. Estudio sobre el mecansimo de la polinización y fertilidad de las flores de la piña de la variedad Cambrey. Univ. Central del Ecuador. Fac. de Ing. Agron. y Med. Vet. Quito (Mimeografiado) 44 p.

17. Porres, M.A. y0S. Rivera De Leon. 1975. Cultivo de la piña. Departamento de Divulgación Agrícola. Ministerio de Agricultura, Guatemala. 13 p.

18. Py, C., y M. Tisseau, 1969. La piña tropical. Ed. Blume. Barcelone. 278 p.

19. Py, C., J.J. Lacoeuilhe et C. Teisson. 1984. L'ananas, sa culture, ses prodiits. G.P. Maisonneuve & Larose. Paris 562 p.

20. Ramirez, O.D.; H. Gandia y H. Velez-Fortuño 1970. Two new pineapple varieties for Puerto Rico. J. Agric. Univ. Pureto Rico 54 :417-428.

21. Salazar. C. 1956. La piña "Cabezona". Rev de Agric. de Puerto Rico. 44 (1) : 51-58.

22. Wee, Y.C. 1974. The Masmerah. A new cultivar for the Malaysian Pineapple Industry. World Crops 26 (2): 64-67

Cuadro 1. Zonas productoras de piña en el mundo, produccion y principales variedades utilizadas

Zonas productora	Produccion (1000TM)	Variedad
Africa		
Costa de Marfil	350	'Cayena Lisa'
Sud-Africa	237	'Cayena Lisa', 'Queen'
Kenya	160	'Cayena Lisa'
Zaire	153	'Cayena Lisa'
Congo	105	'Cayena Lisa'
Norte y Centro América		
U.S.A.	549	'Cayena Lisa', 'Hilo'
México	400	'Esmeralda', 'Cayena Lisa'
Sur América		
Brasil	841	'Pernambuco', 'Cayena Lisa'
Colombia	140	'Perolera', 'Cayena Lisa'
Ecuador	140	'Cambray', 'Cayena Lisa'
Asia		
Tailandia	1439	'Cayena Lisa'
Filipinas	1300	'Cayena Lisa'
India	660	'Cayena Lisa'
Viet-Nam	380	'Cayena Lisa'
China	295	'Cayena Lisa'
Indonesia	230	'Cayena Lisa'
Bangladesh	160	'Cayena Lisa'
Malaysia	160	'Singapore Spanish'
Oceanía		
Australia	180	'James Queen' 'Ripley', 'Cayena Lisa'

OBSERVATIONS SUR LA RESPONSE DE *XANTHOSOMA SAGITTIFOLIUM* A DES TRAITEMENTS GIBBERELLIQUES EN VUE DE SA FLORAISON

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RESUME

X. sagittifolium cv Malanga rouge a été traité à 250 et 1500 ppm avee de la gibberelline en 1983. La floraison a atteint 99% avec 250 ppm meilleur traitement. Mais, en 1984, ce même traitement a été décevant sur ce cultiva comme sur d'autres. Faut-il en rendre responsable l'infestation du terrain par *Pythium myriotylum* an agent de dépérissement du Malanga? Par ailleurs, de déformations des rhizomes secondaires consecutives au traitement gibberellique apparaissent affecter la génération végétative suivante.

ABSTRACT

X. sagittifolium cv Malanga rouge was treated in 1983 with 250 and 1500 ppm gibberellic acid. Flowering reached 99% with 250 ppm which was the best treatment. But, in 1984, this same treatment was disappointing over this cultivar as well as on others. Can this be related to the plot infestation by *Pythium myriotylum*, an agent of the tannia leaf burning disease? Meanwhile, deformations of secondary rhizomes resulting from the gibberellic treatment seem to affect the next vegetative generation.

Cette brève note évoquera deux aspects du comportement de *X. sagittifolium* qui ne semblent pas avoir été décrits dans les publications concernant la floraison de cette espèce.

Depuis quelques années, les Aracées alimentaires sont davantage étudiees. On en veut pour preuve non seulement le nombre important d'articles ou de communications à des congrès (ceux de l'ISTRC par exemple de 1979, 1983 et 1985 (cf. la bibliographie)), mais encore les ouvrages successifs édités sous les directions de Wang Jax-Kai (1983) et de Chandra (1985). Parmi les recherches sur *X. sagittifolium*, outre celles concernant les maladies, en particulier le pantropical "dépréissement du Malanga" (Nzietchueng, 1983; 1985 Laguna et al. 1983; Adams et al. 1985, Hountounji et Messiaen, 1985) on mentionnera celles concernant la floraison (McDavid et Alamu 1976 ; IITA, 1978; Jordan 1979; Alamu et al. 1982). On soulignera aussi que la morphologie même de l'espèce en relation avec les descriptions variétales ou la classification botanique est aussi à l'ordre du jour.

Le développement d'un programme de recherche important basé en Dominique a eu des effets d'entrainement a l'INRA et nous a conduit à rechercher la maîtrise de la floraison de *X. sagittifolium*, étape indispensable à un programme eventuel d'amélioration génétique dont la nécessité se révèle en l'absence de bonnes variétés resistantes et de traitement aisé a l'égard du "déperissement du Malanga".

Rappelons enfin que *X. sagittifolium* est culture non négligeable dans les Antilles françaises et sa relative régression y est certainement due a l'absence de variabilité face aux nouvelles contraintes de l'agrosystème (Risede, 1985). La floraison spontanée de certains cultivars (ex. Malanga violet) est très irrégulièrement observée. Aucune fructification ni germination n'a été localement observée.

Materiel et Methods

Parmi les 9 variétés de notre collection, le "Malanga violet" (ou Malanga rouge) était le plus abondant, son apparente rusticité ayant conduit à le multiplier. Risede (1985) en donne la description que l'on trouvera en Annexe.

A cette variété seule utilisée en 1983–1984, se sont ajoutées en 1984–1985 toutes les autres dont on allègera cette note des descriptions, compte tenu de leur faible réponse générale dans cette expérimentation préliminaire.

Pour aborder la maitrise de la floraison, comme on l'a indiqué, on disposait des publications de plusieurs recherches qui toutes aboutissaient a l'efficacité de l'acide gibberellique GA3, mais avec d'importantes divergences de dosage. Nous avons alors decide de comparer les effets de 1.500 ppm appliqués a l'IITA (Wilson, 1980). à ceux de 250 ppm appliqués à l'UWI (Alamu et al., 1982).

Les applications ont été faites le 20 Octobre, en 1983, sur deux parcelles contigues de Malanga violet, le reste des plantes longeant ces deux paracelles, en nombre équivalent, non traitées, constituant le témoin. A la date du traitement les plantes avaient 5 à 6 feuilles en moyenne.

En 1984, le traitement a été limité à la dose de 250 ppm, appliquée le 24 Aout sur une partie des lignes de chaque variété. Leur stade de croissance etait moins homogène. On soupçonnait déjà la parcelle, installé à proximité d'un bas-fond mal drainé, d'être atteinte d'un déséquilibre physiologique sinon pathologique.

Le controle de la situation sanitaire a été effectué par A. Hountounji dans de cadre de ses travaux déjà cités sur la pathologie du Malanga.

L'examen des récoltes des parcelles de Malanga Violet n'a eu lieu qu'en 1984 en ce qui concerne les parcelles traitées. Leurs descendances végétatives ont été observées en 1985.

Resultats

Floraison

En 1983–84, les premières floraisons de Malanga Violet ont été observées 90 jours environ après les traitements pour les deux doses. Bien que l'absence de répétition interdise des comparaisons quantitatives rigoureusement significatives, les pourcentages

observés de 99% de floraison avec 250 ppm et 53% avec 1500 ppm doivent être mentionnés. Les plantes témoins n'ont pas fleuri bien que la même année on ait observé 2 plantes fleuries dans une parcelle de 15 de cette même variété, en collection.

En 1984–85, les quelques floraisons observées n'ont pas dépassé le 1/3 des effectifs traités des variétés fleuries et certaines, dont le Malanga Violet, n'ont pas du tout fleuri. Des floraisons ont été observées, à des taux non discriminants et toujours faibles, à la fois chez des plantes non traitées et traitées de certaines variétés.

La situation sanitaire en 1984-85

Bien avant le traitement, des zones irrégulières de la parcelle présentaient des jaunissements foliaires accusés et même du nanisme. A l'époque du traitement, A. Hountounji relevait les symptômes caractéristiques deu dépérissement du Malanga; outre les symptômes aériens ci-dessue la réduction voir la suppression des racines, les nécroses à leurs extrémités et la petitesse des tubercules. II devait par la suite isoler, non seulement des plantes les plus affaiblies, mais de tout échatillon le *Pythium myriotylum*, dont le rôle parait capital dans ce syndrome parasitaire.

Morphologie southerraine et traitement gibberellique

La récolte des tubercules des parcelles de Malanga Violet traitées en 1983, offrait une fréquence anormalement élevée de tubercules secondaires plus ou moins ramifiés, et ce beaucoup plus marquée pour la parcelle traitée a 1500 ppm. Bien que de tels accidents soient occasionnellement observables dans des cultures usuelles de cette variété, les plantes témoins n'en présentaient pas. Toute les plantes traitées observées avaient l'anomalie, seul le nombre de tubercules secondaires affectés par plante et le degré de ramification variaient. A cette ramification était associée, au moment de l'arrachage, un net retard de germination de ces tubercules secondaires sur ceux des plantes témoins.

Remis en culture séparément en 1984, les tubercules des trois origines (témoin, 250 et 1500 ppm) ont confirmé à la levée la prolongation apparente de dormance liée à la gibberelline. A leur récolte en 1985, quoique fortement atténuee, la tendance à la ramification était de nouveau repérable dans la descendance végétative des plantes traitées.

Conclusion - Discussion

Sauf que les faits rapportés constituent dans leur conjonction un ensemble de données originales, ils n'ont rien de surprenant à partir des connaissances antérieures.

Wilson (1980) avait déjà soullgné la nécessité de determiner la dose de gibberelline efficace en fonction des clones et de leur état physiologique; la dépression végétative d'origine pathologique et son cortège d'altérations métaboliques et hormonales peuvent évidemment inhiber l'induction à la floraison par l'acide gibberellique chez *X. sagittifolium*.

II est par ailleurs bien établi (Krishnamoorthy, 1975) que les gibberellines peuvent modifier la domiance apicale et les dormances. Les travaux de Wickham (1983) chez les ignames en ce qui concerne la dormance en sont un exemple, L'application de gibberelline au tubercule de pomme de terre, par ailleurs, conduit à des modifications de cette nature dans la descendance végétative (Rostroprowicz et Ryzaczewska, 1980).

Les implications de tels traitements sur la valeur agronomique des tubercules-semences de *X. sagittifolium* et la valeur d'utilisation alimentaire de la récolte n'ont pas été encore véritablement étudiées.

En ce qui concerne l'application de ces données à l'objectif initial de la maitrise de la floraison, une bonne phytotechnie s'avère nécessaire au succès, et il y a lieu désormais d'étudier la "rémanence" de l'induction à la floraison chez les descendances végétatives de plantes traitées.

References bibilographiques

Publications collectives générales sur les Aracées alimentaires

A. Congres

Proceedings of the Vth Symposium of ISTRC. Manila, Philippines, 1979.

Proceedings of the International Seminar on Taro, 1979, IFS.

Proceedings of the VIth Symposium of ISTRC, Lima, Peru, 1983. CIP.

Communications du VIIe Symposium de l'ISTRC, Gosier, Guadeloupe INRA.

B. Ouvrages

Wang, J.K. "Taro: A review of *Colocasia esculenta* and its potentials". 1983.

S. Chandras, (ed) *Edible aroids.* Oxford University Press, 1985.

Publications spécialisees

Adams H., Pattanjalidial and Clark., A. (1985) Ariod improvement in the Eastern Caribbean: An update of the ARIOD/ARROWROOT Project. VIIe Sympsoium ISTRC. Guadeloupe.

Alamu S., McDavid C.R. and Duncan E.J.(1982). Production of viable seed in gibberellic acid-treated tannia *(Xanthosoma sagittifolium* (L). Schott) plants *Trop. Agric. Trinidad* 59 (4) 333-334.

Hountondji A. et al. (1984). Premières observations sur le dépérissement du Chou Caraïbe *(Xanthosoma sagittifolium)* en Martinique. *Buttetin Agronomique Antilles Guyane.* 3 22-28

Hountondji A. et Messiaen, C.M. (1985). Les orientations de la lutte contre le dépérissement du Malanga *(Xanthosoma sagittifolium)* dans les Antilles, VIIe Symposium ISTRC. Guadeloupe.

IITA (1978), Annual report of the International Institute of Tropical Agriculture pp 57-39.

Jordon Molero F.L.(1979.) The imprevement of Yautia *(Xanthosoma* spp) by hybridization. XVIth Annual Meeting Caribbean Food Crops Society. Santo-Domingo. Abstract.

Krishnamoorthy H.N. (1975). *Gibberelins and plant growth,* Wiley Eastern Limited. New Delhi. 356 pp.

Laguna G.I., Salazar G.L. and Lopez F.J. (1983.) Fungal and bacterial diseases of Ariods:*Xanthosoma* ssp and *Colocasia esculenta* (L). Schott, in Costa-Rica. CATIE, Technical Bulletin No. 10.29 pp.

McDavid, C.R. and Alamu S. (1976). Promotion of flowering in tannia *(Xanthosoma sagittifolium)* by gibberellic acid. *Trop. Agric.* **38 (4) 321-325.**

Nzietchueng S. (1983). Etudes sur la pourriture racinaire du macabo *(Xanthosoma sagittifolium)* au Cameroun. I. Symptomatologie et étiologie de la maladie. *Agron. Trop:* **38** (4) 321-325.

II. Quelques aspects de l'épidémiologie et moyens de lutte. *Agron. Trop.* 38 (4) 321-325.

Nzietchueng S. (1985). Quelques caractéristiques physiologiques de *Pythium myriotylum,* agent pathogène de la pourriture racinaire du Macabo *(Xanthosoma sagittifolium)* au Cameroun. VIe Symposium ISTRC. Guadeloupe.

Risede J.M. (1985). Observations préliminaires sur la situation du Madère *(Colocasia esculenta)* et du Malanga *(Xanthosoma sagittifolium)* en Guadeloupe, Mémoire de fin d'Etude. ISTOM.

Rostroprowica S. et Rykaczewska K. (1980) Attempts increase the number of stems and of tubers formed on the potato plants which develop from a single tuber Biuletyn Instytutu Ziemniaka (1980) No. 25, 95–10. (Abstract in P.B.A., n° 8871, 1983).

Wickham D. (1983). Extension of dormancy in tubers of tropical yams *(Dioscorea* spp.). Rootcrops in the Caribbean. Proceedings of the Caribbean Regional Workshop on Tropical Root Crops. Jamaica. April 10-16.

Wilson J. (1980). Cocoyam breeding by flower induction, pollination and seed germination. International Institute of Tropical Agriculture. Nigeria. Manual Series No(4) 15 pp.

A PHENOTYPIC CLASSIFICATION OF THE EDIBLE TANNIA *(XANTHOSOMA* SPP (L.) SCHOTT) CULTIVARS OF THE EASTERN CARIBBEAN

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ABSTRACT

A functional, reliable and simple classification based on cormel flesh colour, cormel skin texture and petiole colour was developed and applied to 83 tannia clones collected in five islands of the Eastern Caribbean. Eleven elite tannia cultivars were identified which fell into three categories.

1. **white flesh/rough skin/green petiole**
2. **white flesh/smooth skin/green petiole**
3. **purple flesh/smooth skin/purple petiole**

The elite cultivars will serve the short-term improvement needs of tannia cultivation through their multiplication and distribution. The data on the entire collection can be utilised in longterm genetic improvement programmes.

RESUMEN

Una clasificación funcional, honesta y simple basada en el color de la pulpa del brote, la textura de la cascara del mismo y el color de pecíolo, fué desarrollada y aplicada a 83 clones de ocumo, recogidos en cinco islas del Caribe Oriental. Once cultivares selectos de ocumo fueron identificados y ellos se encuentran clasificados en tres categorias:

1. **pulpa blanca/cascara rugosa/peciolo verde**
2. **pulpa blanca/cascara lisa/peciolo verde**
3. **pulpa morada/cascara lisa/peciolo morado**

Los cultivares selectos serviran a la necesidad de tener un mejoramiento a corto plazo, del cultivo del ocumo, a travez de su multiplicación y distribución. Los datos de toda la colección pueden ser utilizados en programas, a largo plazo, del mejoramiento genético.

The edible cormels, produced by the numerous species which belong to the genus *Xanthosoma* (L.) Schott (Family: *Araceae)* have been a source of food for the earliest peoples of the Tropical Americas. The genus is distributed from Brazil, north to Mexico, but the cultivated genotrypes are centred in and around the Caribbean (Purseglove, 1972).

The crop is called "tannia" (in the English speaking countries), "malanga" (in the French speaking countries), "yautia" or "tiquisque" (in the Spanish speaking countries) and "new cocoyam" and "macabo" (in Africa).

The literature on tannia improvement in the Caribbean is "sparse". A similar observation was made by Spence (1970) a decade and a half ago. In comparison with work done on cassava, sweet potatoes, yams and white potatoes in the region, tannia is a poor and distant relation. However, the great potential of this crop was recently realised by researchers in Cuba, Puerto Rico and Trinidad.

Matienzo (1965) collected and described the tannia cultivars of Puerto Rico and general crop improvement was reported by Abuna – Rodriguez *et al.* (1967). Purseglove (1972) attempted a classification of the genus based mainly on basal lobes, colour of petioles and corm/cormel flesh colour. More recently Volin and Beale (1981) hybridized white, yellow and pink fleshed types and concluded that the agronomic characters of flesh colour, plant height, number and shape of cormels were controlled by four or more gene pairs; and that the genetic variability observed provided "the possibility of identifying new clones with the best traits of both parents".

Gooding and Campbell (1961) put together a regional collection of tannia clones and recognised 15 cultivars. The remanant of this collection with 51 accessions in Trinidad was included in this work.

Genetic improvement of tannia, as described by Spence (1970) aims at identifying the most suitable plant ideo-types of clones with greater productivity and resistance to pests and diseases and must be based on a clear understanding of the range of variability in plant characters. Elucidation of the inheritance of these characters and the accurate classification of the species and cultivars are essential basic information for crop improvement.

This study was aimed at the classification of the tannia cultivars commonly grown in St. Vincent, St. Lucia, Grenada, Dominica and Trinidad. The choice of characters studied was based on the criteria of ease of observation, consistence and usefulness in agronomic improvement.

The specific objective of this study was identify the morphological characters associated with the "elite" clones; i.e. those possessing high productivity, consumer acceptability and good general adaptability for short term multiplication and distribution.

Materials and Methods

Tannia clones were collected in 1982/83 from cultivations in the important tannia growing regions in Dominica, St. Lucia, St. Vincent and Grenada. The CARDI collection in Trinidad, based on the Food Crop Programme of the ICTA/RRC/UWI Faculty of Agriculture, was also included. The germplasm collections were planted with each cultivar represented by a minimum of ten clones in single rows. Agronomic practices and general crop care measures were applied to provide optimal growth conditions. Replanting and observations commenced in 1982 similar to the smaller collections in the four smaller islands.

A list of tannia descriptors was developed and utilised for recording observations on the phenotypes. The description was made as simple and clear cut as possible. Cormel flesh colour fell into three distinct classes:

white flesh (devoid of pigment),
yellow flesh

and

purple flesh (varying degrees of pale pink to dark purple)

Cormel skin texture was described as smooth or rough. The former denoted cormels without "bud-eyes" (i.e. lateral meristems) protruding above the level of epidermal cells, giving the cormel a smooth appearance. Rough skin cormels were covered with few to numerous protruding "bud-eyes". Petiole colour: the varying shades of green and purple of the exposed length of petioles of plants older than 22 weeks.

Shape of mature cormels was defined as bulbous or rhizoid. Plant height was the length of the petiole of the second open leaf from ground level to the point of attachment with the lamina.

Observations and data were based on at least two seasons' growth and the means of at least ten clones of every cultivar.

Results and discussion

The tannia accessions, which were observed in five germplsam collections over two seasons, are listed in Tables 1–5. The phenotypic characters presented for each accession were very functional and useful as marker traits. The characters of cormel skin texture, cormel flesh colour and petiole colour were found to be the most useful. Observations indicated their high penetrance from one clonal generation to another and between environments unlike other traits such as suckering, maturity range, productivity and others. Accordingly, the clones would be described mainly by means of these three characters.

Classification of clones by three major characters of cormel flesh colour, cormel skin texture and petiole colour

The data presented in Tables 1 – 5 showed that three main types of flesh colour, purple, white and yellow, were recorded. Within these groups of clones was a range of shades of purple from very pale pink to deep purple. White-fleshed clones exhibited the least variation.

Table 1 Description of the Tannia Cultivars of Dominica

Item No.	Vernacular Name	Cormel Flesh Colour	Cormel Skin Texture	Petiole Colour	Suckering at Maturity (0,+)	Productivity	Maturity
1	Sasan Male	white	rough	green	+	medium	early
2	Rabess or Bruce	white	smooth	green	0	high	early
3	Bruser	white	smooth	dark green	0	medium	medium
4	Sasan Female or Toby or Elsine or Chou Bouton	white	rough	green	+	medium	early
5	La Soie	white	rough	green	+	medium	medium
6	Deie	yellow	rough	purple	+	medium	medium
7	Too good to market	yellow	rough	purple	+	medium	medium
8	St. Lucia or Jamaique	purple	smooth	purple	0	high	late
9	Flood	pink	smooth	green	0	high	late
10	Jerusalem	pink	smooth	green	0	high	late

Note: Purple Flesh Colour was recorded as 5RP8/5; Yellow flesh colour was recorded as 2.54 8/9. Petiole colour varied from green approx. 7.5gy 7/5, light purple 5RP7/8 to dark purple 5RP4/3: all colours based on Munsell colour chart for plant tissues.

Table 2 Description of the Tannia Cultivars of St. Lucia

Item No.	Vernacular Name	Cormel Flesh Colour	Cormel Skin Texture	Petiole Colour	Suckering (+,0)	Productivity	Maturity
1	Jamaica	purple	smooth	purple	0	medium	late
2	Dominique	white	smooth	purple	0	medium	late
3	Six-months	white	smooth	purple	0	medium	early
4	Roseau	white	smooth	green	0	medium	medium
5	Bucco	white	rough	green	+	low	early
6	Jamaica Red	purple	smooth	purple	0	medium	late
7	Marishaw	white	rough	green	+	medium	early
8	UWI 22/57	purple	smooth	purple	0	medium	late
9	Breece	white	rough	green	+	medium	early
10	Blanc	white	rough	green	0	medium	early
11	UWI27/57	purple	smooth	purple	0	medium	late
12	UWI33/57	purple	smooth	purple	0	medium	late

Table 3 Description of Tannia Cultivars of St. Vincent

Item No.	Vernacular Name	Cormel Flesh Colour	Cormel skin texture	Petiole Colour	Suckering at maturity (+,0)	Productivity	Maturity
1	John Shott	white	rough	green	+	low	early
2	Red Seed Tannia	purple	smooth	purple	0	good	medium
3	Barbados white	white	smooth	green	0	good	medium
4	Grand Ba	yellow	smooth	purple	0	medium	medium
5	Nut Tannia	white	smooth	green	0	medium	early

Table 4 Description of the Tannia Cultivars of Grenada

Item No.	Vernacular Name	Cormel Flesh Colour	Cormel skin Texture	Petiole Colour	Suckering at maturity	Productivity	Maturity
1	John Swift	purple	smooth	purple	0	high	late
2	Marblay	purple	smooth	purple	0	medium	medium
3	Jimmy Roge or Bajan	white	smooth	green	0	medium	early
4	Button Tannia or Jigger Tannia	white	rough	green	+	medium	early
5	Eddoe Tannia or Nut Eddoe	white	smooth	green	+	medium	early

Table 5 Description of 51 tannia clones in the germplasm collection in Trinidad

Item No.	Vernacular name	Number	Cormel flesh colour	Cormel skin texture	Petiole colour	Shape of cormel	Productivity
18	White Chaguanai	05/56	white	smooth	green	rhizoid	high
17	Dearies Tannia	09/56	white	smooth	green	rhizoid	poor
16	Charanelle	12/56	white	rough	green	medium	medium
15	Tobago	09/57	white	rough	light green	rhizoid	poor
13	Tannia Eddoes	11/57	white	rough	dark green/ dark purple	rhizoid	very poor
7	_____	13/57	white	rough	green	medium	high
14	Coura Tannia	16/57	white	rough	light green	rhizoid	poor
9	Red Tannia	21/57	white	smooth	green	rhizoid	poor
10	Molkon	22/57	white	rough	green	rhizoid	poor
11	Red Tannia	25/57	white	rough	light green/ light purple	medium	medium
42	Sanssan	30/57	white	rough	green	rhizoid	poor
43	White Bruce	31/57	white	smooth	green	rhizoid	poor
44	Balizier	33/57	white	rough	green	rhizoid	poor
45	Sanssans	34/57	white	smooth	green	rhizoid	poor
46	Chou Bouton	37/57	white	rough	green	medium	poor
48	Chou Yance Rouge	39/57	white	rough	green	rhizoid	poor
50	Lavechardiere	44/57	white	rough	green	rhizoid	medium
2	_____	44/57/B	white	rough	dark green	rhizoid	medium
51	_____	X/57	white	rough	light purple	rhizoid	poor
1	Long finger	01/58	white	rough	light green/ purple	rhizoid	low
3	Guinea Coco	02/58	white	_____	light green	_____	poor
4	My White Lady	05/58	white	_____	light green	_____	poor
5	Bamboo Coco	06/58	white	_____	green	_____	poor
6	Red Tannia	07/58	white	rough	green	medium	high
40	Deerhorn	08/58/A	white	smooth	green	rhizoid	poor
38	Red Button	09/58	white	rough	light green	rhizoid	medium to high
37	Chou la Pareme	10/58	white	rough	light purple	rhizoid	medium

Table 5 - (Continued)

Item No.	Vernacular Name	Number	Cormel flesh colour	Cormel skin texture	Petiole colour	Shape of cormel	Productivity
36	Bockoy	11/58	white	smooth	green	rhizoid	medium
33	Bisley	14/58	white	rough	green	rhizoid	poor
32	Martinica	15/58	white	rough	green	rhizoid	medium
31	Kelly	16/58	white	rough	green	rhizoid	poor
30	Viequera	17/58	white	rough	light green	rhizoid	poor
29	Dominicana	18/58	white	smooth	green	rhizoid	poor
27	Blanca del Pais	19/58	white	rough	light purple	ovoid	_____
28	Rascana	20/58	white	smooth	green	rhizoid	medium
25	Inglesa	22/58	white	rough	dark green	rhizoid	poor
21	Chacal	01/82	white	rough	green	rhizoid	high
22	Bagatelle	02/82	white	medium	green	rhizoid	high
23	Cuban	03/82	white	rough	light green	bulbous	medium
19	Mamma Tannia	03/56	purple	rough	dark green	rhizoid	_____
41	Pink Bruce	27/57	pink	smooth	light purple	rhizoid	poor
47	Chou Canard	38/57	pink	rough	green	rhizoid	medium
39	_____	08/58/B	pink	rough	light purple	rhizoid	poor
34	_____	13/58	pink	rough	light purple	rhizoid	poor
26	Vinola	21/58	purple	rough	dark green	rhizoid	medium
20	_____	01/74	purple	smooth	_____	rhizoid	poor
8	Chackelle	19/57	yellow	smooth	dark green/purple margin	rhizoid	poor
12	Devil	26/57	yellow	rough	light purple	rhizoid	poor
49	Chou St. Lucia	43/57	yellow	rough	light purple	rhizoid	poor
35	_____	12/58	yellow	rough	light purple	rhizoid	poor
24	_____	10/60	yellow	rough	dark green	rhizoid	poor

Yellow-fleshed cormel colour was linked with rough skin in seven out of eight clones (Table 6). Yellow flesh also appeared in six out of eight clones together with purple petiole. The productivity of yellow-fleshed clones was not high and market acceptability was also low.

White and purple fleshed clones were more common: there were 18 purple and 58 white clones in the collection. White and purple flesh colour occurred together with both smooth and rough cormel skin texture. The smooth skin texture of both colours was preferred to all the other kinds both by consumers and growers. The majority of clones which possessed purple flesh and smooth cormel skin displayed higher dormancy, better keeping qualities and the longest growth periods, whereas the smooth white clones ranged in maturity from early to late. Suckering of the two types of clones, smooth-purple and smooth-white was none to few suckers at maturity. The combination of white-rough out-numbered the purple-rough by 32 to four White-rough clones tended to be the earliest and suckered profusely at maturity. Although eating quality was good, the unattractive appearance of these cormels weighed heavily against them in the market place.

The third character used was that of petiole colour. The main classes observed were varying shades of purple and green. Subtler differences in petiole colouration did appear but will not be considered at this stage. When petiole colour was observed together with the two characters of flesh colour and cormel skin texture, clones exhibited all 12 possible combinations (Fig. 1). The most frequent of the combinations was white flesh - rough skin - green petiole with 31 clones; the combination of white flesh - smooth skin - green petiole with 17 clones came next. Ten clones fell into the group with purple flesh - smooth skin - purple petiole. The other nine combinations occurred with lower frequencies.

From the above, it can be concluded, at this stage, that the number of distinct tannia cultivars present in the five collections cannot be less than 12. This number favourably compares with the findings of Gooding and Campbell (1961) that there were 15 cultivars in the regional tannia collection in Trinidad.

Identification of elite cultivars

The collection and observation of the edible tannia clones led to the identification of the "elite" clones of each of the five islands. The definition of "elite" referred to those clones which exhibited the highest general adaptability, high acceptability by consumers and growers and the highest yields. The comparative evaluation was completed by simultaneous "National Elite Varietal Tests" (CARDI/EDF 1985).

The cultivars which qualified as elite are listed and described in Table 7.

Table 6 - Edible yellow-fleshed tannia cultivars of the Eastern Caribbean

Item No.	Vernacular Name	Cormel Skin Texture	Petiole Colour	Productivity	Island
1	Grand Bay	rough	dark purple	medium	St. Vincent
2	Deie	rough	purple	medium	Dominica
3	Too-good-to-market	rough	purple	medium	Dominica
4	Chackelle	smooth	dark green	poor	Trinidad
5	Devil	rough	light purple	poor	Trinidad
6	_____(10/60)	rough	dark green	poor	Trinidad
7	_____(12/58)	rough	light purple	poor	Trinidad
8	Chou St. Lucia	rough	purple	poor	Trinidad

Corm/cormel Flesh colour	Cormel skin Texture	Petiole Colour	Number of clones
White	Smooth	green	17
		purple	2
	rough	green	31
		purple	2
Purple	smooth	green	2
		purple	10
	rough	green	3
		purple	2
Yellow	smooth	green	1
		purple	1
	rough	green	±
		purple	4

Fig. 1 - Combinations of 3 marker characters used in classification of tannia clones

Table 7 Some Elite Tannia Cultivars of the Eastern Caribbean

Cultivar Name	Island	Flesh Colour	Skin Texture	Petiole colour	Productivity	Suckering
Bruce	Dominica	white	smooth	green	high	0
Breece	St. Lucia	white	smooth	green	high	0
Barbados white	St. Vincent	white	smooth	green	high	0
St. Lucia	Dominica	purple	smooth	purple	high	0
Jamaica	St. Lucia	purple	smooth	purple	high	0
Marblay	Grenada	purple	smooth	purple	high	0
John Swift	Grenada	purple	smooth	purple	high	0
Red Seed	St. Vincent	purple	smooth	purple	high	0
Deerhorn (08/58)	Trinidad	purple	smooth	purple	Medium	0
Bagatelle	Trinidad	purple	smooth	purple	Medium	+
Viquiera	Trinidad	white	rough	green	high	+

The adoption of the classification proposed in Fig. 1 to the elite cultivars listed in Table 7, indicates that the white flesh - smooth skin - green petiole "Bruce" of Dominica is similar to the "Breece" of St. Lucia and the "Barbados White" of St. Vincent. The purple flesh - smooth skin - purple petiole cultivars called "St. Lucia", "Jamaica", "Marblay", "Red Seed" and "Deer Horn (08/58)" all belong to another group. The elite cultivars fall into these two groups with the exeption of "Bagatelle" and Viequiera which are white flesh - rough skin - green petiole types.

In short, the elite cultivars fall into the three broad groups, viz:-

1. White flesh - smooth skin - green petiole
2. Purple flesh - smooth skin - purple petiole
3. White flesh - rough skin - green petiole

Groups 1 and 2 have the highest preference of both consumers and growers. In Groups 3, there existed a variability in the degree of roughness from very few "bud-eyes" to numerous. "Bagatelle" belonged to this group but the roughness of cormels tended to be mild, its adaptability was high and productivity was medium to high. This group of cultivars was mostly preferred by the majority of small subsistence farmers who intercropped the third group with the other two. Cormels of Groups 1 and 2 were mostly marketed and cormels of Group 3 were consumed on farm (CARDI/EDF 1985).

Conclusions

A functional, reliable and simple classification based on cormel flesh colour - cormel skin texture - petiole colour was developed and applied to tannia clones collected in 5 islands of the Eastern Caribbean. Eleven (11) elite cultivars were identified and classified as:

1. white flesh - smooth skin - green petiole
2. white flesh - rough skin - green petiole
3. purple flesh - smooth skin - purple petiole

The elite clones will serve the short term improvement of tannia cultivation through their multiplication and distribution. The data on the entire collection and, the elete clones in particular, can be utilized in longterm genetic improvement programmes.

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References

Abruna-Rodriguez, F; Garcia E.G.B.; Vincente-Chandler, J. and Silva, S. (1967). Experiments on Tannia Production with Conservation in Puerto Rico's Mountain Region. The Journal of Agr. of the Univ. of P.R., Vol. LI No. 2, April, 1967.

Gooding, H.J. and Campbell, J.S. (1961) Preliminary trials of West Indian *Xanthosoma* sp. cultivars. Tropical Agriculture, Trin., 38, 145–52.

Matienzo, A.A. (1965). Identification y descripcion de las Variedades de Yautia *(Xanthosoma)* en la Colecion de la Subestacion en Gurabo, 1965. Estacion Exptl Agri., Universidad de Puerto Rico, Recinto de Mayaguez, P.R.

Munsell, R. (1977). Color charts for plant tissues. Munsell Color, Macbeth, Kollmorgen Corporation, Baltimore, Maryland, U.S.

Purseglove , J.W. (1972). Tropical Crops:Monocotyledons. Longman Group Ltd. pp. 70 – 71.

Spence, J.A. (1970). Growth and Development of Tannia *(Xanthosoma)* sp.). Tropical Root and Tuber Crops Tomorrow, Vol. 2, 1970, p 47.

Volin, R.B. and Beale, A.J. (1981). Genetic Variation in Fl Cocoyam *(Xanthosoma* sp.) Hybrids. Proc. Fla. Stat. Hort. Soc. 94: 235–238, 1981.

CARDI/EDF (1985) Project No. 5100.33.94.041. Semi-Annual Report October 1, 1984 to March 31, 1985. Botanic Gardens, Roseau, Dominica, March, 1985.

TANNIA (*XANTHOSOMA* SPP) PRODUCTION SYSTEMS IN THE WINDWARD ISLANDS

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ABSTRACT

From a survey of tannia (*Xanthosoma* spp.) production systems in Dominica, Grenada, St. Lucia and St. Vincent conducted by the CARDI/EDF: Ariods/Arrowroot Project a description of existing production practices is given and comparisons made between the islands. The major constraints identified were tannia rapid yellowing disease, weed control and limited availability of sufficient planting material. Areas requiring further research are identified.

RESUMEN

Del estudio de sistemas de producción en las islas de Dominica, Grenada, St. Vincent y St. Lucia, llevado a cabo por le instituto CARDI/EDF: Proyecto 'Aroideo/Maranta', damos una descripción y a la vez hacemos una comparacion, de las practicas de produccion de las islas mencionadas. Las mayores dificultadas encontradas fueron, la enfermedad del Amarillamiento rapido del *Xanthosoma* spp., el control de hierbas y la disponibilidad limitada de suficiente material de cultivo. Tambien se identifican las areas que requieren una investigación mas extensiva.

Keywords: Tannia, *Xanthosoma* spp; Production systems; Windward Islands

Tannia (*Xanthosoma* spp.) is an important root crop in the Windward Islands, especially Dominica, where per capita production was 98.7kg. in 1982/83. Tannia accounts for 28 percent of total root crop production in Dominica, and over 16 percent in Grenada, St. Lucia and St. Vincent. Annual production ranges from 7,400 tonnes in Dominica to 400 tonnes in Grenada. (Table 1).

Table 1 Tannia production in the Caribbean, 1982–83.

Country	Production (tonnes)	Per capita production (kg)	% of total root crop production
Antigua	20	0.2	2.9
Belize	10	0.06	5.0
Cuba	75,000	7.6	8.9
Dominica	7,400	98.7	28.8
Dom. Republic	35,000	5.6	16.3
Grenada	400	3.7	6.1
Jamaica	11,746	5.6	5.7
St. Lucia	1,000	7.9	16.6
St. Vincent	4,735	37.0	18.1
Suriname	50	0.1	1.6
Trinidad & Tobago	375	0.3	3.5

Source: Ferguson (1985)

The area under tannia production are estimated at 533, 113, 42 and 40 ha for Dominica, Grenada, St. Lucia and St. Vincent respectively.

Tannia is grown primarily for local consumption; however, limited quantities are exported to regional and extra-regional markets. Exports of tannia from Dominica have been increasing steadily over the past 5 years (Table 2) primarily to markets in the French islands of Martinique and Guadeloupe, and the more northerly Caribbean islands. Trinidad is the biggest importer of tannia in the region and St. Vincent is the major supplier (Ferguson, 1985).

In 1982 the Caribbean Agricultural Research and Development Institute (CARDI) began a four year project funded by the European Development Fund (EDF) for "Increased Production of Aroids (Tannia, Dasheen and Eddoes) and Arrowroot in the Eastern Caribbean." One of the first activities of the project was the undertaking of a detailed survey of aroid production systems in Dominica, Grenada, St. Lucia and St. Vincent, in order to obtain baseline data, and to identify constraints to production.

Table 2 Export of tannia from Dominica, 1980–84.

Year	Tannia exports (tonnes)
1980	55
1981	139
1982	123
1983	174
1984	227

Source: Dominica Market Intelligence Unit, March, 1985.

This paper is a summary of the survey findings with respect to tannia (*Xanthosoma* spp.), and compares tannia production systems in the Windward Islands. Areas requiring further research work are identified.

Methodology

The survey took the form of a structured questionnaire of 75 questions on farm physical characteristics, crop mixes, cultivars, cultural practices, harvest and post-harvest techniques.

Interviews were conducted by project staff and extension agents of the local Ministries of Agriculture. Editing and subsequent corrections were carried out by CARDI personnel. A total of 278 farmers (112 in Dominica, 76 in Grenada, 50 in St. Vincent and 40 in St. Lucia) representing 10 per cent of the tannia farming community, were interviewed.

Results

Cultivars

Farmers in all four islands grew a number of local cultivars, distinguishable primarily by petiole colour, cormel flesh colour and texture of cormel skin. Farmers in Grenada and St. Lucia reported seven commonly grown cultivars, while Dominican farmers

described nine cultivars, and St. Vincent farmers five (Table 3). In all cases a mixture of two or more cultivars were grown.

Table 3 Common tannia cultivars grown in the Windward Islands

Dominica	Purple, Rabess, St. Lucia, Jamaic, Bruce, White, Yellow, Sasan, Elsure
Grenada	Red, Crede, Pink, Purple, White, Bajan, Grand Bay
St. Lucia	Jamaica, Blanc, Bris, Bucco, Button, Eugene
St. Vincent	Barbados Smooth White, John Shott, Red Seed, Nut, Grambe

In each of the islands the two preferred cultivars were a white and a pink-fleshed type. In Dominica 77 per cent of the farmers grew "Rabess" a white-fleshed cultivar, while 45 per cent grew "St. Lucia" (purple-fleshed). Grenadian farmers favoured the "Red" (83 per cent) and the "White" (43 per cent). In St. Vincent all the farmers grew 'Barbados Smooth White' while 50 per cent grew 'John Shott' (white-fleshed).

Choice of cultivar was based on a variety of factors, and the most popular cultivars scored well in all eight categories of responses which were: yield, tolerance to pests and diseases, availability of planting material, marketability, taste, cooking quality, storage quality and tradition.

Crop mixes

Intercropping of tannia was a common practice in all four islands and pure stands of tannia were seldom seen. In most cases the crop mix consisted of tannia and one or more other crops. Tannia was usually the main crop when intercropped with vegetables, and a minor crop when grown in association with perennials.

The species of intercrop found was generally a reflection of the main crop of the island. The most frequent crop mix in all the islands was tannia, dasheen and banana. Tannia and citrus or coconut were common in Dominica, Grenada and St. Lucia. In Grenada tannia was also intercropped with nutmeg or cocoa (Table 4).

Table 4 Crops commonly intercropped with tannia in the Windward Islands

	Dominica	Grenada	St. Lucia	St. Vincent
Dasheen	*	*	*	*
Banana	*	*	*	*
Citrus	*	*	*	
Coconut	*	*	*	
Cocoa		*		
Nutmeg		*		
Eddoe				*
Yam		*	*	*
Sweet potato	*	*		*

Time of planting

In Dominica the main planting season was from May to June. Farmers in Grenada planted from February to April; in St. Lucia from January to May, and in St. Vincent from April to July. The reason identified for planting at these times was the onset of the rainy season. In areas where rainfall was evenly distributed some tannia was planted throughout the year.

Soil texture and topography

Table 5 shows the distribution of tannia farms with respect to soil texture. Clay loams were the most widely used soils for tannia production in St. Lucia, Grenada and Dominica while in Grenada only 25 per cent of the farmers interviewed cultivated tannia on clay loams.

Tannia was seldom cultivated on clays or sandy soils – except in St. Vincent where almost one third of the tannia production was on sand and 44 per cent on sandy loams.

Table 5 Distribution of tannia farms with respect to soil texture in the Windward Islands

	Soil texture			
	Clay	Clay loam	Sandy loam	Sand
	% of Tannia farms			
Dominica	9	63	27	1
Grenada	13	71	13	3
St. Lucia	1	95	3	1
St. Vincent	0	25	44	31

In all the islands more than 50 per cent of the farmers cultivated on soils with a slope of 10 – 30°. Seventy per cent of tannia farmers interviewed in St. Lucia utilized slopes of 30 – 60°. Flat land (< 10°) was used by 38 per cent of farmers in Dominica. Steeper terrain (> 60°) was seldom used. (Table 6).

Table 6 Distribution of tannia farms with respect to topography in the Windward Islands

	Gradient of slope			
	<10°	10–30°	30–60°	>60°
	% of farms			
Dominica	38	64	23	6
Grnada	16	66	18	0
St. Lucia	17	52	70	9
St. Vincent	10	50	40	0

Land preparation

In all of the islands the implements used to prepare the land for planting were the cutlass, the hoe and the fork. Over 75 per cent of the farmers interviewed in Dominica, St. Lucia and St. Vincent planted on mounds, while in Grenada 57 per cent of the farmers preferred to plant on the flat and 34 per cent on ridges.

Few of the farmers in any of the four islands practised minimum tillage (Table 7).

Planting material

The majority of farmers in Grenada (82 per cent) used lateral suckers as planting material; head setts (30 per cent) and corm bits (30 per cent) were used to a lesser extent. Dominica farmers used either

Table 7 Methods of land preparation used by tannia farmers in the Windward Islands

	Mound	Flat	Ridge	Minimum tillage
	% of farmers			
Dominica	76	11	10	3
Grenada	1	57	34	8
St. Lucia	83	10	4	3
St. Vincent	90	5	0	5

lateral suckers (20 per cent) or head setts (32 per cent) as planting material. In St. Vincent lateral suckers (25 per cent), head setts (38 per cent) and corm bits (33 per cent) were all used as planting material although there was some preference for lateral suckers (56 per cent) (Table 8).

Table 8 Types of planting material used in tannia production in the Windward Islands

	Lateral suckers	Head setts	Corm bits	Whole corms	Whole cormels
	% of farmers				
Dominica	20	32	8	9	11
Grenada	82	30	30	6	6
St. Lucia	56	48	30	13	35
St. Vincent	25	38	33	4	–

In all the islands, planting material was selected at harvest of the preceding crop. In Dominica and Grenada the majority of farmers replanted tannia in the same area immediately after harvest. In St. Vincent, immediate replanting of tannia was not practised, 75 per cent of the farmers allowed their fields to lie fallow after tannia production, while 25 per cent planted a different crop species.

Farmers in all four islands cleaned the planting material of soil, roots and rooted portions before planting. Chemicals were not used to treat planting material but a few farmers in Dominica and St. Lucia reported treating their planting material with ashes prior to planting.

Spacing and planting depth

Planting distances varied widely between farmers on the same island. A spacing of 30 - 60cm x 30 - 60cm was used by farmers in all the islands. Farmers in Dominica and Grenada also planted at a spacing of 90 - 120cm x 90 - 120cm, and in St. Lucia at 60 - 90cm. Planting distances varied depending on whether the tannia was planted in pure stand or as an intercrop. When tannia was grown in association with perennial crops, the perennials were dominant and the spacing of the tannia was increased as the trees matured.

Planting depth varied from 7 - 15cm in Dominica to 13 -30cm in Grenada

Fertilizer use

Over 90 per cent of the farmers in Grenada, St. Vincent and St. Lucia, and 75 per cent in Dominica used compound NPK fertilizer on the tannia crop. The formulations used were 16:8:24:2MgO and 16:8:16, prepared for use on bananas and arrowroot respectively. Other fertilizers such as Sulphate of Ammonia and Urea were occasionally used by the minority of farmers. Fertilizer was applied at rates of 60-120g per plant within 7 weeks of planting. A few farmers applied fertilizer twice. The fertilizer was applied either in a circle around the base of the plant or banded; it was not usually incorporated in the soil.

Weed control

Weed control was the most important cultural activity carried out by farmers in all the islands. Weeding was done one to four times in the life of the crop, with more than 50 per cent of farmers weeding twice, and 25 per cent weeding three times (Table 9). Weed control was carried out mainly on the 2-10 week old crop, but several farmers in St. Lucia first weeded after 6–7 months. A few farmers in St. Vincent reported using the herbicide paraquat, but the main method of weed control on all the islands was manual, using hand, hoe and cutlass.

Table 9 Frequency of weed control in tannia in the Windward Island production systems

	No. of weedings			
	1	2	3	4
	% of farmers			
Dominica	6	57	32	5
Grenada	4	71	25	0
St. Lucia	0	68	21	11
St. Vincent	0	48	36	16

Pest and disease problems

Farmers reported no serious pest of tannia, although aphids, white flies, slugs and snails posed an occasional problem. The only disease reported was tannia "leaf burning" which was serious problem in Dominica, St. Lucia and St. Vincent.

Harvest and storage

In all the islands, the tannia crop was harvested 8-12 months after planting (Table 10) depending on cultivar and market demand. Approximately 80 per cent of the farmers staggered the harvest according to market demand and household requirements. Harvesting was done manually, using forks and/or cutlasses. The plants were uprooted and the cormels separated from the corm and cleaned of adhering soil and roots. Occasionally the cormels were removed without uprooting the plant, which was left to produce another crop. Few of the farmers stored the cormels for any length of time, and no storage problems were reported.

Table 10 Period from planting to harvesting of tannia in the Windward Islands

	6–8 months	8–10 months	10–12 months
	% of farmers		
Dominica	12	48	25
Grenada	0	41	59
St. Lucia	0	39	78
St. Vincent	0	63	37

Discussion

The results show that the production systems for tannia are fundamentally similar in all four islands. The main inputs were labour, fertilizer and to a lesser extent herbicides. Since tannia was so often intercropped, it benefitted from inputs into the major agricultural enterprises such as banana, arrowroot, or tree crops.

One of the major constraints to tannia production identified was the tannia 'leaf burning' disease which was reported in Dominica, St. Lucia and St. Vincent, and has more recently been observed in Grenada. Tannia leaf burning now referred to as "tannia rapid yellowing disease" (TRYD) is caused by a severe root rot accompanied by a stunting of growth and a rapid succesive yellowing of the outer leaves (CARDI/EDF, 1985). This disease has had a major impact on tannia production in Dominica, St. Lucia and St. Vincent; Clarendon (1982) reported that 68 per cent of the Dominica crop was affected. The tannia crop of Martinique was also affected by TRYD. The identification of the causal organism and management of the disease has been the major focus of the CARDI/EDF Aroids/Arrowroot Project over the past three years. A workshop on this subject was conducted in Dominica in March 1984 (Adams, 1984).

Limited availability of planting material was another constraint identified by the survey. Although farmers recognized head setts and lateral suckers as better types of planting material, the need to obtain sufficient quantities led to the use of "inferior" planting material. This constraint also led to the use of diseased material which encouraged the spread of tannia rapid yellowing disease. Work done by CARDI/EDF: Aroids/Arrowroot Project (unpublished) has shown that corms, cormels and corm bits are satisfactory planting material, comparable in quality to head setts and lateral suckers, provided sprouting and growth is induced prior to planting. A technique for rapid production of disease-free planting material from corm and cormel bits was developed in Grenada (Adams et al, 1985). Using this technique an output of 10,000 every 20 weeks is achieved.

The third major constraint was weed control. The high rainfall experienced in these islands encouraged the rapid growth of weeds, and weeding was a difficult and time-consuming exercise. The use of herbicides, especially pre-emergent herbicides should greatly reduce the amount of time spent on weeding.

The CARDI/EDF Aroids/Arrowroot Project is currently conducting herbicide trials on aroids.

Frequency and levels of fertilizer application were similar in all four islands. The relatively low productivity of the crop at present, (8 t. ha^{-1}), compared to a potential of 30 t. ha^{-1}, suggests the need for research to determine optimum levels of fertilizer, frequency and timing of application.

More than five different tannia cultivars were reported by farmers in each of the four islands. On the spot observations indicated a number of similarities between cultivars given different names on the same island or on different islands. This discrepancy in cultivar names indicated the need for classification of the cultivars in order to identify the different genotypes which exist in the area and their characteristics. Of special significance is the identification of any source of resistance to tannia rapid yellowing disease. The CARDI/EDF: Aroids/Arrowroot Project has carried out National Elite Varietal Trials in Dominica, Grenada, St. Lucia and St. Vincent and an extensive germplasm collection is being maintained in Trinidad. High producing cultivars in each of the four islands have been identified, and a comprehensive list of tannia descriptors has been developed, leading to the identification of 12 tannia cultivars (Adams et al, 1985).

Conclusions

The survey was successful in providing information on the 'state of the art' of tannia production in the Eastern Caribbean. Production systems were very similar in all four islands. The major areas identified for further research work were:

Identification and management of tannia diseases

Weed control.

Evaluation of planting material.

Fertilizer studies.

Classification of tannia cultivars.

References

Adams H. (Ed.) (1984) Aroid improvement with particular reference to tannia disease. Proceedings of a workshop held in Dominica 6 - 7 June 1984.

Adams, H., Cooper, B., Browne, G., Benjamin, R., James, A. and Pattanjalidial (1985).
A phenotypic classification of the edible tannia cultivars (*Xanthosoma* spp. (L) Schott) of the Eastern Caribbean. CFCS – AHS, 21st Annual Meeting 8 - 13 September 1985, Trinidad.

Adams, H., Pattanjalidial, Brown, G., Cooper, B, and Clarke, A. (1985).
Aroid improvement in the Eastern Caribbean. VII Symposium ISTRC, 1 - 6 July 1985, Guadelope.

CARDI/EDF (1985) Annual Report for Aroids/Arrowroot Project Year III, (in press).

Clarendon, H.E. (1981) Report of post-harvest losses-Consultative Meeting – Vol. 2, Commonwealth Secretariat, London.

Ferguson, T.U. (1985). Root crop production in the Caribbean: An analysis of needs.
Caribbean Collaborative Agricultural Research Network Workshop on Tropical Root Crops. Guadeloupe, 8 - 10 July, 1985.

CARBON DIOXIDE ENRICHMENT ON GROWTH AND YIELD OF SWEET POTATOES *(IPOMOEA BATATAS,* cv GEORGIA JET)

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ABSTRACT

This study was conducted to obtain field data on the growth and yield of sweet potaotes in elevated levels of carbon dioxide (CO_2). Sweet potato plants were planted in open-top chambers as well as in open field plots. The plants were grown at ambient CO_2 with and without chambers, ambient +75, +150, and +300 ppm (90 days). Enriched CO_2 concentration increased the number of tubers and the percentage of dry matter of the tubers. The density, length and diameter of the tubers did not vary significantly in enriched CO_2 levels.

RESUMEN

Este estudio se llevó a cabo con el objeto de obtener información sobre los ensayos relacionados con el desarrollo y la producción del camote con niveles altos de dioxido de carbón (CO_2) Los camotes fueron plantados en camaras sin techos, como tambien, se los cultivó en parcelas de campo. Las plantas fueron cultivadas al ambiente CO_2, en camaras y fuera de ellas, ambiente +75, +150 y +300 ppm (noventa dias). Una concentración mas fuerte de CO_2 incremento el numero de tubérculos. La densidad, el largo y el diámetro de los tubérculos no vario significativamente en niveles altos de CO_2.

The global carbon dioxide (CO_2) concentration is gradually increasing due to fossil fuel consumption, rapid advancement in industrialization and deforestation. It has been estimated that atmospheric CO_2 concentration will be doubled by 2025 (Clark *et al.*, 1982). Extensive literature is now available to demonstrate that elevated CO_2 results in the increase of dry matter accumulation in both vegetation and reproductive components of plants (Wittwer, 1980, 1983; Kimball, 1983).

Although there are a number of reports on the influence of atmospheric CO_2 enrichment on photosynthesis and short-term growth, very few reports are available on crops which have been subjected to CO_2 enrichment during their entire growing season. Furthermore, little information is available on plant responses to CO_2 enrichment under field conditions (Kramer, 1981; Strain *et al.*, 1984). It is therefore, imperative to have a better understanding of the effects of CO_2 enrichment on crop plants.

Reports on the influence of elevated CO_2 levels on tuber crops like radish *(Raphanus sativus* L. 'Whitetip'; Knecht, 1975) and potato *(Solanum tuberosum,* 'Kennebec'; Collins, 1976; Goudriaan and deRuiter, 1983) did not consider the effects of long-term exposure to elevated CO_2. Therefore, more information is needed to understand the overall effects of CO_2 enrichment on growth, development, and yield potential of root crops.

Sweet potatoes *(Ipomoea batatas* L.) were selected as an experimental crop in the southern United States. In addition, sweet potatoes are one of the world's major food crops. Currently, little is known about the responses of sweet potatoes to elevated CO_2 (Strain *et al.*, 1984). Sweet potatoes have widespread growth ranges and, consequently, can be easily grown for experimental purposes. In the present study, CO_2 enrichment has been applied to sweet potatoes in order to investigate its effect on their growth, physiology, and yield under field conditions.

In the summer of 1984, under the sponsorship of DOE and Tuskegee University, experiments were conducted to study the physiological and biochemical effects of enriched CO_2 on sweet potatoes in open top chambers at the George Washington Carver Agricultural Experiment Station, Tuskegee, Alabama. The techniques for the generation of large scale test atmospheres in the field for the purpose of obtaining dose response relationships of crop plants were developed at the USDA Air Quality Laboratory at Raleigh. The main task of the 1984 study at Tuskegee University was to assemble equipment to generate test atmospheres of CO_2 in the field, using open top chambers as the basic exposure unit for studying the responses of sweet potatoes and cowpeas to enriched CO_2.

Plant responses to CO_2 in open top chambers have been demonstrated by several investigators in a variety of crops. This study focused on growth and development of sweet potatoes at levels of CO_2 ranging from the ambient level of 354 ppm to 659 ppm. The effects of CO_2 on leaf and stem weights, stem length, leaf area, and stomatal number and conductance were studied. Additional studies on sweet potatoes included the effects of CO_2 on the weight, chemical content and quality of tubers.

In addition to the field studies, a series of experiments by Tuskegee University scientists conducted at the Duke University Phytotron were completed in 1984. These experiments focused on the biochemical and physiological effects of elevated CO_2 on sweet potatoes grown in controlled environments.

Sweet potatoes grown in open top chambers, at ambient CO_2 concentrations had fewer leaves, less total runner length, and lower fresh and dry weights of shoots, leaves and tubers as compared to sweet potatoes grown in the open field without chambers. These results emphasize the need to quantify more carefully the environmental differences between open top chambers and the open field. These chamber effects need to be considered when drawing conclusions about the effects of elevated CO_2 on the growth and yield of plants grown in open top chambers.

While shoot growth in sweet potatoes increased with increasing CO_2, few of the effects were large enough to be significant. However, the percentages of nitrogen and protein nitrogen in sweet potato leaves decreased significantly at higher CO_2 concentrations. The total fresh weight of tubers increased significantly at the higher levels of CO_2, due primarily to the increase in the number of tubers. This suggests a shift in the partitioning of photoassimilates toward

tubers with increasing CO_2. There were no differences in the density of stomates or in stomatal conductances in sweet potato leaves. Analyses of tubers indicated that protein, total carotenoids and insoluble dietary fiber all decreased with increasing CO_2, while dry matter content increased with increasing CO_2. Taste panel tests indicated small but significant preferences in some test categories for potatoes grown at the highest CO_2 level.

In phytotron studies with pot-grown sweet potatoes, plants grown at 675 or 1000 ppm CO_2 showed increases in the length of the main stem, total branch length, the number of branches and leaf area as compared to those grown in 350 ppm CO_2. At each harvest interval the production of total dry matter increased in response to increases in the level of CO_2. Specific leaf weight also increased with increased CO_2 concentrations. At the final harvest, the dry weights of roots and tubers increased 1.8 and 2.6 times in plants grown at 675 and 1000 ppm CO_2, respectively, compared to those grown at 350 ppm. Carbon dioxide enrichment resulted in early tuber maturation in sweet potatoes.

References

Bhattacharya, N.C., Biswas, P.K., Bhattacharay, S., Sionit, N. and Strain, B.R. (1985) Growth and yield response of sweet potato *(Ipomoea batatas)* to atmospheric CO_2 enrichment. *Crop Sci.* (in press).

Clark, W.C., Cook, K.H., Moreland, G., Weinberg, A.M., Totty, R.M., Bell, P.R., Cooper, L.J., and Cooper, C.L. (1982) The carbon dioxide question: A perspective for 1982. *In:* W.C. Clark (ed.) *Carbon Dioxide Review,* Clarendon Press, Oxford. pp. 3 - 43.

Collins, W.B. (1976) Effect of carbon dioxide enrichment on growth of potato plant, *Hortscience.* **11** 467 - 469.

Kimball, B.A. (1983) Carbon dioxide and agricultural yield: an assemblage and analysis of 430 prior observations. *Agron. J.* **75** 779 - 788.

Knecht, G.N. (1975) Response of radish to high carbon dioxide, *Hortscience* **10** 271 - 275.

Kramer, P.J. (1981) Carbon dioxide concentation. photosynthesis and dry matter production. *Bioscience* **31** 29 - 33.

Strain, B.R., Sionit, N., and Cure, J.D. (1984) Direct effects of carbon dioxide on plants and communities: a bibliography. Dept. of Botany, Duke University, Durham, North Carolina, 70 pp.

Wittwer, S.H. (1980a) Carbon dioxide and climatic change: an agricultural perspective. *J. Soil Water Conserv.* **35** 116 - 120.

Wittwer, S.H. (1980b) Environmental and society consequence of a possible CO_2 induced climate change on agriculture. Paper presented at annual meeting of Am. Assoc. Adv. Sci., San Francisco, Jan. 5.

Wittwer, S.H. (1983) Rising atmospheric CO_2 and crop productivity. *Hort. Sci.* **18** 667 - 673.

A SYSTEMATIC APPROACH TO YOUNG CITRUS TREE CARE PROBLEMS IN FLORIDA

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ABSTRACT

Over 10 million young citrus trees have been planted each year for the past several years in Florida, largely as a result of disease and several serious freezes. These young trees require intensive management and labor inputs for survival, resulting in a plea from growers for assistance in dealing with the many problems associated with young tree care. Grower problems have been delineated by using an extension survey document. The information generated from this survey has then been used in determining research priorities. Areas currently under investigation include (among others) cold protection, weed and sprout control, irrigation, and fertilization. Technology transfer of the research is accomplished through local grower meetings and research demonstrations. The result of this program has been to successfully weld the research-extension components and provide sound production information to Florida citrus producers.

RESUMEN

Se ha sembrado mas de 10 millones de arboles jovenes de cítrico en los últimos años en la Florida, mayormente como resultado de enfermedad y varias heladas serias. Estos arboles jovenes requieren manejo y labor intensivo para sobrevivir, resultando en una petición de los cultivadores para asistencia en tratar con los muchos problemas asociados con el cuidado de arboles jovenes. Estos problemas han sido delineados por un documento de encuesta. Se ha usado la información generada por esta encuesta en determinar las prioridades de investigación. Las areas bajo investigación activa incluyen protección del frío, control de malezas y brotes, riego, abonamiento, y otras. La transferencia de la tecnología de investigación se logra a través de reuniones de cultivadores y demostraciones. El resultado de este programa ha sido unir exitosamente los componentes de investigación y extensión y proveer información práctica para productores de cítricos en Florida.

Young citrus tree planting in Florida is taking place at an unprecedented rate. Several freezes in recent years, problems with citrus blight and most recently, citrus canker, have resulted in widespread planting activity. Prior to the canker outbreak, 10 million young citrus trees were being planted per year according to the Florida Department of Agriculture, Budwood Registration Bureau.

Not only have many hundreds of acres of new groves been planted in the southern (warmer) portions of the state, but many groves are being replanted elsewhere in Florida. Even groves largely undamaged by cold have been losing a larger than normal number of trees due to other adversities.

Therefore, planting and care of young citrus trees has become a major portion of most Florida growers' production programs. Once relegated as a miscellaneous task, young tree care has become a very important, expensive and time-consuming job for most citrus producers. This increase in importance has caused growers to seek information on all aspects of young tree care.

Considerable knowledge exists in most areas of production technology for bearing citrus trees, but little was known about the most efficient procedures for growing nonbearing trees. Some work had been done on nutrition (2), weed control (5) and other aspects of young tree care, but there had not been an organized effort to programmatically deal with the various aspects of the problem.

Identifying Major Problems

Extension faculty in the Fruit Crops Department meet quarterly with Extension Agents working with citrus in Florida. These are meetings designed to provide opportunities for groups to work closely with each other on major goals. Agents received so many requests for information on young tree care in 1983 that it was decided to make this area a major program for the next several years.

A new section was written for the 1984 Extension Plan of Work on citrus young tree care and the program submitted to the Federal Extension service for consideration as a major program. These steps insured that the program would be properly evaluated on a regular basis to determine its efficacy.

The first step in developing such a major program is establishing benchmark data. A survey document was prepared which was used to determine the current status of young tree care in Florida, indicate research and extension needs and provide benchmark data against which the program could be judged to determine its success.

Space limitations will not permit full details of the survey document but in summary the form requests information about the following:

(a) What are the major problems in young tree care and how serious are they?
(b) What are the major causes of tree loss?
(c) What are the costs of young tree care?
(d) How widely used are some of the newer and more innovative young tree care practices?
(e) In what areas of young reee care would additional information be helpful?

Answers to these questions help establish research priorities and provide benchmark data which can later be used to determine the cost-effectiveness and impact of the extension/research program.

Research and Extension Program

Results from the survey of citrus growers were used to identify and prioritize research efforts. More information was needed on weed control, soil moisture conservation, use of slow-release fertilizers and cold protection. As a result, research work was initiated on the use of mulches and slow-release fertilizers (4), tree wraps (3) and microsprinklers plus wraps for cold protection (1). Results from this research have been presented at meetings of the Florida State Horticul-

tural Society and published in the Proceedings. Several magazine articles have been prepared to further enhance distribution of research results.

The Extension phase of the program involves providing detailed research information to Extension Agents so they can further disseminate the results by way of newsletters and through word of mouth. Once each year, usually in October and November, there is a concerted effort by all Extension Agents and specialists to saturate the industry with young tree care information. This is done through magazine articles, newsletters, radio and television programs, This intensive extension educational approach produces an impact far greater than by scattering the same resources over a longer period of time.

As the research generates information, demonstration plots are set up with growers in various locations in the state. Adoption of new practices by growers is often best accomplished by the classical Extension demonstration methods. Cooperators are selected by local Extension Agents to assist in demonstrating new technology. These people are usually recognized leaders within the industry, so their adoption of new practices almost ensures that others will follow their example. A field day or other type of grower meeting is scheduled about the time data is collected from the demonstration to further spread the information. Growers can then see for themselves and form opinions based upon observation and not have to depend on reading about other people's experience with the practice.

Evaluation

No program should be judged without sound evaluation. This is difficult to do in most Extension endeavors but not if one plans ahead. Evaluation of our program can be made be seeing how far growers have come since the earlier benchmark survey was made. A re-survey using the same or similar survey document will test the effectiveness of the extension program by determining level of acceptance by growers, checking if costs are reduced and testing if problems have been solved.

Accurate evaluations cannot be made unless good benchmark data were established before the program commenced. This pre-program evaluation will return many benefits to program coordinators when held accountable for results.

Summary and Conclusions

Extensive planting of millions of young citrus trees in Florida for the past several years has created problems for growers which are seen as opportunities for a comprehensive research/extension program. Pre-program surveys establish benchmark data for later program evaluation and provide direct grower input into determining critical research priorities.

Research results are disseminated through publications, grower meetings and other classical Extension methods. Field demonstrations and field days for growers are an important part of the adoption process. A subsequent evaluation is used to evaluate efficacy of the total program.

Literature Cited

1. Davies, F.S., L.K. Jackson, and L. W. Rippetoe. 1984. Low volume irrigation and tree wraps for cold protection of young Hamlin orange trees. Proc. Fla. State Hort. Soc. 97: 25–27.

2. Koo, R.C.J. (Ed.) 1984. Recommended fertilizers and nutritional sprays for citrus. Bul. 536C. IFAS, Univ. of Fla.

3. Jackson, L.K., D.W. Buchanan, and L.W. Rippetoe. 1983. Comparison of wraps and banks for citrus cold protection. Proc. Fla. State Hort. Soc. 96: 29–31.

4. Jackson, L.K. and F.S. Davies. 1984. Mulches and slow release fertilizers in a citrus young tree care program. Proc. Fla. State Hort. Soc. 97: 37–39.

5. Singh, M. and D.P.H. Tucker. 1984. Evaluation of herbicides for water-ring treatments in citrus. Proc. Fla. State Hort. Soc. 97: 51–53.

ADAPTATION OF TEMPERATE CROPS TO A TROPICAL ENVIRONMENT

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ABSTRACT

Introduced cultivars of apple, peach, fig, strawberry, grapes, and other temperate fruits have grown well under lowland tropical conditions. There is variation in adaptability between species and cultivar. Continuous warmth does not trigger the fruit's chilling requirement mechanism; instead, flowering and fruiting occur after drought induced dormancy. Polination characteristics are erratic compared to temperate conditions. Fruits tend to be undersized but of excellent quality.

RESUMEN

Selectas variedades de manzana, melocotón higo, fresa, uvas y otras frutas de clima templado introducidas en terrenos llanos en países tropicales han crecido bien. Hay diferencias en la adaptabilidad de algunas especies y variedades. El calor contínuo no provoca el mecanismo que requere el enfriamiento, sino que las plantas florecen y dan fruto después de un estado latente inducído por sequía. Las características de polinizactión son irregulares comparadas con las que ocurren en condiciones templadas. La frutas tienden a ser pequeñas pero de excelente calidad.

Flower induction is critical for the successful adaptation of any fruiting plant into a new environment. For tropical crops, flower induction is moisture dependent. Mangoes (3), citrus (8), Barbados cherries (Michelini, unpublished data) and other tropicals, flower and fruit when the proper amount of rain follows dry conditions. Temperate pears also fruit more heavily when water stressed (7). Moving tropical crops to the subtropics, where they receive a combination of dry and cold weather, can result in a heavy, concentrated bloom.

Temperate fruits have adapted to seasonal cold weather by the process of dormancy. Dormancy is the condition of the plant where it will not grow immediately, even though temperatures and moisture conditions are favorable (10). In temperate climates, dormancy begins with the onset of short days and cool weather. It is characterized by the slowing and eventual cessation of active vegetative growth. Prior to abscission, leaves continue to manufacture carbohydrates, storing them in the stems and roots. In many temperate-zone plants vegetative buds convert to flowering buds in a process called induction, which is then followed by vernalization, or cold induced promotion of flowering (10). Once dormant, the plant must complete its internal cycle before beginning normal "spring" growth. This cycle will be productive only after the satisfaction of the chilling requirement as measured by chilling units.

Chilling units are timing criteria set for temperate fruits. Each individual plant needs cold weather to satisfy its physiological dormancy (11). Once satisfied, the plant responds to favorable environmental conditions with growth.

The chilling requirement is essentially a protective mechanism which evolved to keep the plant dormant pending resumption of warm weather. The biochemical reaction begins when temperatures drop to about 15 degrees C, and proceeds most rapidly at temperatures between 5 and 9 degrees C (14). Interestingly, plants from extremely cold climates have lower chilling requirements than more temperate climates, due to the shortage of 0 to 10 degree C temperatures (13).

At about 15 degrees C, certain tropical and subtropical fruits exhibit another temperature sensitive reaction in the flowering process. Loquat, lychee, longan, and cherimoya (1) need cool temperatures to set bloom buds and flower. However, the Amboina lychee does set fruit at sea level in Puerto Rico (Dr. Martin, personal communication), and cherimoya x sugar apple hybrids (atemoyas) set well at sea level.

This highlights the variability of chilling requirements. Plant breeders have selectively reduced the chilling needs of many fruits, giving plantsmen increased opportunities to grow fruit under no-chill conditions.

The literature mentions very little of temperate crops responses in a tropical environment.

Plant Materials

Strawberries have no specialized winter chilling needs (2). Day length is more important, with both short day and day neutral varieties available (13). Cool weather and short days promote runner growth, and runners produce better fruit than mother plants more than one season old. While cool weather is not necessary for flowering, it is beneficial for higher production. Strawberries grown under highland tropical conditions yield up to 22,000 pounds per acre.

Florida Belle, a short day strawberry cultivar, was introduced to Barbados and planted at 250 meters elevation. Flowering was nearly continuous from mid-January through June. Production was moderate, with half pound per plant average, under inconsistent cultural practices. Runners started in early March and each set from 4 to 6 fruits shortly after establishing themselves on their own roots.

Plants grown under sprinkler irrigation produced 15 gr. fruits of excellent quality. With the retail value approaching US $14.00 per kg. in Barbados, it appears that supplying the admittedly small market could be quite profitable. The main disease is *Mycosphaerela* sp., which is controllable at higher elevations but eventually killed 25 transplants at sea level.

Strawberries typically decline after the first year or two of production, due to excessively heavy crown formation and build-up of nematodes. Solutions are to periodically import new stock plants, move the production area, mulch heavily to discourage nematodes, or apply nematicides regularly.

Grapes have a successful history of culture in the tropics. Their flower buds are initiated in the mature wood of the current season's growth. Flowers appear when new shoots arise from axillary buds, usually

after pruning. Old, unnamed vines exist on Barbados, some fruiting on unpruned wood as the vine extends new growth. Grapes will bear twice per year. Crops are managed by pruning hardened wood, then adding fertilizer and water. Bunches may be over 30 cm. in length and weigh up to 2 kg. Berry development is small to normal. Uneven ripening is a major complaint from growers. Ethephon will be sprayed on vines this year, to assist in uniform ripening.

While good table quality fruits are grown in Barbados, the vines have not produced as well as the wine varieties. With retail prices of US $8.00 per pound, any successful producer of table grapes will stimulate increased plantings.

Successful cultivars include Cardinal, a red grape grown in Barbados for over 100 years. Pink Chardonnay, Pinot Noir, and the Puerto Rican cultivar Fortuna Blanca have all grown well. Thompson seedless and Ribier have been prone to diseases and lacked vigor.

The "Anna", a 150 hour apple bred in Israel, and the "Dorsett Golden" a 150 hour apple found in the Bahamas, were introduced into Barbados. Both are reported to be self-unfertile under Florida's spring conditions (Dr. Sherman, personal communication). Both exhibited erratic midsummer bloom and subsequent fruit set during rains following early summer drought.

Introduced apple trees have flowered in all parishes of Barbados. Flowering is most often associated with water induced growth following drought, usually in May or June. Fruit set is moderate to excellent, with all 15 trees in one 2 year planting setting from 10 to 35 fruit each. Leaf stripping increases flower bud formation and improves uniform bud break.

Fruits are concentrated on terminal growth and often occur in clusters. Fruits are rather small at sea level, but have been nearly normal sized (2 to 2½ ins.) in diameter when grown at 600 ft. + elevation. Parthenocarpy is common on single trees, normal color is achieved, and the flavour is excellent.

Full sun and wind protection are necessary. Occasional pests such as scale, mite and aphid infestation have been observed and controlled. Powdery mildew, fireblight, *Sclerotia rolfsii,* and *Cercospora* sp. leafspots are encountered.

The loquat *(Eriobotria japonica)* originated in south east China. It is now a very successful commercial crop in Israel and is grown around the world. There are numerous cultivars from Japan, California, India and Israel which ripen from April to June.

Isolated seedling trees found in Barbados were observed fruiting. One tree at about 150 meters elevation bore fruit every year, according to the owners. The fruits were small but tasty, and the seeds germinated normally.

"Champagne" and "Golden Nugget" cultivars were introduced along with about 300 seeds. These trees flowered and fruited within 2 years of grafting. After moving Champagne by itself to sea level, it flowers year round and only occasionally sets small, seedless fruit. Knight reported that Champagne is self-infertile (4).

Fruit set on all trees tends to take place in January or February, which coincides with Barbados' cool season. It is likely that individuals exist that will set fruit at slightly higher temperatures, allowing for production at lower altitudes than is presently possible.

Thinning has not been necessary, as is practiced in loquat producing areas. Barbados has no *Anastrepha* sp. fruitflies, an important production consideration.

Upper elevation plantings show promise to supply year round fruit for both local and markets created and maintained by other producers. Selection of locally adapted varieties is advisable.

Most blueberries need their full chilling requirement for optimum fruit set (5), but the chilling requirement varies among cultivars (6). Aliceblue and Beckyblue, two recently released rabbiteye/northern high bush hybrid blueberries, were grown in containers. Blueberries require very acid soil (pH 4.5), which is scarce in Barbados. Normal appearing flowering and ripening occurred one year after introduction. The bushes eventually declined after becoming chlorotic and losing all vigor.

Another cultivar, Sharpblue, has been found to be a good producer in Homestead, Florida, where they grow as evergreens. It would be appropriate to run field tests on some acid volcanic soils before coming to any conclusions regarding the adaptability of blueberries to the tropics.

Peaches vary considerably in their chilling requirements and in their genotype response when grown in a variety of locations and climates (11). This variability suggests that tropical peaches should be achievable.

Early introductions into Barbados have flowered and fruited, though none as well as hoped. The cultivar which was expected to flower the best, since it sets bloom very early in the Florida growing season (warm temperatures, not strongly short day sensitive) has grown well, flowered, but not fruited. As this cultivar (Flordagold) requires 350 hours of chilling, perhaps a longer dry spell will increase the number of blooms.

Okinawa, a 50 hour peach, has had little difficulty in growing or flowering. As their age increases, and given a long dry spell, it is expected that fruit production will increase. More selection will have to be practiced before an overall acceptable variety is found.

Results and Discussion

Markets do exist for the above mentioned fruits. The change in food habits, the increasing tourist trade, and the increased pressure on agricultural self-sufficiency will all stimulate interest in temperate crops. For the farmer, the high prices people are willing to pay for "imported" fruits are a definite incentive towards production. Strawberries, loquats, and grapes show the most potential for economic gain.

Strawberries will grow and fruit well under good horticultural conditions. The fruit has a high demand and high value. Florida Belle is an excellent (though small compared to the California cultivars) fruit, adapted to warmer conditions than more northern cultivars, and readily available. Small-scale plantings have been successful, but farmers are reluctant to provide all of the cultural requirements necessary for top production. These include thorough soil preparation, fumigation or nematode treatments if the soil is "old", irrigation, mulch, and training for their laborers.

Loquats should prove excellent fruits when grown above 500 meters. New, high yielding Israeli cultivars should be imported. A one to two acre trial planting at the appropriate elevation should be started. This crop will soon be grown in Martinique.

Grapes are popular, adaptable, and have had some experience in the tropics. Their production constraints are minimal. Each of the islands should begin planting some of the local vines and import new vines to establish the basis for future expansion.

Apples are a novelty, but are surprisingly easy to grow. The breeding is rather complex, so the future for them is limited by funding.

Peaches and blueberries have proven to be the most difficult to adapt to the tropical conditions. It is expected that peaches will eventually be manipulated to fruit heavily. Blueberries are marginal at best, as their chilling mechanism appears rigid.

Flowering is a hormonally controlled response of plant tissues to external stimuli. There are complex induction and feedback mechanisms, often involving minute quantities of bio-active gibberelins, auxins, abscissic acid, and the yet undetermined florigen (9). The diversity of plants and their sometimes contradictory reactions further complicates the physiologists' work.

While refraining from bio-chemical rationalization and verification, it is important to try to understand the effect of inputs on the flowering system of fruiting plants.

Cold or drought stress are both effective in slowing vegetative growth and putting the plant in a dormant or semi-dormant state. Cold weather directly affects the scion by slowing the growth process. Drought indirectly affects the scion by slowing root growth. Drought effects will be more difficult to measure accurately.

Drought stress occurs above a presently undetermined soil moisture tension value measurable with soil tensiometers. Added water may tend to reverse the effects of drought on flowr bud formation much the same way that warmth affects chilling requirements. With current low-chill apple cultivars, low soil moisture conditions for periods of about six to eight weeks appear to be sufficient to set bloom buds. When no chilling occurs, yet trees grow, flower, and fruit within normal limits, it can be assumed that the plant has effectively substituted for chilling.

Through the process of dormancy, whether slight or pronounced, the internal hormonal reactions shift towards flowering response. The longer the reaction continues, the more dramatic its results. Flowering response is characterized by short or complete lack of internodal growth, the accumulation of carbohydrates in stem tissues, the near cessation of root growth, and the initiation of differentiated flowering tissues, often manifested by enlargement of flowering buds.

The application of paclobutrazol, a powerful GA synthesis inhibitor, has resulted in less vegetative growth, better flowering and higher yields (7). It appears to be effective in shifting the growth/flower reaction towards flowering.

The dormant plant is now ready for the environmental stimulation (warmth or water) necessary for the flowers to complete their development and open.

This reaction is effected by auxin levels. Trees with heavy fruit set are not likely to flower until the fruit is removed. Leaves, especially young growing terminals, produce auxins, which when translocated through the phloem tissue inhibit axillary bud sprouts. Likewise, heavy fruit set inhibits vegetative growth, and especially axillary buds. When the growing terminal is cut, or fruit removed, axillary buds sprout. On some heavy flowering tropicals, these axillary buds often contain flowers.

It may be that high auxin levels interfere with the GA/flowering hormone equilibrium process and inhibit both reactions. Low auxin levels may allow the reaction to proceed, with a bias towards the flowering reaction.

Chilling may be an evolved practice for cold climate plants. It may be a specialized form of the hormonal flowering cycle common to all plants, that, while critical in its "native" environment, becomes superfluous in a new environment.

Considering an admittedly small number of plants, those with the greatest heterozygosity (apples, grapes, strawberries) appear most adaptable. It is hoped that by further simultaneous study of both tropical and temperate fruits, some leads into the physiology of flowering will surface.

Literature Cited

1. Bourke, D. 1976. Annona sp., 223–224. The propagation of tropical fruit trees, R.J. James. (ed.). Commonwealth Agr. Bur.

2. Braun, J.W., W.J. Kender 1985. Correlative bud inhibition and growth habit of the strawberry as influenced by application of gibberellic acid, cytokinin, and chilling during short daylength. J.Amer. Soc. Hort. Sci. 110 (1): 28–34.

3. Embleton, T.W., W.W. Jones 1966. Avocado and mango, pp. 55–56 N.F. Childers, ed. Fruit Nutrition. Horticultural Publications, New Brunswick, N.J.

4. Knight, R. 1985. Newsletter, Rare Fruits Coun. Int., Vol. 19 (6), June: pp. 53–55.

5. Lyrene, P.M. and T.E. Crocker 1983. Poor fruit set on rabbiteye blueberries after mild winter: possible causes and remedies. Proc. Fla. State Hort. Soc. 96: 195–198.

6. Lyrene, P.M. and W.B. Sherman 1984. Breeding early ripening blueberries for Florida. Proc. Fla. State Hort. Soc. 97: 322–325.

7. Mitchell, P.D., P.H. Jerie, and D.J. Chalmers 1984. The effects of regulated water deficits on pear tree growth, flowering, fruit growth, and yield. J. Amer. Soc. Hort. Sci., 109 (5): 604–606.

8. Reuther, W. 1980. Climatic effects and quality of citrus in the tropics. Proc. Amer. Soc. Hort. Sci., Trop. Reg. vol. 24: 15–28.

9. Salisbury, F., and C. Ross 1968. Plant hormones and regulators, pp. 444–480. In Plant Physiology, Wadsworth Publ. Co., Belmont, Calif.

10. Salisbury, F., and C. Ross 1968. Responses to low temperatures and related phenomena pp. 553–582. In Plant Physiology, Wadsworth Publi. Co., Belmont, Calif.

11. Sherman, W.B., J. Rodriguez and E.P. Miller 1984. Progress in low-chill peaches and nectarines from Florida. Proc. Fla. State Hort. Soc. 97: 320–322.

12. Stang, E.J. and G.G. Weis 1984. Influence of paclobutrazol plant growth regulator on strawberry plant growth, fruiting and runner suppression. Hort. Sci. 19 (5): 643–645.

13. Stushnoff, C. and H. Quammie. 1983. Adaptation of specific climatic and soil environments, pp 267-273. In J. Moore and J. Janick (eds). Methods in Fruit Breeding, Purdue Univ. Press, West Lafayette, Ind.

14. Young, E. and D.J. Werner 1985. Chill unit and growing degree hour requirements for vegetative bud break in six apple rootstocks. J. Am. Soc. Hort. Sci. 110 (3): 441-413.

MECHANIZED CASSAVA PRODUCTION IN BARBADOS

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ABSTRACT

Barbados has well developed pig and poultry industries but the main feed ingredients are imported from extra-regional sources. The use of chipped cassava as a substitute for some of the imported corn used by feed manufacturers is being investigated by CARDI. Cassava has been grown locally for many years mainly for human consumption but methods have not been scientific and yields have been low. New varieties, mechanisation of planting and harvesting operations and improved agronomic practices are being introduced in an effort to increase efficiency and to produce the crop at a competitive price. In addition the drought tolerance of cassava makes it a useful altenative crop for the dry marginal areas of the island.

RESUMEN

Las industrias porcina y, avícola de Barbados están bien desarrolladas pero los ingredientes más importantes de la la alimentación son importados de fuentes extra-regionales. El uso de pedacitos de yuca como sustituto de una parte del maíz importado por los fabricantes del pienso, está siendo investigodo por CARDI. La yuca ha sido cultivada localmente por muchos años, principalmente para el consumo humano, pero los métodos no han sido científicos y el rendimiento ha sido bajo. En un esfuerzo por aumentar la eficiencia y producir el cultivo a un precio competitivo, se están introduciendo: newvas variedades, mecanización de la siembra y recolección, y mejores prácticas agronómicas. Además, la tolerancia a la sequía de la yuca la convierte en una alternativa útil en las áreas secas marginales de la isla.

Keywords: Cassava; Mechanised production; Animal feed; Barbados

This paper will discuss the progress made in a Cassava for Livestock Feed Project currently being carried out by CARDI. The project is part of a larger Farming Systems Research and Development (FSR/D) Project funded by USAID. An earlier cassava project set up by the Barbados Ministry of Agriculture during the 1970's sought to reduce imports of wheat by producing a composite flour containing 10 per cent cassava flour. The present project is building on the research results of that project and has established pilot commercial plantings on sugar estates to test the feasibility of producing cassava as an ingredient for livestock feed.

Background

Barbados has a reasonably well-developed livestock sector, particularly in the areas of dairying, poultry and pork production. In fact, self sufficiency has been attained in whole chicken, table eggs, and fresh pork with importation of only specific cuts of pork for the growing processing industry. The island's demand for fresh milk is fully supplied by its 31 dairy farmers.

In spite of this, virtually none of the ingredients used in the manufacture of livestock feeds is produced locally. In fact, not only in Barbados, but in all the CARICOM States, the main ingredients of animal feeds are imported from extra-regional sources. During 1984, Barbados imported 25,000 tonnes of corn for use in animal feed manufacture.

Substitution of some of these corn imports by locally grown cassava would save considerable foreign exchange. Production of calories $ha^{-1}.day^{-1}$ is higher for cassava than for any other staple food crop (Toro and Atlee, 1980). Furthermore, because of its drought tolerance, cassava could contribute to the diversification of Barbados' agriculture by providing a useful alternative to sugar-cane, particularly in the drier, marginal areas of the island. In addition, under local conditions, pests and diseases are not normally major problems on cassava if the crop is well managed, and therefore specialised high clearance crop protection equipment is not likely to be necessary as would be the case with corn.

Of course, cassava is not a new crop to Barbados. Its importance and production increased during World War II when Government introduced compulsory measures for increasing local food production. The Vegetable Production (Defence) Control Order (1942) made it mandatory for all sugar estates to plant at least 35 per cent of all arable land in food crops. Cassava was one of the crops widely grown to comply with this Order. Government then erected a processing plant in 1943 to produce flour for human consumption, and meal for livestock, from cassava and sweet potatoes. The capacity of the plant was approximately 12 tonnes of flour per day.

After the War, when shipping facilities improved, and the island returned to many of its former sources of food, the plant was closed. Since then, acreages of cassava have been small, widely scattered and often interplanted with other crops. Cassava has been generally neglected, operations have been manual, inputs negligible and yields low.

Cassava production for animal feed

If cassava production for animal feed is to be feasible, the current production system has to be vastly improved. The price of dried cassava chips delivered to the feed mill will have to be competitive with the price of imported corn, bearing in mind that cassava has 80 per cent of the nutritional value of corn.

If this is to be achieved, and the farmer is to make a reasonable profit, yields must be high and production methods must be efficient to keep the cost of production to a minimum. The FSR/D Project is attempting to achieve these objectives by introducing a number of improved practices based on the recom-

mendations of authorities, such as CIAT, and by establishing the crop on a pilot commercial scale on estates to facilitate the study of its feasibility under commercial conditions.

Toro and Atlee (1980) state, that although experimental yields greater than 70 t ha^{-1} have been obtained, the average yield of cassava roots worldwide is only 9.4 t. ha^{1} . Cock (1985) has suggested that the lack of suitable disease and pest resistant varieties, poor quality planting material and sub-optimal agronomic practices are important reasons for the low yields in farmers' fields. The results of 5 years of regional trials at eight locations in Colombia conducted by CIAT, have shown threefold increases in the yields of local varieties by the use of selected and treated planting material, adequate soil preparation, optimum planting density and timely weed control (CIAT, 1979). Yields can be increased even further by the introduction of new disease and pest-free cultivars.

In this paper attention will be restricted to:

- establishment of pilot commercial acreages
- soil preparation
- mechanised harvesting
- chipping and drying

Establishment of pilot commercial acreages

Two out of a targeted 2.4 ha of cassava were established in July and August 1985, in the low rainfall areas of St. Lucy, St. Philip and Christ Church. These plantings will be used to test the improved mechanised production system (see below) and to record costs and returns for the crop with improved practices.

The system of cultivation includes the following:

- variety and spacing
- planting materials
- fertilizer application
- weed control

If results are encouraging, recommendations will be passed on to interested growers.

Towards a mechanized system.

Soil preparation

Mechanised planting and harvesting require specialised cultivation. Fields are disc harrowed, ploughed and furrowed. Ridges must be straight so that the planter does not run off course. If mechanised harvesting is to be carried out without damage to tubers accurate planting is important.

After fertilizer is applied with a Vicon Broadcast Fertilizer Spreader with a Carib Agro Industries Banding Attachment, a moulding operation is done to produce steep sided ridges of a uniform height of about 30cm and width of 168cm.

Mechanised planting

At present, a locally built planter originally designed by Chandler (1973) to plant yams is being tested. It consists of a subsoil tine, moulding discs, planting boxes, an operator's seat and a large tube through which the material is dropped, all attached to a double tool bar. Carib Agro Industries Ltd., a subsidiary of Barbados Sugar Industry Limited modified the implement to plant cassava stakes. The modification involved the addition of two metal wings and a cross bar at the end of the tube to guide the stakes into a horizontal position.

The 168cm ridge coincides with the normal tractor wheel spacing used by most sugar estates. With an 83cm ridge, it is felt that weathering would be a problem, and ridges would be almost flat by harvest time. Chandler (1973) while experimenting with the mechanisation of yams, noted that this would mean that the harvesting implement would have to travel at a depth below the general level of the ridge and adjacent furrow, the result being that too large a volume of soil would have to be loosened and possibly inverted, and exposure of tubers would most likely be poor. Further, there would be the increased risk of meeting large boulders at that depth which could severely damage harvesting implements. Steep sided ridges facilitate correct positioning of stakes in the ridge.

An intra-row spacing of 60cm is used to achieve the CIAT-recommended plant population of 10,000 plants ha^{-1}. Planting depth is approximately 10cm. The planter currently being used has no mechanism for accurately spacing plants. This is regulated by the speed of the tractor and the speed at which the operator places the stakes in the tube. However, with a little practice, operators have been able to achieve quite accurate spacings. A Kubota 7500 tractor in low range and third gear at 1400 rpm is used at one estate, and works satisfactorily. Planting rate is 1.2 to 1.6 ha day^{-1}, with one tractor driver and one planter operator.

The planter places stakes in a horizontal position. The literature on planting position records conflicting views. Toro and Atlee (1980) reported that Fernando and Jayesundera found that vertical planting gave superior yields while Brandao found that in heavy soils, vertically planted stakes bore roots nearly 5cm deeper, and yielded 30 per cent more than those planted horizontally, but the horizontally planted crop was easier to harvest. Chan is quoted as finding no differences in yield from horizontal, vertical or inclined planting of 15cm stakes. It would appear that, in general, horizontal planting 5–10cm deep can be recommended for dry climates and when mechanical planting is used. The system also facilitates mechanised harvesting since roots are nearer to the surface.

Carib Agro Industries plan to make a number of improvements to the planter as long as cassava production appears feasible. These will include a more accurate spacing mechanism and a depth adjustment. Normanha as quoted by Toro and Atlee (1980) states that the highest degree of cassava crop mechanisation in Brazil has been attained by using a two row planter, made in Brazil, which simultaneously accomplished furrowing, fertilising, horizontal planting, covering of stakes and compaction of the soil after planting.

Mechanized harvesting

Preliminary mechanised harvesting trials have been done, using a locally built yam digger. The design of the machine is based on a method pioneered by a UK-firm and developed locally by Carib Agro Industries along with Barbadian farmers.

It consists of a U-shaped digging share made from a 1.6cm plate edged with a 1.6cm meridian steel

cutting tip. The tractor PTO drives a gearbox linked by a crank to a set of separating fingers which gently bounce the roots out of the ridge. The digger mounts on a range of tool bars.

A test was carried out on two local varieties in a farmer's field which had not been prepared for mechanical operations and where the ridges were reasonably flat. Cassava stems were first slashed with a cutlass to a height of 10–15cm before the machine passed over them. Labour required for this operation was in the vicinity of 4.4 man hours ha^{-1}.

A Ford 7600 tractor driven in 2nd gear, low range, at approximately 1200 rpm did a satisfactory job. However, it is also possible to use a tractor of 65–75 hp. with the digger.

Tubers up to 51cm in length were harvested with minimal damage to the tips of the tubers. Harvesting rate was 1.2-1.6 ha day^{-1}. By comparison, one man harvested approximately 0.25 ha day^{-1} manually under moist soil conditions when the plant was held by the stem and pulled out of the soil. Under dry soil conditions, a fork would probably have to be used. This would not only further reduce the rate of harvest but possibly do more damage to tubers.

A second harvester – from Agri Projects International Ltd. – was tested on a very small area. Again the cultivation had not been done to suit mechanical operations. The machine is a single conveyor lifter which places the separated roots on top of the dug row behind the machine. The working depth is down to 40cm below soil level. This machine will have to be tested further before a full evaluation could be made.

Chipping of cassava tubers

Cassava tubers are extremely perishable, deteriorating with 24 hours of harvesting. The crop must therefore be chipped and dried promptly after harvest. Chipping and drying also reduce HCN content to a safe level in those varieties with a high initial HCN content.

A chipper built by CARDI – Jamaica is at present being tested. The blade is a Malaysian type with some modification. The machine produces a "French-fry" type of chip in most cases, but requires some adjustments and modifications to reduce the amount of "fines" as well as the number of large unchipped pieces. Preliminary tests indicate that the chipping rate is in the vicinity of 680-1000 kg hr^{-1}.

Drying of chips

Chips must be dried from over 60 per cent to 14 per cent moisture if they are to be safely stored. At present fresh chips are spread at a density of about 10 kg m^{-2} in a high roofed building with a smooth concrete floor. In the absence of direct sun, turning of the chips with a rake every hour is very important to facilitate uniform drying, which is completed in about 5 days.

This method is only a temporary measure since a dryer which will utilise flue gases from sugar factories is currently being manufactured and is expected to be in operation during the next sugar-cane harvest season.

Conclusion

If this pilot project demonstrates that cassava production for animal feed is a profitable commercial enterprise, it is hoped that growers will take advantage of the opportunity to diversify their agriculture as well as to contribute to foreign exchange savings and to the further development of the livestock sector.

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References

CIAT (1979) Annual Report, Cali, Colombia.

Chandler, I.D. (1973) Mechanisation of yam production in Barbados with special reference to planting. Handout prepared for Field Day at *11th Ann. Mtg. Caribb. Food Crops Soc.*, Barbados.

Cock, J.H. (1985) *Cassava - New potential for a neglected crop* Westview Press Inc., Colorado, U.S.A. 191 pp.

The Vegetable Production (Defence) Control Order (1942) Barbados Department of Science and Agriculture. Annual Reports for years 1940 - 41, 1942 - 43, 1945 - 1946.

Toro, J.C. and Atlee, C.B. (1980) Agronomic practices for cassava production – A literature review. *In* E.J. Weber M.J.C. Toro and M. Graham (Eds.) *Cassava cultural practices* Proceedings of a Workshop in Bahia, Brazil, 19–21 March 1980, IDRC 15 le 13–28.

A TWO-MACHINE SYSTEM FOR MECHANICAL PREPARATION AND PLANTING OF CASSAVA STEM CUTTINGS

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ABSTRACT

A P.T.O. driven machine capable of rapidly cutting cassava stems into uniform planting sticks of any desired length, and a two-row machine capable of planting these sticks on ridges or flat land at desired inter-and intra-row spacings, were designed, fabricated and evaluated. The stem cutting machine prepared planting sticks at about 3 times the rate normally achieved with manual cutting, and produced a higher quality of cut and a higher degree of uniformity of stick length. The two-row planter gave near perfect inter-row spacing and variations in intra-row spacing and planting depth were comparable to those achieved with manual planting. Planting rates of 0.6 ha hr^{-1} were achieved in a commercial 20 ha trial.

RESUMEN

Se diseñaron, fabricaron y evaluaron dos máquinas de transmisión P.T.O. una, capaz de cortar rápidamente tallos de yuca en trozos uniformes (iguales) de cualquier tamano deseado; y otra de dos surcos, capaz de sembrar estos trozos en serranías o llanos, en espacios deseados entre y dentro de los surcos. La máquina cortadora de tallos preparó trozos para plantar a una velocidad tres veces mayor que la del corte manual y produjo cortes de mayor calidad y mayor grado de uniformidad en el tamaño de los trozos. La máguina sembradora de dos surcos produjo espacios entre surcos casi perfectos; y tanto las variaciones en los espacios dentro de los surcos como la profundidad de los sembradíos fueron comparables a las que se obtuvieron sembrando manualmente. Se logró una tasa de 0.6 hectáres por hora en una prueba comercial de 20 hectáreas.

Traditionally, cassava planting sticks are cut manually from whole stems using a machete or other type of knife. The stem is held in one hand and cut manually into lengths approximating the desired stick length (Lozano *et al.*, 1977; Lorenzi, 1980). The cutting activity is usually followed by manual collection and chemical treatment of the cut sticks. The manual preparation of sticks is inherently slow and leads to significant variations in stick length. Work rates for manual cutting and collection of sticks at the University of the West Indies (UWI) vary from 250 sticks per man-hour for measured sticks to 300 per man-hour for sticks whose lengths are visually estimated.

Manual planting is rather time-consuming and labour intensive. An average of 12 man-days is required in Trinidad to plant a hectar of cassava.

Given the scarcity and high cost of agricultural labour in the Region, large-scale production of cassava would necessitate mechanization of stake preparation and planting activities.

This paper describes the design and evaluation of a two-machine system for high-volume preparation (cutting, collection and chemical treatment) and planting of cassava sticks.

Design requirements of the machines

Stem cutting machine

The design requirements considered for the stem cutting machine were as follows:

(1) Capability to cut stems into sticks of any length between 150 and 300 mm
(2) A clean, vertical transverse cut of the stem
(3) Ability to cut stems rapidly into planting sticks
(4) High uniformity of stick length
(5) Provision for adequate sterilization of cut sticks
(6) Provision for collection of the cut sticks
(7) Capability of being driven from the P.T.O. shaft of a standard tractor so as to eliminate the need for an auxiliary power source.
(8) Ease of transportation from one location to another.

The machine was essentially an integrally mounted table saw consisting of a welded steel frame and fitted with legs so that it stood rigidly on the ground during operation. Two shafts were fitted to the frame: an input shaft, which could be coupled directly to the PTO shaft of a standard tractor, and an output shaft on which the cutting element (a large-diameter circular saw blade) was mounted. Power was transmitted from the input to the output shaft by means of a triple V-belt and sheave drive designed to ASAE Standard S 211.3 (ASAE, 1984). A sheave diameter ratio was selected so as to achieve an output shaft speed of approximately 2,000 revolutions per minute (rpm).

In operation, a bundle of cassava stems is fed from the rear of the machine until contact is made with a pre-set stick length control plate, and then brought into contact with the rotating blade. Immediately after being cut, the sticks fall directly into a removable tank (mounted below the blade) in which they are simultaneously collected and chemically treated.

Cassava Planter

The design requirements for the machine were as follows:-

(1) Opening of a planting furrow to a pre-determined depth
(2) Placement of planting sticks (one at a time) horizontally at the bottom of the furrow
(3) Planting of sticks at desired uniform inter-row and within-row spacing
(4) Provision for selecting different inter- and intra-row spacings to achieve various plant population densities
(5) Complete coverage of the planted sticks with soil
(6) Planting of two rows of sticks simultaneously, but with a provision for upgrading the machine to a 3-row planter
(7) Ease-of transport from one field to another
(8) Provision of an acceptable level of comfort for planter operators
(9) Simplicity of construction and operation
(10) Relatively low cost

The planter was essentially a two-row, semi-automatic, integrally mounted machine fed manually with pre-cut sticks prepared by the cassava stem-cutting machine described above. It consisted of a main tool carrier on which the following functional components were mounted:-

(1) A hopper for carrying the planting sticks
(2) A delivery chute and furrow opener assembly
(3) A stick covering device
(4) An intra-row spacing device
(5) Operators' seat and foot rest assemblies.

The intra-row spacing was controlled by a spacing wheel fitted with a standard bicycle bell as a signalling device, and having a circumference equal to the desired within-row spacing. With the completion of one complete revolution of the wheel, the bell was activated and two operators riding on the planter each responded to the signal by releasing a cassava stick into the delivery chute.

Performance evaluation of the machines

Stem cutting machine

Machine performance was determined for two frequently used stick lengths of 200 and 250mm. During the test, at least 200 sticks were cut with the machine at each stick length setting. The time required to cut each batch of sticks was recorded and a sample of randomly selected sticks was retained from each batch for statistical analysis. The performance criteria on which the evaluation was based were as follows:-

- uniformity of stick length
- quality of the cut
- rate of stick preparation
- efficiency of collection of cut sticks

Uniformity of stick length was evaluated by randomly sampling the cut sticks and determining the mean stick length, the standard deviation of stick length, the coefficient of variation and the uniformity coefficient.

The quality of cut of a sample of sticks prepared by the stem cutting machine was visually assessed, the standard for comparison being a perfectly even and vertical face obtained by cutting a straight stem very carefully.

The rate of stick preparation (number of sticks prepared per hour) was calculated from the time taken to cut and collect 200 sticks at each stick length setting, while the efficiency of stick collection was evaluated by observing the percentage of cut sticks in a given run which fell directly into the collection box.

Cassava planter

The two-row cassava planter was evaluated on River Estate loam soil at the UWI Field Station on both ridged and flat land. In both cases, an intra-row spacing of 90cm and an inter-row spacing of 1m were used and during the test the following activity times were recorded:- (1) the time required for the planter to cover a distance of 100m, (2) the turning time at the headland, and (3) the time required to fill the hopper with planting sticks.

The planter was evaluated based on the following criteria:-

- uniformity of intra-row spacing
- uniformity of planting depth
- planting rate
- degree of coverage of the planted sticks.

The uniformities of intra-row spacing and planting depth were evaluated in a manner similar to that described for uniformity of stick length.

Planting rate was determined by calculating the effective field capacity of the planter using equation (1) (after Hune, 1977 and Kepner *et al.*, 1980)

$$c = S\,w\,e/10 \quad \ldots\ldots\ldots\ldots \quad (1)$$

where c = effective field capacity (ha hr^{-1}); S = speed of operation (km hr^{-1}), w = rated width of implement (m); and e = field efficiency (expressed as a decimal).

The degree of coverage of the planted sticks was assessed visually by observing the percentage of sticks that was adequately covered with soil by the covering mechanism of the planter.

Results and discussion

Uniformity of stick length

Frequency distributions of measured stick lengths at the two settings are presented in Figure 1, and statistics calculated from these data are presented in Table 1. The table indicates that the length of sticks prepared by the stem cutting machine is normally distributed, and that the uniformity of length of such stakes is high, the uniformity coefficient, Cu, being almost equal to one. There was no appreciable difference in uniformity of stick length between the two stick length settings, indicating that the stick preparation machine is likely to produce acceptably uniform sticks at any stick length setting.

Quality of cut

The quality of cut obtained was generally good since over 90% of the sticks examined were cut in a near perfect transverse manner. The power and speed of rotation of the cutting element were such that even the thickest stems were cleanly cut. In the few instances where stems received angular cuts. the

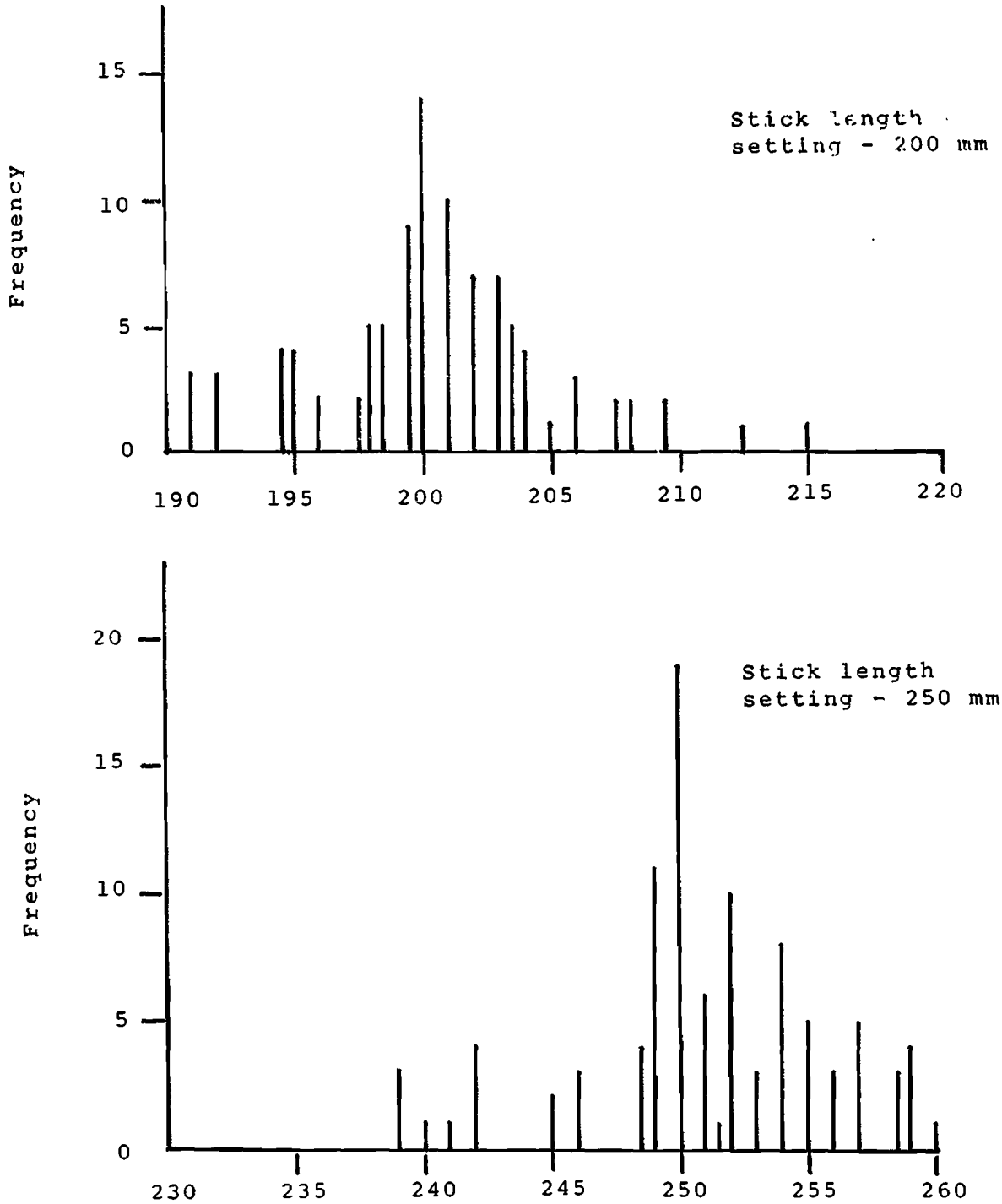


Figure 1. Measured lengths of two samples of 100 sticks cut at two different stick length settings.

Table 1. Summary of statistical analysis of observed data for stakes cut at two stake-length settings.

Statistics	Stake-length setting (mm)	
	200	250
Sample size, n	100	100
Sample mean, x	200.69	250.86
Sample Standard Deviation, s	4.39	4.70
Uniformity Coefficient, Cu	0.80	0.98
Lower Confidence Limit	200.25	250.39
Upper Confidence Limit	201.13	250.86

angularity was attributable to curvature and irregularity of shape of the stems at the points where the cuts were made.

Rate of stick preparation

The stem cutting machine was operated by two men, one of whom fed the machine with whole stems, while the other interchanged full and empty stick collection boxes and maintained the required concentration of chemical sterilant in the collection box. At stick length settings of 200 and 250mm sticks were cut, collected and treated at rates of 38 sticks min^{-1} and 32 sticks min^{-1} respectively, yielding production rates of 11,400 and 9,600 sticks per 10-hour man-day.

As indicated earlier, work rates for manual preparation of cassava planting sticks at the U W I. Field Station range from 2,000 sticks per 10-hour man-day for measured sticks to 3,000 sticks per man-day for sticks whose lengths are visually estimated. The use of the stem cutting machine herein described therefore offers a time saving of 4:1 which, for large scale cassava production, may be highly significant.

Uniformity of intra-row spacing and planting depth

Figures 2 and 3 give frequency distributions for intra-row spacing and planting depth respectively, while Table 2 summarises the statistics calculated from these distributions, based on procedures outlined by Bhattacharyya and Johnson (1977). For both ridged and flat land, the parameters are seen to be normally distributed.

The relatively high values of uniformity coefficients obtained for these two parameters on both ridged and flat land indicated that the machine performed acceptibly in both situations. However, the lower standard deviations obtained for both parameters when planting on ridges as opposed to flat land, indicated that the planter's performance on ridges was somewhat superior. In addition, work carried out by Granger (1985) has shown that, in a commercial setting in Trinidad, the uniformity of intra-row spacing and planting depth obtained with this planter was at least as good as and, in several cases, better than that achieved with manual planting.

Planting rate

During the tests, an average of 20.5 mins. were lost per hour of planter operation due to time for turning at headlands, refilling of the hopper and clearing blockages around the furrow-opener, resulting in a field efficiency of 0.66. The speed of operation was 5 km hr^{-1} and the effective (rated) width of the planter was 1.8m. These values, when substituted into equation (1) yielded an effective field capacity of 0.6 ha hr^{-1} which, for 8 - and 10 - hour work day, is equivalent to planting rates of 4.8 and 6.0 ha day^{-1} respectively.

Since three persons are required to operate the planter (one tractor driver and two planter operators) the above planting rates represent productivities of 1.6 and 2.0 ha man-day^{-1} respectively. Based on manual planting rates at UWI Field Station, comparable productivity figures for manual planting are 0.09 and 0.13 ha man-day^{-1}. It is evident, therefore, that use of two-row mechanical planter can very significantly increase labour productivity and reduce the time required for crop establishment.

Degree of coverage of planted sticks

In almost all cases, the cassava sticks were adequately covered with soil after being planted. In the few instances where coverage was incomplete, this was due to the presence of physical obstructions, such as stones or plant residue, which temporarily blocked the action of the covering coulters.

References

American Society of Agricultural Engineers (1984) ASAE Standard: ASAE S211.3 V-Belt drives for agricultural machines. *ASAE Standards – 1984.* 31st. ed., pp. 124–132, ASAE, St. Joseph, MI.

Bhattacharyya, G. K. and Johnson, R. A. (1977) *Statistical concepts and methods,* New York; John Wiley & Sons, pp. 233 – 275.

Granger, L. (1985) A field evaluation of a two-row cassava planter and harvester. Report submitted in partial fulfilment of requirement for B.Sc. Agriculture, UWI. (Unpubl.)

Hunte, D. (1977) *Farm power and machinery management,* 7th ed., Iowa: Iowa State Univ. Press, pp. 1–5.

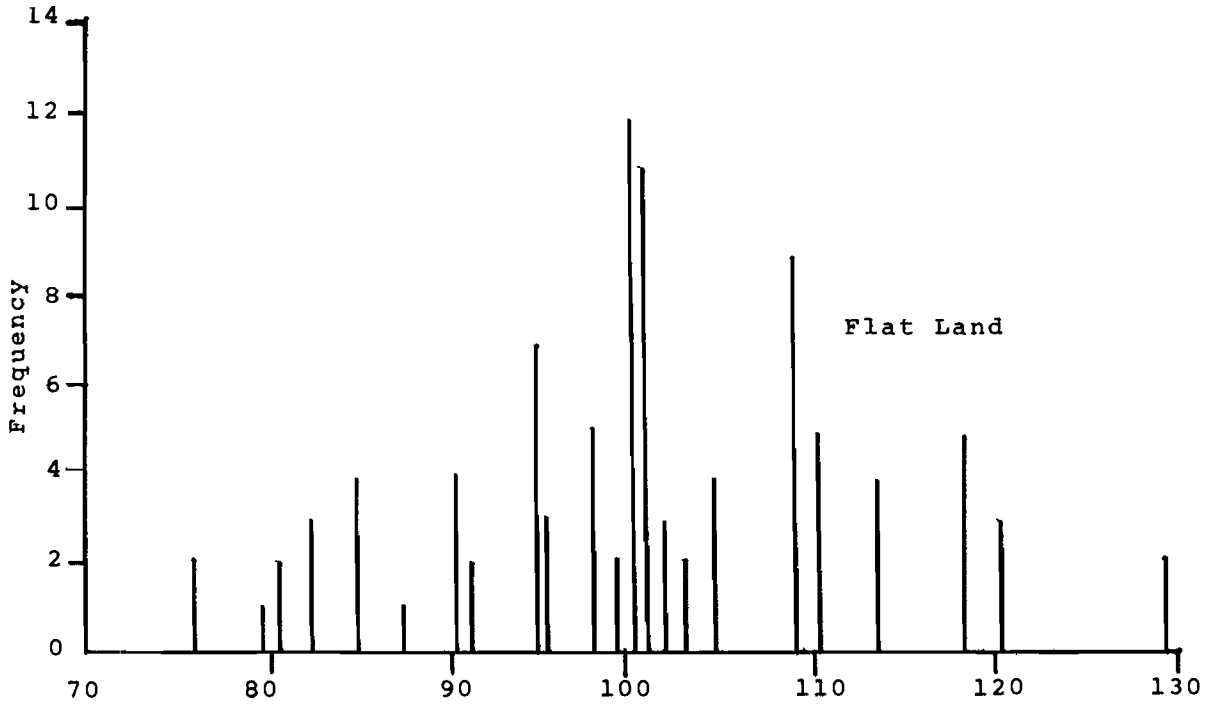
Kepner, R.A., Bainer, R. and Barger, E.L. (1980) *Principles of farm machinery,* 3rd ed., New York: AVI, pp. 195–208.

Lorenzi, J. O., Normanha, E. S. and De Concercao, A. J. (1980) Cassava production and planting systems in Brazil. *Proc Workshop on Cassava Cultural Practices* Bahia, Brazil. (Eds. E.I. Weber, M.J.C. Toro, and M. Graham.)

Lozano, J. Carlos, Toro M. Julio Cesar, Castro, Abelardo and Bellotti, Anthony C. (1977) *Production of cassava planting material.* Cassava Information Centre, CIAT, Colombia. C.A.

Table 2. Summary of statistical analysis of observed data for intra-row spacing (n=100) and planting depth (n=75)

	Intra-row spacing (cm)		Planting depth (mm)	
	Ridged land	Flat land	Ridged land	Flat land
Nominal dimension	100	100	100	90
Sample Mean, X	102.73	100.14	102.56	90.76
Sample Standard Deviation, s	8.12	14.27	13.09	14.32
Uniformity Coefficient Cu	0.92	0.89	0.87	0.91
Lower Confidence Limit (95% Level)	101.14	97.34	99.59	88.97
Upper Confidence Limit (95% Level)	104.32	102.94	105.52	92.55



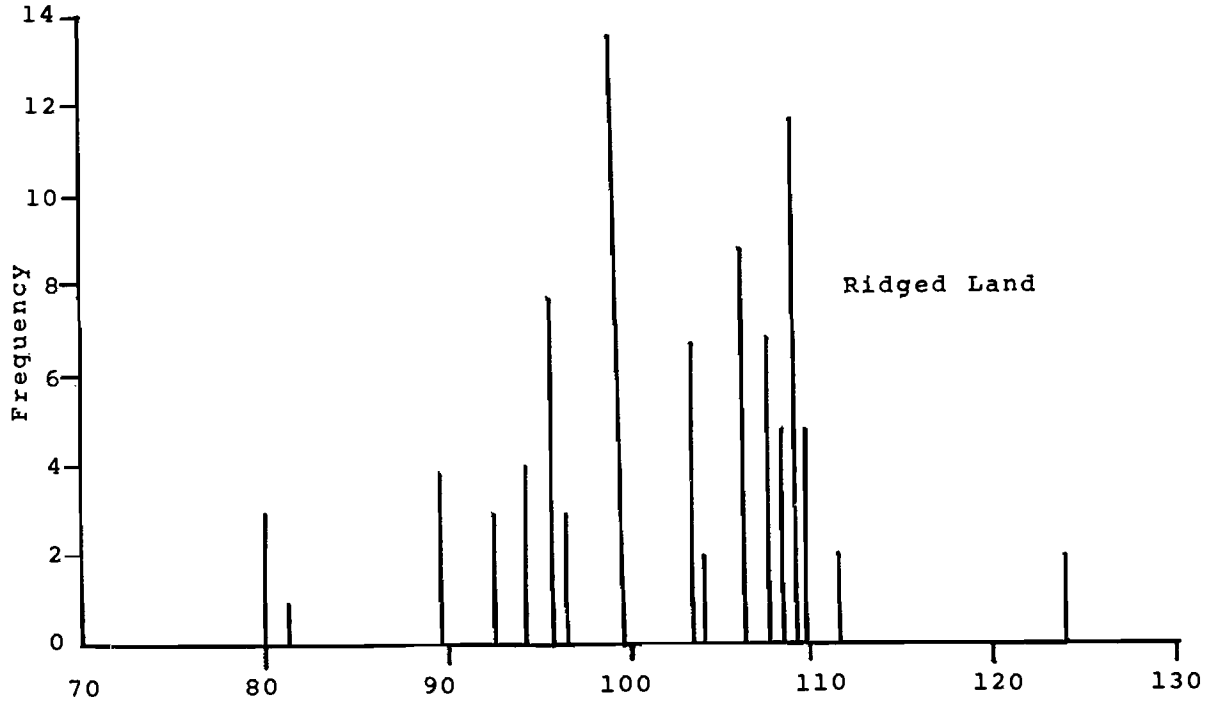
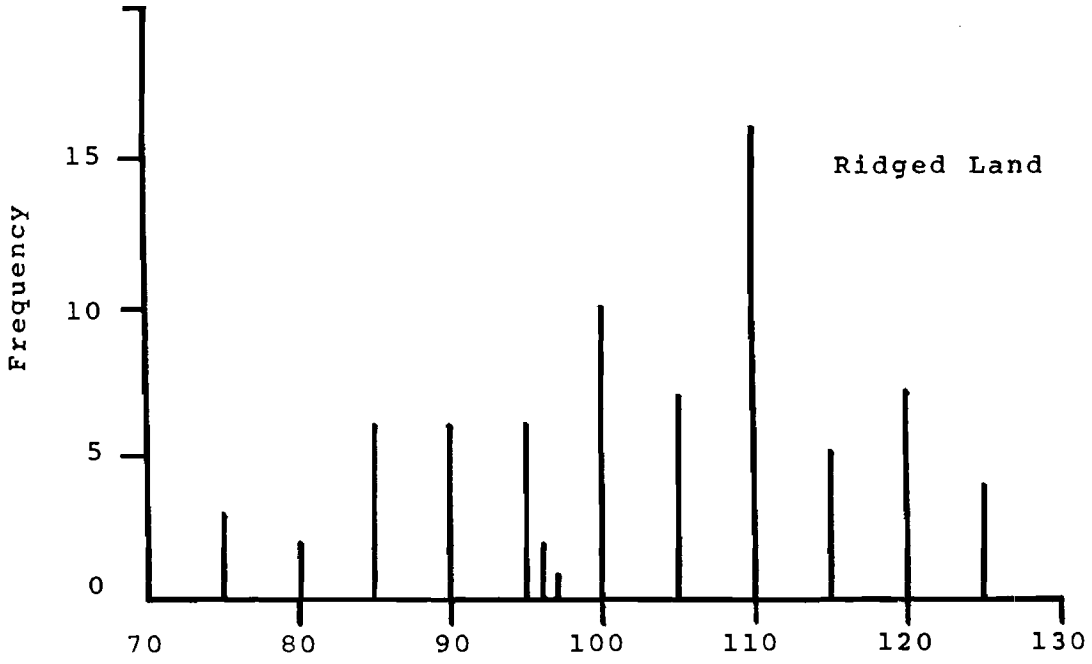


Figure 2. Observed intra-row spacings for two samples of sticks planted on ridged and flat land.



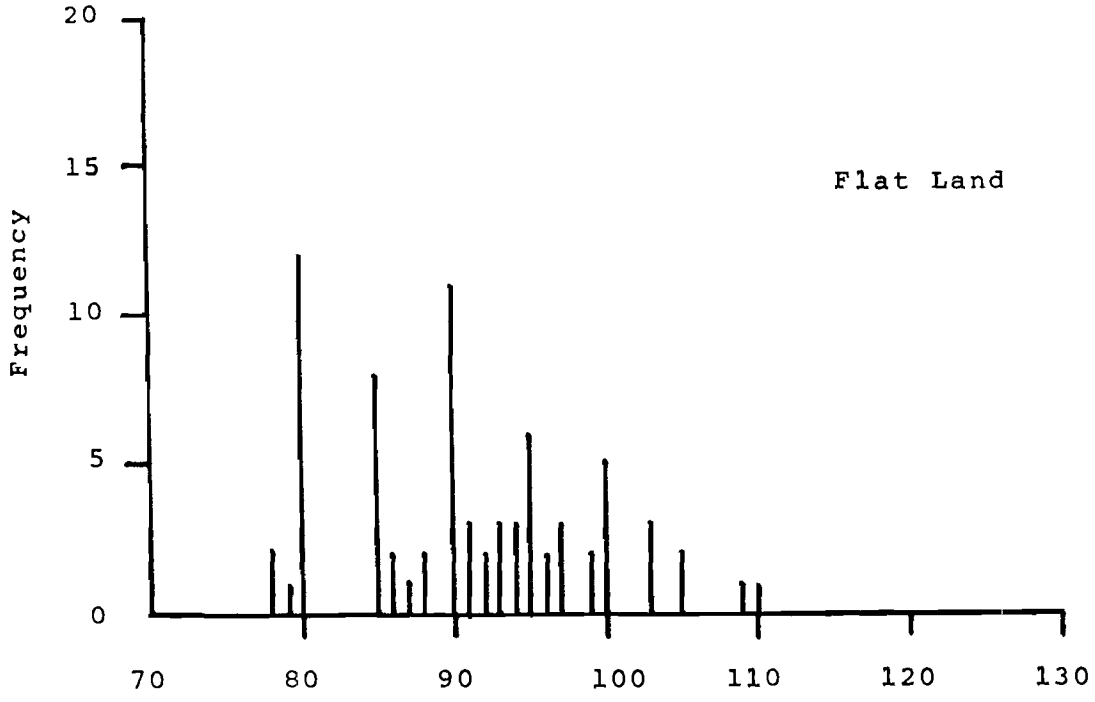


Figure 3. Observed planting depths for two samples of 75 sticks planted on ridged and flat land.

EFECTOS DEL "RAYADO MARRON" DE LA YUCA SOBRE EL RENDIMIENTO Y ALGUNAS PROPIEDADES FISICAS DEL ALMIDO NATIVO

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RESUMEN

Se seleccionaron clones de yuca susceptibles y tolerantes al rayado marrón. Sus raíces se almacenaron al ambiente (25–30°C; 40–55% HR) y en refrigeración (5–6°C; 80–90% HR) durante 72 y 144 horas. Se determinó el rendimento de almidón en la pulpa fresca. Se caracterizó los almidones mediante su capacidad de hinchamiento, la solubilidad y la amilografía en suspensiones acuosas.
Mediante observaciones visuales y una documentación fotográfica del avance del deterioro se seleccionaron los clones 'UCV 2459' y 'UCV 2129' como muy susceptibles y los clones 'UCV 2320' y 'UCV 2277' como muy tolerantes al rayado marrón.
Hubo influencia del tiempo y tipo de almacenamiento sobre los rendimientos del almidón, su hinchamiento, solubilidad, temperatura de empaste y conducta amilográfia. El almacenamiento de las raíces modificó progresivamente las curvas de viscosidad.

ABSTRACT

Cassava clones were selected for their susceptible and tolerant symptoms to the physiological disorder called "Vascular streaking". Their roots were stored at room temperature (25°C – 30°C, 40% – 55% RH) and at 5°C – 6°C, 80% – 90% RH for 72 and 144 hours.
The length and type of storage influenced the starch yields and solubility and swelling properties of fresh roots. Also there were changes in the starch.
Paste - viscosity in aqueous suspension was registered by an amylograph - Branbender.
Through visual observations and a series of photographs 'UCV 2459' and 'UCV 2129' clones were classifed as very susceptible and 'UCV 2320' and 'UCV 2277' as tolerant to vascular streaking.

Las regiones tropicales suministran grades posibilidades para el desarrollo de cultivos de ciclo largo, tales como la yuca, la caña de azúcar y las musáceas; gracias a una constante y alta temperatura y energía radiante, lo que permite a estas plantas brindar los más elevados rendimientos energéticos por hectárea y por año a nivel mundial (11).

En Venezuela el cultivo de la yuca rinde en promedio 10 Ton/ha con una mínima utilización de insumos, las cuales son equivalentes a 3.5 Ton/ha de cereales (8); esta producción es extremdamenta importante, pues el país importa alrededor del 65% de los cereales que requiere, siendo en su mayoría destinados a las producciones avicolas y porcinas (14).

Si bién, la yuca constituye una alternativa valiosa dentro de la agricultura tropical, hay un serio problema en el almacenamiento de sus raíces tuberosas frescas después de la cosecha, debido a alteraciones de la pulpa que se manifiestan como finas estrías, primero azuladas y luego marrones, a través de los haces vasculares, conocidas como "rayado marrón". Posteriormente este tejido se descompone y es invadido por organismos saprófitos que aceleran el proceso (10).

Este trabajo fue diseñado para seleccionar aquellos clones de yuca que manifiesten la mayor susceptibilidad y la mayor tolerancia al "rayado marrón"; así como, evaluar el efecto del deterioro sobre el rendimiento, y ciertas propiedades físicas del almidón nativo (no modificado) en los clones seleccionados.

Materiales y metodos

El material empleado fue proporcionado por la Facultad de Agronomia, Universidad Central de Venezuela, e incluye los clones de yuca de mejores caracteristicas agronomicas y comerciales.

I. Selecction Del Clon Mas Susceptible Y Del Mas Tolerante Al "Rayado Marron"

La selección se efectuó en plantas de 6 meses de edad de los clones 'UCV 2459, 'UCV 2626', 'UCV 2578', 'UCV 2292', 'UCV 2277', 'UCV 2320', 'Valencia' y 'UCV 2129'.

De cada clon se cosechó una planta y de ella, se seleccionaron 4 raíces reservantes comerciales, 2 de las cuales se cortaron a nivel de pedúnculo y las 2 restantes, a 5cm aproximadamente de la zona proximal. Todas las raíces se identificaron, se pesaron y se colocaron sobre un mesón a temperatura ambiente (23°C – 30°C).

Las observaciones se realizaron a las 48 y a las 144 horas. Se consideró que éstas, eran suficientes para determinar cual clon era más susceptible y cual más tolerante al "rayado marrón".

Al cabo de las 48 horas se hicieron cortes longitudinales y transversales a 2 raíces de cada clon (una con pedúnculo y otra seccionada transversalmente a 5cm de la zona proximal) a fín de evaluar el avance del estriado vascular, Se estimó iniciado cuando aparecieron manchas oscuras iguales o mayores a 2mm.

A las 144 horas se repitió el procedimiento con las dos raíces restantes por clon. Paralelamente se registró el avance del deterioro a través de una documentacioñ fotográfica.

II. Evaluacion De Algunas Propiedades Fisicas De Los Almidones Bajo Distintos Tratamientos

En esta segunda etapa del trabajo se utilizaron los clones 'UCV 2320', muy tolerante, y 'UCV 2459', muy susceptible al "rayado marrón", producto de la selección realizada previamente.

Tratamientos:

Una vez cosechadas, las raíces de 12 meses de edad se sometieron de forma inmediata a los siguientes tratamientos:

A. Conservacion al ambiente:

Temperatura: 25°C – 30°C
Humedad relativa: 40% – 55%

B. Refrigeración:

Temperatura: 5°C – 6°C
Humedad relativa: 80% – 90%

Los valores de temperatura y humadad relativa se obtuvieron a través de un Higrotermógrafo Weather Tromic, Modelo 5025.

Toma de muestras:

El muestreo se realizó siempre sobre material fresco y en la medida en que el daño causado por el "rayado marrón", se incrementaba en función del tiempo de post-cosecha para cada uno de los tratamientos aplicados.

A medida que se realizaba la toma de muestras tal como lo indica el Cuadro 1, se procedió inmediatamente a la extracción del almidón. Para ello, las raices de yuca se lavaron, se les eliminó la corteza, se pesaron 500g de pulpa, se cortaron en trozos pequeños y se molieron con agua en una licuadora. A continuación se separó el almidón de la suspensión acuosa por lavados sucesivos con agua a través de un tamíz de tela de algodón, el cual se comprimió sucesivamente en forma manual hasta extraer todo el líquido, dejándose sedimentar hasta el día siguiente. Posteriormente y en repetidas ocasiones, se eliminó la suspensión sobrenadante por decantación y se lavó el almidón sedimentado, resuspendiéndose en un nuevo volumen de agua. El almidón decantado se secó en estufa con corriente de aire durante 24 horas a una temperatura de 50°C. Finalmen te se molió en un mortero y se colocó a temperatura ambiente (27°C) en envases plásticos herméticamente tapados para su posterior análisis.

Cuadro 1. Toma de las muestras para cada tratamiento respecto al tiempo de post-cosecha.

Tiempo (h)	Clon UCV 2459		Clon UCV 2320	
	Ambiente	Refrigeración	Ambiente	Refrigeración
0	$X(T_0)$	-	$X(T_0)$	-
72	$X(T_{3A})$	$X(T_{3R})$	$X(T_{3A})$	$X(T_{3R})$
144	$X(T_{6A})$	$X(T_{6R})$	$X(T_{6A})$	$X(T_{6R})$

X= toma de muestras.

Rendimiento (%) de almidón luego de secado a 50°C, en la pulpa fresca de 4 clones de yuca, previamente sometidos a distintas condiciones de almacenamiento (g almidón/100 g pulpa fresca).

El almidón seco se pesó y cada valor obtenido correspondió al contenido del mismo en 500 gramos de pulpa fresca. El rendimiento se expresó en porcentaje (gramos de almidón/100g de pulpa fresca).

Hinchamiento y solubilidad:

Para determinarlos se usó el método de Leach el al. (7). Se tomó un tubo de centrífuga previamente pesado al cual se agregó un gramo de almidón. Se le añadió 36ml de agua destilada y se introdujo en un baño de María a la temperatura deseada (55, 65, 75, 85°C) por 30 minutos, agitando frecuentemente para mantener la suspensión; transcurrido el tiempo se extrajo el tubo, se secó exteriormente, se dejó enfriar y se lavó el agitador con poca agua (menos de 3ml); posteriormente se agregó agua destilada hasta completar 40ml y se centrifugó durante 10 minutos a 350 r.p.m. Luego se separó el precipitado del sobrenadante.

El precipitado se secó a 45°C por 15 minutos en estufa con corriente de aire; luego se dejó enfriar y se pesó; por diferencia de peso se obtuvo el hinchamiento. Del sobrenadante se tomó una alícuota de 10ml, se colocó en un beacker previamente pesado y se evaporó a sequedad en una estufa a 120°C durante 4 horas; se dejó enfriar durante 30 minutos en un desecador y se pesó para calcular la solubilidad, la cual representa el residuo seco o fracción soluble, correspondiente al gramo de almidón original.

Las formulas para calcular el hinchamiento y la solubilidad son las siguientes:

$$\text{Hinchamiento} = \frac{C - B}{B - A} \times 100$$

$$\text{Solubilidad} = \frac{E - D}{B - A} \times 400$$

A = Peso del tubo vacío
B = Peso del tubo con muestra
C = Peso del tubo luego de calentar a 45°C por 15 minutos
D = Peso del beacker vacío
E = Peso del beacker después de calentar a 120°C

Amilografia:

Para medir la viscosidad de la pasta del almidón se utilizó el viscoamilógrafo Brabender de velocidad constante, siguiendo la metodología de Mazurs y colaboradores (9) usada para pastas de pH 5 a 7, con una concentración de 6% de almidón. La curva se trazó calentando la suspensión de almidón desde 30°C hasta 95°C, manteniendo la pasta a 95°C durante 10 minutos y enfriándola a 50°C, donde se mantuvo por 10 minutos y se enfrió hasta 30°C.

Resultados y Discusion

1. SELECCTION DEL CLON MAS SUSCEPTIBLE Y DEL MAS TOLERANTE AL "RAYADO MARRON"

Mediante una evaluacion visual del avance del deterioro fisiologico en las raices de yuca y una documentacion fotografica del mismo se seleccionaron a los clones 'UCV 2459' y 'UCV 2129' como los mas susceptibles y a 'UCV 2320' y 'UCV 2277' como los mas tolerante al "rayado marron". Entre ellos, el clon UCV 2459 (muy susceptible) y el clon UCV 2320 (muy tolerante) manifestaron un comportamiento extremo con relacion al tiempo que transcurre desde la cosecha de las raices hasta el iniciodel deterioro.

II. *EVALUACION DE ALGUNAS PROPIEDADES FISICAS DE LOS ALMIDONES BAJO DISTINTO TRATAMIENTOS*

La determinación de rendimiento de almidón se realizó en raíces de 12 meses de edad, de los clones 'UCV 2459', UCV 2129' (amargos y susceptibles al "rayado marrón") y 'UCV 2277' (amargo y tolerante) y 'UCV 2320' (dulce y tolerante al deterioro); los resultados se observan en el Cuadro 2.

Cuadro 2. Rendimiento (%) de almidón luego de secado de 50°C, en la pulpa fresca de 4 clones de yuca, previamente sometidos a distintas condiciones de almacenamiento (g almidón/100 g pulpa fresca)

Tratamiento	Clones 'UCV 2129'	'UCV 2459'	'UCV 2277'	'UCV 2320'
T_o	24,00	32,36	19,38	15,92
T_{3A}	18,34	20.02	15,62	14,65
T_{3R}	12,39	14,30	18,68	15,44
T_{6A}	10,94	9,34	15,54	12,46
T_{6R}	12,02	10,04	15,56	13,34

Observando los tratamientos testigos de los 4 clones se puede notar que existen diferencias en cuanto al contenido de almidón de sus raíces, obteniéndose los mayores porcentajes en aquellas amargas. Los rendimientos obtenidos de las raíces del tratamiento T_0 se ubican dentro del rango señalado por la literatura para raices de yuca, el cual oscila entre 12% y 33% (5, 15).

Así mismo, se observa que, enfunción del tiempo de almacenamiento, las mayores variaciones se presentan en los clones susceptibles.

Como era de esperarse, el mayor rendimiento en almidón se obtiene en las raíces recién cosechadas (T_0) y su contenido en los mismos se modifica por las condiciones de almacenamiento. Así se observa que las pérdidas se incrementan con el tiempo de almacenamiento y son mayores en las raíces conservadas al ambiente, lo cual coincide con Pacheco (13), con excepcion de los tratamientos T_{3A} y T_{3R} en los clones 'UCV 2459' y 'UCV 2129' (susceptibles).

Según Booth (1, 2) durante el almacenamiento ocurren conjuntamente con las pérdidas de agua, disminución en el contenido de materia seca por la respiración; se trata de pérdidas endógenas naturales, unidas a las pérdidas de agua por transpiración y marchitez. En el caso del almacenamiento de papas, Burton (4) ha señalado que ocurre una continua conversión de almidón a azúcar, y de una forma de azúcar a otra, y de azúcares a almidón. Se ha aislado -Braverman (3) - la fosforilasa -P- enzima de la papa que puede sintetizar a partir de glucosa 1-fosfato una cadena lineal de amilosa, dado que la reacción de fosforilación es reversible:

n (α glucopiranosa - 1 fosfasto) $\rightleftharpoons$ amilosa + n (H_3PO_4); para que se inicie la reacción debe existir una sustancia "cebo" en forma de polímero pequeño de glucosa.

Probablemente este proceso sea la respuesta al por qué, en los clones susceptibles, el contenido de almidón fue mayour en el tratamiento T_{3A} que en el T_{3R}.

En los clones tolerantes ('UCV 2277' y 'UCV 2320') se observa poca variación en el contenido de almidón a lo largo del tiempo de almacenamiento, con una mayor transformación del polímero en aquellas raíces conservadas al ambiente.

De lo anteriormente expuesto se puede afirmar, que el almacenamiento provoca pérdidas en términos de cantidad y calidad de las raíces de yuca, siendo éstas mayores en los clones susceptibles al "rayado marrón".

Analisis de los resultados de hinchamiento y solubilidad

Como se esperaba, hubo un mayor hinchamiento con incrementos de la temperatura en los almidones de ambos clones (Cuadro 3). Este comportamiento es consecuencia del efecto de la temperatura sobre los enlaces de hidrogeno, debilitándolos y permitiendo la absorción progresiva de agua por el gránulo; este proceso continúna hasta la temperatura de gelatinización del almidón; en la cual el gránulo presenta su máximo hinchamiento antes de que ocurra su ruptura y posterior solubilización (6).

Los almidones del clon susceptible ('UCV 2459') manifiestan un grado de hinchamiento variable de acuerdo al tratamiento post-cosecha aplicado. Aquellos que hinchan lentamente, evidencian un debilitamiento progresivo de las fuerzas de asociación dentro del gránulo (tratamientos T_0 y T_{3A} del clon UCV 2459). En contraste, los almidones del clon tolerante ('UCV 2320') hinchan en forma brusca bajo los distintos tratamientos, excepto el T_{6A}.

Cuadro 3. Porcentaje de hinchamiento a diferentes temperaturas de los almidones de 2 clones de yuca, sometidos preciamente a distintas condicines de almacenamiento.

Temperaturas (°C)	Clones	Tratamientos To	T_{3A}	T_{3R}	T_{6A}	T_{6R}
55	UCV 2459	36, 23	159, 19	67, 05	107, 04	102, 59
	UCV 2320	153, 49	272, 74	263, 18	190, 25	148, 96
65	UCV 2459	750, 46	495, 91	1033, 39	1630, 39	1380, 19
	UCV 2320	1855, 37	2052, 23	2021, 56	1595, 78	1897, 96
75	UCV 2459	1833, 91	975, 30	2795, 63	3039, 41	3219, 04
	UCV 2320	3143, 56	3202, 51	3202, 05	2551, 72	3193, 39
85	UCV 2459	2466, 78	1385, 00	3206, 86	3199, 08	3270, 83
	UCV 2320	3204, 94	3185, 46	3161, 93	3246, 90	3182, 36

El valor más alto de hinchamiento es alcanzado por los almidones del tratamiento T_{6A} en el clon susceptible, ('UCV 2459') y por los almidones del tratamiento T_{6A} en el clon tolerante ('UCV 2320').

Es interesante destacar que el clon UCV 2320 manifiesta un poder de hinchamiento superior que el clon UCV 2459; esto es indicio, de una mayor porosidad de sus gránulos del almidón, lo cual permite una mayor absorción y reacción del agua caliente de la suspensión con los enlaces de hidrógeno de las moléculas; así mismo, puede ser consecuencia de una major elasticidad de los enlaces de asociación molecular, lo cual le confiere al gránulo un mayor grado de hidratación y por consiguiente, un poder de hinchamiento superior.

Se observa, que el hinchamiento incrementó con la temperatura en los distintos tratamientos postcosecha aplicados, con ligeras variaciones en el clon tolerante ('UCV 2320') a 85°C para los tratamientos T_{3A}, T_{3R} y T_{6A} con respecto a la temperatura inmediata inferior, los cuales se consideran insignificantes (Figura 1 y 2).

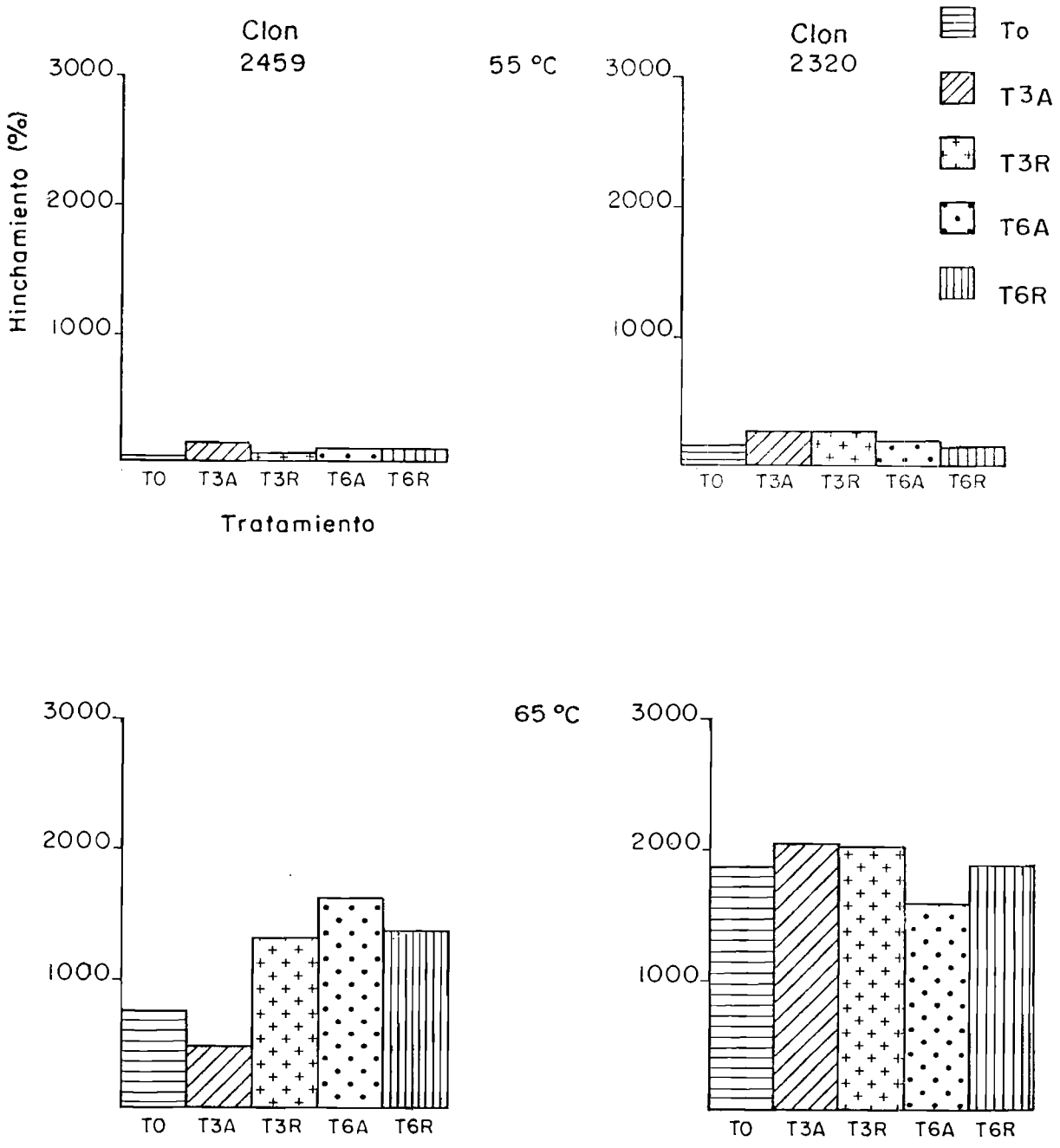

FIGURA 1. Histogramas de porcentajes de hinchamiento a 55ºC y 65ºC, de los almidones de los clones de yuca 'UCV 2459' y 'UCV 2320', sometidos previamente a distintas condiciones de almacenamiento.

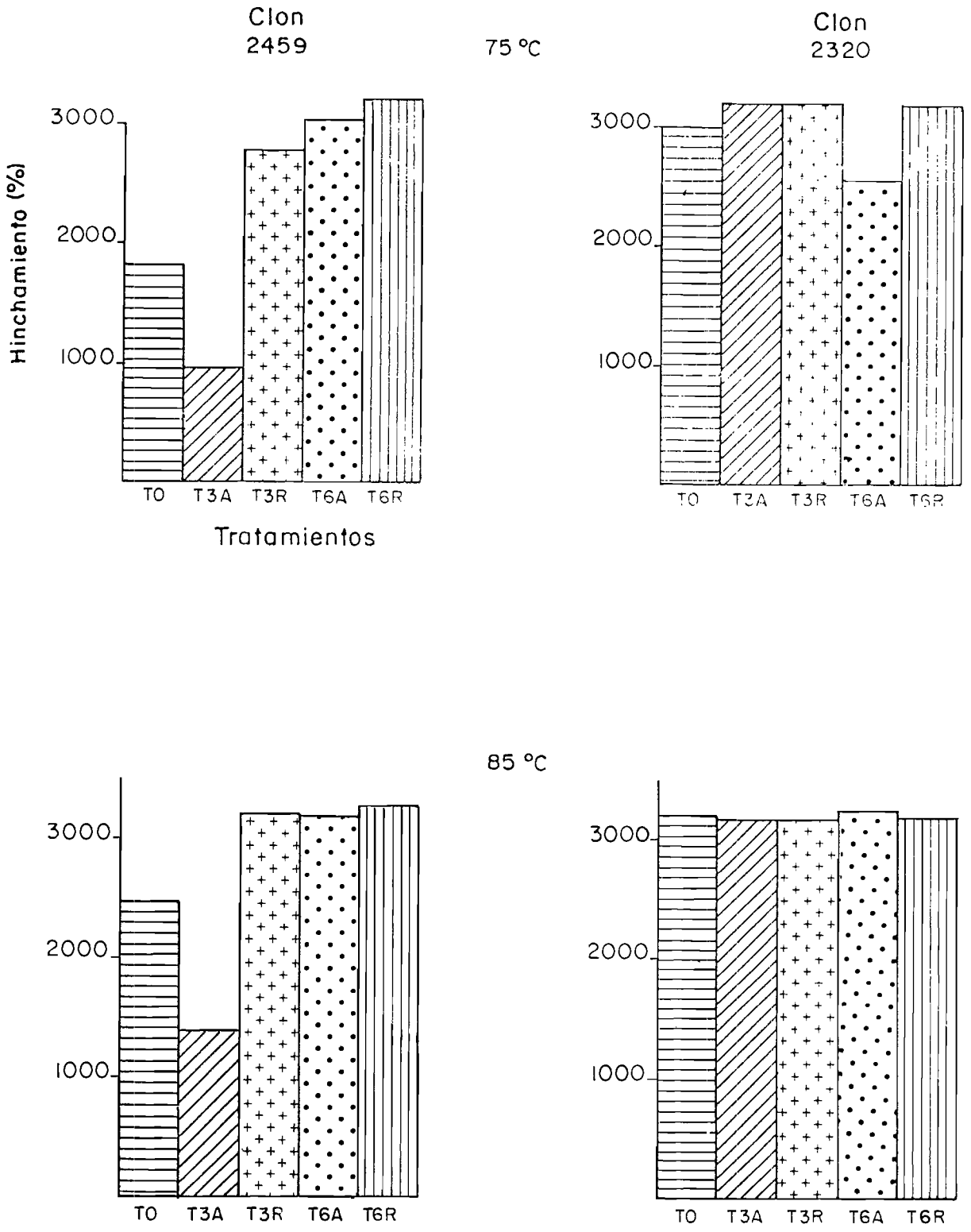

FIGURA 2. Histogramas de porcentaje de hinchamiento a 75ºC y 85ºC, de los almidones de los clones de yuca 'UCV 2459' y 'UCV 2320', sometidos previamente a distintas condiciones de almacenamiento.

Analizando los valores de hinchamiento obtenidos para cada tratamiento, se encuentra que éstos son prácticamente mínimos a 55 °C en ambos clones, en otras palabras no pued observarse una tendencia definida a esta temperatura, a diferencia de las restantes; T_0 representa el tratamiento testigo, el comportamiento de almidón nativo de yuca no sometido a almacenamiento. Se observa claramente, que este almidón no almacenado presenta un grado de hinchamiento inferior con relación a los restantes. Este comportamiento se manifiesta en ambos clones y a las distintas temperaturas con excepción del clon UCV 2320 a la temperatura de 75 °C y 85 °C cuyos valores de hinchamiento no difieren de los otros obtenidos en el almacenamiento. El comportamiento del almidón del tratamiento T_0, observando las gráficas de las figuras 1 y 2, permite deducir que de algun modo, el almacenamiento tiene un efecto sobre el grado de hinchamiento del gránulo.

Al analizar el comportamiento de los almidones del clon UCV 2459 bajo el tratamiento T_{3A}, especialmente si éste se compara con el tratamiento T_{6A} y con la curva de viscosidad del mismo T_{3A} (Figura 4), se puede deducir que ha ocurrido en estos almidones la formación de nuevos enlaces entre las moléculas adyacentes (enlaces cruzados), de una forma similar a la empleada en la technología de los alimentos al producirse los almidones llamados modificados.

En la formación de estos enlaces posiblemente hayan intervenido otras moléculas provenientes de fragmentos de almidón desintegrado, mono y disacáridos, etc., los cuales, en los gránulos de almidón sin hinchar reaccionan con los grupos hidroxilo de las moléculas vecinas, formando de esta manera una estructura reticular con enlaces cruzados cuya función es reforzar los puentes de hidrógeno dentro del gránulo, pudiendo así resistir la ruptura durante la cocción y controlar el hinchamiento (6). Con el incremento del tiempo de almacenamiento al ambiente y por consiguiente del deterioro (tratamiento T_{6A} del clon UCV 2459), estos nuevos enlaces se debilitan y el hinchamiento aumenta.

El comportamiento de los gránulos de almidón el calentamiento en el clon UCV 2320, fue muy similar en los distintos tratamientos (Figuras 1 y 2). A diferencia del clon susceptible ('UCV 2459'), aquel no manifesto variaciones notables en cuanto al grado de hinchamiento entre dichos tratamientos. Es importante destacar que los almidones sometidos a los tratamientos T_{3A} y T_{3R} mostraton un grado de hinchamiento muy similar bajo las diferentes temperaturas; con los tratamientos T_{6A} y T_{6R} para el mismo clon hubo algunas diferencias a 65 °C y 75 °C.

Las diferencias en cuanto al nivel de daño alcanzado determinó posiblemente, en este caso, el comportamiento de sus gránulos de almidón durante el calentamiento.

Los porcentajes de solubilidad encontrados para los almidones de ambos clones se muestran en el Cuadro 4. Su determinación se realizó a las temperaturas de 55 °C, 65 °C y 75 °C en todos los tratamientos.

En vista de que no hubo marcadas diferencias entre los valores obtenidos para los distintos tratamientos en las temperaturas mencionadas, se tomo el valor promedio y se tabuló y graficó el porcentaje de solubilidad para los rangos de temperatura: 55 °C – 65 °C y 65 °C – 75 °C.

En los histogramas de la Figura 3, se observa que la solubilidad del almidón incrementa con la temperatura. Al igual que el grado de hinchamiento, el porcentaje de solubilidad alcanzado por las almidones del clon UCV 2320, fue mayor que aquel logrado por los almidones del clon UCV 2459 en los distintos tratamientos; no obstante, los valores indican una solubilidad moderada en todos ellos. Los almidones mas solubles son aquellos del tratamiento T_{6R} en el clon susceptible ('UCV 2459') y los del tratamiento T_{3R} en el clon tolerante ('UCV 2320').

Cuadro 4. Procentaje de solubilidad a diferentes rangos de temperatura, de los almidones de 2 clones de yuca, sometidos previamente a distantas condiciones de almacenamiento.

Rangos de temperatura (°C)	Clones	Tratamientos				
		To	T_{3A}	T_{3R}	T_{6A}	T_{6R}
55-65	UCV 2459	3, 57	5, 11	3, 66	4, 85	5, 85
	UCV 2320	6, 56	7, 00	8, 15	5, 42	7, 14
65-75	UCV 2459	8, 47	9, 24	11, 29	9, 19	11, 50
	UCV 2320	11, 45	10, 09	12, 83	12, 39	11, 60

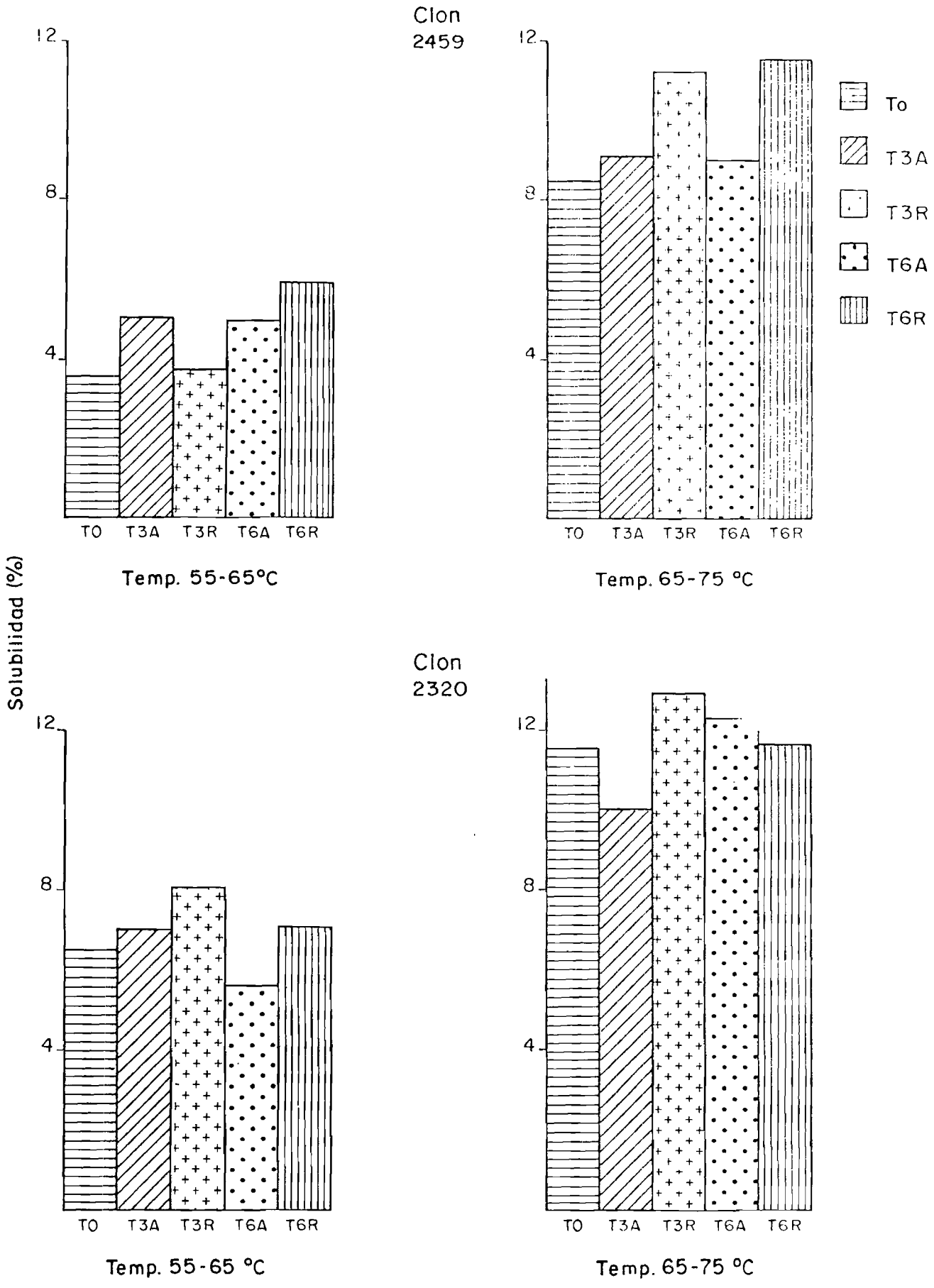

FIGURA 3. Histogramas de porcentaje de solubilidad a diferentes rangos de temperatura, de los almidones de los clones de yuca 'UCV 2459' y 'UCV 2320', sometidos previamente a distintas condiciones de almacenamiento.

Analisis de las propiedades reológicas de los almidones nativos bajo distintos tratamientos

Observando los amilogramas obtenidos para los almidones nativos de los clones de yuca sometidos a diferentes tratamientos post-cosecha, se destacan las variaciones en la temperatura de empaste y viscosidad de dichos almidones (Cuadro 5, Figuras 4 y 5). Los almidones del tratamiento testigo (T_0) del clon UCV 2459 empastan o gelatinizan a una temperatura más alta (68 °C)que los almidos del mismo tratamiento del clon 'UCV 2320 (65°C), lo cual evidencia mayor grado de asociación en las zonas amorfas de los gránulos en el primero.

Los rangos de temperatura de gelatinización varian con los distintos tratamientos, para el clon UCV 2459. Las temperaturas iniciales en el clon tolerante ('UCV 2320') son muy próximas, llegando a coincidir en algunos casos; dichas temperaturas varían entre 64 °C y 65 °C y las finales entre 77 °C y 86 °C. En el clon susceptible ('UCV 2459') la temperatura inicial oscila entre 67 °C y 71 °C y la final entre 76 °C y 95 °C, lo cual permite deducir que el deterioro de la raíz juega un papel importante en el comportamiento de las pasta de almidón durante su cocción. Así mismo, se observa que los valores de viscosidad máxima alcanzados por los almidones del clon UCV 2320 coinciden en todos los tratamientos con excepción del T_{64} y son, en todos los casos, superiores a los logrados por el clon UCV 2459.

El declive de la viscosidad de la pasta de almidón cuando se mantiene la temperatura constante a 95 °C durante 10 min., es un indice de su estabilidad durante la cocción y ésto se correlaciona positivamente con el grado de hinchamiento, de modo que aquellos almidones que hinchan más, son más susceptibles a la ruptura (6).

De acuerdo con ésto y según se observa en la figura 5, el clon UCV 2320 manifiesta de modo general un declive pronunciado de su viscosidad comparado con el clon UCV 2459 lo cual tiene, a su vez, relación directa con el menor grado de asociación de sus moléculas y por consiguiente, su mayor facilidad para hinchar.

El clon tolerante ('UCV 2320') presenta curvas de viscosidad muy semejantes entre sí; las diferencias que existen se manifiestan principalmente durante la etapa de enfriamiento, donde ocurre una gelificación o reaglomeración de moléculas, por la expulsión del agua y la formación de nuevas fuerzas intermoleculares, cuya magnitud está en función del tiempo y tipo de almacenamiento. La retrogradación incrementa con el tiempo de almacenaje y es mayor en los almidones conservados al ambiente.

Para este mismo clon, el amilograma correspondiente al tratamiento T_{6A} presenta ciertas diferencias con relación a los restantes; entre ellas: requiere mayor tiempo para alcanzar la máxima viscosidad siendo ésta menor que las logradas por las pastas de almidón de los otros tratamientos, esto tiene relación directa con su reducido grado de hinchamiento, analizado anteriormente. Su comportamiento cuando se mantiene la temperatura constante durante 10 minutos a 95 °C es semejante al de las otras curvas, sin embargo, durante la etapa de enfriamiento manifiesta el mayor grado de interacción molecular (retrogradación).

En las curvas de viscosidad del clon UCV 2459, se nota que aún cuando siguen una tendencia similar (con excepción de tratamiento T_{3A}), existen diferencias que justifican su mención.

Se observa que las pastas de almidón manifiestan una marcada variación en cuanto a su rango de temperatura de gelatinización, lo cual a su vez se traduce, en diferencias con relación al tiempo requerido para alcanzar la máxima viscosidad. Así tenemos que aquellos almidones que hinchan más, muestran los más altos picos de viscosidad y la mayor inestabilidad de su pasta cuando son sometidos al efecto del calor y agitacion constantes.

Observando las curvas se destaca que las pastas de los almidones de los tratamientos T_{3A} y T_{3R} necesi-

Cuadro 5. Propiedades reológicas tomadas de las curvas amilográficas de almidones al 6% de humedad en dos clones de yuca sometidos a diferentes condiciones de almacenamiento.

Almidón		Temperatura de empaste (°C)	Viscosidad en unidades Brabender (UB) Máxima	Luego de 10 m a 95°C	Luego de 10 m a 95°C	a 50°C	Luego de 10 m a 50°C	30°C
To	2459	68	910	500	340	360	380	400
	2320	65	980	480	350	430	480	580
T_{3A}	2459 *	71	340	340	340	420	460	520
	2320	64	980	410	320	420	480	600
T_{3R}	2459	70	900	480	300	280	300	340
	2320	64	980	400	320	410	460	500
T_{6A}	2459	-	-	-	-	-	-	-
	2320	65	940	560	400	520	680	770
T_{6R}	2459	67	940	340	260	300	320	360
	2320	65	980	540	420	560	600	680

(*) Material insuficiente

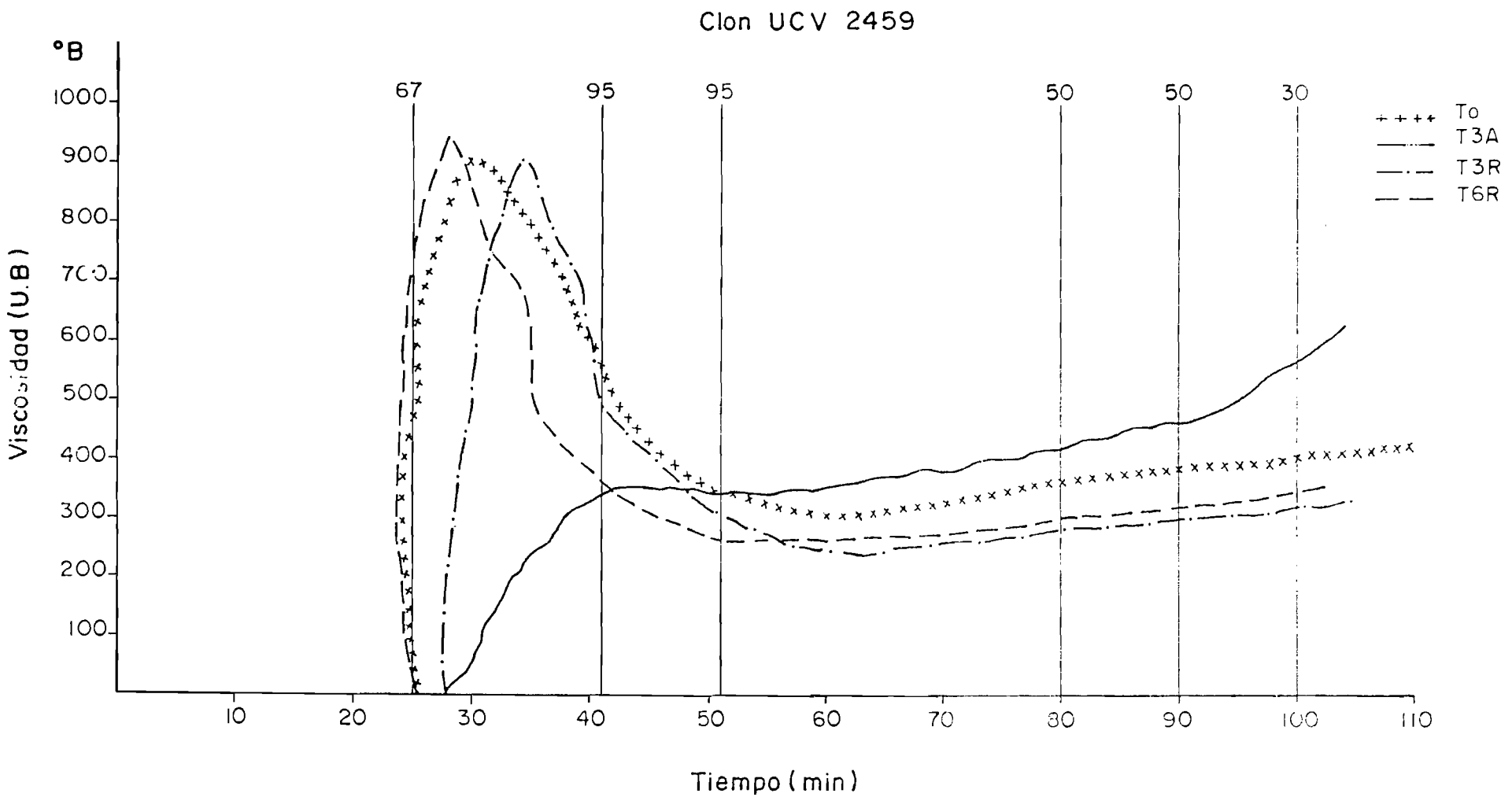

FIGURA 4. Amilogramas de almidones del clon de yuca 'UCV 2459', sometido previamente a distintas condiciones de almacenamiento.

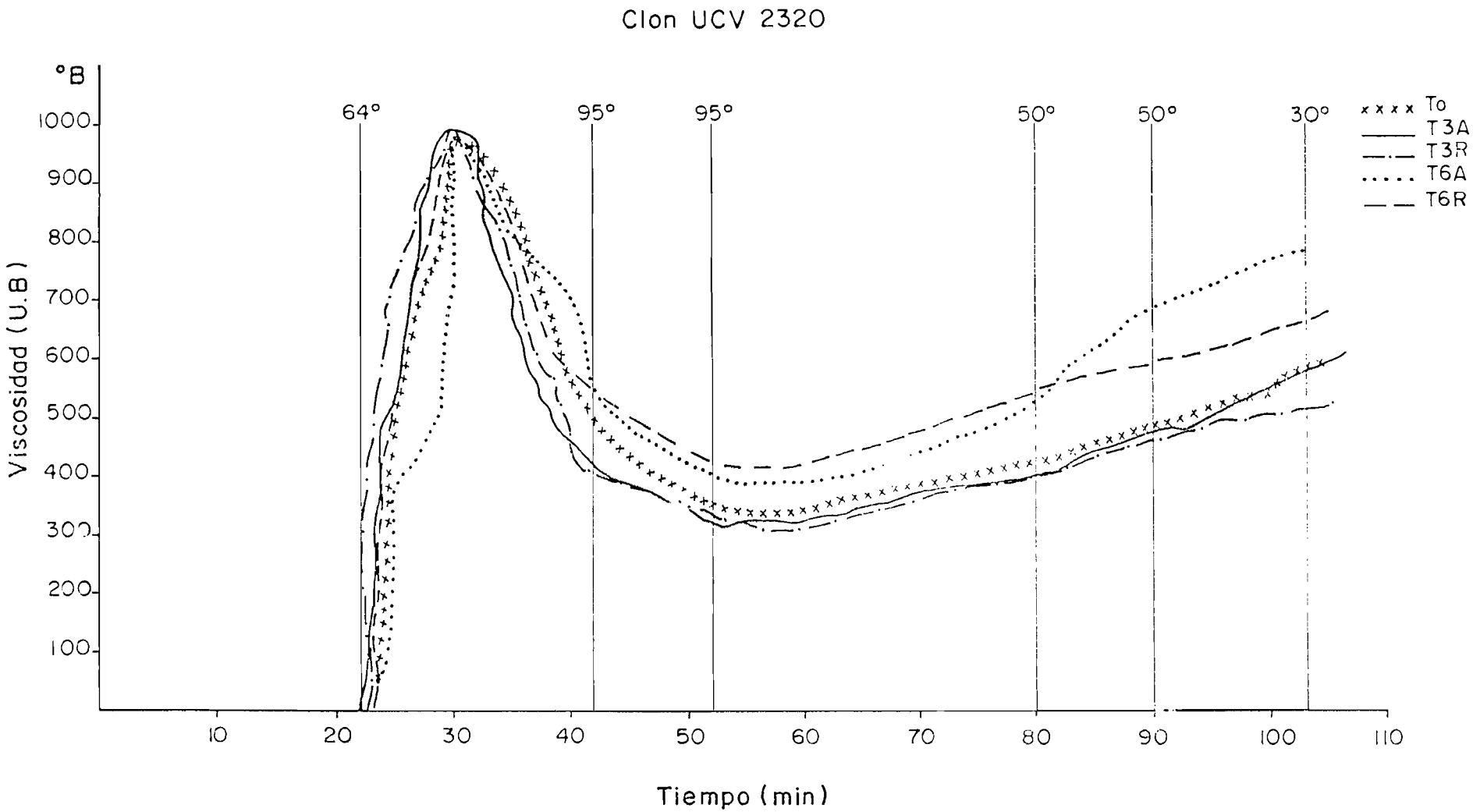

FIGURA 5. Amilogramas de almidones del clon de yuca 'UCV 2320', sometido previamente a distintas condiciones de almacenamiento.

tan mayor tiempo para iniciar la elevación de su viscosidad, lo cual significa que en sus almidones existe un mayor grado de asociación intermolecular. Ejemplo típico de ello, lo constituye el almidón del tratamiento T_{3A}, cuya pasta sufrió una modificación producto de la formación de nuevos enlaces, lo cual se manifiesta en una viscosidad moderada y una alta retrogradación durante la etapa de enfriamiento. Este resultado coincide con los señalados por Pacheco (12), quién menciona que las curvas de viscosidad de raíces almacenadas se modifican progresivamente, no siempre para empeorar; en algunos casos, las raíces almacenadas producen almidones con buenas curvas de viscosidad.

Con relación al tratamiento T_{6A} del clon UCV 2459, no pudo realizarse el amilograma correspondiente, dado que no se dispuso de suficiente material. El uso de un método diférente para obtener dicho amilograma, no hubiese permitido la realización de un análisis comparativo.

Conclusiones

1. De los clones seleccionados en la Etapa 1 del trabajo, el clon UCV 2459 (muy susceptible) y el clon UCV 2320 (muy tolerante) manifestaron un comportamiento extremo con relación al tiempo que transcurre desde la cosecha de las raíces hasta el inicio del deterioro.

2. Aunque los síntomas del deterioro post-cosecha de los clones 'UCV 2459' y 'UCV 2320' son los mismos, la diferencia estriba en que en éste último, el daño se desarrolla en un período de tiempo mayor, dependiendo de tratamiento post-cosecha aplicado.

3. Las raíces de yuca de ambos clones conservadas al ambiente manifestaron síntomas de deterioro dentro de las primeras 48 horas. El almacenamiento en refrigeración (5°C – 6°C) conservó las raíces en buenas condiciones, no observándose el daño a lo largo del período de preservación establecido (6 días).

4. Los materiales genéticos ('UCV 2320', 'UCV 2277', 'UCV 2459' y 'UCV 2129') mostraron ciertas diferencias en su rendimiento en almidón. Los más altos porcentajes dueron manifestados por los clones amargos.

5. Los rendimientos obtenidos de las raíces del tratamiento T_0 se ubican dentro del rango señalado por la literatura. Tales rendimientos se modifican en función del tiempo y tipo de almacenamiento. Las mayores variaciones se manifestaron en los clones susceptibles ('UCV 2459' y 'UCV 2129').

6. Los patrones de hinchamiento y solubilidad progresiva obtenidad de los gránulos de almidón de ambos clones cuando son calentados en agua, indicaron una débil asociación molecular dentro del gránulo, la cual fue más pronunciada en el clon tolerante ('UCV 2320').

7. La temperatura de empaste varió en función de tiempo y tipo de almacenamiento en el clon susceptible ('UCV 2459'); en contraste, no se manifestaron mayores variaciones en el clon tolerante ('UCV 2320').

8. El amidón nativo de yuca es frágil, inestable a la cocción y al manejo mecánico. El almacenamiento de las raíces modificó progresivamente las curvas de viscosidad, principalmente en el clon susceptible ('UCV 2459'). Las raíces del clon UCV 2459 conservadas 3 días al ambiente produjeron almidones con menor hinchamiento y mayor estabilidad a la cocción y fuerza mecánica.

9. El almidón nativo de yuca se puede emplear en la industria textil y de papel, pero por su textura elástica o cauchosa, es indeseable en la industria de alimentos.

Recomendaciones

A. Se recomienda realiza ensayos que permitan evaluar la susceptibilidad de los materiales genéticos al "rayado marrón" de la raíz en función de distintas épocas de cosecha.

B. Llevar a cabo nuevos ensayos con períodos de almacenamiento prolongados y realizando la toma de muestras de almidón a intervalos de tiempo menores, con el propósito de obtener información con un mayor rango de seguridad, con relación al efecto que el deterioro post-cosecha de las raíces de yuca ejerce sobre el hinchamiento y solubilidad del almidón y la viscosidad de sus pastas.

C. Evaluar la modificación que sufre la viscosidad de las pastas de almidón en raíces sometidas a distintos métodos de almacenamiento.

ReferenciasBibliograficas

1. Booth, R.H. 1974. Post-harvest deterioration of tropical root crops: losses and their control Tropical Science, 16; 49–63.

2. Booth, R.H. 1977. Storage of fresh cassava *(Manihot esculenta)* 11 Simple storage techniques Expl. Agric. 13: 119–128.

3. Braverman, J.B.S. 1980. Introduccion a la bioquimica de los alimentos. 3a. Ed. Omega. Barcelona. Espana (5): 63–77, (7) y (8): 90–110; (12): 190–191.

4. Burton, W.G. 1966. The potato . Ed. Veenman y Zonen Wageningen. Holland. pp. 210–251.

5. Edwards, D. 1974. The industrial manufacture of cassava products. An Economic study. Trop. Prod. Inst. Chap. 1. 22p.

6. Leach. H.W. 1965. Gelatinization of starch. In Starch: chemistry and technology. Whistler and Paschal (eds) Academic Press. New York. Vol. 1 Chaper XII.

7. Leach, H.W. *et al.* 1959. Structure of the starch granule. 1. Swelling and solubility patterns of various starches. Cereal Chemistry, 36 (6):534 pp.

8. M.A.C. 1973. Anuario 1972. Miniserio de Agricultura y Cría. Caracas, Venezuela. pp. 170–177.

9. Marzus, E. *et al.* 1957. Graphical analysis of the Barbender viscosity of various starches. Cereal Chem. 34 (3): 141–152.

10. Montaldo, A. 1979. La yuca o mandioca. Instituto Interamericano de Ciencias Agricolas de la O.E.A. San Jose, Costa Rica 381 pp.

11. Montaldo, A. *et al.* 1979. La yuca y su agronidustria. (Anteproyecto de Programa de Desarrollo sometido a consideración del Ministerio de Agricultura y Cria). Pub. Mis Fac. Agronomia U.C.V. 24 pp.

12. Pacheco, J.A. de C. 1952. Alteracoes de qualidade de fécula o armazenamento das raizes de mandioca. Bragantia (Campinas) 12 (7/8): 297.

13. Pacheco, J.A. de C. 1954. Alteracoes do teor de amido durante armazenamento das raizes da mandioca. Bragantia (Campinas) 13 (Nota 6): XV – XVI.

14. Pacheco P., H.P. 1980. Producción agropecuaria y la seguridad y Defensa Nacional. M.A.C. Desarrollo General de Desarrollo Agrícola. p. 21.

15. Shipman, L. 1967 Industrial aspects. In Starch: Chemistry and technology. R.L. Whistler and Paschall, (eds.) Academic Press, New York.

FEEDING OF CASSAVA SILAGE TO GROWING PIGS
A PRELIMINARY TRIAL

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ABSTRACT

Freshly harvested cassava roots were chopped manually with a machete into slices of 1 to 6cm thickness and ensiled in 45 gallon (180 litres) barrels the following day with either 2% salt or 50% final molasses by weight. After an ensiling period of 7 days material was removed daily for feeding to pigs. Growing pigs, balanced for sex and litter, were fed in groups of 4 with either (a) a corn/soybean meal ration (b) a ration with 50% corn replaced by salt-ensiled cassava and soybean meal, or (c) a ration with 50% corn replaced by molasses-ensiled cassava and soybean meal. A vitamin/mineral mix was fed with each ration at the rate of 30 grams per head per day. The animals were adapted for 14 days and the experimental period ran for 23 days when supply of the ensiled cassava was exhausted. The average daily gains (g) of the pigs on the three rations during the 23–day experimental period were 509, 510 and 447, respectively, and were not significantly (P>.05) different.

RESUMEN

Raíces de yuca acabadas de cosechar fueron cortadas manualmente con un machete en trozos de un espesor de 1–5 cm y ensiladas el día siguiente en barriles de 45 galones (200 litros) con 2% de sal o 50% de melaza líquida, por peso. Después de un período de ensilaje de 7 días, se utilizó de esta materia diariamente para alimento de cerdos. Cerdos en crecimiento balanceados por sexo y cría fueron alimentados en grupos de cuatro, con una cualquiera de: (a) una ración de maíz/soja, (b) una ración con el 50% del maíz sustituído por un ensilaje salado de yuca y soja (c) y una ración con el 50% del maíz sustituído por un ensilaje de yuca con melaza y soja. Una mezcla de vitamina/mineral fue dada diariamente en cada ración con una proporción de 30 por cabeza. Los animales estuvieron en un proceso de adaptación que duró 14 días y el período experimental se extendió por 23 días, cuando el suministro de yuca ensilada se agotó. El aumento promedio de peso diario de los puercos alimentados con las tres raciones durante el período experimental de 23 días fue de 509, 510 y 447, respectivamente y no hubo una diferencia (P> .05) significativa.

Several root-crops can be fed to livestock (Gerpacio *et al,* 1974; Jeffers and Haynes, 1967; Gohl, 1981; Yeh, 1982) but commercially cassava *(Manihot* spp.) is used most extensively (Muller *et al,* 1974; CIAT, 1978 a).

It can be fed fresh, or processed by chipping, dehydration and grinding. In these forms it can be stored, and incorporated into complete feeds for livestock. While processing is effective, it increases the cost of the final product and is probably more appropriate for large-scale operations. An alternative to processing is ensiling. Reports indicate that cassava can be ensiled for both human (Yen, 1978) and livestock (CIAT, 1978 b) consumption. In the latter case, salt was used in the ensiling process. To investigate the usefulness of the process, a research programme was undertaken to study different methods of ensiling cassava and the practical application of feeding the ensiled product to pigs. This paper reports the results of a preliminary experiment undertaken to determine the feeding value of cassava ensiled with salt and final molasses. The programme has subsequently been expanded to include the ensiling of other crops such as sweet potatoes and rejected bananas.

Materials and methods

Cassava grown on the Central Experiment Station was harvested approximately two years after planting, excess soil washed-off under pressurised water and chopped by hand with a machete into slices varying in thickness from 1 to 6cm. The chopped material was ensiled the following day with either 2% salt or in 50% final molasses by weight. The ensiled material was mixed by hand and stored in steel drums of 45 gallons (180 litre) capacity. This was followed by mixing once per day with a wooden paddle. The first batch of cassava was ensiled on the 13th September, 1984 and feeding of that batch commenced on the 21st September, 1984. The second batch was ensiled on the 20th September, 1984 and feeding commenced on the 16th October, 1984.

The ensiled cassava was mixed with other ingredients and fed to wearned crossbred pigs balanced for sex (females and barrows) and litters. The pigs were held in groups of 4 after being assigned to the different rations. An adaptation period of 14 days was used to allow for a gradual introduction of the molasses-ensiled cassava. The actual experimental period was 37 days. The ingredient composition of the rations offered to the pigs is shown in Table 1. The daily feed offered to each pig is also shown in Table 1. Both salt and molasses-ensiled cassava were used to replace 50% corn in the ration on an approximate dry matter basis. The rations were calculated to supply nutrients as recommended by NRe (1978) and their partial nutrient composition is shown in Table 2. At the end of the experimental period 2 animals (one female and one barrow) from each group were slaughtered and backfat measurements taken.

The data obtained in the study were statistically analysed according to procedures outlined in Steel and Torrie (1960).

Table 1. Ingredient composition of rations fed per head daily according to live-weight

Ration	Ingredient	Weight of ingredient (g) for animals 10-20 kg	Weight of ingredient (g) for animals 20-35 kg
Control	Corn	722	1166
	Soybean meal	280	360
	Vitamin/mineral mix [1]	30	30
Salt-ensiled cassava	Corn	361	583
	Soybean meal	280	360
	Salt ensiled cassava	1050	1700
	Vitamin/mineral mix	30	30
Molasses-ensiled cassava	Corn	361	583
	Soybean meal	280	360
	Molassess ensiled cassava	600	975
	Vitamin/mineral mix	30	30

[1] Contained: 46.67% Dicalcium phosphate, 26.67% limestone, 20.00% salt and 6.66% of a commercial swine vitamin/mineral premix composed of (per gram) vit A 4800 IU, vit D_3 1000 U, vit E 4 mg, vit K 0.8 mg, Folic Acid 0.2 mg, Nicotinic Acid 4 mg, Pantothenic Acid 2.4 mg, vit B 2 mg, vit B_1 0.8 mg, vit B_{12} 4 meg, Pyridoxine 0.8 mg, Biotin 10 meg, 10.56 mg, Se 0,04 mg, Cu 5.6 mg, Fe 32 mg, Mn 20 mg, Zn 40 mg and Co 0.64 mg.

Table 2. Partial nutrient composition of the three rations offered per head daily (calculated on a dry matter basis) according to live weight.

	Control		Cassava-salt silage		Cassava-molasses silage	
	10-20 kg	20-35 kg	10-20 kg	20-35 kg	10-35 kg	20-35 kg
Metabolizable Energy (MJ)	14.55	28.22	14.17	21.69	13.59	20.79
Lysine (g)	10.5	14.1	9.8	12.8	9.8	12.8
Trypotaphan(g)	2.3	3.2	2.0	2.7	2.0	2.7
Threonine (g)	8.1	11.2	6.8	9.2	6.8	9.2
Methionine (g)	3.3	4.7	2.7	3.7	2.7	3.7
Calcium (g)	6.3	6.5	6.3	6.4	6.3	6.4
Phosphorous (g)	3.7	4.2	3.4	3.7	3.4	3.7
Vitamin A (IU)	9600	9600	9600	9600	9600	9600
Vitamin D (IU)	2000	2000	2000	2000	2000	2000

Results and discussion

Observations indicated that the salt-ensiled cassava remained firm and hard with little or no disintegration for 14 to 21 days after ensiling. However, liquid collected in the container and was probably cellular in origin. After 21 days, the slices of cassava became soft and pulpy. There was some insect infestation when the container was not sealed.

Molasses was very effective for ensiling cassava. The slices remained firm and hard throughout the feeding period. However, they became light to dark brown in colour and this was probably due to the presence of molasses in the cassava tissue. There was some fermentation of the mixture as evidenced by an alcoholic odour. The amount of alcohol produced was not determined but was not expected to be high. The ensiled mixtures were readily accepted by the animals and no ill effects were observed over the experimental period.

The average initial weight (kg), final weight (kg), daily gain (g) and the backfat thickness (cm) are given in Table 3.

The average daily gains (g) of the animals on the different treatments over the experimental period were 509, 510, and 447 for the control, salt and molasses-ensiled cassava rations respectively. The differences in the average daily gain were not significantly ($P > .05$) different. Since the metabolizable energy content of cassava on a dry matter basis is somewhat higher than corn (NRC, 1978; Gohl, 1981, Muller *et al.*, 1974) then animal performance is not expected to be significantly different. With the

Table 3. Average liveweights and average daily gains of weaned pigs fed on a control diet and two rations containing cassava silage.

	Control	Silage	
		Salt/ cassava	Molasses/ cassava
Average final weight (kg)	30.25	27.75	25.75
Average initial weight (kg)	17.83	16.03	15.48
Average daily gain (g)	509[a]	510[a]	447[a]
Backfat thickness (cm)	4.17	3.68	4.04

[a] - Means in the same row with identical supercsripts are not significantly (p>.05) different.

molasses-ensiled cassava ration, however, the average metabolizable energy of the mix on a dry-matter basis is lower than the corn/soybean ration but animal performance was not significantly different ($P > .05$), although the average daily gain was numerically lower. The effect on average daily gain of the lower metabolizable energy in the molasses/cassava treatment will become greater (i.e. a greater decline in average daily gain) as the liveweight of the animal increases. This could be eliminated, at least partially, by substituting the molasses/cassava ration for corn on a metabolizable energy basis rather than a dry matter basis.

The feed conversion efficiency (FCE) was not calculated because of the short feeding period. It would be interesting to see FECs with the silage rations.

The backfat thickness was measured on two animals (one female and one barrow) in each treatment but no statistical analysis was carried out on these measurements (Table 3). Animals on the control diet appeared to have more backfat than those on the cassava silage diets.

Diarrhoea, a problem associated with the feeding of final molasses to pigs (Willett *et al*, 1946; Blanco *et al* 1964; Brooks and Iwanga, 1967; Preston and Willis, 1969) but not with high-test molasses (Mac Leod *et al* 1968; Velazquez *et al* 1969, 1970) was not observed in the animals fed the molasses-ensiled cassava. This was probably due to the low level of molasses in the diet.

References

Blanco, V., Raun N.S. and Vagas E. (1964) Molasses as a major energy source for swine. *J. Animal Science* 23 868 (abst.).

Brooks, C.C. and Iwanaga I.I. (1967). Use of cane molasses in swine diets. *J. Animal Science* **26** 741–745.

CIAT (1978 a) Cassava-based feedstuffs: cause for concern in the EEC. *Cassava Newsl.* CIAT. No. 3 p. 7.

CIAT (1978 b) Swine limit Annual Report, 1978, CIAT, Cali, Columbia, S.A.

Gerpacio. A.L., Roxas, D.B., Uichanco, N.M., Roxas, N.P., Custadio, C.C., Mercado, C., Gloria L.A. and Castillo, L.S. (1974). Tuber meals as cabohydrate sources in broiler rations. *In: Animal feeds of tropical and sub-tropical origin.* TPI Conference, 1974.

Gohl, B.I. (1981). *Tropicalfeeds* F.A.O. Animal Production and Health Series No. **12**, FAO, Rome.

Jeffers., H.F. and Haynes, P.H. (1967). A preliminary study of the nutritive value of some dehydrated tropical roots. *Proc. Int. Symp. Trop. Root Crops.* (Eds: E.A. Tai *et al*) St. Agustine, Trinidad, W.I.

Mac Leold, N.A., Preston T.R., Lassota, L.A., Willis M.B. and Velazquez, M. (1968). Molasses and sugar as energy sources for pigs. *Rev. cubana Cienc Agric.* **2** 205-210.

Preston, T.R. and Willis M.B. (1969). Sugarcane as an energy source for the production of meat. *Outlook on Agriculture* 6 29-35.

Steel, R.G.D., and Torrie J.H. (1960). Principles and procedure of statistics, Mc Graw– Hill, Toronto, Canada.

Velazquez, M., Ly, J. and Preston, T.R. (1969). Digestible and metabolizable energy values for pigs of diets based on high-test molasses or final molasses and sugar. *J. Animal Science* **29** 578-580.

Velazquez,M. Preston T.R. and Mac Leod, N.A. (1970.) Dia-ammonoum phosphate as a subsitute for protien in high-test molasses diets for growing pigs. *Rev. cubana Cienc. agric,* 4 105-110.

Willett, E.L., Work, S.H., Henke, L.A. and Maruyama, C. (1946). Cane molasses for pigs from weaning to weight of seventy pounds. *Hawaii Agric. Exp. Sta.* Tech. Bull No. 3.

Yeh. T.P. (1982). Utilization of sweet potatoes for animal feed and industrial uses: potential and problems. *In: Sweet potato.* Proc. First Int. Symp. [R.L. Villareal and T.D. Griggs (eds.)] Asian Vegetable Research and Development Center, Tainan, Taiwan, China.

Yen, D.E. (1978). The storage of cassava in Polynesian Islands. *Cassava Newsl* CIAT. No. 3 pp. 9-11.

THE POTENTIAL FOR THE USE OF GIBBERELLIC ACID IN STORAGE OF YAMS, *DIOSCOREA ALATA*

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ABSTRACT

Gibberellic acid (GA_3) may be used to prolong dormancy in yams, *D. alata* and thus extend the shelf-life of treated tubers. The feasibility of using this treatment commercially, was assessed by comparing the break-even cost of treated tubers with the average retail price. Three GA_3 treatments: 50 ppm for 24 hours, 100 ppm for 21 hours and 500 ppm for 9 hours, and two treatment dates: January and April, were considered. The most economic and practical treatment was found to be 100 ppm GA_3 for 21 hours, applied in April. This treatment resulted in an extension of dormancy for 10 weeks, and the tubers were available until July.

RESUMEN

Estudios hechos en Trinidad han demostrado que el ácido gibberellico GA_3, prolonga el período de inactividad en tubérculos de D. alata por 10 a 17 semanas, dependiendo del tiempo del tratamiento y la concentración de GA_3 usada. Aquí se discute el resultado de tratar ñames en enero y abril. Un análisis breve del costo del tratamiento demuestra que sería económicamente factible tratar tubérculos con 100 ppm GA_3 para prolongar su disponibilidad por 10 semanas más.

Keywords: Yam; *Dioscorea alata;* Storage; Gibberillic Acid

Yam, *Dioscorea spp.*, is an important root crop in the Caribbean. The tubers are grown primarily for local consumption, although a number of the islands export to the United States and United Kingdom. Production of yams in the region was 305,000 metric tons in 1982/83, representing 15% of total root crop production (Ferguson, 1985).

Dioscorea alata is one of the most popular yam species and is widely grown in Antigua, Barbados, Montserrat, St. Kitts and Trinidad (Table 2). Tubers of *D. alata* experience a natural dormancy of 3–4 months after which sprouting, weight loss and loss in palatability occurs. Work done at the University of the West Indies by Wickham (1981) and subsequently by Jordan (1984) has shown that it is possible to prolong dormancy in tubers of *D. alata* by the application of gibberellic acid (GA_3).

The major advantage of using GA_3 to extend shelf-life is that there is no need for any specialised facilities or storage requirements, other than the usual precautions to prevent pest and disease damage. However before GA_3 can be recommended for use in commercial storage, it is necessary to estimate the cost of treatment. The current high cost of GA_3 (TT$4.25/gram) would seem to be a major constraint to its use on a large scale.

This paper examines the feasibility of using GA_3 in yam storage, by comparing the break even cost of treated tubers with the average retail price of yams.

Background

Jordan (1984) working with tubers of *D. alata* cv. 'White Lisbon' has shown that the extension of dormancy obtained by treatment with GA_3 is a function of concentration, and duration of exposure to the treatment solution. In addition, response to a given treatment varied depending on the date of application. Thus tubers treated in April (on breakage of dormancy) experienced an extension of domancy 1 week longer than tubers treated after harvest in January. Breakage of dormancy was defined as sprouting in 20% of tubers.

Tubers harvested in January experienced a natural dormancy of 13 weeks, and extension of dormancy was defined as the additional dormancy period measured from that time.

Table 1 shows the effect of three GA_3 treatments, applied in January and April, on extension in dormancy and availability of 'White Lisbon' yams. Jordan (1984) also reported that weight loss of dormant tubers was 0.5% per week on a fresh weight basis.

Methodology

The final break-even cost of treated tubers was calculated based on the cost of materials, labour and storage. The final cost was adjusted to take into account shrinkage due to weight loss during storage. All prices are quoted in TT dollars, and are prevailing prices in 1982/83.

Table 1. Effect of GA_3 on extension of dormancy and availability of *D. alata* cv. 'White Lisbon' tubers

GA_3 treatment	Date of treatment	Extension of dormancy	Minimum limit of availability
50 ppm/ 24 hrs	Jan	5.5	June
	Apr	6.5	
100 ppm/ 21 hrs	Jan	9.0	July
	Apr	10.0	
500 ppm/ 9 hrs	Jan	13.5	August
	Apr	14.5	

Source: Jordan (1984)

Cost of GA_3

The cost of GA_3 required to treat 1kg of yams was calculated as shown in Table 2. The cost varied between \$0.20 to \$2.00 depending on the concentration of GA_3 used. It was assumed that the GA_3 solution was used only once.

Table 2. Cost of GA_3 required to treat 1.0 kg of yam with a solution containing 50 ppm, 100 ppm or 500 ppm GA_3

*Volume of treatment solution 1/1.05 = 0.95 litres
Quantity of GA_3 required to prepare 0.95 l of 50 ppm solution = 0.0475 g

Cost of GA_3 =\$4.25 per g
Cost of GA_3 required to treat 1 kg of yams with a solution of:
50 ppm GA_3 = 0.0475 × 4.25
=\$0.20
100 ppm GA_3 =\$0.40
500 ppm GA_3 =\$2.00

*Calculated as volume of water displaced by 1 kg of yam of density 1.05 kg/l.

Initial cost of yams

It was assumed that the yams were purchased prior to treatment at the prevailing farm-gate price. Thus tubers treated in January cost \$1.66 per kg and the cost of tubers treated in April was \$0.93 per kg (Table 3).

Table 3. Average farm price per kilogram of 'White Lisbon' Yam in 1981

Month	Price per kg.
January	1.66
February	1.91
March	2.09
April	0.93
May	0.99
June	0.88

Source: Central Statistical Office, Index of Retail Prices, Quarterly Agricultural Report, 1977-1981.

Ministry of Agriculture, Planning Division, Republic of Trinidad and Tobago.

Labour

The cost of labour required to treat 1.0 kg of yams was \$0.18, calculated as shown in Table 4. The duration of the various procedures was estimated based on experience gained conducting experiments.

Table 4. Cost of labour required to treat one kilogram of yam with GA_3

[1] Time required to treat 225 kg[2] of yams

Operation	Duration (hrs)
Wash tubers	2
Mix chemical	1/2
Immerse tubers	1/2
Remove tubers	1
Pack	1
Unpack	1
TOTAL	6 hours

Time required to treat 1 kg $= \frac{6}{225}$ hours

[3] Cost of labour =\$6.77 per hr

Cost of labour per kg of yam treated $= \frac{6.77 \times 6}{225}$

=\$0.18

[1] Does not include time for which tubers are immersed in treatment solution
[2] Minimum weight of yam treated in experiments
[3] Hourly wage of male casual worker at the University Field Station, 1981.

Storage costs

The cost of warehouse storage was 0.2¢ per kg per week. Tubers treated in January had to be stored 13 weeks longer than tubers treated in April.

Shrinkage

Average weight loss during storage was 0.5% per week on a fresh weight basis. Tubers treated in January lost 6.5% more weight than tubers treated in April.

Break-even cost

The break-even cost of treated tubers was calculated as shown in Tables 5 and 6. The final cost shown here is the cost of tubers towards the end of the period of their availability. The break-even cost of tubers treated with 500 ppm was \$5.09 per kg and \$3.67 per kg for tubers treated in January and April respectively.

Tubers treated with 100 ppm GA_3 cost \$3.05 per kg and \$1.80 per kg, and those treated with 50 ppm GA_3 cost \$2.69 and \$1.49 per kg, for January and April – treated tubers respectively.

Discussion

The break-even cost of tubers treated with 500 ppm GA_3 was substantially greater than the cost of tubers treated with 50 or 100 ppm GA_3. The extension of shelf life achieved by treatment with 500 ppm GA_3 was 4 weeks longer than that obtained by the next best GA_3 treatment. However, the cost of that extra 4 weeks of storage increased the break-even cost by 67% and 104% in January- and April-treated tubers respectively. In both cases the break-even price exceeded the maximum price paid for yams during

Table 5. Estimated break-even cost of 1 kg of yam treated with GA_3 in the second week of January (at harvest)

	GA_3 treatment		
	50 ppm/ 24 hr	100 ppm/ 21 hr	500 ppm/ 9 hr
[1] Cost of yams	1.66	1.66	1.66
Cost of labour	0.18	0.18	0.18
Cost of GA_3	0.20	0.04	2.00
Minimum shelf-life (wks from date of treatment)	19.5	23	27.5
[2] Cost of storage (2¢ per week)	0.39	0.46	0.55
%weight loss during storage (0.5% per week)	9.75	11.5	13.75
Break-even cost at the end of the storage period	$2.69	$3.05	$5.09

[1] Farmgate price of 1.0kg 'White Lisbon' tubers in January 1981
[2] 1981 cost of warehouse dry storage

Table 6. Estimated break-even cost of 1 kg of yam treated with GA_3 in the last week of April (on breakage of dormancy)

	GA_3 treatment		
	50 ppm/ 24 hr	100 ppm/ 21 hr	500 ppm/ 9 hr
[1] Cost of yams	0.93	0.93	0.93
Cost of labour	0.18	0.18	0.18
Cost of GA_3	0.20	0.04	2.00
Minimum shelf-life (wks from date of treatment)	6.5	10	14.5
[2] Cost of storage (2¢ per week)	0.13	0.20	0.29
%weight loss during storage (0.5% per week)	3.25	5.0	7.25
Break-even cost at the end of the storage period	$1.49	$1.80	$3.67

[1] Farmgate price of 1kg 'White Lisbon' tubers in April 1981
[2] 1981 cost of warehouse dry storage

the year (Table 7). It is clear that the high cost of GA_3 makes treatment with 500 ppm GA_3 uneconomic, in spite of the extension in shelf life.

Treatment with 100 ppm GA_3 extended the shelf life of tubers for an additional 3.5 weeks, compared to the extension obtained by treatment with 50 ppm GA_3. The difference in the cost of the two treatment was $TT 0.36¢ and $TT 0.31¢ in the January- and April-treated tubers respectively. However, at both dates, the break-even cost of tubers in both treatments remained below the maximum price paid for yams during the year. A study of Table 7 shows that the additional cost of treatment with 100 ppm GA_3 would be offset by the increased price paid for yams stored for an extra 3.5 weeks.

Table 7. Average farm price per kg of 'White Lisbon' yam in 1981

Month	Price per kg
January	2.47
February	2.20
March	2.20
April	2.42
May	2.20
June	2.34
July	3.00
August	2.84
September	3.20
October	2.89
November	2.76
December	2.42

Source: Central Statistical Office, Index of Retail Prices, Quarterly Agricultural Report, 1977-1981.

Ministry of Agriculture, Planning Division, Republic of Trinidad and Tobago.

Treatment in April resulted in a lower break-even cost than treatment in January, and the availability of the tubers was extended for an additional week. The reduced cost of tubers treated in April was due primarily to the low farm price of yams at the time of treatment. In addition, the period of storage required, and the weight loss experienced were much less than that encountered by tubers treated in January.

It is possible that the break-even costs estimated here may be reduced by economies of scale, once the treatment is done commercially. By using the solution to treat several batches of tubers the cost of treatment would be further reduced. Jordan (1984) has shown that it is possible to use a given GA_3 solution for up to three times with no reduction of effectiveness.

Conclusions

Treatment with 100 ppm GA_3 would seem to be an economic and practical method of extending the period of availability of *D. alata* yams on the market. Such a treatment would guarantee that farmers would be able to market their yams at a reasonable price instead of being forced to dispose of the surplus rapidly and at a low price once dormancy is broken. In fact, production of *D. alata* could be increased in order to take advantage of the extended marketing period.

The potential for the treatment is assessed based on Trinidad prices in a Trinidad market. The analysis would have to be repreated in other countries in order to estimate the cost of treatment under different conditions.

References

Ferguson, T.U. (1985). Root crop production in the Caribbean: An analysis of need. Caribbean Collaborative Agricultural Research Network Workshop on Tropical Root Crops. Guadeloupe, July 9–10, 1985.

Jordan, A. (1984). The effect of gibberellic acid on the storage of tubers of *D. alata*. M. Phil. Thesis. U.W.I. Library, 111 pp.

Wickham, L.D. (1981). The extension of dormancy in tropical yams, *Dioscorea spp.* Ph.D. Thesis, U.W.I. Library, 154 pp.

RECENT DEVELOPMENTS IN POSTHARVEST HANDLING, STORAGE AND TRANSPORT OF FRUITS, VEGETABLES AND ORNAMENTALS

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ABSTRACT

State-of-the-art techniques used in the handling, storage and transport of perishable horticultural produce are presented. Emphasis is given to methods of quality evaluation, cooling, packaging and storage. Equipment and instruments which can be used for estimation of produce quality both in the field and at the research laboratory level are highlighted. The applicability of techniques to current postharvest systems in the Caribbean is examined.

RESUMEN

Se presenta las técnicas avanzadísimas que se utilizan en el manejo, el almacenamiento y el transporte de productos hortícolas que no se conservan bien. Se hace hincapié en los metodos de evaluación cualitativa, la refrigeración, el empaquetado y el almacenamiento. Se destaca los equipos y los instrumentos que se pueden utilizar para estimaciones cualitativas de los productos agrícolas, tanto en el laboratorio de investigación como fuera. Se examina las posibilidades de la aplicación de estas técnicas a los sistemas agrícolas actualmente utilizados en el Caribe en el período posterior a la cosecha.

In the Caribbean region, there has been an intensification of efforts to increase agricultural production with the aim of increasing self-sufficiency in food production and opportunities for export of agricultural produce. Postharvest technology plays an important role in reducing the tremendous losses which occur in distributing products and maintaining quality specified by domestic and foreign markets.

Many of the techniques used to handle perishables in developed temperate countries are not directly applicable to tropical areas. This is mainly the result of the unique physiological requirements of tropical produce, as well as the lack of infrastructure and/or capital required to implement these technologies. The selection and adoption of appropriate postharvest technologies are critical to the development and success of production-marketing systems in tropical regions.

This paper examines techniques used for handling perishables and their adaptability to tropical systems of production and marketing. Recommendations for improvements in handling, storage and distribution of tropical perishables are also given.

Harvesting

In the Caribbean, as well as in the more developed regions, fruits and vegetables are predominately harvested manually. The advantages of hand harvesting include selective harvest (accurate maturity selection and multiple harvests), minimum damage and economy. In addition, the small sizes of holdings and the availability of family labour often preclude the use of mechanical harvesting methods in the Caribbean.

The use of harvesting aids for fruits and vegetables is rapidly increasing. Harvey and Jeffers (9) developed a harvesting aid that successfully lifted yams *(Dioscorea* spp*)*, sweet potatoes, carrots and onions. More recently Harvey (personal communication) designed a two-row mechanical harvesting aid which lifted cassava *(Manihot* spp*)* with low levels of tuber damage.

Other types of harvesting aids include belt conveyors which move the commodity to a central loading or in-field handling device, scoops with protruding rods on their ends used to comb through some berry crops, and platforms or movable worker positioners with bins and other containers for accumulating the produce, used in crops such as bananas and papayas.

Picking poles are used extensively for harvesting mangoes and papayas. In Hawaii papayas (var. 'Solo') are harvested with the aid of a long-handled suction cup which is positioned over the stylar end of the fruit. Twisting the handle removes the fruit from the tree. In Thailand, a papaya picking implement has been developed for small orchards on hilly terrain. The implement consists of a pole and a bag. The top half is made of canvas and the bottom of nylon mesh. The mesh enables the picker to see the fruit and accurately position the blade. The harvested fruit falls into the bag, which is then lowered to the ground (2).

Picking bags and aprons are also useful harvesting aids. One such apron, recently developed by CARDI, has two compartments which allow for in-field grading. Zippers at the base facilitate emptying and minimize bruising. The apron has been recommended for harvesting of ochroes, peppers and cotton. A similar bottom-dump picking bag is used in California for harvesting stone fruits. It is essentially an open-ended bag with a base fold, the corners of which are fastened with two cords which are hooked to the sides of the bag during filling. The bag is emptied by releasing the cords and allowing the produce to fall through the open base.

A fairly recent development is night harvesting using lights erected on a mobile boom. The practice is common for cantaloupes and has the advantage of reduced cooling needs by taking advantage of night temperatures.

Packaging and packaging materials

Packages for horticultural produce should provide:

- Protection against handling abuse in marketing and distribution channels.
- Accommodation for temperature management of the produce during pre-cooling, storage and ripening.

- Wet-strength and compressive-strength characteristics compatible with in-package cooling operations, high volume packaging operations and handling systems in distribution channels.
- Consumer appeal, if used for display and promotion.

Field containers

Metal or plastic buckets are typically used for softer fruits in most of the larger production systems. The trends toward standardization and metrication of package types, unitization of pallet loads, and the use of packages for display in consumer channels, have led to an increasing use of in-field packages for some commodities. Within organizations or geographical areas, however, the trend is now towards the use of returnable plastic containers.

In the Caribbean, woven baskets, polypropylene sacks and wooden crates are commonly used as field and shipping containers for harvested perishables. While these containers have the advantages of high capacity and economy, they are less than ideal with respect to the level of damage to the produce they contain. Possible improvement can be achieved by more careful filling using supplemental packaging materials such as liners, wraps, trays, cups, shims, and pads, stacking containers within their design limits, and proper venting of containers. As trends in unitization and metrication of package sizes continue, it will soon become necessary for Caribbean countries wishing to capitalize on the opportunities for export to conform to specifications for package size and design.

In the United States, trends in packaging have gone from wood to corrugated containers, from hand packing to mechanical volume-fill and tight-fill packing with vibration settling, and from single package handling to unitized handling on pallets and slip sheets.

Recent trends in the use of polyethylene as a packaging material include the use of pallet covers, liners, and shrink wraps for individual fruit. TECTROL Atmosphere bags have been used successfully for strawberry shipments. The bag is sealed onto the pallet and a modified atmosphere is then injected. The bag can be left in place through warehouse rotation and transit (30). Perforated polyethylene bags are used for lining banana boxes destined for distant markets (Ramirez, personal communication).

Individual shrink wrapping of fruit, is receiving increased attention. Experiments with temperate and tropical fruits indicate that this method has high potential for reducing moisture loss and decay as well as increasing shelf life (3, 11, 18).

Transport

Trends in the transportation of produce deal mainly with temperature management and minimization of damage caused by abrasion, vibration or compression. Many of the techniques, although simple and practical in concept, have tremendous effects on maintenance of quality of the harvested produce.

Some of these techniques include:-

- Grading of access roads to eliminate ruts, potholes and bumps.
- Restriction of transport speeds to levels that will avoid free movement of produce.
- Reduction of tyre pressures on vehicles to reduce shock absorbance by produce.
- Use of air suspension systems on transport equipment. Surface marking injury levels are proportional to acceleration levels of containers carrying produce. As much as a 50% reduction in acceleration level of containers was possible with the installation of air suspension systems on truck and trailer axles (15).
- Inspection of container surfaces to determine potential for injury to produce.

The following temperature protection practices would be useful, especially under Caribbean conditions.

- Shading of the harvested produce under natural or artificial shade.
- Covering loads with light-coloured (silver or white) tarpaulin. The tarpaulin should be supported to maintain an air space over the load. Wetting the tarpaulin will further reduce warming by providing an evaporative cooling surface.

Refrigerated containers, used mainly for commodities imported into the Caribbean, are increasingly being used for transport and short-term storage of perishables. Considerable progress is being made in improving temperature management capabilities of refrigerated containers. Major developments include the manufacture of bottom-air delivery trailers with 6-cm deep T-beam floors and modification of refrigeration units by adding higher capacity fans to overcome air resistance offered by tight loads (13).

Cooling

Effective cooling and temperature management are essential for successful marketing. The choice of a cooling method depends on product adaptability, rate of cooling desired, potential for re-warming, type of packaging, package handling system, and cost.

A recent development in room cooling is the use of cooling bays. A single large room is divided into bays, air channels are constructed to direct air flow into each bay. The advangage of the system is that when cooling is complete, the air supply can be reduced independently of other bays (15).

Under Caribbean conditions, room cooling, forced-air cooling, and evaporative cooling seem to be best suited to the postharvest handling systems currently in use. Evaporative cooling techniques are very energy efficient and economical. Their main limitation is that air can be cooled only to the wet bulb temperature. In the less humid islands such as Antigua and Barbados, low wet-bulb temperatures would facilitate the use of evaporative cooling as a pre-cooling method. Minimum temperatures can, however, be reduced in the more humid islands by using multi-stage systems (29).

Storage

Recent advances in the storage of perishables have focused on the modification of atmospheric composition (carbon dioxide, oxygen and ethylene levels) in the storage environment.

A promising new development currently under evaluation for controlled atmosphere (CA) storage, is

the use of nitrogen separators or generators. Compressed air is circulated through molecular sieve beds, which separate nitrogen from other components. The N_2 produced is then used to flush the CA room and reduce the oxygen level.

During the past few years, there has also been an increase in the use of molecular sieve scrubbers for carbon dioxide control.

Ethylene has both beneficial and harmful effects on harvested horticultural products. The beneficial effects of ethylene in controlling ripening can be achieved by applying ethylene in liquid or gaseous form or by using the ethylene evolved from ripening fruit. Liquid sources include C_2H_4 – releasing chemicals such as ethephon. This chemical is registered in the USA and widely used for preharvest applications. It is also very popular as a postharvest dip for accelerating ripening of tomatoes and bananas in Trinidad and Tobago. Calcium carbide has been in use for many years by Caribbean farmers for 'forcing' (inducing synchronized flowering) pineapples and for ripening tomatoes. Carbide, as it is more commonly known, releases acetylene when it reacts with water. Simple reactors are available and can be used in partially vented spaces to ripen or degreen fruits under conditions where ethylene is not available (Reid, personal communication). The method may have potential for commercial application in rural areas in the Caribbean where compounds like Ethrel may be unavailable or too expensive.

Shot, trickle and flow-through methods, are currently available for applying ethylene gas in ripening rooms. With shot systems, there are difficulties in temperature management and gas monitoring. Trickle and flow-through systems are more widely used and have been proven to be safe and efficient for citrus degreening (32) and tomato ripening (25).

The detrimental effects of ethylene include accelerated senescence and loss of green colour in cucumbers and leafy vegetables, accelerated ripening of fruits, russet spotting of lettuce, development of bitterness in carrots, sprouting of root crops, senescence and 'sleepiness' in flowers and abscission of florets and calyces in potted ornamentals and melongene, respectively.

Strategies for protecting harvested perishables from these effects include avoidance, removal and inhibition The elimination of sources of ethylene is the best method for protecting perishables, especially under Caribbean conditions. Compatible product mixes should be used during transport, storage and display; ethylene-sensitive commodities should be isolated from ethylene-generating commodities such as ripening and decomposing fruits, exhaust from internal combustion engines, and cigarette smoke.

The removal of ethylene from the air can be achieved by ventilation with fresh air. Where ventilation cannot be used for removal, ethylene can be scrubbed from the atmosphere by trapping and/or conversion to other products.

Despite the large number of reagents and techniques which have been tested for ethylene removal in storage, potassium permanganate is the only one in commercial use. The compound must be adsorbed on a suitable carrier with a large surface area in order to be effective. Celite, vermiculite, silica gel, alumina pellets, perlite and expanded glass have all been successfully used as carriers (23). A number of scrubbers are available in the form of a sachets, filters, blankets and tubes.

Studies carried out on the storage of bananas (14) and green plantains (10) in polythene bags containing potassium permanganate scrubbers have shown that ripening can be delayed for as long as 25 days, at tropical ambient temperatures. The method, therefore, has considerable potential for use in the Caribbean in inter-island trade of fruits, vegetables and root crops. Banana shippers have found that the use of permanganate scrubbers causes burning of the fruit and that the additional weight increase in shipping boxes results in uneconomical shipping rates (Ramirez, personal communication). Experiments in the Philippines on the shipment of tomatoes with potassium permanganate carriers showed no apparent delay in the ripening of the fruits (8).

New catalytic-type absorbers, which allow lower combustion temperatures for warming up of gases for the production of oxidation products from ethylene, are being developed (Reid, personal communication). Another technology for ethylene removal which seems promising but which has yet to be commercially developed is the use of UV light (22). Also, there is potential for biological removal of ethylene using soil bacteria as a sink for atmospheric ethylene (1).

Controlled Atmosphere, Modified Atmosphere and Low Pressure Storage (CAS, MAS and LPS, respectively) offer potential for inhibition of ethylene. The use of LPS systems is not widespread and attempts at hypobaric storage and transportation have met with limited success (23).

Postharvest treatments

Many postharvest treatments are often applied to fruits, vegetables and root crops in order to control physiological and pathological changes which may impair quality.

Treatments to control disease

A technique recently developed for cassava *(Manihot esculenta)* to control the two types of postharvest deterioration, vascular discolouration and microbial deterioration, involves dipping the harvested roots in a 0.4% thiabendazole solution and packing in polyethylene bags. The fungicide prevents microbial growth and the bags provide the temperatures and relative humidities needed for the prevention of the vascular discolouration (5). Treating and packing the roots must be done on the farm. A delay of as little as 4 hours after harvest can increase losses after one week of storage from 2% to over 30%. Two weeks is the maximum recommended storage time. After this period, starches are converted to sugars, giving cooked roots an undesirable sweet flavour.

During the past 15 years, postharvest chemical treatments have been introduced for the control of storage losses due to infection in many major food crops. Benomyl and related benzimidazole compounds are still standard postharvest fungicide treatments where their use is permitted.

The use of fungicide-impregnated pads and wraps may have some potential for use in shipped commodities in the Caribbean. Sumbali and Mehrotra (28) used iodine-potassium wrappers to control storage decay of pome fruits. Burning of citrus fruits in boxes containing spent biphenyl pads was, however, reported for some shipments exported from the

U.S. to Holland (Hoogendoorn, personal communication).

The future of current chemical treatments cannot be regarded as secure because of (1) the emergence of tolerant strains of *Botrytis* and *Penicillium;* (2) requirements for establishment of residue tolerances for postharvest chemical treatments and (3) standardization of practices for the application of chemicals to crops (6, 7). The latter two factors have important implications for the export of commodities from the Caribbean to Europe and the United States.

Although restriction of chemical usage may encourage new advances in nonchemical postharvest decay control, there may not be significant results for many years. In the meantime, expanded research on the best use of available and newly developed chemicals appears to be the most appropriate strategy to reduce postharvest losses caused by infection (17).

Insect control treatments

Insect control treatments currently used for harvested fruits and vegetables primarily involve the use of fumigants, such as ethylene dibromide (EDB), methyl bromide (MB), and hydrogen cyanide. EDB has recently been shown to be both carcinogenic and mutagenic; alternative treatments to EDB are being actively sought.

Cold treatments (10 days at 0 °C) have been found to give control of some fruit flies in apples, oranges and pomegranates. They are not suitable for highly perishable or chilling-sensitive commodities such as avocado, papaw, mango, tomato and pepper. Cold treatments may be used only for commodities which can be made tolerant to low temperatures or for commodities for which length of storage time is not critical (16).

Until very recently, a combination hot water/EDB treatment was used for control of Mediterranean fruit fly infestation in papayas shipped from Hawaii. Restriction on the use of EDB has led researchers at the USDA–ARS Laboratory in Hilo, Hawaii to develop a 1-hour double-dip heating treatment. Fruits are submerged in water at 42°C for 40 minutes, followed by 20 minutes at 49°C. The first dip kills eggs of the fruit fly which tend to lie 2 - 5mm under the skin of the fruit. The treatment has potential for use on other crops (27; Chan, personal communication).

The most publicized alternative treatment for insect control is the use of gamma radiation. A recent proposal by US Food and Drug Administration (FDA) to allow treatments up to 1 KGy (100 Krad) on foods (31), as well as promising results of studies on insect sterilization, make the use of radiation appear promising. A number of factors should, however, be considered. These include detrimental effects from dose levels below 1 KGy, logistics of application of the treatment, economics of the treatment, and social and public reaction to consumption of irradiated foods (4, 23).

The type of postharvest handling produce receives and the physiological and physical condition of the produce have an effect on losses incurred. For example, fruits with high vitality exhibit considerable resistance to fungal attack, while stressed or senescent fruits are often disease prone. Handling procedures should emphasize methods which maintain product quality and which directly or indirectly limit the potential for invasion and development of pathogens.

Treatments to retard ripening and senescence

Various coatings and dips are in use for delaying ripening in fruits. Coatings such as Tal Prolong® and Pick 'N' Save® utilize a modified micro-atmosphere around the product. They are transparent and tasteless sugar-based films which are non-toxic and edible. Reportedly, these products slow down respiration and metabolism as well as retard ripening by restricting the rate at which gases and water vapour move across the fruit skin. Pick 'N' Save® is being offered in a kit and is suitable for apples, pears, cherries and plums (12).

Calcium compounds have been used to dalay ripening and senescence in some fruits. Singh and Chauhan (26) showed that treatment of guavas *(Psidium guajava)* with calcium nitrate solution delayed the onset of senescence and maintained edible quality of the fruit for over 6 days. Recent studies in Australia with tomatoes, mangoes and avocadoes have shown that infiltration of calcium chloride into the freshly harvested fruits delays ripening. Treated tomatoes remained green indefinitely and the ripening time for mangoes and avocadoes was increased by about 40% (21).

Measurement and detection systems

Psychrometric properties of the air (such as temperature and relative humidity) and levels of atmospheric gases (such as ethylene, oxygen and carbon dioxide) are commonly measured storage parameters. A dewpoint hygrometer being developed for laboratory use is the chilled-mirror hygrometer. The morror mounted on the instrument is chilled to a specified dewpoint temperature. The onset of condensation on the surface of the mirror is detected by a change in reflectance which can then be easily measured electronically.

Ethylene detectors being developed for use in commercial storage include the Snoopy detector which can detect ethylene only at high levels (1 ppm). It has been tried with limited success in apple storages in England and New Zealand (19). Spot checks in transit shipments may easily be carried out using detector tubes which have a sensitivity limit of 1 ppm of ethylene. A new ethylene detector currently under development is a photoionization detector. The instrument is based on the reaction of ozone and ethylene. The wave length of the light emitted in the reaction is specific and can be easily measured after magnification in a photomultiplier tube.

Conclusions and recommendations

In the Caribbean, the benefits of several of the technologies described can be achieved using simple, yet effective practices. Careful harvesting, use of precooling methods such as evaporative and forced-air cooling, careful filling of produce into containers, the use of protective packaging materials, improvement in temperature management during transport and storage, avoidance and removal of ethylene during transport, storage and display, the use of ethylene releasing solutions for ripening, and the use of heat treatments for insect and disease control, offer the greatest benefits.

Sophisticated technologies such as controlled atmosphere, modified atmosphere and hypobaric (low pressure) storage need to be evaluated in terms

of their suitability for tropical commodities and in terms of their cost effectiveness. Cooling methods such as hydrocooling and vacuum cooling are unfeasable in the Caribbean due to the high level of quality control and operational skills required for efficient management of such facilities, in addition to their high costs.

Literature Cited

1. Abeles, F.A. 1982. Ethylene as an air pollutant. *In* Symp. on Ethylene in Agriculture and Forestry. Agr. For. Bull., Univ. of Alberta, Edmonton. 5(1) : 4–12.

2. ASEAN. 1981. A new papaya picking implement. ASEAN Food Handling Newsletter, July 1981.

3. Ben Yehoshua, S. 1983. Extending the life of fruit by individual seal packaging in plastics film: Status and Prospects, Plasticulture 58 : 45 – 58.

4. CAST 1984. Irradiation of plant products. Comments from CAST.

5. CIAT (Centro Internacional Agricultura Tropical). 1984. TDRI/CIAT Collaboration to reduce postharvest deterioration of cassava. Cassava Newsletter 8 (2) :4.

6. Coomes, T.J. and J.F. Howlett. 1985. The regulation of postharvest chemical treatment in the UK and Europe – past, present and future. *In:* Use of pesticides to control postharvest losses in food crops. Chem. and Ind. 87–90.

7. Edney, K.L. 1985. Fungal rotting in stored fruit. *In:* Use of pesticides to control postharvest losses in food crops. Chem. and Ind. 75–77.

8. Esguerra, E,B. and E.V. Labios. 1984. Evaluation of potassium permanganate carriers during the transport of tomatoes. Postharvest Res. Notes 1 (2).

9. Harvey, W. O'N. and J.P.W. Jeffers. 1973. Attempts at mechanical harvesting of root crops in Barbados. Proc. Carib. Food Crops Soc. 11 : 259-264.

10. Hernandez, I. 1972. Storage of green plantains. Tech. Rept. 144, J. Agric. Univ. Puerto Rico.

11. Idol, R.C. 1983. Individual seal wrapped fruit from the perspective of a packaging company. Presented at the University of California Postharvest Pest Control Course, Apr. 13, 1983.

12. International New Product Newsletter. Fruit coating. Aug. 1985. 1.

13. Kasmire, R.F. 1984. Progress in product transit temperature management. Perish. Handl. 55 : 2.

14. Liu, F.U. 1970. Storage of bananas in polyethylene bags with an ethylene absorbent. HortSci. 5 : 25-27.

15. Mitchell, F. 1985. Cooling horticultural commodities. *In:* Postharvest technology of horticultural crops, Cooperative Extension, University of California, Special Publication 3311, p. 28.

16. Mitchell, F. G. and A.A. Kader. 1985. Postharvest treatments for insect control. *In*: Postharvest technology of horticultural crops. Cooperative Extension, University of California. Special Publication 3311,p. 100.

17. Ogawa, J.M. and B.T. Manji, 1984. Control of postharvest diseases by chemical and physical means. *In*: Postharvest pathology of fruits and vegetables: Postharvest losses in perishable crops, Publ. NE – 87, UC Bull 1914 (ed. Moline, H.E.).

18. Packaging Digest: Wrapping up long life. October 1983.

19. Reid, M.S. 1985. Pulse treatments with silver thiosulphate and sucrose improve the vase life of sweet peas. Perish. Handl. 57.

20. Reid, M.S. 1985. Postharvest handling of lily of the nile flowers. Perish. Handl. 57.

21. Scott, K.J. 1984. Methods of delaying the ripening of fruits. ASEAN Horticultural Product Handling Workshop Report, ASEAN Food Handling Bureau, Kuala Lumpur.

22. Scott, K.J. and R.B.H. Wills. 1973. Atmospheric pollutants destroyed in an ultraviolet scrubber. Lab. Practice 22 : 103–106.

23. Sherman, M. 1985. Control of ethylene in the postharvest environment HortSci. 20:27-60.

24. Sherman, M. 1985. Irradiation of fresh fruits and vegetables. Handl. Florida Veg. 85 (1) : 2.

25. Sherman, M. and D.D. Gull. 1981. A flow-through system for introducing ethylene in tomato ripening rooms. Vegetable Crops Fact Sheet, Florida Coop. Ext. Serv. VC-30.

26. Singh, K. and K.S. Chauhan. 1981. Effect of postharvest calcuim treatments on the storage life of guava fruits. Indian J. Agric. Sci. 51(1):44-47.

27. Sommer, N.F. 1985. Postharvest handling systems – tropical fruits. *In:* Postharvest technology of horticultural crops. Cooperative Extension, University of Carlifornia, Special Publication 3311, p. 164.

28. Sumbali, G. and R.S. Mehrotra. 1983. Control of postharvest diseases of temperate fruits by chemical, and treated wrappers. Indian Phytopath. 36 (2): 270 - 273.

29. Thompson, J.F. 1985. Storage systems *In:* Postharvest technology of horticultural crops. Cooperative extension, University of California. Special Publication 3311, p. 49.

30. TRANS FRESH Corporation 1985. When do you take the TECTROL bag off? Report No. 102.

31. U.S. Govt. 1984. Federal Register 49 (31) : 5714 –22.

32. Wardowski, W.F. and A.A. McCornack 1973. Recommendations for degreening Florida fresh citrus fruits. Fla. Coop. Ext. Serv. Cir. 389.

THE POTENTIAL FOR CONTROLLED ATMOSPHERE STORAGE OF SOME CARIBBEAN CROPS

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ABSTRACT

Modified atmosphere storage can increase the storage life of certain perishable crops beyond what is normally expected in refrigerated storage. This involves a change in the gaseous composition of the atmosphere surrounding the crop, with carbon dioxide and oxygen being principally affected. This technique may have potential for extending the storage life of tropical crops and avoiding the effects of chilling injury.

This paper reviews the state of research and examines the potential for controlled atmosphere storage of avocado, *(Persea americana)*, breadfruit *(Artocarpus altilis)*, cabbage *(Brassica oleracea)* and mango *(Mangifera indica)*, crops which are important to the Caribbean region.

RESUMEN

Almacenamiento en atmósfera modificada puede aumentar la vida poscosecha de ciertos cultivos de caracter perecedero a mas de lo que normalmente se espera en almacenamiento refrigerado. La modificación en atmósfera se trata de un cambio en la composición gaseosa de la atmósfera alrededor del producto, con dióxido de carbón y oxígeno siendo los principalmente afectados. Esta técnica puede tener éxito en extender la vida poscosecha de cultivos tropicales y en evitar los efectos de daño por el frío.

Este informe revisa el estado de investigación hasta hoy en día y examina la posibilidad de almacenamiento en atomósfera modificada para el aguacate *(Persea americana)*, fruta de pan *(Artocarpus altilis)*, repollo *(Brassica oleracea)* y mango *(Mangifera indica)*, cultivos de importancia a la region del Caribe.

The importance of fresh fruits and vegetables has resulted in considerable trade in these commodities which provide essential nutrients in the human diet. There are considerable postharvest losses, however, in these fresh fruits and vegetables. Figures varying from 25 to 80% have been reported for loss of these commodities (19, 39).

In the Caribbean Islands, the need to reduce such losses cannot be over-emphasised. A Commonwealth Secretariat Report (61) provided the following summary with respect to the perishable crop storage:

"(i) All the islands are engaged in the production of perishable commodities which are seasonally produced.

(ii) Agriculture is export oriented and the bulk of the unexported fruit is thrown away. At times they are simply left in the field to rot.

(iii) Postharvest losses are extremely high, rising to about 50%.

(iv) Research, training programmes and on going projects are generally minimal or non-existent, so that the position in a number of territories today is as it was many years ago with little being done to reduce postharvest losses. In one or two instances where research has been finalised in specific areas, there has been no follow up action and losses continue unabated."

To date, the above position remains unchanged. It has been suggested that for many countries, increased availability of food crops can be achieved through improved conservation and storage techniques rather than efforts only aimed at increasing production levels. The development of improved storage methods for Caribbean crops could impact on the economics of many islands as follows:-

(i) A reduction in the importation of perishable commodities that are seasonally produced in the Caribbean, and hence a savings in foreign exchange.

(ii) Increased exports of Caribbean crops to overseas markets particularly to North America and Europe.

This paper reviews the state of the art with respect to research on storage of some selected Caribbean crops, viz; avocado, breadfruit, cabbage and mango. Emphasis is given to storage techniques which employ modification of the atmosphere.

Avocado *(Persea americana)*

Refrigerated storage

Numerous recommendations have been made with respect to temperature ranges for the storage of different varieties of avocados. These are usually related to production sites, duration of storage, and transportation demands.

Reports on cold storage of avocados date as far back as 1907 when Higgins (29) reported a successful export of Hawaiian avocados to San Francisco. Later, Harold (24), reported that Hawaiian avocados may be stored green at 2.2°C for 6 to 8 weeks thereafter ripening in 2 to 5 days.

Overholser (38) found that a temperature of 4.5°C was satisfactory for all California avacado varieties tested except the 'Fuerte' which required 7.2°C to prevent blackening of the skin. In general, a temperature of 0°C was found to be too low since it led to skin discolouration. However, it was mentioned that some varieties may be satisfactorily stored at 0-2°C for up to two months while others kept for 4–6 weeks.

The first reports of cold storage of West Indian varieties were made by Wardlaw (63) and Wardlaw and Leonard (64). The preliminary observations suggested that of the 33 varieties tested, 22 were not sufficiently cold-resistant to withstand a temperature of 5–12°C for a period of 15 – 20 days without developing characteristic discolouration. The remain-

ing varieties, for example the 'Pollock', ripened normally at 21°C after being held for 15–20 days at 4.5°C. An additional storage period of 10 days at 4.5°C caused slight abnormal changes to gradually be developed. These results were confirmed by Smith (50) and Ward (67). In addition, Ward (67) reported that contrary to expectations, a pure Guatemalan type, 'Panchoy', grown in Trinidad was found to be subject to chilling injury in storage.

Many recommendations have since been made for the cold storage of different cultivars of avocado. For 'Taylor', Lyle (36) reported a storage temperature of 5–6°C without indicating the length of storage time. In Florida, Hatton *et al*, (26), found that the best storage temperature for the locally grown fruit was 15°C. Erickson and Tadaaki (18) found that 'Hass' was in acceptable condition after being kept for 32 days at 9°C.

In Israel, workers studied the behaviour of 'Etinger', 'Fuerte' and 'Nabal' stored for 1, 2, 3 and 6 weeks at 0, 2, 4 and 6°C. They found 'Nabal' from Guatemalan stock, to be most tolerant to the storage conditions tested.

In Egypt, Abou Aziz *et al* (1) reported that 10°C was the best temperature for storing the Mexican variety 'Duke' for periods of up to two weeks.

Arriola *et al* , (4) reported that among the varieties stored in Guatemala, 'Hass' can be stored for three weeks at 12°C, wheras 'Azteca', 'Guatenca' and 'Fuerte' withstood slightly shorter storage periods. When these varieties were stored at 7°C, ripening was retarded by 4 to 6 days.

It appears that the Mexican and Guatemalan varieties and their hybirds such as 'Hass' and 'Fuerte' are more resistant to cold than the West Indian varieties.

Modified atmosphere storage

In an effort to extend the shelf life of avocados, a fair amount of research has been reported with modified atmosphere storage. A wide range of recommendations, dependent upon variety, are put forward.

In Israel, Aharoni (2) stored 'Fuerte' at 8°C and 12°C in polyethylene bags for 23 days and 'Nabal' for 46 days. Fruits stored at 14, 15 and 17°C softened and many rotted.

In Grenada, Halkon (23) investigated the use of packing treatments. He reported that sealed polyethylene bags prolonged storage life more than any other treatment. In one trial, polyethylene wrapped avocados required an average of 20 days to soften, whereas the unwrapped fruit took 12 days. Although no definite conclusions were drawn nor recommendations it was noted that fruit stored below 12.7°C for more than one week generally showed some form of chilling injury.

Audit and Scott (5) working in Australia packed 'Hass' avocados individually in sealed polyethylene bags and experimented with potassium permanganate as an ethylene absorbent. The fruits were then stored at 10°C and ripened at 20°C after they began to soften. Packing fruit in these bags markedly increased the storage life and softening was further delayed by the use of potassium permanganate. There was no apparent deterioration in the eating quality 40 to 50 days after storage, but the occurrence of anthracnose usually made it necessary to terminate storage, even though the fruits were quite firm. These results were confirmed by ICAITI (30) and Scott and Chaplin (48).

Chaplin and Hawson (13) further investigated the use of polyethylene bags at ambient temperatures for various storage times. The modified atmosphere which developed in the bags retarded ripening and helped fruit stay firm. Abnormal ripening characteristics were observed, however, when storage temperatures were high and storage time exceeded 8 days.

Several researchers have used combinations of CO_2 and O_2 in controlled atmospheres to extend the useful storage life of fruit. In Florida, Hatton and Reeder (27) investigated storage of 'Lula'. Using a constant flow system to purge the ethylene gas, they reported limited success initially with CA storage using 1% O_2 and 9% CO_2 levels at 10°C. The flow was adjusted so that fruit respiration would not reduce to O_2 level below 1 to 1.5% O_2, a condition where injury was likely to occur. One hundred per cent of 'Lula' avocados stored at 2% O_2 and 10% CO_2 at 7°C were in acceptable condition after 20 or 40 days, while all fruit decayed when stored in air. External darkening and percentage weight loss were significantly lower for fruit held in CA than in air. Vakis *et al* (59) also showed that 10% CO_2 storage atmosphere reduced the incidence of chilling injury of 'Taylor' avocados.

Spalding and Reeder (52) observed that all fruits of 'Lula' and 63% of 'Booth' were acceptable after 60 days storage under 10% CO_2 and 2% O_2 at a temperature of 7°C. Bleinroth *et al*, (10) found that among the nine varieties studied in South America at a temperature of 7°C in an atmosphere of 10% CO_2 and 6% O_2, 'Prince' and 'Wagner' had the longest storage life, 37 days in CA and subsequently, 2 days in air.

In Israel, Apelbaun *et al* (3) found that reducing the atmospheric pressure in the refrigerated storage chamber at 6 °C markedly retards avocado ripening. The effect was found to be more pronounced when the pressure was reduced below 100 mm Hg. Fruit stored at 760 and 200 mm Hg ripened in 35 and 50 days respectively, while the fruit stored at pressures below 100 mm Hg remained unripe for 70 days in storage. The best storage pressure tested for avocado was 60 mm Hg. Although ripening was markedly retarded under sub-atmospheric conditions, all fruits ripened normally several days after being transferred to normal atmospheric pressure and a temperature of 14°C. This showed that the fruit retained the ability to undergo normal ripening processes, including developing proper texture and taste.

Breadfruit *(Artocarpus altilis)*

Breadfruit has an extremely short storage life under normal conditions and is considered unpalatable as soon as it becomes soft and sweet. This factor results in difficulties with respect to marketing breadfruit locally when there is an export potential in temperate countries (9). Even transport by air is a difficult proposition.

Detached breadfruit has a high respiration rate, reaching a climacteric peak of above 3ml CO_2 per kg/hr at 20°C five days after harvest (6). Information on methods of storage and on the storage life of breadfruit is limited. Several methods for preserving breadfruit have been reported including fermentation (8). Passam *et al*, (41) reported that segments of peeled breadfruit which have been boiled for a short period and frozen at – 15°C could be stored for

approximately 11 weeks. After cooking, frozen samples compared favourably in flavour, colour and texture with fresh breadfruit. Ward (62) in his investigations on ensilage in Jamaica reported that the product was unfit for human consumption. It was also mentioned that breadfruit slices in a brine solution are canned for local and export markets.

Thompson *et al* (57) studied the effect of maturity, temperature and wrapping treatments on breadfruit of the yellowheart and whiteheart types. The temperatures studied were 27.7°C, 12°C and 7°C. It was reported that storage at 25° – 28°C resulted in complete softening of the fruits in 2–4 days while at 12.5°C, softening occured in 8.3 days. At 7°C, softening was greatly delayed. When ripening eventually began, it was irregular and abnormal either because of prolonged storage or transfer to ambient conditions. They also found that soluble solids developed within 3–4 days at 28.5 °C and even more rapidly when fruits were transferred from 12.5°C to ambient temperatures. However, some fruits which were stored at 2.5 °C accumulated little soluble solids either during storage or when removed to ambient conditions. It was postulated that softening appears to be associated with the accumulation of soluble solids, a process which normally accompanies the ripening of climacteric fruits. In other experiments, 38 µm polythene bags (150 gauge) were found to significantly extend storage life at both high and low temperatures. At 24.5 ° C, the extension was from 2.8 to 14.1 days and at 12.5 ° C, from 8.3 to a maximum of 21.5 days. During storage, the fresh green appearance was maintained. When fruits ripened, they did so normally. In addition, storage life appeared to be unaffected by either the stage of maturity at harvest or harvesting method. Fungal and bacterial infections were uncommon. Additionally, when fruits were removed to ambient conditions from storage below 12°C, it was consistent with the hypothesis that chilling injury occurs under such conditions.

The increase in the storage life of breadfruits packed in polyethylene bags was further confirmed by Marriot *et al*, (37) in Jamaica. Sealed 25 um polyethylene bags (100 gauge). and 50 µm bags (200 gauge) were used. The mean time to softening for unwrapped fruits was found to be 5.2 days, whereas for polythene wraps these times were 7.1 and 18.7 days respectively. Softening was usually internal for unwrapped fruit and those in 100 gauge bags; it was usually superficial and accompanied by browning for fruit in 200 gauge bags. In addition, storage life was greater for fruits harvested partially mature (light green, closely packed fruit segments) compared to fully mature (dark green, large fruit segments) fruits.

In Trinidad, Passam *et al*, (41) reported that breadfruit of a local whiteheart type enclosed in polyethylene bags could be stored in a fresh marketable state at 14 ° C for up to 10 days. Inclusion of an ethylene oxidizing agent did not improve storage significantly.

Cabbage *(Brassica oleracea)*

Storage

There has been little reported on refrigerated storage of cabbage in the Caribbean. In Trinidad, Trotman (58) reported that cabbage was placed in cold storage due to a large crop and unremunerative prices. The objectives were to avoid waste and relieve markets and also to obtain information on the possibility of storing locally grown varieties. Unwrapped cabbages were packed in crates normally used for the export of grapefruits. They were cooled by air blast. Temperatures ranged between 2.2 ° C and 5.5 ° C for the first 5 weeks and between 4.4 ° C to 15.5 ° C for 4 additional weeks. Relative humidity was practically 100% for the first two weeks and varied between 82–90% for the remainder of the storage time. As the storage was operated commercially, it was necessary to sell as much as possible, hence the removal of cabbage from storage was based on market conditions. Cabbages were first removed after five weeks and the last batch after nine weeks. Weight loss for withdrawn cabbages varied between 5% and 13% whereas trimming losses varied between 8% and 22%. It was reported that cabbages were unattractive in appearance when withdrawn from cold storage, the outer leaves being wilted and brownish, though the hearts were sound and in good condition. Taste was evaluated but it was noted that as the storage time increased, deterioration extended more deeply into the head. It was concluded that the net saleable weight declined at a rate of about 5% per week.

Outside of the Caribbean area, there has been a substantial amount of research on refrigerated and modified atmosphere storage for long term preservation of temperate cultivars of cabbage. Parsons (40), reported that cabbages were stored in crates lined with perforated and non-perforated polyethylene as well as in unlined crates. They were stored for various periods at 0 °C, 3.3 °C and 7.2 °C. Cabbages stored at 7.2 °C deteriorated more rapidly than those stored at lower temperatures. Approximately 80% of the cabbages placed in storage remained edible after 8 weeks at 0 °C, 6 weeks at 3.3 °C and 4 weeks at 7.2 °C. Moisture loss, trimming losses and fresh green colour retention were best for polyethylene lined as compared to unlined crates. The use of polyethylene liners was beneficial at all experimental temperatures for prolonging the storage life and maintaining the original quality of the cabbage.

Isenberg and Sayles (31) attempted the long term storage of Danish cabbage in New York. Tests were conducted at 0 °C ± 0.5 °C using walk-in refirgerators with individual compartments of plywood. Atmospheres were developed from bottled gas and were flushed daily. In a series of experiments over a four year period, atmospheres were tested in combinations ranging from 2.5% to 10% for both CO_2 and O_2 for periods of 125–200 days. Atmospheres containing in excess of 5% of either CO_2 or O_2 were not better than air. When tested were conducted at 4.5°C, there was a considerable increase in storage rots so that cabbage would have not been accepted commercially. Thus this treatment was eliminated after initial tests. Further observation yielded no marked internal changes in any of the treatments where CO_2 and O_2 levels were 5% or less. The cabbage stored at 2.5% O_2 and CO_2 was often abnormally sweet, but cabbage stored at 2.5% O_2 and 5% CO_2 was much more acrid to taste, similar to fresh cabbage in the field. Air stored cabbage was flavourless. Trimming was generally low. The most prominent aspect of cabbage in modified atmosphere storage was the reduction in the rate of colour loss.

Several subsequent reports were in agreement with the conditions reported above. Van Den Berg and Lentz (60) found storage life between 3.5 °C, 4.5 °C

and 7.8 °C was limited to 4–5 months and 2–3 months respectively, and at 0–1 °C there was little rotting and internal growth after 7 months storage. In addition, they found the storage of cabbage at a RH near saturation (98–100%) reduced decay, moisture loss and colour loss substantially when compared to 90–95% RH. Geeson (21, 22) found storage life up to 10 months at 0–2°C, 3% O_2 and 5–6% CO_2 with remainder being nitrogen. Furry *et al* (20) summarized similar results but noted the necessity for the reduction of ethylene gas concentration to a very low level. Wang (61), found that Chinese cabbage was not saleable without extensive trimming after 3 months of storage in air at 0 °C but in 1% O_2 and at 0°C they were still saleable after 5 months of storage with only slight trimming. No off-odour, off-flavour, or other symptoms of sub-oxidation were found at the end of 5 months storage at 1% O_2 at 0°C.

Hicks and Ludford (28), reported on the effects of low ethylene levels (1 ppm) on the storage of cabbage. Ethylene was found to have a definite detrimental effect on the appearance of cabbage when added to air atmosphere but little effect on controlled atmosphere. Similarly, weight loss in storage was greatest in air plus ethylene as was the decrease in total sugars.

Mango *(Mangifera indica)*

Refrigerated storage

It was noted by Thompson (54) that the minimum temperature for the storage of West Indian mango cultivars has been given as 4–7°C (49), 8.6°C (7) or 6 to 7°C and for Florida cultivars, 10°C (45). Below these temperatures in cold storage, or on subsequent removal to higher temperatures it was generally found that fruits do not ripen normally. Wardlaw and Leonard (65) reported that chilling may be manifested in several ways including the production of skin blemishes, failure to develop normal colour on ripening, failure to ripen on removal from cold storage and a notable decline in pathogenic resistance. It was further stated that susceptibility to chilling injury varies with maturity at harvest, season and the duration of exposure to low temperatures. Fungal diseases are common in stored fruits, the most important being anthracnose. Pennock and Mandonado (43) and Smooth and Segall (51) showed that hot water treatment of mango fruits reduced the incidence of anthracnose decay.

Thompson (54) investigated the storage of West Indian mangoes with respect to cultivars, wrapping, temperature, size and shape, and maturity at harvest. It was found that different cultivars harvested in the same area and stored under the same conditions showed different degrees of susceptibility to disease development. Placing fruits in polyethylene bags significantly delayed ripening but led to physiological breakdown of tissue probably caused by CO_2 toxity after prolonged storage. It was further reported that fruits stored at lower temperatures had less weight loss. No fungal lesions developed with storage temperature of 8.5°C for 6 weeks, whereas mangoes stored between 13°C and 16°C were badly rotted after 4 weeks and those stored at 21°C rotted after 2 weeks. Fruit stored at 10°C for 14 days showed excessive fungal development. Fruit stored at 7°C for 26 days, however, ripened normally when moved to a higher temperature. Generally fruit at Stage B maturity* stored best with little evidence of fungal development over a 28 day period. The flavour of the ripened fruit was consistently good. Thompson (54) concluded that no evidence of chilling could be detected in storage at 5°C and above. Immature fruits did develop chilling symptoms when stored below 10°C; Stage B proved optimum for storage over a period of three to four weeks. The optimum temperature was not specified. In addition a shorter storage life was characteristic of more mature fruits.

In further experiments, trial shipments to the United Kingdom were successful at 4°C for 2 days followed by 13°C for 10 days. A more detailed evaluation of wrapping was highlighted. West Indian cultivars 'Julie' and 'Ceylon' harvested at Stages B and C** were reported to be commercially highly acceptable (55).

Samoya de Arriola (47) reported that fruits of the 'Mamey' variety grown in Guatemala stored best at 12°C at which temperature the fruit remained in good condition for 21 days. Lower temperatures induced chilling symptoms. Passam (42) investigated the storage of some West Indian varieties in Trinidad which had the potential for export. A temperature of 14°C was selected, corresponding to the temperature used for shipping bananas to Europe. At ambient temperature, fruits of all cultivars ripened in 3–8 days; at 14°C, storage life ranged from 12 to 18 days for the 'Graham', 16 days for the 'Julie' and 13 days for the 'Hayden'. Beyond this period, fruits ripened in a further 3–8 days when removed to ambient temperature. Enclosing the fruit in polythene extended the storage life by an additional 2 days for 'Julie', 4 days for 'Graham' and 15 days for 'Hayden', but with this method occasional off flavours developed.

Controlled atmosphere storage

Banarjee *et al*, (7), reported that mangos stored in an atmosphere containing over 15% CO_2 did not develop the normal red or orange colour, but instead developed a pale yellow colour. The flavour, however, was good. Karmarkar and Joshi (35), reported that a CO_2 concentration of up to 11% had no depressing effect on the respiratory activity of mangos. Kapur, *et al* (34) found the quality of 'Alphonse' mangos unimpaired when stored in an atmosphere of 7.5% CO_2 for 35 days at 8.5°C; similarly, 'Raspuri' mangoes could be stored for 49 days at 5.5 °C to 7°C. Fruits were unimpaired and they ripened satisfactorily within 3 days of removal from CA storage.

Hatton and Reeder (27) investigated the response of 'Keitt' mangos to storage in several types of controlled atmosphere at 12.8°C. This temperature was previously noted to be the optimum one for 2 to 3 weeks cold storage of most Florida mangoes. The best condition tested for maintaining quality during storage was 5% O_2 and 5% CO_2 for 20 days. Diplodia stem-end decay was the most evident factor limiting the duration of storage. Weight loss and softening were considerably reduced compared to fruit stored in air. It was concluded, however, that the small time advantage gained by storage in controlled atmosphere precluded its practical use.

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* Stage B – A stage of maturity where the shoulder is raised above the hollow where the stem end is inserted.

** Stage C – A further stage of maturity at which the fruit is at the point of becoming soft.

Bleinroth *et al* (11) working in South America had better results.

The varieties, 'Carlota', 'Hayden', 'Jasmin' and 'Soa Quiriro' were subjected to CA storage because of their susceptibility to temperatures below 8°C. Under normal refrigerated storage at 8°C with a RH of 90%, 'Carlota' and 'Hayden' lasted for 2 weeks and 'Jasmin' and 'Sao Quiriro' for 3. 'Hayden' could be stored for 30 days while 'Carlota', 'Jasmin' and 'Sao Quirior' lasted for 35 days at 8°C and 90% RH in an atmosphere containing 10% CO_2, 6% O_2 and 84% N_2.

Kane and Marcellin (33) reported 'Julie' and 'Amelie' had a storage life of approximately 4 weeks at 11 to 12°C when CO_2 levels were increased to 5% and O_2 levels decreased to 5%.

Discussion and conclusions

West Indian avocado varieties seem to be least tolerant to cold storage with a life of 15 days at 12 °C. Polyethylene wrapped fruits had a storage life of 15–20 days (23). Florida avocados subjected to controlled atmosphere storage lasted for 40 days (52). Wardlaw and Leonard (64) noted that some West Indian avocados showed surprising tolerances to gas storage, including some that were chilling sensitive. No definite conclusions were drawn however, and no further research on CA storage conditions using West Indian varieties was reported.

Breadfruit can be exported successfully as a whole fruit providing conditions for its safe storage are well defined. Storage in sealed polyethylene bags below a temperature of 12°C for over 8 days results in chilling injury (57) whereas storage in perforated bags has no effect (56). These results suggest that CA storage should be investigated.

In temperature countries, storage conditions for cabbage are well defined. Some cultivars respond favourably to long term (about 8 months) storage at 0–1°C, 2.5% O_2 and 5% CO_2 (20). There is an absence of information, however, with regards to the storage of West Indian varieties. Since this vegetable can be considered seasonal, long term storage is necessary if a year round supply for local consumption at relatively constant prices is to be maintained.

Hatton and Reeder (27), did not find controlled atmosphere storage of mangos encouraging, whereas Bleinroth (11), noted that the storage life of certain varieties doubled under CA conditions. Kane and Marcellin (33) noted that the variety 'Julie' (which has considerable export potential) showed improved storage in CA. Passam (42) indicated that for West Indian mango varieties, storage life increased for polyethylene wrapped fruits. It was also noted, however, that off-flavours and symptoms of CO_2 injury developed.

This review on the storage of avocados, breadfruit, cabbage and mangos shows that there is considerable scope for research in the Caribbean in order to obtain optimum storage conditions for, domestic varieties of these crops. While some attempt has been made to reach this goal for crop storage under normal refrigerated conditions, CA storage has been studied only superficially. This may also be true for other perishable crops growing in the Caribbean.

Literature cited

1. Abou Aziz, A.G., F.K. Abdel-Wahak, *et al* 1975. Effect of different storage temperature on keeping quality of avocado fruit. Curr. Sci. 44: 56–57.

2. Aharoni, Y., *et al* 1968. Effects of gradually reducing temperature and polyethylene wraps on the ripening and respiration of avocado fruit. Israel J. Agr. Res. 18 (2) : 77–82.

3. Apelbaun, A.G., *et al* 1977. Prolonging storage life of avocado fruit by subatm. press. HortSci. 12 (2) : 115–117.

4. Arriola, M.C. de, J.F. Menchu and C. Roltz. 1976. Seminar on Tropical Fruits (OAS – MEXICO).

5. Audit, D.D and K.J. Scott. 1973. Storage of 'Hars' avocadoes in polyethylene bags. Trop. Agric. 50 : 241–243.

6. Baile, J.B. and D.E. Baccus. 1970. Respiratory patterns of tropical fruits of the Amazon Basin. Trop. Sci. 12 : 93–104.

7. Banerjee, B.N., D.C. Karmarkar and G. R. Row. 1934. Investigations on the storage of mangoes. Agric. and Livestock in India:4 . 36–53.

8. Barrau, J. 1957. L' arbre a pain oceanic. J. Agr. Trop. Bot. Appl. 4 . 117–123.

9. Bell, Jess-Mary K. and D.G. Coursey. 1971. Tropical Vegetables in Britian. Trop. Sci. 13 : 251–263.

10. Bleinroth, E.W., *et al.* 1977. Storage of avocado at low temperature in CA. (Pt.). Coletanea de Inst. de Techn. de Alimentos (Brazil) 8(2) . 587-622.

11. Bleinroth, E.W., J.L.M. Garcia and Y. Yokomizo. 1977. Low temperature CA conservation of four varieties of mangoes (Pt.). Coletanea de Inst. de Techn. de Alimentos. 8(1) : 217–243.

12. Bharath, P.M. 1968. A guide to production of major vegetable crops in Trinidad and Tobago. Ministry of Agriculture, Lands and Fisheries, Trinidad and Tobago. p. 2–4.

13. Chaplin, G.R. and M.G. Hawson. 1981. Extending the post harvest life of unrefrigerated avocado fruit by storage in polythylene bags. Sci. Hortic. 14(3) : 219 226.

14. Chaplin, G.R., K.J. Scott and B.I. Brown. 1982. Effects of storing mangoes in polyethylene bags at ambient temperature. Singapore J. of Primary Ind. 10(2) : 84-88.

15. Charles, W.B. 1976. Cabbage growing. Ext. Bull. No. 20. Dept. Agric. Ext. University of the West Indies. Trinidad.

16. Commonwealth Secretariat 1981. Report of post harvest losses consultative meeting. Caribbean. July 1981, Vol. 1 : 37.

17. Coursey, D.G. and F.J. Proctor. 1975. Towards the quantification of post harvest loss in horticultural produce. Acta Hortic. 49 : 55–65.

18. Erickson, L.C. and Y. Tadaaki. 1964. Calif. Avocado Yearbook 48 : 92–94 (cited from: Arriola. M. *et al*, 1979. Tropical Foods : Chem. and Nutr. 2 : 609 – 624.

19. Food & Agriculture Organisation of the United States. 1977. An analysis of an FAO Survey of postharvest food losses in developing countries. Rome (1977).

20. Furry, R.B., F. Isenberg and M.C. Jorgensen. 1981. Postharvest controlled atmosphere storage of cabbage. Search Agric. (USA) No. 19, 17 pp.

21. Geeson, J.D. 1979. CA keeps coleslaw greener. Grower (UK) 92 (14) : 36 – 38.

22. Geeson, J.D. and K.M. Browne. 1980. Controlled atmospheric storage of winter white cabbage. Ann. Appl. Biol. 95 (2) : 267–272.

23. Halkon, W.A. 1969. Transport and storage experiments with avocado pears. Unpbl. Thesis D.T.A. University of the West Indies.

24. Harold, E.V., 1930. The avocado Hawaiian Agric. Expt. Sta.

25. Hatton, T.T. and W.F. Reeder. 1965 Controlled atmosphere storage of Keitt mangoes. Proc. Carib. Reg. Ameri. Soc. Hort Sci. 10 : 114-119

26. Hatton, T.T., W.F. Reeder and C.W. Campbell. 1965. Ripening and storage of Florida avocadoes. USDA, Market Res. Rep 697. 13 pp.

27. Hatton, T.T., and W.F. Reeder. 1965. Controlled atmosphere storage of Lula avocadoes – 1965 tests. Citrus Ind. 46 (10) : 29–31.

28. Hicks, J. R. and P.M. Ludford. 1981. Effects of low ethylene levels on storage of cabbage. Acta Hortic. 116: 65–73.

29. Higgins, J.E., 1907. Marketing Hawaiian fruits. Bulletin No. 14, Hawaiian Agric. Expt. Sta.

30. ICAITI. 1974–1975. Trimestral Report (Oct.–Dec. 1974). Regional program for Scientific and Tech. Development – OAS.

31. Isenberg, F.M. and R.M. Saules. 1969. Modified atmos pheric storage of Danish cabbage. J. Amer. Soc. Hort. Sci. 94 : 447–449.

32. Jeffers, W. 1972. Some problems involved in the production of vegetables in the Commonwealth Caribbean. In: Proc. Seminar/Workshop on Horticultural Development in Caribbean. March 1972.

33. Kane, O. and P. Marcellin. 1979. Effects de l'atmosphere controlée sur la conservation des mangues (varietes Amelie et Julie). Fruits (France) 34 (2) : 123–129.

34. Kapur, N.S., K.S. Rao and H.C. Srivastava. 1962. Refrigerated gas storage of mangoes. Food Sci. 11 (8) : 228–231.

35. Karmarkar, D.V. and B.M. Joshi, 1941. Respiration studies of the Alphonse mango. Indian J. Agric. Sci. XI (IV) : 993–1005.

36. Lyle, R. 1933. Avocado Storage. Fla. Agric. Expt. Sta. Dept. Hort.

37. Marriot, J., C. Perkins and B.O. Been. 1979. Some factors affecting the storage of fresh breadfruit. Sci. Hortic. 10 (2) : 177–181.

38. Overholser, E.L. 1925. Cold storage behaviour of avocadoes. California Avocado Assoc. Ann. Rept. 1924–25.

39. Pantastico, E.B. and Q.K. Bautista. 1976. Postharvest handling of tropical vegetables. HortSci. 11 : 122–124.

40. Parsons, C.S. 1959. The effect of temperature and packaging on the quality of stored cabbage. Proc. Amer. Soc. Hort. Sci. 74 : 616–621.

41. Passam, H.C., D.S. Maharaj and S. Passam. 1981. A note on freezing as a method of storage of breadfruit slices. Trop. Sci. 23 (1) : 67–74.

42. Passam, H.C. 1982. Storage of some local and introduced mango varieties in Trinidad. Sci. Hortic. 16 (2) : 171–177.

43. Pennock, W. and G. Mandonado. 1962. Hot water treatment of mango fruits to reduce anthracrose decay. J. Agr. Univ. Puerto Rico. 64 (4) : 272–283.

44. Peters, F.E. and P.A. Wills. 1956. Dried Breadfruit. Nature 178 : 1252.

45. Popenoe, J. 1956. Storage of Keitt mango at different temperatures, 1955. Fl. Mango Forum pp. 13 – 16

46. Purseglove, J.W. 1968. Tropical Crops. Dicotyledons. Longmans. London. 719. pp.

47. Samoya de Arriola, M del C. 1973. Almacemiento de mango (Mango Storage). Proc. Trop. Reg. Amer. Soc. Hort. Sci. 17 : 104–124.

48. Scott, K.J. and G.R. Chaplin. 1978. Reduction of chilling injury in avocadoes stored in polyethylene bags. Trop. Agric. 55 : 87–90.

49. Shill, A.C. 1934. Report of the marketing officer, Trinidad. Oct. 1932 – June 1934. pp. 21–24. P.O.S. Gov't Printing Office.

50. Smith, F.E.V. 1936. West Indies Fruit and Vegetable Bull. I. by I.C.T.A. Trinidad, B.W.I.

51. Smooth, J.J. and R.H. Segall. 1963. Hot water as a postharvest control of mango anthracrose decay. Pl. Dis. Reporter 47 : 739–742.

52. Spalding, D.H. and W.F. Reeder. 1972. Quality of 'Booth 8' and 'Lula' avocadoes stored in controlled atmosphere. Proc. Fla. Sta. Hort. Soc. 85 : 337–341.

53. Stother, J. 1971. The market for fresh mangoes in selected Western European countries. Trop. Prod. Inst. Rept. G59. London 26 pp. (cited by Passam, 1982).

54. Thompson, A.K. 1971. [a]. The storage of mango fruit. Trop. Agr. 48 (1) : 63–70.

55. Thompson, A.K. 1971. [b]. Transportation of West Indian mango fruits. Trop. Agric. 48 (1) : 71–77.

56. Thompson, A.K. *et al.* 1973. Effects of humidity on ripening of plantain bananas. Experimentia 30 (1) : 35–36.

57. Thompson, A.K., B.O. Been and C. Perkins. 1974. Storage of fresh breadfruit. Trop. Agri. 51 (3) : 407 – 415.

58. Trotman, A.E. 1946. A note on the storage of Trinidad grown cabbage. Trop. Agric. 23 (7) : 129–130.

59. Vakis, N., *et al.* 1970. Chilling injury in tropical and subtropical fruits III. The role of CO_2 in suppressing chilling injury of grapefruit and avocadoes. Proc. Trop. Reg. Amer. Soc. Hort. Sci. 14 : 89–100.

60. Van den Berg, L. and C.P. Lentz. 1973. High humidity storage of carrots, parsnips, ritabages and cabbage. J. Amer. Soc. Hort. Sci. 98 : 129–132.

61. Wang, C.Y. 1983. Postharvest responses of Chinese cabbage to high CO_2 treatment and low O_2 storage, J. Amer. Soc. Hort. Sci. 108 (1) : 125–129.

62. Ward, J.F. 1960. Investigations 1956/7 Breadfruit storage trial. Bull. Ministry Agr. Lands. Jamaica 57 : 84–85.

63. Wardlaw, C.W. 1934. Preliminary observations on the storage of avocado pears. Trop. Agric. 11 (2) : 27–35.

64. Wardlaw, C.W. and E.R. Leonard. 1935. The storage of avocado pears. Trop. Agric. 12 (5) : 132–133.

65. Wardlaw, C.W. and E.R. Leonard. 1936. The storage of West Indian mangoes. Low temp. Res. Sta. I.C.T.A. Trinidad, Memoir 3.

66. Wardlaw, C.W. 1937. Tropical fruits and vegetables. An account of their storage and transport. Trop. Agric. 16 (7) : 320–233.

67. Wardlaw, C.W. 1938. The avocado in the West Indies. Trop. Agric. 15 (10).

ACCUMULATION OF NITRATES IN LETTUCE *(Lactuca sativa)* DURING STORAGE FROM DIFFERENT GROWING MEDIA

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ABSTRACT

The values of nitrate accumulation in lettuce in all the media (bagasse, rice, coffee, soil, wood shaving, horse manure and sawdust) over the 20 day storage period was above the recommended WHO limit of 500 ppm. Lettuce grown in coffee exhibited the highest NO_3–N (2700–2880 ppm) after 10 days. Lettuce from soil (control), rice, and wood shavings had the highest NO_3–N after 5 days whereas in horse manure, coffee, sawdust and bagasse the highest NO_3–N was after 10 days. Lettuce from horse-manure, coffee and bagasse had a general decline in NO_3–N after 10 days unlike soil, rice, wood shavings and sawdust which had the opposite effect. Despite the varying trend in NO_3–N during storage, for lettuce from all the media except rice, visual quality was good after 20 days. Bagassee and sawdust appeared to produce the lowest NO_3–N and highest quality ratings during storage.

RESUMEN

En todos los medios (fibra de caña de azúcar, arroz, cafe, tierra, virutas de madera, abono de caballo y serrín), la acumulación de nitratos en lechugas durante un período de almacenamiento de 20 días fue superior al límite de 500 ppm recomendado por la OMS. Las lechugas cultivadas en el medio con base de cafe presentaron el nivel más alto de NO_3 – N (2700 - 2880 ppm) al cabo de 10 días. Las lechugas cultivadas en tierra (el control), arroz y virutas de madera presentaron el nivel más alto de NO_3 – N al cabo de 5 días, mientras que las que fueron culitvadas en abono de caballo, cafe, serrín y fibra de caña de azúcar sufrieron un descenso global al cabo de 10 días; se produjo lo contrario en la tierra, el arroz, las virutas de madera y el serrín. A pesar de las variaciones en los cambios del contenido de NO_3 – N durante el almacenamiento en todos los medios – salvo el arroz – las lechugas presentaron una buena apariencia al cabo de 20 días. Según las observaciones, el cultivo de lechugas en un medio de fibra de caña de azúcar o de serrín produce el nivel más bajo de NO_3 – N y la mejor calidad durante el almacenamiento.

Nitrate accumulation in plants is a natural phenomenon resulting from uptake of the nitrate ion in excess of its reduction and subsequent assimilation. The accumulation of nitrate is dependent on and related to the genetic makeup of the plant, the nitrate-supplying power of the soil and the environmental conditions under which the plant is grown (14). Previously, the main interest in connection with nitrates in vegetables and drinking water was geared towards cyanosis (methaemoglobinaemia), caused by the reduced form of nitrates namely nitrites. More recently, the main concern is the in vivo synthesis of nitrosamines, because of their potential carcinogenicity (10, 20). Taylor and Lijinsky (26) and Sander *et al.* (21) postulated that repeated intake of minute amounts of nitrosamines is more dangerous than a larger single dose. Although the nitrate content of vegetables can be high, nitrite content of vegetables is relatively low (7).

Nitrate may be converted to nitrite during storage of plant products as a result of bacterial action or plant reductase activity (13). Nitrite enters the stomach, where amides or amines are present to form nitrosamines (9, 11, 16, 18). There is no obvious direct link between total nitrate intake and nitrate concentration in the saliva. However, an intake above 40g of nitrate per day will lead to a pronounced increase of nitrate in the saliva (24). It is therefore necessary to aim for the lowest possible intake of nitrate and nitrite for humans and animals (23).

Most vegetables respond to a high nitrogen supply with increased yields, but they also show high nitrate accumulations in the tissue. This is enhanced in so-called nitrophilic plants like head lettuce, spinach, radish and various crucifers (27). Although various local conditions such as soil, climate, temperature, water relations and light intensity may play important roles in nitrate accumulation, fertilization deserves special attention since the availability of nitrate in the root zone and the nitrate concentrations of plant tissues can be related to the amount and kind of nitrogen fertilizer used.

The availability of a wide range of nitrogen fertilizers, indicates a potential risk to growers attempting to utilise the cheapest soil medium supplemented with artificial fertilizers to boost growth and subsequent yields in leafy vegetables such as lettuce. The attainment of higher yields would necessitate some form of storage for the increased supplies. In view of the conversion of nitrates of nitrites and the subsequent build up of nitrites that can occur under refrigeration, this study was initiated to examine the accumulation of nitrates in lettuce grown in different media during storage at 8–9 °C.

Materials and methods

Lettuce heads *(Lactuca sativa,* cv. 'Mignonette Bronze') were obtained from the Vegetable Section, Central Experiment Station, Ministry of Agriculture,

Lands and Food Production, Trinidad and Tobago, where they were grown in separate plots consisting of seven different media: bagasse, coffee, horse manure, rice husks, sawdust, wood shavings and soil (control). The fertilizers used were 13:13:21 and sulphate of ammonia at 13 days after transplanting, followed by another application of 12:12:17 (2), 23 days after transplanting. The application rate was 14g per plant.

Lettuce heads were transported in plastic crates to the Biochemistry Laboratory 10 minutes after harvest, washed thoroughly and submerged in water for 20–25 minutes to simulate pre-storage hydro-cooling conditions. Initial water temperature was 2–3°C; the temperature rose no more than 5°C during the treatments. Lettuce heads were air-dried for 15 minutes at ambient temperature and individually seal-packaged in high density polyethylene (HDPE 0.025mm thick) and stored at 8–9°C for 1, 5, 10, 15 and 20 days.

After each storage interval, each head of lettuce was examined for visual quality which was rated as 1 = unusable, 3 = unsalable, 5 = fair, 7 = good and 9 = excellent (6); fresh weight; percentage fresh weight loss; dry matter which was taken after drying in a hot air oven at 70°C for 48 hours; and nitrate content. The nitrate content was determined by the method of Harper (8). An extracting solution was made up of cupric sulphate pentahydrate, silver sulphate and distilled water and added to the sample (250mg) and shaken with activated charcoal. Calcium hydroxide and magnesium carbonate were added after shaking and the mixture was left to stand for not more than 20 minutes. The solution was filtered and an alliquot of the filtrate was evaporated to dryness on a sand bath. After removal from the sand bath, phenol disulphonic acid, water and sodium hydroxide solution with E.D.T.A. di-sodium salt were added. After cooling the colour developed was measured at 440mu on colorimeter. The range of the nitrate standard solution used for calibration was from 0 to 20 mg NO_3.

There were two replicates, with each replicate being an individual head of lettuce. Data were analysed as a completely randomized design, with a factorial arrangement of variables, and significance tested by the F-test and Duncan's multiple range test where applicable, after trans-formation for ranking (25).

Results

One day refrigerated storage

Samples of head lettuce from all the media had NO_3–N values above the recommended World Health Organisation (WHO) limit of 500 ppm (22) on a dry weight basis on the first day of harvest (Table 1). Heads from horse manure had the highest fresh weight (Fig. 1) and dry weights (Table 2). This corresponded with the highest NO_3–N level (Table 1). Similarly, lettuce heads from coffee and soil (control) had high fresh weights (Fig. 1), high dry weights and high NO_3–N values (Tables 1, 2). An opposite trend was noted for heads from the rice husk medium, i.e. low dry weight and fresh weights but a corresponding high NO_3–N content (Fig. 1, Tables 1, 2). Sawdust grown heads had low fresh and dry weights as well as low NO_3–N content while bagasse and wood-shavings showed minor differences in dry weight, 3.1 and 3.3g and NO_3–N content, 1718 and 1604 ppm (Tables 1, 2).

Five days' refrigerated storage

Despite a mean fresh weight loss of 4.1 per cent from all heads, there was no indication of wilting or discolouration (Table 4). Ratings for visual quality (Table 3) was not affected after 5 days at 8–9°C. The relationship between dry weight and NO_3–N content of lettuce heads grown in horse manure, soil (control), coffee, rice and sawdust appeared to be consistent with the results obtained when heads were examined previously and after a post-harvest period of 5 days at 8–9°C. Although heads taken from sawdust had the lowest dry weight, they also had the lowest NO_3–N content together with high quality ratings (Tables 1, 2, 3). The difference in dry weight between bagasse and wood shavings was 0.3 per cent while that of NO_3–N content was 830 ppm. The NO_3–N value of lettuce heads from sawdust was significantly lower ($P = 0.01$) than all the other media except bagasse (Table 1).

Ten day's refrigerated storage

During this storage period both NO_3–N content and dry weight of lettuce heads from soil (control) were lower than from coffee and horse manure, even though visual quality ratings were still high for all three media (Tables 1, 2, 3). Among all the media, samples from horse manure had the highest NO_3–N

Table 1. Effect of different soil media on the accumulation of NO_3 -N in lettuce after 1, 5, 10, 15 and 20 days at 8 - 9°C.

	Storage period (days)					
Growing medium	1	5	10	15	20	Mean
Bagasse	1718	959	1133	931	866	1121
Rice husks	2251	2463	1625	2289	2330	2192
Coffee	2047	2339	2747	2430	2238	2360
Wood shavings	1604	1789	1643	1446	1777	1652
Horse manure	2658	2777	2872	2460	2339	2621
Sawdust	811	743	909	717	1058	848
Soil (Control)	2184	2528	1972	1984	2421	2218
Mean	1896	1943	1843	1951	1861	1859

Error Variance = 32,426 Error d.f. = 28

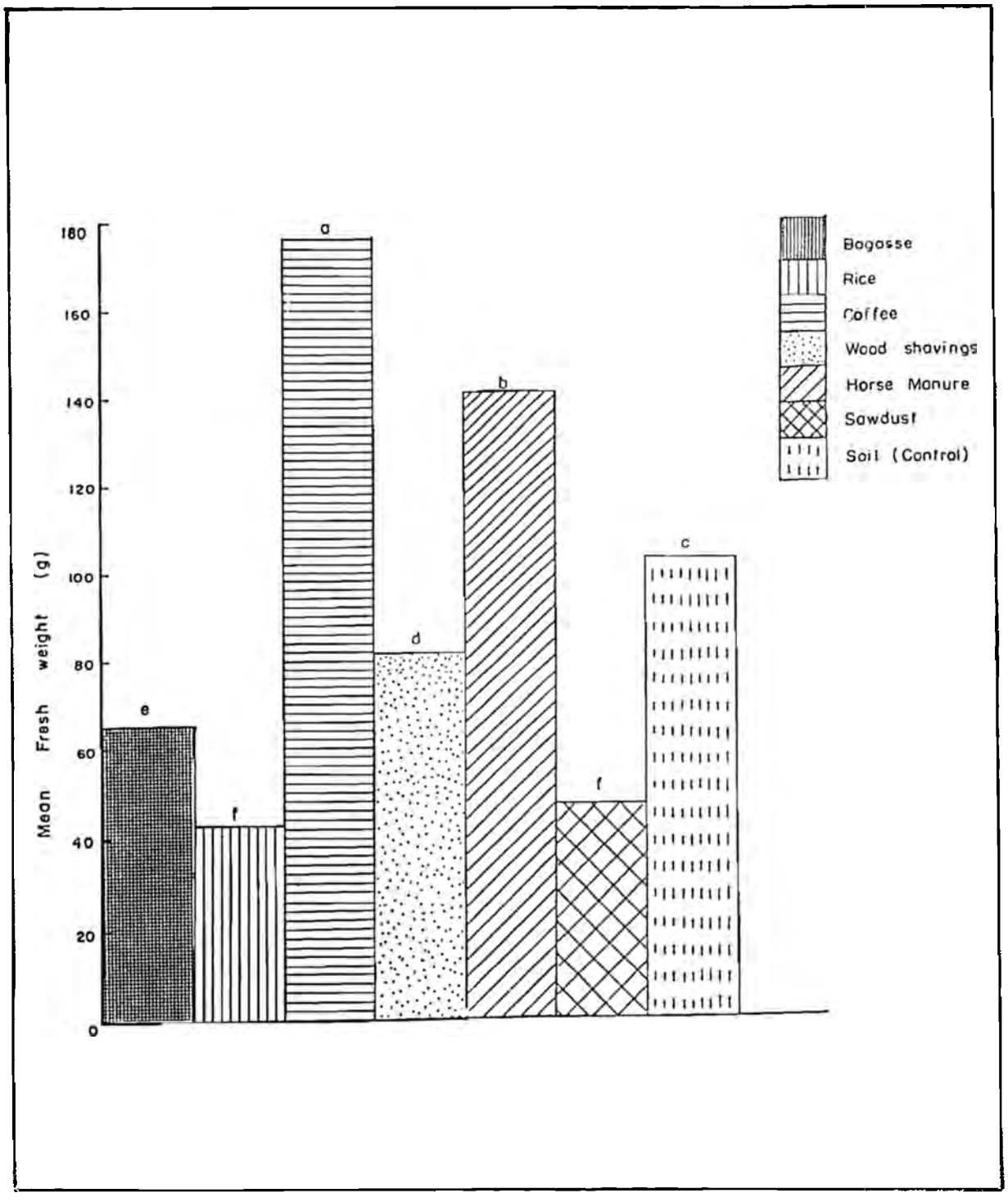

Figure 1: Mean pre-storage fresh weight (g) of lettuce heads from different media[z].

z Mean separation in each coloum for each treatment by Duncan's multiple range test; means not suffixed by the same letter are statistically different (P = 0.05).

Table 2. Effect of different growing media on the dry weight of lettuce after 1, 5, 10, 15 and 20 days at 8 - 9°C.

	Storage period (days)					
Growing medium	1	5	10	15	20	Mean
Bagasse	3.1	2.9	3.0	3.4	3.2	3.1
Rice husks	2.2	2.1	3.0	1.9	2.4	2.3
Coffee	6.0	5.1	7.1	7.3	6.3	6.4
Wood shavings	3.3	4.0	3.7	3.9	4.1	3.8
Horse manure	6.6	6.4	6.8	5.9	3.8	5.3
Sawdust	2.0	2.6	3.4	2.3	1.7	2.4
Soil (Control)	4.2	5.0	5.0	4.7	3.6	4.5
Mean	3.9	4.0	4.6	4.1	3.6	4.0

Error Variance = 2.4 Error d.f. =2.8

value, the lowest percentage fresh weight loss and no effect on quality (Tables 1, 3, 4). Samples from the rice husk medium had a significant (P = 0.05) reduction in NO_3–N after 10 days at 8–9°C with excellent keeping quality. From the sawdust medium, lettuce heads had high quality ratings but the lowest NO_3–N when compared to the other soil media (Tables 1, 3). Although the dry weight and quality of samples from bagasse and wood shavings were similar (Tables 2, 3), the percentage fresh weight loss in the former medium was significantly higher (P = 0.01) while NO_3–N content was significantly lower (P = 0.05) than the latter medium (Tables 1, 4). Among all the media, only samples from sawdust and bagasse had significantly (P = 0.05) lower NO_3–N values than soil (Table 1).

Fifteen days' refrigerated storage

The quality ratings, as indicated by distinct brown discolouration at the butt end and slight wilting of the outer leaves of lettuce heads from the rice and soil media, were significantly (P = 0.05) lower than the other media (Table 3). Even after 15 days at 8–9°C, the lettuce heads from horse manure and coffee had high quality ratings but elevated NO_3–N values (Tables 1, 3). Lettuce heads from the rice medium had the lowest dry weight and showed a significant decline in quality and an increase in NO_3–N content when compared to the previous storage periods (Tables 1, 2, 3). Although there were only minor changes in storage quality of lettuce heads from bagasse and sawdust, the values of NO_3–N were approximately three times lower than that of rice, coffee or horse manure (Tables 1, 3). Lettuce heads from wood shavings had lower NO_3–N content, dry weight and percentage fresh weight loss but similar quality ratings when compared with coffee and horse manure (Tables 1, 2, 3, 4).

Twenty days' refrigerated storage

Lettuce heads from bagasse and sawdust had lower NO_3–N values (P = 0.01) and maintained high quality ratings in contrast to the other media (Tables 1, 3). Although samples from soil (control) appeared to have good keeping quality after 20 days at 8–9°C, they had the highest NO_3–N and fresh weight loss (Tables 2, 3, 4). Samples from coffee and horse manure continued to have good quality ratings but high NO_3–N values (Tables 1, 3). The NO_3–N values from wood shavings were lower than from coffee, horse manure, soil and rice husks but higher than those from bagasse and sawdust (Table 1).

During this storage period, lettuce heads from rice husks had the lowest quality ratings as indicated. Leaves had oval to irregular lesions that ranged from yellow to brown. In some cases the lesions coalesced to form larger, uniformly coloured, depressed patches. The margins of the outer leaves had a scorched soggy appearance making these heads unmarketable. It must be noted that, along with the poor quality, these heads also showed a high NO_3–N content comparable to that of samples grown in coffee, horse manure and soil.

Discussion

Despite a constant fertilizer regime in terms of type and application rate, there were differences in NO_3–N values among the media at the end of every storage period. This is in agreement with the views of Maynard *et al* (14) that different media can result in variations with regards to uptake, assimilation, translocation and accumulation of nitrates in plants. Previous work by Barker (3) and Peet *et al.* (19) indicated that, due to mineralization and nitrification, nitrate is the primary soil-derived N-form

Table 3. Effect of different growing media on the visual quality of lettuce after 1, 5, 10, 15 and 20 days at 8 - 9°C.

	Storage period (days)				
Growing medium	5	10	15	20	Mean
Bagasse	9.0	9.0	8.5	8.0	8.6
Rice husks	9.0	9.0	7.0	4.0	7.3
Coffee	9.0	8.5	8.5	7.5	8.4
Wood shavings	9.0	9.0	8.3	7.5	8.5
Horse manure	9.0	9.0	8.8	8.0	8.7
Sawdust	9.0	9.0	8.5	8.3	8.7
Soil (Control)	9.0	9.0	7.0	7.5	8.1
Mean	9.0	8.9	8.1	7.3	8.3

Error Variance = 17.2 Error d.f. =28

Ratings : 1= unusuable 9= excellent

Table 4. Effect of different growing media on percentage fresh weight loss of lettuce after 1, 5, 10, 15 and 20 days at 8 - 9°C.

	Storage period (days)				
Growing Medium	5	10	15	20	Mean
Bagasse	5.4	6.2	7.3	7.6	6.6
Rice Husks	3.9	5.1	6.2	6.1	5.4
Coffee	3.6	4.6	5.4	6.1	4.9
Wood shavings	3.6	3.9	4.4	5.4	4.3
Horse manure	3.2	3.6	4.9	6.3	4.5
Sawdust	4.2	4.5	5.1	6.5	5.1
Soil (Control)	4.9	5.0	5.1	8.0	5.8
Mean	4.1	4.7	5.5	6.6	5.2

Error Variance = 7.3 Error d.f. =28

regardless of the source of N applied. Therefore, within limits as much nitrate can be accumulated from organic fertilizers as from nitrate carriers if sufficient time is allowed for mineralization to occur.

It is possible that due to greater microbial activity application of the fertilizers had an additive effect in causing a faster uptake, assimilation, translocation and accumulation of NO_3–N in the coffee, horse manure and soil media. The elevated levels of NO_3–N in these media can be related to a more rapid rate for mineralization and nitrification. Barker (3) pointed out that media composed of dried materials would mineralize slowly resulting in lesser nitrate accumulation in the plant tissue. Among the dried materials making up the media in this study, rice husks appeared to mineralize fastest, and consequently had heads with the highest NO_3–N values while sawdust was the slowest resulting in heads with the lowest NO_3–N value.

The fact that NO_3–N values from lettuce heads grown in the rice husk medium were comparable to those of horse manure, coffee and soil may be due to (a) the rapid uptake mechanism and (b) the low capacity for the root system to reduce nitrate, thus a greater proportion of N may have been transported to the shoots as nitrate or a combination of (a) and (b) as suggested by Maynard *et al.*, (14).

Minotti (17) claimed that environmental factors such as light, temperature, carbon dioxide concentration, fertilizer, soil type, etc., may modify tissue nitrate by affecting any or all of the processes of absorption, assimilation and translocation. It may be deduced that, despite the constant fertilizer regime applied to all the media, absorption of NO_3–N in the wood shavings, bagasse and sawdust media was limited due to low availability to nitrates in the root zones thereby resulting in minimal assimilation and translocation rates. By contrast, lettuce heads from the other media produced the opposite effect. The need for further research to investigate the factors that may affect assimilation or translocation and the role involved in regulating nitrates under production systems where a range of media are utilised is therefore warranted.

In contrast to previous studies by Asseo-Bickert (2) which indicated an increase in NO_3–N values for greenhouse lettuce during storage at 5–12°C, this investigation did not reflect a similar relationship. However, in the present study the use of different media, temperature and package may have influenced the variations obtained as the number of days in storage increased. Results from both studies, however, indicate the threat of nitrate toxicity to man from ingestion of lettuce since the values were above the recommended WHO limit of 500 ppm (22).

It was obvious from this study that the technique of individual seal-packaging of lettuce heads from all the media with the exception of rice husks in high density polyethylene (HDPE) extended shelf life up to 20 days. Similar results were obtained by Aharoni *et al.* (1) for lettuce, fruits and other vegetables by Ben-Yehoshua (5) and Mohammed (15) using the same type of packaging material.

The relationship between quality and NO_3–N values of lettuce heads during storage suggested a need for educating those involved in growing and marketing about the risks involved in high NO_3–N levels. Consumer demand for lettuce heads based on quality factors such as size of heads, compactness as well as greeness and lack of leaf wilting without considering the type of growing medium or fertilizer may lead to elevated NO_3–N intake as well. Although size, fresh weight and compactness of heads were not used to evaluate quality in this study, growers should possibly be encouraged to utilise sawdust in preference to other media because of low NO_3–N values and high quality rating. Despite this, consumers may still opt for heads grown in horse manure, coffee or soil since their evaluation of quality usually does not include a knowledge of NO_3–N levels as an important factor. This lack of consumer knowledge emphasizes the need to establish baseline data for other nitrophilic vegetables. Lettuce heads from the rice husk medium may receive unfavourable recommendation because of their low fresh weight (Fig. 1), low dry weight (Table 2) and high NO_3–N values (Table 1), with a tendency to senesce most rapidly. It is possible that the drastic increase in NO_3–N after 15 and 20 days of storage which also corresponded with a similar decline in quality (Table 3) could have been related to microbial contamination as suggested by Vogtmann *et al.*

Visible wilting was noted in lettuce heads that had 6 percent loss in fresh weight. (This is in agreement with Barger (4) and Lipton and Barger (12)). Samples from bagasse and rice husks reflected this after the 10 and 15 day storage intervals (Table 4). Although the sealed high density polyethylene bags (HDPE) would have insured an effective barrier to water vapour transmission and attained a relative humidity of 95–100 per cent, the type of heads from bagasse and rice husks, i.e. not as compact and having a greater surface area, may explain the fresh weight loss differences as indicated in this study.

The results of this study indicate that the demand from toxicologists for a reduction in the daily nitrate intake from lettuce ought to be given serious consideration. Important inputs may come from proper refrigeration, timely consumption patterns, the incorporation of low nitrate-accumulating cultivars, fertility and management practices to result in restricted nitrate concentration, and the manipulation of the most suitable medium as well as environmental variables into the crop production scheme.

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Literature Cited

1. Aharoni, N. and S. Ben-Yehoshua. 1973. Delaying deterioration of Romanine lettuce by vacuum cooling and modified atmosphere in polyethylene packages. *J. Amer. Soc. Hort. Sci.* 98(5) : 464–468.

2. Asseo-Bickert, A. 1983. Nitrate development in hearted greenhouse lettuce. *Rev. Hort. Suisse* 56(10) : 304–306

3. Barker, A.V. 1975. Organic versus inorganic nutrition and horticultural crop quality. *Hort. Sci.* 10: 50–53.

4. Barger, W.R. 1961. Factors affecting temperature reduction and weight-loss in vacuum-cooled lettuce. *U.S. Dept. Agr. Mktg. Res. Rept.* 469 pp.

5. Ben-Yehoshua, S. 1978. Delaying deterioration of individual citrus fruit by seal packaging in film of high density polyethylene. 1. General effects, *Proc. Int. Soc. Citriculture.* Sydney, Australia pp 110-115.

6. Brecht, P.E., L.L. Morris, C. Cheyney and D. Janecke. 1983. Brown stain susceptibility of selected lettuce cultivars under controlled atmosphere and temperatures. *J. Amer. Soc. Hort. Sci.* 98 : 261–264.

7. Committee on Nitrate Accumulation. 1972. Accumulation of nitrate. *Natl. Acad. Sci.,* Washington, D.C.

8. Harper, H.J. 1924. A method to determine nitrates in plant tissues. *Ind. Eng. Chem.* 16 : 180.

9. Heyns, K. 1973. Uber Nitrosamine in der Nahrung. *J. Getreide Mehl Brot* 27 : 249–253.

10. Kelly, M.G., R.W. O'Hara, R.H. Adamson, K. Gadekar, C. Botkin, W.H. Reese and W.T. Kerber. 1966. Induction of hepatic cell carcinomas in monkeys with N-nitrosodiethylamine. *J. Nat. Cancer Inst.* 36 : 323–351.

11. Lijinsky, W. and S.S. Epstein. 1970. Nitrosamines as environmental carcinogens. *Nature* 255 : 21–23.

12. Lipton, W.J. and W.R. Barger. 1965. Market quality of head lettuce in relation to delays between harvest and precooling and temperature after cooling. *U.S. Dept.* Agr. ARS 51–5.

13. Luhrs, C.E. 1973. Nitrogenous compounds in the environment. In: (Ed. Mrak) *Hazardous Materials Advisors Committee* U.S. Environ. Prot. Agency, Washington D.C. 159–173.

14. Maynard, D.N., A.V. Barker, P.L. Minotti, and N.H. Peck. 1976. Nitrate accumulation in vegetables. *Adv. Agron.* 28 : 71–118.

15. Mohammed, M. 1984. Storage of sweet peppers and tomatoes in polymeric films. *M.Sc. Thesis.* University of Guelph.

16. Mohler, K., O.L. Mayrhofer and E. Hallermayer. 1972. Das Nitrosaminproblem aus der Sicht des Lebensmittelchemikers. *Zeitschrift fur Lebensmitteluntersuchung und forschung* 150 : 1–11.

17. Minotti, P.L., 1975. Plant nutrition and vegetable crop quality. *Hort. Sci.* 10 : 54–56.

18. Neurath, B. and O. Schreiber. 1974. Investigations on nitrosamines in the human environment. *I.A.R.C. Sci. Publ.* 9 : 211–220.

19. Peck, N.H., D.J. Cantille, R.S. Shallenberge and J.B. Bourke. 1971. Table beets and nitrogen. *Agron. J.,* 63 : 130–132.

20. Sander, J. and F. Schweinsberg. 1972. Wechselbeziehungen zwischen nitrat, nitrit und cancerogenen N-Nitrosoverbindungen. *Zentralblatt fur Bakteriologie und Hygiene, 1 Abtl. Orig.* B. 156 : 299–340.

21. Saunder, J., F. Schweinsberg and H.P. Menz. 1968. Untersuchungen uber die Entsthung cancerogener nitrosamine im Magen. *Hoppe-Seyler's Zeitschrift fur physiologische Chemie* 349 : 1691–1697.

22. Sanni, S.N. 1983. A. survey of nitrate-nitrite in vegetables in Bania environs. *J. Plant Foods* 5(2) : 75–79.

23. Schlatter, C. 1978. Nitrate in Lebensmitteln des Bundesamtes fur. *Gesundheits wesen Bern* 451–455.

24. Spiegelhalder, B., G. Eisenbrand and R. Preussmann. 1976. Influence of dietary nitrate on nitrite content of human saliva: possible relevance to in vivo formation of N-nitroso compounds. *Food and Cosmetic Toxicology* 14 : 545–548.

25. Steel, G.D.R. and H.J. Todrie. 1960. Significant studentized ranges for five percent and one percent level new multiple range test. *Principles and Procedures of Statistics. A. Biometrical Approach* 586–587.

26. Taylor, H.W. and W. Lijinsky. 1975. Tumor induction in rats by feeding heptamethylamine and nitrite in water. *Cancer Res.* 35 : 812–815.

27. Vogtmann, H., A.T. Temperli, U. Kunsch, M. Eichenberge, and P.Ott. 1984. Accumulation of nitrates in leafy vegetables grown under contrasting agricultural systems. *Biolog. Agric. and Hort.* 2 : 51–68.

QUALITY ATTRIBUTES OF BANANA FRUIT AS AFFECTED BY CHILLING AND NON-CHILLING TEMPERATURES

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ABSTRACT

Preclimacteric banana fruits were held for 8 days at chilling temperatures (5°C or 10°C) followed by storage at 16°C; or held continuously at a non-chilling temperature (16°C). Yellow colour development of the banana peel was severely retarded in fruits held for 8 days at either 5°C or 10°C. After transfer to 16°C, abnormal colours developed in the form of grey, brown and black hues. Total soluble solids (TSS), titratable acidity (TA), and pulp to peel ratio were lower in fruits held at either 5°C or 10°C than in fruits held at 16°C. After transfer to 16°C, the TA of fruits previously held at 5°C increased rapidly and remained significantly higher than that of unchilled fruits. The TA of fruits previously held at 10°C did not increase significantly until the 14th day. Pulp to peel ratios of chill-injured fruits eventually attained values which were typical of normal ripened fruits but by that time the appearance of the peel was unprepossessing. The development of chilling symptoms appeared to be greater in fruits held at 10°C than at 5°C. However, after the increase in temperature, fruits previously held at 5°C sustained a higher chilling index than fruits previously held at 10°C.

RESUMEN

Se almacenó unos frutos de banano preclimatéricos a unas temperaturas frigoríficas (5° o 10°C) por 8 días para trasladarios después a 16°C; otros fueron almacenados contínuamente a una temperatura no frigorífica (16°C). Se observó un grave retraso en el desarrollo del color amarillo en la piel en los frutos almacenados a 5°C y 10°C por 8 días. La temperatura fue elevada hasta 16°C, y la piel de los frutos dañados por frío presentaron un desarrollo anormal de color, es decir, hubo tonos de gris, marrón, y negro. El total de sólidos solubles (TSS), la acidez valorable (TA), y la coeficiente pulpa-piel fueron más bajos en los frutos almacenados a 5°C y a 10°C que en los almacenados a 16°C. Tras el traslado a 16°C, se aumentó rápidamente la TA de los frutos anteriormente almacenados a 5°C y se mantuvo a un nivel significativamente más alto que la de los frutos no refrigerados. En los frutos anteriormente almacenados a 10°C, la TA no sufrió ningún cambio significativo hasta el decimocuarto día. La coeficiente pulpa-piel de los frutos dañados por frío terminaron por alcanzar unos valores típicos de frutos normalmente madurados, pero a esas alturas, la piel presentaba un aspecto poco atractivo. La evolución de los síntomas de congelación parecía más intensa en los frutos almacenados a 10°C que en los almacenados a 5°C. Sin embargo, tras un aumento de la temperatura, los frutos anteriormente almacenados a 5°C presentaron un índice de congelación mas alto que los anteriormente almacenados a 10°C.

Keywords: Banana; Chilling, Quality

Most horticultural crops of tropical and subtropical origin, when exposed to low, non-freezing temperatures, undergo a marked physiological dysfunction referred to as chilling injury. Although the phenomenon of chilling sensitivity has been recognized for centuries, most of the impetus for the study of chilling injury has resulted from the economic problems associated with handling, marketing and storage of horticultural products. As a result, most of the research has been concerned with time – temperature responses, temperature tolerances and external characteristics of injury. Despite more recent efforts to investigate the cellular mechanism for chilling injury, there exists still an incomplete understanding of what constitutes low temperature resistance and just how low temperatures result in injury.

Bananas, the edible fruit of the genus *Musa* are sensitive to chilling injury. The cultivation of bananas is limited to tropical and subtropical regions, hence fruits must be transported over long distances before they are available for consumption in temperate areas of the world. The commercial acceptability of fruits depends in part on the absence of ship ripe fruits and the absence of rots and blemishes; both of which may be considerably reduced by low temperature storage of fruits in transit. However exposure of fruits to temperatures below 12°C (Wilkinson, 1970) result in chilling injury, hence temperatures during transit must be maintained above 12°C.

Chilling injury poses a serious problem to the banana industry because of its effect on quality and wastage. Chilling injury of green bananas is characterized by delayed ripening and when severe enough by the complete failure of pulp ripening (Wardlaw, 1972). Haard and Timbie (1979) suggested that there is a discoordination of the biochemical events characteristic of normal ripening when banana fruits are chilled. The present research was initiated in order to investigate how this abnormality in ripening affects some important quality attributes of banana fruit when subject to severe (5°C) and marginal (10°C) chilling temperatures compared to fruits stored at a non-chilling temperature (16°C).

Materials and methods

Preparation and treatment of fruits

Non-ethylene treated, preclimacteric fruits of *Musa* (AAA Group) with a colour index of 2, according to the scheme of von Loesecke (1950) were used. Fruit hands were divided into individual fingers which were randomly assigned to the following storage treatments: (a) 5°C for 8 days followed by storage at 16°C; (b) 10°C for 8 days followed by storage at 16°C and (c) continuous storage at 16°C. Throughout the experimental period, chamber temperature fluctuated no more than 1°C. Relative humidity was maintained between 95–100% by including petri dishes contain-

ing moist filter paper in each chamber and was monitored with an Abbean model AB167B dial hygrometer. Fruits from each treatment were sampled at 2-day intervals to assess the following quality attributes:-

Fruit colour development

The development of fruit colour was assessed by visual comparison with the description of fruit colour given by von Loesecke (1950) and modified by Abou-Aziz *et al.* (1976) to include colour development by chilled fruit (Appendix I). A numerical color index which corresponded to the peel colour of uninjured or chill-injured fruits was ascribed to fruits at each 2-day interval and is reported as the mean ± S.E. of 5 replicates of one fruit each.

Development of chilling injury symptoms

The development of chilling injury symptoms was quantified using the scale adapted from Poland and Wilson (1933) (Appendix II). A numerical chilling index (0 to 4) which corresponded to the injury symptoms of chill-injured fruits was ascribed to fruits at each 2-day interval and is reported as the mean ± S.E. of five replicates of one fruit each.

Total soluble solids (TSS)

A drop of banana pulp juice was squeezed through a nylon sieve onto the lens of a Fisher hand refractometer and the % TTS was read directly. TSS is reported as the mean ± S.E. of four replicates of one fruit each.

Titratable Acidity (TA)

Forty-five g of banana pulp were homogenized with 90 g distilled H_2O and 30 g of the homogenate were titrated to an endpoint of pH 8.1 with 0.1N NaOH. Titratable acidity is expressed as mg malic acid per gram of banana pulp and is reported as the mean ± S.E. of 4 replicates of one fruit each.

Determination of pulp: peel ratio

Whole and peeled banana fruits were weighed to obtain gross and pulp wieght. Peel weight was derived by the difference between gross and pulp weight and the pulp to peel ratio was calculated as a quotient of the pulp and peel weights. Each value of pulp: peel ratio represents the mean ± S.E. of 6 replicates of one fruit each.

Results and discussion

Fruit colour development

Yellow colour development was significantly retarded in fruits held at both chilling temperatures (5°C and 10°C) compared to fruits held at the non-chilling temperature (16°C). The development of brown and black colours was observed in chill-injured fruits on the 12th day and this became progressively greater with time. Unchilled fruits attained a colour index of 6 (Figure 1), the stage of consumer preference (Peacock, 1980) by the 14th day. Chill-injured fruits never attained this stage of consumer preference.

Desai and Deshpande (1975) suggested that yellow colour development in the banana fruit is probably influenced by the activity of chlorophyllase enzyme which breaks down chloroplasts with the formation of compounds such as chloroplast pigments which are rapidly destroyed by unspecified oxidases (Goodwin and Mercer, 1972). During the ripening process as chloroplasts are destoryed, the appearance of carotenoids is substantially enhanced accounting for the yellow colour.

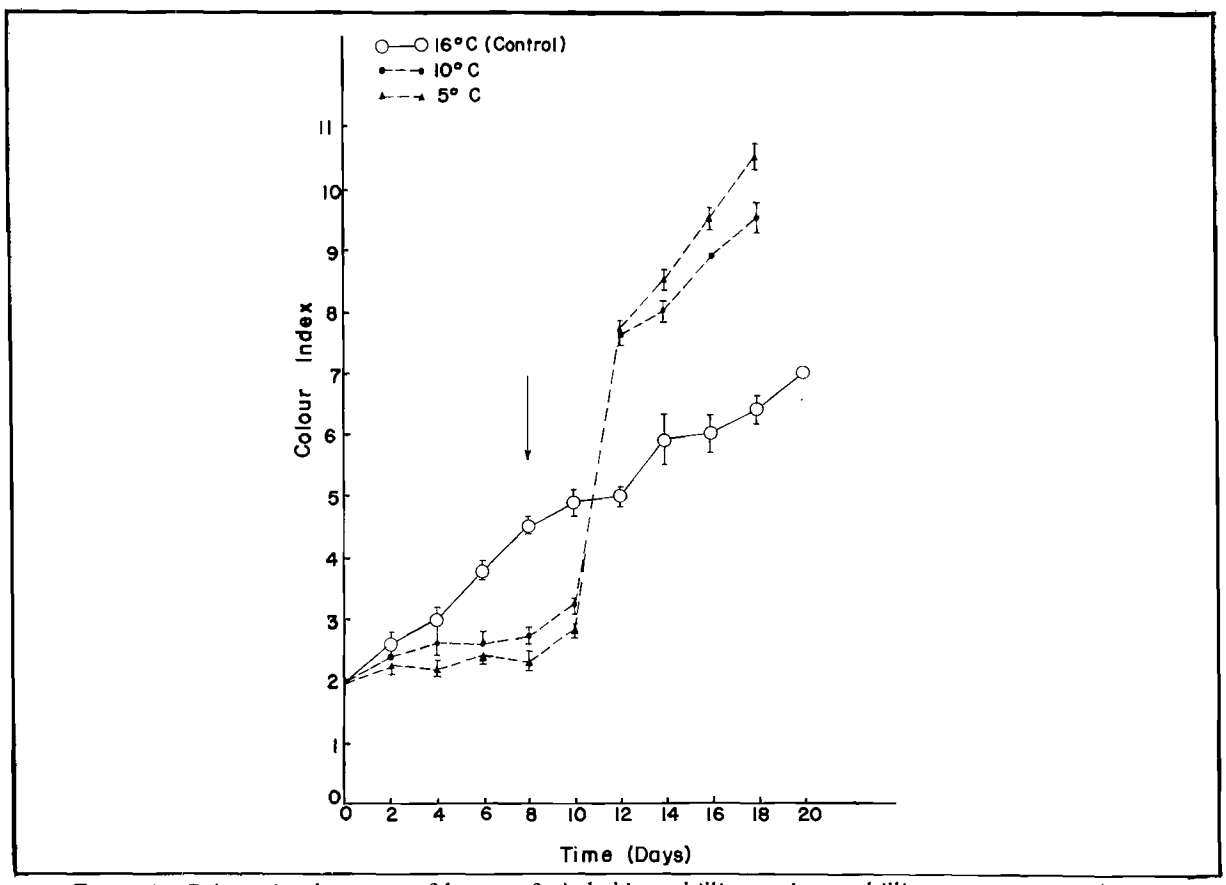

Figure 1 Colour development of banana fruit held at chilling and non-chilling temperatures. Arrow (↓) indicates time at which chilling temperatures (5° and 10°C) were raised to 16°C.

Murata and Ku (1966) suggested that since low temperatures reduced tissue content of ascorbic acid which inactivates oxidative browning reactions, it is possible that quinones accumulate in chilled fruit and undergo secondary reactions to give the brown colouration associated with chill-injured fruit. Abd El-Wahab and Nawwar (1977) identified 3, 4-dihydroxyphenylethylamine as the major phenolic constituent in banana peel and suggested that it may be oxidized to dark coloured substances more readily at low temperatures.

The retardation of yellow colour development in the banana fruit as a result of exposure to chilling temperatures may be due then, to the masking of the yellow colour by the dark coloured substances which are formed at low temperatures. Alternatively, low temperatures may inhibit the activity of chlorophyllase enzyme responsible for degreening so that the yellow colour of the carotenoids is not unmasked.

Development of chilling injury symptoms

There was no incidence of chilling injury at 16°C since this temperature is above the critical threshold temperature for injury of the banan fruit. Incidence of injury became apparent on the 4th day for fruits held at 5°C and 10°C (Figure 2). The degree of injury became progressively more acute with time and the severity of injury was greater at 10°C than at 5°C over the 8-day storage period at chilling temperatures. After the storage temperature was increased to 16°C, the rate of symptom development increased more rapidly in fruits previously held at 5°C than at 10°C. By the 20th day, fruits from both chilling treatments were entirely brown/black and were indistinguishable.

The apparent increased severity of injury symptoms sustained by fruits held at the higher chilling temperature is similar to the phenomenon observed with peaches and plums by van der Plank and Davies (1937), who suggested that the incidence of chilling injury was related to the interaction of 2 opposing factors: an equilibrium factor by which lowering the temperature increased the disposition towards injury and a kinetic factor by which higher temperatures promoted the manifestation of injury symptoms. Fidler (1968) suggested that visible results of low temperature injury arise from the disturbance of metabolism, hence there may be latent injury which is more severe at lower temperatures and a secondary visible effect which develops less rapidly at low temperatures.

Total soluble solids (TSS)

The TSS content of fruits held at 5°C and 10°C was significantly lower than that of fruits held at 16°C (Figure 3). Despite the rapid increase in TSS content of chill-injured fruits observed 4 days after the temperatures were increased to 16°C, the maximum TSS values for chilled fruit remained significantly lower than that of unchilled fruit.

In as much as total soluble solids are essentially sugars, it would be expected that increases in TSS values are accounted for by the process of starch hydrolysis. Madamba *et al.* (1977) found that the regression coefficient between total sugars and TSS was highly significant and in the order of 0.992. The significantly lower TSS values of banana fruit pulp during storage at 5°C and 10°C compared to 16°C suggests that there is considerable retardation of starch hydrolysis at low temperatures. Even when chill-injured fruits reach the senescent stage which occured by the 16th day (Figure 1), the starch content was higher and sugar content lower than unchilled fruit. The lower the chilling temperature, the more severely retarded was the process of starch hydrolysis.

Titratable acidity (TA)

The TA of pulp tissue from fruits stored continuously at 16°C increased rapidly over the first 4 days, remained relatively constant over the next 4 days and then declined steadily (Figure 4). During the 8-day storage period that fruits were held at either 5°C or 10°C, the increase in TA was significantly lower than that of fruits held continuously at 16°C. Following the increase in storage temperature to 16°C, the TA of fruits previously held at 5°C increased rapidly for 4 days and then remained relatively constant, whereas in fruits previously held at 10°C, there was no significant increase in TA until the 14th day, after which TA values declined steadily.

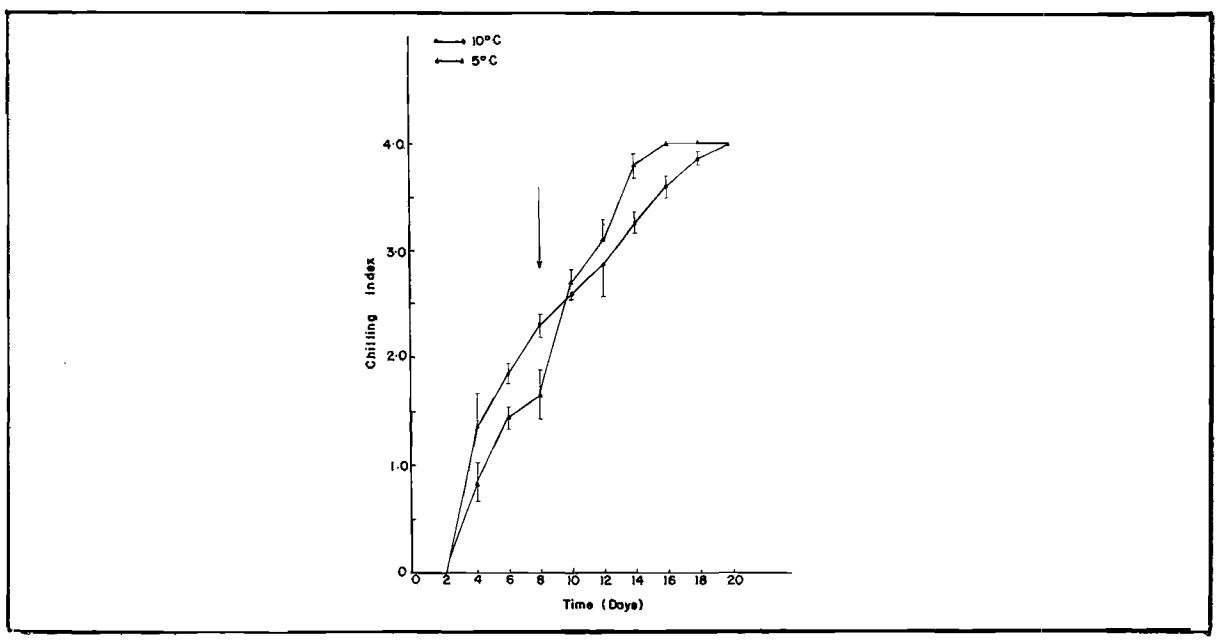

Figure 2 Development of chilling symptoms in banana fruit held at chilling temperatures. Arrow (↓) indicates time at which chilling temperatures (5° and 10°C) were raised to 16°C.

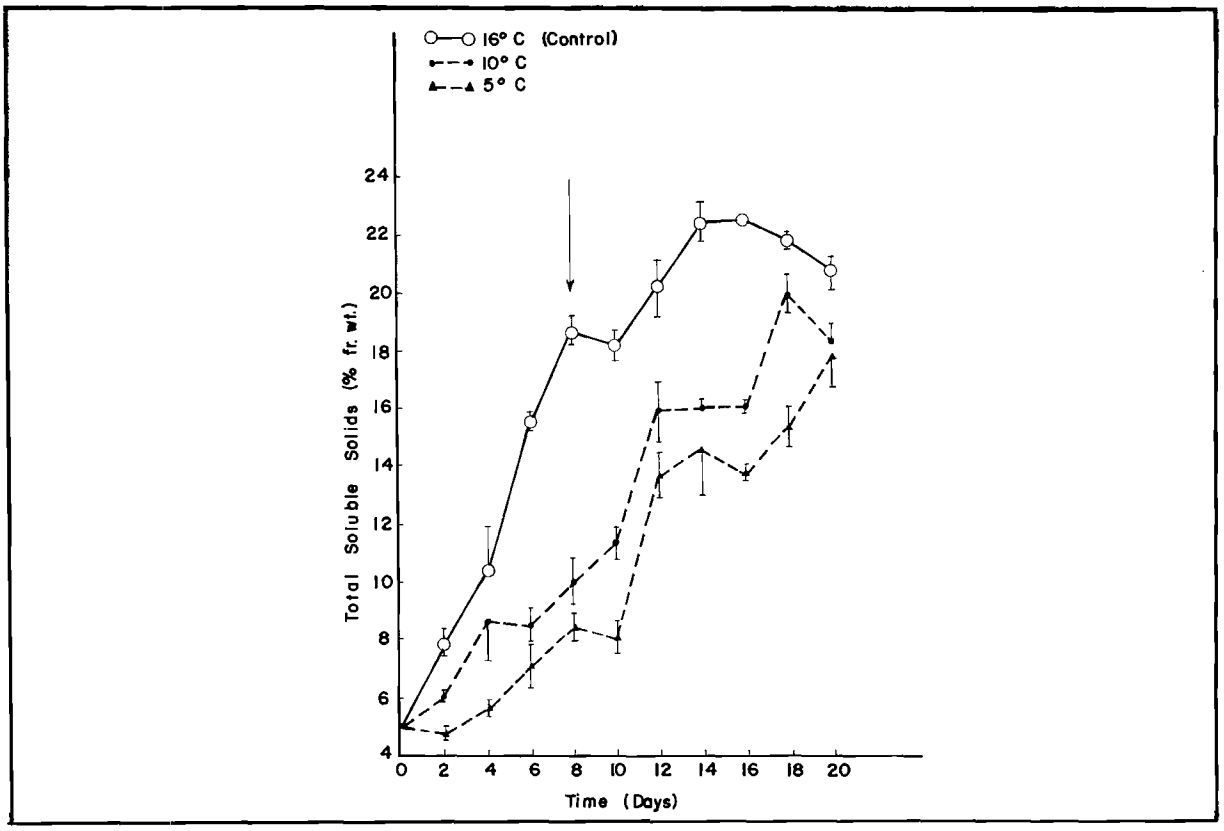

Figure 3 Total soluble solids of pulp tissue from banana fruits held at chilling and non-chilling temperatures. Arrow (↓) indicates time at which chilling temperatures (5° and 10°C) were raised to 16°C.

Changes in TA have been explained in terms of starch hydrolysis by Madamba *et al.* (1977), who suggested that sugars formed from starch hydrolysis underwent further conversion to organic acids during the early stages of ripening which account for the increase in TA. When the TA attains its maximum value, the conversion of sugars to acids slows down. TA decreases when starch reserves have been depleted by continuous hydrolysis and acids continue to undergo further metabolic transformation to CO_2 and H_2O (von Loesecke, 1950).

Desai and Deshpande (1975) related acidity changes to changes in the mechanism of the respiratory process. These authors explained the increased acidity observed in banana fruit during ripening as being due to an obstruction in the proton transfer process. Due to increasing water content in the pulp as a result of osmotic transfer (von Loesecke, 1950; Charles and Tung, 1973), the gas exchange process becomes inefficient providing little or no O_2 required in the final phase of proton transfer, thus protons accumulate and due to the limited buffering capacity of banana pulp, this is manifested as increased acidity.

Results obtained in the present investigation may be explained using both of the above hypotheses. The lower rate of increase in TA of banana fruits held at 5°C and 10°C may be due to a possible retardation of the rate of conversion of starch to sugars, hence less sugars would be available for organic acid transformation at the chilling temperatures. In addition, the lower concentration of sugars in chill-injured banana fruit pulp would reduce the osmotic transfer of H_2O from peel to pulp, hence sufficient O_2 may be present in the pulp tissue to avoid proton accumulation. The increased TA values observed after the temperatures were increased to 16°C may be explained by increased rates of starch to sugar conversion and increased osmotic transfer of water from peel to pulp. The significantly higher TA values for chill-injured fruits compared to unchilled fruits at the end of the storage period may be due to larger starch reserves in the chill-injured fruit pulp which would prevent metabolic transformation of organic acids to CO_2 and H_2O.

Oxalic acid in bananas is completely water soluble and represents about 50% of the total acidity of unripe 'Gros Michel' pulp but decreases during ripening to 60% of its original value, suggesting that the ripening banana is capable of metabolizing this acid (Wyman and Palmer, 1964). Feeding of oxalate-^{14}C to banana slices confirmed that it is metabolized (Palmer and Wyman, unpublished, as quoted by Palmer, 1971). The higher TA observed in chill-injured banana fruit observed at the end of the experimental period suggests the possibility that chill-injured fruits may have a reduced ability to metabolize oxalic acid.

Pulp: peel ratio

After the first 8 days, the pulp: peel ratio of fruits held at 5°C and 10°C was significantly lower than that of fruits held continuously at 16°C, (Figure 5). After all storage temperatures were adjusted to 16°C, the pulp: peel ratio of fruits previously held at 5°C and 10°C remained significantly lower than that of unchilled fruit until the 22nd and 18th day, respectively.

The pulp: peel ratio of banana fruits is related to the osmotic transfer of water from the peel to the pulp due to the accumulation of sugars in the pulp during ripening, (von Loesecke, 1950). The lower pulp: peel ratio of fruits stored at chilling temperatures may be due to retardation of starch to sugar conversion at lower temperatures (Barnell, 1940),

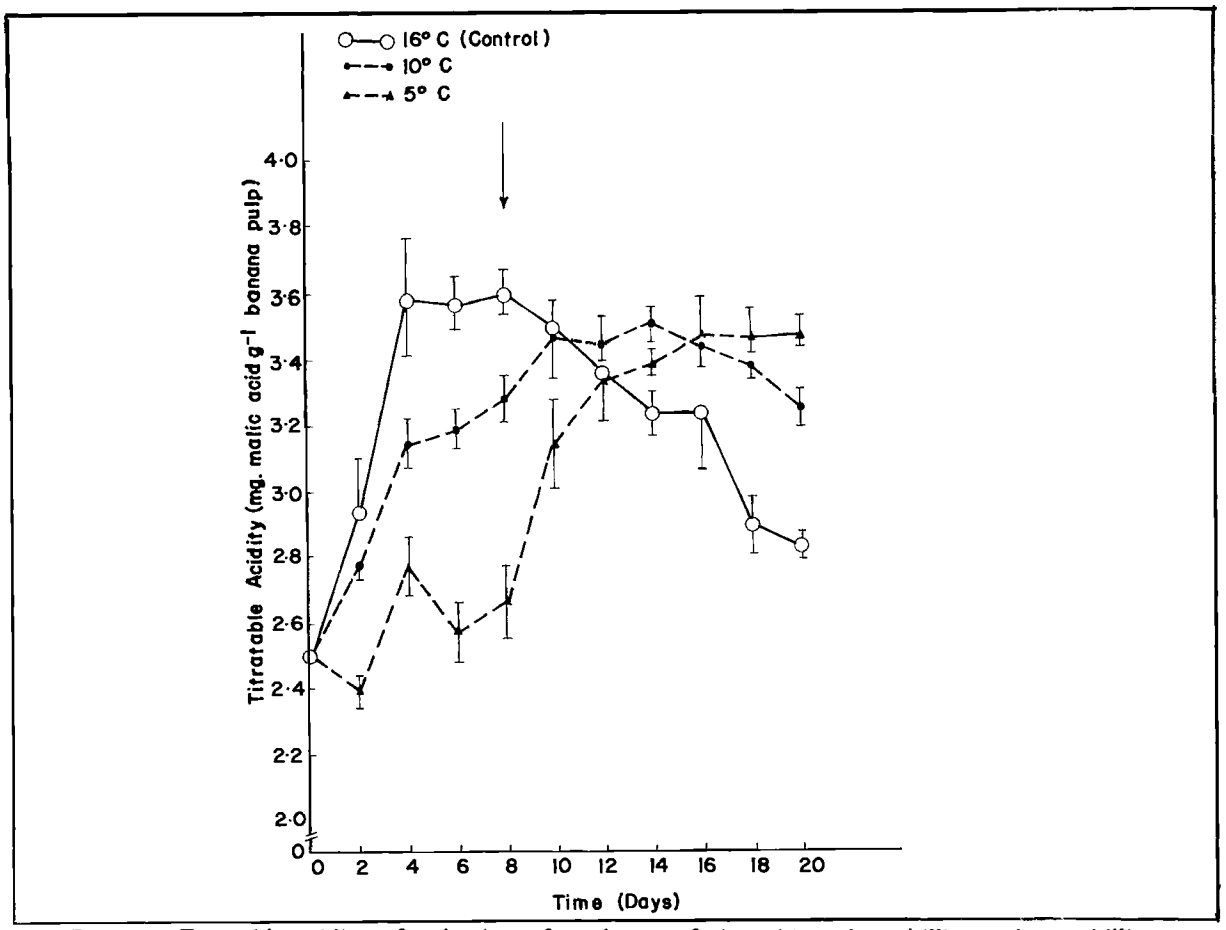

Figure 4 Titratable acidity of pulp tissue from banana fruits subjected to chilling and non-chilling temperatures. Arrow (↓) indicates time at which chilling temperatures (5° and 10°C) were raised to 16°C.

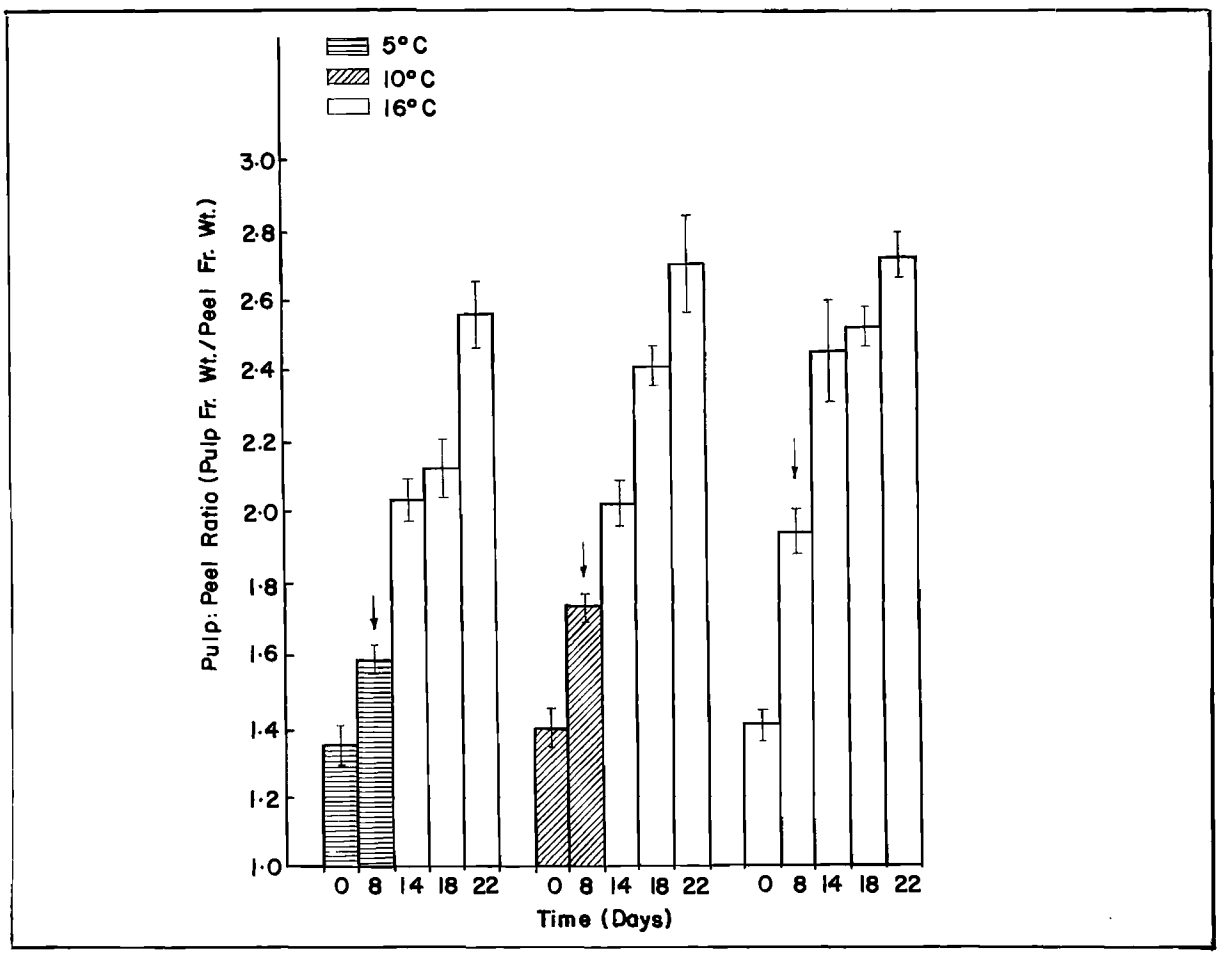

Figure 5 Pulp: peel ratio of banana fruits at various stages during storage at chilling and non-chilling temperatures. Arrow (↓) indicates time at which chilling temperatures (5° and 10°C) were raised to 16°C.

which would result in a lower concentration of sugars in chilled fruit pulp compared to unchilled fruit pulp. The increase in pulp: peel ratio observed in chilled fruit after storage temperatures were adjusted to 16℃ may be accounted for by more rapid conversion of starch to sugars resulting in greater osmotic transfer of water from peel to pulp.

The range of values for pulp: peel ratio that is typical of normally ripened bananas at the eating-ripe stage is between 2.2 and 2.7 (von Loesecke, 1950). Unchilled fruit attained a pulp: peel ratio within this range after 14 days (Figure 5). Despite the previous chilling treatments at 5℃ and 10℃, chill-injured fruits eventually attained a pulp: peel ratio within the acceptable range after 18 and 22 days respectively. By this time colour indices were 10.6 and 9.5 for fruits chilled at 5℃ and 10℃ respectively (Figure 1), values indicative of abnormal colour development (Appendix 1). The chilling index of fruits from both 5℃ and 10℃ approached 4 at this time indicative of severe injury (Figure 2). Therefore, by the time that the pulp: peel ratio of chill-injured fruits had attained values within the range that is acceptable for consumption the appearance of the fruits was unacceptable.

Summary

Exposure of green banana fruits to a severe (5℃) and marginal (10℃) chilling temperature for an 8-day period followed by storage at a non-chilling temperature (16℃) caused substantial deterioration of fruit quality resulting in commercially unacceptable fruit. Both chilling temperatures had retarding effects on the development of fruit colour, and on the increases in TSS, TA and pulp: peel ratio, with the degree of retardation being more acute at the more severe chilling temperature (5℃). An anomalous relationship between chilling temperature and the development of chilling injury symptoms was observed, where fruits held at the marginal chilling temperature sustained a higher chilling index than fruits held at the severe chilling temperature. This phenomenon is similar to that observed with peaches and plums by van der Plank and Davies (1937). After the increase in storage temperature, the rate of symptom development increased more rapidly in fruits previously held at 5℃ than at 10℃.

References

Abd El-Wahab, R.K. and Nawwar, M.A.M. (1977) Physiological and biochemical studies on chilling injury of banana. *Sci. Hortic.* 7 373-376.

Abou Aziz, A.B., El-Nabawy, S.M., Abd El-Wahab, R.K. and Abd El-Kader, A.S. (1976) Chilling injury of banana fruits as affected by variety and chilling periods. *Egypt J. Hort.* 3 37-44.

Barnell, M.R. (1940). Studies in tropical fruits, VIII. Carbohydrate metabolism of the banana fruit during development. *Ann Bot.* 4 39-71.

Charles, R.J. and Tung, M.A. (1973). Physiological, rheological and chemical properties of bananas during ripering. *J. Fd. Sci.* 38 456-459.

Desai, B.B. and Destipande, P.B. (1975). Chemical transformations in three varieties of banana *(Musa paradisicaca* L.) fruits stored at 20 °C. *Mysore, J. Agric. Sci.* 9 634-643.

Fidler, J.C. (1968). Low temperature injury in fruits and vegetables *In*: J. Hawthorne and E.J. Rolfe (eds.) *Low temperature biology of foodstuffs.* Pergammon Press, pp. 271-283.

Goodwin, R.W. and Mercer, E.I. (1972) Plant growth substances, *In*: P.N. Campbell and K.S. Dodgson (eds.) *Introduction to plant biochemistry.* Pergamon Press, New York pp. 324-342.

Haard, N.F. and Timbie, D. (1973). Chilling injury in green banana fruit: Changes in peroxidase isozymes in soluble and particulate pools *J.Fd. Sci.* 38 642-645.

Madamba, L.S.P., Baes, A.U. and Mendoza, D.B. (1977) Effect of maturity on some biochemical changes during ripening of banana *(Musa sapientum* l.c.v. Lakatan) *Fed. Chem.* 2 177-183.

Murata, T. and Ku, H.S. (1966) Studies on postharvest ripening and storage of banana fruits *J. Fd. Sci. Technol.* 13 466-470.

Palmer, J.K. (1971) The banana. *In:* A.C. Hulme (ed.) *The biochemistry of fruits and their products,* vol. 2., Academic Press, London.

Peacock, B.C. (1980) Banana ripening – Effect of temperature on fruit quality. *Queensl. J. Agric. Anim. Sci.* 37 39-45.

Poland, G.L. and Wilson, R.M. (1933) Banana chilling studies. I. Effect of low temperatures on appearance and edibility. *United Fruit Co.,* Res. Dept Bult 46.

Van der Plank, J.E. and Davies, R. (1937). Temperature cold injury curves of fruit *J. Pomol.Hort. Sci.* 15 226-247.

Von Loesecke, H.W. (1950). *Bananas*, 2nd ed., Interscience Pub., New York.

Wardlaw, C.W. (1972) *Banana diseases including plantains and Abaca* 2nd ed., Longmans, London.

Wilkinson, B.G. (1970). Physiological disorders of fruits after harvesting *In:* A.C. Hulme (ed.) *The biochemistry of r fruits and vegetables and their products,* vol. 1. Academic Press pp. 537-554.

Wyman, M. and Palmer,J.K. (1964) Organic acids in the ripening banana fruit *Plant Physiol.* 39 630-633.

APPENDIX I - Colour index of banana fruits in relation to development of peel colour during ripening (1–7) and as a result of chilling injury (8–11). After von Loesecke (1950) and modified by Abou-Aziz *et al.*, (1976).

Colour Index	Peel Colour
1	green
2	green – trace of yellow
3	more green than yellow
4	more yellow than green
5	green tip
6	all yellow
7	yellow flecked with brown
8	dull green with large brown areas
9	more than 50% brown or dull green
10	almost all brown or smoky grey
11	black

APPENDIX II - Chilling index as a function of symptom development in bananb fruits. Adapted from Poland and Wilson (1933).

Chilling Index	Symptom Description
0	no abnormality
1	slight dullness – trace when compared to unchilled fruit
2	medium dullness – fruit may be saleable but not attractive
3	severe dullness – peel is dull grey or brown
4	All brown – peel may be entirely brown, often black green

SWEET CORN POTENTIAL FOR CULTIVATION IN TRINIDAD AND TOBAGO

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ABSTRACT

Results of research work conducted in the Faculty of Agriculture on sweet corn *(Zea mays* L. var. *saccharata* Sturt) are discussed and the potential for the cultivation of the crop indicated. A new high yielding (over 35,000 marketable cobs per ha) synthetic cultivar, Local F7, developed at the University is identified.

RESUMEN

Los resultados del trabajo de investigación del choclo (*Zea mays* L. var. *saccharata* Sturt) llevados a cabo en la Facultad de Agricultura son discutidos y la posibilidad para su cultivo es indicada. Se identifica una variedad, sintética-criolla F7 de gran rendimiento (más de 35,000 mazorcas para mercadeo/ha), desarrollada en la Universidad de West Indies.

Keywords: Sweet Corn, Trinidad & Tobago

Field corn *(Zea mays)* is a popular crop in Trinidad & Tobago where it is grown by small farmers often in mixtures with pigeon pea *(Cajanus cajan)* especially during the wet season (June - December) It is generally harvested at the green immature stage (milk stage) and used in lieu of sweet corn *(Zea mays* var. *saccharata* Sturt.)

In Trinidad & Tobago sweet corn has not been grown commercially to any great extent; up to 1980 production had been confined mainly to semi-commercial activity at the now closed University of the West Indies Texaco Food Crops Farm (Cropper and Brathwaite, 1977; Brathwaite, 1979). There are a few reports on sweet corn production and processing investigations (Vlitos and Davies, 1964; Cropper, 1975, 1976; Cropper and Ferguson, 1977), and Cropper (1972) demonstrated the crop's potential for production and processing.

Consumption of imported frozen and canned sweet corn has been increasing, but there has always been much interest in sweet corn for local fresh marketing and processing. In 1979 work on sweet corn was initiated in the Cereals and Other Grains Research Programme of the Faculty of Agriculture. The major objective of the project was the identification of high quality sweet corn cultivars suitable for local cultivation and the determination of agronomic optima for their economic production by farmers in suitable cropping systems. This paper summarises the main findings of the investigations and introduces the locally developed sweet corn synthetic cultivar.

Cultivar evaluation

A number of cultivars were imported, mainly from the United States of America, for local evaluation. All of the cultivars were hybrids except the synthetics PR 50 and Sure Sweet from Puerto Rico. Few of the evaluation trials were carried out during the dry season because of the lack of adequate and reliable irrigation facilities. All trials were randomized and plots measured 3.0m x 2.25m. Seeds of each cultivar were hand planted at a depth of about 5cm in mounds 25cm apart along rows spaced at 75cm; at least two seeds were planted per mound. The plants were thinned to one plant per mound 1 week after germination. Table 1 presents three years' data on those cultivars which showed acceptable germination and produced cobs. The high yield potential of many of the cultivars is clearly indicated. Because of the paucity of seed, a few cultivars (Calico King, XPH 2553, Yukon, and the AVX and GH cultivars) were not evaluated every year during the period. Cultivars were normally ready for harvest 15 to 20 days after silking and cobs with silk turning dark brown were harvested 64 to 72 days after planting. Cultivars like PR 50, Tendertreat, Sugar Loaf, Florida Staysweet, CXP 514, AVX 2540, Mainliner, White Lightning Hawaiian Super Sweet, Sweet Tennessee, GH 3045, GH 3045, GH 2269, GH 2581, Golden Queen Banner, Resistall, XPH 2553, and Calico King consistently produced two marketable ears per plant.

Table 1. Performance of sweet corn cultivars on River Estate loam soil in Trinidad[a]

Cultivar	Marketable ear yield (1000's/ha)	Dehusked ear weight (g)	Dehusked ear length (cm)	Plant height (cm)
Local breeding line	54.2	157	18.1	150
Sure Sweet	55.8	125	15.9	160
PR 50	49.8	155	16.9	162
Tendertreat	67.5	171	23.3	138
Snow Queen	58.3	174	21.3	107
Sugar Loaf	43.0	150	17.4	98
Terrific	32.4	154	17.5	121
Reliance	50.0	111	14.2	77
Florida Staysweet	43.7	123	18.6	102
CXP 514	47.5	121	16.5	105
AVX 5641	48.4	129	17.9	105
AVX 2519	46.4	155	17.8	104
AVX 2562	40.5	154	18.2	118
AVX 2540	34.0	151	19.6	117
AVX 2539	54.0	165	18.4	111
Mainliner	43.3	195	22.3	88
Miracle	44.5	154	22.3	88
Monarch Advance	33.5	174	20.1	108
NK 199	38.9	164	17.4	116
Paramount	33.5	146	18.9	92
Yukon	37.2	154	19.6	90
White Lightning	34.7	134	16.5	112
Hawaiian Super Sweet	16.3	125	19.0	115
Mini-Max	22.8	106	17.4	77
Sweet Tennessee	51.7	146	28.6	114
Jubilee	69.3	136	18.3	104
GH 3045	41.0	130	16.4	91
GH 2269	75.1	128	16.8	122
GH 2581	33.4	140	17.7	93
GH 1901	99.7	63	12.9	67
Golden Queen	50.5	137	17.1	113
Banner	36.5	139	17.4	104
Resistall	48.6	123	16.8	112
Reward	88.9	57	13.1	54
XPH 2553	20.3	125	16.7	80
Calico King[b]	-	164	20.6	95
Atlantic	52.3	150	19.0	180

[a] Summary of results from ranted field trials conducted over a 3-year period.
[b] Few marketable ears were produced

Consumer acceptability

Consumer acceptability tests have formed an important aspect of the research project. Many testers have reported favourably on most of the cultivars and stated that they would purchase them if they were on sale at reasonable prices. All testers showed preference for cultivars with yellow, cream, and white kernels, in descending order, but accepted white types when yellow or cream types were unavailable. Table 2 presents typical evaluation results on the local breeding line.

Table 2. Taste testing: results from 77 respondents evaluating the sweet corn local breeding line F_7 in Trinidad

Question	% of respondents replying
1) *Cooking preference*	
Boiled	100
Roasted	0
2) *Taste*	
Very sweet	18
Moderately sweet	78
Not sweet	3
3) *Hardness for chewing*	
Too hard	6
Too soft	6
Just right	88
4) *Size*	
Reasonable	83
Too small	17
5) *Other comments*	
Too glutinous	4
Immature	9
Need for more	8
Satisfactory	79

Plant nutrition

Sweet corn is a heavy feeder and responds to a high level of soil fertility. Results from trials indicate that although fertilizer rates will vary depending on a number of factors including soil type, plant density and rotations, a blanaced, well timed, fertilizer programme is essential for optimum yields. An adequate supply of plant nutrients should be available during the early growth stages of the plant and there should be enough to maintain steady rapid growth up to harvest. Acceptable yields of high quality marketable ears have been produced on River Estate loam soil at the University Field Station (where the majority of the studies were conducted) with a combined basal application of 60kg N ha^{-1}, 20 kg P_2O_5 ha^{-1}, and 50kg K_2O ha^{-1} followed by an application of 60kg N ha^{-1} four weeks later as a banded side dressing. Studies on other soil types suggest that an alternative general recommendation in the absence of soil test data is the basal application of at least 300kg ha^{-1} of a complete fertilizer, e.g. 20:10:10: or 15:7:7, followed by 60kg N ha^{-1} as a banded side dressing at four weeks. Studies are still in progress.

Plant density

Studies have shown that plant density and plant spacing have a significant affect on the uniformity of the crop, size of ears and ear yields, and quality of weed control. Generally, ear yields have been increased by planting more plants per unit area; the number and size of ears per plant decrease as plant density increases. Results show that the optimum plant desnity varied depending particularly on the cultivar, type and fertility and moisture status of the soil. Under conditions of limited moisture availability on Cunupia clay soil a density of 30,000 plants ha^{-1} was found to be optium in cultivars 'PR 50'. 'CXP 514' and the local breeding line. A similar density was adequate on a Las Lomas clay loam of limited fertility status. In a trial in which densities above 50,000 plants ha^{-1} were evaluated, all densities gave good yields but consumers complained that ears were excessively small and variable. To date, the summary results suggest that, under normal conditions, a plant density range of 35,000 to 48,000 plants ha^{-1} is satisfactory for good yields of acceptable quality ears in the cultivars evaluated.

Weed control

In Trinidad & Tobago manual methods are still commonly employed for the control of weeds in corn. Many herbicides are registered for use in field corn in the United States of America but the inclusion of sweet corn in rotations with vegetables which are often susceptible to the common triazine herbicide residues, and the greater susceptibility of sweet corn cultivars to herbicide injury necessitates the local evaluation of these herbicides in the crop. Table 3 presents herbicide treatments which provided good weed control without significant crop injury and acceptable yields of marketable ears of sweet corn with little or no residue carryover on different soil types. Predominant weeds on many of the experimental sites included *Amaranthus* spp., *Brachiaria* spp., *Digitaria* spp., *Echinochloa colonum, Eleusine inidca, Euphorbia* spp., *Phyllanthus amarus,* and *Setaria* spp. Best results were often provided by pre-emergence combinations of atrazine (1.0kg a.i. ha^{-1}) + alachlor (2.0kg a.i. ha^{-1}) and alachlor (2.0kg a.i. ha^{-1}) + metribuzin (0.6kg a.i. ha^{-1}). *Rottboellia exaltata* has become a problem at specific locations and is now the subject of a special project.

Table 3. Recommended herbicide treatments (kg a.i./ha) for weed control in sweet corn[a].

Pre-plant incorporated treatments
Alachlor (1.5 - 2.0)
Atrazine (1.0 - 1.6) + alachlor(1.5 -2.0)
Atrazine (1.0 - 1.6) + butylate (3.0 - 4.5)
Cyanazine (1.0 - 1.6) + butylate (3.0 - 4.5)

Pre-emergence treatments
Alachlor (2.0)
Alachlor (2.0) + metribuzin (0.6)
Alachlor (1.0 -1.6)
Atrazine (1.0 -1.6) + alachlor (1.5 - 2.0)
Atrazine (1.0 - 1.5) + metolachlor (1.5 - 2.0)
Cyanazine (1.0 - 1.6) + alachlor (1.5 - 2.0)
Cyanazine (1.0 - 1.6) + metolachlor (1.5 - 2.0)

Poste-mergence treatments
2-4D amine salt (0.25 - 0.75)
Atrazine (1.0 - 2.0)
Bentazon (0.75 - 1.0)
Linuron (0.75 - 1.0)
Paraquat (0.5 - 1.0)

[a] At least 85 % control. Summary information from eight field trials mainly on River Estate and St. Augustine loams and Cunupia clay soils with different cultivars including the synthetics 'Sure Sweet', 'PR 50', 'Local Breeding lines' and the hybrids 'Mainliner' and different coded AVX germplasm materials.

Cost and returns

Table 4 presents the labour requirement in sweet corn production on three farms with different levels of mechanization. A mean labour requirement for the production of one hectare was 132 mandays. Harvesting and crop protection practices made the major demands on labour.

Economic data presented in Table 5 show that the mean gross margin on the selected farms was TT$39,182 per ha with a mean total variable cost of production of TT$9,735. All the farmers in the study realised profits.

Table 4. Labour requirement in sweet corn production:three private farms in Trinidad.

Cultural operation	Labour requirements on private farms [a] (mandays/ha)		
	Farm 1[b]	Farm 2[c]	Farm 3[d]
Land preparation	2.5	7.5	8
Planting	25	10	26
Irrigation	-	-	8
Fertilizing	10	12	10
Chemical weed control	-	5	6
Hand weeding and moulding up	25	10	15
Chemical pest and disease control	15	16	15
Harvesting	59	64	56
Post-harvest handling	2	1	1
Total	138.5	125.5	130

[a] The local breeding line (F_7) was grown on all farms except Farm 1 where cultivar 'Atlantic' was grown.

[b] All operations were done manually except land preparation which invloved one rotavation.

[c] Full mechanical land preparation which involved brush cutting, disc/ploughing and two rotavations. Planet Junior planter and Planet Junior fertilizer drill were used for planting and fertilizer application, respectively.

[d] Full mechanical land preparation as on Farm 2. All other operations were carried out manually.

Table 5. Analysis of cost and returns of sweet corn production on private farms inTrinidad[a].

Area planted (ha)	Gross returns (TT$/ha)	Total variable cost of production (TT$/ha)	Gross margin (TT$/ha)
0.10	56380	10315	46065
0.15	40126	10125	30001
0.25	56650	9385	44265
0.28	42153	8375	33778
0.05	52272	10473	41799
Mean	48916	9735	39182

[a] All rainfed crops planted in April - May 1985. Cultivars 'Atlantic' and 'PR 50' were grown on the 0.05 and 0.28 ha areas, respectively. The local F_7 was grown at all other sites. TT$2.42 = US$1.00.

A new synthetic cultivar

Breeding work involving an open pollination of a group of genotypes conducted as part of the Research Programme has resulted in the development of a F_7 generation, a specific line of which is about ready for release as a new synthetic cultivar. The original crosses were made at the University of the West Indies in 1981. Selections were subsequently made amongst populations on the basis of specific characteristics including cob size, yield, plant characteristics and taste, and rated for disease and pest tolerance. Replicated field trials at different locations were conducted. In all trials the synthetic cultivar gave yields of over 35,000 marketable ears ha^{-1}. Table 6 presents statistics on the synthetic.

Table 6. Characteristics of the local (Trinidad & Tobago) sweet corn synthetic cultivar F_7.

Maturity	70 days
Plant height	172 cm
Ear height	63 cm
Ear length	18-20 cm
Ear weight	155 g
Kernel colour	Light yellow
No. of rows	10 - 12
Pericarp	Very good
Flavour	Very good
Ears per plant	2

In general the synthetic is a rugged performer suitable for either field or backyard cultivation. The ear is enclosed in a tight husk with excellent protection. The ears are tapered and have good tip fill. Recent analyses indicated that the synthetic contains similar total sugar as imported hybrids CXP 514 and Monarch Advance and the synthetics PR 50 and Sure Sweet.

Conclusion

Results obtained with the numerous trials clearly indicate that the production of high yields of acceptable quality ears of sweet corn is possible in Trinidad & Tobago. A number of the imported hybrids are quite adaptable. However, under conditions of limited soil fertility and soil moisture availability, many of these hybrids do poorly. The foregoing data clearly indicate the significant potential of the local synthetic cultivar in terms of yield, quality of ears and acceptability to consumers. There are several advantages to be derived from the adoption of such a synthetic; its maintenance and the production of seeds for farmers is easy; such cultivars can be moved easily from farmer to farmer and be saved by farmers from year to year; seed production costs are reasonable.

Although many successful crops have been produced in the project there are areas which urgently require further work; continuation of breeding work for the development of disease-resistant cultivars; control of corn grass; a study on a new disease which appears to be bacterial stalk rot caused by *Erwinia* spp. (personal communication ; Dr. Elango, Departmental of Plant Sciences and Biochemistry, University of the West Indies); and the interface between production and processing. Praedial larceny can also be a serious problem.

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References

Brathwaite, R.A.I. (1979). News from Texaco Food Crops Farm. Depart. of Agric. Extension, University of the West Indies, Extension Newsletter **10** 19–21.

Cropper, J. (1972). The prospects for vegetable processing in Trinidad with particular reference to pigeon peas and sweet corn. Paper presented at 10th Annual Meeting, Caribb. Food Crops Soc., Puerto Rico. 16 pp.

Cropper, J. (1975). Texaco Food Crops Farm Annual Reports 1972–73 and 1973–74. Dept. of Agric. Econ. and Farm Management, University of the West Indies, Trinidad. 52 pp.

Cropper, J. (1976). Texaco Food Crops Farm Annual Report 1975–75, Dept. of Agric. Econ. and Farm Management, University of theWest Indies, Trinidad. 35 pp.

Cropper, J. and Brathwaite, R.A.I. (1977). An evaluation of one approach to the promotion of agricultural development in Trinidad and Tobago: The Texaco Food Crops Farm. Paper presented at 14th Annual Meeting, Caribb. Food Crops Soc., Guadeloupe. 35 pp.

Cropper, J. and Ferguson, G. (1977). Texaco Food Crops Farm Annual Report 1975–76. Dept. of Agric. Econ. and Farm Management, University of the West Indies, Trinidad. 52 pp.

Vlitos, A.J. and Davies, W.N.L. (1964). Experimental production of several new sweet corn varieties for canning, and for fresh market use in Trinidad. Proc. Caribb. Food Crops. Soc. **2** 73–87.

BREEDING AND AGRONOMIC PERFORMANCE OF CORN CULTIVARS AND HYBRIDS DURING THE PAST FIVE YEARS IN PUERTO RICO

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ABSTRACT

Corn research activities conducted at the Tropical Agriculture Research Station (TARS), USDA-ARS, Mayaguez, Puerto Rico during the past five years are reported. The breeding programme utilizing recurrent selection has been successful in improving local and temperate zone populations. Progress has been made in transferring desirable genes to the local sweetcorn cultivar Suresweet. Numerous corn introductions from Central America and other tropical countries have been evaluated and high yielding selections identified for further studies. Based on numerous field studies, yields of over 8,000 kg ha^{-1} can be expected utilizing superior commercial hybrids under intensive management with the application of up to 120 kg N ha^{-1} at a population density of over 40,000 plants ha^{-1}.

RESUMEN

Este es un informe de investigación del maiz, llevado a cabo durante los últimos cinco anos, en la Estación de Investigacion de Agricultura Tropical (TARS), USDA-ARS en Mayaguez, Puerto Rico. El programa de mejoramiento, de selección reciproca-contigua, ha sido exitosa en cuanto se refiere al mejoramiento de poblaciones criolla y de la zona templada. Se hicierón avanzes en el transferimiento de genes, beneficiosos para la variedad criolla de choclo, Suresweet. Numerosas introducciones de maiz de America Central y de otros paises tropicales han sido evaluadas y selecciones de alto rendimiento fueron identificadas para llevar a cabo estudios mas amplios. Basados en estudios de campo es posible obtener rendimientos mayores de 8000 kg/ha, utilizando híbridos comerciales superiores, llevados a cabo bajo un manejo intensivo, con aplicaciones de hasta unos 120/kg/N/ha y con una población de mas de 40,000 plantas/ha.

Keywords: Breeding, *Zea mays*, Puerto Rico

Exceeded only by wheat and rice, corn *(Zea mays* L), the third most important cereal grain in the world, plays an important role in feeding millions of people throughout the world (Sotomayor-Rios and Weibel, 1983). According to USDA (1984), production in the United States during 1983/84 was 106,781,000 tonnes of a world total of 344,058,000. During the same period mean corn yield ranged from 0.09 to 1.89 tonnes ha^{-1} in Central America and was 5.12 tonnes ha^{-1} in the U.S. Excellent yields in the United States and other developed countries are attributed to the use of advanced technology at the farm level, plus the ability of superior hybrids. Puerto Rico has a limited production of cereal grains. Nevertheless over 500,000 tonnes year^{-1} are imported for livestock feed (Vicente-Chandler, 1984). According to data obtained by the authors, Puerto Rico could reduce the heavy importation of cereals if 50,000 ha of land were devoted to intensively cultivated corn and/or sorghum. In southern Puerto Rico over 3,000 ha of fertile flat land are being intensively utilized for commercial vegetable production during October through March, remaining idle during the rest of the year. Corn as well as sorghum are rotational crops providing an additional income to farmers outside the winter vegetable season and also improving the physical properties of the soil.

The objective of this paper is to summarize research findings on corn breeding and management conducted at the Tropical Agriculture Research Station (TARS), USDA-ARS, Mayaguez, Puerto Rico during the past five years. Most of the studies reported were conducted on a typical tropical Oxisol and should be applicable to other sites with similar soils in the Caribbean and elsewhere in the tropics.

Materials and methods

The experiments reported in this article were conducted at the following locations: (1) Isabela Experiment Farm of the Tropical Agriculture Research Station (TARS), USDA, ARS, Mayaguez, Puerto Rico. (2) The Agriculture Research and Development Center of the Agricultural Experiment Station, University of Puerto Rico at Lajas, Puerto Rico. (3) A private farm at Sabana Grande, Puerto Rico.

The Isabela farm is located in northwestern Puerto Rico, 128m above sea level at 18° latitude N and 67° longitude W. Mean monthly temperatures range from 21.6 to 26.2° C. Mean annual rainfall is 1658 mm. The soil is a Tropeptic Haplorthox, clayey, kaolinitic, isohyperthermic. It is highly weathered, leached with clays of low activity, and has a moderately high percentage base saturation throughout the profile. Crops on this soil do not consistently respond to added K, but have a moderate response to P and a good response to N and Zn.

The Lajas farm is located in southwestern Puerto Rico, 33m above sea level at 18° latitude N and 67° longitude W. Temperatures range from 22.6 to 31.4° C. Mean annual rainfall is 1194mm. The soil is a Vertisol clay (Udic Chromustert, very fine, montmorillonitic, isohyperthermic) with an organic matter content of 2.5 per cent. Soil pH is 6.3.

The Sabana Grande farm is located in southwestern Puerto Rico 33m above sea level at 18° latitude and 67° longitude. Temperatures range from 18.9 to 31.4°C. Mean annual rainfall is 1194mm. The soil is a Fraternidad clay (Udic Chromustert, very fine, montmorillonitic, isohyperthermic) with an organic matter content 2.3 per cent. Soil pH is 6.4.

Standard practices were utilized in the management of the different experiments conducted. These practices were described previously by Quiles–Belén (1983), Torres-Cardona and Sotomayor-Ríos (1983) and Torres-Cardona *et al* (1985). The corn germplasm consisted of populations and cultivars of a broad genetic background. For instance, outstanding corn populations from the International Maize and Wheat Improvement Center (CIMMYT), Mexico and the Central American Cooperative Improvement Program

(PCCMCA), were utilized as a source material for genetic and agronomic studies.

Improvement through breeding: a reciprocal recurrent selection scheme (Hallauer, 1972) has been utilized in the improvement of local corn cultivars "Diente de Caballo" (DC), "Mayorbela" (M), and temperate zone populations OHS9 and OHS10. Two improvement cycles have been completed. The pedigree method is being utilized in the improvement of the sweetcorn, Suresweet, developed at TARS, Mayaguez, a cultivar which is highly resistant to *Heliothis zea,* the corn earworm. The kernel pericarp of Suresweet is being improved by transferring the gene brittle–1 from Hawaiian Super-sweet No. 9, a high sucrose cultivar developed by Brewbaker (1977). Five cycles of selection have been completed using bite tests. The test is conducted 22 days after pollination at a late sweet corn stage, when kernel toughness is greater than at prime sweet corn stage, to ensure identification of the most tender ears. In this procedure the top half of each ear, is removed and subdivided for two testers while the bottom half is left to mature for seed production.

Management studies: (a). Twenty seven corn cultivars from the PCCMCA programme were evaluated at two planting dates (October, 1982 and March, 1983) at Isabela, Puerto Rico for yield and a series of agronomic traits.

(b). Thirty six corn cultivars and hybrids from PCCMCA were evaluated during 1983 at Isabela, Puerto Rico for yield and a series of agronomic traits.

(c). Twenty corn populations from CIMMYT, Mexico were evaluated at two planting dates during 1982–83 for grain yield and a series of agronomic traits.

(d). The effect of N levels (20, 40, 60, 120, 180 and 240 kg ha^{-1}) and population densities (20,000, 40,000 and 80,000 plants ha^{-1}) on commercial hybrids Pioneer 304 C, Pioneer 5800 and DeKalb XL 670 were studied at Sabana Grande and Isabela during 1983.

(e). Five commercial hybrids, DeKalb XL 560, Pioneer 304 C, DeKalb EXA 815, DeKalb XL 670 and DeKalb EXA 816, were evaluated at two planting dates (September and May) during 1984 for yield and a series of agronomic traits.

Results and discussion

Corn breeding: preliminary results from the reciprocal recurrent selection improvement programme indicate that after two cycles of breeding and recombination, OHS9 and OHS10 yields were superior to those of M and DC. The most promising combinations obtained were those with OHS10, M and DC, with yields over 5,000 kg ha^{-1}, which were comparable to check variety Pioneer Hybrid 304 C (Table 1). In the sweet corn breeding programme F5 families of the cross Suresweet x Hawaiian Supersweet No. 9 are very promising and an early release of this material will be made this year.

Table 1 Yield comparison of corn cultivars Diente de Caballo (DC), Mayorbela (M), OHS9 and OHS10 their crosses and S_1 bulks after two reciprocal recurrent selection cycles, 1982 – 85, Puerto Rico.

Genotypes	Reciprocal recurrent selection cycle 1	2	X
	kg ha^{-1}		
DM x M	5191	5598	5395
DC x OHS9	4759	4779	4768
DC x OHS10	4915	5709	5312
M x DC	4886	5412	5149
M x OHS9	4080	3900	3990
M x OHS10	5011	5103	5057
OHS9 x DC	4234	4810	4522
OHS9 x M	4270	4677	4474
OHS9 x OHS10	4011	4836	4424
OHS10 x DC	4618	5709	5164
OHS10 x M	5360	5641	5501
OHS10	2896	4177	3502
DC	2991	3652	3322
M	2808	3812	3310
OHS9	3619	3963	3791
OHS10 x OHS9	4257	4339	4298
DS S_1	2806	3165	2986
M S_1	3739	3348	3544
OHS9 S_1	2076	3107	2592
OHS10 S_1	1933	2918	2426
Pioneer X304 C (check)	5629	6089	5859

Management studies: Significant differences between cultivars and planting dates were obtained for grain yield and most traits (study (a), Materials and methods). Cultivar Tico V–6, from Costa Rica produced the highest grain yields across planting dates (6,407 kg ha^{-1}), significantly superior to the remaining cultivars (Table 2) (Torres-Cardona and Sotomayor-Rios, 1983). Correlation coefficients between grain yield and leaf area index, plant height, ear length and ear diameter were highly significant, ranging from 0.86 to 0.95 (Table 3).

Significant differences between genotypes for grain yield and most traits were obtained (study (b), Materials and methods). Cultivars ICTA HB-33, CENTA H-3 and CENTA HE-20, all from the PCCMCA programme, were the top yielders with 5,982, 5,749 and 5,524 kg ha^{-1}, respectively, significantly higher than the remaining cultivars (Fig. 1).

Significant differences were observed for most traits including grain yield (study (c) Materials and methods). The best two populations were Across 7728 and Cuyuta 7929 with grain yields of 5,814 and 5,808 kg ha^{-1}, respectively. These means were not significantly different from that of Pioneer Hybrid 304 C, the check variety (6,029 kg ha^{-1}) (Fig. 2).

Table 2. Grain yield, leaf area index, plant height, ear length and ear diameter of 27 corn cultivars across planting dates at Isabela, Puerto Rico, 1982-83.[1]

Cultivars	Grain yield	Leaf area index	Plant height	Ear length	Ear diameter
	(kg/ha)		(cm)	(cm)	(cm)
TICO V-6	6407a	3.74 a	247 b	19.0 a	5.4 a
PNIA HB-1	6212 b	3.45 cd	246 bc	19.1 a	5.4 a
H-5	6134 bc	3.67 b	249 a	18.7 b	5.4 a
TICO V-7	6013 cd	3.74 a	247 ab	18.8 b	5.5 a
Hibrido SIATSA H-1	5873 de	3.73 a	247 ab	19.2 a	5.4 a
HE-16	5825 e	3.42 d	243 def	18.2 c	5.5 a
HB-33	5724 e	3.64 b	247 ab	18.2 c	5.4 a
HE-102	5720 e	3.48 c	247 c	18.6 b	5.4 a
HG-82	5218 f	3.23 e	242 efgh	15.7 f	4.7 efg
Tocumen 7428	5045 g	3.22 e	243 def	16.7 d	4.9 bcde
La Máquina 7843	4987 gh	3.12 f	242 efgh	14.8 ijk	4.9 bcde
Alajuela - 2	4916 gh	3.06 g	2435 cd	15.6 f	5.0 bc
EX-811	4828 hi	2.98 h	243 def	15.2 g	4.7 fg
UNP -1	4740 i	3.02 gh	243 def	15.6 f	4.8 cdefg
HA-44	4692 i	3.08 fg	241 fghi	16.5 e	4.8 cdefg
B-555	4490 j	2.71 j	240 ijkl	14.9 ijk	4.8 cdefg
EX-815	4341 j	2.72 j	238 lmno	15.0 hi	4.8 cdefg
Los Diamantes 8043	4315 k	2.92 i	241 fghi	14.7 jkl	4.8 cdefg
Sintético Hondueño	4257 kl	2.42 m	239 klmn	14.2 n	5.0 bc
ICTA T-101	4220 kl	3.04 ghi	243 def	14.9 ijk	4.9 bcde
ICTA B-1	4099 lm	2.77 j	239 klmn	14.7 jkl	4.7 fg
HB-67	4027 mn	2.41 m	237 no	14.7 jkl	4.8 cdefg
H-3 4022 mn	4022 mn	2.64 k	239 klmn	15.1 gh	4.7 fg
TICO V-1	3985 mn	2.46 m	240 ijkl	14.7 jkl	4.7 fg
Tocumen 80 A	3928 n	2.44 m	240 ijkl	14.9 ijk	4.7 fg
H-9	3622 o	2.57 l	237 no	14.5 lm	4.9 bcde
Alajuela -1	3516 o	2.42 m	237 no	14.5 lm	4.9 bcde
$\bar{x}$	4858	3.04	242	16.2	5.00
C.V. (%)	3.15	1.95	7.2	1.23	3.19

[1] Means followed by a letter in common do not differ significantly (P=.05) according to Duncan's multiple range test.

Table 3. Correlation coefficients between grain yield and leaf area index, plant height, ear length and ear diameter of 27 corn cultivars across planting dates at Isabela, Puerto Rico, 1982-83.

	Leaf area index	Plant height	Ear length	Ear diameter
Grain yield	0.95**	0.91**	0.93**	0.86**

** Significantly different from zero at P =0.01

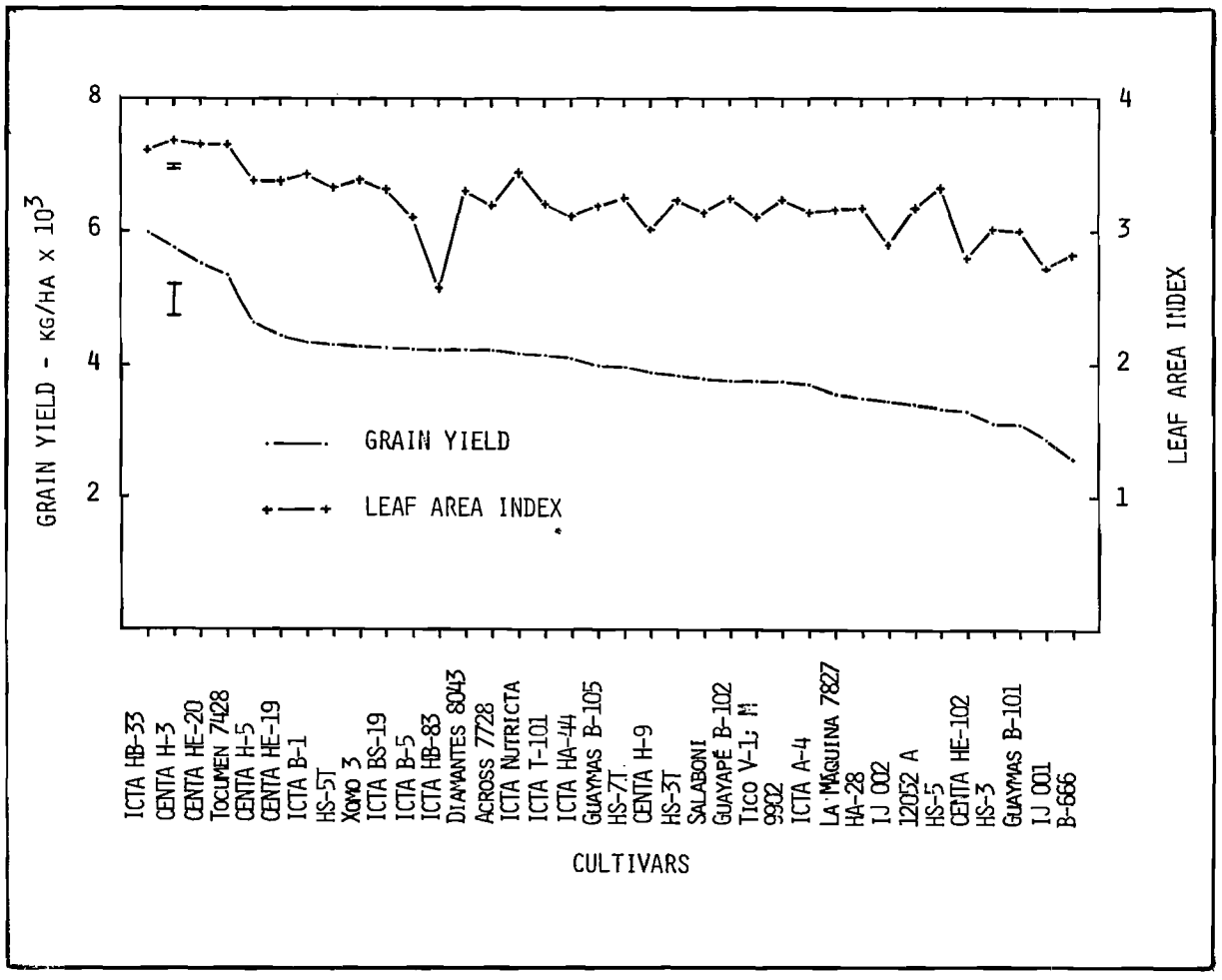

Figure 1 Grain yield and leaf area index of 36 corn cultivars at Isabela, Puerto Rico, 1983.

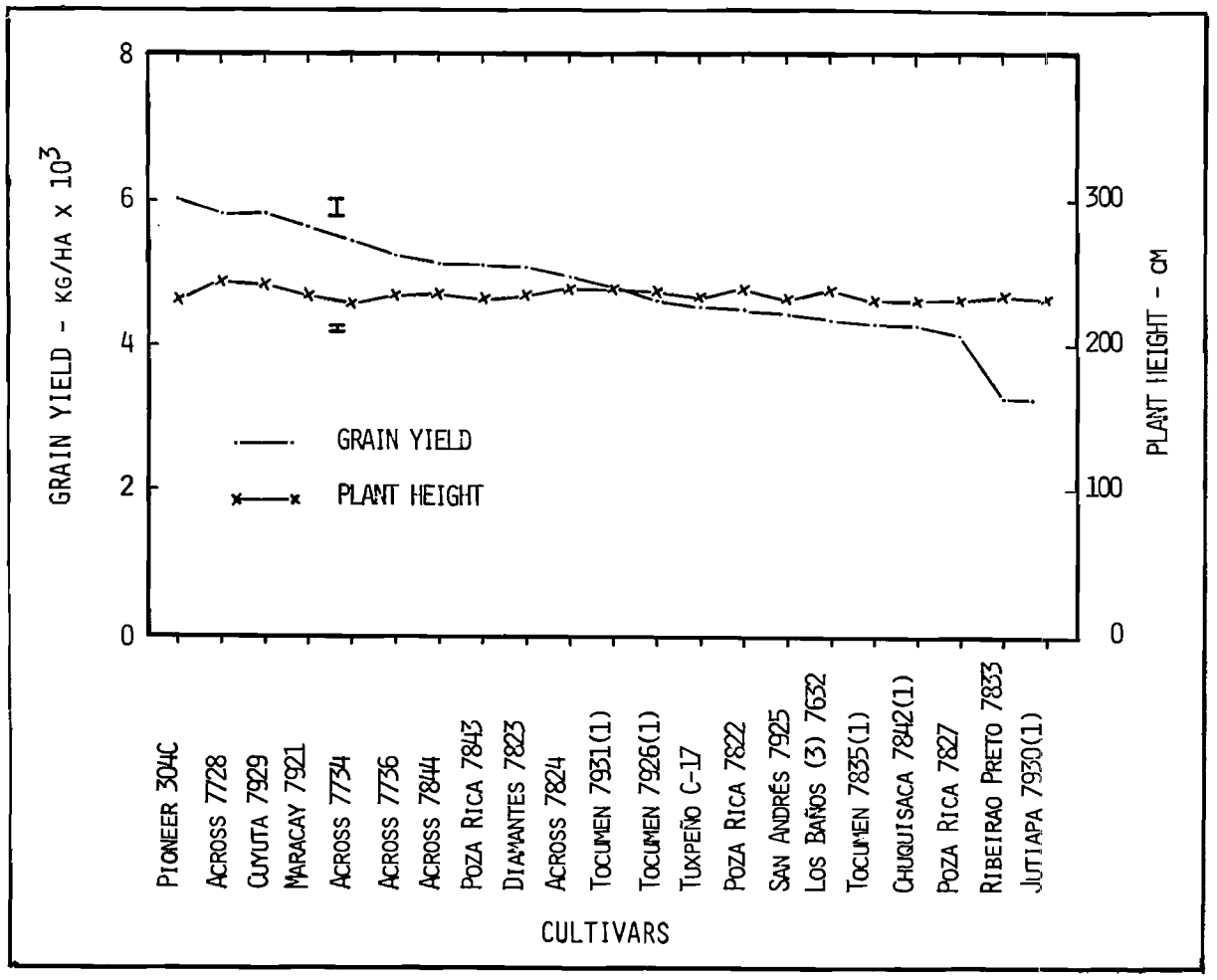

Figure 2 Grain yield and plant height of 21 corn cultivars across planting dates at Isabela, Puerto Rico, 1982 – 83.

Significant differences from grain yield and most traits were obtained for locations, N levels, hybrids, population densities and their interaction (study (d) Materials and methods). Average maximum yields of 8,890 kg ha^{-1} (Pioneer Hybrid 304 C) resulted from the application of 120 kg N ha^{-1} at a population density of 40,000 plants ha^{-1} (Isabela), although 88 per cent of such yields were obtained with the application of the initial 60 kg N ha^{-1} (Table 4) (Quiles-Belén, 1983).

Table 4. N Level and polulation density effect on grain yield of three corn hybrids at two locations in Puerto Rico, 1983.[1]

	Hybrids and Polulation Densities (plants/ha)									
	Dekalb XL 670			Pioneer X304 C			Pioneer 5800			
N Level	20000	40000	80000	20000	40000	80000	20000	40000	80000	x̄
	kg/ha									
	Isabela									
0	2505 a	4745 c	4153 b	3286 a	5580 c	5003 bc	3245 b	4951 b	4507 c	4219 d
60	2945 a	7243 ab	4658 b	3762 a	7836 ab	5619 ab	4366 a	6398 ab	5181 ab	5334 b
120	3459 a	8218 a	6135 a	4051 a	8890 a	6253 a	3844 ab	7195 a	5568 ab	5957 a
180	2943 a	6188 bc	6338 a	3967 a	8019 ab	4948 c	3616 ab	6139 ab	5802 a	5329 b
240	3142 a	6168 bc	4437 b	3262 a	7283 bc	4535 bc	4046 ab	6671 ab	5050 abc	5066 c
x	2999	6512	4434	3666	7522	5472	3823	6271	5222	
	Sabana Grande									
0	4045 a	6128 d	5028 d	3974 c	6425 a	5999 b	4239 ab	5298 d	4824 d	5107 c
60	5087 a	7151 ab	6413 a	5329 a	8040 a	6528 ab	4854 a	6019 cd	6453 ab	6208 ab
120	4714 a	8820 a	6205 abcd	4683 abc	7910 a	7415 a	4673 ab	6862 ab	6707 a	6443 a
180	4412 a	7388 ab	6313 ab	4455 abc	7869 a	6284 ab	3965 a	7231 a	5959 abc	5986 b
240	4365 a	7166 ab	6284 abc	4916 ab	7696 a	6854 ab	5403 b	6153 ac	6022 abc	5995 b
x̄	4525	7331	6049	4671	7588	6616	4447	6313	5993	

[1] Means followed by a letter in common do not differ significantly (P=.05) according to Duncan's multiple range test.

During 1983/84 and at the Agricultural Research and Development Center at Lajas, Puerto Rico, the effect of N levels (0, 40, 80, 120, and 160 kg ha^{-1}) and planting dates (September 1983 and May 1984) were studied on two commercial hybrids (Pioneer X304 C and Dekalb XL 670). Significant differences were obtained among N levels for all the agronomic traits studied. The mean maximum grain yield (7,114 kg ha^{-1}) was obtained with the application of 120 kg N ha^{-1} (Table 5) (Torres-Cardona *et al*, 1985). These results are comparable to those obtained by Quiles-Belén (1983) at Sabana Grande, Puerto Rico.

Combined analysis of variance showed significant differences among planting dates, hybrids and their interactions for grain yield and most traits studied (study (e) Materials and methods). The highest yielder was Dekalb XL 560 (7,713 kg ha^{-1}) which significantly exceeded the remaining hybrids (Table 6). Based on cost estimates obtained by the authors and assuming a grain yield of about 7.5 tonnes ha^{-1}, the net profit for growing field corn in Puerto Rico would be $397 ha^{-1}.

Table 5. N level effect on grain yield of two corn hybrids at two planting dates in Lajas, Puerto Rico, 1983-84.

	September, 1983		May, 1984		
N Level	Pioneer X304C	DeKalb XL 670	Pioneer X304C	DeKalb XL 670	x̄
	kg/ha				
0	2422	3238	2373	2943	2744
40	6012	5467	56585	5314	5620
80	6983	6205	6565	6501	6564
120	7210	7168	7087	6904	7114
160	7105	6989	6889	6989	6993
x̄	5946	5813	5720	5730	

Table 6. Grain yield, plant height and leaf area index of fivecorn hybrids across planting dates at Lajas, Puerto Rico, 1983-84 [1].

Hybrids	Grain yield	Plant height	Leaf area index
	kg/ha^{-1}	m	
Dekalb XL 560	7713 a	2.5 d	4.8 a
Pioneer X304 C	6860 b	2.7 b	4.7 a
Dekalb EXA 815	6776 b	2.7 c	4.7 a
Dekalb 670	6764 b	2.6 c	4.7 a
Dekalb EXA 816	3793 c	2.9 a	4.2 c
x̄	6381	2.7	4.6

[1] Means followed by a letter in common do not differ significantly (P=.05) according to Duncan's multiple range test.

References

Brewbaker, J.L. (1977) Hawaiian Super-Sweet No. 9 *Hort. Science* **12** (4) 355–356.

Hallauer, A.R. (1972) Development of single cross hybrids modified reciprocal selection. *Eighth Ann. Ill. Corn Breed. School.* Univ. Ill., Mar. 9–10.

Quiles-Belén, A. (1983) Respuesta del maiz a la fertilización nitrogenada y densidades poblacionales en dos localidades de Puerto Rico. M.S. Thesis, Univ. P. R., Mayaguez Campus, Mayaguez, Puerto Rico.

Sotomayor-Ríos, A. and Weibel, D. (1983) Grain crops. *In:* Martin, F.W. (Ed.), *Handbook of tropical food crops.* CRC Press, Boca Raton, Florida.

Torres-Cardona, S. and Sotomayor-Ríos, A. (1983) Response of corn (*Zea mays* L.) to planting dates in Puerto Rico. *Proc. CFCS Annual Meeting*, Puerto Rico.

Torres-Cardona, S., Sotomayor-Ríos, A. and Quiles-Belén, A. (1985) Response of two commercial corn hybrids to five N levels at two planting dates in Puerto Rico. *Proc. XXXI PCCMCA Annual Meeting,* Honduras..

USDA (1984) *Agricultural statistics,* U.S. Gov. Printing Office, Washington, D.C. pp. 30–37.

Vincente-Chandler, J. (1984) Comentarios sobre una agricultura productiva para Puerto Rico. *Revista Colegio de Agronormos de Puerto Rico,* Oct. – Dic. pp. 7–8.

RESPONSE OF FORAGE SORGHUM TO TWELVE PLANTING DATES IN PUERTO RICO

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ABSTRACT

Cytoplasmic male-sterile sorghum ATx623 (*Sorghum bicolor* (L.) Moench) was crossed with male parents Millo Blaco (MB) (photoperiod sensitive), and Greehleaf (GL) (photoperiod insensitive). The genotypes were planted on the 15th day of each month during 1984 and harvested at 60 day intervals, Dry forage yield (DFY), crude protein yield (CPY), leaf area (LA), plant height (PHt), rust incidence (R) and *in vitro* dry matter digestibility (IVDMD) were calculated for each cutting. Analysis of variance showed significant differences among genotypes (G) and planting dates (PD) x G interaction for all traits except dry matter content (DMC) and IVDMD. All traits showed significant differences among PD. ATx623 x GL had nearly constant production (3–4 tonnes ha^{-1} $harvest^{-1}$). ATx623 x MB fluctuated from appoximately 3 tonnes ha^{-1} per harvest from December to January plantings to 7.68 tonnes ha^{-1} $harvest^{-1}$ at the June planting. Genotypes showed similar IVDMD at all harvests. During long day plantings photoperiod sensitive sorghums showed less R than the insensitive types. The excellent DFY, CPY and IVDMD, and low R incidence of photoperiod sensitive genotypes during long days make them valuable materials for intensively managed tropical sorghum. ATx623 and MB proved outstanding for developing superior F_1 forage sorghum hybrids in Puerto Rico.

RESUMEN

Sorgo fitoplásmico estaminado y esteril ATx623 (*Sorghum bicolor* (L.) Moench), fue cruzado con parentescos estaminados, – Millo Blanco (MB), (sensitivo a la luz) y Grennleaf (GL), (insensitivo a la luz) –. Los genotipos fueron plantados el quince de cada mes, durante el año 1984 y cosechados cada sesenta dias. El rendimiento de forraje en seco (DPY), rendimiento de proteina en bruto (CPY), superficie de la hoja (LA), altura de la planta (PHt), incidencia de la Roya (R) y la digestibilidad de materia seca *in vitro* (IVDMD), fueron calculados para cada cosecha. Un análisis de la variables mostrarón una diferencia significativa, de los genotipos (G) y de las fechas de siembra (PD) x interacción en todos los puntos mencionados anteriormente, excepto el conteniod G, de materia seca (DMC) y el IVMD. Todos los rasgos mostraron diferencias significativas entre las PD. AT623 x GL casi tuvieron una producción constante (3–4 ton/ha/cosecha). AT x 623 x MB fluctuarón de aproximademente 3 ton/ha/cosecha en siembras de Diciembre a Enero, a 7.68/ton/ha/cosecha en la siembra de Junio. Los genotipos mostraron un IVDMD durante todas las cosechas. Durante las siembras de tipo de dia largo, el sorgo sensitivo a la luz mostró una incidencia menor al ataque de la Roya que, el de aquellos del tipo insensitivo. Los excelentes DPY, CPY y IVDMD y la baja incidencia al ataque de la Roya de los genotipos sensitivos a la luz durante los dias largos, hacen de ellos un material de valor para las praderas de sorgo tropical, manejadas intensivamente. AT x 623 y MB mostraron ser sobresalientes para desarrollar un sorgo de forraje hibrido F1, en Puerto Rico.

Keywords: Forge sorghum, Photoperiodism, Puerto Rico

Garner and Allard (1923), coined the term photoperiodism to define plant response to daylength. Later studies demonstrated that the nyctoperiod (length of night), rather than length of day, was actually the operative factor in control of plant responses (Gardner *et al*, 1985). According to Miller *et al.* (1968) the response of tropical varieties to photoperiod has prevented universal use of much of the germplasm which exists in many short-day species, including sorghum (*S. bicolor* L. Moench). Studies by Quinby (1967) have shown that sorghum varieties differ in maturity because they respond differently to photoperiod and temperature. According to these authors differences in the temperate zone sorghums are apparently controlled by four gene loci with an allelic series at each locus. In plantings made for 12 consecutive months in 1964 and 1965 at Mayaguez, Puerto Rico by Miller *et al.* (1968) the effects of daylength on number of days to anthesis and plant height were observed in 15 tropical sorghums and compared with seven U.S. sorghums and a set of eight maturity genotype testers. These authors were able to bring all types into flower at about the same time in the said location by planting from mid-September through mid-November when daylength was below the critical level for these varieties. The U.S. sorghums were unaffected by changes in the photoperiod, whereas significant correlations were observed between days from planting to anthesis and plant height in most of the tropical sorghums.

The effect of planting dates and consequently the influence of photoperiodism on the yield and agronomic characters of tropical sorghums has not been studied in Puerto Rico. On the other hand, the photoperiodic effects on crops such as *Tephrosia vogelii, Pennisetum typhoides, Zea mays* and other short-day tropical species have received considerable attention (Barnes and Burton, 1966; Irvine and Freyre, 1966; Mc Clelland, 1928).

The objectives of this study were: (1) to determine the influence of photoperiod on plant height, leaf area and dry forage yield of photoperiod sensitive and photoperiod insensitive forage sorghums, and (2) to establish planting dates for optimizing yield and nutrient content of forage sorghums in Puerto Rico.

Materials and methods

The experiment was conducted at the experiment farm of the Tropical Agriculture Research Station (TARS), USDA, ARS, S & E, at Isabela, Puerto Rico, approximately 18° N latitude. Environmental conditions were relatively uniform throughout the year (Table 1). Daylength varies from 13.13 to 11.02

Table 1. Mean monthly daylengths, mean monthly maximum rainfall, and mean monthly maximum temperature at Isabela, Puerto Rico in 1984.

Month	Mean day length (hours *)	Mean rainfall (cm)	Mean temperature (°C)
January	11.11	2.41	23.3
February	11.30	14.94	22.2
March	11.02	2.97	23.8
April	12.32	1.68	25.2
May	12.59	13.56	25.3
June	13.12	18.19	25.9
July	13.07	7.52	25.6
August	12.43	20.50	26.2
September	12.14	26.70	25.7
October	11.44	37.36	25.3
November	11.17	7.19	21.6
December	11.04	0.80	22.3

* Longest day 13.13 (June 21), shortest day 11.02 (December 20); 12-hour days occur March 13 and September 29.

hours. Mean monthly temperatures varied from 21.6 to 26.2° C. The soil at the Isabela location is an Oxisol (Tropeptic Haplorthox). Rainfall follows a common pattern for the tropics with a marked dry season from December to March and an over-all monthly average of 136.5mm. Moisture was not a limiting factor, however, since irrigation was applied as needed.

The four genotypes were: Millo Blanco (MB), a local forage sorghum; hybrid ATx623 x MB (photoperiod sensitive); Greenleaf (GL) a sudangrass; and ATx623 x GL (photoperiod insensitive). Female parent ATx623 is a cytoplasmic male-sterile commonly utilized for grain and forage hybrid production.

Plantings of the four sorghums were made on the 15th day of each month starting in January during 1984. The experimental design was a randomized complete block with four replications. For weed control propazine [2-chloro-4, 6-bis (isopropylamino) -s-triazine] was applied at a rate of 2.5 kg of active ingredient ha^{-1} immediately after planting. At planting, and after each 60-day cutting interval a 15:5:10 fertilizer was applied to all plots at a rate of 560 kg ha^{-1}. Before each cutting, measurements were made of plant height (from the ground to the midpoint of the upper leaf blade) and leaf area (by a portable area meter-Model LI-300 Lamba Instruments Corporation). Yields of green forage (GFY), dry forage (DFY) and crude protein (CPY) were calculated for each cutting. Samples were analyzed for dry matter content (DMC) and crude protein content (CPC) at TARS and *in vitro* dry matter digestibility (IVDMD) was determined at the University of Georgia based on the Tilley and Terry (1963) two-stage technique. Analyses of variance and regression techniques were utilized in interpretation of the data, according to Snedecor and Cochran (1967).

Results and discussion

Miller *et al.* (1968) found that individual varieties of sorghum have different critical photoperiods which inhibit floral development. In this study the flowering of Millo Blanco and its hybrid was delayed when planting was from February through September (11.3 – 12.1 hours of light). On the other hand, Greenleaf sudangrass and its hybrid flowered throughout the year, although earlier during long days (Table 2). The advantage of utilizing photoperiod sensitive forage sorghums is that they remain vegetative during the season of long days, thus maintaining a forage of high quality. It is essential to test and compare photoperiod sensitive and insensitive sorghums to determine how each can best be utilized to optimize forage production and quality in the tropics.

The combined analysis of variance showed that planting dates (PD) had F values that were significant for all traits. Significant differences were also observed among genotypes (G) and G x PD interaction for DFY, CPY, CPC, PHt, LA and R (Table 3).

Photoperiod sensitive sorghums require over 60 and in some instances 120 or 180 days to flower in the tropics during seasons of long days. This effect is clearly illustrated for Puerto Rico in Fig. 1. Previous

Table 2. Flowering responses of photoperiod insensitive and photoperiod-sensitive forage sorghums grown in successive monthly plantings at Isabela, Puerto Rico, in 1984.

	Photoperiod-insenstitive sorghum		Photoperiod sensitive sorghum	
Month	Greenleaf (GL)	ATx623xGL	Millo Blanco (MB)	ATx623xMB
January	+ [1]	+	+	+
February	+	+	- [2]	-
March	+	+	-	-
April	+	+	-	-
May	+	+	-	-
June	+	+	-	-
July	+	+	-	-
August	+	+	-	-
September	+	+	-	-
October	+	+	+	+
November	+	+	+	+
December	+	+	+	+

[1] + = Flowering in 60 days or less.
[2] - = Not flowering in 60 days.

studies by the authors have demonstrated a consistent relationship of leaf area (LA) with sorghum forage yields. In this study LA increased with increasing daylength up to the 15 June planting in the photoperiod sensitive sorghums, then decreased steadily through the 15 December planting. A comparison of planting dates during the short-day period (15 January) versus the long-day period (15 June), showed a 29 per cent and 27 per cent increase in LA in the sensitive and insensitive male parents, respectively (Fig. 2). Miller *et al.* (1968) showed that PHt and days to flower were closely correlated in nearly all of 11 sorghum varieties. Hybrid Millo Blanco PHt increased 33 per cent from the 15 January to the 15 June planting, while the corresponding increase for Milo Blanco male parent was significantly higher (60 per cent) (Fig. 3). Greenleaf sundangrass and its hybrid PHt increased 19 and 5 per cent from 15 January to 15 July and from 15 January to 15 August plantings, respectively. The photoperiod sensitive forage sorghums Millo Blanco hybrid and its male parent responded to planting at the time of longest days (15 June) with increases of 143 and 104 per

Table 3. F values for the combined analysis of variance of dry forage (DFY) and crude protein (CPY) yields, day matter (DMC) and crude protein (CPC) contents, plant height (PHt), leaf area (LA), *in vitro* dry matter digestibility (IVDMD) and rust (R) incidence in forage sorghums grown at Isabela, Puerto Rico.

Source of variation	DF	DFY	CPY	DMC	CPC	Ht	LA	IVDMD	R
Planting Date (PD)	11	110.08**	93.71**	9.32**	17.59**	91.64**	68.72**	7.46**	11.38**
Replications (R)	36	0.09^{NS}	1.35^{NS}	0.49^{NS}	1.64*	1.20^{NS}	0.81^{NS}	1.29^{NS}	1.25^{NS}
Genotypes (G)	3	252.30**	233.58**	0.54^{NS}	4.18**	841.41**	713.25**	1.63^{NS}	76.08*
PDxG	33	22.53*	18.47**	0.93^{88}	4.54**	18.61**	9.03**	1.18^{NS}	6.43**
Contrasts									
Greenleaf (GL) vs									
Millo Blanco (MB)	1	344.65**	289.14**	0.66^{NS}	0.12^{NS}	114.77**	761.96**	2.63^{NS}	4.06*
Hybrid (H)	1	406.60**	411.4**	0.28^{NS}	7.64**	1303.41**	1377.53**	1.05^{NS}	223.48*
(GL vs MB) H	1	5.65*	0.14^{NS}	0.66^{NS}	4.80*	106.05**	0.28^{NS}	1.20^{NS}	0.71^{NS}

* Significant at the 0.05 probability level
** Significant at the 0.01 probability level.

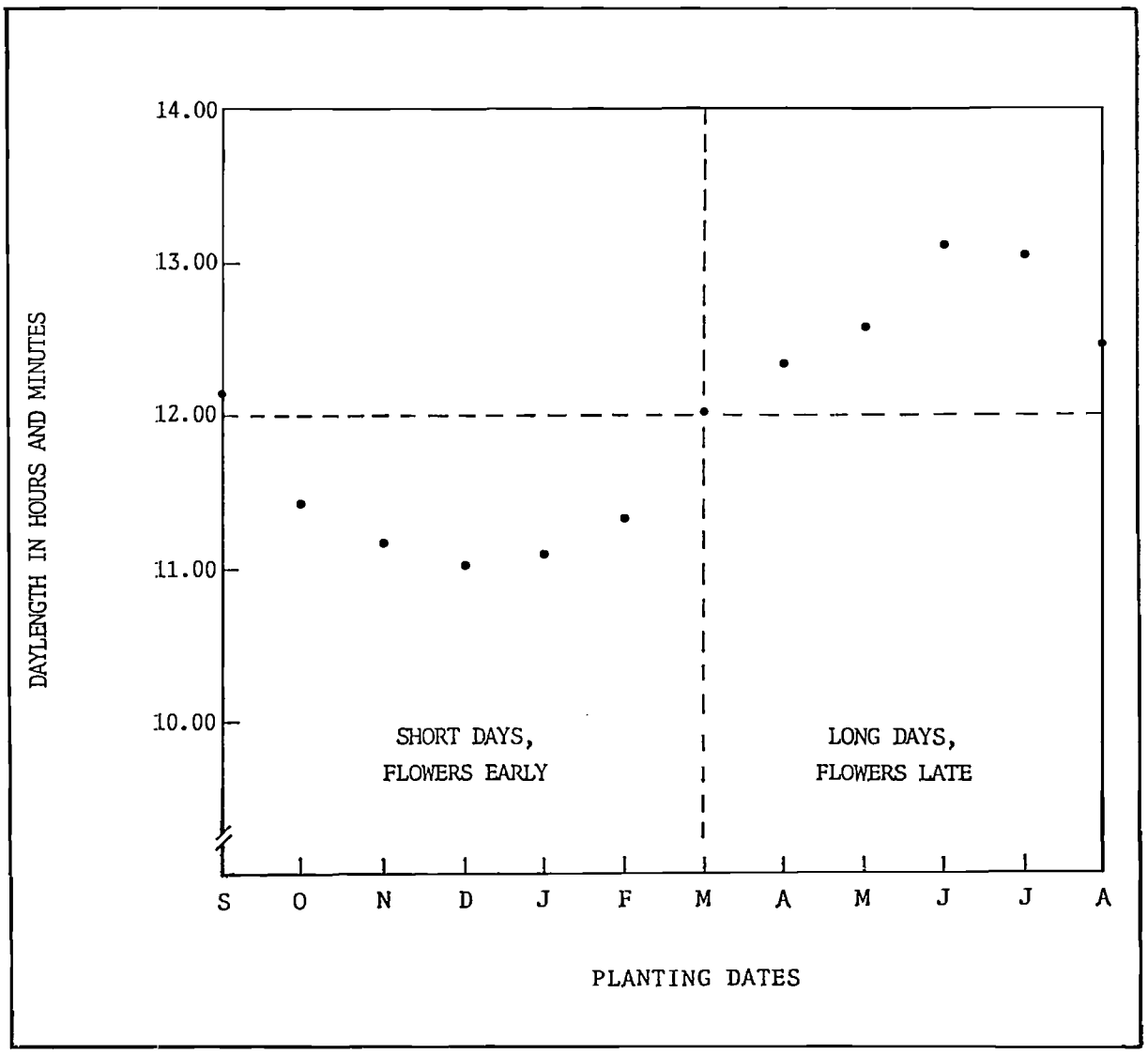

Figure 1 Relationship between planting dates and daylength of sorghum in Puerto Rico.

cent in DFY, respectively, compared with the 15 January planting (Fig. 4). However, in the case of Greenleaf sudangrass hybrid and its male parent the same comparison showed increases of only 1 and 15 per cent respectively.

The *in vitro* dry matter digestibility (IVDMD) was affected by PD although no clean cut differences among genotypes were observed in this criterion. The IVDMD per cent ranged from 51.2 to 59.7 and from 51.6 to 61.6 in the photoperiod insensitive and photoperiod sensitive sorghums, respectively (Table 4).

Differences among PD for DFY were dramatically demonstrated in photoperiod sensitive forage genotypes in 12 monthly plantings. A significant effect of less magnitude was found in photoperiod insensitive genotypes.

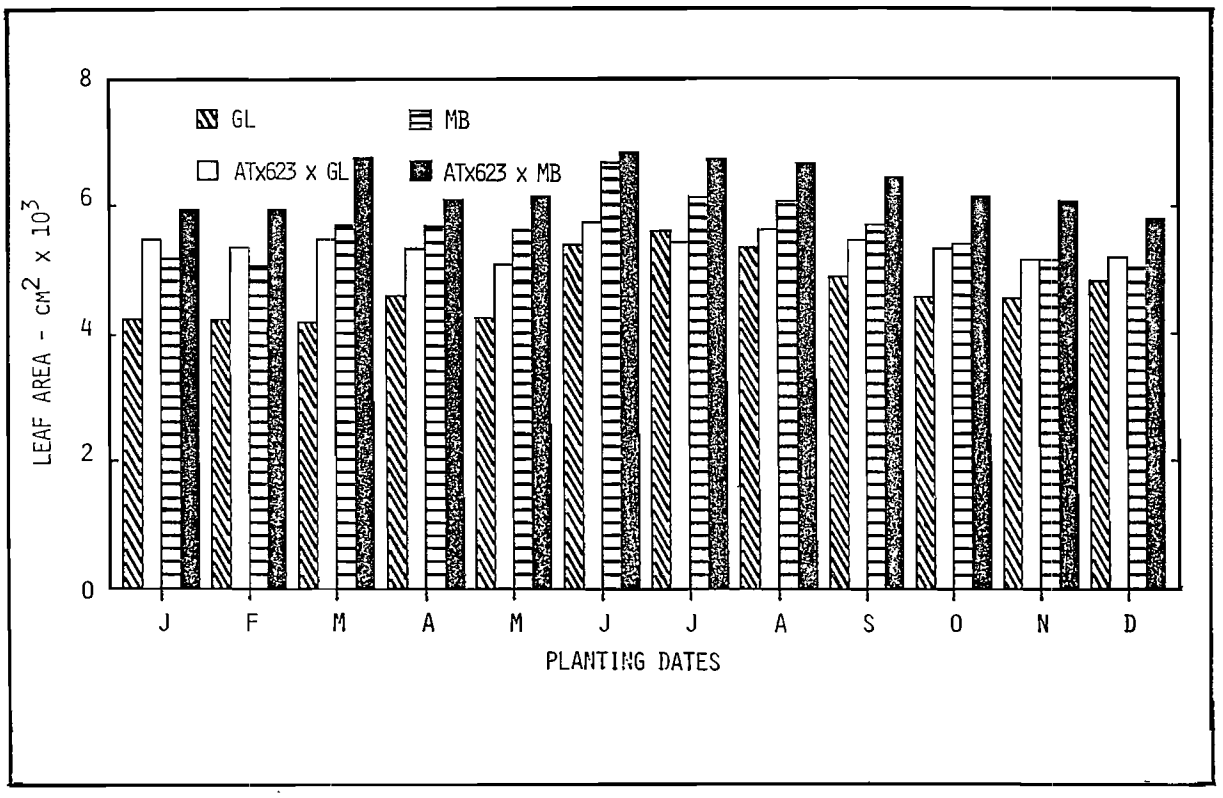

Figure 2 Photoperiodic response of Greenleaf sudangrass (GL), ATx623 x GL (photoperiod insensitive); Millo Blanco (MB), ATx623 x MB (photoperiod sensitive) in leaf area, genotypes planted at 1-month intervals, and harvested 60 days afterwards at Isabela, Puerto Rico, 1984.

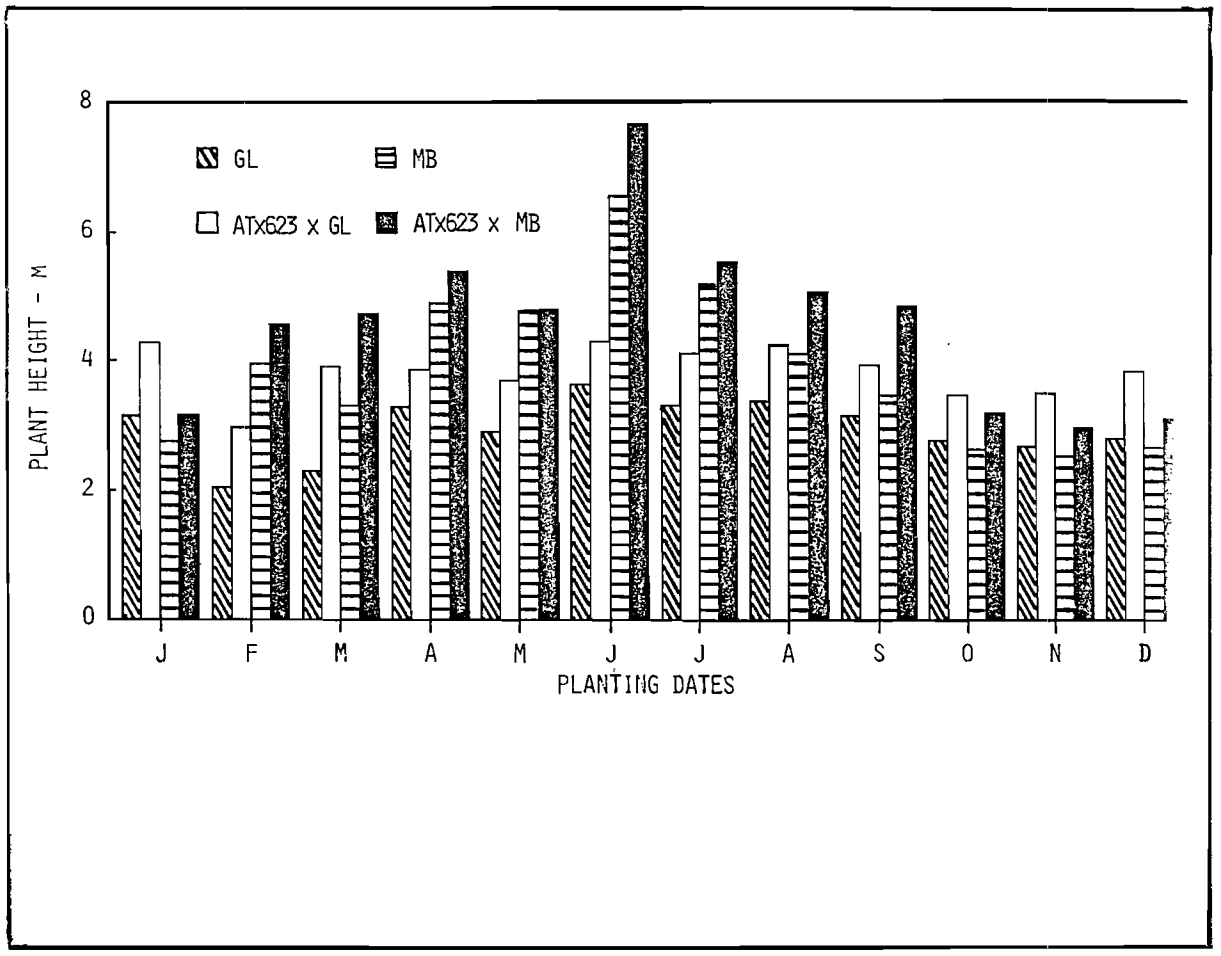

Figure 3 Photoperiodic response of Greenleaf sudangrass (GL), ATx623 x GL (photoperiod insensitive); Millo Blanco (MB), ATx623 x MB (photoperiod sensitive) in plant height, genotypes planted at 1-month intervals, and harvested 60 days afterwards at Isabela, Puerto Rico, 1984.

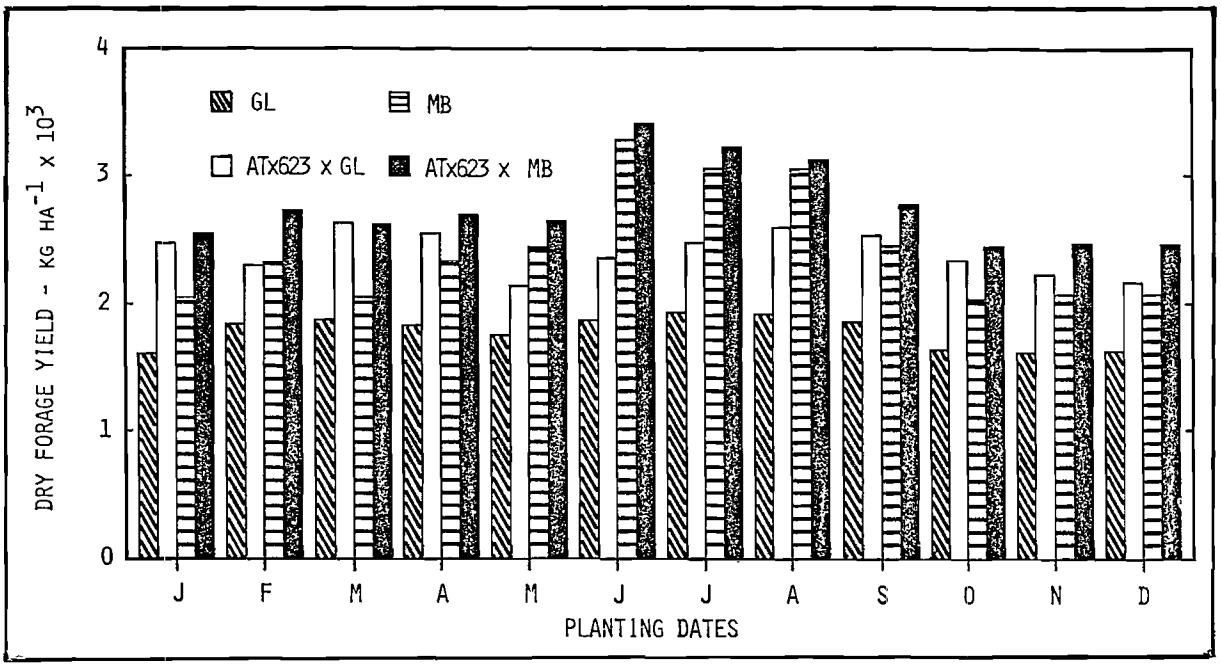

Figure 4 Photoperiodic response of Greenleaf sudangrass (GL), ATx623 x GL (photoperiod insensitive); Millo Blanco (MB), ATx623 x MB (photoperiod sensitive) in dry forage yield, genotypes planted at 1-month intervals, and harvested 60 days afterwards at Isabela, Puerto Rico, 1984.

Table 4. Mean *in vitro* dry matter digestibility of photoperiod-insensitive and photoperiod-sensitive forage sorghums grown in successive monthly plantings at Isabela, Puerto Rico, in 1984.

	Photoperiod-insenstitive sorghum		Photoperiod sensitive sorghum	
Month	Greenleaf (GL)	ATx623xGL	Millo Blanco (MB)	ATx623xMB
January	55.8	57.9	58.8	56.8
February	51.2	56.9	53.6	51.6
March	59.7	59.7	61.6	60.7
April	54.4	52.5	57.3	54.8
May	59.2	56.5	60.7	56.5
June	57.7	56.7	57.5	57.9
July	56.0	57.0	57.4	54.3
August	58.1	56.3	54.8	56.2
September	55.3	54.6	57.0	55.9
October	56.1	54.3	55.9	56.0
November	55.7	55.4	57.4	57.1
December	57.0	56.1	54.9	55.8
X	56.4	56.2	57.2	56.1

References

Barnes, K.K., and Burton, G.W. (1966). Tropical environment of Puerto Rico useful for studying day length sensitivity in Pearl Millet. *Crop Sci.* 6 212-213.

Gardner, F.P., Pearce, P.B. and Mitchell, R.L. (1985) *In: Physiology of Crop Plants XII,* 296-319.

Garner, W.W. and Allard, H.A. (1923). Further studies in photoperiodism. The response of the plant to relative length of day and night. *J. Agr. Res.* 23 871-920.

Irvine, J.E. and Freyre, R.H. (1966). Effect of planting time and photoperiod on *Tephrosia vogelii. Agron. J.* 48 49–51.

McClelland, T.B. (1928). Studies of the photoperiodism of some economic plants. *J.Agr. Res.* 37 603-628.

Miller, F.R., Barnes, D.K. and Cruzado, H.J. (1968). Effect of tropical photoperiods on the growth of sorghum when grown in 12 monthly plantings. *Crop Sci.* 8 499-502.

Quinby, J.R. (1967). The maturity genes of sorghum. In: Norman, A.G. (Ed.). *Advances in Agronomy* XIX 267–305, Academic Press.

Snedecor, G.W. and Cochran, W.G. (1967). *Statistical methods.* The Iowa State Univ. Press. 6th Ed., Iowa, U.S.A., pp. 39–84.

Tilley, J.M.A., and Terry, R.A. (1963). A two-stage technique for the *in vitro* digestion of forage crops. *J. Britt. Grassland Soc.* 18 104-111.

GAS EXCHANGE AND WATER STATUS OF PIGEON PEA CULTIVARS IN PUERTO RICO

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ABSTRACT

The photosynthetic and transpiration rates of various cultivars of pigeon pea (*Cajanus cajan* (L.) Millsp.) were measured using a portable infrared gas analyzer system at the Fortuna Experimental Station in Puerto Rico. The 16 lines studies were long-day determinate types and showed great variability at 4.5 months after planting with respect to plant height (0.85–2.1m), photosynthetic rate (0.19 – 0.85mg CO_2 m^{-2} $sec.^{-1}$) and transpiration rate (263 – 556mg H_2O m^{-2} $sec.^{-1}$). Conductances also varied over a 3–fold range. Leaf nitrogen and chlorophyll were also measured for correlation with photosynthesis. The 16 lines have been shown to have distinct physiological attributes.

RESUMEN

La tasa fotosintética y de transpiración de varias variedades de gandúl (*Cajanus cajan* (L.) Millsp.) fueron medidas, usando un sistema portátil de análisis infrarojo de gas, lo cuál se llevó a cabo en la Estación Experimental La Fortuna en Puerto Rico. Las dieciséis variedades que fueron estudiadas eran de tipo determinado y de día largo y mostraron gran variabilidad, a los cuarenta y cinco dias despues de haber sido plantadas, en lo referente a: la altura de la planta (0.85–2.1m), tasa fotosintética (0.19–0.85mg $CO_2/m^2/sec$), tasa de transpiración (263-556mg $H_2O/m^2/sec$). La conductancia tambien varió en una escala mayor de tres veces. La cantidad de nitrógeno y de clorofila tambien fueron medidas para poder correlacionarlas con la fotosintésis. La dieciséis variedades mostratón tener atributos fisiológicos diferentes.

Keywords: Gas and water exchange, *Cajanus cajan.*

Pigeon pea (*Cajanus cajan* (L.) Millsp.) is a significant crop within the Caribbean Basin, noted for its drought resistance, general hardy nature, low nutrient requirements, and N-fixing *Rhizobium* associations. It is a valued food crop and is ubiquitous not only under standard cultivation practices, but also in the wild, or as a doorstop plant. Major selection work of the pigeon pea is underway in many areas to improve its qualities. These efforts are aimed, among others, at dwarfing, enhancing determinant growth, and producing long-day flowering types.

The availability of organized field trials of pigeon pea at several of the Research and Development Centers of the University of Puerto Rico's Agricultural Experimental Station made it feasible for the experiments described below to be performed on many lines under the same field conditions in conjunction with standard screening programmes. This paper only briefly describes the work in progress. The project will continue at other sites in Puerto Rico and with other aspects such as whole plant and crop modeling to determine carbon balance and allocation.

Materials and methods

Plant material

This research was carried out on experimental plots established by investigators of the Horticulture Division, College of Agronomic Sciences, University of Puerto Rico, Mayaguez who are working to screen 16 lines of pigeon pea (Morales 1985, personal communication) for determinant flowering and insensitivity to day length. The planting was done in April 1985 in four replicate blocks made up of 16 plots of the individual pigeon pea lines. Each plot was planted with four 6m rows at a 0.9m x 0.3m spacing. The plants were not fertilized, but other normal cultivation practices were followed. Average plant height for each line was measured at the same time as photosynthetic rate.

Gas exchange

Leaf gas exchange was measured using a portable system (LI–6000 Portable Photosynthesis System, LI–COR, Inc., Lincoln, NB). The system allows the simultaneous measurement of the fluxes of carbon dioxide and water vapour from a leaf, leaf and air temperature, and incident quantum flux or photosynthetically active radiation (PAR – solar radiation between 440 and 700 nm). Determinations for a single leaf can be made in less than one minute.

For the automatically collected data and the leaf area, the system calculates photosynthesis, transpiration, leaf conductance, and an internal leaf CO_2 concentration. An integral data storage circuitry allows the accumulation of over 100 single leaf measurements. Data can be dumped onto a printer or computer system.

Measurements were made at the Fortuna Station about 4 months after planting. A single block of the four replicates was chosen at random, and within its 16 plots five replicate leaves from each line were tested with the portable photosynthesis system. After measurement the leaflets were harvested, put on ice, and transported to San Juan for further analysis.

Leaf area, leaf specific weight and chlorophyll content

The freshly harvested leaflets (5 replicates from 16 lines) were refrigerated until the area was determined with an optical area meter (LI – 3000 with belt conveyor, LI–COR, Inc., Lincoln, NB). A single disk (4.25cm² area) was cut from one leaf of each of the 16 lines for chlorophyll determination. The remaining material was dried to a constant weight at 65°C and the leaf specific weight (g m^{-2})calculated.

The dimethyl sulfoxide (DMSO) chlorophyll extraction technique was used (Hiscox and Israelstam, 1979). This method uses a direct extraction of the chlorphyll from a whole piece of leaf tissue in DMSO

at 65°C without any other treatment. After 15 min. to 3h (depending on leaf toughness) the extract is decanted and read directly for optical density on a spectrophotometer at 645 and 663nm. For the purposes of this research, where physiological processes were determined on a leaf area basis, the chlorophyll contents were calculated on both a mg g^{-1} fresh weight and mg dm^{-2} basis.

Nitrogen and carbon contents

The dried leaf samples were ground through a 40 mesh sieve in a Wiley mill in preparation for analysis in a Carlos Erbe C-H-N analyzer. This instrument allows the simultaneous determination of C, N and H from a single *circa* 1mg sample. Analytical yield and sensitivity were calculated using standards from the National Bureau of Standards. Calculations were made to allow analysis of the data on both weight and area bases.

Results and discussion

Plant material

The photosynthetic rate measurements were made 4 months into the growth cycle of the 16 lines of pigeon pea, but the lines were clearly at different stages of development at that time. All but two of the lines (206 and 207) had flowered by the measurement date, and most had reached the podding stage, some with dried pods.

This wide variation in phenological state reflects on the range of days needed by the lines to reach flowering, and has been reported in many studies (Abrams *et al.*,1969; Clarke, 1984; Hammerton, 1976). The lines which flower and pod late have more time to allocate photosynthate for growth rather than the strong sink of flowering and pod filling. It is not coincidental that two of the taller lines were those still without flowers. The heights of the 16 lines ranged (Table 1) from 0.85 to 2.13m, with an average of 1.4m. The size range was peaked towards the mean values (Fig. 1).

Table 1. Mean leaf area, leaf specific weight, nitrogen content, photosynthetic rate and transpiration rate of 16 pigeon pea lines in Puerto Rico

Line	Leaf area (cm^2)	Leaf specific weight (g/m^2)	Cholorophyll (mg/dm^2)	N (%)	Photosynthetic rate ($mg/m^2/h$)	Transpiration rate ($mg/m^2/s$)
201	13.7	44.6	48.1	5.4	0.62	477.5
202	10.3	55.8	49.7	3.6	0.78	-
203	28.9	50.2	46.4	3.9	0.79	433.8
204	20.6	41.7	46.6	5.7	0.85	458.4
205	21.4	58.5	47.6	3.8	0.28	419.8
206	25.1	49.1	51.1	4.5	0.27	445.4
207	16.0	55.7	48.8	4.6	0.43	469.6
208	27.0	49.0	56.1	5.2	0.64	431.7
209	17.0	40.6	45.0	3.4	0.28	537.9
210	27.9	54.6	45.5	3.8	0.40	434.1
211	29.2	50.4	47.6	-	0.39	378.3
212	27.6	46.5	46.0	-	0.19	386.1
213	26.9	59.7	50.4	3.6	0.27	262.9
214	31.0	57.2	53.0	3.6	0.39	322.0
215	16.6	49.5	49.9	4.5	0.79	556.5
216	20.0	54.7	52.1	4.5	0.48	496.6

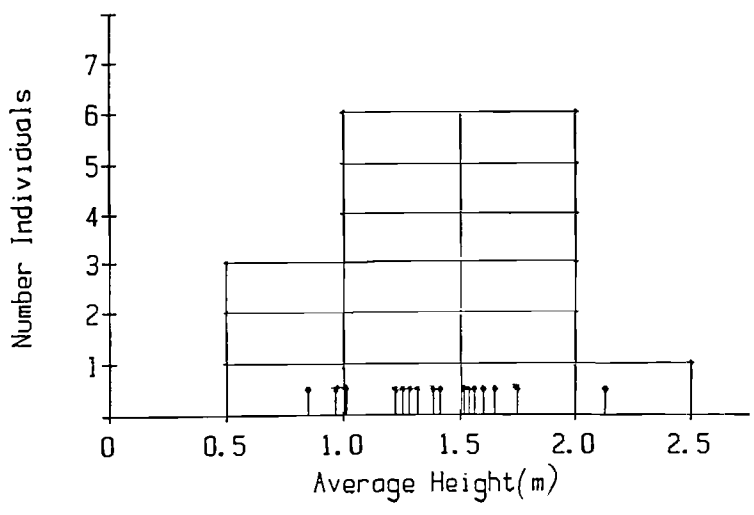

Figure 1. Distribution of average heights among 16 pigeon pea lines in Puerto Rico.

Gas exchange

Although leaf photosynthetic rate is not a direct indicator of potential harvest yield (Kramer, 1981), it is an important indicator of the relative carbon acquiring capabilities of plants. The complication of direct correlations between carbon uptake and yield lie in the often neglected sources of carbon loss such as root and stem metabolism, root turnover, chewing and sucking insect predation, and carbohydrate leakage through the roots.

The maximum photosynthetic rates observed under ambient conditions among the 16 lines of pigeon pea at Fortuna ranged from 0.19 to 0.85mg CO_2 m^{-2} $sec.^{-1}$, the average value was 0.49mg CO_2 m^{-2} $sec.^{-1}$. Ambient air temperatures were 35 – 39 °C and light levels 1000–1900 micromols quanta m^{-2} $sec.^{-1}$ (PAR). Transpiration rates ranged from 262.9 to 556.5 mg H_2O m^{-2} $sec.^{-1}$ with an average of 434.0mg H_2O m^{-2} $sec.^{-1}$. The lowest photosynthetic rates and warmest leaves were generally associated with the low transpiration rates due to stomatal closure (lower conductance to water vapour) and reduced evaporative cooling (Figs. 2 and 3).

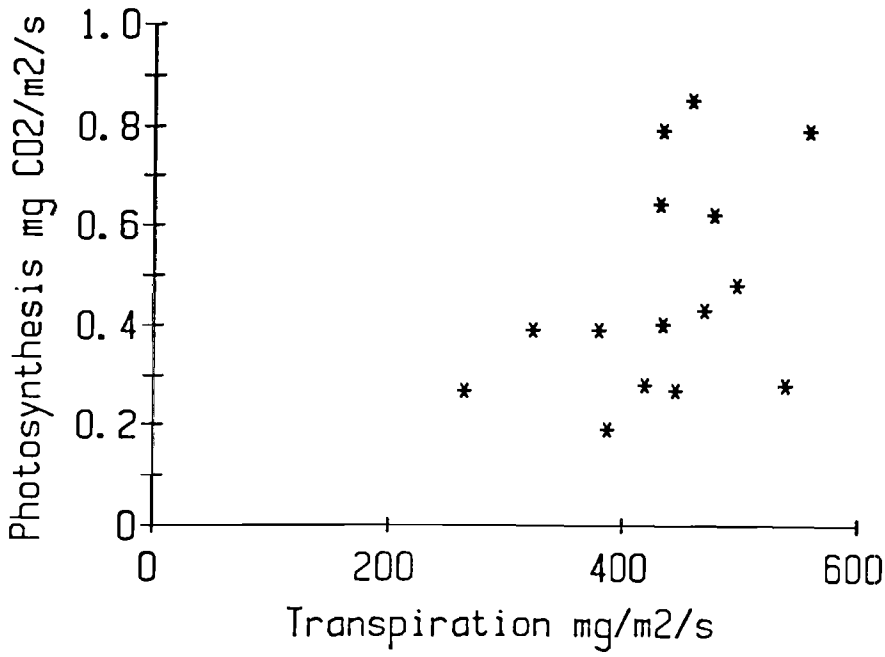

Figure 2. Correlation of observed transpiration with leaf photosynthesis of 16 pigeon pea lines.

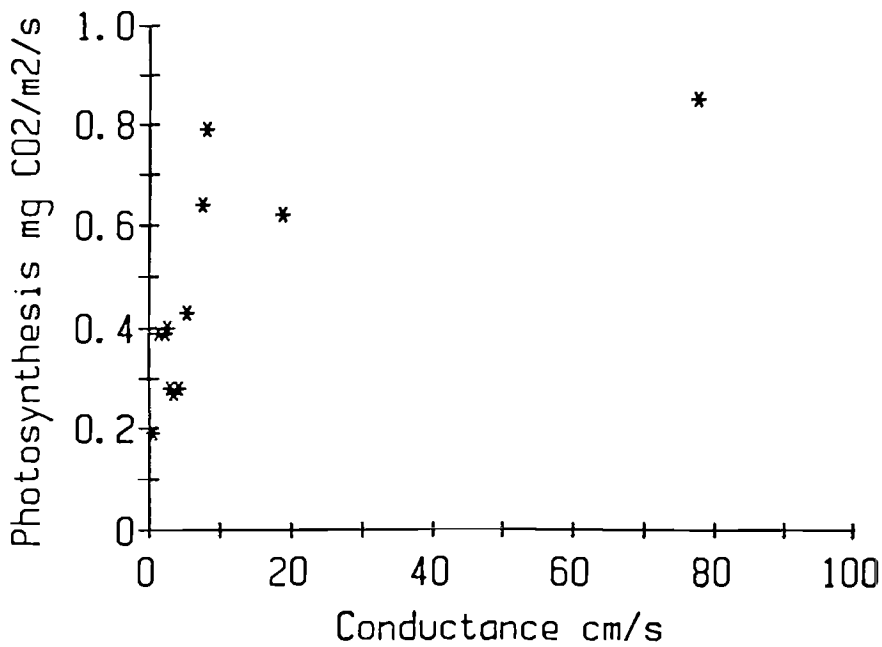

Figure 3. Relationship of conductance of leaf photosynthesis for 16 pigeon pea lines.

Chlorophyll

Although appearing uniformly green, the total chlorophyll content of the leaves ranged from 1.91 to 2.38 mg g^{-1} fresh weight (45.0 to 56.1 mg per dm^2), there being a 25 percent difference between the extremes (Table 1). Given unlimited resources (nutrients, water, light), a plant within a single species should present higher photosynthetic rates with a higher chlorophyll content (Fig. 4). The DMSO chlorophyll extraction method proved very useful; the leaves were a translucent white at the end of the extraction, indicating complete removal of chlorophyll.

Leaf area

Leaf area index is not too reliable for precise comparisons since only the youngest age class of fully expanded levels was used. The leaf size depends to a great extent on the environment during leaf expansion. Also, the sample size was small. Nonetheless, a wide range of individual leaf areas was recorded. The smallest leaf area was only 7.75 cm^2, the largest 38.7 cm^2. The overall average for the 80 samples was 22.4 cm^2.

Leaf size has considerable effect on leaf energy budget and temperature. The only observation of leaf temperatures below air temperature was made in the two plants with the smallest leaves (lines 202, 217). Leaves are cooled by re-radiation of infrared radiation, evaporation of water from transpiration and convection. A small leaf is a more efficient shape for convective heat transfer (Gates, 1980).

Leaf specific weight (LSW)

Leaf densities of single leaves ranged from 40.6 to 66.90g m^{-2}, however, the average LSW was 52.2g m^{-2}. The range of average LSW between lines (five leaves per line) was 40.6 to 59.7g m^{-2} (Table 1).

Nitrogen and carbon contents

Nitrogen is a critical element involved in many physiological processes, especially photosynthesis and protection against herbivory via secondary metabolic compounds. In both agricultural and native plants, photosynthesis is positively correlated with leaf N level. Pigeon pea presents a special case,

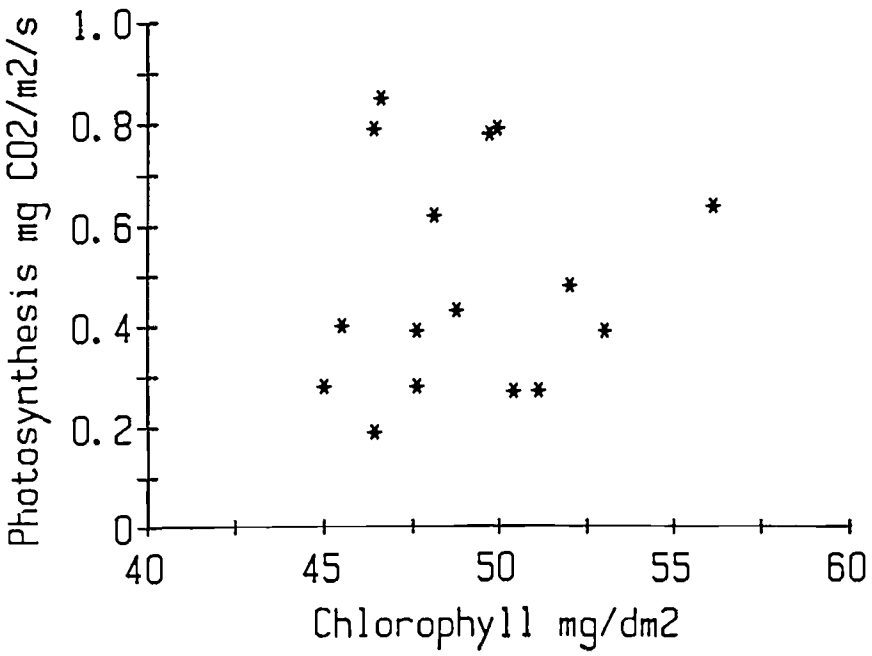

Figure 4. Relationship of chlorophyll content on an area basis with photosynthesis of 16 pigeon pea lines.

as with other legumes, in that it can acquire N through the fixative capabilities of the *Rhizobium sp.* bacteria associated with its roots.

The plantings used in this trial were unfertilized, although soil available N levels may have been high due to residual nitrogenous fertilizers on site from previous field trials. Irregardless of previous treatments, the leaf N levels were higher than in non–N fixing plants, and greater than other reports for pigeon pea (Sheldrake and Narayanan, 1979). The minimum leaf nitrogen level was 3.4 per cent, the maximum 5.7 per cent – a 2.3 per cent range, or 67 per cent increase from the lowest to the highest value. When nitrogen is adjusted with the leaf specific weight from a percent to an area basis, much of the difference between the lines is eliminated (Figs. 5 and 6).

Carbon content of the leaves reflects on both the structural carbon (cellulose, lignin) and the non-structural carbohydrates (starch, sucrose, other photosynthetic products). In itself the C content is not too useful, but C:N ratios can be calculated which give an idea of the potential attractiveness of leaf material to herbivores. The higher the C:N, the more intractable and less 'attractive' the material to a chewing insect. They select leaves by N content. The C:N ratios ranged between 9.6 and 16.4; the mean was 12.9.

Conclusions

Photosynthesis was highly variable between the 16 lines of pigean pea tested. There were marked differences in chlorophyll content, nitrogen content,

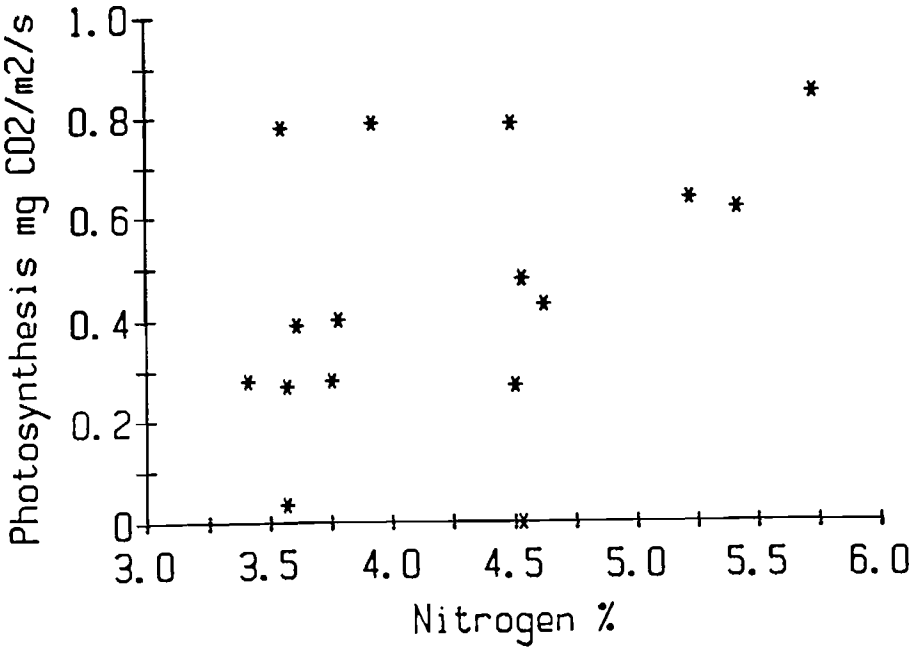

Figure 5. Per cent leaf nitrogen versus leaf photosynthesis for 16 pigeon pea lines.

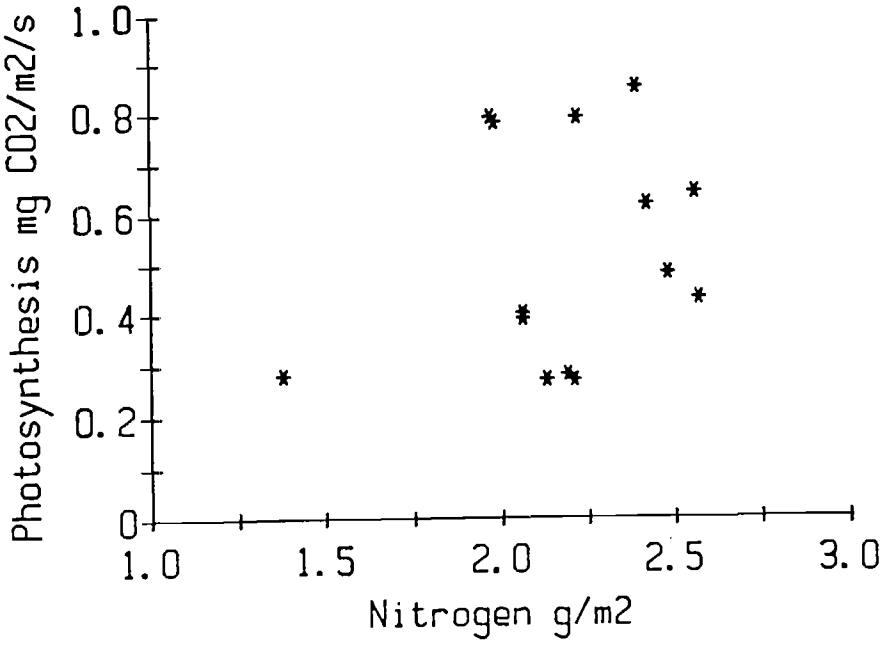

Figure 6. Leaf–N (g/m^2) versus observed leaf photosynthesis for 16 pigeon pea lines.

area and specific weight of the leaves, but water related factors such as transpiration and conductance seem to have the greatest effect on gas exchange. This is not surprising in a planting of such variety of leaf area index, plant height, and phenological state. It will be interesting to pursue future projects with an element of modelling to study the carbon balance and allocation effects on yield and growth parameters.

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References

Abrams, R., Velez-Fortuno, J. and Lopez Garcia, J. (1969) The interaction of variety and environment in pigeon peas *(Cajanus cajan)* trials. *J.Agric. Univ. Puerto Rico* 53 61-66.

Clarke, B.A. (1984) Flowering and plant height of thirty pigeon peas *(Cajanus cajan* (L.) Millsp.) in response to three sowing dates in Barbados. *Proc., 19th Annual Meeting, Caribbean Food Crops Soc.* Puerto Rico.

Gates, D.M. (1980) *Biophysical ecology.* Springer-Verlag, New York. 611 pp.

Hammerton, J.L. (1976) Effects of planting date on growth and yield of pigeon pea (*Cajanus cajan* (L.) Millsp.). *J. Agric. Sci. Camb.* 87 649–660.

Hiscox, J.D. and Israelstam, G.F. (1979). A method for the extraction of chlorphyll from leaf tissue without maceration. *Can J. Bot.* 57 1332–1334.

Kramer, P. (1981) Carbon dioxide concentration, photosynthesis, and dry matter production. *BioScience* 31 19–33.

Sheldrake, A.R. and Narayanan, A. (1979) Growth, development and nutrient uptake in pigeon peas *(Cajanus cajan). J. Agric. Sci. Camb.* 92 513–526.

COWPEA RESEARCH AT THE CARICOM FARMS PROJECT IN BELIZE

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ABSTRACT

Cowpea, *Vigna uniguiculata* (L.) Walp. var. California No. 5, was recommended as the second crop in an upland rice/grain legume combination to be grown at the Caricom Farms project site in Belize. High rainfall, susceptibility to seedling and pod rot diseases and uneven maturity made this variety unsuitable for inclusion in the cropping programme. A screening programme was developed over the last two years (1983–85) using varietal accessions from the Caribbean, Latin America and Africa. Trials were conducted on the Vertisols of the Spanish Lookout series which are calcareous in nature. Varieties were assesed for seed colour, seed size, growth, habit, yield and cooking quality. Results so far have indicated that varieties Vita 3 (red-seeded) and Laura B (black-eyed type) have consistently yielded over 1,600 and 1,100 kg ha^{-1} (14 per cent M.C.) respectively. Other varieties have yielded in excess of 1,500 kg ha^{-1} but have been evaluated only during one cropping season.

RESUMEN

El caupí, *Vigna unguiculata* (L.) Walp. var. California No. 5, fue recomendado como el segundo cultivo entre una combinacion de arroz de zona alta y leguminosa de grano, la cuál se la plantaría en el proyecto de Fincas del Caricom en Belize. Alta incidencia de lluvias, suscepibilidad a la pudricíon de plántulas y vainas y una maduración irregular, hicierón que esta variedad no fuese adecuada para ser inculida en el programa de cultivación anteriormente mencionado, En los dos últimos años (1983-85), un programa de selección fue desarrollado, utilizando lineas experimentales del Caribe, Latino America y Africa. Se llevarón a cabo ensayos del Vertisol de la serie Spanish Lookout, los cuales son de naturaleza calcarea. Las variedades fueron evaluadas de acuerdo a color y tamaño de la semilla, crecimiento, habitos y rendimiento y condisiones optimas de cocción. Hasta el momento los resultados han indicado que las variedades, Vita 3 (de semilla roja) y Laura B (de semilla moteada negra), consistentemente rindierón mas de 1600 y 1100 kg/ha (14% M.C.) respectivamente. Otras variedades rindierón más de 1500 kg/ha, pero estas fueron evaluadas solamente durante una siembra.

Keywords: *Vigna unguiculata*, Variety testing, Belize.

Cowpea *Vigna unguiculata* (L.) Walp. is an important food legume in many Caribbean countries. Its use in Belize, however, is not widespread (McGann, 1984). Production of the crop is limited, and the only confirmed production of commercial significance was 10ha produced by one farmer in 1982–83 with a reported yield of 1,000 kg ha^{-1}.

Cowpea production at Caricom Farms Ltd.

Caricom Farms Ltd. (CFL) was established in 1982 as a joint project between the governments of Belize and Jamaica and the Caribbean Food Corporation. The project is financed during its pilot stage (5 years) by the European Development Fund of the EEC. One of the objectives of the project was to produce upland rice and cowpea for export to the Commonwealth Caribbean Community (Caricom). These products are now either being imported into the region or are in deficit production. Belize could therefore benefit from such market conditions if it could produce cowpea successfully. Table 1 shows the importation of black-eye pea into Barbados and Trinidad and Tobago for the years 1981–83. Data in the Table indicate a potential market of 1,100 tonnes that could be satisfied by production of cowpea in Belize. Demand is expected to increase. Thomas (1980) estimated that total food legume demand in the Caricom region would increase from 77,000 tonnes in 1978 to 89,000 tonnes in 1988 (Table 2). Cowpea would form part of this increased demand.

The first attempt at commercial cowpea production was not very successful and a yield of only 500 kg ha^{-1} was achieved. Variety California No. 5 was grown. Climatic conditions at the project site during the time of year when cowpea can be grown in the rice rotation were those of high rainfall and high relative humidity.

The period between mid-December and mid-March in theory would be the ideal time for planting. Rainfall recorded for this period in the 1983–84 cropping season was 325mm. During the first two weeks of this period (mid to end December) 102mm of rainfall was recorded. Planting during this time exposed germinating seedlings to waterlogged conditions hence causing seedling rot. The dry season begins normally in March and therefore late planting runs the risk of water stress at the podding/maturity stage.

Table 1: Important of black-eye peas into Barbados and Trinidad & Tobago, 1981-83.

Year	Description	Unit	Barbados	Trinidad & Tobago	Total
1981	Quantity	Kg	172,270	802,665	974,935
	Value	EC$	499,531	2,255,076	2,754,607
1982	Quantity	Kg	210,893	770,031	980,924
	Value	EC$	527,454	1,950,616	2,478,070
1983	Quantity	Kg	227,343	879,670	1,107,013
	Value	EC$	512,436	1,823,470	2,335,900

Source: Agri-Systems (Jamaica) Ltd. (1984) - Evaluation of Caricom Farms Belize for the Caribbean Food Corporation.

Table 2: Total legume demand and production in the Commonwealth Caribbean.

Country	Total prodn. (Tonnes)	Total required[1] (Tonnes)	Deficit in prodn. (Tonnes)	Projected requirement in 10 years[2] (Tonnes)
Trinidad & Tobago	1,130	19,854	18,724	21,577
Grenada	36	1,791	1,755	2,169
Barbados	248	4,534	4,286	4,737
St. Vincent	175	1,698	1,523	1,756
St. Lucia	58	2,146	1,088	2,598
Dominica	N.A.	1,362	N.A.	1,394
Antigua	39	1,381	1,342	1,592
St. Kitts	139	1,213	1,074	1,230
Monsterrat	20	243	223	246
Jamaica	5,170	36,872	31,702	42,931
Bahamas	N.A.	3,601	N.A.	5,242
Belize	1,800	2,463	663	3,255

1. Based on recommendatioon of 18.66kg/capita/yr.

2. Based on 1978 population growth rate.

N.A. = not available

Source: Thomas (1980)

The soil types at the project site are Vertisols of the Spanish Lookout and Young Gal series. These have moderately deep top soils of 30–90cm depth. They are dark grey to black with very poor internal drainage (Birchall and Jenkins, 1978) and are predominantly clay with a marl subsoil and with mottling occuring increasingly below 20cm. Soil pH ranges between 6.5 and 7.5. Soil P and Mg levels are low; N is moderate and K fairly high.

The soils become saturated very rapidly and dry out just as quickly. In dry periods they crack and this if it is very severe can cause root damage to the crop.

At maturity variety California No. 5 becomes highly susceptible to pod rot if climatic conditions are similar to those described above; the result being poor quality discoloured grains. California No. 5 was therefore not considered a suitable variety for commercial production under the prevailing conditions and this led to the temporary suspension of cowpea production. It was decided that efforts should be concentrated therefore on selection of a variety or varieties which are adaptable to local growing conditions.

The role of the research programme

The research programme began in 1983 with its objective being to find a cowpea variety or varieties which could be grown at the project site on a commercial basis.

Certain selection criteria were established. These in prioritised order were:

a) High yielding varieties whose production can be mechanised i.e. erect, pods at the top of the canopy or above it.

b) Tolerance to local conditions i.e. high rainfall and heavy soils.

c) Short duration.

Black-eye (i.e. cream seeded with black-eye) and red-seeded varieties would be given preference for market considerations but other seed colours would nevertheless be investigated.

Four trials were conducted over two cropping seasons; 1983/84 and 1984/85.

Materials and methods

Field trials were conducted using seed material received from external sources along with California No. 5 which was obtained from the Agriculture Department in Belize. Experimental design for all trials except Trial 2 was the complete randomised block. All trials with this design were replicated three times except Trial 3 which had four replications. Trial 2 was unreplicated and was used mainly for seed multiplication and observation.

Trials were planted either under conventional tillage or minimum tillage conditions (Trials 3 and 4) Fertilizer was applied by hand prior to planting, into furrows 10cm deep.

Trials 1 and 2 were given 100 kg ha^{-1} each of Triple Super-phosphate (TSP), Diammonium Phosphate (DAP) and K-mag. Trials 3 and 4 were supplied with 100 kg ha^{-1} each of DAP and Magnesium Oxide (MgO) and 70 kg ha^{-1} of Sulphate of Potash. All trials had 10 kg ha^{-1} of a micro-nutrient mixture containing Ferrous Sulphate, Zinc Sulphate, Copper Sulphate, Manganese Sulphate and Solubor in the ratio of 15:10:6:5:5. Rhizobium inoculant was applied to all seeds before planting.

Plot size used was 10m x 3m for Trials 1 and 3 while Trial 4 had a plot size of 5m x 2m. Trial 2 was planted from 1 to 3 rows of 5m length depending on seed availability. Planting distance was 10cm within rows spaced at 35cm.

Herbicide application for trials under conventional tillage was alachlor (Lasso) given pre-emergence at 6.6 litres ha^{-1} in 400 litres of water. For minimum tillage plots in addition to alacholor, paraquat and glyphosate (Round-up) at 2.5 and 1.5 litres ha^{-1} respectively were applied pre-emergence in 400 litres of water. Volunteer rice was hand weeded from plots with conventional tillage as needed. All plots were treated once with monocrotophos (Nuvacron) at 330g a.i. ha^{-1} for control of leaf eating beetles at the seedling stage.

Plots were harvested by hand. Trials 1 and 2 were threshed manually while Trials 3 and 4 were threshed using the Votex Rice fan thresher modified for threshing grain legumes.

Trial 1 was planted twice on December 15, 1983 and January 5, 1984. Varieties evaluated were Vita-3, Local Jamaica (Yvon Clay), ER-7, Laura-B and California No. 5.

Trial 2 was planted January 12, 1984 with varieties Queba Cadeira, CNC-0434, CNC-27E, EMAPA-822 (Vita-3), Vita-2, EPACE-6, EPACE-1, Laura-B, TUMA-1180, Yvon Clay, EMAPA-821, Manaus, California No. 5, ER-7 and UCRI.

Trial 3 was planted January 5, 1985 with nine varieties selected from Trial 2.

Trial 4 was planted twice on January 15 and January 18, 1985 with varieties IT82E–18, IT82D–789, IT82D–889, Vita-3, Laura-B and California No. 5.

Observations were recorded on days to flowering, days to harvest, 100 grain weight, yield and rainfall during the cropping period. Data are presented in Tables 3 to 9.

A cooking evaluation was carried out on Vita-3, Laura-B and California No. 5 after the 1983–84 trials (Trial 1). Other varieties were not evaluated as their grain size was below the minimum acceptable one of 14g per 100 grains, a decision made subsequent to the planting of Trial 1.

One half cup of each variety was pressure cooked in a Prestige pressure cooker at 1.07 kg cm^{-2}. Grains were cooked for 10, 15, 20, 25 or 30 minutes at full pressure. Twenty grains were selected from each variety and the degree of cooking assessed. Cooked status was determined by squeezing the grain between thumb and fore-finger. Four categories of cooking were recognised:

i) Very soft – grains began to crush on being held
ii) Soft – grains crushed easily with light pressure
iii) Fairly hard – grains resisted crushing but were crushed with extra pressure
iv) Hard – grains did not crush even with extra pressure

Grains within categories very soft and soft were considered adequately cooked. Results are presented in Table 10.

Results and discussion

Trial 1 - planted on 15 December 1983 and 5 January 1984

Data presented in Table 3 indicate that varieties Vita-3 and Local Jamaica yielded significantly more than other varieties at both times of planting. California No. 5 performed very poorly during the first planting but yielded as good as Laura-B and ER-7 for the second planting. During the December planting, California No. 5 was seriously affected by *Cercospora* sp. and *Fusarium* sp. It was considered that this was related to the high rainfall during the crop cycle as well as the susceptibility of California No. 5 to the diseases.

Rainfall data recorded at CFL during the period of experimentation are presented in Table 4. The December planted crop had 326mm of rainfall compared to 210mm recorded for the crop planted in January. The seedling stage is a critical period of crop development; excess moisture during this period exposes seedlings to diseases, reduces crop vigour and causes death of seedlings. The December planted crop had 102.8mm of rain during this period compared to 31mm for the January planted crop. California No. 5 was observed to be most adversely affected by the higher rainfall conditions. There was also higher rainfall from the flowering to maturity stages for the December crop.

Trial 2 – planted on 12 January, 1984

This trial was not replicated and was used mainly for seed multiplication. Varieties were selected from this set for testing in future experiments. Criteria used were 100-grain weight (a minimum of 14g) and plant type as regards mechanisation i.e. semi-erect to erect plant types were preferred. Varieties selected from this trial and used in Trial 3 were CNC-27E, EMAPA-822 (Vita-3), Vita-2, CNC-0434, EPACE-1, EPACE-

Table 3: Data on cowpea varieties planted at Caricom Farms 1983-1984.[1]

	Planted on 15 December, 1983					Planted on 5 January, 1984				
Characteristic Assessed	Vita-3	Local Jamaica	ER-7	Laura B	Cal 5[3]	Local Jamaica	Vita-3	ER-7	Laura B	Cal 5[3]
Days to 50% flowering	57	61	56	54	54	N.A.	N.A.	57	54	54
Days to harvest	89	89	80	80	80	85	86	88	81	85
Av. plant ht. (cm)	38	36	29	25	29	34	31	30	21	25
Lodging (Yes/No)	Yes[2]	Yes[2]	No	No	No	Yes[2]	Yes[2]	No	No	No
No. pods/plant	6	13	13	10	8	12	6	13	13	15
No. seeds/pod	17	11	8	7	4	10	11	9	7	6
100 grain wt (g)	20	10	9	17	20	10	17	9	14	19
Yield g plot)	5,278	4,876	3,530	3,425	1,228	5,124	5,055	3,564	3,494	2,929
Yield (kg/ha)	1,759a	1,622a	1,177b	1,142b	409c	1,708a	1,685a	1,188b	1,165b	976b

1. Figures are the average of 3 replications.

2. Lodging estimated at less than 20%.

3. California No. 5

Yields with the same letters were not significantly different at P = 0.05 (DMRT)
LSD (kgha) were 307 and 465 respectively for December and January planted trials.

Table 4: Rainfall during crop development for cowpea planted in December 1983 and January 1984 at Caricom Farms.

Days after planting	Stage of crop development	Rainfall (mm) 15 Dec. 1983 planted	Rainfall (mm) 5 January 1984 planted
1 - 14	Seedling	101.8	31.0
15 - 28	Vegetative	40.5	57.1
29 - 42	Vegetative	75.5	77.2
43 - 56	Vegetative	54.7	11.3
57 - 70	Flowering/Podding	40.9	20.4
71 - 84	Maturity	12.1	12.8
Total		325.5	209.8
Av. no days to harvest		84	85

6, Laura-B, and TUMA-1180. Quebra Cadeira had the highest yield per plant and the highest 100-grain weight (27g) but was not selected for further testing as it was a prostrate type and therefore not suitable for mechanisation. It might be a useful variety for cultivation by small farmers. Data from this trial are given in Table 5.

Trial 3 – planted on 5 January 1985

The results of this trial are presented in Table 6. Variety CNC-27E yielded 2,144 kg ha^{-1} which was significantly better than all other varieties except CNC-0434 and California No. 5. California No. 5 performed well in this trial compared to Trial 1 in 1983–84 but it only yielded significantly higher than EPACE-6. It was noted that time taken to complete the crop cycle was extended to 90 or more days and this may have been a result of the lack of moisture during the early crop life.

Table 5: data on 15 cowpea varieties planted at Caricom Farms Ltd. on 12 January, 1984.

Variety	Days to harvest	Plant height (cm)	No. plants harvested	No. pods/ plant	No. Seeds/ pod	Seeds color	100 - grain wt. (g)	Yield/ plant (g)
Quebra Cadeira	81	17	11	27	6	White	28	44
CNC - 27E	81	35	41	14	10	Brown	15	16
EMAPA - 822	75	33	81	81	9	Red	16	14
Vita - 2	83	27	80	10	10	Red	17	14
CNC - 0434	84	42	131	11	11	Cream	14	12
EPACE - 6	79	42	93	11	9	Brown	19	12
Laura - B	75	17	77	12	5	Cream	16	10
TUMA - 1180	83	34	105	2	11	Red	18	10
Yvon Clay	79	26	102	13	9	Brown	10	10
EMAPA - 831	76	25	93	12	9	Brown	11	11
EPACE - 1	76	25	138	13	8	Brown	13	9
MANAUS	76	28	106	17	9	Brown	9	8
California No. 5	78	25	81	12	6	Cream	20	8
ER - 7	83	27	87	17	8	Cream	10	7
UCR - 1	79	10	76	6	4	Red	8	2

Table 6: Data[1] on nine cowpea varieties planted January 5, 1985 at Caricom Farms Ltd.

Variety	Days to 50% flowering	Days to harvest	Plant height (cm)	No. pods/ plant	No. Seeds/ pod	Seeds color	100 grain wt. (g)	Yield (g/plot)	Yield (kg/ha)
CNC - 27E	58	92	61	13	13	Brown	15.9	6,431	2,144 a
CNC -0434	57	94	58	16	12	Cream	16.0	5,554	1,852 ab
California - 5	52	89	53	13	9	Cream	20.5	5,533	1,845 abc
Vita - 3	57	95	55	8	14	Cream	20.2	5,168	1,723 bcd
TUMA - 1180	53	93	53	11	13	Red	18.8	5,168	1,723 bcd
Laura - B	58	89	56	13	11	Cream	13.6	5,132	1,711 bcd
Vita - 2	58	91	52	10	13	Red	19.9	5,131	1,711 bcd
EPACE - 1	57	96	53	10	11	Brown	19.0	4,532	1,647 bcd
EPACE - 6	57	97	53	7	11	Brown	15.2	4,532	1,352 d

[1] Values are the average of four replications.
Yields followed by the same letters were not significantly different at P - 0.05 (DMRT) LSD (kg/ha) = 368.59

Trial 4 – planted on 15 and 18 January 1985

Data from this trial (Table 7) indicated that variety Vita-3 yielded significantly more than all other varieties; its mean yield was 1,983 kg ha^{-1}. There were no significant yield differences between the other varieties. Again the life cycle of the crop was extended beyond 90 days.

The second experiment in this trial, (data in Table 8) again showed Vita-3 yielding significantly more than the other varieties with 2071 kg ha^{-1}.

Rainfall data recorded for the duration of Trials 3 and 4 are presented in Table 9. Total rainfall for planting dates 5 January, 15 January, and 18 January 1985 were 167.9, 167.4 and 220.3mm respectively. As mentioned elsewhere there was very little rainfall during the period immediately after the trials were planted. This may have delayed the crop somewhat hence the average number of days taken to harvest was increased from 84 for 1983–84 trials to between 91 and 97 for 1985 trials. Although the effects of the dry period have not been adequately determined, indications were that this delayed the onset of flowering and hence maturity. The inadequate supply of water during vegetative growth decreases the rate of initiation of main stem leaves, (Summerfield *et al.*, 1984).

This would tend to reduce leaf area index. Maximum leaf area index (3 for determinate varieties) usually coincides with initiation or appearance of the first flowers in determinate varieties. Since the varieties used can be classified as determinate or semi-determinate it would be safe to assume that the dry period may have affected them in some way.

Cooking quality

Data in Table 10 indicate that Laura-B and California No. 5 were cooked within 15 minutes in the pressure cooker. For Vita-3 however, only 25 per cent of the grains were cooked at this time and even after 30 minutes only 95 per cent were cooked. It would therefore seem that Vita-3 is not an easily cooked variety.

Table 7: Data[1] on six cowpea varieties planted on 15 January, 1985 at Caricom farms Ltd.

Varities	Days to 50% flowering	Days to harvest	Plant height (cm)	No. pods/ plant	No. seeds/ pod	Seed colour	100 grain wt. (g)	Yield (g/plot)	Yield (kg/ha)
Vitra - 3	59	93	59	12	13	Red	20.9	1,983	1,983 a
IT 82^D - 789	59	91	49	13	11	Brown	19.9	1,408	1,408 b
IT 82^D - 889	56	91	41	12	13	Red/Brown	18.6	1,307	1,307 b
IT 82^E - 18	59	94	53	11	11	Brown	18.6	1,259	1,259 b
California No. 5	59	90	52	15	10	Cream	20.0	1,288	1,288 b
Laura - B	62	89	50	16	9	Cream	15.4	1,191	1,191 b

[1] Values are the average of 3 replications.
Yields followed by same letter were not significantly different at P - 0.05 (DMRT) LSD - 444.4 kg/ha.

Table 8: Data[1] on six cowpea varieties planted January 18, 1985 at Caricom Farms Ltd.

Varieties	Days to 50% flowering	Days to harvest	Plant height (cm)	No. pods/ plant	No. seeds pod	Seed Colour	100 grain wt. (g)	Yield (g/plot)	Yield (kg/ha)
Vita - 3	N.A.	97	46	11	10	Red	21.6	2,071	2,071 a
IT 82^E - 18	57	96	47	13	10	Brown	20.5	1,688	1,688 b
California No. 5	54	96	51	14	10	Cream	21.1	1,666	1,666 bc
IT 82^D - 789	55	96	48	12	11	Brown	18.1	1,494	1,494 bcd
Laura - B	55	96	45	13	10	Cream	16.7	1,486	1,486 bcd
IT 82^D - 889	56	97	43	8	9	Dark Brown	14.7	1,237	1,237 d

[1] Values are the average of 3 replications.
Yields followed by same letters were not significantly different at P - 0.05 (DMRT) LSD - 336.8 kg/ha.

Table 9: Rainfall during crop development for cowpea planted in January 1985 at Caricom farms Ltd.

Days after planting	Stage of crop development	Rainfall (mm) 5 Jan planting	15 Jan. planting	18 Jan. planting
1 - 14	Seedling	4.5	11.2	21.9
15 - 28	Vegetative	21.9	1.7	6.7
29 - 42	Vegetative	6.7	65.1	62.1
43 - 56	Vegetative/flowering	62.1	33.4	62.1
57 - 70	Flowering/Podding	31.4	16.3	16.3
71 - 84	Podding	16.3	25.0	25.0
85 - 98	Maturity	25.0	14.7	56.9
Total		167.9	167.4	220.3
Av. no days to harvest		93	91	97

Table 10: Cooking evaluation of three cowpea varieties

Cooking time (min.)	% of grains cooked		
	Laura B	California 5	Vita 3
10	80	95	0
15	100	100	25
20	100	100	65
25	100	100	65
30	100	100	95

Summary

Based on results obtained over the last two years (1983–85) the most consistent high yielder has been Vita-3 (See Table 11). In all trials it has yielded in excess of the equivalent of 1,600 kg ha^{-1} of grain at 14 per cent Moisture Content and up to 2,000 kg ha^{-1} once. It is red-seeded with an average of 100-grain weight of 20g. The plant type is semi-erect with pods within the canopy. It has been selected for testing on commercial size demonstration plots for mechanical harvesting.

Laura-B, a black-eye type, has also been selected for commercial testing It has not yielded as high as Vita-3 but its potential lies in its being a substitute for the black-eyed California No. 5. It has never yielded below 1,100 kg ha^{-1} in all the trials conducted along with Vita-3 and California No. 5 under five rainfall regimes (Table 11). California No. 5 seemed to perform better under low rainfall conditions. Since these conditions cannot be predicted with a great degree of accuracy, California No. 5 is therefore considered a high risk variety and its use is not being recommended for commercial production at CFL.

Other promising varieties from the 1985 trials, namely CNC-27E, CNC-0434 and TUNA-1180, will be further evaluated experimentally before commercial testing.

The future of Cowpea production in Belize and CFL

Belize is 75 per cent self-sufficient in its production of grain legumes for human consumption (See Table 2). the bulk of this production being in the form of red kidney bean *Phaseolus vulgaris* (L.). Deficits at present are made up from imports from the neighbouring countries of Guatemala and Mexico with a small amount being imported from North America. There is hence little incentive to expand cowpea production on a large scale for local consumption.

The orientation of the Caricom Farms cowpea project is therefore a channel its research and development efforts towards the selection of varieties which are acceptable and can be marketed on the export markets, mainly the Caricom market. Barbados and Trinidad and Tobago are markets which can be targeted in the short term. Jamaica and Guyana although beset by money problems are also potential markets. The market size in 1983 was 1,100 tonnes for Barbados and Trinidad and Tobago and the demand should increase. This means that at least 1,000 ha of land for potential production for export needs to be tapped. Land for this is available in the Belize River Valley where the CFL project is located.

With this in mind the research programme is concentrating its efforts towards selection of suitable varieties and the development of production packages for commercial adaptation. It is possible that commercial varieties will be released within a year for use on CFL commercial fields. About 100ha will be grown at first with a projected expansion in 1991 of 400ha.

As far as the country of Belize is concerned, varieties now being tested will be shared with the government agencies reponsible for research and development for possible evaluation in other districts. Successful testing could open up whole new production enterprises for farmers and potential foreign exchange earnings for Belize. The future therefore looks promising for cowpea production in Belize.

Table 11: Yield and rainfall during crop growth of three cowpea varieties at five different times of planting at Caricom Farms.

Planting date	Rainfall during crop (mm)	Yield (kg ha)		
		Vita - 3	Laura - B	California No. 5
1983 - 12 - 15	326	1,759	1,142	409
1984 - 01 - 05	210	1,685	1,156	976
1985 - 01 - 05	168	1,723	1,711	1,845
1985 - 01 - 15	167	1,983	1,191	1,288
1985 - 01 - 18	220	2,071	1,494	1,666

References

Agri-Systems (Jamaica) Ltd. (1984) Evaluation of Caricom Farms Ltd., Belize C/A for the Caribbean Food Corporation.

Birchall C.J. and Jenkins R.N. (1979) *The soils of the Belize River Valley, Belize.* Volume 1. Land Resources Development Centre Supplemental Report 15, Surrey, England.

McGann, Joseph A. (1984) The performance of five cowpea, *Vigna unguiculata* (L.) Walp., varieties at Caricom Farms Ltd. Paper presented at the *Sixth National Agricultural Research Development Symposium,* Belize. September 1984.

Summerfield R.J.., Pate J.S. *et al* (1984) *The physiology of cowpeas.* Unpublished Mimeograph - University of Reading.

Thomas, A. (1980) Position Paper on Food Legumes in the Commonwealth Caribbean with particular reference to the role of CARDI. Paper presented at the *Legume Seminar,* Research and Development Department, Ministry of Agriculture, Jamaica.

PATTERNS OF N LOSS IN A NIGERIAN SOIL

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ABSTRACT

An experiment was conducted on a bare well drained soil of the Apomu Series, classified as a Quartzipsamment (USDA). The loss patterns of 100kg N ha^{-1} of ammonium sulphate, sulphur coated urea (SCU) and urea were compared during ten weeks in the rainy season. After approximately 25mm of rainfall the soil was sampled at 15cm intervals down to 90cm. Measurements of the inorganic N (NH_4–N and NO_3–N) showed: a) SCU had no advantage over the other forms of N used, b) there was little evidence of leaching, c) volatile losses were possible during the first seven days after addition and could have been 29% and 71% for ammonium sulphate and urea respectively; and d) all the added N was lost by 40 days after addition.

RESUMEN

Se realizó una experiencia en un suelo raso bien drenado de la serie Apomu, con clasificación de Quartzipsamment (USDA). Se compararon los patrones de pérdida de 100 kg Nha^{-1} de sulfato de amonio, de urea revestida de sulfato (SCU) y de urea por diez semanas dudante la estación lluviosa. Tras aproximadamente 25mm de precipitación, se tomó muestras del suelo a intervalos de 15cm de profundidad hasta 90cm. Las mediciones del N inorgánico (NH_4 – N y NO_3 – N) demostraron que: (a) la SCU no ofrecía ninguna ventaja comparada a las otras formas de N que se utilizaron; (b) había poca evidencia de desalación; (c) había una posibilidad de pérdidas por evaporación durante los primeros siete días posteriores a la añadidura. Estas pudieron haber sido del 29% en el caso del sulfato de amonio y del 71% en el caso de la urea; y (d) la totalidad del N añadido se perdió dentro de los 40 días posteriores a la añadidura.

Keywords: Fertilizer–N loss; Nigerian soil

With continuous cropping in the humid zone of Western Nigeria maintenance of adequate nitrogen in the soil appears to be a major problem (Vine, 1953; Kang, Donkoh and Moddy, unpublished data). This may be attributed in part to leaching losses of the native and fertilizer N with continuous cropping.

There is some evidence to support this: Chesney (1967) showed that applied NO_3–N was rapidly leached to below the 45–60cm depth within 4–6 weeks of application, similarly Hardy (1946) found that 1000mm of continuous rainfall caused rapid leaching.

It is assumed that after rapid nitrification added fertilizer–N would be rapidly leached. However, there is little direct evidence to support this. Two experiments were conducted to examine the loss pattern of added N. Three sources of N (ammonium sulphate, urea and sulphur-coated urea) were used in a field experiment. In a second laboratory experiment changes in the form of mineral N from ammonium sulphate and urea added to the same soil were followed over a 28-day period.

Materials and methods

Field experiment

The experiment was conducted at the International Institute of Tropical Agriculture (IITA) at Ibadan (7° 23'N, 3° 56'E) located in the humid zone of western Nigeria, during the 1973 rainy season from June to August.

The land had been under secondary forest until two years earlier, and in the previous year was used for a sulphur response trial. The soil is mapped as Apomu series (Psammentic Ustorthent, USDA classification). It is very well drained with a loamy sand texture containing a uniform 7.6 per cent clay to 90cm depth and underlain with a laterite gravel layer. Some of the characteristics of the soil at various sampling depths are given in Table 1.

Table 1 . Some characteristics of the Apomu soil at the site of the field experiment, IITA, Nigeria.

Depth (cm)	pH in H_2O	Organic C (%)	Total N (%)	CEC (me/100g)	Bulk density (g/ml)	Moisture content (at 0.1 bar g/100ml)
0-15	5.9	0.64	0.064	3.0	1.42	8.76
15-30	6.3	0.38	0.041	2.5	1.43	6.79
30-45	6.4	0.02	0.027	3.0	1.32	4.87
45-60	6.3	0.11	0.022	2.3	1.39	5.33
60-75	6.5	0.07	0.018	2.1	1.31	4.68
75-90	6.7	0.10	0.011	2.2	1.30	5.12

Three N sources; ammonium sulphate (21 per cent N, 24 per cent S), urea (46 per cent N) and sulphur-coated urea (34.1 per cent N, 20.8 per cent S) were compared in a randomized complete block design with four replications. Control plots had no added N. The sulphur-coated urea (SCU) used was obtained from TVA, Muscle Shoals, Alabama, USA, and has a

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dissolution rate of 15 per cent in the first 7 days. The fertilizers were compared with bare fallow. Each fertilizer was uniformly broadcast in a single application at a rate of 100 kg N ha^{-1}. Ammonium sulphate and urea as crystals, and the SCU as granules, were raked into the top 1cm of soil. Plot size, was 5.0m x 4.5m. The plots were kept free of weeds.

Field samples were taken using a 10cm diameter bucket auger to a depth of 90cm at 15cm intervals. Five samples, taken at each depth from each plot, were combined for storage at 20°C and subsequent analysis. In order to keep the SCU granules intact the samples were not crushed.

Laboratory experiment

Changes in the form of the mineral N from ammonium sulphate and urea were followed in the laboratory using surface Apomu soil (0-15cm). The N source was added to 100g samples of air-dry soil in polythene bags at a rate of 100 ppm N, and water was added to 70 per cent field capacity. The bags were sealed and incubated at 20°C, 30°C and at field temperature. Samples were taken for analysis at four-day intervals up to 28 days. The temperature of the field was measured twice daily; the average was 26°C.

NH_4–N and NO_3–N concentrations were measured in KCl extracts of the soil samples (Bremner and Keeney, 1966). Urea–N was measured by the method of Douglas and Bremner (1970), but it could not be detected later than 24 hours after being added to the soil. Soil pH was measured using a water to soil ratio of 2.5:1.

Climatic observations

Some of the climatic data recorded during the course of the experiment are shown in Table 2. Evaporation values were obtained from open pan evaporation. Drainage values were estimated from rainfall and evaporation.

Results and discussion

Samples of the soils to 90cm depth immediately prior to application of the fertilizers showed average contents of 67, 84, 94 and 103 kg ha^{-1} of mineral N in the ammonium sulphate, urea, SCU and control plots respectively. These high amounts and the variability between plots caused the subsequent changes to be less clear than expected.

The calculated drainage (Table 2) gives an indication of the periods during which loss by leaching could be expected. These were at 26,40 and 60 days. Statistical analysis of the data showed no significant changes in mineral N below a soil depth of 30cm. For each treatment all the added N seemed to have been lost by 40 days, following a period of intense rain.

Leaching losses

The mineral-N changes during the first 40 days (Fig. 1) shows that there was little loss of N by leaching. The SCU treated plots showed only slight changes in mineral N before 26 days. This would be expected since the granules would only slowly release the urea. However, under conditions of heavy and prolonged rainfall, when it would have been expected that SCU would reduce losses, the granules burst releasing all the remaining urea. This accounts for the increase at 40 days which was mainly due to an exceptionally high N content of one of the replicates.

The evidence against loss by leaching comes mainly from considering the ammonium sulphate and urea treatments. Loss from the 0–15cm depth is not accompanied by significant accumulation in the 15–30cm depth. Furthermore there does not seem to have been appreciable nitrification of the added N to NO_3. The largest increases in the NO_3–N content of the 0–15cm depth were 7.3 (at 18 days) and 10.1kg N ha^{-1} (at 7 days) for ammonium sulphate and urea respectively. Therefore the losses which occurred by 7, 18, 26 and 40 days were due mainly to loss of NH_4–N.

Nitrogen leaching in the humid tropics has mainly been measured indirectly. Vine (1953) reported some evidence of NO_3 leaching in the humid zone of Western Nigeria. Fayemi (1966) ascribed the advantage for maize of split N applications over a single application to the smaller leaching loss. It is only work done subsequently, in the Caribbean, which supports the above findings (Gabriel, 1983; Nkrumah, 1983).

Table 2. Rainfall and evaporation during the period of the field experiment

Time after fertilizer application (days)	Rainfall (R)* (mm)	Evaporation (E) (mm)	Calculated drainage (R-E) (mm)
0	0	0	0
7	15.5	20.1	-4.6
18	42.4	39.4	3.1
26	42.4	14.6	27.8
40	235.5	35.6	199.9
45	9.3	13.4	-4.1
50	52.9	51.4	1.5
60	99.1	27.2	71.9

* A total of 234.8 mm of rain was recorded from June 1973 to start of the trial on 6 July 1973; 14.5 mm were recorded one day prior to fertilizer application.

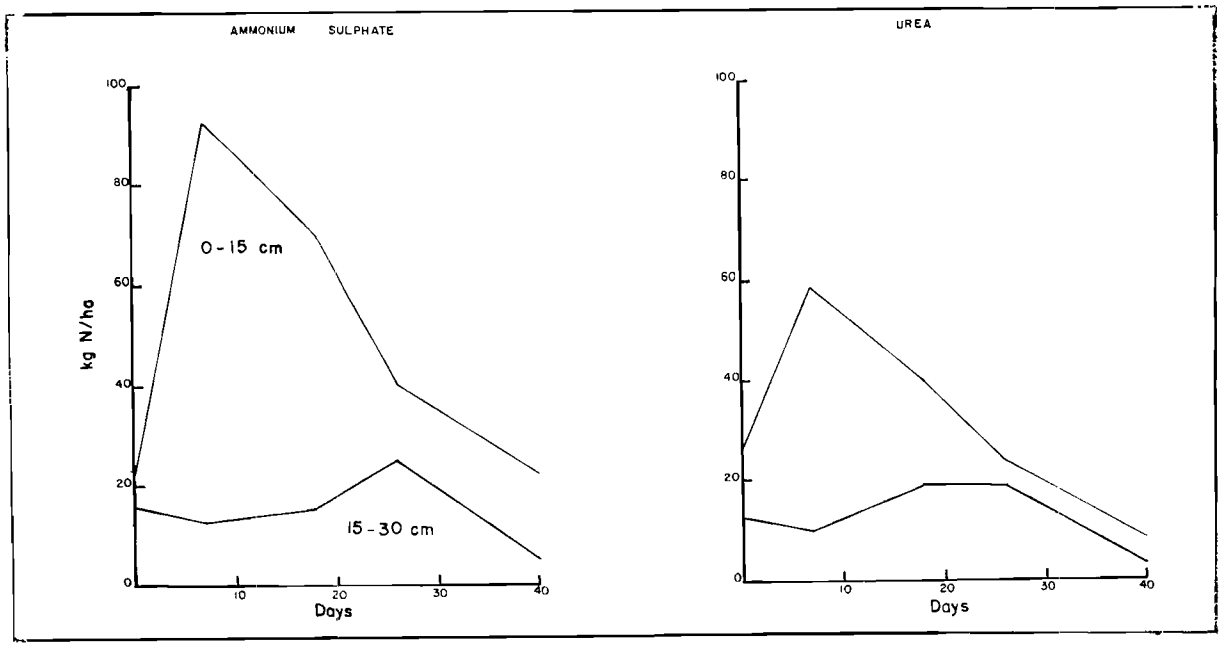

Fig. 1a. Changes in total inorganic N (NH_4–N + NO_3–N) in the 0 - 15 and 15 - 30cm depths of Apomu soil during 40 days.

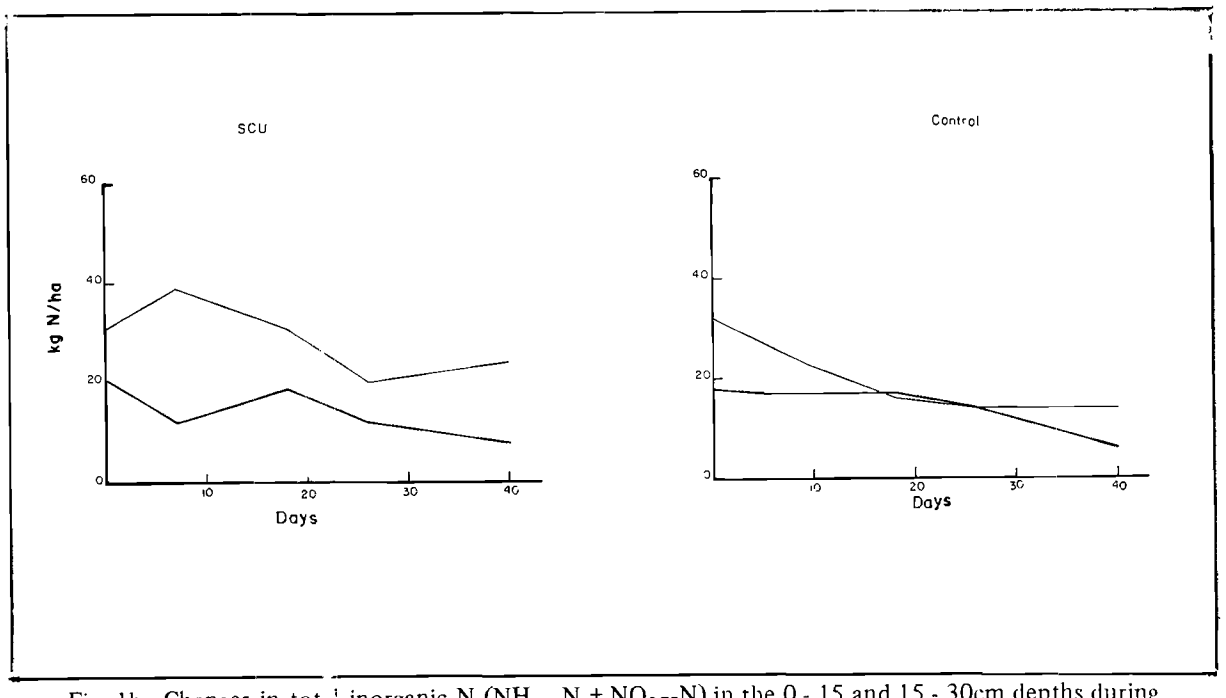

Fig. 1b. Changes in total inorganic N (NH_4–N + NO_3–N) in the 0 - 15 and 15 - 30cm depths during 40 days.

NH_4–N losses

Table 3 shows the losses of NH_4–N during the first 40 days of the experiment:

Table 3. Loss of NH_4–N (kg N ha^{-1}) from the 0–15cm depth of the plots treated with ammonium sulphate or urea and control plots during 40 days.

Period (days)	Ammonium sulphate	Urea	Control
0 – 7	34.29	78.23	4.63
7 – 18	26.04	8.24	0.00
18 – 26	26.68	11.07	7.02
26 – 40	15.76	9.74	4.47

NH_4–N was lost more rapidly from urea than ammonium sulphate, all the added N being lost by 26 and 40 days respectively. The loss of NH_4–N from ammonium sulphate was fairly evenly spread throughout the 40 days, ranging from 34.3kg N ha^{-1} to 15.8 kg N ha^{-1} in the 0–7 and 26–40 day periods. NH_4–N loss from urea was much more dramatic, the largest loss being 78.2 and the smallest 9.7 kg N ha^{-1} for the 0–7 and 26–40 day periods respectively.

It is possible that NH_4–N can be lost from the mineral N fraction by denitrification. Allison (1963) suggested that the decomposition of ammonium nitrate could be the cause of gaseous loss of N. Also it is possible that anaerobic zones could be present in a supposed aerobic soil. Both these mechanisms of loss would not seem to account for the large losses which occurred in the present trial.

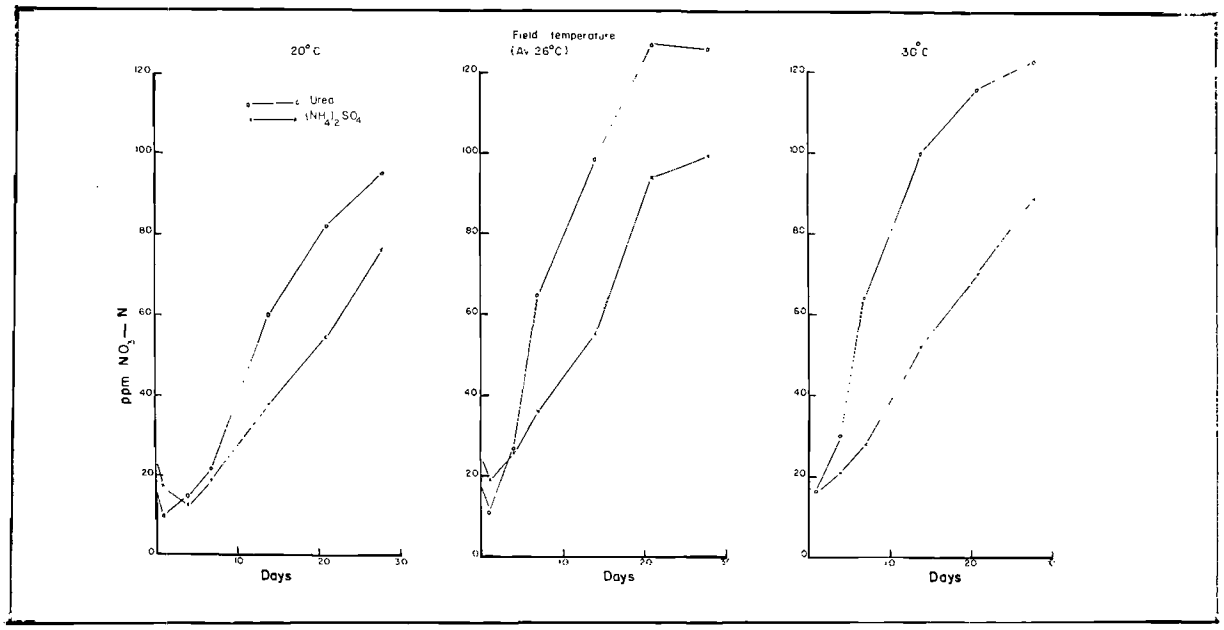

Fig. 2 Mean NO_3 – N content of Apomu soil treated with $(NH_4)_2$ SO_4 and urea incubated at 20°C, field temperature and 30°C for 28 days.

The more rapid loss from urea than ammonium sulphate suggests loss by volatilisation, which occurs because of the pH rise when urea hydrolizes (Gasser, 1964). Acquaye and Cunningham (1965) also reported substantial losses of urea as compared to ammonium sulphate with shallow incorporation into soil. Measurements of the soil pH in the field experiment missed the rise due to urea hydrolysis but this was noticed in the incubation experiment to be discussed later.

The loss from ammonium sulphate is unexpected. Possible explanations are: (a) that there was immobilization and (b) that the exchange of SO_4^{--} for OH^- produced locally high pH values which induced volatilization.

Laboratory experiment

Incubation at 20°C, 30°C and field temperature (FT) showed clearly that nitrification in Apomu soil is rapid (Fig. 2). The rate of nitrification was temperature dependent: 30°C ≐ FT > 20°C. Little or no moisture loss occurred with incubation at these temperatures. At 40°C (results not presented), however, there was significant moisture loss. This is in agreement with work done by Eno (1960).

The rate of nitrification was also dependent on source of N. The urea treated soil had a faster rate at each temperature; nitrification had started by 7 days at 20°C and by 4 days 30°C and field temperature.

The respective times for ammonium sulphate were 14 and 7 days. By 28 days nitrification of the NH_4–N derived from urea was essentially complete whilst that from ammonium sulphate was not.

There was no loss of NH_4–N from the mineral fraction (Table 4).

In fact it would seem that there was release from the organic or clay fraction during incubation. The fluctuation in the field temperature did not significantly affect either the rate of nitrification or the recovery of the added N.

During the first four days of incubation the pH of the urea treated soil was 1.2 units higher (pH 7.3) than initially. By the end of the experiment the pH was essentially the same as that of the ammonium sulphate treated soil, i.e. 5.4. The pH of the ammonium sulphate treated soil had dropped 0.6 units from an initial value of 6.0. Therefore urea hydrolysis causes an initial increase of pH which can be easily missed in measuring the pH of a field sample. This increase could be responsible for the much faster initial rate of nitrification.

Table 4: Percentage recovery of urea and ammonium sulphate after 28 days incubation at 20°C, 30°C and field temperature (FT)

Fertilizer	Percentage recovery		
(100 ppm)	20°C	30°C	FT
Urea	104	110	115
$(NH_4)_2SO_4$	115	126	127

It would seem that it is the wetting and drying cycles in the field which are the critical factor in the removal of NH_4–N from the mineral fraction. Whether the NH_4–N is lost by volatilisation or immobilised requires further work.

Conclusions

i. Under the conditions of the field trial added N can be considered completely removed from the mineral fraction by 40 days.

ii. There was little or no leaching of added N.

iii. It is NH_4–N and not NO_3–N which is removed. This could be either by volatilisation and/or immobilisation.

iv Since this removal occurred only under field conditions and not in the laboratory, the wetting and drying conditions in the field seem to be critical.

References

Acquaye, D.K. and Cunningham, R.K. (1965) Losses of nitrogen by ammonia volatilisation from surface applied N in tropical forest soils. *Trop. Agric. (Trinidad)* **42** 281-292.

Allison, F.E. (1963) Losses of gaseous nitrogen from soils by chemical mechanisms involving nitrous acid and nitrites. *Soil Sci.* **96** 404-409.

Bremner, J.M. and Keeney, D.R. (1966) Determination of isotopic ratio of different forms of nitrogen in soils 3: Exchangeable ammonium, nitrite and nitrate by extraction and distillation methods, *Soil Sci. Soc Am. Proc.* **30** 577–582.

Chesney, H.A.D. (1967) *Denitrification in some Trinidad soils.* M.Sc. thesis, University of the West Indies Library, Trinidad, (unpubl.)

Douglas, L.A. and Bremner, J.M. (1970) Extraction and colorimetric determination of urea in soils. *Soil Sci. Soc. Am. Proc.* **34** 859–862.

Eno, C.E. (1960) Nitrate production in the field by including the soil in plastic bags. *Soil Sci. Soc. Am. Proc.* **24** 277-279.

Fayemi, A.A. (1966) Effects of time of nitrogen application on yield of maize in the tropics. *Expl. Agric.* **3** 101-105.

Gabriel, L. (1983) *The recovery of added* ^{15}N *in a cropped West Indian soil.* PhD thesis. University of the West Indies Library Trinidad, (unpubl.)

Gasser, J.K.R.G. (1964) Some factors affecting losses of ammonia. *J.Soil Sci.* **15** 258-272.

Hardy, F. (1964) Seasonal fluctuations of soil moisture and nitrate in a humid tropical climate (Trindad, W.I.) *Trop. Agric. (Trinidad)* **23** 40-49.

Nkrumah, M. (1983) *Crop utilization of added N, movement of* NO_3^-*-N and transformation of* $(NH_2)_2CO$*–N over varying seasons.* M.Sc. thesis, University of the West Indies Library, Trinidad (unpubl.)

Vine, H (1953) Experiment on maintenance of soil fertility at Ibadan, Nigeria 1922–51. Pt. 1 Introduction and review of the period 1922–33. *Emp. J. Expl. Agric,* **21** 65-85.

SAP TESTING OF NITRATE NITROGEN IN TOMATO

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ABSTRACT

The usefulness of conventional tissue testing techniques is limited for monitoring and adjusting the nitrogen (N) status of rapidly growing crops, such as many vegetables, because of the frequent unavailability of sufficiently quick and reliable test results. The nitrate N status of *Lycopersicon esculentum* 'Celebrity' was monitored in a greenhouse study using "Merkoquant" quick-test nitrate strips to determine the effects of plant-to-plant variation and variation in leaf position and time of day on the levels of nitrate N detectable in petiole sap. Nitrate N levels decreased from 2800 ppm in 28-day-old plants to below 400 ppm in plants older than 68 days. Sap nitrate N concentrations were equal in the top, middle, and bottom of the canopy of 28-day-old plants, but decreased more rapidly in the top of the canopy as the plants developed. Tissue analysis results and sap test results concurred in showing that N availability had been growth limiting. No differences in sap nitrate concentrations were detected between 10 a.m., 12 p.m., and 2 p.m.

RESUMEN

La utilidad de técnicas convencionales para analizar tejidos de plantas para vigilar y ajustir el nivel de nitrógeno en cultivos de creciminento rápido, tales como muchas hortalizas, es limitada debido a la frequente indisponibilidad de resultados suficientes rápidos y seguros. El nivel de nitrógeno en forma de nitrato de *Lycopersicon esculentum* 'Celebrity' fue vigilado en un estudio de invernadero usando laminas de nitrato de ensayo rápido "Merkoquant" para determinar los efectos de variación entre plantas y la variación en posición de hoj y tiempo del día sobre los niveles de nitrato encontrados en la savia del peciolo. Los niveles de nitrato bajaron de 2800 ppm en plantas de 28 días de edad a menos de 400 ppm en plantas mayores de 68 días de edad. Las concentraciones de nitrato en la savia eran iguales en la parte superior, la parte intermediana y la parte mas baja de plantas de 28 dias de edad, pero decrecieron mas rapido en la parte superior de las plantas mientras éstas se desarrollaron. Resultados del análisis de tejidos y de la savia concurrieron que la disponibilidad de nitrógeno limitaba el crecimiento. No se notó ninguna diferencia en la concentración de nitrato en la savia entre 10 a.m., 12 p.m. y 2 p.m.

Keywords: Nitrate-N; N-fertilizers; Sap tests; Tomato

Nitrogen is one of the most important nutrients for crop production. It is also one of the most difficult to manage because both N supply in the soil and N demand by the crop are sensitive to environmental influences, including rainfall, temperature, and light intensity, over which the grower has little or no control. These factors can cause significant changes in crop N status and consequently can influence crop yields unpredictably.

Growers may overfertilize to reduce the risk of N deficiency developing in their crops, but this approach is not without its drawbacks. Besides wasting costly fertilizer, excessive N applications can result in poor stand establishment, reductions in crop quality, and losses in crop yield (6).

Plant tissue analysis is a useful tool for determining whether N supply to a crop is keeping pace with N demand by the crop. Nitrate N is a particularly sensitive indicator of crop N status, varying greatly and rapidly between plants adequately and inadequately supplied with N. However, conventional tissue testing procedures are of limited usefulness for the purpose of monitoring and making adjustments to current crop N status because of the time delays and expenses involved in obtaining tissue test results from testing laboratories.

Rapid, accurate, and inexpensive nitrate testing has recently begun to appear feasible using "Merkoquant" test strips. The cost of a nitrate analysis is only about U.S. $0.20. The nitrate determination can be made in 2 minutes or less. Results of limited field testing of horticultural crops with these nitrate strips have yielded nitrate values broadly comparable to those obtained with more elaborate laboratory procedures (4). There would seem to be great potential for using test-strip methodologies to improve N fertilization practices throughout the tropics in areas not served adequately by tissue testing laboratories.

A number of factors appear to influence the concentration of nitrate found in plants, including leaf position (1, 2, 7) and time of day (3, 7). Plant-to-plant variability also can be considerable (7). The impact of these factors needs to be characterized in detail to facilitate the development of effective interpretive guidelines for using sap nitrate testing in a monitoring role. The purpose of this experiment was to determine the significance of plant-to-plant variation and variation in leaf position and time of day on paper-strip analyses of nitrate in the petiole sap of greenhouse-grown tomato plants.

Materials and methods

Eighty 'Celebrity' tomato plants were grown in a greenhouse for 88 days commencing in October 1984 in pots containing 0.015 m^3 of 2 peat: 1 perlite: 6 vermiculite (by volume) amended with 4.8 kg m^{-3} dolomite, 0.11 kg m^{-3} gypsum, 0.7 kg m^{-3} Micromax slow release micronutrients (Sierra Chemical Co., Milipitas, California), and 1.1 kg m^{-3} concentrated superphosphate (ON-20P-OK). The pots received 20 ppm N and 100 ppm K continuously during 3 irrigations of 2 liters each per day fully delivered 1 hour before predetermined petiole sap sampling times of 10 a.m., 12 p.m., and 2 p.m. Air temperature and an estimate of the average percent of cloud cover throughout the day were recorded daily. Photosynthetically active radiation (PAR) was measured periodically on sap sampling days.

Sap nitrate sampling at 10 day intervals began 28 days from seeding. At 12 p.m. each sampling day, 3 groups of 10 randomly chosen plants each were selected. Petioles were excised from the top of the canopy of the first group of plants (youngest fully unfurled leaf), from the middle of the canopy of the second group of plants (youngest fully expanded leaf), and from the bottom of the canopy of the third group of plants (lowest healthy leaf). Ten petioles also were excised from the top of the canopy of 10 randomly selected plants at 10 a.m. and 2 p.m. Sap was rolled out of the petioles using a thick pen barrel and immediately applied to the nitrate-sensitive area of a Merkoquant test strip. Nitrate N concentration was then determined by comparing the color developed in 2 minutes on the strip with the accompanying chart of color standards. Concentrations above the range of the standards were determined by timing color development to the darkest intensity on the standardizing chart (114 ppm) and using an equation reported to describe this relationship (7) as follows:

$$NO_3\text{-}N\ [ppm] = 10^{4.25-1.085 \log 10^{t\ [sec]}}$$

On each sampling day, 5 plants were harvested and analyzed for dry weight and N content of vegetative and reproductive structures.

Results and discussion

Mean daily maximum and minimum air temperatures in the greenhouse during the experiment were approximately 30°C and 20°C respectively. Photosynthetically active radiation during clear periods was about 1100 µmol m^{-2} s^{-1}, but only about 300 umol m^{-2} sec^{-1} when cloudy. Skies were clear about 75% of the time during most of the experiment, but the frequency of clear conditions dropped below 50% during a period of cloudy weather between days 68 and 78.

Total dry weight accumulation increased at a slightly accelerating rate throughout the experiment (Fig. 1). The rate of vegetative and total growth was noticeably reduced during the cloudy period between days 68 and 78. The rate of increase in flowering and

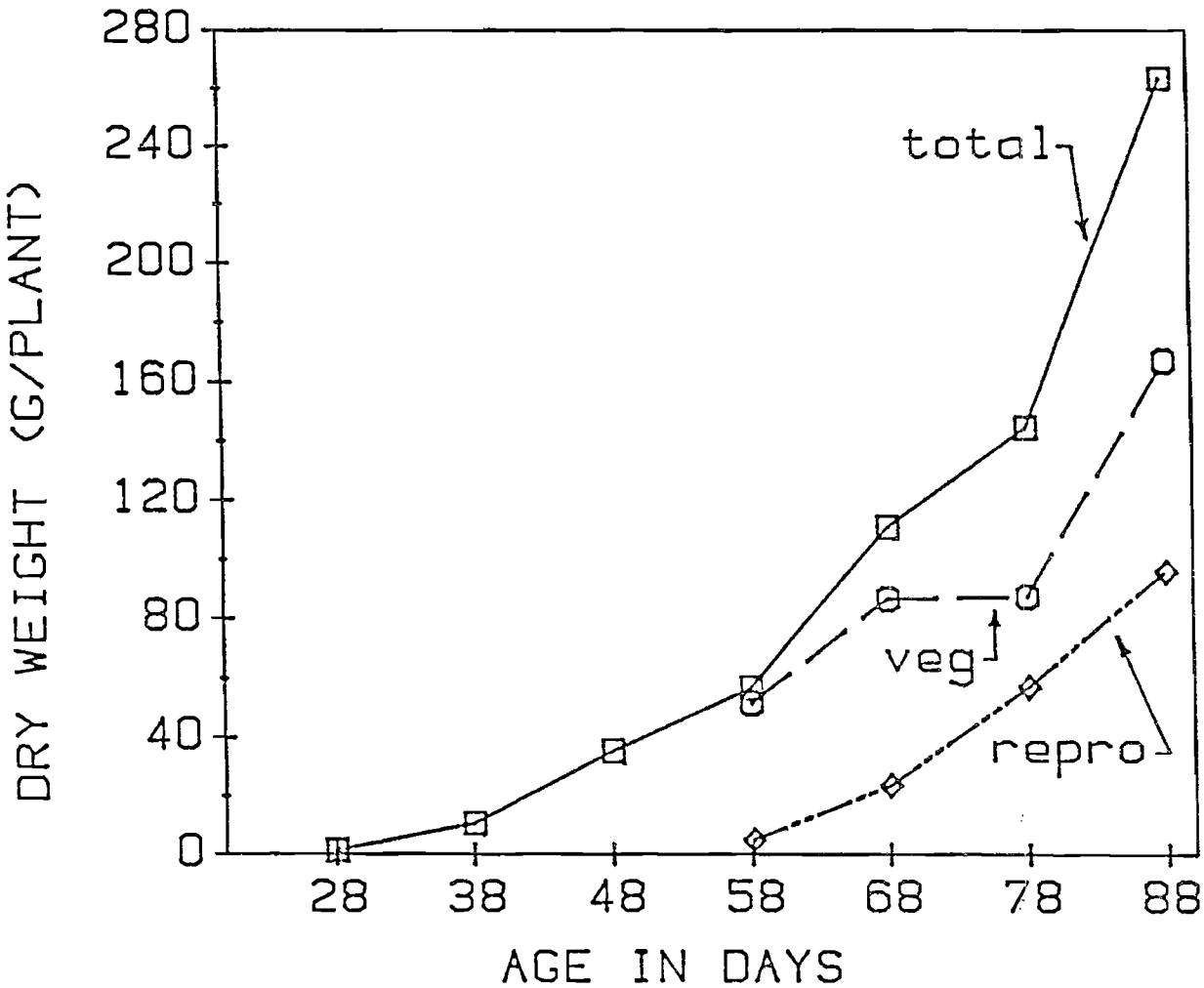


Fig. 1. Dry weight accumulation of 'Celebrity' tomatoes grown in a greenhouse at UH - Manoa between October 1984 and January 1985.

fruiting structures was unaffected. Patterns of N accumulation in the crop closely paralleled patterns of dry weight accumulation (Fig. 2). Total N percentage in the top leaf petioles declined steadily throughout crop development, falling from 4.5% at the start of the sampling period to below 1% by fruit initiation (day 68). This low value at fruiting indicated that a condition of N deficiency had developed during the experiment, despite the deep green and vigorous appearance of the plants. Sap nitrate test results also had indicated the development of N deficiency (Fig. 3). In general, nitrate N levels decreased from about 2800 ppm in 28-day-old plants to below 400 ppm in plants older than 68 days. Recent studies involving nitrate sap testing with field tomatoes indicate that about 1000 ppm nitrate N is desirable in plants of this latter age to produce maximum yields (5). Sap nitrate monitoring would have allowed a quick corrective response to the development of the N deficiency.

Sap nitrate N concentrations were equal in the top, middle, and bottom of the canopy of 28-day-old plants, but decreased more rapidly in the top of the canopy than lower in the canopy as plants developed. The greater sensitivity of upper leaves to N deficiency has been previously noted (1).

Plant-to-plant variability in sap nitrate concentrations in field crops has led to the recommendation that at least 20 plants be sampled and the results averaged to ensure a reliable mean value (7). In this experiment, variability in the 10-plant sample resulted in a LSD between means of 300 ppm (Fig. 3) This LSD would have been adequate to indicate deficiency in the 68-day-old crop based on a critical value of 1000 ppm. It is reasonable to find plant-to-plant variability less of a problem in greenhouse grown crops.

Diurnal fluctuation in nitrate N with peak values around 8 a.m. and 3-fold lower values by 4 p.m. have been reported (3). In this experiment nitrate N concentrations did not vary greatly or consistently between 10 a.m. and 2 p.m. (Fig. 4). Other recent work has failed to corroborate a significant diurnal effect on sap levels over the day, although a low number of replicates may have masked the results (7). Aditional work is needed to determine whether sap testing guidelines require standardization of test time, or whether equally useful information can be obtained throughout the day.

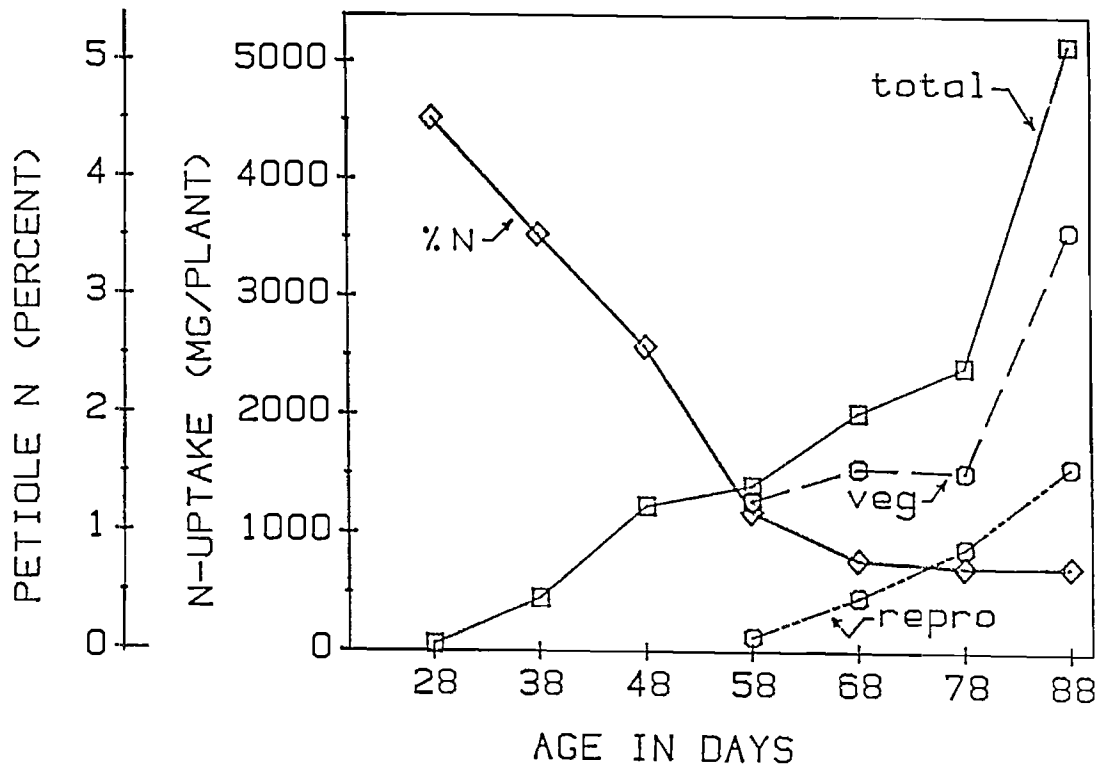
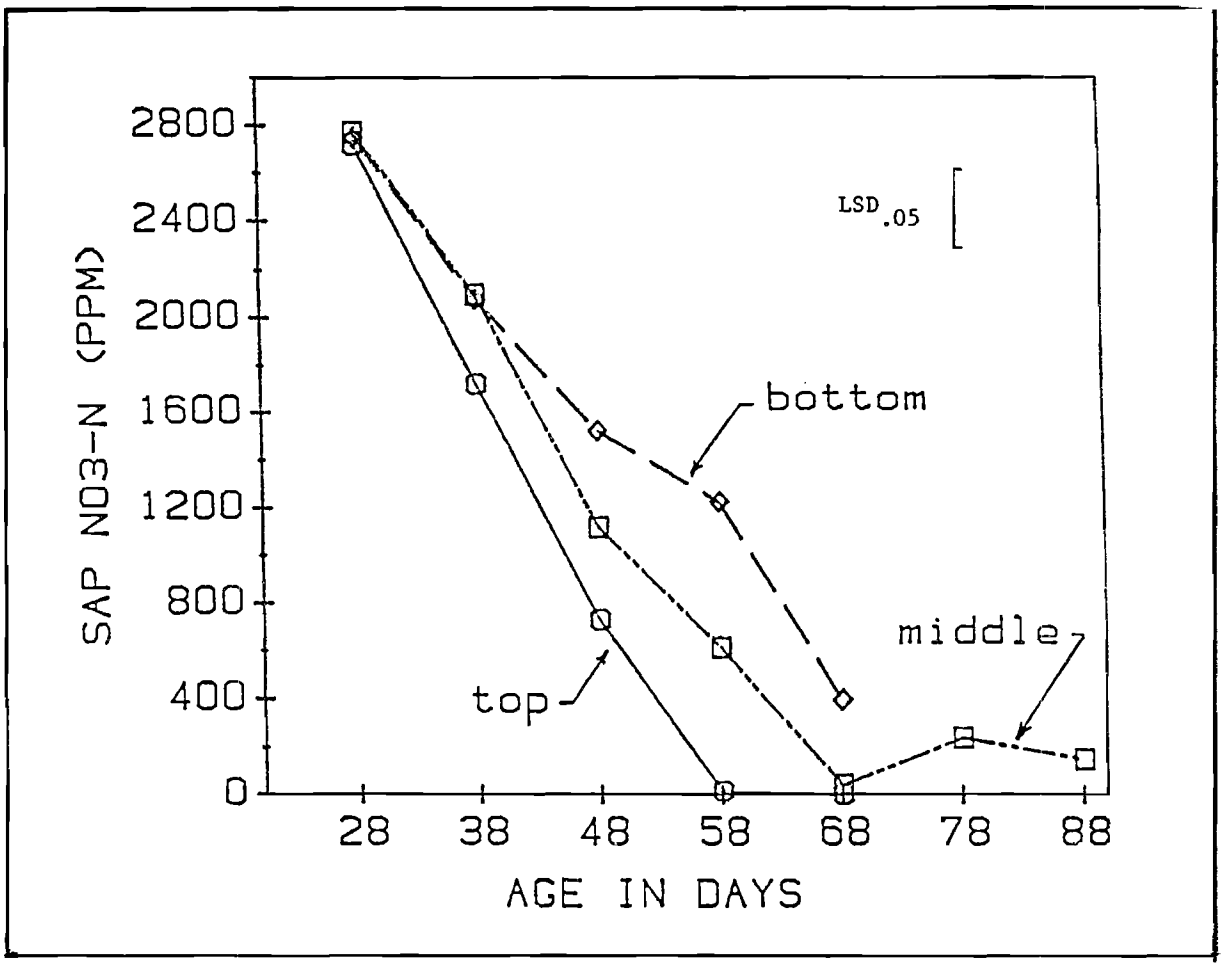


Fig. 2. Nitrogen content of 'Celebrity' tomatoes grown in a greenhouse at UH - Manoa between October 1984 and January 1985.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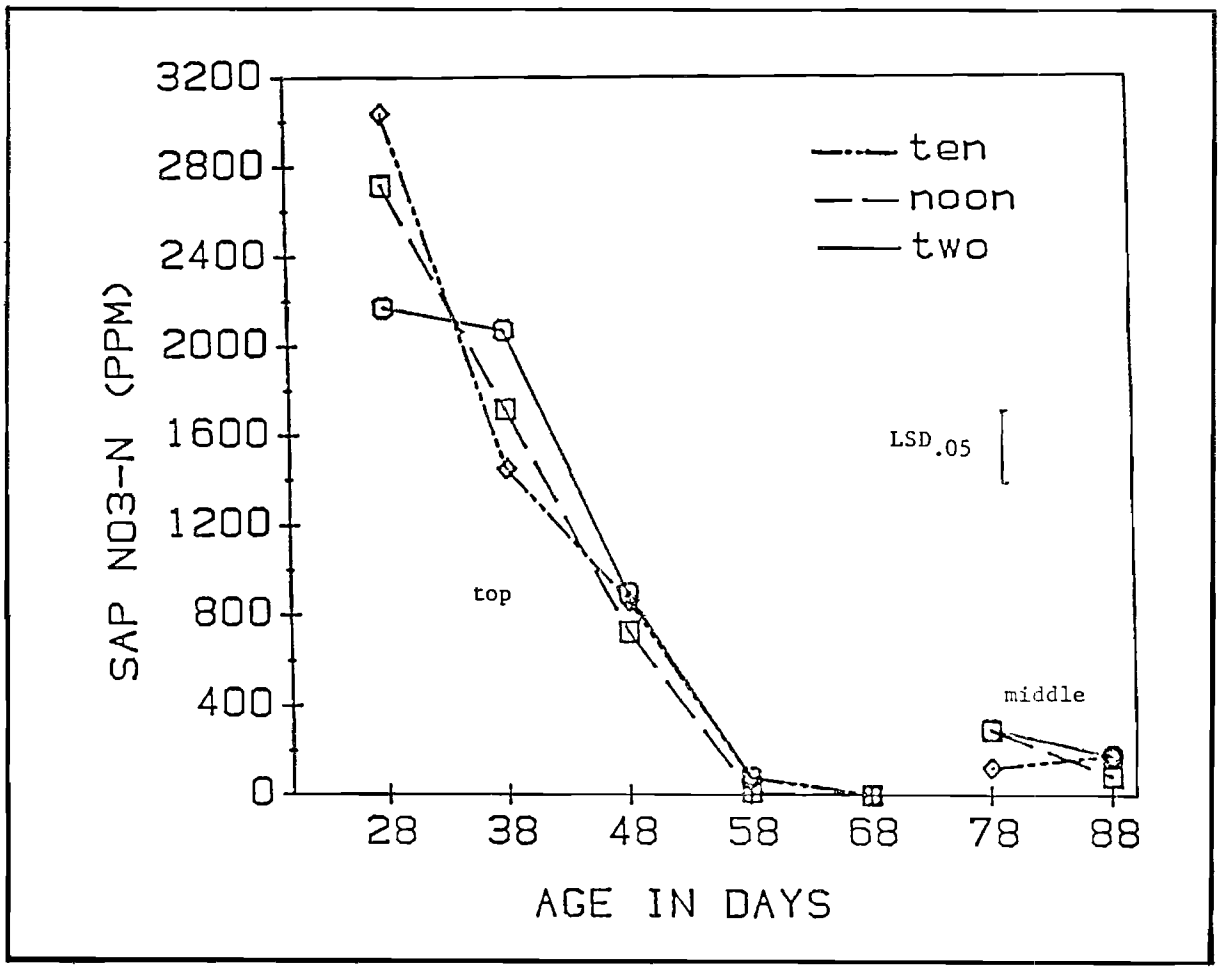
AGE IN DAYS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AGE IN DAYS

Literature Cited

1. Gomez-Lepe, B.E. and A. Ulrich. 1974. Influence of nitrate on tomato growth. J. Am. Soc. Hort. Sci. 99: 44 – 49.

2. Hernando, V., M.E. Garcia Lopez de Sa, and P. Azuara. 1982. Selection of the most appropriate leaves for sap analysis during the first period of tomato plant growth. p.227–231. In: A. Scaife (ed.) Plant nutrition 1982. CAB. Slough, U.K.

3. Minotti, P.L. and D.L. Stankey. 1973. Diurnal variation in the nitrate concentration of beets. Hort. Sci. 8: 33–34.

4. Prasad, M. and T.M. Spiers. 1984. Evaluation of a rapid method for plant sap nitrate analysis. Comm. in soil Sci. Plant Anal. 15: 673–679.

5. Prasad, M. and T.M. Spiers. 1985. A rapid nitrate sap test for outdoor tomatoes. Scientia Horticulturae 25: 211–215.

6. Scaife, A. and B.G. Bray. 1977. Quick sap tests for improved control of crop nutrient status. ADAS Q. Rev. 27: 137–145.

7. Scaife, A. and K.L. Stevens. 1984. Monitoring sap nitrate in vegetable crops: comparison of test strips with electrode methods, and effects of time of day and leaf position. Comm. in Soil Sci. Plant Anal. 14: 761–771.

SOLUBLE SALTS INTERPRETATION FOR ORNAMENTAL FOLIAGE CROP PRODUCTION

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ABSTRACT

During the last few years, experiments have been conducted with potting media and fertilizer as variables. Soluble salts of the media and plant ratings were sometimes determined. Comparisons of the levels of soluble salts and plant growth indicated soluble salts readings are a poor indicator of the potting media ability to produce satisfactory foliage plants.

RESUMEN

Durante los ultimos anos, se ha conducido investigaciones con diferentes mezclas de tierra y abonos. De vez en cuando se determinó los niveles de sales solubles en las mezclas de tierra y el comportamiento de las plantas. La comparación de los niveles de sales solubles y el crecimiento de las plantas indicaron que el nivel de sales solubles no es un indicador seguro de la capacidad de una mezela de tierra para producir plantas ornamentales satisfactorias.

Satisfactory plant growth requires macro and microelements, normally supplied by specific fertilizers. Addition of fertilizer increases soluble salts levels, actually soluble ions, in the medium. To determine soluble salts levels, a conductivity meter is used since dissolved salts increase electrical conductivity. Horticulturists use soluble salts levels to indicate fertility level desired for plant production. If a plant is chlorotic or necrotic, roots are usually examined and sometimes soluble salts of the soil determined. If levels are too low, additional fertilizer is suggested and if levels are too high removal of fertilizer (soluble salts) by heavy applications of water to the soil is suggested.

Four methods to determine soluble salts levels are: (1) 1:2 – soil:water, by dry weight; (2) 1:2 – soil: water, by volume; (3) saturated paste and (4) leachate. The dry weight method should not be used for potting media because of the variability of bulk density of the different mixtures used for growing plants. The volume procedure is commonly used because of its simplicity. One volume of soil is added to 2 volumes of water, mixed, and usually allowed to stand for about 15 minutes with occasional stirring. The electrode of the conductivity meter can be placed directly in the solution, or the solution can be filtered prior to measuring conductivity. The saturated paste procedure had been recommended because readings obtained by this method are said to approximate those in the root environment, but variations in water holding capacity of potting mixtures suggests this may not be much of an advantage. The procedure for saturated paste is the most complex since the soil sample is moistened until a glistening paste is obtained. Obtaining the same degree of glistening each time can lead to errors in reproduction. After glistening is obtained, vacuum is applied to extract the solution and conductivity determined. Although the leachate method is not commonly used, it is the easiest to conduct. Water is poured through the medium in the container which is in a beaker. Fifty to 100 ml of leachate is collected and conductivity determined. This method allows frequent sampling without removal of soil or distrubing the root system.

Unfortunately, many types of electrical conductivity meters are used and units of measurement differ. The usual unit is mhos, but the reading could be micromhos (mhos x 10^{-6}) millimhos (mhos x 10^{-3}) or mhos x 10^{-5}. Numerous tables have been printed with ranges for the interpretation of these readings, (Table 1).

During the last few years, experiments have been conducted at AREC-Apopka, Florida, with potting media and fertilizer as variables. Soluble salts of the media and plant ratings were sometimes determined. A summary of soluble salts of the media and con-

Table 1. Interpretation[z] of soluble salts readings (mhos x 10^{-5}) for 1:2 air dry soil (peat or light weight mix) to water by volume (A) and saturated paste (B) methods (5).

Mohs x 10^{-5}	Rating	Remarks
A 0–50 B 0–100	Low	Need fertilizer
A 51–100 B 101–132	Medium	Satisfactory
A 101–175 B 133–164	High	Desirable
A 176+ B 165+	Very High	Leach

[z] There is no guide for leachate soluble salts.

dition of the plants is contained in Table 2.

An examination of Table 2 clearly reveals the difficulty of determining the adequacy of a potting medium or feritlizer program by soluble salts readings. Media containing plants with the worst indicators (grade or height) had 11 ratings in the low range, 3 in the medium range, 4 in high and 4 in the very high range. Media containing plants with the best indicators had an almost identical rating: 12 in the low range, 3 medium, 6 high and 1 in the very high range. When comparing the worst and best ratings of the same plant, ratings were the same 11 times, went from a high to a low rating 6 times and from a low to a high rating 5 times. Plants with a

Table 2. Comparisions of growth indicators with soluble salts of potting media.

Species	Reference	Mohs × 10 worst	Mohs × 10 best	Indicator worst	Indicator best	Method	Time of reading	Rating Table 1 worst	Rating Table 1 best
Aglaonema	4	6	5	3.5[p]	3.9	2:1, vol	Initial	Low	Low
commutatum	9	149	218	2.2[p]	4.6	Sat. paste	Initial	Med	High
Alphelandra	1	12	27	1.9[p]	3.1	2:1, vol	Final	Low	Low
squarrosa	2	27	45	3.2[p]	3.9	2:1, vol	Final	Low	Low
Brassaia	3	242	161	1.8[p]	3.9	2:1 vol	Final	V.high	High
actinophylla	6	205	51	14[c]	23	2:1, vol	Initial	V.high	Med
	9	149	156	3.4[p]	4.6	Sat. paste	Initial	High	High
	11	515	185	15[w]	24	Leachate	Final		
	11	690	300	122[w]	182	Leachate	Final		
	12	310	155	3.8[p]	4.1	Leachate	Initial		
	12	85	70	3.8[p]	4.1	Leachate	Final		
Calathea									
makoyana	9	158	155	2.0[p]	4.4	Sat. paste	Initial	High	High
Chamaedorea									
elegans	11	730	225	6	8	Leachate	Final		
Chrysalidocarpus									
lutescens	7	0	19	1.2[p]	4.1	2:1, vol	Final	Low	Low
Dieffenbachia	1	24	45	26.3[c]	28	2:1, vol	Final	Low	Low
maculata	2	47	80	26[c]	28	2:1, vol	Final	Low	Med
	3	164	142	2.2[p]	4.4	2:1, vol	Final	High	High
	10	34	208	2.1[p]	3.9	2:1, vol	Final	Low	High
	12	110	50	3.7[p]	3.9	Leachate	Initial		
	12	40	40	3.7[p]	3.9	Leachate	Final		
	12	150	165	3.6[p]	4.8	Leachate	Initial		
	12	40	60	3.6[p]	.8	Leachate	Final		
Ficus									
benjaminas	13	171	262	3.8[p]	4.5	2:1, vol	Initial	High	V.High
	13	51	53	3.8[p]	4.5	2:1, vol	Final	Med	Med
Maranta									
leuconeura									
erythroneura	9	705	200	13[w]	15[w]	Leachate	Final		
Monstera									
deliciosa	4	207	14	33[c]	38	2:1, vol	Initial	V. high	Low
Nephrolepis	1	5	29	26[c]	31	2:1, vol	Final	Low	Low
exalatata	2	66	21	30[c]	33	2:1, vol	Final	Med	Low
	4	3	3	3.7[p]	3.9	2:1, vol	Final	Low	Low
Pellionia									
pulchra	8	50	59	14[c]	17	2:1, vol	Final	Low	Med
Peperomia									
obtusifolia	8	50	59	14[c]	59	2:1, vol	Final	Low	Med
	10	234	22	2.4[p]	22	2:1, vol	Final	V. high	Low
	11	680	158	9[w]	158	Leachate	Final		
	11	621	172	116[w]	172	Leachate			
Philodendron	1	20	18	24[c]	26	2:1, vol	Final	Low	Low
scandens	2	64	49	21[c]	23	2:1,vol	Final	Med	Low
oxycardium	11	225	690	8[w]	10	Leachate	Final		
Pilea									
involucrata	8	48	59	12[c]	13	2:1, vol	Final	Low	Med

[c] Centimeters
[p] Plant grade, 1= poor, 5=excellent
[w] Weight in g

grade of 3.0 or above (considered salable) were growing in 8 soil mixes with low soluble salts, 2 with medium levels, 8 with high salts and 1 with very high soluble salts.

Summary

Results of this compilation show that soluble salts readings are a poor indicator of the potting media ability to produce satisfactory, salable foliage plants.

Literature Cited

1. Conover, C.A. and R.T. Poole. 1977. Influence of irrigation method and fertilizer source and level on growth of four foliage plants. Proc. Fla. State Hort. Soc. 90: 312–313.

2. Conover, C.A. and R.T. Poole. 1977. Influence of potting media and fertilizer source and level on growth of four foliage plants on capillary mats. Proc. Fla. State Hort. Soc. 90: 316–318.

3. Conover, C.A. and R.T. Poole. 1981. Influence of light and fertilizer levels and fertilizer sources on foliage plants maintained under interior environments for one year. J.Amer. Soc. Hort. Sci. 106 (5): 517–574.

4. Conover, C.A. and R.T. Poole. 1983. Utilization of *Melaleuca quinquenervia* as a potting medium component for greenhouse production of foliage plants. HortScience 18 (6): 886–888.

5. Joiner, J.N. ed. 1981. *Foliage Plant Production.* Prentice-Hall, Inc. Engelwood Cliffs, N.J. 07632. 613 pp.

6. Poole, R.T. and W.E. Waters. 1972. Evaluation of various potting media for growth of foliage plants. Proc. Fla. State Hort. Soc. 85: 395–398.

7. Poole, R.T. and C.A. Conover. 1975. Media, shade and fertilizer influence production of the Areca palm, *Chrysalidocarpus lutescens* Wendl. Proc. Fla. State Hort. Soc. 88: 603–605.

8. Poole, R.T. and C.A. Conover. 1977. Influence of medium, container size and water regime on growth of *Pellionea pulchra* N.E. Br. and *Pilea involucrata* (Sims) Urb. Proc. Fla. State Hort. Soc. 90: 319–320.

9. Poole, R.T. and C.A. Conover. 1979. Melaleuca bark and solite as potential potting ingredients for foliage plants. Proc. Fla. State Hort. Soc. 92: 327–329.

10. Poole, R.T. and R.W. Henley. 1980. Fertilization and water use of *Dieffenbachia maculata* and *Peperomia obtusifolia.* Proc. Fla. State Hort. Soc. 93: 162–164.

11. Poole, R.T. and R.W. Henley. 1981. Constant fertilization of foliage plants. J. Amer. Soc. Hort. Sci. 106 (1): 61–63.

12. Poole, R.T. and C.A. Conover. 1982. Influence of leaching, fertilizer source and rate, and potting media on foliage plant growth, quality, and water utilization. J. Amer. Soc. Hort. Sci. 107 (5): 793–797.

13. Poole, R.T. and C.A. Conover. 1985. Growth of *Ficus benjamina* in combinations of peat, sand and *Melaleuca.* HortScience 20 (3): 383–385.

14. Waters, W.E. and W. Llewellyn. 1968. Effects of coated-slow-release fertilizer on growth responses, chemical composition and soil salinity levels for foliage plants. Proc. Fla. State Hort. Soc. 81: 380–388.

TIMING OF MACROELEMENT SPRAYS FOR OPTIMUM ABSORPTION BY CITRUS

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ABSTRACT

Six percent solutions of 12-6-6 liquid fertilizer were applied in the morning, at noon, and in the evening to 3-year-old 'Hamlin' and 'Valencia' orange, *Citrus sinensis* (L.) Osbeck, trees on sour orange, *C. aurantium* L., and Volkamer lemon, *C. limon* Burm. f., rootstock. The trees were in pots in the open. Leaf samples were taken immediately before spraying and 7 days after spraying and analyzed for N, P and K. The experiment was repeated 3 times. Rain within 12 hours of application sharply reduced uptake of the applied material. The best application time under the semi-tropical conditions of the experiment (36 °C day temperature, 23 °C night temperature, relative humidity 30 to 100%) was evening.

RESUMEN

Soluciones de seis por ciento de abono liquido 12-6-6 fueron applicados por la mañana, al mediodía y al anochecer a árboles de naranja (*Citrus sinensis* (L.) Osbeck) 'Hamlin' y 'Valencia' injertados en patrones de naranja agria (*C. aurantium* L.) y limon Volkamer (*C. limon* Burm. f.). Se mantuvo los arboles in cestos al aire libre. Se tomó muestras de hojas imediatemente antes y siete días después de la aplicación foliar para analisís de nitrógeno, fósforo y potasio. El experimento fue repetido tres veces. Lluvia dentro de doce horas de aplicación redujó la absorción de los nutrientes aplicados. Bajo las condiciones semi-tropicales de experimento (36 °C durante el dia, 23 °C de noche) el mejor tiempo para aplicar la materia era al anochecer.

Keywords: Citrus, Fertilization, N, P, K, Rb, Chlorophyll.

Attempts to supply all or part of the nutrients needed for citrus tree growth by nutrient sprays on the leaves go back well over 100 years. There was a period of particularly intensive work in the 1950s and 1960s (3, 4, 5, 6, 7, 12, 13). Much of the early work was done with urea and phosphorus, the latter especially because it is available in easily handled radioisotope form. Later, however, especially with citrus, the emphasis has been on minor elements (10). Foliar applications were particularly useful when soil conditions prevented effective ground applications (8, 11). The macroelement requirements of trees can be supplied by leaf sprays, but so many applications are necessary that it becomes uneconomical. When macroelement sprays are used as a supplementary source of N, P, and K, the amount applied to the soil can be decreased, thereby reducing pollution of the ground water.

Reproducibility and interpretation of results of foliar absorption studies have been difficult. The problems of application, control of temperature, leaf surface moisture, relative humidity, concentrations of the external solution, and distinguishing absorption from adsorption and from transport have been difficult to resolve (7, 13). In general, absorption is increased directly with the time during which the treated area is kept moist (4). There are differences in absorption between compounds (3), a positive influence of light indicates the involvement of an active process, and hydrogen ion exchange involving organic acids may be part of the process (5, 6).

Macroelement sprays for citrus in the past have been hampered by the difficulty of maintaining a nonphytotoxic pH while keeping the nutrient elements in solution. Formulations containing urea, aqua ammonia, phosphoric acid, potassium hydroxide and ammonium thiosulfate, among other compounds, which do not form precipitates at pH's near neutrality, have appeared on the market. Their main use is on nursery stock where the dark green leaves resulting from N-P-K sprays increase the sales appeal of the trees, but they are also applied to bearing groves. The purpose of this study was to determine which time of the day was optimal for maximum absorption of the applied nutrients under the humid, near tropical conditions of Florida's summer weather.

Materials and methods

Three-year-old 'Hamlin' and 'Valencia' orange trees on sour orange and Volkamer lemon rootstocks, respectively, growing in 25-cm-wide, and 25-cm-deep pots were used in the study. The trees were about 80cm tall, many of them carried fruits, and they were maintained in the open under Florida ambient conditions. The experiment was repeated 3 times, twice in May and once in July. Temperature and humidity were monitored in a standard weather station with a hygrothermograph. Lots of 7 trees were used for each treatment. Five leaves were collected from each tree immediately before and 7 days after spraying. Six percent solutions of a commercial 12 N – 2.6 P – 6.5 K formulation (Liquid Flo-mix, B.V.C. Distributing Company, Inc. Moultrie, GA) with nitrogen in urea form, P as phosphoric acid, and K as potassium hydroxide were applied with a motor-driven hand-sprayer at 8:15 a.m. (morning), 12:45 p.m. (noon) and 6:30 p.m. (evening). In the tests in May, the sprayed trees were returned to the holding area 3 hr after spraying. In July, the sprayed trees were kept under the eaves of the building for 5 days, exposing them to ambient temperatures and humidity, but protecting them from rain. In May, 50 ppm Rb was added as rubidium nitrate. In July 3 samples of 5-mm diam discs were collected from each cultivar in each treatment, each sample consisting of 20 discs collected from 2 trees. The discs were taken from the same leaves before and 8 and 12 days after spraying and analyzed for chlorophyll, using extraction with 3 5-ml portions of ice-cold 80% acetone and measuring absorbance of the extract at 645 and 663 nm as described by Arnon (1). The 5-leaf samples collected before and after spraying were washed with Dreft detergent solution with a soft brush, rinsed in tap water and then 4 times in distilled water, dried at 65 °C, ground to 20-mesh size and analyzed for

total N by micro-Kjeldahl, for P colorimetrically (2), and for K by flamephotometry. Rubidium in the May tests was determined by atomic absorption. The t-test was used for statistical analysis.

Results and discussion

Both 'Hamlin' and 'Valencia' responded the same way to the N–P–K sprays applied (Tables 1 and 2). Nitrogen was absorbed most efficiently and there were highly significant increases in leaf N at all 3 application times, but the increase in N concentration, as reflected in larger t values, was most consistent with the evening applications. This was also true for P in 'Hamlin' trees, where morning application produced no significant rise in P. In 'Valencia' trees, morning and evening sprays were about equally effective in raising the P level, with a weaker effect from sprays at noon. The potassium in the sprays gave only a weak response in leaf K, probably because of the already high K levels (9) and an N/K antagonism in absorption (R.C.J. Koo, personal communication). Morning and noon sprays had no significant effect. Evening K applications produced a small rise significant at a lower level ($p = 0.05$) than the increases in N and P ($p = 0.01$). Rubidium, often used as a stand-in for K in experiments (7), was added in an attempt to get better sensitivity because its normal level is low (about 20 ppm). Rubidium absorption, however, was about equal at all 3 spray times in 'Hamlin' leaves and was significant only after sprays at noon in 'Valencia' leaves.

The chlorophyll measurements before and after the third test in July were an attempt to measure the effectiveness of the sprays by means other than changes in nutrient concentrations. Comparing the chlorophyll levels before and 8 and 12 days after spraying (Fig. 1) showed a steady, continuous drop in the unsprayed trees. Spraying in the morning brought about a rapid rise in chlorophyll, but little or no further change after 8 days. Spraying at noon had little effect on chlorophyll. Spraying in the evening caused an initial decrease in chlorophyll concentration, followed by an increase 12 days after spraying. This seems to show an initial effect reciprocal to nutrient uptake (Tables 1 and 2). A possible explanation may be a slight toxicity immediately following application, because the P and K levels in the leaves were higher than the satisfactory range recommended for Florida citrus (9).

The total picture of the results of this experiment suggests that evening is the best time for foliar application of N–P–K because of maximum absorption. This agrees with reports that the longer the applied spray material remains wet the better the uptake (4). Relative humidity during the May and July tests reached 100% every night; daytime relative humidity was between 30 and 60%. Temperatures varied from 36 °C during the day to 23 °C at night. 'Hamlin' on sour orange trees dropped about 5% of their leaves after being sprayed in the morning, possibly because of higher original nutrient levels and rapid drying with salt formation on the leaf surface. None of the other trees in the tests dropped a significant quanitty of leaves.

The differences in N–P–K absorption were small enough so that in field work economic or scheduling considerations could override the advantage of better absorption in the evening. Rain decreased the

Table 1. N, P, K and Rb concentration in the leaves of Hamlin orange/sour orange trees before and 7 days after spraying with these elements in the morning, at noon, and in the evening (means of 3 tests, 7 replications)

	%N			%P			%K			ppm Rb[w]		
	Before	After	t-value	Before	After	t-value	Before	After	t-value	Before	After	t-value
Morning	2.53±.32[x]	2.83±.20	-6.73**[z]	0.210±.041	0.229±.041	-1.82	2.28±.69	2.16±.69	1.01	25±10	39±9	-3.47**
Noon	2.42±.28	2.71±.23	-4.83**	0.197±.028	0.233±.047	-2.84*[y]	1.65±.19	1.63±.15	0.33	23±8	37±8	-2.84*
Evening	2.26±.22	2.82±.32	-7.56**	0.202±.057	0.246±.077	-3.50**	2.07±.48	2.19±.48	-2.28*	18±6	25±5	-3.98**
Controls	2.43±.21	2.39±.25	1.16	0.201±.036	0.191±.027	1.25	1.77±.35	1.84±.45	-0.67	-	-	-

[z] Difference before and after significant at the 1% level (t-test).
[y] Difference before and after significant at the 5% level (t-test).
[x] Standard deviation.
[w] Based on 2 tests only.

Table 2. N, P, K and Rb concentration in the leaves of Valencia orange/Volkamer lemon trees before and 7 days after spraying with these elements in the morning, at noon, and in the evening (means of 3 tests, 7 replications)

	%N			%P			%K			ppmRb[w]		
	Before	After	t-value	Before	After	t-value	Before	After	t-value	Before	After	t-value
Morning	2.10±.38[x]	2.48±.34	-5.51**[z]	0.193±.045	0.193±.045	-6.89**	1.72±.39	1.75±.42	-0.64	21±9	21±11	-1.96
Noon	2.04±.38	2.54±.39	-5.84**	0.191±.030	0.229±.031	-4.67**	1.96±.63	2.00±.66	-0.52	22±7	38±10	-3.67**
Evening	1.96±.25	2.49±.29	-7.80**	0.194±.040	0.227±.042	-6.04**	1.54±.36	1.64±.31	-2.24*[y]	19±9	26±7	-1.76
Controls	1.86±.22	1.76±.24	1.86	0.174±.021	0.167±.031	1.14	1.37±.22	1.36±.21	-0.08	-	-	-

[z] Difference before and after significant at the 1% level (t-test).
[y] Difference before and after significant at the 5% level (t-test).
[x] Standard deviation.
[w] Based on 2 tests only.

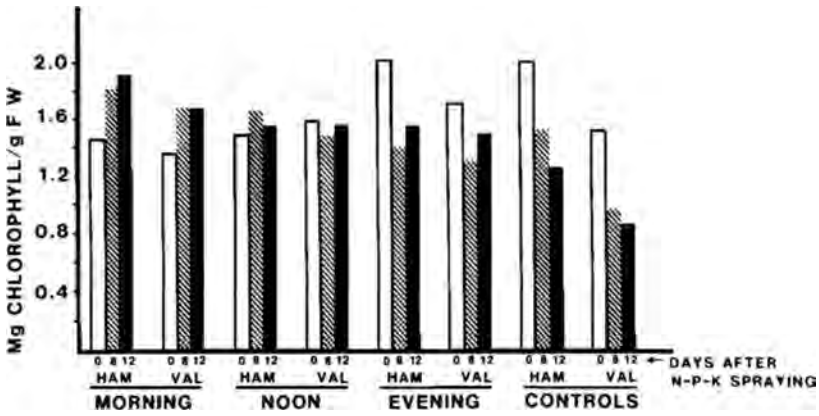

Fig.1 Chlorophyll concentration (mg/g FW) in selected leaves before and 8 and 12 days after N-P-K sprays

amounts taken up in the May tests compared to the July test where the trees were kept protected from rain for 5 days. Washing the leaves 2–72 hr after Mg sprays gave similar results (8). Evening application, when feasible, still seems to be worthwhile under conditions similar to those of the experiment, especially when K absorption is important.

Literature Cited

1. Arnon, D.I. 1949. Copper enzymes in isolated chloroplasts. Polyphenoloxidase in *Beta vulgaris*. Plant Physiol. 24: 1–15.

2. Barton, C.Y. 1984. Photometric analysis of phosphate rock. Anal. Chem. 20: 1068–1073.

3. Bukovac, M.J., and S.H. Wittwer. 1957. Absorption and mobility of foliar applied nutrients. Plant Physiol. 32: 428–435.

4. Bukovac, M.J., and S.H. Wittwer. 1961. Absorption and distribution of foliar applied mineral nutrients as determined by radioisotopes, p. 215–230. In: Walter Reuther (ed.). Plant analysis and fertilizer problems. Amer. Inst. of Bio. Sciences, Washington DC.

5. Franke, W. 1967. Mechanisms of foliar penetration of solutions. Ann. Rev. Plant Physiol. 18: 281–300.

6. Gustafson, F.G. 1956. Absorption of CO^{60} by leaves of young plants and its translocation through the plant. Amer. J. Bot. 43: 157–160.

7. Jyung, W.H., and S.H. Wittwer. 1964. Foliar absorption – an active process. Amer. J. Bot. 51: 437–444.

8. Koo, R.C.J., and T.W. Young. 1969. Correcting magnesium deficiency of limes grown on calcareous soils with magnesium nitrate. Proc. Fla. State Hort. Soc. 82: 274–278.

9. Koo, R.C.J. (ed.) 1984. Recommended fertilizers and nutritional sprays for citrus. Bull. 536D, IFAS, CREC, Lake Alfred, Florida and USDA, Orlando, Florida.

10. Labanauskas, C.K., W.W. Jones, and T.W. Embleton. 1961. Field studies on interrelationships of micronutrients and nitrogen in leaf tissue when applied as foliar sprays on citrus, p. 244–256. In: Walter Reuther (ed.). Plant analysis and fertilizer problems. Amer. Inst. of Bio. Sciences, Washington, DC.

11. Smith, P.F. 1966. Citrus nutrition, p. 174–207. In: N. F. Childers (ed.). Temperate to tropical fruit nutrition. Horticultural Publications, Rutgers – The State University, New Brunswick, NJ.

12. Swietlik, D., and M. Faust. 1984 Foliar nutrition of fruit crops. Hort. Rev. 6: 287–355.

13. Wittwer, S.M., and F.G. Teubner. 1959. Foliar absorption of mineral nutrients. Amer. Rev. Plant Physiol. 10: 13–32.

EFFECTS OF VAM FUNGAL INOCULATION ON SOUR ORANGE SEEDLINGS IN BARBADOS

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ABSTRACT

Sour orange citrus seed were planted in adjacent fumigated (98% methyl bromide/2% chloropicrin) and nonfumigated seedbeds both of which were inoculated with 3 vesicular-arbuscular mycorrhizal (VAM) fungus treatments and compared to a control. The treatments were the VAM fungi *Glomus mosseae* and *G. intraradices,* both from Florida, and an unidentified VAM fungus in roots from a local citrus orchard. The seedbed soil was a coral clay with a pH of 7.6, 1.6% organic matter, 3 ppm P, and had been fallow for 3 years. Early growth was rapid in the nonfumigated bed and variably delayed in the fumigated bed. Later growth of citrus in the fumigated plot was consistent and similar among the fungus treatments. In the fumigated plot *G. intraradices* (P = 0.001) and *G. mosseae* (P = 0.01) significantly increased growth compared to the control. Percent infection and vesicle and hyphal ratings were higher in citrus inoculated with both *Glomus* species compared to the control and compared to infection in citrus plantings on the Island. Conversion of the grassland site to a citrus seedbed resulted in slightly less growth overall in the fumigated than non-fumigated site. Both *Glomus* species adapted to a change in soils and climate.

RESUMEN

Se sembró algunas semillas de naranjua agria lado a lado en dos semilleros, el uno fumigado (98% de bromuro de metilo/2% de cloropicrina), el otro no fumigado. Se inoculó los dos lotes con tres (3) tratamientos del hongo vesicular-arbuscular micorrizal y se los comparó con un control. En los tratamientos se utilizó los hongos VAM *Glomus mosseae* y *G. intraradices,* los dos emanantes de Florida, así como un hongo VAM no identificado presente en raices recogidas a un huerto de cítricos indígeno. La tierra del semillero era compuesta de una arcilla coralina con un pH de 7, 6; 1.6% de materia orgánica; 3ppm P; y había estado en barbecho durante 3 años. El crecimiento inicial fue rápido en el semillero no fumigado y variablemente retrasado en el semillero fumigado. El crecimiento posterior de los citricos en el semillero fumigado fue constante y parecido entre los diferentes tratamientos con el hongo. En el semillero fumigado, *G. intraradices* (P = 0.001) y *G. mosseae* (P = 0.01) incrementaron significativamente el crecimiento en comparación con el control. El porcentaje de infección y los valores vesículas e hifales fueron más elevados en los cítricos que fueron inoculados con las dos especies de *Glomus* en comparación con el control por una parte, y por otra, con la infeccion en los citricos plantados en la isla. La conversion de una dehesa en un semillero para cítricos resultó en una tasa global de crecimiento un poco más bajo en el semillero fumigado que la que fue observada en el semillero no fumigado. Ambas especies de *Glomus* se adaptaron a un cambio de suelos y de clima.

THE EFFECTS OF STAGE OF MATURITY AND DATE OF CUTTING ON THE CRUDE PROTEIN AND MINERAL PROFILE OF FIVE *BRACHIARIA* SPECIES

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ABSTRACT

Five *Brachiaria* species: *B. humidicola, B. decumbens, B. mutica, B. radicans* and *B. ruziziensis* with *Digitaria decumbens* are standard were planted on Piarco Fine Sand soil at Central Experiment Station, Centeno, Trinidad, using a split plot design with grasses as main plots and re-growth cutting intervals: 4, 6 and 8 weeks as sub-plots, in order to study their effects on crude protein (CP), calcium (Ca), phosphorus (P), magnesium (Mg), potassium (K), sodium (Na), copper (Cu), iron (Fe), manganese (Mn) and zinc (Zn) content of the grasses. There were four replicates per treatment and the grasses were cut at four different dates. Among grasses there were significant differences for Mg, K, Na, Cu and Fe ($P < 0.001$) and for CP, Ca, P, Mn, Zn ($P < 0.05$). The levels of CP, P, Mg, K, Na, Cu, Fe and Zn decreased ($P < 0.001$) with increase in stage of maturity of grasses. There were significant differences ($P < 0.001$) among dates of cutting for all parameters studied except Mg ($P < 0.05$). The results are discussed in the light of the requirements of grazing beef and dairy cattle and sheep and goats.

RESUMEN

Se plantaron cinco especies de *Brachiaria: B. humidicola, B. decumbens, B. mutica, B. radicans* y *B. ruziziensis,* con *Digitaria decumbens* como modelo, en un suelo arenoso fino de Piarco en la estación experimental central a Centeno, Trinidad. Se utilizó un diseño de semillero dividido, con los terrenos principales de hierba e intervalos de corte del nuevo crecimiento: 4, 6 y 8 semanas como sub-terrenos, para estudiar sus efectos en el contenido de proteina cruda (CP) calcio (Ca), fósforo (P), magnesio (Mg), potasio (K), sodio (Na), cobre (Cu), hierro (Fe), manganeso (Mn), y cinc (Zn) en la hierba. Se repitió cada tratamiento cuatro veces, y se cortó la hierba en cuatro fechas diferentes. Entre las hierbas, se notó grandes diferencias en Mg, K, Na, Cu y Fe ($P < 0{,}001$) y en CP, Ca, P, Mn, Zn ($P < 0{,}05$). Los niveles de CP, P, Mg, K, Na, Cu, Fe y Zn ($P < 0{,}001$) sufrieron un descenso a medida que avanzó la madurez de las hierbas. Hubo diferencias significativas ($P < 0{,}0001$) entre las fechas de corte para todos los parámetros estudiados con excepción de Mg ($P < 0{,}05$). Se examina los resultados, teniendo en cuenta los requisitos para el apacentamiento de granado vacuno, tanto de engorde como lechero, así como de ovejas y cabras.

A SYSTEMS APPROACH TO SMALL FARMER WEED CONTROL

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ABSTRACT

Small farmers in the Eastern Caribbean generally rely on a sequence of manual operations for weed control. Gramoxone is the most commonly used weedkiller, but its use may be limited to land preparation, especially in food crop systems, and in tree crop systems. The labour-intensive nature of the existing systems may lead to delays in weed control, where other farm activities have a prior demand on labour. Changes to the components of weed control systems should recognise the holistic nature of the farm system. Changes should not unduly increase cash costs, unless additional income can be generated, not displace labour that cannot be gainfully employed elsewhere (on the farm), nor adversely affect food supplies and food security.

RESUMEN

Pequeños agricultores de la region Este del Caribe, generalmente siguen y dependen de una serie de operaciones manuales, para el control de las hierbas. El herbicida de mas uso es el Gramoxone, pero su uso puede que se limite a la preparación del terreno a cultivar, especialmente en los sistemas de cultivos alimenticios y de frutales. La naturaleza de la labor intensiva de los sistemas presentes, puede ocasionar retrazos en el control de las hierbas, especialmente, cuando otras labores de finca requieran prioridad. Los cambios en los componentes del sistema del control de hierbas deben hacerse, reconociendo la naturaleza total de los sistemas de la finca. Los cambios ha efectuarse o ya efectuados no deben incrementar indebidamente los gastos monetarios, a no ser que se pueda generar renta adicional, tampoco deben desplazar a los trabajadores a no ser de un trabajo a otro en la misma finca, y ni tampoco deben tener un efecto adverso en el suministro ni en la garantia de obtención de los alimentos.

Keywords: Small farms; Weed control.

Small farmers in the Eastern Caribbean generally have a "system" of weed control, which commences with land preparation and usually ends with a weed fallow when the crop has been reaped. For most small farmers, the system comprises an entire sequence of manual operations but in some countries they may be able to hire a tractor for land preparation. Some use herbicides to augment manual land preparation and weed control operations.

Since weed control is only one activity of many in crop production, it may compete with others for labour, which is usually in limited supply. These other activities may take precedence over weed control. For example, banana cutting must have priority since there is a shipping deadline to meet. Land preparation and planting, at the start of the rainy season, may take precedence over weed control in crops already established. This is simply the farmer optimising the use of a scarce resource over the entire farm. It is also possible that, because the damage due to weeds is apparently less dramatic than that due to, for instance, armworms, leaf-cutting ants or mildew, pest and disease control by chemicals may assume priority over weed control.

Materials and methods

Most of this paper is based on data from a survey conducted in 1984–85 in nine islands of the Eastern Caribbean, namely, Antigua, Dominica, Grenada (and Carriacou), Montserrat, Nevis, St. Kitts, St. Lucia and St. Vincent. A total of 788 farmers (mostly with less than 2.6 hectares) were interviewed, each for a specific production system – which may have been only one of the two or more on the farm (Hammerton, 1985 a, b, c and unpublished).

Results

Table 1 shows the mean rankings given by farmers' to four activities as users of labour. A low value indicates a high rank: that is, many farmers ranked that activity one or two. It is evident that weed control is a major user of crop labour in five islands, and second to land preparation, as a user of labour, in the other four islands. Data on farmers' perceptions of weeds as a source of crop loss are too bulky to present here. In vegetable-based systems, insect pests were generally ranked higher than weeds as sources of crop loss, but in aroid-and banana-based systems, weeds were generally perceived as the major source of loss. Table 2 shows the percentages of farmers using herbicides pre-planting only (i.e. in land preparation), post-planting only (i.e. for "in-crop" weed control), and both pre- and post-planting. Overall, 41% of the farmers surveyed used herbicides: the high values for Dominica and St. Lucia reflect the banana-based systems surveyed in these two countries. In all the systems studied in Antigua, at least 50% of farmers used herbicides. Relatively few farmers used herbicides post-planting only: much more frequent was pre-planting use only or both pre– and post-planting use.

A total of 18 herbicides was used (Table 3). "Gramoxone" was the most commonly used: 310 out of 321 (or 96%) of farmers using herbicides used "Gramoxone" and for most farmers it was the only herbicide. After Gramoxone, the most commonly used were "Roundup" and "Reglone" - both mainly used in Antigua. All the other herbicides recorded a frequency of use below 3%. Overall, 27% of farmers used more than one herbicide (Table4). Noteworthy is the 34% of surveyed farmers in Antigua who used three herbicides – with a further 7% using more than three. This may reflect availability, but availability may reflect demand.

Table 1. Mean rankings[1] of four activities as users of labour: means of production systems, by countries.

	ACTIVITY				
	Land preparation	Pest/disease control	Weed control	Harvesting	No. of farmers
Antigua	3.0	2.7	1.3	2.8	110
Dominica	1.3	3.7	1.8	3.1	82
Grenada	1.3	3.6	1.7	3.6	137
Carriacou	2.1	-	1.4	2.2	27
Montserrat	2.2	3.5	1.5	3.0	94
Nevis	2.2	3.7	1.2	3.0	49
St. Kitts	1.5	3.5	1.8	3.3	73
St. Lucia	1.8	3.2	1.9	3.1	78
St. Vincent	1.8	3.7	1.6	3.5	106
Mean[2]/Total	1.9	3.4	1.6	3.2	756[3]

(1) Farmers were asked to rank on a scale of 1 (biggest user) to 5 (smallest user).
(2) Weighted means
(3) Less than total number of farmers due to non-responses

Table2. Percentages of farmers surveyed using herbicides pre-planting only, post-planting only and both pre-and post-planting, and the total using herbicides, by countries.

	Pre-only	Post only	Both Pre- and post-	Total uising	Total Nos. of farmers
Antigua	23	5	36	64	118
Dominica	12	15	46	73	97
Grenada	15	-	3	18	137
Carriacou	7	-	-	7	27
Montserrat	10	3	8	21	95
Nevis	2	-	2	4	50
St. Kitts	3	3	4	10	75
St. Lucia	22	11	39	72	79
St. Vincent	38	3	15	56	110
Mean/Total	17	5	19	41	788

Table 3. The herbicides used, by mode of action.

Contact	Soil-acting	Systemic
Gramoxone (310)***	Dacthal (7)	Agroxone (5)
Kerosene (1)	Eptam (1)	2,4-D (1)
Reglone (44)	Gesagard (3)	Dalapon ** (1)
	Gesaprim (1)	Fusilade (3)
	Hyvar- X (1)	Round-up (56)
	Karmex (1)	
	Lasso (9)	
	Maloran (3)	
	Tok* (8)	

* can have some contact action
** can have soil activity
***Number in parentheses indicates number of farmers using each herbicide

Table 4. Percentage of farmers using herbicides, who used one, two, three or more than three herbicides, and the number of herbicides used, by countries.

	Percentage of farmers using herbicides using the following number of herbicides				Number of herbicides used[1]
	1	2	3	>3	
Antigua	41	18	34	7	9
Dominica	76	18	6	-	5
Grenada	76	24	-	-	3
Carriacou	100	-	-	-	1
Montserrat	55	30	10	5	4
Nevis	100	-	-	-	1
St. Kitts	71	29	-	-	3
St. Lucia	93	7	-	-	3
St. Vincent	89	6	2	3	5
Mean	73	15	10	2	18[2]

[1]Including Gramoxone
[2]Total number of different herbicides used by farmers in the survey

Land Preparation Systems

Fig. 1 gives examples of the land preparation systems used in different production systems. Only in Antigua, Nevis and St. Vincent were significant numbers of farmers using tractors for primary cultivations, recorded. Elsewhere, manual methods were almost universal. It is evident that there were many variants. In Antigua for example (Fig. 1a), a few farmers planted vegetables apparently with no further work following a tractor cultivation; more common was to form beds and plant. Other farmers used a heavy hoe or forked before forming beds. A few applied a herbicide – but it is not clear which – before hoeing and/or forking and planting. In St. Lucia (Fig. 1d), in root crop-based systems, cutlassing was invariably the first operation. This was followed either by burning, forking, ridging or moulding, or burning was omitted, and the weeds incorporated or removed. In St. Vincent, in peanut-based systems (Fig. 1e), cutlassing and burning, were followed by hoeing and herbicide (Lasso) application, or by tractor cultivation, in some cases followed by forking, or, by forking or hoeing, all before ridging or preparation of planting holes, and planting. An alternative was tractor cultivation, followed by herbicide application and by ridging or planting on the flat.

Post-planting Weed Control Systems

For in-crop weed control, the systems are less clear-cut, perhaps because they depend on weed growth, the stage of crop growth, and variations in crop duration. Also weeds are sometimes allowed to grow during the latter part of crop growth to provide forage, or for soil conservation during the fallow period. Fig 2 illustrates some of the systems observed. In Banana-based systems in Dominica (Fig. 2b) cutlassing is the most commonly used first operation, to be followed by other manual operations, moulding-up or Gramoxone. These operations, in turn, are followed by mulching, hand-pulling or moulding-up, and the cycle may be repreated – or one or more specific activities may follow. An alternative is Gramoxone, followed by a second Gramoxone application or manual operations. These again may be repeated. In aroid-based systems in St. Vincent (Fig. 2e) hand-pulling may be the first operation, following by hoeing and moulding-up, or by an early moulding-up. Fewer farmers use Gramoxone early, followed by hoeing and moulding-up or these two operations occur in the reverse order. A few farmers hoe, handpull and mould-up. Another example of the variations recorded is in the corn/pigeon pea systems in Carriacou. Most farmers hoe and mould-up first, with subsequent variations which include cutlassing, hand-pulling and hoeing (Fig. 2a). A minor variant is cutlassing first, followed by moulding-up, and, later, in a few cases, by hoeing.

Thirty-one per cent of farmers did not allow weeds to grow between crop seasons (Table 5). The percentage was least in Carriacou, where 67% allowed weeds to grow to provide animal feed. A weed fallow for feed was relatively uncommon in Dominica and St. Lucia. Except for Carriacou, at least 40% of the farmers surveyed allowed weeds to grow to "rest the soil" (i.e. restore fertility), and, except for Nevis and St. Kitts, less than 40% allowed weeds to grow to "hold the soil" (i.e. as a conservation or anti-erosion measure).

Discussion

How can these existing systems be improved at acceptable cost and consistent with the farmers' overall objective? Changes to the present production system may be acceptable if there are cost savings and/or increase in income, but food security must be safeguarded. Reductions in labour requirements may be acceptable if the labour saved can be usefully employed elsewhere, but savings in family labour will not give cash savings.

There are several components that can be considered to improve weed control systems. These include –

– use of power, especially for land preparations;

Table 5. Percentages of farmers surveyed not allowing weeds to grow between crops and reasons for allowing weeds to grow between crops, by countries (1)

	Nos. allowing	Reasons for allowing: Animal feed	To rest the soil	To hold the soil	No. of farmers
Antigua	33	20	47	27	114
Dominica	25	17	61	29	96
Grenada	40	32	46	22	130
Carriacou	15	67	4	22	27
Montserrat	28	34	42	38	85
Nevis	20	33	53	61	49
St. Kitts	26	32	57	43	72
St. Lucia	39	10	41	34	79
St. Vincent	28	38	58	19	106
Means (2)	31	28	49	31	758(3)

(1) Percentages do not sum to 100% as many farmers allowing weeds to grow gave two or three reasons.
(2) Weighted means
(3) There were some non-responses.

- improved hand tools;
- herbicides for land preparations;
- herbicides for post-planting weed control;
- minimum tillage;
- mulching; and
- live mulches and intercrops.

The use of power tillers and walking tractors is a possibility where soil texture and topography permit their effective use. Capital costs are relatively high for farmers with limited incomes. Experiences in St. Vincent (CARDI, 1984a) with walking tractors suggest overuse: they were used where cultivation was not really necessary. In some places as in St. Kitts (CARDI 1984c) power tillers are used for pre-planting and for inter-row weed control.

There are several low-cost hand tools – rotary hoes, scuffles etc. – that can facilitate inter-row weed control, provided that the soil is friable and weeds are small. Row planting is desirable, but low cost hand pushed seed drills or planters are also available. Experience in St. Kitts has been encouraging (CARDI, 1984c), but the potential for such tools on heavy soils in wet weather is probably low. Weed wipers are potentially useful for in-crop weed control, especially of perennials, but there are a limited number of herbicides suitable for use in wipers – and they tend to be expensive materials.

As adjuncts to land preparation, herbicides offer great scope, but entail a cash cost. They may not save the labour for land preparation, but may reduce in-crop weed control costs. Farmers in Antigua use "Round-up" in land preparation to control perennial weeds, and farmers elsewhere use "Gramoxone" (and to a lesser extent, "Reglone") in land preparation. "Fusilade", and other "recent" grass killers, and possibly 2, 4–D, could also be used in this way. Dalapon should be relatively inexpensive, and might also be useful in land preparation for tolerant (non-graminaceous) crops.

Post-planting, many farmers rely, at least partially, on directed or shielded sprays of Gramoxone, but such treatments are only practical in tall growing crops. Even though Gramoxone does not control – or gives only temporary control of - many weeds, it may save hand labour. There is clearly a scope for the use of residuals in many crops. Few banana growers apparently use residuals, in spite of WINBAN recommendations (WINBAN, 1985). Only six out of ninety farmers with banana-based systems in Dominica and St. Lucia used residuals. This may reflect intercropping – but few farmers would intercrop all their bananas.

For most broad-leaf crops, over-the-top grass killers are now available (by apparently little used). There are few broad-leaf weed killers locally available for use in broad-leaf crops. "Dacthal" – a broad spectrum herbicide suitable for use in several vegetable crops – is little used. No doubt the limited range of herbicides available, and the sporadic supply, reflect a lack of demand.

Herbicide application by small farmers in the Eastern Caribbean is invariably by knapsack sprayers. These require a supply of water, which is often available only at a distance. Controlled droplet applications (e.g. the Herbi) would obviate the need for water, but require batteries and special formulations not locally available. The Birky does not require special formulations and uses volume rates (of water) of only 20 to 30 l ha^{-1}. Batteries are not required. Birky sprayers are not (yet) available in the Eastern Caribbean. It is not (yet) clear whether they can be used with contact herbicides. The use of very low volume nozzles, in conventional knapsack sprayers, is another way of reducing volume rates, However this may not be effective with contact herbicides especially where weeds are large.

Minimum tillage is used in some crops especially bananas, but tillage may be necessary if an intercrop is to be taken. It is probable that some farmers cultivate unnecessarily – perhaps because they prefer

to plant into clean, trash-free land. Minimum tillage for aroids was successful in St. Vincent (CARDI, 1984b), and many other crops can probably be established this way. Herbicides especially "Round-up" can minimise perennial weed growth during the early stages of crop establishment.

Mulching has been shown to increase yields of certain vegetable crops and to reduce the number of weedings required, in Antigua (CARDI, 1983). Under wetter conditions, mulches may harbour slugs. The practice merits evaluation for several crops under varying agro-ecological conditions, not only as a means of reducing weeding, but to protect the soil surface and reduce capping.

Live mulches, especially of legumes, are an attractive idea. Possible disadvantages include competition for water, and the costs of establishment and management. Management is definitely a problem with viny legumes such as kudzu *(Pueraria phaseoloides)* and dolichos *(Lablab niger)*. More recently perennial peanuts *(Arachis* spp) have been used: these form a dense, low ground cover. There is the risk that live mulches could become weeds (i.e. persist when no longer required). Intercrops are commonly used, less as a weed control component than as a means of increasing land utilization. They are valuable in generating income during the establishment phase of the main crop, especially bananas and sugar-cane (Rao and Edmunds, 1980).

The diversity of farm systems, of resources and farmer objectives, implies that there are no simple or universally acceptable systems that can be recommended. Guidelines on the options, and on the criteria to be applied in developing recommendations, need to be worked out.

Acknowledgements

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References

CARDI (1983) CARDI–USAID Small Farm Systems Research Project # 538-0015). Final Report 1978–82. Vol. IV, CARDI, St. Augustine, Trinidad. pp 8–5 to 8–8.

CARDI (1984a). *New production technology.* Report to Barclays Bank International Ltd. CARDI, St. Vincent.

CARDI (1984b) Quarterly Reports FSR/D Project, St. Vincent. CARDI, St. Vincent.

CARDI (1984c) *Development of technology for peanut production:* Final Report. CARDI, St. Augustine, Trinidad. pp 82–117.

Hammerton (1985a). *Weed control in Dominica.* CARDI, St. Lucia.

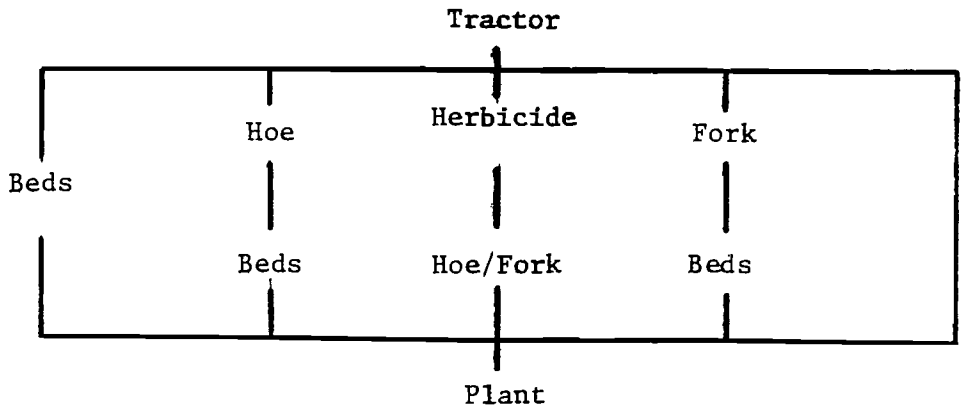
Hammerton (1985b). *Weed control in St. Lucia.* CARDI St. Lucia.

Hammerton (1985c). *Weed control in St. Vincent.* CARDI St. Lucia.

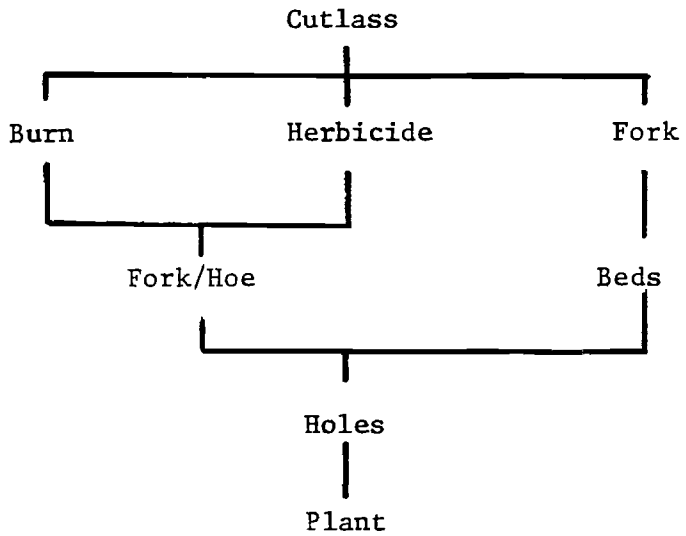
Rao, M.M. and Edmunds, J.E. (1980). Multi-storied cropping with bananas. Advisory Bull. 18. WINBAN Research and Development Division, St. Lucia. 7 pp.

WINBAN (1981). *Banana growers manual.* WINBAN Research and Development Division. St. Lucia. pp. 21.

(a) Antigua: vegetable-based systems



(b) Dominica: banana-based systems



(c) Nevis: cotton-based systems

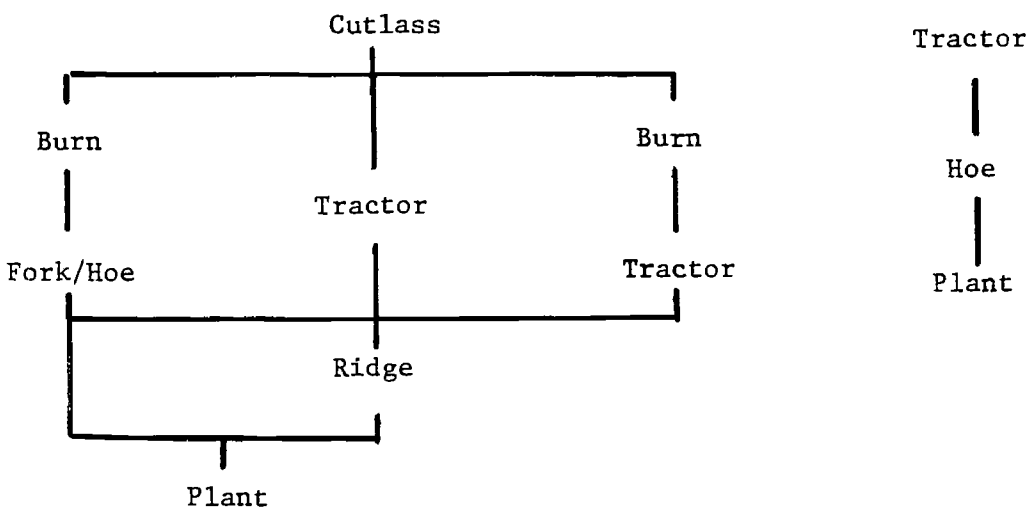
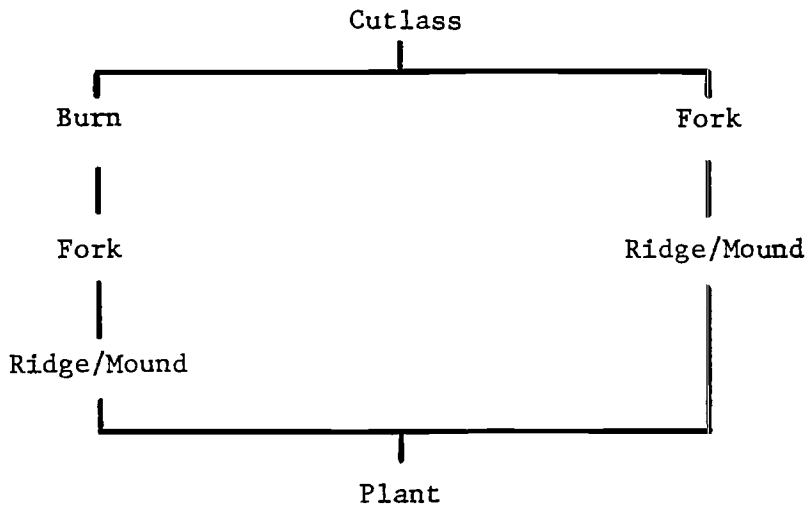
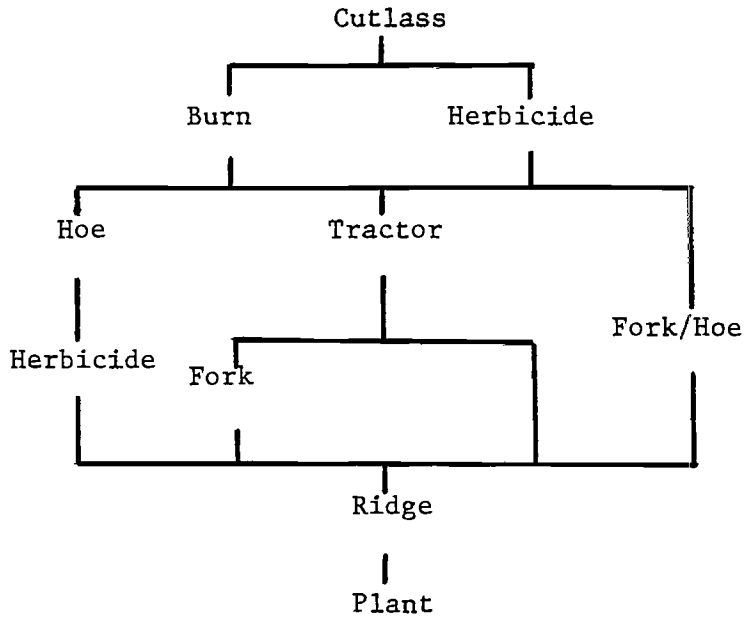


Fig. 1 Land Preparation Systems in selected production systems in the Eastern Caribbean. Frequency decreases left to right.

(d) St. Lucia: root crop-based systems



(e) St. Vincent: peanut-based systems



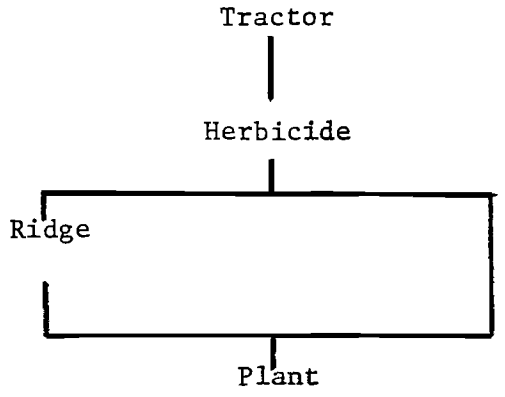
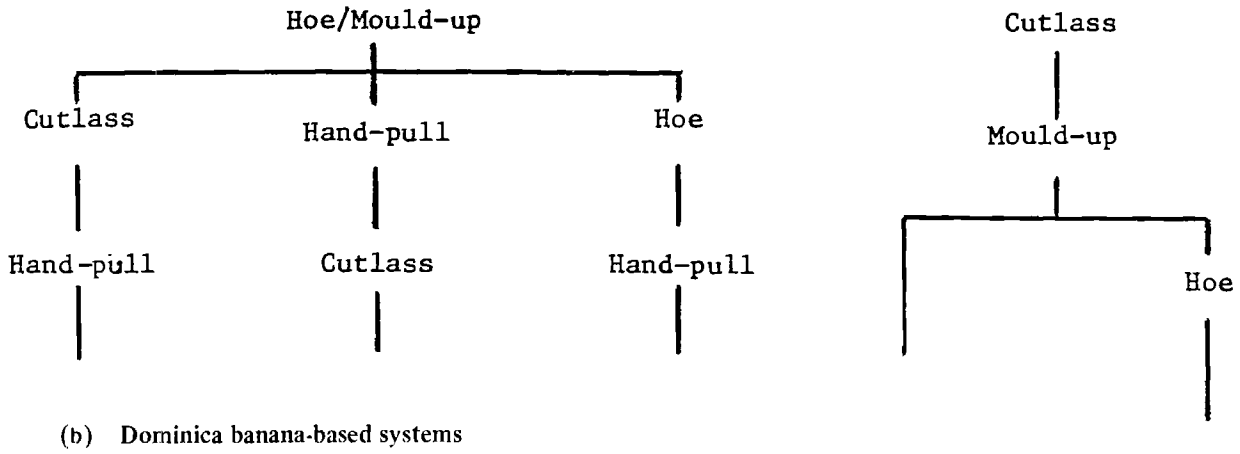
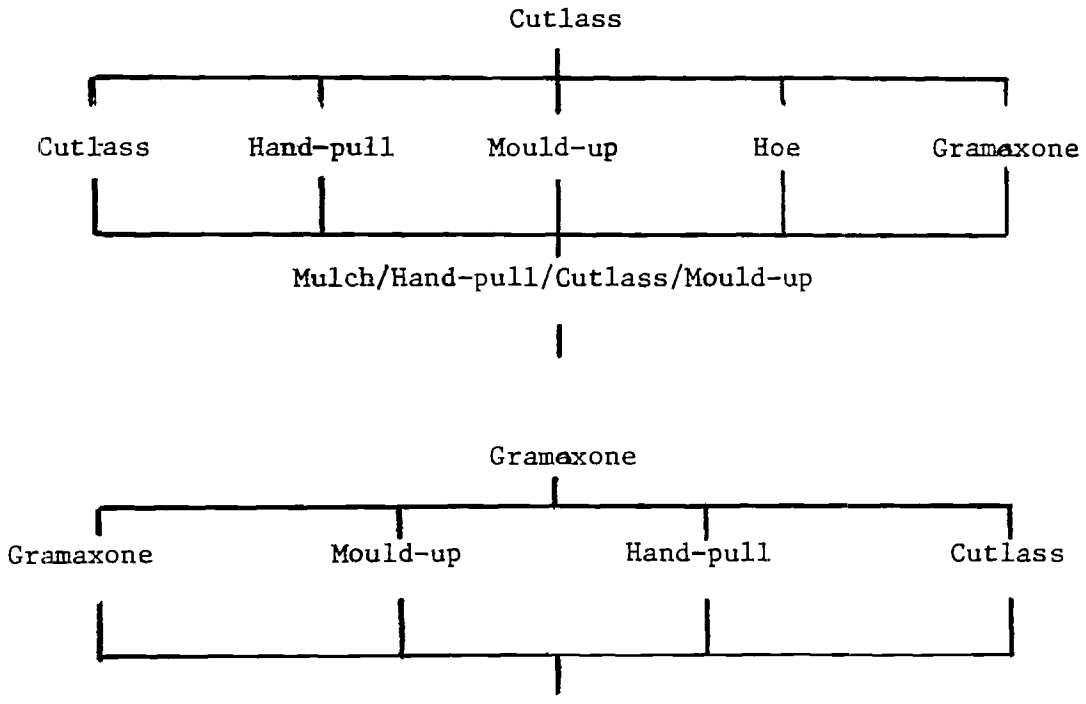


Fig. 1 Land Preparation Systems in selected production systems in the Eastern Caribbean. Frequency decreases left to right.

(a) Carriacou: corn/pigeon pea systems



(b) Dominica banana-based systems



(c) Montserrat: vegetable-based systems

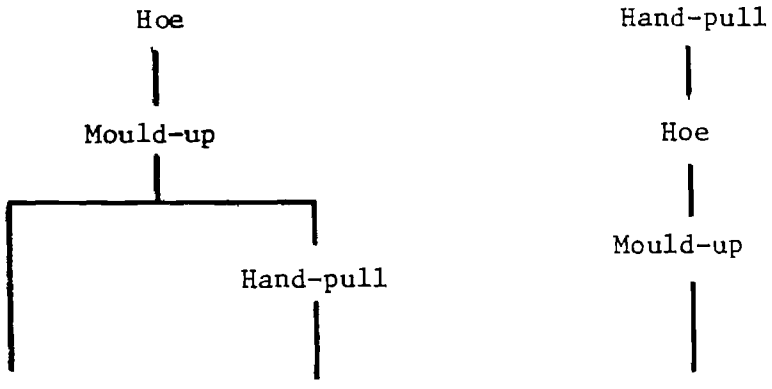
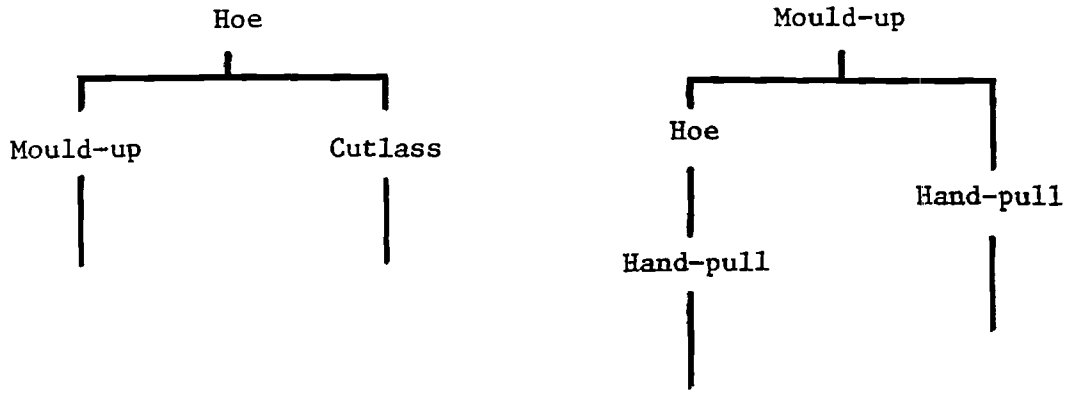
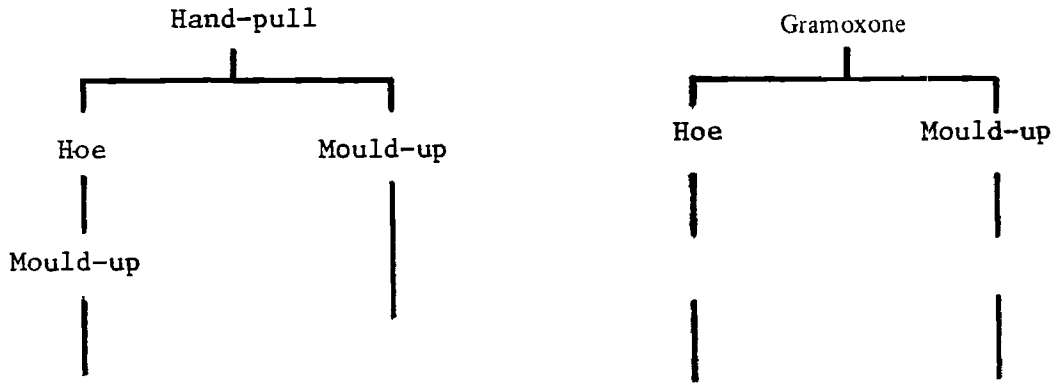


Fig. 2 Weed Control Systems ("in-crop") in selected production systems in the Eastern Caribbean. Frequency decreases left to right.

(d) Nevis: cotton-based systems



(e) St. Vincent aroid-based systems



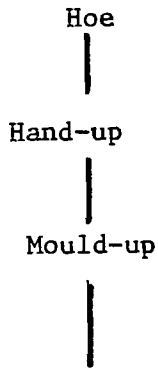


Fig. 2 Weed Control Systems ("in-crop") in selected production systems in the Eastern Caribbean. Frequency decreases left to right.

AN APPROACH TO THE PROBLEMS AND PROSPECTS OF VEGETABLE PRODUCTION IN TRINIDAD AND TOBAGO

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ABSTRACT

Trinidad and Tobago depended heavily on imported food crops over the past decade due to the availability of foreign reserves generated by oil revenue. However, the international glut brought about an unexpected downturn in the economy of the country. Under these circumstances a critical analysis of the problems and prospects of the local food production system is of utmost importance. Over the past two years an abundance of vegetable crops has been produced locally causing an apparent over-production problem. Nevertheless, the major problems facing vegetable production in Trinidad and Tobago at present include: Land tenure, Irrigation, Wet season production, Financing, Standard varieties, Pest and diseases control, Post-harvest (transportation, storage), Marketing, Processing and Export. These problems and their prospects are discussed and possible solutions are suggested.

RESUMEN

Durante los ultimos diez años, Trinidad & Tobago dependió mayormente de las importaciones de productos alimenticios y esto fue debido a las reservas de divisas creadas por la producción del petroleo. Sin embargo la "saturación" internacional del mismo, ocasionó un desbalance en la economia del pais. Debido a estas circunstancias, un análisis crítico de los problemas y del sistema de las prespectivas de la producción local de cultivos alimenticios, es de gran importancia. En los últimos dos años la producción local sobreproducción. Ahora sin embargo, los mayores problemas aparente de que se enfrenta la producción de hortalizas en Trinidad & Tobago son: tenencia de tierras, irrigación, producción durante la estación de lluvias, financiamineto, variedades fijas, control de plagas y de enfermedades, post-cosecha (transporte, almacenamiento) mercadeo, procesamiento y exportación. En este estudio, discutimos estos problemas y sus prespectivas y sugerimos soluciones posibles a los mismos.

During the past decade and consequent upon the significant increase in revenue generated by Trinidad and Tobago petroleum industry, critical emphasis was placed on the diversification of the economy particularly as this relates to the energy-based and financial sectors. During this period, too, there seems to have been a steady decline in agricultural production in the country and in consequence Trinidad and Tobago became increasingly dependent on imported food material including vegetables and food crops.

Important socio-economic manifestations in that period included the abandonment of agricultural jobs by significant numbers of workers formerly employed in the agricultural sector and an enhanced rural-urban population drift.

The resultant reduction of available labour exacerbated by the "Special Works Programme" severely affected if not crippled the major earners of foreign currency in the agricultural sector e.g. the Citrus, Cocoa, Coffee and Coconut industries.

This paper attempts to appraise the existing problems associated with vegetable production in Trinidad and Tobago and to assess the prospects for that subsector in the forseeable future.

The present status

During the past two years vegetable production has risen beyond the consumer demands as more and more people turn to agriculture. Factors contributing were, increased availability of labour consequent upon wide-spread retrenchment, an increase in the number of training programmes, an improved technology among the farming community and the increased popularity of backyard gardening.

Certain vegetables, however, tend to attract more profit than others resulting in definite commodity preferences which are reflected in the trend of production of selected vegetable crops as shown in Figure 1. It appears from the figure that tomatoes dominated the market. Cabbage ranks second in production, despite a sharp decline during 1982–84 seasons, which decline was apparently related to the high infestation levels of cabbage bud-worm *(Hellula* sp.) observed recently in this country. Cucumber and melongene maintained the same level of production showing a minor increase during 1983–84 seasons.

The average wholesale price (Figure 2) also indicates that tomatoes were the best selling vegetable attaining a peak wholesale price of $TT 8 kg^{-1} in 1982, declining to $TT 6.8 kg^{-1} and $TT 5.4 kg^{-1} during 1983, 1984 respectively.

Present trends of vegetable production which resulted in the banning of tomatoes and cabbage importation indicates that local vegetable production in Trinidad and Tobago can provide most of the consumer needs year-round. This of course is conditioned with resolving the major problems which include: Land tenure, Irrigation, Wet season production, Financing, Standard varieties, Pest and disease control, Post-harvest (transportation, storage), Marketing, Processing and Export.

Problems and prospects

1. Land tenure

Most vegetable farmers operate on marginal lands. Table 1 shows that the arable land under tomatoes is 0.5% of the total arable land in the country (82,402 ha), whereas cabbage and other vegetable crops occupy 3.62%. The Table also shows that the average hectareage/holding ranges between 0.29 – 0.45 ha. Farms of this size are uneconomical to be utilized under full-time farming. In some areas farmers are operating under a system of land tenure on State-owned land on a monthly basis. In other areas there are 3434 holdings, of average size 2 ha., occupied by squatters on state and private lands totalling 6,599 ha. Uneven distribution of state lands shows that 8% of farmers own 40% of total farm land comprising 80 ha. On the other hand 45% of farmers own only 7%

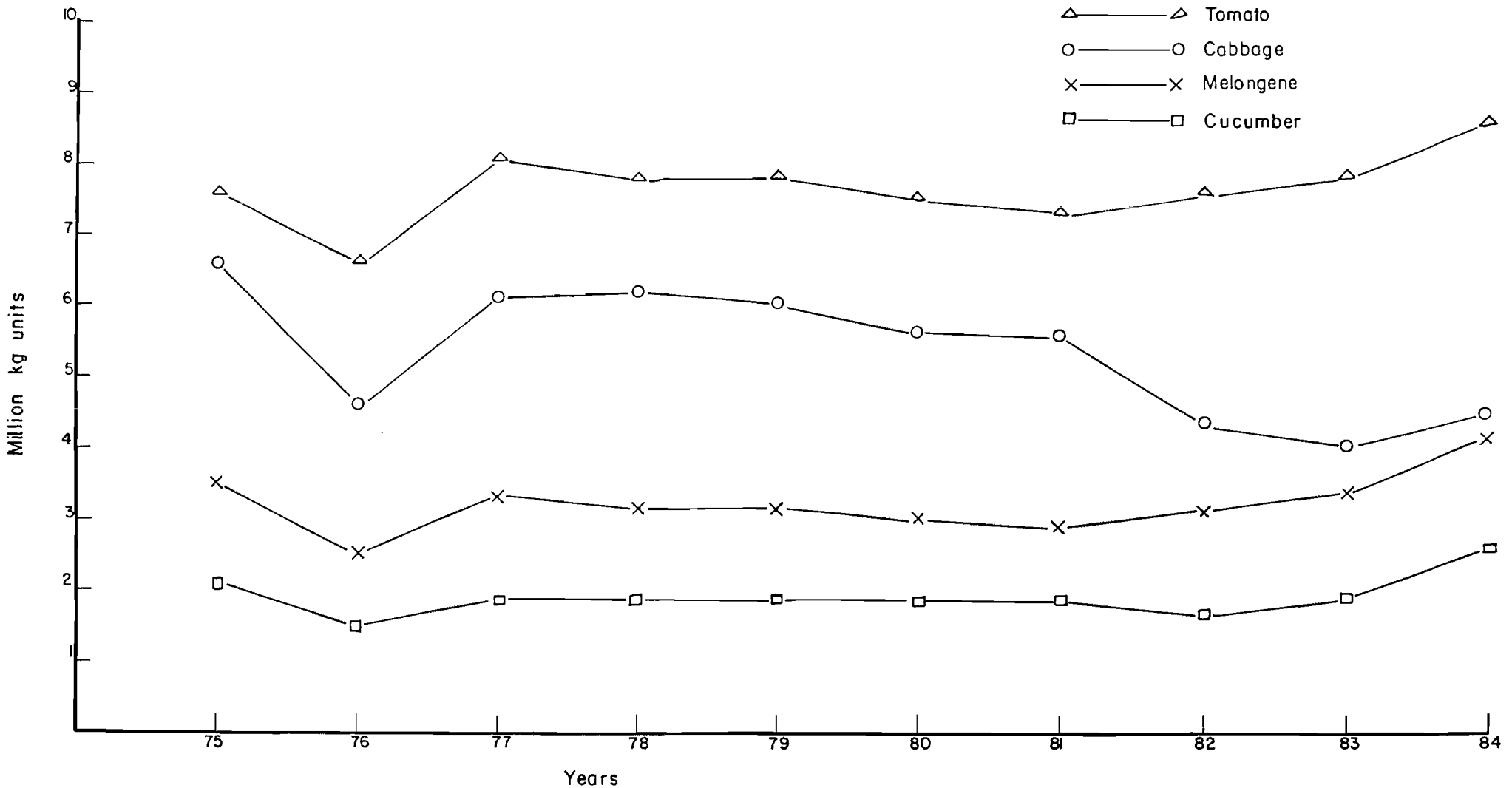

Figure I: Estimated local production of selected vegetable crops in million kg. units (1975-1984) in Trinidad and Tobago.

(Source C.S.O.)

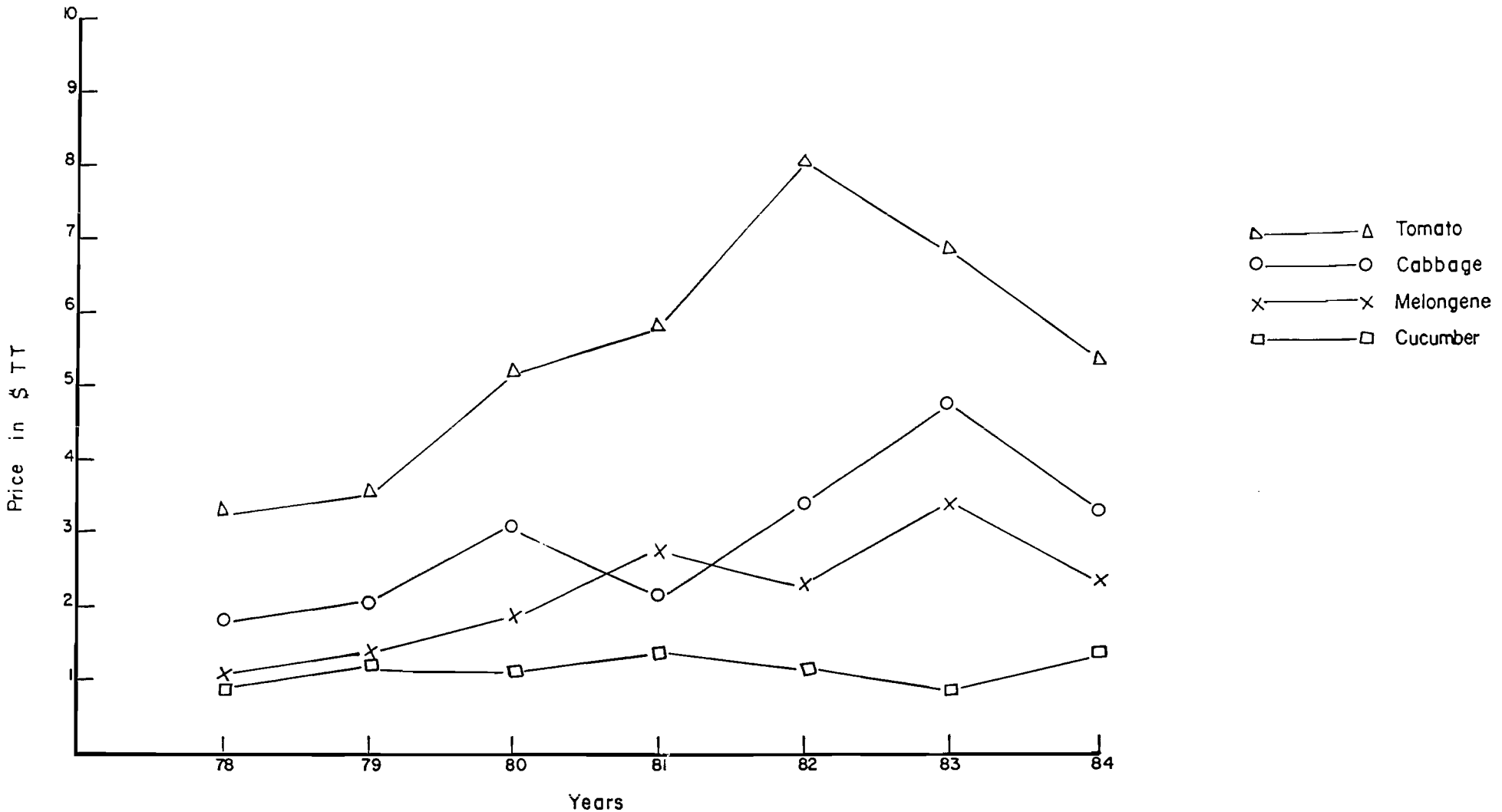

Figure 2 : Average wholesale price per kg. of selected vegetable crops (1978 - 1983) in Trinidad and Tobago.

(Source C.S.O.)

Table 1. Hectarage and location as at May 1982 of sole and mixed vegetable crops in Trinidad and Tobago

Crop/ Location	Cabbage	Tomato	Other vegetable crops	Mixed food crops
St. George	148	195	741	46
Caroni	10	63	730	46
Nariva/Mayaro	2	6	74	21
St. Andrew/St. David	7	10	173	17
Victoria	11	98	537	41
St. Patrick	13	25	447	21
Tobago	5	14	84	9
Total hectareage	196	411	2786	201
Total no. of holdings	615	1415	6179	501
Avg. hec. per holding	0.319	0.290	0.450	0.390
% of total to arable	0.24	0.50	3.38	5.77

Total arable land in Trinidad and Tobago = 82,402 ha.
Source: Central Statistical Office

of farm land on farms of less than 2 ha. This pattern of land distribution indicates the overfragmentation of land. Allowing for the small size of Trinidad and Tobago, and the high population density, limited scale farming would appear uneconomic except for farms in fertile soil of close market proximity. Additional problems are lack of surveyors which tend to prolong the process of acquiring agricultural land to a great extent. Housing schemes which have expanded recently due to the need for building new homes are closely associated with land tenure problems. Most vegetable producing areas are poorly supplied with the required infrastructure especially access roads and marketing facilities. The provision of security of land tenure is the key-word for sound vegetable production.

2. Irrigation

A severe constraint of successful vegetable production is caused by limited irrigation facilities during the dry season. Watering is largely manual which can be inefficient and counter-productive. A cost appraisal of staked tomato by the Central Statistical Office (1983) shows that irrigation cost per hectare amounts to TT $4,450.00. This cost is substantial and does affect the final unit cost.

A resolution of the problem surrounding irrigation resides in the adoption of simple and acceptable technological improvements e.g. overhead sprinklers. Admittedly the cost may be beyond many vegetable farmers, however, farmers co-operatives can seek the technical expertise of the Field Engineering Division of the Ministry of Agriculture, Lands and Food Production (MALFP) in implementing such systems.

3. Wet season production

In the humid tropics (Trinidad and Tobago) high rainfall leads to soil erosion, leaching of soil nutrients, waterlogging and a rapid growth of weeds. Simultaneously the thick dense cloud cover functions as a solar barrier thus preventing an adequate amount of sunshine from reaching the crop canopy. The low level of solar energy (300 – 350 cl cm^{-2} day^{-1}) experienced during the rainy season adversely affects vegetable production in the tropics. In temperate regions vegetable crops grown in the summer obtain twice the amount of solar energy available in the humid tropics.

For yield maximization in the wet season an alternative to outdoor vegetable production is needed. The undercover production systems e.g. hydroponics which have recently been employed by some of the more innovative farmers are ideally suitable to fill the gap which had persisted for a long time. This objective is so far awaiting fulfillment. Taking a close look at hydroponics production of some vegetables during 1984 season one can observe a positive result with respect to tomatoes and lettuce (Table 2).

For hydroponics to be effective in Trinidad and Tobago, full understanding of the system by farmers is a necessary prerequisite to efficient vegetable production. In recognition of this fact the Crop Research Sub-division of the MALFP is in the process of initiating a research project in hydroponics to assist farmers in acquiring the necessary scientific knowledge. At present work in soilless culture is done with encouraging results.

4. Financing

Farm credit is operated by two financing agencies, Republic Bank Ltd. and the Agricultural Development Bank (ADB). However, both facilities are conditioned by proper land ownership or collateral arrangements. Most of the beneficiaries are plantation farmers. Vegetable farmers as discussed earlier lack a proper land tenure, hence they are not eligible for such credit. Moreover the size of holdings and the marginal land under vegetable crops is another impediment. This problem can be resolved by immediate regularization of land tenure in both private and state-owned land. A major contributor to ease this situation is the enhancement of the activities of co-operatives and credit unions and their commitment to agriculture.

Table 2. Total quantity of vegetable crops produced by the undercover system in Trinidad during January-December 1984

Type of crop	Unit of quantity	Total Jan. to Dec.	Quantity harvested Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Tomato	kg	228,262	9,067	5,165	6,556	12,977	6,089	4,311	10,711	36,745	40,917	30,138	33,721	31,873
Lettuce	heads	453,500	32,900	44,200	49,900	49,200	43,200	20,000	18,600	28,000	28,600	40,700	42,800	55,400
Patchoi	bundles	22,550	-	-	10,000	10,000	-	-	-	-	-	300	200	2,050
Cucumbers	kg	13,929	1,556	1,333	1,333	640	2,200	1,600	1,956	933	-	1,822	267	289
Sweetpepper	kg	3,291	1,333	44	44	22	-	-	-	325	219	188	227	289
Celery	bundles	2,000	-	-	-	2,000	-	-	-	-	-	-	-	-

Source: Central Statical Office, 1985.

5. Standard varieties

The varietal situation is very critical, farmers tend to obtain their own seeds either through the garden shop in their neighbourhood or via direct purchase of improved exotic varieties, in the absence of a dependable and continuous seed testing programme, particularly as this relates to seedborne diseases. Smuggling seeds into the country is a national crime committed by some farmers without realizing the serious implications behind it. The indiscriminate purchase of seed material gives way to the possible emergence of unrealiable seed sources. The vegetable seed improvement industry is very profiteering, hence a guard against adulterated seed material is very essential for vegetable farmers. Recently a high price tomato seed variety has been found to be the lowest yielder even during the dry season.

6. Pest and disease control

Pest and diseases commonly encountered in vegetable production are numerous. Farmers tend to depend heavily on chemical control which adds to the total cost of production. Pest control in cabbage amount to TT $4,332.59 ha^{-1} (C.S.O. 1983). It is stated that chemicals are major pollutants of the environment and unless their effects are carefully monitored and their use properly managed they can result in serious damage to the environment and to the health of people. Misuse of pesticides can greatly increase their hazards.

Indiscriminate use of pesticides can cause the development of resistant strains of insects which might require new chemicals for their control. Mixed cocktails of pesticides are not unusual for farmers e.g. Malathion, Aldrin and Cupravit (Barrow 1982).

More effective and profitable vegetable production can be assured by the use of multiple resistant, high yielding cultivars and improvement of field sanitation together with a defined crop rotation.

7. Post-harvest

The system of vegetable production is geared for the fresh market consumer. This gives the farmers no alternative in cases of overproduction (as has happened in 1983–85 with respect to tomato and watermelon). Farmers have no storage facilities in their farm, they pack and deliver to the wholesale market centres in a very short space of time. The traditional methods of packaging, the long distances of transport, and the inappropriate manner in which vegetables and fruits are handled leads to a great deal of post-harvest losses. Barrow (1981) reported that the FAO (1979) estimated the post-harvest losses of perishable produce of Trinidad and Tobago was 116,000 metric tons including fruits, vegetables and root crops. He also reported that in 1979 the Central Marketing Agency (CMA) dumped approximately 31047kg of produce valued at TT$213,502.34.

The prospects of storage of vegetables are encouraging after the recent opening of a new $TT8m cold storage facility plant by the CMA. This facility addresses itself to the needs of farmers who wish to store their produce in case of overproduction. It is also anticipated that the mobile refrigerated container storage facility shall be utilized in distributing perishable goods to other remote areas.

8. Marketing

The major problem associated with marketing fresh vegetables is the wholesale market. Due to its centralization farmers have to travel long distances to sell their produce. Transactions are made in a haphazard manner between farmers and venders or middle-men. The Central Market is congested in such a way that proper display of the produce is impossible. Other related problems include security, lighting etc. The marketing problem can be possibly solved by decentralization of marketing locations to make it possible for farmers to sell their produce with the minimum inconvenience. The improvement of infra-structure and the consultation of farmers organisation in matters associated with proper marketing strategy is of vital importance.

9. Processing

Trinidad and Tobago has a number of processing plants which operate on imported concentrates. Sammy (1972) reported that the fruit and vegetable segment of the food processing industry uses about 80% imported raw material.

Hope (1981) stated that the most dynamic of the food processing industries have been fruit and vegetables which have attracted a large number of small operators and provided a basis for a sound cottage industry. To expand on the existing cottage industry and building a steady processing one there is a need for diversification of production from fresh market produce to processing.

Processing plants require an adequate and reliable source of locally produced raw material at reasonable price. Farmers need to orient their thinking with respect to the long term benefits of a dependable contract market as provided by a processing industry.

10. Export

The cost of production is admittedly high in Trinidad and Tobago due to many factors in comparison with the other Caribbean Islands. However, instances of overproduction coupled with the anticipated cold storage facility, give certain vegetable crops an opportunity to compete in North American Markets during the dry season.

For farmers to secure a place in the export market, cost of production has to be reduced significantly.

This is a real challenge which requires proper crop management and favourable conditions in marketing the commodity abroad. This cannot be achieved without investigating the different aspects of the particular market.

Prospects of vegetable production in the forseeable future

This can be summarized into the following:-

(1) A clear indication demonstrated by the government policy in reducing food import bill by $TT36m in the banning of cabbage and tomato imports.

(2) The formulation of a new policy designed to encourage domestic production of exotic vegetables e.g. onion, carrots and beetroot under guaranteed price.

(3) Land tenure regularization is possible in the near future with the establishment of Survey Department at the Unversity of the West Indies, St. Augustine.

(4) Improved level of technology in vegetable production available to farmers.

(5) Highly dedicated research scientists at the Central Experiment Station, Centeno, MALFP, currently engaged in applied vegetable production research.

(6) Active role played by the Extension Services Division in conducting intensive training programmes in all aspects of vegetable production.

(7) Positive response of the CMA to farmers organizations with respect to efficient marketing through decentralization of marketing outlets, cold storage facilities and even distribution of produce.

(8) The commitment of the private sector (Chamber of Industry and Commerce 1983) in supporting self-sufficiency food policy.

Conclusion

Beckles (1980) stated that Trinidad and Tobago economy, unlike that of the rest of the Commonwealth Caribbean is not based completely on agriculture, but is in fact fuelled by the Petroleum sector. As petroleum is a "wasting" asset there is need for diversification to ensure long-term viability of the economy. It is to be agro-industrial sub-sector, among others, that this country must look to increase its earning power.

The agricultural sector has declined in the last decade due to a number of factors. Hope (1981) stated that insufficient agricultural services, a widening urban-rural wage differential, rising production costs and a weak marketing system for domestic food crops have contributed to the general decline of the agricultural sector.

For vegetable production effectiveness in the economy and in the domestic food production systems, strong sound research at the national and regional levels is of vital importance. Extension services and domestic marketing facilities are the back-bone of successful vegetable production industry.

Acknowledgements

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References

Barrow, R.M. (1981) Post-harvest losses in Trinidad and Tobago, First Consultative Meeting on Post-Harvest losses in the Caribbean. U.W.I., St. Augustine, July 19–24, pp 11. Central Experiment Station Library, Centeno.

Barrow, R.M. (1982) An update on pesticide use in Trinidad and Tobago, pp 26. Central Experiment Station Library, Centeno.

Beckles, K. (1980) Agricultural marketing in Trinidad and Agri-Business, the local potential. Seminar, Central Experiment Station Library, Centeno.

F.A.O. (1984) Agricultural development in the Republic of Trinidad and Tobago, problems and prospects. Report of the Agriculture Sector Programming and Evaluation Mission. FAO, Rome, Italy.

Hope, K.R. (1981) Agriculture and economic development in the Caribbean . Food Policy, November pp. 253–265.

Jones, M.T. (1985) Insect pest control problems in crops of Trinidad and Tobago. Agricultural Extension Bulletin No. 3, March, MALFP, Trinidad.

Sammy, G. (1972) An approach to food processing development in Trinidad and Tobago, UWI., St. Augustine.

THE BACKYARD PRODUCTION SYSTEM
A Solution For Low Family Nutrition in Dominica

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ABSTRACT

The Caribbean Agricultural Research and Development Institute (CARDI), through the USAID funded Farming Systems Research and Development Project, is currently evaluating a model Backyard Production System, designed to improve the nutrition of rural small farm households in Dominica.

The model, which consists of the farm household, livestock pens, feed plot, fenced vegetable plots, seedling nursery and compost heap, provided vegetables and eggs to the household at low cost. Data for 10 months show that additional vegetable consumption was 17.5kg, 62.kg and 14.2kg on Farms 1, 2 and 3 respectively. Egg consumption per month increased from 0 to 7.3, 31.6 and 36.0 and value of production was EC$617.20, $240.44 and $309.20 on Farms 1, 2 and 3 respectively. Establishment costs were EC$716.12, $350.12 and $647.25 whereas monthly operating costs were EC$141.25, $9.91 and $28.92 for Farmers 1, 2 and 3 respectively. Meat production and consumption were neglible.

RESUMEN

El Instituto de Investigación y Desarrollo Agrícola del Caribe (CARDI), a travez del Proyecto de Sistemas de Agricultura de Investigacion y Produccion, auspiciado por la USAID, esta evaluando al presente un modelo prototípo de un Sistema de Producción en los solares, el cual se ha disenado para mejorar la nutrición alimenticia en los hogares rurales de los pequeños agricultores, en Dominica. El modelo, el cual consiste de: la casa de estancia, corrales, parcela de alimentación para los animales, parcelas avalladas, de hortalizas; vivero y area de recolección del estiercol-provee de verduras y huevos al hogar, a un bajo costo. Datos obtenidos durante diez meses, mostrarón que el consumo adicional de verduras fue de 17.5 kg, 62. kg y de 14.2 kg en las fincas 1, 2 y 3 respectivamente. El consumo de huevos por mes subió de 0 a 7.3, 31.6 y 36.0, siendo el valor de la porducción de EC$ 617.20, $240.44 y $309.20 en las fincas 1, 2 y 3 respectivamente. Los costos de establecimiento fueron de EC$716.12, $350.12 y $647.25, mientras que los costos operacionales mensuales fueron de EC$41.25, $9.91 y $28.92 para las fincas 1, 2 y 3 respectivamente. El consumo y la producción de carne fueron negligibles.

The Commonwealth of Dominica, located in the Eastern Caribbean has a total land area of 752 km². It is characterized by mountainous topography, steep slopes, average annual rainfall ranging from 1250mm to 7,500mm, a dry season usually from January to April and average annual maximum and minimum temperatures of 27 and 20°C respectively. Data from the national farm register conducted in 1979 show that only 33% of the 751 km² land area is cropped. Additional cultivation is restricted by the mountainous terrain and heavy rainfall. These factors also influence the distribution of agricultural production.

The island is divided into 20 Agricultural Extension Sub Districts (SD) to facilitate technology transfer. In 1982 SD3 and SD4, north central to north eastern districts, were targeted by the Caribbean Agricultural Research and Development Institute (CARDI) for improvement in the nutrition of rural small farm families.

Of the 1418 ha of assorted vegetables cultivated in Dominica only 2.3% and 0.9% are located in SD3 and SD4 respectively. However, these are the most prominent areas of tree crop, banana included, and root/tuber crop production whereas highest vegetable production is located in SD12 and SD17 near the urban centres of Roseau and Portsmouth. Henderson and Gomes (1979), in their islandwide survey of 120 small farmers, indicated that the most frequent consumed foods were banana and root crops which were produced by the farmers on their holdings. Seventy percent of the farmers examined indicated that they consumed foods high in protein, vitamins and minerals (such as meat, eggs and vegetables) however these amounts were negligible and were purchased from various markets. Small quantities of vegetables were produced on parcels 1.0km to 6.4 km from the household primarily for sale and were not readily available to the farm household. SD3 and SD4 rank 1 and 7 respectively in terms of number of livestock. These animals are not slaughtered on a regular basis to provide meat for the household but were kept by the farmers as a form of security.

CARDI, through the Small Farms Research Project funded by USAID, completed a time series study of 20 farmers throughout the island from March 1982 to March 1983 (CARDI, 1983). Data for two farmers in SD3 and one in SD4 show that consumption of food produced on the farm ranged from 902.7 kg to 1625.9 kg for the period (Table1). An average of 90% were of the foods high in starch such as bananas, plantains, tannia, dasheen, yams, touslemois and breadfruit. Of the food consumed, 0% to 6.4% was meat and the remainder was fruit and vegetables. This diet was suplemented by small quantities of other purchased foods such as rice, flour, potatoes, peas, salted and canned meat and fish. These data were consistent with those reported by the Social Centre and the Food and Nutrition Council in Dominica. They reported that lack of nutritous food was one of the major causes of malnutrition in children, particularly evident in SD4.

The situation described above resulted in CARDI introducing a Backyard Production System or Integrated Production System for the Farm Kitchen model on these three farms in order to alleviate the nutritional problem.

The objectives of the system were:

1. To design and establish a self-sustaining production system which could keep the farm household continuously supplied with fresh meat, eggs and vegetables that are high in protein, vitamins and minerals.

Table 1. Amount (kg) of crops and livestock products produced and consumed by three rural farm households from March 1982 to March 1983.

Extension Subdistrict Family size	SD3 3	SD4 4	SD5 5
Crops			
Banana	429	684	211
Plantain	45	12	222
Tannia	49	138	70
Dasheen	197	271	45
Yam	88	201	45
Touslemois	-	100	-
Breadfruit	143	95	-
Peas and beans	10	4	2
Tomato	1.5	6	14
Pumpkin	5	45	-
Cucumber	-	-	19
Corn	-	0.9	1.2
Mustard	-	5	-
Avocado	5	-	45
Grapefruit	-	17	31.4
Sugar cane	-	12 meters	-
Other vegetables	8	1	3
Sub-total	975.5	1597.9	902.6
Livestock			
Chicken	15	-	-
Goat	7	22	-
Sheep	45	-	-
Cattle	-	25	-
Sub-total	67	47	0
Total	1,042.5	1,626.9	902.6

Source: CARDI, Small Farm Systems Research Project.

2. To reduce the farmer's expenditure on these foods.

The model is currently being evaluated by the Farming Systems Research and Development Project funded by USAID. Data collected for the period May, 1984 to February 1985 are presented and discussed herein.

Materials and methods

Backyard Production Systems models were established by CARDI in cooperation with three farm households based on the conceptual model described by Adams. This occured over a period of 6 months. CARDI provided the cost of most of the inputs and the farmer provided the labour. The model consisted of:

Fenced vegetable plot: A shade-free area, approximately 65m^2 was selected close to the farm house at each location. Size of 8 to 10 raised garden beds therein ranged from 2.1m to 4.8m long by 1.0m to 1.7m wide. The land was cleared using a cutlass, forked, and organic manure incorporated before planting. These were planted with recommended varieties of vegetables such as carrot, tomato, cabbage, lettuce, celery, dwarf bean and sweet pepper. The area around the vegetable beds within the fence was reserved for planting seasoning herbs and other vegetables such as okra, pussley and bhagi. The vegetable plot was fenced, using chicken wire supported by live gliricidia posts to obviate praedial larceny and livestock damage. Leaves of the gliricidia were fed to the rabbits. The fence supported vining vegetables such as christophene, runner bean, cowpea, lima bean, squash and spinach. The available area was supplemented on one farm by erecting four trays, 2.1m x 1.0m x 0.1m and 1.0m above the ground using discarded zinc sheets and local carapite wood. These were filled with a mixture of compost and soil.

Vegetable seed bed: Either using the design described earlier for the trays or discarded metal containers, small seedbeds 0.12m^2 were erected. These were used primarily to produce seedlings of cabbage, lettuce and tomato, which were transplanted at 4 weeks. The young seedlings were protected against heavy rainfall by coconut leaves placed on the seedbeds.

Livestock and livestock pens: Chickens for eggs and meat and rabbits for meat were consisered appropriate protein sources by the three farmers selected because of familiarity, ease of management, availability of inputs and accessibility to available technology. In addition, one farmer established a pond, approximately 21m^2 in surface area to raise fresh water talapia fish and erected a pen, 1.0m^3 for housing his regular catches of feral agouti and opposum.

Dual purpose pens for chickens and rabbits were erected on two of the farms and separate units on the other. In all cases materials used in pen construction were wood, collected from the neighbouring forest; chicken wire, purchased in Roseau; and either galvanized sheets or discarded tin. In the dual purpose pens, the rabbit cages were placed within the chicken house in an accessible position 1.0m to 1.5m above the ground. Overall pen dimensions were 3.7m x 2.3m x 1.8m and 3.6m x 3.2m x 2.0m for dual purpose pens on Farm 1 and Farm 3 respectively. The front to the pens was 15cm higher than the back. The rabbit and chicken houses on Farm 2 were 3.1m x 1.0m x 0.5m and 3.8m x 3.0m x 1.7m respectively. On all farms the size of individual rabbit cages varied from $0.8m^3$ to $2.7m^3$. Laying boxes $0.5m^3$ were provided in dual purpose pens whereas in the sole chicken house an area 1.7m x 1.3m x 1.0m was set aside for laying. Each farmer was provided with 30 Rhode Island Red chickens and two New Zealand White rabbits from local sources. The males of the poultry were used for meat and the females for breeding and eggs.

Feed plot: An area 7.8m by 5.1m was planted with Desmodium and Guinea grass which were harvested periodically and fed to the rabbits. Cultural practices were similar to those described for vegetables.

Compost heap: Two pits, $0.7m^3$ to $1.0m^3$ were dug next to the livestock pens in order to facilitate easy movement of pen manure. One pit at a time was filled with alternate layers of waste from the kitchen and vegetable plot, and manure from the livestock pens. During filling, the contents were stirred periodically. Occasionally ammonium sulphate was added to assist rotting. Once full, the pit was covered with soil and left for three months, after which the compost was harvested and then distributed to the vegetable plot. Two farmers supplemented this source of manure by collecting decomposed leaves from the nearby banana boxing plant.

Farm household: The three farm households selected had previously participated in the CARDI Survey of 20 Small Farmers. Family sizes for Farmers 1, 2 and 3 were 3, 4 and 6 respectively. The farm household assisted in choice of crops based on tastes, needs, nutritive value and agroclimatological adaptation. The farm household assisted in record keeping and spent a maximum of 2 man hours daily managing the system.

The relationship between components of the model is illustrated in Figure 1. The following parameters are being assessed for evaluation of the model during biweekly visits to the three farms.

1. Establishment costs
2. Maintainance costs
3. Egg production and consumption
4. Meat production and consumption
5. Vegetable production and consumption
6. Expenditure on foodstuffs
7. Revenue from sale of surpluses
8. Labour use
9. Flows between components
10. Production and use of compost
11. Foodstuffs from other parts of farm
12. Economic analysis

To date collection on parameters 9, 11 and 12 has not begun.

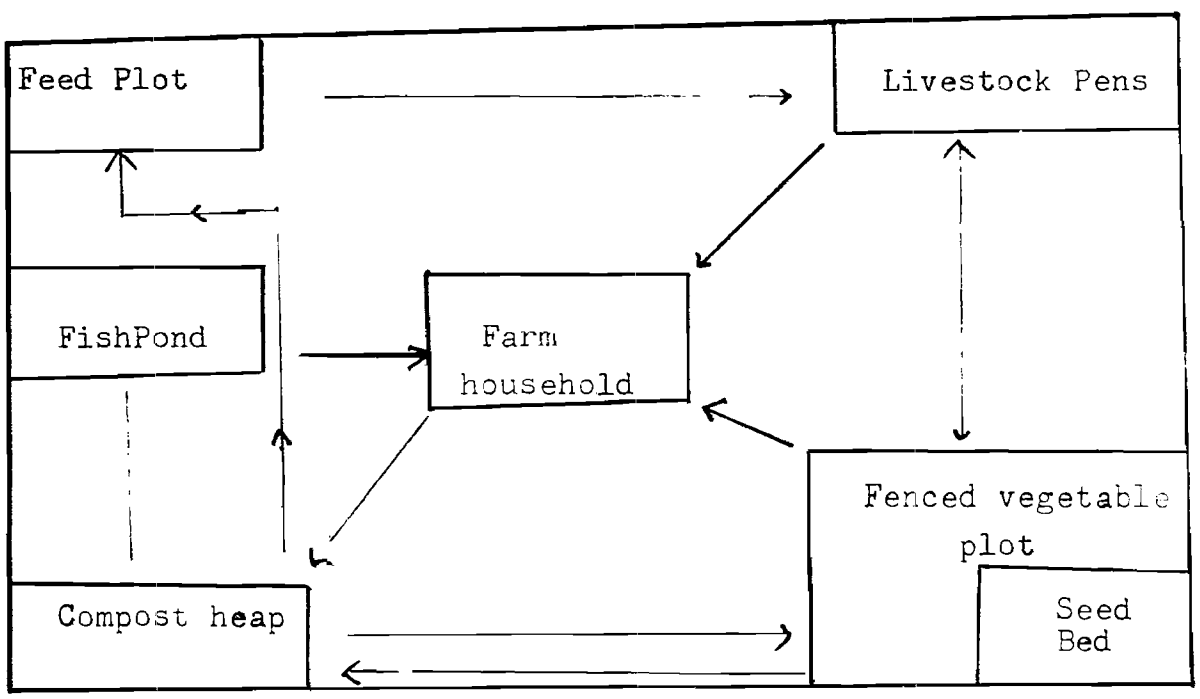

Figure 1: Schematic diagram of model Backyard Production System on three farms in Dominica.

Results and discussion

Results shown in Tables 2, 3, 4, 5 and 6 are summaries of the data collected to date on the Backyard Production Systems. Establishment costs were EC$711.62, $350.12 and $647.25 on Farms 1, 2, and 3 respectively for seeds, fencing, livestock, feed and labour. On all farms fencing was the major cost ranging from 56% to 62% of the total costs. Variation in costs is attributed to differences in size of the various components on each farm and the quality of wire provided on Farm 2 when compared with Farms 1 and 3. During this establishment period, the value of meat, vegetables and eggs produced by the system was EC$700.25, $588.21 and $481.50 on Farms 1, 2 and 3 respectively. These compare favourably with the establishment cost.

Maintenance costs, borne largely by the farmer, were primarily for seed, animal feed, wire, wood and nails for repairs to livestock houses and fences, and labour. Chemical inputs such as pesticides, fertilizer and medicines were negligible as recommended by Adams (1981) in his description of the conceptual model.

Average monthly cash expenditures from September 1984 to February 1985 were EC$41.25, $9.91 and $28.92 on Farms 1, 2 and 3 respectively (Table 3). These are higher than those for the pre-intervention period as Farmers 1 and 3 did not have backyard systems and farmer 2 spent only EC$4.00 providing seed for his vegetable garden over 1 year.

The higher cash expenditure and labour use on Farm 1 was associated with the high cost, $35.21 per month, of repairing the livestock houses and the fence, which also necessitated use of hired labour. Farmer 3 placed more emphasis on poultry for egg production and consequently his main expenditure was for poultry feed which was 79% of the cost of biological materials.

The cost of biological materials also included EC$11.00 and $8.00 for the purchase of fertile eggs to be hatched on Farms 1 and 2 respectively and EC$20.00 for purchase of a pair of rabbits on Farm 3. These expenditures were necessitated because of the high incidence of rabbit deaths and poultry diseases which it is hoped will be alleviated by regular visits by the Ministry of Agriculture Veterinary service and improvement in animal husbandry. The costs of livestock and the structural costs were sporadic whereas seed costs occurred nearly every month as the farmers maintained a steady supply of vegetables to the household.

Other inputs which did not require cash outlays were recorded, for example, decomposed banana leaves, 312.0 kg and 248.0 kg, and rabbit manure 31.0 kg and 15.0 kg, on Farms 1 and 3 respectively, were incorporated into the vegetable beds. Inputs on Farms 2 and 3 included 3.5 kg of feral agouti and 24.0 kg of opposum respectively, caught in the nearby forest.

Data in Table 4 indicate that Farmer 1 was the most committed to the success of the model. Seventy two percent and 81% more time was spent on the Backyard Production System than on Farms 2 and 3 respectively. The majority of labour on all farms was used in the livestock and vegetable components where the wives also assisted.

Variable production and consumption data were recorded for three farms, (Table 5). Egg production ranged from 42.8 per month on Farm 3 to 9.0 per month on Farm 1. Eighty-one percent to 100% of the eggs were consumed by the farm households, and small quantities were sold by Farms 1 and 3. Highest egg consumption per person per month recorded, was 7.9 eggs on Farm 2. Though these figures are low they are an improvement on the pre-intervention period when no eggs were produced by any of the

Table 2. Materials and cost of establishing three model Backyard Production Systems in Dominica

	Farm 1		Farm 2		Farmer 3	
Input	Quantity	Val ($)	Quantity	Val ($)	Quantity	Val ($)
Seed	23 pks	11.50	8 pks	4.00	17 pks	6.50
Labour	63 hrs	118.12	23 hrs	43.12	42 hrs	78.75
Fencing	1 roll	400.00	1 roll	204.00	1 roll	400.00
Feed	56.8 kg	82.00	22.7 kg	34.00	77.3 kg	73.00
Chickens	30	60.00	30	45.00	33	69.00
Rabbits	4	40.00	2	20.00	2	20.00
Total		711.62		350.12		647.25

Table. 3 Average monthly cash expended and labour used to maintain three Backyard Production Systems from September 1984 to February 1985 in Dominica

Farmer	Cash expenditure on materials (EC$)			Labour used (Man-hours)		Cost	Total
	Chemical	Biological	Structural	Family	Hired	EC$	EC$
1	0.20	4.17	35.12	20.4	1.3	1.67	41.25
2	0.58	1.83	7.50	4.8	0.00	0.00	9.91
3	0.00	19.96	8.96	4.3	0.00	0.00	28.92

Table 4. Labour (man hours) spent on each component of the Backyard Production System over a six-month period in Dominica

Farmer	Labour (man hours)					
	Veg. plot	Compost	L/Stock	Hunting	Feed plot	Fish pond
1	45.25	12.0	74.5	0	0.25	0
2	12.75	0	9.0	3.0	0	4.0
3	9.5	2.0	7.0	7.0	0	0

Table 5. Average monthly production and consumption from three model Backyard Production Systems from establishment to February 1985 in Dominica.

Farm	Item	Production	Consumption	Sold	Revenue
1	Eggs	9.0	7.3	1.7	0.83
	Meat 9kg)	1.2	1.2	-	-
	L/stock (rabbits)	24.0	0.4	1.1	11.11
	Vegetables (kg)	20.9	17.5	3.4	15.72
	Compost (kg)	15.1	15.1	-	-
2	Eggs	31.6	31.6	-	-
	Meat (kg)	2.2	2.2	-	-
	L/stock (rabbits)	1.8	0.6	0.1	1.2
	Chicken	0	0.4	-	-
	Vegetables (kg)	6.2	6.2	-	-
3.	Eggs	42.8	36.0	6.8	4.10
	Meat (kg)	0.6	0.6	-	-
	L/stock (poultry)	7.4	1.2	-	-
	Vegetables (kg)	14.3	14.2	0.1	1.00

farm households. On Farms 1 and 2, an average of 4.0 and 1.8 rabbits were borne per month respectively, and 7.4 chickens were hatched monthly on Farm 3.

Livestock deaths were not quantified on any of the farms, though these did occur. These losses were attributed to the low level of animal husbandry practised relative to the exotic breeds used. Use of local breeds is now being instituted to solve this problem. These losses were one of the contributing factors to the low average monthly meat consumption recorded, 0.6kg to 2.2kg. On Farms 2 and 3, 0.6kg and 4.0kg of feral meat per month respectively was also consumed. Additional meat was provided from the shop and periodic slaughter of other livestock.

The model provided the farm households with an increased quantity and wider range of fresh vegetables which were more readily available on a daily basis. Average monthly vegetable production was 20.9kg, 6.2kg and 14.3kg on Farms 1, 2 and 3 respectively (Table 5). These figures are greater than those recorded for the same farmers previously, 2.0kg, 5.1kg and 3.3kg per month averaged over 12 months (Table 1). Most of these vegetables were consumed by the farm household. The higher production on Farm 1 was associated with the greater use of labour and use of compost, 15.1kg per month, and decomposed banana leaves collected from the boxing plant. Where neither of these inputs was used, as on Farm 2, production was comparatively low and there was no surplus for sale.

All the farm households sold either livestock, eggs or vegetables. Average total monthly cash receipts were EC$27.66, $1.20 and $5.10 on Farms 1, 2 and 3 respectively. These amounts represented 67%, 12% and 18% of the cash used to operate the systems on Farms 1, 2 and 3 respectively. Though the model was not commercially oriented it was self-sustaining. One contribution of the System to the farm household was savings on food expenses which were measured in terms of the value of the commodities used by the farm household from this system. Based on average local market prices, the value of commodities produced on Farms 1, 2, and 3 were EC$1,371.25, $868.65 and $790.70 respectively. These were higher than establishment plus operating expenses on Farms 1 and 2 by 37% and 112% respectively but less by 4% on Farm 3.

Data from September 1984 to February 1985, show that cash expended on vegetables for the farm household was negligible (Table 6) due to the consistent supply of vegetables from the Backyard Pro-

Table 6. Food expenditure for three farm households, from September, 1984 to March 1985, in Dominica.

Farmer	Beef/chicken/ fish	Cereals/ rice	Legumes/ pluses	Vegetables	Total
1	19.50	2.60	3.60	3.00	28.70
2	1.54	1.30	1.38	-	4.22
3	30.79	1.65	1.42	2.75	36.60

duction System. The highest expenditures were made on meat and fish. Rice and dried peas and beans had to be purchased since the climate of the area was not conducive to their production, however the System supplied green mature peas and beans.

Conclusion

To date the Backyard Production System has been able to increase consumption of eggs, meat and vegetables by the farm household at low cost. These items were either not previously produced by the household for their consumption, as in the case of eggs, or only a limited range was available some distance from the home, as in the case of vegetables. Attention must be directed to improving livestock management and changing consumption patterns, with corresponding changes in nutritional status. Continued evaluation of the model will include economic analyses. The success of the model to date can be measured in terms of its introduction into the South East and North East Extension Districts of Dominica by the Social Centre, Food and Nutrition Council and other extension agents.

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References

Adams, H. (1981) A model intensive, integrated production. system for the farm kitchen. CARDI, Dominica.

CARDI (1983) Biweekly Survey of Twenty Small Farmer's in Dominica. Unpublished. Output of CARDI USAID Small Farm Systems Research Project.

Henderson, T.H., and Gomes P.I. (1979) *A profile of small farming in St. Vincent, Dominica and St. Lucia.* Report of a Baseline Survey for CARDI, Department of Agricultural Extension, U.W.I., St. Augustine, Trinidad.

INTEGRATION OF WHITE POTATO INTO THE VEGETABLE PRODUCTION SYSTEMS OF MONTSERRAT

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ABSTRACT

In 1984 an integrated programme to reintroduce white potato into the vegetable production system was initiated in Montserrat by the Ministry of Agriculture. Technology development for the crop which is CARDI's responsibility, has major objectives of increasing productivity through more efficient use of planting material and more adaptable varieties. Multilocational evaluation of eight Dutch varieties has confirmed the standard variety Desiree as the most adaptable of those tested, however, Bartina (pink) and Frisia (brown) out-performed Desiree under ideal growing conditions producing larger, more uniform tubers. Both these varieties seem to have a higher susceptibility to soil-borne diseases but are more tolerant than Desiree to early and late blights. Preliminary trials on tuber production from true potato seed (TPS) were successful and the technique of rapid stem propagation as a means of producing planting material was evaluated. The effect of employing CARDI's Farming Systems Research and Development methodology within this programme is examined.

RESUMEN

El Ministerio de Agricultura de Montserrat, en el año 1984, inició un programa integrado para reintroducir el cultivo de la papa, en el sistema de producción de hortalizas. CARDI tiene la responsabilidad de desarrollar la tecnología para este cultivo. Sus mayores objetivos son: de incrementar la producción mediante, el uso mas eficiente del material para el cultivo y, el uso de variedades mas adaptables. La evaluación de localización multiple de ocho variedades de origen holandes, establecé a la varieded comun, Desiree, como a la mas adaptable entre las que fueron ensayadas. Sin embargo bajo condiciones ideales de crecimiento las variedades Bartina (rosada) y Frisia (café) rindierón más que la variedad Desiree y produjeron tubérculos mas grandes y uniformes. Ambas de estas variedades parecen ser mas susceptibles a enfermedades originadas en el suelo pero, resisten mejor que Desiree al *Phytophthora infestans* y a la *Alternaria solani*. Ensayos preliminares sobre la propagacion, mediante semillas (TPS), del tubérculo fueron exitosas y la técnica de propagación vegetativa-rapida de un segmento del tallo para obtener material para el plantio, fué evaluada. En ésta presentacion, se analiza el efecto que se obtendrá al utilizar el sistema de investigacion de Agricultura y metodología del desarrollo de CARDI, con relación a este programa.

White potato (*Solanum tuberosum* L.) is known to have been cultivated on a home garden scale in Montserrat as early as the 1940's. The first reference to the crop in Department of Agriculture reports was in 1949 when the variety Red Bliss, introduced from the United Kingdom, was grown at the Grove Agricultural Station in an adaptability test (Leeward Islands, 1949). In a statistical report prepared in 1950 (Anon, 1950) Irish Potato was mentioned as an export crop, a total of 750kg being sent to Antigua. In the same year the Government Marketing Depot was on record as having sold 455 kg of seed potato to farmers. Again in 1965 there is a record of sales of 2585 kg of seed potato valued EC$601.94 to the farming community (Government of Montserrat, 1966).

Today in Montserrat potato persists as a major carbohydrate staple in the diet despite availability of locally produced root crops. In 1982 imports totalled 142,100kg valued at EC$180,000. Figures for subsequent years show gradual increases and 1985 imports are projected at 160,000 kg. Shipments are scheduled on a fortnightly basis to fit in with currently available storage space, however, it has been demonstrated that good quality imported or locally grown material will store for up to 12 weeks without significant deterioration.

The value of potato imports represents a significant proportion of the total value of primary agricultural commodities and food imports into the country and the Government of Montserrat with its current policy of food import substitution is anxious to reinstitute local production of the crop as one of the means of achieving that objective. Farmers have also expressed willingness to resume production provided good seed material is made available. It would seem that the major attractions to the farmer are the certainty of a guaranteed market and the value of the crop both as a quick cash earner and a farm household staple for which cash income is currently outlaid.

This paper reports on the progress of field trials on varietal adaptability conducted during 1984/85 and summarises investigations into the use of alternative sources of planting material. On-farm cultural practices and production constraints were also catalogued to provide a basis for revising and upgrading Research and Development Programme objectives.

Materials and methods

(i) Varietal trials

Six varieties from De ZPC in Holland and two recommended commercial varieties were planted out in randomised complete block trials at three on-farm locations and at the Ministry of Agriculture field station at the Grove. Each trial was replicated three times. The locations represented variations in altitude from 50m to 500m above sea level as well major soil types and cropping histories as listed below in Table 1. In addition single row plots of the eight varieties were established in commercial fields at two other on-farm locations and were managed by the farmer along with the rest of his crop.

Table 1. Location, altitude and field history of vareital trial locations in Montserrat

Location	Alt(m)	Soil family sub-group	Field history
Rileys (1)	450	Typic Tropudalfs	Continuous cropping of vegetables, roots, and tuber crops
Rileys (2)	450	Typic Tropudalfs	Fallow 10 years
Lees	250	Typic Tropudalfs	Continuous cropping of vegetables
Grove	50	Udic Haplustalfs	Continuous cropping of vegetables
Richmond	50	Udic Haplustalfs	Cotton
Farrells	400	Typic Tropudalfs	Pasture/sweet potato, vegetables

Varieties and their characteristics are listed in Table 2. All material was well sprouted before planting. Seed tuber size ranged from 3.5 to 6.0 cm; all tubers were planted whole.

Table 2. Varietal descriptions of White Potato

Varieties	Colour characteristics
Baraka	Brown
Bartina	Pink
Caspar	Brown
Concurrent	Brown
Desiree	Pink
Flaminco	Pink
Frisia	Brown
Mona Lisa	Brown

All plots were 5m x 4m except at Grove which were 2.5m x 4m. All plots had ridges of 1m in width. Planting was patterned after the farmer's practise of single rows on each ridge (¾ way down) with plants spaced 30cm apart resulting in a plant population of 30,000 plants ha^{-1}. Three fertilizations were done, viz – a preplant spot application of 400kg ha^{-1} of 12:24:12 and 100kg ha^{-1} triple super phosphate below the seed tuber followed by a side dressing of N (55kg ha^{-1}) at 30 days and K (50kg ha^{-1}) at 50 days. Pest control was routine and comprised pre-plant row application of Furadan (carbofuran) and insecticide/fungicide sprays every 7 to 10 days after the fourth week of growth. Two hoeings were done during which weeding and hilling up operations were accomplished simultaneously. Because of heavy rains toward maturity harvesting was done earlier than anticipated. Tubers were separated into grade 1 ($>$ 3.5cm), grade 2 (2.5–3.5cm) and unmarketable (marbles, greens, spoilt and damaged tubers). Grade 1 tubers were put in storage to evaluate sprouting and storage life.

(ii) Evaluation of True Potato Seed (TPS)

The CIP methodology (Malagamba *et al.*, 1983) for the cultivation of true potato seed was employed in the evaluation of four varieties viz. – Atzimba, Avenir, Estima and Provita. Seed was treated with 0.002% Giberellic acid and sown in nursery boxes on 26 July, 1984. Two nursery mixes were usd comprising equal proportions of soil and compost and equal proportions of coarse sand and compost. Transplanting at an on-farm location at Hermitage (450m above sea level) was done 6 weeks after planting in single rows on ridges with plants spaced 15cm apart. Routine field husbandry included hand weeding, hilling up, fertilizing (preplant and two sidedress applications) and pest control every 10 – 14 days. Harvesting was done on 14 November, 1984 and tubers were graded into two sizes, above and below 20mm, and put in storage.

(iii) Tuber production from stem cuttings.

The rapid multiplication technique for potatoes as developed by Bryan *et al.* (1981) of the International Potato Centre was successfully modified in 1983 to provide Vietnamese farmers with an inexpensive source of commercial planting material (Van Vyen and Vander Zaag, 1983). This technique in modified form was field tested to determine the feasibility of adapting it to local conditions.

Nine tubers each of two varieties – Concurrent and Bartina – were planted in nursery boxes and allowed to germinate. Cuttings were taken at 5cm to 8cm and planted in a sand/compost rooting medium with half the cuttings being treated with rooting hormone and the other half untreated. Rooted cuttings were lifted and planted in the field alongside an equivalent number of tubers of each variety. 20 cuttings and 20 tubers of each variety were used in 3m row lengths with 2 rows per ridge. The observation was unreplicated. Harvesting of both treatments was done simultaneously and yields compared.

(iv) On-farm monitoring of potato production

In order to establish an agronomic baseline to permit identification and evaluation of production constraints in the field, three farms were selected for detailed monitoring of production practices. In addition a further five farms were visited on a regular basis throughout the cropping season - November 1984/April 1985 - and observations were made. Information was also gathered from other agencies which had direct relationships with the potato crop viz. Ministry of Agriculture, the Development Finance and Marketing Corporation (DFMC) and CARDATS. Data recorded in accordance with guidelines set out in CARDI's FSR/D Metholology included field methodology, pest and disease incidence, crop status, cropping sequences and cost of production. This information was compiled into an end-of-crop report for the Ministry of Agriculture and is being used as a resource document by the multidisciplinary team to assist in planning of the current crop.

Results

(i) *Varietal trials*

Rileys (1):

The crop in this trial was severely decimated by an unidentified stem wilt complex which, from visual evaluation seemed to have been caused by *Fusarium* sp., *Rhizoctonia* sp. and to a lesser extent *Sclerotium* sp. The most severe effects on the disease were recorded on the varieties Baraka, Bartina and Frisia. The variety Desiree demonstrated a marked tolerance and all other varieties were significantly affected. Table 3 presents ungraded yields of marketable tubers. Analysis of the trial indicated non-significance due, as expected, to the high yield variability across replicates, however, Desiree yielded consistently higher and in fact had a yield of 11.8 tonnes ha^{-1} almost twice as high as any other variety.

Table 3. Rileys(1): Mean[1] tuber yields of White Potato

Variety	Mean (t/ha)	Gradeout %[2]
Baraka	3.67	78
Bartina	5.67	81
Caspar	5.08	68
Concurrent	6.08	76
Desiree	11.83	78
Flamenco	6.58	79
Frisia	6.58	68
Mona Lisa	6.83	71

C.V. = 43.1 %

[1] Mean of three replications

[2]Gradeout %: Marketable tubers as a percentage of total yield.

Experiment showed no significance

The history of this field showed repeated cultivation of root crops viz. tannia, dasheen and sweet potato, in the past three years and it is felt that this may have been responsible for the high level of pathogenic inoculum in the soil. It was also obvious that some sections of the field were more severely affected than others.

Rileys (2):

This trial was located 400m uphill from Rileys (1) on a similar soil type, the major difference being that the land was in fallow and under secondary growth for over 10 years prior to its use for this trial. Table 4 presents data from this trial in which the highest performance for all locations was attained. The variety Frisia performed best with over 20 t ha^{-1} and was significantly better than the others. Bartina, Caspar, Desiree and Mona Lisa also performed well, however, Bartina had the superior advantage of a higher grade-out percentage and good tuber configuration. The small size of Desiree tubers is clearly demonstrated in the mean tuber weight and grade-out status. Unlike Rileys (1) there were no problems with wilt diseases and final plant stands were good in all plots.

Lees:

This trial was planted in early December and was subjected to severe weed infestation during the critical growth period. There was also evidence of a stem wilt complex similar to that in Rileys (1) but not as severe. Table 5 sets out harvest data for this trial. Yields were poor, however the varieties Bartina, Frisia and Mona Lisa seemed more able to compete with the heavy weed infestation than Desiree which was at the bottom of the table. In spite of the low yields the tubers of Bartina and Caspar attained good marketable size.

Table 4. Rileys(2): Mean[1] tuber yields (t/ha) of White Potato and mean tuber wt (g)

Variety	Mean yield* (t/ha)	Tuber wt.(g) gd 1	gd 2	Gradeout %†
Baraka	10.83 c	93	19	92
Bartina	17.50 b	107	23	97
Caspar	17.67 b	78	21	88
Concurrent	13.42 c	100	29	85
Desiree	17.25 b	87	28	78
Flamenco	13.50 c	73	35	85
Frisia	21.83 a	104	26	89
Mona Lisa	18.17 b	94	28	86

C.V. = 11%

* Means followed by same letter are not significantly different (1%) according to Duncan's Multiple Range Test.

† Gradeout %: Marketable (grade 1) tubers as a percentage of total yield

[1] Mean of three replications.

Table 5. Lees: Mean[1] tuber yields (t/ha) of White Potato and mean tuber wt. (g)

Variety	Mean yield* (t/ha)	Tuber wt.(g) gd 1	gd 2	Gradeout %†
Baraka	2.35 b	62	31	74
Bartina	6.50 a	112	42	76
Caspar	5.50 a	192	29	62
Concurrent	5.50 a	71	23	78
Desiree	2.17 b	86	38	81
Flamenco	3.83 b	75	29	76
Frisia	6.17 a	89	28	75
Mona Lisa	6.67 a	74	27	74

C.V. = 18.95%

* Means followed by the same letter are not significanlty different (1%) according to Duncan's Multiple Range Test.

† Gradeout%: Marketable (grade 1) tubers as a percentrage of total yield

[1] Mean of three replications

Groves:

This trial was the last to be planted in mid-December, 1984. It was affected by early blight *(Alternaria solani)* in the final 4 weeks before harvest. In a visual rating done before harvest the varieties Concurrent and Frisia rated highest while Baraka, Bartina and Caspar seemed most tolerant. Yields were modest with the best being Caspar (6.67t ha^{-1}) See Table 6.

Table 6. The Grove : Mean[1] tuber yields (t/ha) of White Potato and mean tuber wt. (g)

Variety	Mean Yield* (t/ha)	Tuber wt.(g) gd 1	gd 2	Gradeout %†
Baraka	7.00 b	na	na	na
Bartina	11.67 a	114	39	76
Caspar	12.33 a	70	34	66
Concurrent	7.33 a	105	40	63
Desiree	9.67 b	111	26	76
Flamenco	5.67 b	106	36	55
Frisia	9.00 a	na	na	na
Mona Lisa	9.67 a	85	27	79

C.v. = 21.84%

* Means followed by same letter are not significantly different (1%) according to Duncan's Multiple Range Test

† Gradeout %: Marketable (grade 1) tubers as percentage of total yield

[1] Mean of three replications.

Single row commercial plots:

Data from the on-farm single row commercial plots are presented in Table 7. Bartina yielded highest at both locations and also had the highest proportion of marketable tubers (See Table 7). At the Farrells location there was some wilting similar to that previously described and in fact the farmer suffered severe losses of his commercial crop in certain sections of his field. At Richmond, harvesting was done earlier than the planned 90 day period and it was evident that the variety Caspar was still immature and is much later than the others. At that location which was the earliest planted, Flamenco did not germinate.

(ii) True Potato Seed (TPS) Evaluation

Germination of seed in the nursery occured within 10 days of sowing and seedlings attained transplantable size in 6 weeks from sowing. Virus symptoms were observed in the nursery and rogueing was necessary. All cultivars were affected but Provita seemed most susceptible. In the field, it was necessary to rogue plants which were infected with virus and with pathogens. Harvesting was done 10 weeks after transplanting. Tubers of all cultivars were small and ranged in size from 35mm to marbles. Most were in the 25mm to 20mm range – See Table 8.

Table 7. Single row on-farm White Potato varietal evaluation in Montserrat: Yields (t/ha) and gradeout % — Farrells and Richmond

Variety	Farrells Yield	Farrells Gradeout %	Richmond Yield	Richmond Gradeout %
Baraka	3.36	79	9.92	86
Bartina	10.75	90	12.08	95
Caspar	6.75	62	2.33	55
Concurrent	6.96	87	9.65	78
Desiree	7.46	51	9.92	83
Flamenco	2.79	68	-	-
Frisia	9.60	70	9.46	80
Mona Lisa	6.25	80	7.38	83

Table 8. White Potato from True Potato Seed — Tuber yields (g/row)

Cultivar	Plants	Tuber wt (g)
Provita	66	795
Atzimba	83	662
Estima	53	515
Avenir	58	500

Sprouting of all cultivars in storage was initiated 14 weeks after harvest. This material was put out in a varietal evaluation test in March 1985, however, the presence of virus disease symptoms in over 40% of the crop resulted in its being abandoned.

(iii) Tuber production from stem cuttings

The hormone treated cuttings commenced root initiation in 6 days while the untreated stems took 10 days. There was 100% take for the hormone treated stems and 92% for the untreated. Table 9 sets out time periods for the various stages compared with tuber production.

Yields from the two systems are compared in Table 10. Both varieties were affected by the potato virus complex which resulted in plant losses equivalent to approximately 25%. Extrapolated yields equated over 16t ha^{-1} ungraded potatoes for both varieties from stem cuttings and much higher from tubers.

Tubers were not graded, however, tuber quality from both treatments was generally poor with an unusually high proportion of mis-shapen and re-sprouted potatoes. This may have been a function of the heavy clay soil in which the observation was conducted.

Table 9. Time periods (days) in various stages of establishment of rooted cuttings and tubers of White Potato in Montserrat

	Stem cuttings	Tubers
Setting of seed potatoes	0	43
Cutting	14	-
Root initiation cuttings	22	-
Transplanting of rooted cuttings	43	-
Maturity	110	124

Table 10. Yield(t/ha) data comparisions of White Potato grown from stem cuttings and tubers in Montserrat

Variety	Extrapolated yields (t/ha) Stem cuttings	Tubers
Concurrent	16.1	22.9
Bartina	16.7	35.0

(iv) On farm monitoring

Only the most important elements of agronomic aspects of the on-farm monitoring exercise are reported here.

Land preparation:

All mechanised land preparation is done by the Ministry of Agriculture Tillage Division and as for all other crops is a standardised plough/harrow and ridge operation. The width of ridges or banks is fixed at 1m.

Planting and plant populations:

All farmers plant a single row on each ridge with seed spaced approximately 0.4m resulting in a plant population of 25,000 plants ha^{-1}.

Preparation of planting material:

Three of the farmers surveyed cut their planting material and in all cases suffered varying levels of the wilt complex earlier described. This occured even in situations where seed pieces were well cured and treated with fungicide.

Weed control/hilling up:

Done as a single hand hoeing operation. Up to three hoeings may be done during the life of the crop. The wide ridges and single rows suit the farmers purpose during these operations. No chemical weed control was used.

Fertilizing:

All farmers fertilized their crop, however practices varied considerably from the recommended triple application (at planting and two side-dressings) to a single application during the initial hilling up at 25 to 30 days. Two farmers used pen manure in the planting holes instead of inorganic fertilizer. Most farmers used the recommended 12:24:12 formulation, however none of the farmers surveyed applied the full recommended quantity and in most cases less than half was applied.

Pest and disease control:

Only two of the eight farmers surveyed owned or had free access to crop spraying equipment. All farmers were however, acutely aware of the need for a prescheduled pest/disease control programme and they either borrowed equipment or hired the services of the Ministry of Agriculture Plant Protection Unit. The most serious disease condition turned out to be the stem wilt condition caused apparently by a complex of pathogens including *Rhizoctonia* sp., *Fusarium* sp., and perhaps *Pythium*. Early blight, *Alternaria solani*, and late blight *Phytophthora infestans* were not major problems and appeared very late in the crop.

Cropping sequences and rotations:

The main potato crop is planted as a monoculture after any of the range of food and vegetable crops grown by the farmer. Efforts to avoid solanaceous crops prior to or after the potato crop are not always fulfilled. However, attention has been directed to the aroids and sweet potato as possible hosts of the pathogens responsible for the stem wilt problem earlier described.

General discussion

The work completed to date as well as the general observations made on-farm have provided useful indicators as to the direction the on-going research and development programme should take as well as modifications to the existing production techpack.

(i) Varietal adaptability trials will continue. The two promising varieties Bartina and Frisia, will be further tested in selected on-farm locations in the coming season alongside Desiree.

(ii) Stem wilt complex: Attempts to identify the causal organisms will be made. The effect of aroids as a previous crop to potato will be examined in relation to the incidence of the condition.

(iii) Plant populations are way below the recommended levels for small farm production. To the farmer, the current crop spacing means ease of weeding and hilling up, lower costs of planting material per unit area, but also higher weeding costs, lower yields and less efficient utilization of inputs. On-farm trials with narrower rows and double rows will be initiated.

(iv) Using cut planting material: It would seem advisable in the circumstances of ease of predisposition of cut seed tubers to soil pathogenes, to avoid this practise, and have farmers plant only whole tubers. Size of seed tubers is an important consideration, since farmers purchase seed by weight. Seed tuber production and carry over of material for use as seed must be cautiously approached because of the attendant problems encountered especially under tropical lowland environments.

Acknowledgements

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The valuable contribution of other members of the CARDI Country Team is also acknowledged.

References

Anon. (1950) Export commodities from Montserrat – 1950. Ministry of Trade and Production, Montserrat.

Anon. (1976) Potato trials in Montserrat W.I., Ministry of Agriculture, Montserrat: Technical files.

Bryan, J.E. Melendez, G. and Jackson, M.T. (1981) *Stem cuttings - A rapid multiplication technique for potatoes.* International Potato Centre, Guide Book. 1/3.

Government of Montserrat (1965) Ministry of Trade and Production report: Department of Agriculture.

Leeward Islands (1949) Annual Report of the Agricultural Departments. 6 pp.

Malagamba, P. *et al* (1983). *True potato seed - An alternative method for potato production.* International Potato Centre, CIP Series III.

Montserrat Department of Agriculture (1966) Annual Report 1966, Ministry of Trade and Production.

Van Uyen and Vander Zaag, P (1983). Vietnamese farmers use tissue culture for commercial potato production. *Am. Potato J.* 60 873-79.

PRODUCTION SYSTEMS RESEARCH: SOME METHODOLOGICAL CONSIDERATIONS

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ABSTRACT

The major limitation of traditional station-based research is its failure to account for the multiplicity of socio-economic and ecosystemic variables that determine the success or failure of the farmer. Production systems research however focuses on the farm and the farmer using station-based research to complement the farm-based work. This paper deals with the issues involved in the ex-ante analysis of the factors affecting farm profitability. These considerations result in the identification of research opportunities vis-à-vis cost of research and the definition of the domain of recommendations. The instruments used in this exercise are identified and briefly discussed. The ex-post analysis of the results of the research efforts using economic evaluation criteria lead to the selection of alternatives or modified systems which may improve the farm. Some of these economic criteria are discussed. The paper recognises the tremendous virtues of production systems research but notes the factors (political, social, economic) which influence the adoption of alternatives.

RESUMEN

La mayor limitación de la investigacion tradicional-en al sede (estación experimental) – es la falta de considerar la multiplicidad de variables socio-economicas y ecosistemáticas, las cuales determinan el éxito o el fracaso del agricultor. Sin embargo, la investigación de sistemas de la producción, concentra sus miras en la finca y en el agricultor utilizando, investigación-en la sedepara complementar el trabajo en la finca. Este informe trata de puntos involucrados en el análisis "ex-ante" de los factores que afectan las ganancias de la finca. Estas consideraciones resultan en la identificación de oportunidades de investigación en lo referente a, el costo de la investigación y la definición del "dominio de recomendaciones." Las técnicas y metodos utilizados en este ejercicio so identificados y discutidos brevemente. El análisis "ex-post" de los resultados de la investigación, utilizando un criterio economico de evaluación, facilita la selección de alternativas o sistemas modificados, lo cual mejora la finca. Algunos de estos criterios de la investigación de sistemas de producción, pero apunta los factores (políticos, sociales, economicos) que influyen la adopción de alternativas.

Keywords: Production Systems Research

The differences between conventional research (station-based) and on-farm research are significant. Experiment station-based research, the research strategy which most of us are familiar with, focuses on specific components of the farm e.g. selection of new varieties, herbicide trials, fertilizer trials, soil amelioration, animal breeding, energy nutrition, pasture germplasm etc. Usually these components are selected for emphasis because, in the judgement of the researcher, the specific components are the most limiting factors in improving farmer productivity.

The other important assumption of the researcher is that when the selected component is ameliorated farm improvement will necessarily result i.e. all other conditions will remain more or less the same. Those familiar with the experiences of farmers in their ongoing interaction with the sociopolitical systems and the agroclimatic variables will appreciate that the improvement of one component of the farm system, no matter how important, may not necessarily lead to increased productivity. In fact the dislocation created by the new improved component may well lead to a deterioration in farm profitability.

It is the importance which the researcher attaches to the whole farm system vis-à-vis its components that distinguishes on-farm research, farming systems research, production systems research or whatever it may be called from conventional experiment station type research.

The rest of this paper will focus on the tools and strategies used in production systems research to accomplish its major objectives:–

the improvement of the productivity of the whole farm given the social, economic, political and agro-climatic circumstances of the farm or farmer.

Steps in production system research. The logical steps (approach) in the production systems research are not unique to it but are much more critical to the success of production systems research than they are to that of station-based research (Fig. 1). Briefly, production systems research methodology consists of characterization, design and testing activities all leading to the selection of alternatives adjudged to be capable of improving farm productivity and/or profitability within the recommended domain.

Farm characterization: Characterization provides data for the ex-ante analysis which identifies the opportunities for research and the limitations. The aim of characterization is to take into account the circumstances of the farm or farmer which influence the factors limiting productivity and their possible solutions and to enable the researcher to take into account the variability among the groups of producers or farmers in order to make the investigation more efficient. These circumstances of the farm include:–

(1) Farmer's goals and his resource constraints.
(2) Markets for both products and inputs.
(3) Institutional issues such as land tenure, credit, extension.
(4) Governmental policies.
(5) Natural factors (climate, pests, diseases, weeds, soil etc.)

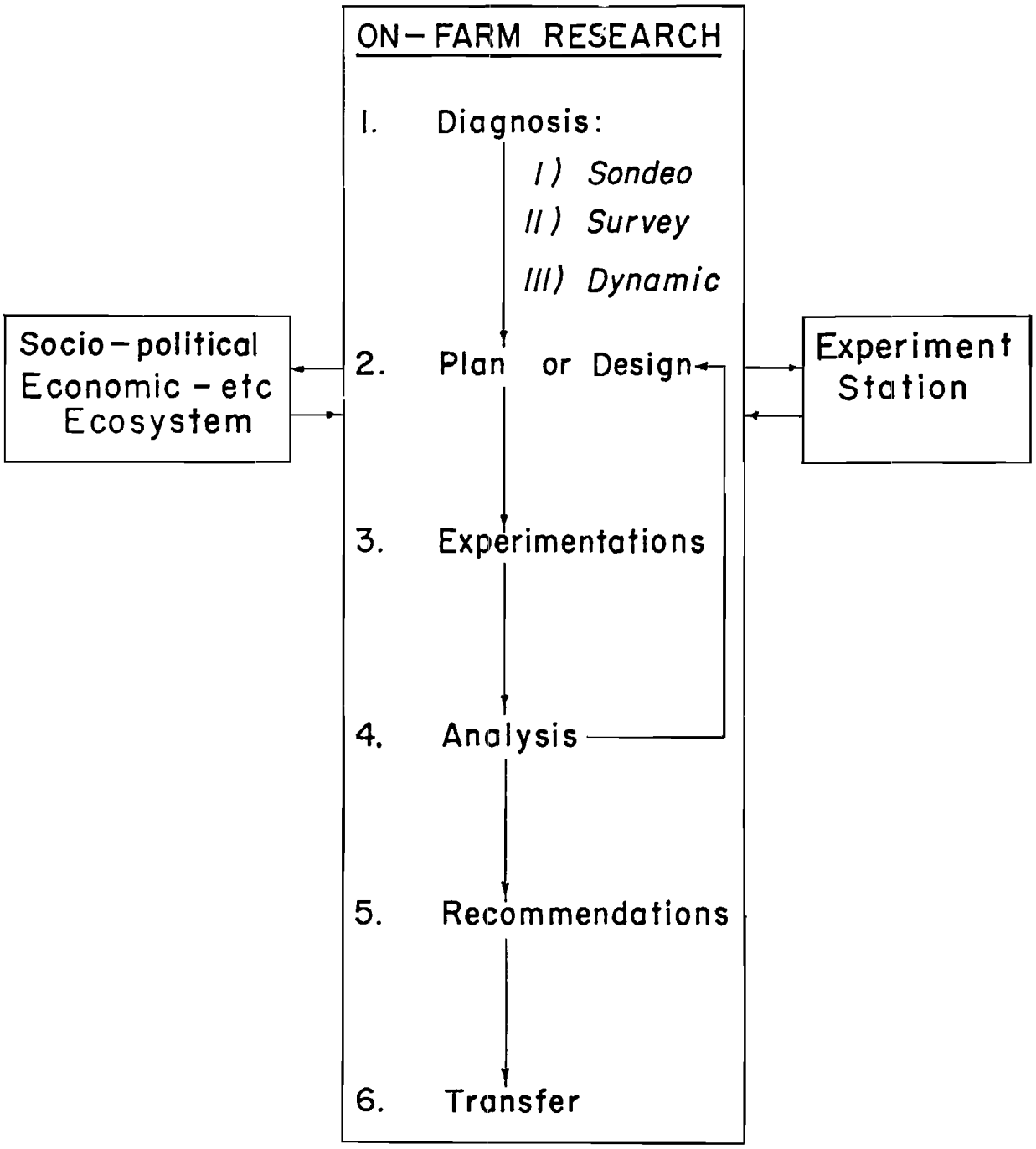


FIGURE 1: Schematic of Research Strategy

The researcher attempts to define the circumstances of the product as perfectly as possible. In this he uses a number of diagnostic strategies:–

(a) Sondeo)
) (static diagnosis)
(b) Survey)
(c) Monitoring studies over time (dynamic diagnosis)

These diagnostic approaches should not necessarily be seen as phases in the methodology, but as they should be, as aids in the investigation.

The Sondeo is an informal survey usually by a multidisciplinary team without the use of formal questionnaires. The Sondeo is a reconnaissance survey. Other sources of static diagnostic information are published and unpublished information from e.g. census, government publications, interviews with officers (vets, extension etc.) in the region of interest. Because all these sources of information refer to the farmer's circumstances at one point in time they are referred to as static diagnostic data.

The dynamic diagnostic information is obtained by gathering data on the relevant or specific aspects of the farm of interest over a given length of time. By so doing the changes on the farm due to voluntary or involuntary reasons are picked up in the farm system. This type of diagnosis indicates the importance of factors identified in the static diagnosis. Dynamic diagnosis also provides data for doing economic analysis where flow or time are important.

Both static and dynamic diagnosis provide information which enables the researcher to design or select alternatives aimed at improving farm productivity or profitability.

Information from diagnosis is used to identify the factors limiting production, their causes and possible solutions. Diagnostic information also helps in the planning of investigations. Solutions are first sought from existing knowledge (literature) and only when existing knowledge cannot provide solutions should experimentation be initiated. It is therefore obvious that adequately planned production systems research ensures that research resources are efficiently utilized and that duplication of research is kept to a minimum.

Simple statistical procedures like means, simple frequencies, cross tabulations and mean comparisons of two sub-populations (students t-test) are used in handling survey data to enable the researcher to identify factors that limit production or income and the interaction between these factors and the farmers current practice.

Domain of recommendation: A domain of recommendation is a group of farmers or producers whose circumstances, social or economic or ambient are sufficiently similar such that the same recommendation is appropriate for all of them.

> Domain of recommendation does not necessarily indicate zones; region of adoption or adaptation does.

The domain of recommendation is very important for the researcher and is within his competence to define. The domain of recommendation helps him (the researcher):

1) to identify groups of producers who have the same problems of production
2) To identify appropriate solutions for those problems
3) To select representative sites for experimentation
4) To analyse experimental data
5) To make recommendations for the use of a well-defined group of producers.

Criteria for selecting priorities for research:

1) The activities selected must be of great importance in influencing the income of the farmer
2) The activity selected must use important quantities of the scarce resources of the producers (land, labour, capital)
3) The problem or factor limiting productivity should be identified within the selected activity or potential source of loss and/or important to income
4) The problem or limiting factor should be common to a relatively large group of producers, or the domain of recommendation should be sufficiently large.

Selection of possible solutions: will involve consideration of:

1) The technical factors involved
2) Yield
3) Risk
4) Compatibility with the production system
5) Cost of the research.

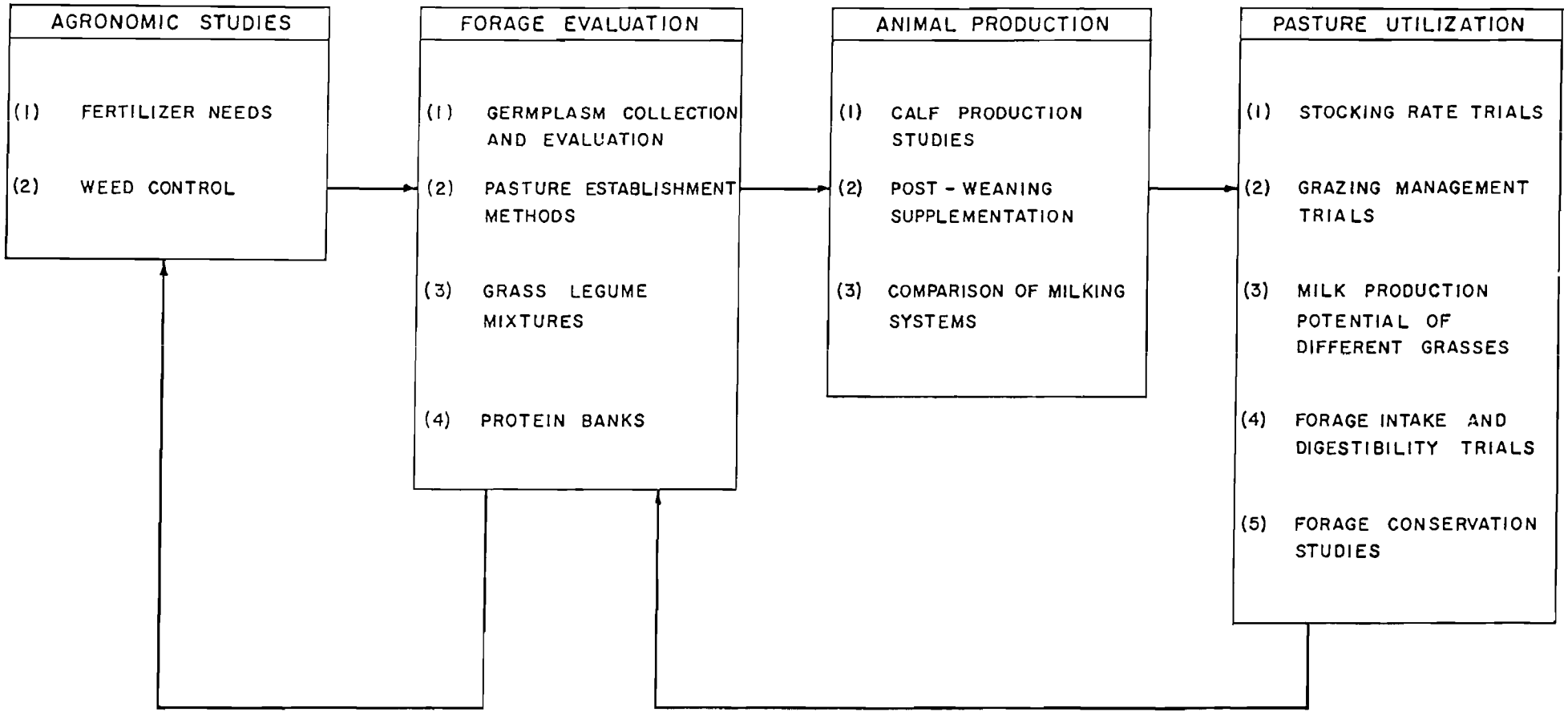
Design of alternatives: Farm characterization results in a clear definition of the existing system of production on the farm, the indentification of the factors limiting production and their potential possible solutions. Knowledge of all the above enables the researcher to design possible alternatives to the existing systems on the farm. The alternatives could be subjected to economic analysis (ex-ante) before the alternatives are tested to indicate their potential benefits or the opportunities for research. At this stage mostly simple economic analysis e.g. partial budgeting techniques are used to estimate the net benefits of the alternatives *vis-à-vis* the existing system(s).

On the basis of the ex-ante analysis of the alternatives the following may happen:

1) The alternatives appear to be definitely better than the existing system indicating the need for testing of the alternatives
2) The alternatives are worse than the existing system indicating the need to study the farm system further to identify the most important limiting factors and their possible solutions. These will lead to the design of new and probably better alternatives. In this case testing or experimentation is clearly not indicated.
3) Certain components of the alternative need to be researched. This will directly lead to component research of the experiment station type. The results of these will be fed back and may lead to the retention of, or modification of, the alternative as now conceived (Fig. 2).

The number of options could well be several fold. The points made above have been selected to highlight the complexities of the analytical effort needed before a decision is made to undertake additional expensive experimentation.

FIG. 2. DETAILS OF COMPONENT RESEARCH ACTIVITIES



Testing (Experimentation): Having chosen the promising or potential alternatives, these are tested under the farm conditions obtaining in the domain of recommendation. The results of this testing may lead to the further modification of the alternatives and further testing. Above all, the testing activities will provide real data with which to do ex-post economic analysis, the results of which will enable the researcher to chose an alternative to recommend for adoption.

Analysis: The results of the testing activities have to be subjected to a number of analyses:-

1) Statistical
2) Economic

Here again lies a very important difference between farm-based and station-based research. While in station-based research there is an inordinate emphasis on statistical comparisons, the importance of these is diminished in farm-based research. Economic analysis assumes a much greater emphasis. The reasons for this are rather obvious. Farm-based experimentation does not lend itself to the clearcut choices of randominzation, stratification, relplication and uniformity.

The importance of economic analytical tools in production systems research is so great that the following section is devoted to a brief consideration of some of the analytical tools used in the evaluation of tested alternatives.

Economic analytical tools: Some of the economic tools available for the evaluation of alternatives include –

1) Partial budgeting (net benefit estimation)
2) Production functions aimed at optimization of production or minimization of costs.
3) Costs including opportunity costs, fixed and variable costs
4) Prices, both at the farm gate and at the market
5) Marginal analysis
6) Cash flow analysis including the use of the tools of internal rate of return (information for this will usually become available from the dynamic diagnosis exercise). Cost of capital etc.
7) Linear programming – mainly used to allocate resources and select products.

One or a combination of these economic tools should be used in the choice of alternatives. For example the use of partial budgets is further discussed below:

Partial budgets are designed to analyse the profitability of proposed changes in the operation of a farm where the change is relatively small. Only the changes in **costs** and **income** are included in a partial budget and the total of additional costs and reduced income are compared with the total of additional income and reduced costs to find the estimated change in profit (net benefit).

Partial budgeting can be a very useful and powerful tool for analysing the many small or marginal changes in farm plans which a manager may wish to consider. The partial budget is an alternative to the use of the production function analysis but it should be appreciated that it is easier but also less precise. The production function approach is particularly useful for the evaluation of continuous data for example in the estimation of optimum fertilizer rates.

This presentation has argued that the evaluation and choice of alternatives should be based on the results of objective criteria derived from, for example, the use of standard economic tools. After all the farmers objective is to improve productivity and profitability.

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MARKETING TILAPIA: INNOVATION RESEARCH CONSIDERATIONS AND AN ANALYSIS OF NEW PRODUCT DIFFUSION AND ADOPTION

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ABSTRACT

This paper explores selected theoretical tenets of innovation diffusion/adoption in the context of product technology and product marketing. The approach discusses the need to integrate the underpinnings of demand-supply diffusion strategies and ecological variation factors in technological research. The introduction of tilapia as the topic of study provides a suitable model for ex post facto examination of the process of advancing technological innovation in under-developed settings. Data collected in a recent survey of trial tilapia consumers provides some possible predictive indicators for market assessments, consumer adoption studies and posits some relative issues of strengths and weaknesses for research design considerations. In sum, consumer adoption behaviors tend to depend on adequacy of the new product to substitute for both supply and demand situational requirements plus socio-ecological conditons.

RESUMEN

Esta presentación, explora reglas teóricas selectas sobre la adopción y difusión innovativa en lo que se refiere a la tecnología y mercadeo de productos. Se discute la necesidad de, integrar la base de la oferta y demanda de las extrategias de difusión y de los factores de variación ecológicos, en el campo de la investigación technológica. La introducción del pescado, Tilápia, como el tópico de estudio, ofrece un modelo adecuado para llevar a cabo indagaciones subsecuentes del proceso de innovaciones técnicas avanzadas, cuando se las encuentra en situaciones de subdesarrollo. Datos recolectados en una reseña de prueba, reciente, de los consumidores de la Tilápia, ofrecen algunas predicciones para, asesorar el mercado, para llevar a cabo estudios los cuales indiquen la aceptación que el consumidor muestre hacia el producto y, postulan algunos puntos relativos de las ventajas y desventajas que se encuentren, para asi considerar, diseños de investigación. En total, se deduce que la aceptacion y preferencias del consumidor dependen de la calidad del producto y de las condiciones socio-ecologicas y, para que asi, exsista una situación de oferta y demanda.

Keywords: Tilapia; Marketing

Over the past forty years or so a growing body of knowledge has and is being generated which directly relates to how new ideas or newly generated knowledge is being and should be utilized. One of the most broadly-used phrases for this area of inquiry is the "diffusion of innovations". The definition proposed by Katz *et al.* (1963) is one of the best for describing the concept of diffusion as it applies to the spreading of the acceptance of new ideas. They define diffusion as the cumulative acceptance over time of some specific idea, or practice by individuals, groups, or some other adopting unit, linked to specific channels of communication, to a social structure, and to a given system of values or culture. The idea, practice, or product is most commonly referred to as an innovation. This implies that the particular product being proposed for acceptance is not now being used by the particular adopting unit and is therefore perceived as "new" by them.

Within the forty-year span of diffusion of innovation interest, distinct thoughts about the concept have emerged, The earlier works on the conceptual framework conducted by Lionberger (1960), Katz (1960), and Rogers (1962) focused on the processes of adoption based on the conditional needs and attributes of individuals. Today, this kind of perspective is often referred to as the "demand-side" of diffusion/adoption. In more recent works, Brown (1981) introduces the "supply-side" perspective of diffusion/adoption. This approach views the innovation as a product that is limited in quantity and marketed to a specific target population. Finally, during roughly the same recent period in time, the factor of socio-ecological conditions emerged in context with the diffusion of innovation models. In effect, the socio-ecological conditions encompasses the overlooked aspects of societial influences (institutions and customs) which impact the overall success and/or failure ratio of adoption, regardless of which perspective (supply or demand) is taken. Works conducted by Demerath (1975), Blaikie (1975) and Weinstein (1975) underscore the significance of needed intimate familiarity and understanding of the social situations trying to be affected by the diffusion practitioner.

The existing body of knowledge pertaining to diffusion and adoption studies imply that certain tenets are necessary in the theoretical model. Traditional emphasis on the factor of communication has been softened to a great degree by more recent findings that suggest the importance of the "market and infrastructure perspective" (Brown, 1982). From this perspective, the emphasis or focus is placed on the process by which innovations and the conditions for adoption are made available to individuals or households. Thus, communications of the product and the product's distribution or availability constitute the overall process of diffusion. On the other side of the issue, the decisions to adopt the product are dependent upon social and/or economic characteristics and conditions.

Figure 1 depicts the conceptual model that was introduced by Brown (1982).

In sum, the review of literature on the topic of diffusion of innovation reveals perspective models which attempt to best explain and/or predict adoption behaviours. This exploratory study dealing with the diffusion and adoption of a food product (tilapia) examines the concept in a comprehensive manner in an effort to understand and rationalize an effective approach for research practitioners to follow in the development of future studies and programs on diffusion.

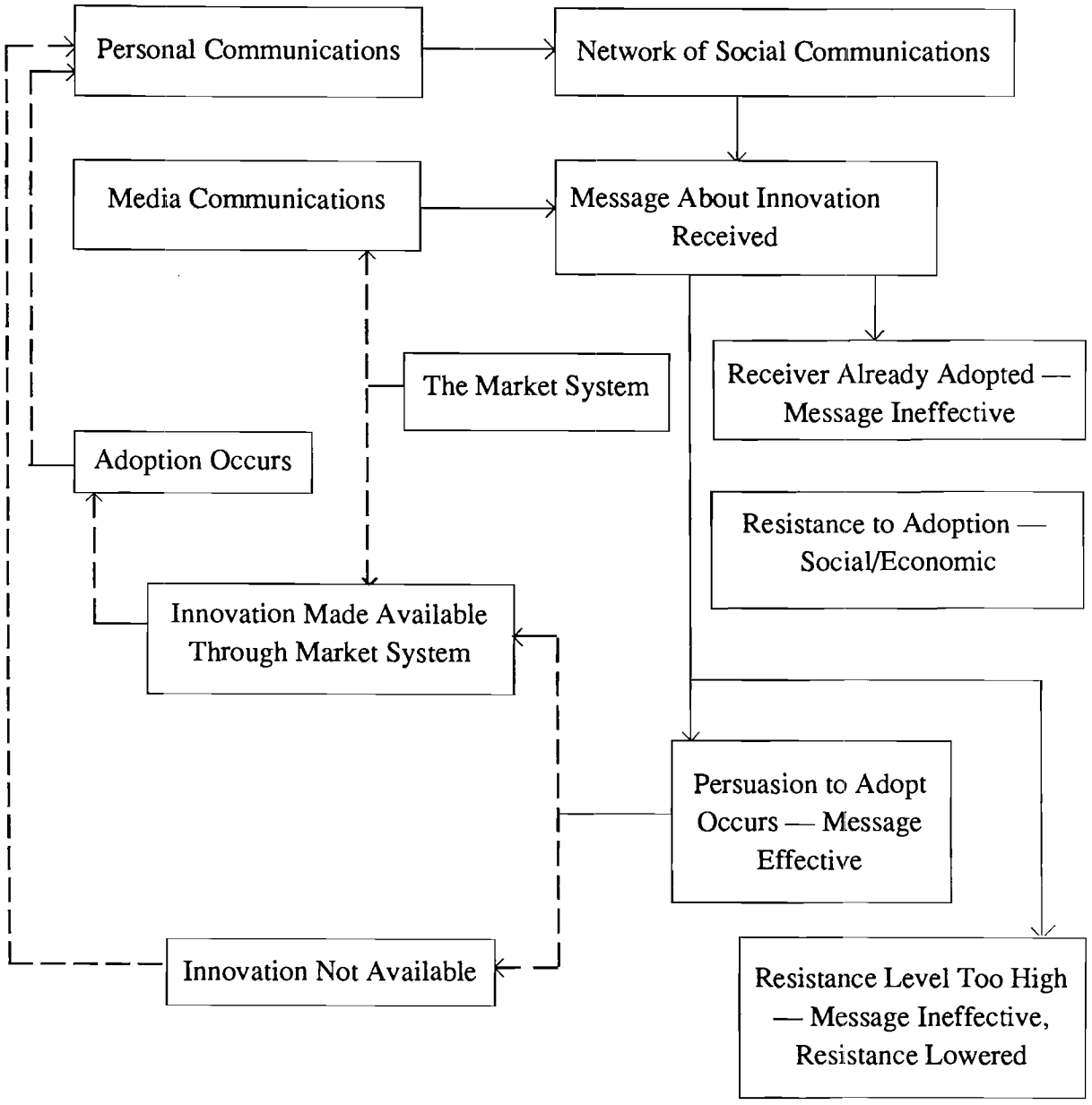

Figure 1: Flow diagram of the adoption perspective (Brown, 1982)

The application of diffusion/adoption research in tilapia marketing on St. Croix

The population of the U.S. Virgin Islands is in a unique situation. Exposure to innovations of all kinds is a routine of daily life, and such exposure is evidenced on the islands by previous adoption behaviour artifacts like commercial radio and cable television, advanced telephone systems, daily newspapers from New York and Miami, and a multitude of other items which grows longer every day. Even with the advanced daily opportunities of exposure to new products or innovations, there are limitations. These relate to availability, patterns of distribution, socio-economic characteristics and conditions. For example, cable television is present, but not available for everyone, and there are existing empty buildings that only a year or so ago represented modern discount department store technology. Who is responsible for these limitations and failures? The supplier? The consumer?

Rather than attempt to resolve specific answers to the aforementioned questions, researchers at the College of Virgin Islands-Agricultural Experiment Station CVI–AES decided to look more directly at a production issue they have been involved with for the past five years. Fish consumption in the Virgin Islands and throughout the Caribbean is a traditional, a normative and a natural (given the vast water resources) phenomenon. A survey conducted on St. Croix revealed 80% of a sample of 312 respondents ate fish at least once a week, and 68% indicated that they usually purchased their fish fresh. The issues of concern that prompted the Experiment Station to pursue aquacultural experiments focused on three points: 1) The assumption that fish was important to the local diets (as was confirmed by a 1979 survey and governmental censuses of commercial fishing activities in the Virgin Island waters), 2) The concern about ciguatoxin (human affliction of ciguatera poisoning from reef fishes) and 3) Reducing the high levels of fish and seafood importations.

The preliminary results of the aquaculture experiments in freshwater pond, cage, and closed-circuit (hydroponic) environments indicate that there is solid economic feasibility for production. The scientists are now expanding their research under saltwater conditions. One very important factor which has resulted from the years of study involves the type of fish that is best suited for aquaculture on the islands, both in terms of physical attributes and economic viability. The fish which emerged as the most appropriate was the tilapia, a hearty species which thrives under the conditions that are offered in the Caribbean environment. These fish are very common in the diets of many regions in Africa and Asia, but are not a familiar fish in the Virgin Islands. Thus, a new issue evolved from the production-related research; that which involves diffusion and adoption.

Factors Affecting Diffusion and Adoption on St. Croix

The contemplation of factors to consider under a multidimensional construct of diffusion and adoption offers a particular challenge when one must select the relative variables for study. Assessment of supply and demand, channels of communication, preference choices, and socio-economic situations pose an array of avenues for determining probabilities of adoption or rejection. As mentioned previously, the economic feasibility model of raising tilapia has been developed, but the actual commercial venture is yet to occur. Thus, there exists the absence of a supply-side case, and a demand-response case as well. Therefore, the exploratory study must rely upon data provided by a trial market which was established at the experiment station facilities.

A set of assumptions provided the guidance for the development of a survey instrument. Basically, these assumptions were reasoned from considerations of communications, socio-cultural, and socio-economic situations known to exist on St. Croix. Because of the size of the Island, established social networks, travel patterns and local news media utilization, it was assumed that sales information could be adequately disseminated to the general public via the local newspaper and the posting of signs on the primary traffic artery. Secondly, it was assumed, from official fishing activity statistics, that the probable trial sale customers would be consumers of pot-fish (rather than the commercial-restaurant buyers who purchase most of the locally-caught deepwater fishes) and would prefer the red variety of tilapia (because of its resemblence to snapper) over the black tilapia. Finally, it was assumed (because of taste tests conducted in 1979 which indicated a 96% taste acceptance) that a sample of repeat customers would indicate their priority of selection based on taste preference over other kinds of fish.

Methodology

During the winter through mid-summer of 1985 fish sales were conducted each Friday on the St. Croix campus of the College of the Virgin Islands. In order to facilitate a sampling of previous purchasers/consumers of tilapia, a decision was made to conduct a survey during the last month of sales. A survey was designed to collect data on social and ethnicity characteristics, consumer behaviors, personal preferences, and comparative opinions. From such data it was anticipated that analysis could give some indications of whether or not CVI-AES as a supplier, created its own clientele, whether or not there was an emerging demand for the food source offered, and whether or not a pattern based on socio-ecological conditions was being effected.

Sample characteristics

The sample taken over the four Friday sales days in June and July was relatively small with only 31 respondents. This sample of previous buyers represented 63% of the total customers during this buying period. Surveys were administered by Experiment Station personnel, and respondents were offered a free fish for their willingness to participate in the study. Selected characteristics of the sample are illustrated in the following table.

Table 1. Selected sample characteristics of talapia consumers (N=31)

Ethnic Identity:	West Indian	63%
	Puerto Rican	0%
	Continential	26%
	Asian	11%
		100%

Average number of persons residing in household	3.42	
Range	1–9	
Percent of people in household who like to eat fish	100%	
Average age of respondent	41.4 years	
Sex distributon of respondents	53% Female	
	47% Male	
Length of residency in the Virgin Islands	Entire Life	84%
	> 10 yrs.	8%
	> 5 yrs.	5%
	< 5 yrs.	3%

Patterns of responses on selected items/questions

The response patterns for items and questions relating to consumer behaviors, preferences and comparative opinions are presented in Table 2.

Table 2. Responses to selected items/questions on behaviours, preferences and opinions of talapia consumers

1. How do you prefer to buy fish?		
	Fresh	100%
	Live	58%
	Dressed	42%
2. How do you prefer to prepare fish:		
	Boiled	58%
	Fried	35%
	Other	7%

3. Type of fresh find normally purchased: Ranking

Snapper	1
Blue Runners	2
Dr. Fish	3
Grouper	4
Goat Fish	5

4. Average amount spent on fish purchases each month

Mean	$54.16
Range	$20.00 to $100.00

5. Taste comparison between tilapia and ocean fish:

Prefered tilapia	16%
Preferred ocean fish	26%
No preference	58%

6. Would you prefer to buy tilapia over other fish if it was available in the local markets?

Only if fresh ocean fish is not available	53%
Yes, even if fresh ocean fish is available	47%

7. Would you prefer to buy red-coloured tilapia to the fish you are buying now?

Yes	11%
No	26%
No preference	63%

8. Would you be willing to pay more if the tilapia were cleaned and/or filleted?

Yes	68%

9. How important are the following criteria in making your choice of which fish and how much to buy?

		Very Important	Somewhat Important	Not Important
a	Price	53%	15%	32%
b	Freshness	95%	5%	-
c	Taste	79%	21%	-
d	Convenience to market	26%	37%	37%
e	Ciguatera fish poisioning	32%	32%	36%

10. How did you originally find out about the fish sale at CVI-AES?

a	Informed by someone else	21%
b	Saw the signs on the roadway	47%
c	Read the notice in the newspaper	26%
d	Heard the radio announcement	6%

Implications from the responses

Exploratory studies such as this one on tilapia marketing are intended to derive fundamental tendencies or baseline information that will improve future research efforts. The implications from the responses to the Ten items measured provide certain directions and confirmations for diffusion/adoption research on St. Croix. However the data should not be generalized for the development of hypotheses or tests of hypotheses in other social settings.

With respect to preference questions (1,2,5,6,7), the sample generates a descriptive pattern which implies a strong preference for fresh fish (regardless of whether it is tilapia or ocean fish), that the sample population tends to be native and traditional (based on their preferred methods of fish preparation), and that there is only a slight preference for purchasing fresh ocean fish over fresh tilapia. In general, the overall response patterns indicate that there is not an overwhelming specific demand for tilapia, but there is a very high demand for fresh fish. A preliminary conclusion from this finding would be that some other factor (i.e., market shortages, increased cost for ocean fish, significant discounted market priced tilapia) is required to accelerate adoption.

The supply-side perspective is also somewhat vague with respect to the response patterns. Respondents indicated a willingness to pay more for a dressed product, but were not influenced significantly by other important supply-criteria considerations (question 9). Convenience to market and the availability of a poison-free product; plus, the opportunity to purchase a red variety of tilapia (which resembles their #1 choice in fresh ocean fishes), has little incentive for predicting adoption based on supply.

Responses to the awareness of the innovation (communication channels: question 10) did confirm the notion that the population has adopted a multidimensional use of information systems. The overall implication from the response to this item is that researchers and extension personnel can rely upon these media to effectively disseminate on the island.

Summary

It is evident by the exploratory study that generalizations and assumptions which emerge in the well-intended activities of research and extension can be hampered by shortcomings in a basic knowledge of socio-ecological conditions. The logic of a supply and demand approach to solving problems with innovation is often thwarted by the less-logical norms, values, customs, traditions and behaviors of people. Problem identification by professionals always carries some risks of being incorrect or misdirected. It is necessary to recognize that the more sophisticated the effort taken in problem identification, the more likely that the research conducted to resolve the problem will be effective and the more likely the research effort itself will be more efficient. It is unlikely, for example, that the high incidence of fish consumption on St. Croix, the high level of importation of fish, and/or the presence of a ciguatoxin threat will significantly affect an increase in the adoption of tilapia as a substitute food product. Basic information about the population's needs, attitudes toward changes in behaviours, and preferences can stimulate an entirely new perspective in problem-solving research. Social and situational analysis is a

highly-recommended pre-requisite for innovation diffusion/adoption practices.

In sum, the baisc tenets of the multi-dimensional model of diffusion/adoption appear accurate, as well as interdependent. The cyclical scenario generated by the tilapia study implies that supply and demand are not sufficient conditions to merit or predict absolute adoption, even with the effectiveness of communications. Social and cultural considerations appear to constitute an equal conditional status. Further study involving the tilapia issue will be conducted in 1986 to examine the effects of commercial marketing on adoption rates in St. Croix.

References

Brown, L.A. (1982) *Innovation diffusion: A new perspective.* Methuen, New York.

Busch L. (1979), Marketing tilapia in the Virgin Islands. *Proceedings of the 10th Annual Agricultural Food Fair of the Virgin Islands.* College of the Virgin Islands-Cooperative Extension Service, St. Croix, U.S. Virgin Islands.

Katz E. (1960), Communication research and the image of society: Convergence of two traditions. *American Journal of Sociology,* 65, 435-440.

Katz E., Levin M.L. and Hamilton, H. (1963) Traditions of research in the diffusion of innovations. *American Sociological Review.* April 27, 237-252.

Rogers, M. (1962) *Diffusion of innoviations.* The Free Press of Glencoe, New York.

DESCRIPTION OF ECHO'S SEEDBANK OF UNDEREXPLOITED FOOD PLANTS

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ABSTRACT

The National Academy of Sciences identified a large number of "underexploited" tropical food plants in the 1970s which should be more widely introduced. However, it is very difficult to obtain seed, especially if you are a development worker rather than a scientist. ECHO has developed a "working seedbank" which sends small packets of these seeds for trial at *no cost* to those working with small farmers as well as to the scientific community. This slide presentation will feature many of these less common plants, as well as a technique of shallow beds suitable for rooftop gardening. Our various services to those working with small farms in the tropics will be briefly described.

RESUMEN

En los años 70, la National Academy of Sciences (Academía estadounidense de ciencias) identificó muchas plantas tropicales alimenticias "sub-explotadas" que deberían ser cultivados de manera más amplia. Sin embargo, es muy difícil obtener semillas, sobre todo si uno es asistente de desarrollo y no científico. Por eso, ECHO ha elaborado un "banco de semillas" que envía paquetitos "prueba" gratuitos de estas semillas tanto a los que trabajan con pequeños agricultores como a la comunidad científica. Esta presentación de diapositivas mostrará muchas de estas plantas menos conocidas, así como una técnica que utiliza los semilleros poco profundos y que conviene muy bien a la jardinería en la azotea. Se describe brevemente los servicios que prestamos a los que trabajan en pequeñas fincas tropicales.

There has been considerable talk at this conference of the tension between our desire to help the small farmer on the one hand and our being evaluated primarily on the basis of publications on the other hand.

I can identify with this. I had a dozen or so publications while doing post-doctoral work at Purdue University. I received my due reward for the publication record. Several other scientists have used and referenced them in their work. However, some dealt with practical solutions to a major problem of Third World farmers. To the best of my knowledge, no Third World farmer or person working with them has implemented that work or even become aware of it.

It has been a delight to work at my present position at ECHO. One aspect of my job is to search out practical, applied information from folks such as yourselves, from publications and from development workers themselves. This is then written up in a newsletter called ECHO DEVELOPMENT NOTES. We send this to about 1200 folks. It is also sent by the Peace Corps to the 50 countries where they have volunteers. We have the satisfaction of knowing that information written today will be read in a couple weeks by folks in many countries who are working shoulder to shoulder with small-holder farmers on a daily basis. We even involve these folks in doing adaptive experimentation themselves.

ECHO is a nonprofit, Christian organization whose primary mandate is to assist workers of any Christian group in their outreach to the small farmer. In practice we extend this to any person who has such a ministry regardless of religious affiliation.

In addition to the newsletter, folks write to us with particular questions. Sometimes they can almost be funny. For example, a worker in Kenya wanted our recommendation for cactus for camel fodder. Someone in Botswana wanted advice on use of leaves of the leucaena tree as feed for his ostriches.

What are Underexploited Plants?

I especially wanted to share with this group about our "working" seedbank. The National Academy of Sciences identified dozens of food plants that had underexploited potential and should be tried much more widely throughout the tropics. They published this in two books: *Underexploited tropical plants with promising economic value* and *Tropical legumes; resources for the future.* These were distributed free throughout the world.

The only problem has been that it is usually terribly difficult to obtain seed. In fact, it is almost impossible for someone working in a remote site with small farmers. To be sure there were sources listed in the book. In most cases, these were scientists who had a grant to work on that plant in the mid 1970 s. You know how grants go. It is unlikely that you will still have money 10 years later. If you did, it is still less likely that it would include money to distribute seed all over the world!

ECHO is growing a great many of these plants on our 5 acre farm in southwest Florida. The seeds are stored in our seedbank and distributed free in small packets to folks working with small farmers (or scientists) for trials and evaluation. We do require that they report back to us with their results. To date we have sent seed to over 50 countries.

But you might be asking yourself why a missionary or Peace Corps worker would be interested in these unusual plants when there are many tropical food plants that grow so lushly and abundantly and are already well accepted?

The answer is that in most cases the person who can afford a reasonable amount of land in a good area that will grow good coffee or bananas or rice, is already growing these and making good money.

If he has questions there are research stations and extension agents to draw upon. The person that the development worker helps usually has only a small amount of land and is very often farming under very difficult situations where it is hard for him to make

any kind of a decent living. Suppose you had 5 acres of land that for much of the year was dry like this. What kind of help would you need to make a living for you, your spouse, and several children?

Another common problem is the farmer who may have land, maybe even a fair amount of it, but the soil is of very poor quality with very few nutrients and poor texture, such as the soil in a poor Haitian refugee community in the Dominican Republic.

Then there are those who must farm very steep land or in regions of exceptionally high rainfall. Perhaps some of these plants have special potential for areas where more common plants are not satisfactory. In the short term, they are likely to be consumed on-site rather than become commercially important. In the long term, some may take off like the potato did in Ireland.

A Description of Several Underexploited Plants

Well, what are a few of these plants like? If you lived in an arid region you might be interested in the **tepary bean** *(Phaseolus acutifoliuis)*. This bean is grown by the Indians in the Sonoran Desert in the Southwest of the United States. After there has been a flash flood in the desert and the waters have receded, they plant the bean. It does not need to rain again for them to get a crop. There is a good chance that the tepary bean could be planted while there were 1 or 2 rains left in the rainy season. The farmer might then be able to harvest a crop during the dry season when there are very few kinds of food plants available.

The beans are fairly comparable to the soup bean or navy bean with which you are probably familiar. ECHO has sent seed of the tepary bean to a number of people around the world. Only a few results have been reported to date. The best results seem to come from areas with somewhat alkaline soil.

The **winged bean** *(Psophocarpus tetragonolobus)* is a good candidate for growing in a rain forest. The pods can be eaten the same way as a green bean. They have four jagged edges which is where it gets the name "winged." In addition to its use as a green bean, all parts of the plant can be eaten. The mature seeds can be eaten like soybeans, and are just as nutritious. (However, they are not very good unless special techniques are used in preparation. We can provide information on this).

The leaves can be eaten like spinach. And when the plant is finally done producing, you can feed the tops to the livestock and dig up the roots where there are tubers that have ten times the protien of our Irish potato. When you remember that protein is the nutrient in shortest supply in the diets of many in the Third World countries, you realize what a difference winged beans could make.

The **jicama** *(Pachyrhizus erosus)* has a lot of potential as a cash crop. Of all the unusual plants that we have examined, I think that it has the greatest potential for southern tier U.S. gardens. The leaves and pods are not edible because they contain rotenone which is a natural insecticide. The edible part is the tuber that forms underground. It is eaten either raw with dip or hot sauce or cooked. When you cook an Irish potato it becomes soft, but when you cook the jicama it remains crunchy like water chestnut. For that reason they are used as a substitute for water chestnuts which are quite expensive.

The **egusi** *(Colocynthus citrullus)* is a plant which is important in large parts of central Africa. It looks much like a watermelon but there is a big difference in taste. The fruit of this plant is bitter and probably somewhat poisonous. So what part of the plant would you eat?

The egusi is grown for its seed. The seeds are larger than watermelon seeds and are eaten in soups, roasted or mashed up like peanut butter. A missionary recently sent ECHO a recipe for egusi pizza. Well, it is doubtful whether many people will eat egusi pizza, but it is a very nutritious food. The hulled seed contains 50% oil and 30% protein.

The **benzolive tree** (*Moringa oleifera* also known as horseradish tree, moringa or mallungay) is an amazing tree. Under good conditions it will even outgrow papaya. In the Philippines it is called "Mother's Best Friend." They strip the leaves and then cook and puree them, much as we do with spinach. This is then fed to babies. It is one of the highest green leaves in calcium and contains considerable amounts of other minerals and of vitamins and protein. Adults enjoy eating it in various kinds of dishes, also.

The pods grow about a foot long. Before they ripen you split them open and put the seeds and material inside of the pod into the stew pot. Like the winged bean every part is nutritious and high in protein.

The flowers bloom just about all year round. It is unusual in this regard and is a very good bee tree. A lady from Haiti told me that she would take the dried seeds of the benzolive, brown them on a skillet, mash them, then put them in boiling water and then collect a very fine cooking oil that would float to the surface.

A scientist working along the Nile wrote that he is using the seeds in water purification. After the floods the water is murky with suspended particles. Human feces and accompanying bacteria are often attached to the particles. By adding a crushed benzolive seed to roughly a quart of water and stirring, the water will become clear within a few hours. Most of the bacteria settle to the bottom with the sediment.

Amaranth *(Amaranthus hypochondriacus, A. cruentus)* is the underexploited plant that probably has the greatest possibility for becoming an important crop in the United States, if any of these plants become important there.

Both the grain and the leaves are edible. The grain is about a tenth the size of a grain of rice, yet there are so many thousands of these grains that you get very good yields.

In situations where subsistence farmers are working, the yields are comparable to corn. In a poor year they would be even better because amaranth is more tolerant of dry weather.

Chaya *(Cnidoscolus chaymansa)*, is sometimes called the spinach tree. This plant is very tolerant to dry weather. It also flourishes in Florida summers with heavy rainfall. I have never seen a chaya bush with either insect or disease problems. The part that is eaten is the leaves. The large leaves are cooked like spinach. It has a pleasant taste, though it is a bit chewy. This native of Mexico and Central America is also used to wrap tamales.

The **wax gourd** *(Benincasa hispida)* has a very attractive fruit. The Chinese call it the winter melon. The white chalky material on the outside is actually a wax that the plant produces and lays down on the surface of the gourd. This keeps microorganisms from successfully attacking it, thus you can store it for up to a year in the tropics without refrigeration. In taste it is similar to a summer squash though perhaps a little bit firmer.

Conclusion

In conclusion, perhaps ECHO can help you to get some of your best, most practical, applied results into the hands of small farmers. If you come across especially interesting information or seed for a specially adapted variety of a common or under-exploited food plant, get in touch with us. If you know folks who are working with small farmers on a daily basis and whose work might be strengthened by being in touch with ECHO, send us their address. We neither charge them or solicit money from them. If we can help you sometime with a small packet of seeds of the underexploited plants, drop me a line.

SOME REFLECTIONS ON THE RELATIONSHIPS BETWEEN AGRICULTURAL DEVELOPMENT AND AGRICULTURAL INFORMATION

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ABSTRACT

This paper gives a presentation of the relationship between production activities and information at first in the general context of human activities, then in the particular relation between agricultural information and agricultural development through research and extension.

The attitudes of information users and producers when they are negative are the first constraints to the development of information and consequently production. Many efforts have been undertaken to improve or to share better the circulation information. Those of UNESCO, FAO and others are discussed.

A presentation of the characteristics of agricultural information, of its importance to agricultural research, extension and development precedes some international systems such as FAO's AGLINET, AGRIS and CARIS and the Interamerican agricultural information system AGRINTER.

The feeling of the need of regional agricultural information activities is recalled before the presentation of the contribution of the INRA Centre for French Antilles and Guiana.

RESUMÉ

Cette communication donne une présentation de la relation entre activités de production et l'information d'abord dans le contexte général des activités humaines puis dans la relation particulière entre l'information agricole et le développement agricole à travers la recherche et la vulgarisation.

Les attitudes des usagers et des producteurs d'information, quand elles sont négatives sont les premiers freins au développement de l'information et par conséquence à la production. Beaucoup d'efforts ont été entrepris pour améliorer ou pour mieux partager la circulation de l'information. Ceux de l'UNESCO, de la FAO et autres organismes sont évoqués.

Une rapide présentation des caractéristiques de l'information agricole, de son importance pour la recherche, la vulgarisation et le développement agricoles précède celle de quelques systèmes internationaux tels que AGLINET, AGRIS et CARIS de la FAO et le système interaméricain d'information agricole AGRINTER.

Le sentiment du besoin d'activités régionales d'information agricole est rappelé avant la présentation de la contribution de l'INRA Centre Antilles Guyane.

RESUMEN

Esta es una presentación, primeramente, de la relación entre las actividades de producción e información en el contenido general de las actividades humanas y, despues, de la relación particular entre la información de agricultúra y el desarrollo agrícola a travez de la investigación y de la extensión.

Las atitudes de los usuarios y de los generadores de la información, cuando son negativas, son los primeros impedimentos hacia el desarrollo de la información y por lo tanto, hacia la producción de la información. Se han hecho muchos esfuerzos para mejorar o para compartir la información sobre la circulación. La UNESCO, la FAO y otros organismos son mencionados.

La presentación de las caracteristicas de la información agrícola, de su importancia para la investigación, la extensión y del desarrollo agrícola, precede aquellos sistemas internacionales de la FAO, como ser, AGLINET, AGRIS y CARIS y el Sistema Interamericano de Agricultúra, AGRINTER.

Antes de presentar la contribuición hecha por la INRA Centro de las Antillas Francesas y de la Guyana, la necesidad de tener un centro regional de información agrícola, es primeramente mencionada.

Every human activity, and, more particularly every production activity in relation with an economic purpose has a component of information. We need more and more information data to carry out anything we need to produce in our daily life.

Human activities have become more and more complex, there are more and more relationships, more and more interference between its various sectors, for instance between research, politics, production, international trade, etc. Planning, financing, preparation of projects request more and more information.

Because of this growing complexity of human activities, of production, of development, the access of information resources and their fast availability, the information mastery have become essential components of economics, of production mastery.

Information: Producers and Users

What is information? Information is knowledge which can and does circulate in a more or less well organized way between people or institutions.

Information, more exactly in the context of scientific research and commodities production, scientific and technical information is a basic need, a basic resource for research, production, development, technology transfer.

We have to remember that a person or an institution can be at one and the same time a producer, a user or an owner of information. Unfortunately people and institutions are not aware enough of this multiple position. That is why very often information resources are badly used and managed.

Attitudes and Policies Towards Information

The increasing importance of information resources may lead to various attitudes

- The producer or the user of information is unaware of its importance: he/she does not use properly and manage well the information he/she has, or has access to.

In fact, it is more and more difficult and expensive to own every bit of information. It is more important to have access to information even if we do not possess it. Because of that, the role and importance of information centres have been increasing.

A bad producer or user of information loses many possibilities of developing, of improving his activities.

- The information user is aware of the importance of documentation but has an egocentric behaviour and keeps it . In this situation, for instance in research activities, this information is not used by colleagues and is not useful for the scientific community.

- The last attitude we shall describe here is a quite positive one. The user or the owner is aware of the importance of the information owned or which he can have access to. Therefore he (or the institution) organizes information circulation and management to give the largest access or use.

The Situations of Scientific and Technical Information

The type of information and users we describe further in the case of agricultural information are the same ones in the general case of scientific and technical information but the importance of information has been perceived earlier and more widely in other activities like industry, modern technics and sciences like chemistry, biological sciences, etc.

Developed countries which have the mastery of production, have also worked to have the mastery of information and particularly this one of scientific and technical information. In developing countries, the institutions very often do not have the awareness of the importance of information or have not sufficient economic resources and trained information technicians to organize and manage their scientific and technical information.

Many institutions, for instance at the international level, United Nations, UNESCO, are aware that the weakness of information and documentation is a constraint to development. So they have several programs like UNISIST, information activities and systems. The final objective of these information activities and systems is to given better access to scientific and technical information so as to develop production, to improve human welfare in the fields of education, industrial development, health, etc.

A particular aspect of these modern information activities and systems is the standardization of the methodologies of the documentary tools to permit computerized processing, exchange between data bases, online retrieval, automatized and fast publishing of bibliographic documents.

The Faces of Agricultural Information

Agriculture is a more and more complex activity sector where information mastery is an important but not always well understood basic component.

What are the types of agricultural information? They are: bibliographic or documentary information, statistical information, technical information, current research information.

The types of users are: planners, public service personnel, policy makers, researchers, administrators, producers and extension workers.

The lack and weakness of agricultural information systems has been recognized as one of the causes of agricultural underdevelopment. Several international, regional or national agricultural organizations (FAO, IICA, etc.) have undertaken activities to improve agricultural information.

Presented below are some information systems established under the Food and Agriculture Orgainsation (FAO).

AGLINET: Worldwide network of agricultural libraries, AGRIS: International information system for the agricultural sciences and technology, CARIS: Current agricultural research information systems.

In Latin America and the Caribbean, several countries, regional and other international institutions are members of AGRINTER, the Interamerican system for agricultural sciences. AGRINTER has been supported by IICA, the Interamerican Institute for Cooperation on Agriculture. CIDIA (Interamerican centre for agricultural documentation, information and communication) located in the IICA headquarters, in San José (Costa Rica) is the coordinating centre for AGRINTER and an AGRIS input centre for Latin America and the Caribbean.

An original aspect of AGRINTER is the possibility of using AGRINTER coupons to pay for orders of documents. These coupons can be purchased in local currency in the national IICA offices and used to pay services requested from the information centres which are members of the AGRINTER Services Network.

An important characteristic of the information systems is that they work on a cooperative and voluntary basis. Many Caribbean countries are still not members of the AGRINTER system.

An important and urgent need of agricultural information which can be very profitable is the information on current agricultural research. Its interest should be obvious: it permits cooperation between researchers, it gives access to the current evolution or results of investigations, it may avoid duplicated studies.

During several technical meetings, like the CFCS meeting, the participants have felt and expressed the need to improve information exchange, the need of a current agricultural research information system for the Caribbean. Why these wishes could not become an objective which CFCS would support?

During the workshop on tuber crops held last July in Guadeloupe, the participants adopted the idea of information exchange through a future tuber crops research network. This proposition of information exchange was done by the Regional Unit of Documentation of the INRA Centre for French Antilles and Guiana.

An Institutional Contribution to Agricultural Information in the Caribbean: The INRA Centre for French Antilles and Guiana

We still have much to do to organize the circulation of agricultural information through the Caribbean but for many years the INRA Regional Unit of Documentation has been doing its best to give information and access to the Caribbean agricultural documents it has been receiving.

This Documentation Unit has settled documentary cooperation with many agricultural institutions of Latin American, the Caribbean and elsewhere particularly in the tropical area.

Among our activities, we have been publishing a reference bulletin which is mailed to many institutions. In this reference bulletin, we draw attention particularly the publications received from Latin America and the Caribbean, on documents which may be interesting for the Caribbean agricultural research and development.

The INRA Regional Unit of Documentation is a member of the AGRINTER system for the French Antilles and Guiana. It is also a member of the AGRINTER Services Network.

Biblography

ARBOLEDA-SEPULVEDA, O. (1982) Una accion compartida para agilizar el aceso a la informacion agricola. 13a Mesa Redondo AGRINTER, Cali (Colombia), 21–24 junio 1982. – Costa Rica: IICA-CIDIA, 14 pp.

ARISTIDE, R. (1977) AGRINTER: Systeme d'information agricole pour l'Amérique Latine et la Caraïbe. Proc. 14th Ann. Mtg. Carib. Food Crops Soc., Guadeloupe-Martinique, 27 juin–02 juillet 1977. Nouv. agron. Antilles–Guyane. 3 (3–4, pt. 1) 177 - 187.

ARISTIDE, R. (1982) Agricultural information in Latin America and the Caribbean: present situations and possibilities. Proc. 18th Ann. Mtg. Carib. Food Crops Soc. Barbados, 22–28 August 1982. 18. 86-97, (also in French).

PAEZ, G. (1979) Necesidad de un sistema de informacion agricola para el Caribe. Proc. 10th Ann. Mtg. Carib. Food Crops Soc. Dominican Republic, 5–11 Agosto 1979. 16, 433–444.

ANNEX 1

Members of SATIS (Socially Adapted Technologies Information Systems

APICA, Association pour la Promotion des Initiatives Communautaries Africaines, BP 5946, Douala Akwa, Cameroun.

ATDA, Appropriate Technology Development Association (Communications), PO Box 311, Gandhi Bhawan, Lucknow, 226001 UP, India.

ATOL, Aangepaste Technologie Ontwikkelinglanden, Blijde Inkomststraat 3000 Leuven, Belgium.

CAMERTEC, Centre for Agricultural Mechanization and Rural Technology, PO Box 764, Arusha, Tanzania.

CATER, Centro Andino de Technología Rural, Casilla 399, Loja, Ecuador.

CCTA, Comision Coordinación de Tecnología Andina, secretaría: c/o Centro Las Casas, Apartado 477, Cusco, Perú CCTA: hay que pedir sus publicaclones del Grupo Talpuy, Apartado 222, Huancayo, Perú.

CEMAT, Centro Mesoamericano de Estudios sobre Technología Apropiada, Apartado Postal 1160, Guatemala Ciudad, Guatemala.

CEPAS/INADES -Formation, Centre d'Etudes pour l'Action Sociale, BP 5717 Kinshasa Gombé, Zaire.

CESTA, Centro Salvadoreña de Technología Apropiada, Condominio Cuscatian, 306 - 25 AS y YCP, San Salvador, El Salvador.

CETAL, Centro de Estudios en Technología Apropiada para América Latina, Casilla 197 - V, Valparalso, Chile.

CORT, Consortium on Rural Technology, A - 89, Madhuvan, New Delhi 110092, India.

COTA, Collectif d'Echange pour la Technologie Appropriée, 18 rue de la Sablonnière, 1000 Bruxelles, Belgique.

CSV, Centre of Science for Villages, Mayan Sangramalaya, Wardha 442001, India.

Dian Desa, Jl Kallurang Km 7, PO Box 19, Bulaksumur, Yogyakarta, Indonesia.

ENDA Tiers Monde, Environnement et Développement du Tiers Monde, BP 3370, Dakar Sénégal. (faire toutes commandes au siège de Dakar).
ENDA América Latina, c/o Naciones Unidas, Apartado Aéreo 091368, Bogota, Colombia. ENDA Bombay, c/o Tata Institute of Social Sciences, PO Box 8313 Deonar, Bombay 40088, India.

ENDA Caraibes, Apartado 21000 Huacal, Santo Domingo, República Dominicana.

GATE, German Appropriate Technology Exchange, GTZ-GmbH, Postfach 5180, D 6236 Eschborn I, West Germany. (Associate Partner)

GRET, Groupe de Recherches et d'Echanges Technologiques, 30 rue de Charonne, 75011 Paris, France. (à partir du 2 avril 1984)

INADES Documentation, Institut pour le Développement Economique et Social, 08,BP 8, Abidjan 08, Côte d'Ivoire.

PCATT, Philippine Center for Appropriate Training and Technology, Manila Suite, 1416 F Felipe Agoncillo St. Ermita, Metro Manila, Philippines 2801.

SEMTA, Servicios Multiples de Technología Appropiada, Casilla 20410, La Paz, Bolivia.

SKAT, Swiss Center for Appropriate Technology, Varnbuelstrasse 14, 9000 St Gallen, Switzerland.

TDAU, Technology Development and Advisory Unit, University of Zambia, PO Box 2379, Lusaka, Zambia.

TOOL, Technische Ontwikkeling Ontwikkelingslanden, Mauritskade 61a, 1092 AD Amsterdam, Netherlands.

VTU, Village Technology Unit, c/o Commissioner for Social Services, PO Box 30276, Nairobi, Kenya.

WCC-CCPD, World Council of Churches, Peoples' Technology Desk, 150 route de Ferney, BP 60, 1211 Genève 20, Suisse.

THE BIOLOGICAL CONTROL OF SUGAR CANE, VEGETABLE AND OTHER CROP PESTS IN BARBADOS AND THE EASTERN CARIBBEAN ISLANDS

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ABSTRACT

Biological control of insect pests in the Caribbean dates back to the early 1900 s. In spite of many failures, several parasites and predators have been successfully established in Barbados and the Eastern Caribbean Islands, for the control of crop pests. Some have provided complete control, while the others have reduced the pest populations considerably and have paved the way for further introductions, and ultimately the economic control of those pests.

In 1974 the biological control of insect pests of horticultural crops in Barbados was reported. Since then a number of other natural enemies were established in Barbados and the Eastern Caribbean islands.

This paper discusses the biological control of the major pests of sugar cane and of some commonly grown crucifers, cucurbits and vegetable crops in the Eastern Caribbean.

RESUMEN

El control biológico de insectos plaga, en el Caribe se llevó a cabo desde los años 1900, en las islas de Barbados y en las del Caribe Oriental. A pesar de muchos fracasos, exsiste un gran número de parásitos y predatores, los cuales se han establecido con gran éxito para la represión de plagas en los cultivos. Algunos de ellos ofrecen un control completo, minetras que los otros han abierto el comino para nuevas introducciones y con miras ultimamente de obtener un control económico de dichas plagas.

En la isla de Barbados en el año 1974, se anunció el control de insectos plaga en los cultivos horticolas. Desde entonces un número de otros enemigos naturales se establecieron en la isla de Barbados y en las islas del Caribe Oriental.

En esta presentación discutiremos el control biológico de algunas de las mas importantes plagas de la caña de azucar y de algunos cultivos comunes, como ser, los crucíferos, cucurbitos y hortalizas, en las islas del Caribe Oriental.

The use of natural enemies for the control of insect pests on sugarcane, vegetables and other crops in the Caribbean has a long history. Investigations on biological control of insect pests in Trinidad and Tobago dates back to the early part of the century, when, following outbreaks of sugarcane froghoppers in 1906–1908, an entomologist, Mr. F.W. Urich, was appointed and Dr. L.W. Gough from England was brought to Trinidad to study the problem. After preliminary investigations, the Reduviid bug *(Castolus plagiaticollis)*, a predator of froghopper in Mexico, was introduced in 1911 (Bennett, 1975). The work continued for several years, with some unsuccessful attempts being made to augment the indigenous natural enemies, viz., egg-parasites, predators (Syrphids) and the Green Muscardine Fungus *(Metarrhizium anisopliae* (Metch.)*)*.

In 1928, J.G. Myers, an entomologist from the parasite laboratory of the Imperial Institute of Entomology, at Farnham Royal (now the Commonwealth Institute of Biological Control, CIBC), arrived in the West Indies to explore the possibilities of biological control of insect pests: he provided valuable information on the major insect pests and their natural enemies (Myers, 1931). The Amazon fly *(Metagonistylum minense* Tns.*)* was discovered and introduced by Myers into Guyana, and provided excellent control of the sugarcane mothborer *(Diatraea saccharalis* (F.)*)*. Subsequently the parasite was introduced and established in St. Lucia, Guadeloupe and Venezuela, but it failed to establish in Trinidad.

Barbados, which is well known for its sustained efforts for the biological control of sugarcane and other crop pests, started an organized biological control programme against sugarcane moth-borer in 1927 under the direction of R.W.E. Tucker. This was continued by other entomologists and remains a very viable programme.

Tucker (1936 and 1954) reported the introduction and establishment of various natural enemies against sugarcane moth-borer, sugarcane root-borer *(Diaprepes abbreviatus* (L.)*)* and white-grub *(Phyllophaga (=Clemora) smithi* (Arrow)*)* on sugarcane; the pink bollworm *(Pectinophora gossypiella* (Saund.)*)* and a leaf defoliator *(Anomis (=Alabama) argillaceae* (Hub.)*)* on cotton; cottony cushion scale *(Icerya purchasi* (Mask.) on citrus, pigeon pea and other plants; cabbage white butterfly *(Ascia monuste monuste* (L.)*)* on cabbage; coconut scale *(Aspidiotus destructor* Sign.*)* and white fly *(Aleurodicus cocois* Curt.*)* on coconut; and against the house fly *(Musca domestica* L.*)*.

Between 1964 and 1984, a large number of natural enemies were introduced into Barbados against various pests, from different parts of the world, and those which were successfully established were subsequently introduced into the Windward and Leeward Islands.

Some of the insect pests against which natural enemies were introduced are discussed below:

Sugar-cane Pests and their Natural Enemies

Sugar-cane Moth-borers *(Diatraea saccharalis* (F.)*)*

Diatraea saccharalis is present in all sugar-cane growing countries in the region, causing substantial crop losses. In Barbados, between 1963 and 1966, the average sugar loss due to the moth-borer damage was 13,911 tons per year (Alam *et al*, 1971). *Diatraea centrella* is another important pest of sugar-cane in the Caribbean, and has been reported from Trinidad, St. Vincent, St. Lucia, Grenada, Guyana and Suriname, causing heavy crop losses. In Guyana where *D. saccharalis* was successfully controlled by the introduction of Amazon fly *(Metagonistylum minense* Tns.*)*, *D. centrella,* which is relatively resistant to the

attack of this parasite, became a major pest and accounts for more than 90 per cent of the borer damage (Bennett, 1969).

Because of the perennial nature of the crop, the overlapping generations of the pest throughout the year, and a number of alternate host plants present in and around the sugar-cane fields, chemical control has not been considered suitable in the West Indies.

In most of the Caribbean islands, and particularly in Barbados, efforts have been concentrated on biological control for the pest. A regular biological control programme against *D. saccharalis* was started in 1927, when the indigenous egg-parasite, *Trichogramma exiguum* Pinto and Platner *(=T. fasciatum* auct. = *T. minutum* auct.*)*, along with a number of strains or species imported from various Caribbean islands, were mass-bred in the laboratory and released in sugar-cane fields annually for some 32 years. Initially, the campaign was considered to be a success. Between 1930 and 1934, the percentage of joints bored was reduced from about 33% to about 15%. During 1959, when the parasite releases were stopped, there was no increase in the moth-borer damage, suggesting that the parasite had attained its maximum potential and was not able to further reduce crop damage.

Between the 1930 s and the 1960 s, a number of egg, larval and pupal parasites were introduced from India, Pakistan, Uganda (East Africa) and the Caribbean (Alam *et al.*, 1971). Of these, two larval parasites, *Cotesia (=Apanteles) flavipes* (Cam.) from India and *Lixophaga diatraeae* (Tns.) from the Caribbean, became established and provided excellent control (Alam *et al.*, 1971 and Alam, 1980). Since 1968, the percentages of joints bored have decreased significantly, and have remained below 5% (the level at which no further control measures are required), except in 1974–75 when it increased slightly.

Since 1968, Barbados has earned an added revenue from sugar of B'ds $1,026,300 to 7,214,400, averaging $2,573,870 per year, from the reduction in damage and losses. The great variations in additional earnings have been due to variations in the commodity price and to the size of the crop.

In St. Vincent, sugar-cane was planted on some 2,000 acres in the 1950's, but cultivation ceased in 1962. In 1975, the crop was re-introduced and at present (1985) some 1,500 acres are under sugarcane. Between 1975 and 1978, some 75 acres of sugarcane were planted at four different localities. The canes were heavily attacked by *D. saccharalis* and *D. centrella*. A survey conducted during February and May 1978, revealed some 75% of stalks and 53% of joints bored.

In February 1978, some 650 adults of *C. (=A.) flavipes* were carried from Barbados and released in a 58 acre plot on the Windward side of the island. The first parasite recovery was made in May 1978, when 31.6% *Diatraea* larvae were parasitised. To augment the existing parasite population and hasten its spread, a further 600 *Cotesia* adults from Barbados were liberated.

Since 1978, with expansion of the acreage under sugarcane, the parasite has also spread and maintained high levels of parasitism, ranging from 24% to 73%, depending on the time of the year.

In May 1985, when the young (plant and ratoon fields) and mature cane fields were surveyed, it was found that *D. centrella* was more abundant in young cane fields, while *D. saccharalis* was more prevalent in mature cane fields. The most important observation made was that, although *C. flavipes* is generally considered to prefer *D. saccharalis* larvae elsewhere, it was more abundant on *D. centrella* larvae, which are generally regarded to be resistant to this and other parasites (Beg and Bennett, 1974). The field parasitism levels for the two species were 13 to 33% for *D. saccharalis* and 67 to 100% for *D. centrella*.

Since the establishment of *C. flavipes* and the increase of the populations of the indigenous natural enemies, particularly the egg-parasites, *T. exiguum* and *Telenomus alecto* Crawford, along with some other biotic (predators and pathogens) and abiotic (wind, water/rain) factors, the moth-borer populations in St. Vincent have been reduced below the economic level of 5%. Between 1978 and 1984, the average levels of joints bored were: 53% in 1978, 19% in 1979, 29% in 1980, 15% in 1981, 8% in 1982, 5% in 1983 and 3% in 1984.

Based on the 1981 total of approximately 1,500 acres of sugarcane, and an average joint infestation of 15%, the Sugar Industry lost about 400 tons of sugar (based on 1.8 tons of sugar/acre, and 0.5% loss of sucrose for every 1% joints bored) during that year. However, during 1984, these losses were reduced to about 67 tons of sugar, which is indeed a substantial saving!

In St. Kitts, Yaseen (1979) reviewed the status of the moth-borer, *D. saccharalis* and its control by the Cuban fly, *Lixophaga diatraeae* (Tns.), and the factors responsible for the increase in the pest populations, which were due mainly to changes in cane varieties, cultural practices and weather conditions. Because of the general increase in the pest populations, the Commonwealth Institute of Biological Control (CIBC) recommended, in the early 1970's, the introduction of another larval parasite, *C. (=A.) flavipes* from Barbados. The parasite was successfully established and provided additional control of the pest. In 1979, the Caribbean Agricultural Research and Development Institute (CARDI) assumed the responsibility for monitoring the pest/parasite situation in St. Kitts, and further releases of *C. flavipes* were made. During the period 1981 to 1984, joint infestation surveys conducted in the island showed that the pest population never exceeded the critical level of 5%. Average annual joint infestation ranged from 2.2 to 3.4%. The two larval parasites, *C. flavipes* and *L. diatraeae*, were consistently recorded in cane fields, although populations were low, mainly due to low host density.

C. flavipes was also successfully introduced into Jamaica and Trinidad (mainly through CIBC, Trinidad), where, along with some indigenous natural enemies, it had provided good control. In Trinidad, during 1980 and 1981, the range of parasitism on *D. saccharalis* was 50–90% (des Vignes, 1985). In Jamaica, between 1980 and 1984, the indigenous larval parasites, *L. diatraeae* and *Agathis stigmaterus* (Cresson), attacked on average of 21% *D. saccharalis* larvae, whereas, during the same period, the parasitism by *C. flavipes* ranged from 0–50% in individual fields. The combined level of parasitism rose from 21% by *Lixophaga* and *Agathis*, to 34% in fields where *Cotesia* was introduced (Falloon, 1985).

Sugar-cane Mealybug *(Saccharicoccus sacchari* (CKll.)*)*

This pest is widely distributed in sugar-cane growing countries throughout the World. In the Caribbean, the pest is distributed in both the Greater and Lesser

Antilles. In Barbados, although generally it has not been a serious pest, it has caused considerable damage in low rainfall areas, particularly during long, dry spells, and damage was more pronounced when associated with moth-borer attack. Although a few indigenous natural enemies were found, their populations were too low to substantially reduce the mealybug infestation.

During the 1970 s an Encyrtid parasite, *Anagyrus saccharicola* Timb. from Uganda (East Africa), was successfully introduced and established in Barbados. Since then the parasite has reduced the pest population by over 90% in the field, and has kept it under excellent control.

A. saccharicola was also introduced into St. Vincent and St. Kitts, where it quickly became established and has provided good control. In the 1970 s, at the request of the Sugar Industries in Guyana and Jamaica, the parasite was supplied from Barbados. Initial recoveries from Guyana were reported by the entomologist from GUYSUCO, but the present status in both countries is not known.

Sugar-cane Root-borer *(Diaprepes abbreviatus* (L.)*)* and Brown Hard-back *(Phyllophaga* (=Clemora) *smithi* (Arrow)*)*

Both these pests are known to have attacked sugar-cane in Barbados for almost 100 years. Usually, after long droughts, the pest appears in epidemic proportions causing heavy crop losses. Fennah (1976, pers. comm.) stated that "this may be due to the fact that an unusually long drought prohibits the adults' emergence. When rain falls after such a drought a massive synchronous emergence occcurs, which swamps the natural control factors".

Tucker (1936) reported the introductions of *Tetrastichus haitiensis* Gahan, *Ufens osborni* Dozier and a *Horismenus* sp. from Puerto Rico and Haiti, against *D. abbreviatus; Campsomeris tricincta* (F.), *Campsomeris trifasciata* (F.), *Myzinum ephippium* (F.), *Myzinum haemorrhoidale* (F.) and *Myzinum xanthonotum* (Roh.), against brown hard-back; and *Ignelater (=Pyrophorus) luminosus* (Illiger) from Puerto Rico, and *Bufo marinus* (Gaint toad) from Guyana, against brown hard-back and root-borer. Of these, *I. (=P.) luminosus* and *B. marinus* became established.

During 1975–84 a number of egg-parasites, viz., *T. haitiensis, Tetrastichus gala* Walker (wrongly identified as *T. marylandensis* Gir.), from Jamaica; *Tetrastichus* spp., from St. Vincent and Montserrat and *Fidiobia citri* Ashmead and *Brachyufens (=Ufens) osborni* (Dozier) from Florida, were introduced against *D. abbreviatus.* All these parasites attack the host eggs when laid between citrus leaves, where these can easily penetrate with their ovipositors, but these parasites have not parasitised eggs laid on sugar-cane leaves, the tissues of which are much harder for these tiny wasps to penetrate with their ovipositors.

During 1984, an entomogenous nematode *(Neoaplectana glaseri)* was obtained from the United States Department of Agriculture (USDA) laboratory in Orlando, Florida, and is being multiplied in the laboratory in Barbados. From the small applications made in sugarcane fields, some recoveries were made. Further work is in progress.

Sugar-cane Jumping Borer *(Elasmopalpus lignosellus* (Zell.)*)*.

The attack of sugar-cane jumping borer is usually associated with the pre-harvest burning of sugar-cane, but recently infestations were recorded in plant cane fields, where the trash cover was poor. In many Caribbean islands, viz., Trinidad, St. Vincent, Antigua. St. Kitts, Guadeloupe, Jamaica and the Bahamas, where pre-harvest burning is a regular practice, the young, germinating tillers are heavily attacked by the pest, producing miniature, dead hearts. However, in Guyana, in spite of widespread burning of sugarcane, jumping borer is not a problem. It seems that, in Guyana, the high moisture content in the fields (in many cases cane stumps are submerged in water), prevents the pest from laying its eggs at the base of germinating tillers.

In Barbados, the pest attacks 24–57% (average 36%) of young tillers. In low rainfall areas, particularly during long, dry spells, such fields become a total loss and need replanting (Alam and Gibbs, 1979).

In Barbados, two larval parasites, *Stomatomyia (=Plagiprospherysa) trinitatis* (Thompson) and *Eucelatoria australis* Townsend, attack some 40% of the pest population. An Ichneumonid, *Macrocentrus* sp., was introduced from Trinidad, but it did not become established (Alam and Gibbs, 1979). However, with the reduction in sugar-cane burning, jumping borer is no longer a serious problem in Barbados.

In Jamaica, where the pest is widespread, some eight parasite species attack the eggs and larvae in the field, and their overall parasitism was 7% in 1974 and 14% in 1975 (Falloon, 1978). Some of these natural enemies could be introduced where the sugar-cane jumping borer is a persistent problem.

Vegetable Crop Pests and their Natural Enemies

Crucifers (Cabbage, cauliflower, radish and other related crops)

In Barbados, some 20 insect species attack these crops. The pests of real economic importance are diamond-back moth *(Plutella xylostella* (L.)*)*, cabbage white butterfly *(Ascia monuste monuste* (L.)*)* and cabbage semi-looper *(Trichoplusia ni* (Hubner)*)*. In Trinidad, cabbage bud-worm *(Hellula phidilealis* (Walker)*)* also causes heavy economic losses.

In the Caribbean in general, and in Barbados in particular, a number of indigneous natural enemies have been recorded, but these do not provide adequate control. As a result, a number of exotic, natural enemies have been introduced from India, Pakistan and the Eastern Caribbean islands against these pests. Some of these have established in Barbados, and later in the other Caribbean islands, and have provided good control.

The Diamond-back Moth *(Plutella xylostella* (L.)*)*

Diamond-back moth is the most serious pest of cabbage, cauliflower and other related plants (Alam, 1982), causing heavy economic losses. In the entire Caribbean, a wide range of pesticides are used at short intervals to control the ravages of this prest, creating new ecological and biological problems. To reduce the dependence on chemical pesticides, a number of parasites obtained from the overseas were tried in Barbados. Of these, two species. (i.e. *Cotesia (=Apan-*

teles) plutellae (Kurdj.) from India and *Tetrastichus sokolowskii* Kurdj. from India, St. Vincent and Montserrat, W.I. have permanently established. More recently, *Diadegma eucerophaga* Horstmann, imported from Pakistan, showed early signs of establishment, but persistent applications of pesticides did not allow the parasite to establish permanently.

At present, *C. (=A.) plutellae* is widespread in Barbados. The estimated annual average range of parasitism between 1971 and 1984 was 18 to 56%. It has been successfully introduced into the Windward and Leeward islands. In Antigua, St. Kits and Nevis, up to 75% of *Plutella* larvae are parasitised.

T. sokolowskii, indigenous to the Eastern Caribbean islands, was also introduced into Barbados from India, St. Kitts and Montserrat. Following releases, it was recovered from many cabbage fields. The levels of parasitism recorded were: 68–100% (average 86%) in 1976; 26% in March and 13% in April, 1980; 9% in 1982 and only 1% in 1983. The great variations in parasitism levels over the years are possibly due to the persistent use of pesticides against various cabbage pests, to which this parasite is more prone, compared to *Cotesia*, which has apparently developed a certain degree of resistance to the common pesticides used in Barbados and the Eastern Caribbean islands.

Cabbage Semi-looper *(Trichoplusia ni* (Hubner)*)*

This is not normally a serious pest in Barbados, but occasionally it attains high populations, causing serious defoliation which necessitates the use of pesticides. During heavy infestations, the pest is attacked by a number of indigenous egg, larval and pupal parasites. A small percentage of eggs is attacked by a *Trichogramma* sp., *Cotesia (=Apanteles)* sp. prob. *plutellae* (Kurdj.) attacks about 17% of young larvae; *Glyptapanteles (=Apanteles)* sp. *(vitripennis* group), a gregarious larval parasite, attacks 0.5 to 2%, and *Euplectrus platyhypenae* How., a gregarious ectolarval parasite, attacks 4 to 50% (Avg. 19%) of young to full-grown larvae. *Brachymeria* sp., a pupal parasite, was reared from 0.5% to field-collected pupae. Two Tachinid larval-pupal parasites, *Winthemia* sp. nr. *pinguis* Fab. and *Winthemia* sp. ? *pyrrhopyga* (Wied.), jointly attack 20 to 36% pest population.

An indigenous species of a polyembryonic, egg-larval parasite, *Copidosoma (=Litomastix)* sp. nr. *truncatellum* (Dalman), attacks 0.5 to 5% of the pest population. A related species of this polyembryonic parasite, *Copidosoma (=Litomastix)* sp. *(truncatellum* group*)*, was introduced from India. This parasite attacks an average of 26% of the semi-looper population on cabbage (Alam, 1982). The parasite has also been introduced into the Leeward and Windward islands.

Cabbage White Butterfly *(Ascia monuste monuste* (L.)*)*

Cabbage White Butterfly remains active throughout the year in Barbados, although, through the greater part of the year, its populations remain low. During the rainy season, it may reach outbreak proportions, when the number of larvae per plant range from 20 to 100, defoliating the plants completely. It is widely distributed in the Greater and Lesser Antilles, South and Central America, and in the U.S.A. It feeds on a large number of cultivated and wild plants (Alam, 1982).

During outbreaks, the pest is attacked by a number of parasites, predators and pathogens. A Tachinid, *Phorocera* sp. ? *parviteres* Aldr. attacks about 14% larvae; *Brachymeria ovata* Say. parasitises an average of 36% pupae on cabbage. A small percentage of eggs is attacked by a *Trichogramma* sp. During the rainy season, when the humidity is high, a Polyhedrosis virus kills some 20% full-grown larvae and 95% pupae.

In Barbados, Tucker (1936) reported the introduction of *Apanteles glomeratus* (L.), a larval parasite, and *Pteromalus puparum* L., a pupal parasite. Alam (1982) reported the introduction of two larval parasites, *Apanteles* sp. and *Horogenes* sp., and of a pupal parasite, *P. puparum* from Pakistan. *A. glomeratus* from Canada, successfully parasitised the *Ascia* larvae both in the laboratory and the field, and, after releases, a few field recoveries were made. However, the establishment was not permanent. *Apanteles* sp. (from Pakistan), although it stung young *Ascia* larvae when placed near them in the laboratory, never completed development.

P. puparum, from Canada and Pakistan, was successfully bred in the laboratory on *Ascia* pupae, and thousands of adults were liberated in heavily infested cabbage fields, but the parasite was never recovered (Tucker, 1936 and Alam, 1982).

In St. Kitts, a larval parasite, *Lespesia aletiae* (Riley) (Tachinidae), attacks some 50% of larvae, and a pupal parasite, *Brachymeria innulata* F. (Chalcididae), over 50% of pupae in the field. These are regarded as good canditates for further introductions into Barbados and the other Eastern Caribbean islands.

Cucurbits (Cucumber, pumpkin and squash)

Although these crops are attacked by a large number of pests, two are of major importance.

Melon-worm, *Diaphania (=Margaronia) hyalinata* (L.)

Melon-worm is the most important. In Barbados, the pest population on cucumber remains relatively small, varying from 0–16% (average 0.4%) larvae per leaf, whereas, on squash and other related species, the larval population is usually very high, causing serious defoliation. Fifteen to 25 larvae per leaf can easily be found.

The natural enemies recorded in Barbados are given in Table 1.

The populations of these parasites vary considerably throughout the year, and have little effect on the control of *Diaphania*. A pupal parasite, *Trichospilus diatraeae* C. & M., introduced from India, is now established in Barbados, and attacks 2 – 5% of pupae in the field.

In St. Vincent, a larval parasite, *Hypomicrogaster diaphaniae* (Mues.), attacks up to 75% of larvae in the field. A small number of adults raised in the laboratory were released in Barbados, but no recoveries were made. Because of its seasonal abundance in St. Vincent, it is worthwhile carrying out a comprehensive breeding and release programme in Barbados and other Eastern Caribbean islands where *Diaphania* is a serious pest.

Table 1. Average percentage parasitism recorded between 1980-84, by *Cotesia* (=*Apanteles*) sp. (*glomeratus* group), *Eiphosoma dentator* (F.), *Brachymeria* sp. and *Trichogramma pretiosum* Riley.

Year	Average percentage parasitism			
	C. (=*A.*) (*glomeratus* group)	*E. dentator*	*Brachymeria* sp.	*T. pretiosum*
1980	13.7	9.8	0.5	—
1981	7.9	4.7	—	—
1982	6.1	2.6	1.0	30.3
1983	10.2	2.4	2.5	51.5
1984	13.6	5.7		

Leaf-miner (*Liriomyza sativae* Blanchard (=*Liriomyza munda* (Frick))

Leaf-miner attacks some 16 vegetable crops and 35 wild plants in Barbados. This dipterous pest usually attacks a high percentage of the leaves of cucurbits. The numbers of mines per leaf vary at different times of the year and also according to the age of the plants. Heavily infested leaves are completely covered by mines, resulting in leaf death. The levels of infestation recorded between 1978 and 1984 are given in Table 2.

Table 2. Average percentage leaf infestation and average number of mines per leaf of *Liriomyza sativae*, for the years 1978 and 1984.

Year	Average per cent leaf infestation	Average number of mines/leaf
Sept. 1978 to Dec. 1980	70	8
1981	71	14
1982	80	8
1983	73	3
1984	78	8

On cucurbits, the pest is usually parasitised by a number of indigenous and exotic parasites, such as *Chrysocharis* spp., *Cirrospilus* sp., *Diaulinopsis* sp., *Diglyphus* sp. and *Opius* sp. The combined levels of parasitism between 1978 and 1984 are given in Table 3.

Table 3. Combined percentage parasitism by five parasites on leaf miners, recorded between 1978 and 1984, in Barbados.

Year	Percentage parasitism	
	Range	Average
1978–80	24–50	37
1981	26–39	20
1982	0–11	4
1983	2–69	21
1984	2–40	19

Besides *Opius* sp., *Chrysocharis* sp. and *Diglyphus* sp. were also introduced from Pakistan, but, because of their incomplete determinations (generic identifications only) it is difficult to say if these parasites became established in Barbados.

Other Crops and Pests

Other important pests, against which a large number of exotic, natural enemies have been introduced and have established in Barbados (and later released in the Leeward and Windward islands) include the following:

Armyworms

Spodoptera spp. (*Spodoptera frugiperda* (J.E. Smith)), *Spodoptera eridania* (Cramer), *Spodoptera latifascia* (Wlk.) and *Spodoptera sunia* (Guenee) are common and attack many crops.

S. frugiperda, the fall armyworm, is the most serious pest of maize and the damage is particularly serious on the young crop. The pest also attacks vegetables, cotton, sweet potato and white and prickly *Amaranthus* spp. (Alam, 1978). Although some 13 parasite species, and a large number of predators, attack the eggs, larvae and pupae in the field (Alam, 1978), it continues to cause serious crop losses. In efforts to reduce these losses, a large number of parasites have been obtained from India and Pakistan (Alam, 1974). Some of these were liberated directly in the fields, while others were mass multiplied in the laboratory and regular releases made over a period of time. As a result of these efforts, some parasites have established permanently, while others were recovered for only a short period of time and then disappeared. The most important establishments were of the egg-parasites, *Telenomus remus* Nixon, *Trichogramma chilotraeae* Nagaraja and Nagarkatti, from India; of the larval parasites, *Apanteles marginiventris* (Cresson) from Pakistan; and of the pupal parasites, *Trichospilus diatraeae* C. and M., from India. Two larval parasites, *Campoletis flavicincta* (Ashmead) from Uruguay and *Campoletis chlorideae* Uchida from India and Pakistan were recovered after realeases, but later disappeared. Of those that established, *T. remus* has played a significant role in the control of *Spodoptera* spp. Over the years, the average, annual parasitism by *T. remus* has exceeded 70%, and as a result the pest population on maize has been significantly reduced. The parasite also attacks the egg-masses of other *Spodoptera* spp. on a wide range of cultivated and wild plants and keeps these species under excellent control.

During the early 1970 s, when onion *(Allium cepa)* was a newly introduced crop in Barbados, plants at the nursery stage were often attacked by another armyworm, *Spodoptera sunia* (Guenee). Repeated applications of chemical pesticides could not prevent serious defoliation, and time and again the crop had to be replanted. As *T. remus* was newly established in maize fields, a few releases were made in onion fields, where almost 100% of egg-masses became parasitised and the problem was solved. Since then, onions have remained free from this pest. Similarly, *S. sunia* was also a problem in cotton fields, but *T. remus* has subsequently controlled the pest efficiently.

Spodoptera eridania (Cramer) and *Spodoptera latifascia* (Wlk.) are the other species which are heavily parasitised in sweet potato, beets, cucurbits and other crops. The parasitism levels average above 75% throughout the year.

Amaranthus spp. are serious weeds in some of the vegetable fields in Barbados, and harbour very large populations of *Spodoptera* eggs. However, these eggs are heavily attacked by *T. remus* and *Trichogramma exiguum* Pinto and Platner *(=T. fasciatum = T. minutum)* and serve as a parasite reservoir for the neighbouring vegetable fields where *Spodoptera* spp. lay their eggs.

In St. Kitts, *Spodoptera ornithogalli* (Guenee) and *Spodoptera latifascia* (Wlk.) were serious pests of peanuts *(Arachis hypogoea). T. remus* was successfully introduced from Barbados during 1980–81, and now attacks over 50% of egg-masses in the fields. As a result, pest populations have been reduced considerably. Since then, routine pesticide applications have been stopped by the National Agricultural Corporation (NACO), resulting in great savings to the farmers.

Cotton Semi-looper *(Pseudoplusia includens* (Walk.)*)*

This is an important pest of tomato, sweet potato, okra, beans and cucumbers, causing serious defoliation. Since the introduction and establishment of the polyembryonic, egg-larval parasite, *Copidosoma (=Litomastix)* sp. *(truncatellum* group*)* from India, the pest populations have been reduced significantly. Average levels of parasitism recorded on these crops were 79% on tomato, 79% on sweet potato, 33% on okra, 58% on beans and 25% on cucumbers (Alam, 1978).

The Yam Scale *(Aspidiella hartii* (Ckll.)*)*

Yam Scale infests yam tubers in the field and increases significantly in storage. Heavily infested tubers become unsightly, affecting their marketability. A local parasite, *Adelencyrtus moderatus* (Howard) *(=A. femoralis* Compere and Annecke), attacks a part of the scale population. The same parasite (possibly a different strain) was also introduced into Barbados from Trinidad. After realeases, the parasite became very abundant, so much so that some farmers reported an outbreak of some unknown pest in their storerooms. Parasitism levels on yam scales was over 95%. Since then, yams have remained relatively free of the pest.

Citrus Blackfly *(Aleurocanthus woglumi* Ashby*)*

Citrus Blackfly was first reported as a serious pest of citrus in Barbados by F.J. Simmonds in 1962. Bennett (1966) reported the successful introduction and establishment of two parasites – *Prospaltella opulenta* Silv. from Mexico and *Eretmocerus serius* Silv. from Jamaica in 1964. The establishment of these parasites saved the small citrus industry in Barbados (Alam, 1974).

The Onion Thrips *(Thrips tabaci* Lind.*)*

This is a serious pest, particularly during the dry season, on onions in Barbados and the Eastern Caribbean islands. Attempts to obtain the parasite, *Thripoctenus* sp., from India have been unsuccessful, but a fungus, *Entomophthora parvispora* MacLeod and Carl, was obtained from Europe. Infection occurred in the laboratory and infected larvae and adults were released in infested onion fields. No recoveries were made in subsequent surveys (Alam, 1974).

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References

Alam, M. M. (1974). Biological control of insect pests of horticultural crops in Barbados. In C.W. Brathwaite, R.H. Phelps and F.D. Bennett (eds.) *Crop Protection in the Caribbean.* pp. 253 – 261.

Alam, M.M. (1978). Attempts at the biological control of major insect pests of maize in Barbados, W.I. *Symposium on Maize and Peanut.* Proc. 15th Ann. Mtg. Carib. Food Crops Soc., Suriname. **15**, 127 – 135.

Alam, M.M. (1980). Biological and ecological factors affecting populations of sugarcane mothborer, *Diatraea saccharalis* (F.) (Lep: Pyalidae) in Barbados, W.I. *Entomophaga* **25** (4), 401 – 414.

Alam, M.M. (1982). Cabbage pests and their natural enemies in Barbados, W.I. *Proc. 18th Ann. Meeting Carib. Food Crops Soc.,* Barbados. **18**, 307 – 320.

Alama, M. M., Bennett, F.D. and Carl, C.P. (1971). Biological control of *Diatraea saccharalis* (F.) in Barbados by *Apanteles flavipes* (Cam.) and *Lixophaga diatraeae* T.T. *Entomophaga* **16**, 151 – 158.

Alam, M.M. and Gibbs, I.H. (1979). Impact of preharvest burning on the pest complex of sugar-cane in Barbados. *Proc. W.I. Soc. Sugar-cane Technol.* **20**, 254 – 264.

Beg, M.M. and Bennett, F.D. (1974). Natural immunity of *Diatraea centrella* to *Paratheresia claripalpis* and *Metagonistylum minense. Proc. ISSCT,* **15**, 411 – 422.

Bennett, F.D. (1969). Tachinid flies as biological control agents for sugar-cane moth-borers. In Williams, J.R. *et al Pests of sugar-cane.* Elsevier, Amsterdam, pp. 117 – 148.

Bennett, F.D. (1975). Biological control of insect pests of agricultural crops with special reference to Trinidad. *J. Agri. Soc., Trinidad and Tobago.* No. **918** 12 pp.

Des Vignes, W.G. (1985). Choice of exotic parasites for the control of *Diatraea* spp. on sugar-cane in Trinidad. *Proc. W.I. Soc. Sugar-cane Technol.* **22**

Falloon, T. (1978). Parasites of *Elasmopalpus lignosellus* (Zell.) Lepidoptera: Pyralidae) on a Jamaican sugar-cane estate. *Proc. ISSCT,* 16 583 – 590.

Falloon, T. (1985). *Apanteles flavipes* (Cam.) (Hym.: Braconidae) in the biological control programme against *Diatraea saccharalis* (Lepid.: Pyralidae) in Jamaican sugar-cane. *Proc. W.I. Soc. Sugar-cane Technol.* **22.**

Myers, J.G. (1931). A preliminary report on an investigation into the biological control of West Indian Insect Pests. *Empire Monthly Board* **42**, London, 172 pp.

Myers, J.C. (1935). Second report on an investigation into the biological control of West Indian insect pests. *Bull Entomol Res.,* **26**, 181 – 252.

Tucker, R.W.E. (1936). Parasites introduced into Barbados for the control of insect pests. *J. Dept. Agri., Barbados,* 5 (1) 22 pp.

Tucker, R.W.E. (1954). Biological control of insect pests in Barbados. *Proc. ISSCT,* **8**, 573 -- 581.

TOWARDS AN IPM PROGRAM FOR CABBAGE PESTS IN TRINIDAD

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ABSTRACT

Cabbage is an important crop in Trinidad. It is serverly damaged by *Pultella xylostella, Hellula phidilealis* and *Trichoplusia ni.* Two parasites *Apanteles plutellae* and *Tetrastichus sokolowskii* were introduced for control of *P. xylostella* in 1970s. These are established, but are adversely affected by chemical pesticides applied against the other pests. *T. ni* has a fairly large complex of natural enemies which may well exert considerable control if chemical pesticides are not used. There is a dearth of natural enemies of *H. phidilealis* and farmers have to rely on chemical pesticides. It requires investigations to develop a pest management system with little disruption of the agroecosystem. It is suggested to establish trials with known parasites of other species of *Hellula,* diseases and manipulation of wild hosts of *H. phidilealis* in cultivations.

RESUMEN

El repollo es un cultivo de importancis en la isla de Trinidad. Es severamente dañado por el *Plutella xylostella, Hellula phidilealis* y *Trichoplusia ni.* Dos parásitos *Apanteles plutellae* y *Tetrastichus sokolowskii,* fueron introducidos con el objeto de controlar al *P. xylostella,* en los años de 1970. Estos parásitos fueron establecidos pero a la vez fueron afectados adversamente por pesticidas químicos los cuales fueron utilizados para combatir otras plagas fuera de las mencionadas. La plaga *T. ni* tiene un amplio complejo de enemigos naturales, los cuales pudiesen ejercer un control considerable si es que no se utilizarian pesticidas químicos. Exsiste una escasez de enemigos naturales del *H. phidilealis,* por lo cual los agricultores no tienen mas alternativa que depender de pesticidas químicos. Se requiere llevar a cabo investigaciones con el objeto de desarrollar un sistema de manejo de plagas, el cual disrupte en lo mínimo el agro-ecosistema. Se sugiere el establecimiento de ensayos, utilizando parásitos conocidos, de otras especies del *Hellula,* enfermedades de la misma y de manipulaciones de huespedes silvestres de *H. phidilealis.*

Cabbage is an important vegetable crop in Trinidad. It is severely damaged by three lepidopterous pests: the diamondback moth *Plutella xylostella,* the cabbage budworm *Hellula phidilealis* and the cabbage looper *Trichoplusia ni.* Farmers resort to frequent applications of chemical pesticides which render the crop uneconomical, produce harmful side-effects and in some instances fail to provide adequate control.

Plutella xylostella was first reported from Trinidad in 1945 (Lamont & Callen), but has attained pest status during the last 15 or so years. The life cycle is remarkably short; a generation may be completed in 14–16 days. The egg, larval and pupal stages last for 2, 8–10 and 3–4 days respectively. Oviposition commences a day after emergence and eggs are laid singly or in groups, usually on the lower leaf surface. Young larvae mine the leaves and, as they grow, riddle the leaves with numerous holes, each about a quarter inch in diameter and several reach the heart of the cabbage.

Yaseen (1974 & 1978) reported the naturally occurring parasites, *Apanteles aciculatus,* and *A.* sp. *(glomeratus* group*)* from larvae, *Spilochalcis hirtifemora* from pupae and *Trichogramma brasiliensis* from eggs, playing an insignificant role in reducing the pest populations and hence, in co-operation with the Ministry of Agriculture, the Commonwealth Institute of Biological Control introduced two exotic parasites *Apanteles plutellae* and *Tetrastichus sokolowskii* and these have become established. However, as cabbage in Trinidad also suffers from damage from *Hellula* and *Trichoplusia,* farmers blanket the crop with chemical pesticides which adversely affect the introduced parasites. This results in the absence or scarcity of *A. plutellae* in the pre-harvest fields. However, since its firm establishment, it becomes abundant in post-harvest fields to an extent that it appears to be controlling outbreaks of *Plutella.*

Trichoplusia ni: Larvae feed on leaves; they are very voracious and strip the plant of foliage. Its outbreaks are sporadic. Yaseen *et al.* (1977) have reported native egg parasites, *Trichogramma brasiliensis, T. perkinsi, T. exiguum (=fasciata)* and an undescribed trichogrammatid, the egg-larval encyrtid parasite, *Litomastix truncatellum (=Copidosoma truncatella),* the larval tachinid parasite *Euceletoria bigeminata,* the braconid *Apanteles marginiventris* (solitary) and *Apanteles* sp. probably *virtripennis* group (gregareous), which may well exert considerable control if chemical pesticides are not used.

Hellula phidilealis: The eggs are laid singly near the mid-rib of young leaves and hatch in 4–6 days. The young larvae feed for a short duration on the surface of the leaf before burrowing into the growing point of young plants or into the mid-rib or axil of a leaf, tunnelling downward into the stalk. In young cabbage plants, the larva bores into the growing point and may cause mortality or retarded growth and frequently there is a proliferation of small heads which are not marketable.

Bennett (pers. comm.) has collected *Bracon thurberiphagae* and *Charops unicinctus,* but there is a dearth of effective natural enemies attacking the pyraustid in cultivated crucifers. Yaseen *et al* (1977) introduced *Bracon hebetor* from India, but it was not recovered. *Hellula* is known to attack *Cleome* spp. (Family Capparidaceae) which grow wild in and around cabbage fields. Alam (1982) has reported *Apanteles* sp., *Chelonus* sp. *nr. mexicanus, Eiphosoma annulatum* and an unidentified tachinid from *Hellula* attacking *Cleome* spp. in Barbados.

In the absence of effective natural enemies of *Hellula* in cabbage, farmers have to rely on chemical pesticides. In order to obtain the maximum benefit of the introduced parasites of *Plutella,* and to allow native, natural enemies of *Trichoplusia* to exert their maximum control potential, the use of chemicals against *Hellula* should be very judicious in that they should be chosen in such a way as to minimize interference with natural enemies. This gives an opportunity for investigations to develop a pest management system with little disruption of the agroecosystem. In order to achieve this objective,

firstly efforts should be made for the biological control of *Hellula*. Thompson (1946) and Herting (1965) and other sources record several parasites and predators of *Hellula undalis* and *H. rogatalis* (Table 1). Recent investigations at the Pakistan Station CIBC have revealed three parasites – *Apanteles midas, Chelonus rufus* and *Bracon* sp. – from *H. undalis* Secondly, to explore possibility of the use of diseases against *Hellula*, the key pest of cabbage. In this regard, in cooperation with CIBC, the Institute of Virology, Oxford made lab tests with several viruses against *Hellula* to select the one which does not disturb beneficial organisms in the cabbage ecosystem and selected the nuclear polyhedrosis virus of *Autographa californica* (AcNPV) for field trials.

Field trials were made in Trinidad by the Institute of Virology, in cooperation with the Ministry of Agriculture and CIBC in Trinidad, in 1984. Small (1984) reported achievement of protection of cabbages against *H. phidilealis* using the baculovirus, AcNPV. The best protection was achieved in nursery beds. Virus control in the field was not satisfactory because of the heavy pest pressure from surrounding, infested areas and the comparatively small experimental plots. It also involved high concentrations of virus to instigate any form of control. These preliminary field trials suggest further investigations, including the search for a more efficient virus that should be effective against both *Hellula* and *Plutella*, which now seem to have become resistant to several

Table 1. Parasites and predators of *Hellula* spp. and their distribution

Natural enemies	Host	Distribution
PARASITES		
Trichogrammatidae		
Trichogramma "minutum"	*Hellula undalis*	Australia
Ichneumonidae		
Campoletis facilis	*H. rogatalis*	USA
Cremastus tibiator	"	USA
Eiphosoma annulatum	*H. phildilaelis*	Barbados
Braconidae		
Apanteles hellulae	*H. undalis*	Senegal &Cameroon
A. midas	"	Pakistan
A. saegeri	"	West Africa
A. sp.	*H. phidilealis*	Barbados & Guyana
Atanycolus sp.	*H. undalis*	West Africa
Bracon hellulae	*H. phidilealis*	Brazil
Bracon hebetor	"	Trinidad
Bracon ? thurberiphagae	"	Barbados
Bracon spp. (2)	"	Mexico
Bracon sp.	*H. undalis*	Pakistan
Chelonus rufus	"	Pakistan
Chelonus sp. nr. *mexicanus*	*H. phidilealis*	Barbados
Chelonus sp.	"	Brazil
Meterorus levivertris	*H. rogatalis*	USA
Bethylidae		
Goniozus (=*Parisierola*) sp.	*H.phidilealis*	Barbados
Tachinidae		
Nemorilla pysti	*H. rogatalis*	USA
Nemorilla sp.	*H. phidilealis*	West Indies
Stomatomyia sp.	*H. rogatalis*	USA
PREDATORS		
Sphecidae		
Stictiella serrata	*H. rogatalis*	USA
Afriopidae		
Neoscona doenitzi	*H. undalis*	Japan
Thomsidae		
Misumena tricuspidata	*H. undalis*	Japan

insecticides, and the development of more effective spray equipment.

Because of the relative abundance of natural enemies of *H. phidilealis* in *Cleome* spp., in contrast to their paucity in cruciferous crops, Bennett (1981) considers it possible that *H. phidilealis* has transferred from *Cleome* spp. to crucifers rather than vice versa. Until satisfactory control of *Hellula* becomes possible by natural enemies or viruses, *Cleome* spp. should be destroyed from the cultivations and the surrounding areas to reduce the chances of the pest invading cabbages. Search should also be made for other wild hosts of *Hellula* in areas in the neighbourhood of cabbage fields and these reserviors of *Hellula* should also be destroyed before the latter moves to cabbage. However, if biological control is achieved *Cleome* spp. and other wild host plants in the surrounding areas may prove useful when cabbages are not in the field, by providing *Hellula* for survival of the introduced parasites.

References

Alam, M.M. (1962) Cabbage pests and their natural enemies in Barbados W.I. *Proc. 18th Ann. Mtg. Carib. Food Crops Soc.* Barbados, 307-320.

Bennett, F.D. (1981) A note on the distribution, host range and natural enemies of *Hellula phidilealis* (Walker) (Pyralidae) a potential pest of crucifers in Mexico. *Paper presented at the Ninth National Biological Control Meeting, Oaxaca, Mexico.*

Herting, B. (1965). *A catalogue of parasites and predators of terrestrial arthropods. Section A Host of Prey/Enemy Vol. VI Lepidoptera Part (Microlepidoptera)* Commonwealth Agricultural Bureaux, England, 218 pp.

Small, D.A. (1984) *The use of baculovirus for control of cabbage pests. Report on a field study in Trinidad.* Institute of Virology, Oxford, UK 143 pp.

Thompson, W.R. (1946) *A catalogue of the parasites and predators of insect pests. Sectional part 7 Parasites of the Lepidoptera (G.M.).* Imperial Parasite Service, Belleville, Canada. 385 pp.

Yaseen, M. (1974) Biology, seasonal incidence and parasites of *Plutella xylostella* (L) in Trinidad and the introduction of exotic parasites into the Lesser Antilles. In: C.W.D. Braithwaite, R.H. Phelps and F.D. Bennett (eds.) *Crop protection in the Caribbean* .The University of the West Indies, Trinidad 237–244.

Yaseen, M. (1978) The establishment of two parasites of the diamond-back moth *Plutella xylostella* (Lap. Plutellidae) in Trinidad W.I. *Entomophaga* 230 111 – 114.

Yaseen, M. Barrow, R.M., Katwaru, G.S. (1977) Preliminary studies in the development of a pest management programme for cruciferous crops in Trinidad and Tobago. *Proc. 14th Mtg. Carib Food Crop Soc.*, Guadeloupe & Martinique 493-501.

QUARANTINE TREATMENT RESEARCH AGAINST THE CARIBBEAN FRUIT FLY IN CITRUS FRUITS

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ABSTRACT

This review summarizes recent research findings with approved as well as potential quarantine treatments to replace ethylene dibromide (EDB) fumigation in the eradication of the Caribbean fruit fly *(Anastrepha suspensa* (Loew). Several million boxes of grapefruit *(Citrus paradisi* Macf.*)* are shipped annually from Florida to Japan; EDB fumigation and the cold treatment are the only approved methods to disinfest fruit of the Caribbean fruit fly. Limitations were found in the commercial use of the cold treatment, because of the presence of cold injury, in cold-intolerant cultivars such as grapefruit. In domestic shipments methyl bromide (MB) has been used for citrus fruits. To avoid phytotoxicity, citrus fruits fumigated with MB must be stored and handled at temperatures higher than those usually recommended. Gamma irradiation showed potential; presently it is not an approved treatment for fruits and vegetables. Phosphine (PH_3) fumigation, which is not approved for citrus fruits, is phytotoxic to grapefruit at conditions required for Caribbean fruit fly mortality.

RESUMEN

Se reportan los resultados de investigaciones recientes que examinaron diferentes tratamientos aprobados y experimentales par remplacer el uso de dibromuro de etileno (EDB) en la eradicación de la mosca del caribe *(Anastrepha suspensa* Loew.*)* Cada año se manda varios millones de cajas de toronja *(Citrus paradisi* Macf.*)* de Florida a Japón; fumigación con EDB y tratamiento con temperaturas bajas son los únicos metodos aprobados para desinfestar la fruta de la mosca del caribe. El uso comercial de temperaturas bajas es limitado debido al daño causado por el frío en especies susceptibles tales como la toronja. En cargamentos domesticos, se ha usado bromuro de metileno (MB) en cítricos. Para evitar fitotoxicidad se ha tenido que almacenar y manejar las frutas fumigadas con MB a una temperatura mas elevada de lo que se recomienda normalmente. La irradiación con rayos gama es un tratamiento potencial, pero todavía no es un tratamiento aprobado para frutas y verduras. Fumigación con Fosfina (PH_3) no es un tratamiento aprobados para cítricos, y es fitotóxico a la toronja en condiciones requeridos para matar la mosca del caribe.

Because of its importance in both domestic and export markets, Florida grapefruit, *Citrus paradisi* Macf., has been the focus of much of the research effort on quarantine treatment methods. Since 1975 Florida citrus fruits have been fumigated with ethylene dibromide (EDB) to eliminate possible infestations of Caribbean fruit fly, *Anastrepha suspensa* (Loew), in fruit shipped to Japan. EDB was used as a domestic quarantine treatment for the control of fruit flies in fruits and vegetables until its registration was cancelled for most uses effective September 1, 1984. Subsequent to cancellation, the U.S. Environmental Protection Agency (EPA) restricted the use of EDB to citrus destined for markets outside the U.S. beginning October 1 until January 31 of the following year. In 1985 such use was extended to May 31, 1985.

Although the cold treatment is approved for citrus fruits, its use for grapefruit shipments to Japan during the 1983–84 season proved to be disastrous. Exporters have reported that losses due to excessive cold injury ran into millions of dollars. Cold-tolerant cultivars such as 'Valencia' orange are readily adaptable to the treatment. No grapefruit has been shipped to Japan using the cold treatment since the problem was encountered. Japanese importers have requested U.S. exporters to fumigate grapefruit with EDB and not use the cold treatment.

While there is no Federal quarantine on the Caribbean fruit fly, the other citrus-producing states require treatment of Florida citrus fruits to rid the fruit of the fly as a condition of entry into their states. Methyl bromide (MB) fumigation has been used with limited success. Phytotoxicity problems have been encountered with oranges and specialty citrus fruits, but grapefruit shipments have been successful as long as temperatures above usual storage temperatures were used. Research data have been provided to the Government of Japan on the effectiveness of MB for the Caribbean fruit fly; additional approval has been received provided commercial tests are conducted. The future use of EDB as a fumigant continues to be uncertain, although low-dose fumigation was found to be effective for the control of Caribbean fruit fly in grapefruit; such doses also resulted in low residue levels (39). It is imperative that modifications of present treatments or new alternate treatments be found to replace EDB.

Phosphine (PH_3)

PH_3 fumigation is used commercially to fumigate against weevils in grain. In Hawaii, PH_3, effectively eliminated the Oriental and Mediterranean fruit flies from fruits other than citrus, and time influenced efficacy more than concentration (35). Studies (37, 38) showed that PH_3 generated from magnesium phosphide FUMI-CELS® could possibly be used as a quarantine fumigant for grapefruit. The tests showed that PH_3 gave 99 to 100% mortality to Caribbean fruit fly after 24-hr exposure to a concentration of 300 to 600 ppm for the first 6 to 8 hr, 73 to 200 ppm concentration during the remainder of the 24-hr period (38). Other tests indicated that Caribbean fruit flies infesting 'Marsh' grapefruit were controlled when fruit were fumigated at 13°C for 96 hr or fruit were fumigated at ambient temperature for 48 hr (37).

In further tests (26) dosages of PH_3 required to eradicate the Caribbean fruit fly caused phytotoxic effects to Florida grapefruit. These efforts were manifested as various forms of rind injury, of which the most serious was rind breakdown (Table 1). Rind breakdown includes pitting and aging; pitting is commonly manifested as dark, sunken, surface

Table 1. Rind breakdown and subsequent decay of 'Marsh' grapefruit fumigated with phosphine[z] (26).

Treatment	Phosphine[y] concentration ppm	Rind breakdown after storage (10°C) 28 days %	Decay after holding (21°C) 7 days %
Refrigeration (ambient 24 hr + 4 days at 10°C)	734	20.0a[x]	14.5a[x]
Ambient (ambient for 3 days)	325	16.8a	8.6ab
Control	0	2.5b	4.9b

[z]Each numerical value represents 12 boxes of fruit (480 fruit), 6 boxes from each of 2 grove sources with half of each fumigated at USDA Orlando.
[y]Average concentration of phosphine generated after 24 hr of fumigation.
[x]Mean separation within columns by Duncan's multiple range test, 5% level.

lesions, whereas aging is found at the stem end around the button in the form of wilt, shrivel, and collapse. Fruit fumigated under ambient conditions had less rind breakdown than similar fruit fumigated under refrigerated conditions. Rind breakdown did not appear until the fruit had been in refrigerated storage at 10°C. During holding for 7 days at 21° significantly more decay was found in fruit fumigated under refrigerated conditions; the extent of decay appeared to be proportional to the amount of rind breakdown that occurred during storage (26).

The phytotoxic effects appear to preclude any possibilities of PH_3 as a practical, commercial fumigant for Florida grapefruit. Also, the length of the PH_3 fumigation period is a major impediment to its use (48 to 72 hr minimum exposure above 20°C).

Methyl bromide (MB)

California grapefruit were reported to be uninjured by MB applied at rates of 2.5 lb/1000 ft^3 at 27°C and 3 lb/1000 ft^3 at 21°(1). Grapefruit were marked and discolored by high rates, and 'Washington' navel oranges *(Citrus sinensis* (L.) Osbeck*)* were spotted or discolored at all rates of MB application. Another report from California indicated that a 2-hr treatment with 2 lb of MB was an injurious concentration to fumigate citrus fruits for insect infestations, although lemons grown in the interior or California that were fumigated at this rate were uninjured (29).

With the Caribbean fruit fly in Florida MB fumigation rates of 40 and 56 mg/liter provided quarantine security for 20 and 80% chamber loading, respectively (3). However, using these rates MB was found to be too phytotoxic to 'March', 'Ruby Red' and 'Thompson Pink' grapefruit; 'Hamlin', 'Pineapple' and 'Valencia' oranges, and 'Temple' *(C. reticulata* X *C. sinensis* (?)*)* (17). Fumigation of grapefruit with MB resulted in peel injury during storage, especially at lowest temperatures (Table 2). The injury was manifested as scald and/or, in a few instances, discolored pitting of the peel. The scaldlike injury became water-soaked in severe instances. Occasionally, an entire lot of fruit would escape MB injury during 4 weeks of storage (simulated transit) but develop excessive decay after holding at 21°C for 7 days. This was especially the case for 'Hamlin', 'Pineapple' and 'Valencia' oranges and 'Temple'. With oranges and 'Temple' the development of symptoms was usually delayed and a general softening of the fruit was detected before symptoms of injury became visible; excessive decay followed.

Recent studies have shown that the combination of MB fumigation and cold storage treatment was effective for controlling infestations of Caribbean fruit fly in grapefruit (4). Commercial scale tests were conducted with MB as a fumigant for Caribbean fruit fly with uniform distribution of MB within a chamber fumigated with 40 g/m^3 for 2 hr in 266 m^3 (6). Residues of MB in fruit were calculated to reach 10 ppb and 1 ppb after 10 and 14 days, respectively, when fruit were stored at 16°C following fumigation.

Gamma irradiation

Gamma irradiation was proposed as a possible quarantine treatment for fruit infested with fruit flies in 1956 (2). The greatest concern was centered on possible injurious effects of irradiation on the fruit itself. Previous work with grapefruit and other fruit indicated that radiation when followed by cold storage or cold temperature shipment may cause injury to the peel (7, 11, 12, 13, 22). Preliminary investigations showed that 25 to 60 kilorad (krad) increased pitting, scald, aging and decay of Florida grapefruit (8). Additional research confirmed that dosages of 60 and 90 krad caused injury, although 15 and 30 krad dosages were acceptable (24, 25). Scald and, especially, rind breakdown of the peel were the types of injury which developed during the storage period. The magnitude of injury at various months of the season are shown according to dosages (Table 3). Biochemical tests showed an improvement of flavour in grapefruit sections, especially at lower dosages (30). No differences were noted in vitamin C content, sugar or acid levels in juice, nor in essential peel oil composition of volatile constituents from irradiated fruit when compared with those from untreated fruit.

A study of effects of irradiation on the mortality of the Caribbean fruit fly showed that none survived grapefruit irradiated at 60 and 90 krad, whereas one

Table 2. Methyl bromide fumigation of Florida grapefruit, 1978-79[z] (17).

Date	Fumigation[y] Ambient temperature (°C)	Cultivar	After 28 days in storage[x] Peel injury %	Decay %
Nov. 14	29	Ruby Red	0	3
		Marsh	0	0
Dec. 1	29	Thompson Pink	3	9
		Marsh	0	8
Jan. 26	10	Ruby Red	11	1
		Marsh	26	3
Feb. 6	20	Ruby Red	11	12
		Marsh	28	13
Feb. 14	16	Ruby Red	10	0
		Marsh	8	0
Feb. 20	19	Thompson Pink	10	0
Mar. 26	17	Ruby Red	0	0
Apr. 16	22	Thompson Pink	3	0

[z]Data for control fruit showed that no peel injury was present and decay did not exceed 5% at any insepction. Decay averaged less than 0.5% for all control fruit.

[y]On each date, cartons of fruit were fumigated with methyl bromide at application rates of 40 or 56 g/m^3 for 2 hr, with 20 and 80% load factors (3 and 12 cartons), respectively, in an 0.8 -m^3 chamber with continuous gas circulation. Pulp temperatures closely matched ambient temperatures.

[x]Cartons of fruit were stored at 16°C before January and 10°C thereafter to avoid chilling injury.

Table 3. Percentage irradiation injury immediately after removal from 28-day storage under optimum conditions[z](25).

		Dosage (krad)					
		0	7.5	15	30	60	90
Test	Date	(%)[y]	(%)	(%)	(%)	(%)	(%)
1	Oct. 81	0.0	—	—	25.9	43.1	60.9
2	Dec. 81	0.0	—	2.2	6.6	17.7	25.9
3	Feb. 82	0.2	—	0.2	3.9	26.2	39.7
4	Apr. 82	3.6	—	7.7	17.3	24.8	35.8
5	May 82	3.6	—	8.9	9.7	18.8	17.7
6	Sep. 82	0.0	0.0	0.0	0.2	1.1	0.0
7	Oct. 82	1.2	3.6	2.7	3.0	5.3	0.0

[z]Test 1 used a total of 320 fruit from 2 lots per irradiation level. All other tests used a total of 640 fruit from 4 lots per level, except for the 90-krad level in tests 6 and 7, where only 40 fruit were used per lot for a total of 160 fruit.

[y]Regardless of severity, all injury combined numerically to compute the percentage of injury.

adult each survived 15 and 30 krad treatments; both died before becoming sexually mature (36).

At present, high costs and lack of assurance concerning consumer acceptance are limiting factors to the use of gamma irradiation.

Cold treatment

Recommended storage temperatures for Florida grapefruit are 10°C for mid - and late-season fruit and 16° for early-season fruit. Grapefruit sustain chilling injury (CI) when exposed to temperatures below 10°, and the susceptibility of CI varies throughout the harvesting season (15, 33). Preharvest conditions in the grove, as well as postharvest handling, may directly affect the extent of CI in stored grapefruit (16). Pre - and postharvest applications of benomyl (41) and postharvest applications of thiabendazole (34) reduced CI. Waxing grapefruit and packaging in film minimized CI (14, 32, 40). Raising the relative humidity to 100% during storage (31), as well as intermittent warming (10, 27), greatly reduced CI.

Temperature preconditioning of grapefruit before low-temperature storage gave some success (15, 23). Constant storage at 1°C for 28 days resulted in excessive CI; however, preconditioning similar fruit for 7 days at 10°, 16° or 21° significantly reduced CI during 21 days of storage at 1° under high humidity conditions (19, 20), and this continued throughout the season for early, midseason and late grapefruit (Table 4). Degreening early grapefruit for long periods of time with ethylene tended to make the fruit more susceptible to CI (18).

Recent research showed that preconditioning grapefruit at 21° and 27°C for 7 days is significantly less effective than preconditioning for a similar period of time at 16° (21). Grapefruit infested with Caribbean fruit fly and stored for 14 days at 2° resulted in 100% mortality (5). Based on this research, the Government of Japan recently approved a cold treatment schedule for Florida grapefruit that is on a sliding scale beginning with 0.6°C for 10 days and extending to 2.2°C for 17 days with the stipulation that 1,500 fruit be held at 26.7°C for 10 days and then cut to determine presence of Caribbean fruit fly larvae. Although moisture loss is a contributing factor, it is noted that it does not appear to be the primary factor in CI (32). In Israel, recent studies showed that by combining the fungicide thiabendazole with cooling of grapefruit, susceptibility to CI can be reduced and the cold treatment can be practiced with a low CI risk (9).

During the 1981–82 season 4 relatively large-scale grapefruit tests were conducted at a commercial storage facility in Florida. Only 1% CI was observed for the entire season on fruit that had been preconditioned at 16°C for 7 days and stored at 1° for 21 days; a slight increase in CI occured during a 7-day holding period at 21° (Table 5). These tests were followed late in the 1982–83 season with an experimental shipment of 16,000 boxes of grapefruit to Japan (unpublished data). Sixty boxes of fruit representing 15 separate lots were retained in Tokyo for study; less than 0.4% of the preconditioned fruit showed CI while the fruit that was not preconditioned showed 2.2%. The following season, 1983–84, excessive losses were sustained in commercial ship-

Table 4. Chilling injury of preconditioned early, midseason, and late Florida grapefruit[z] (19).

Preconditioning and storage treatment[y] °C	Chilling injury after storage Early (%)	Midseason (%)	Late[x] (%)
28 days at 1°	17.2a	17.7a	6.1a
28 days at 16°	0.0b	0.1b	0.0b
7 days at 16°+ 21 days at 1°	0.1b	0.6b	0.4b
28 days at 10°		0.1b	0.0b
7 days at 10°+ 21 days at 1°	-	0.9b	0.1b

[z] Each value represents 1,400, 1,320 and 720 fruit from early-, mid- and late-season harvests, respectively. Mean separation of columns by Duncan's multiple range test, 5% level.

[y] Relative humidity ranged from 88 to 92% for fruit at 1° to 10° C, and from 80 to 92% for those at 16°C.

[x] Controls for late fruit were held for 25 days instead of 28 and preconditioned fruit were held for 18 days instead of 21 days at 1°.

Table 5. Chilling injury of preconditioned Florida grapefruit in a large-scale commercial facility[z] (unpublished data).

Preconditioned and storage treatment[y] °C	Number of fruit	Chilling injury After storage (%)	Chilling injury After holding (7 days at 21°C) (%)
28 days at 1°	4,4125	14a[x]	17a[x]
28 days at 16°	4,431	0b	0b
7 days at 16°+ 21 days at 1°	13,232	1b	1b

[z]Each value represents 4 separate tests from 8 to 11 different lots. Tests were conducted in November 1981, December 1981, February 1982 and April 1982.

[y]Relative humidity ranged from 88 to 92% for fruit at 1°C and from 80 to 92% for those at 16°.

[x]Mean separation of columns by Duncan's multiple range test, 5% level.

ments to Japan. The cause for such losses cannot be fully explained. Proper temperatures and humidity levels were not maintained for the prescribed periods of time and this possibly relates to the large density and mass of thousands of boxes of fruit and the inadequate refrigeration equipment.

Additional research is needed to solve the problem. One approach will be to determine the safety of the fruit in van containers where a relatively small mass of approximately a thousand boxes of fruit is involved. Four citrus tests in California demonstrated that van containers maintained fruit with temperature uniformity throughout the load of 2.0 or 2.2°C for 14 days (28). Use of the cold treatment to Japan compared to EDB fumigation would result in treatment cost increases estimated at 25 to 40 cents per box.

References

1. Armitage, H.M. and J.B. Steinweden. 1946. Tolerance of citrus fruits to methyl bromide as a fumigant. Calif. Dept. of Agr. Bul. No. 35 (1):21–29.

2. Balock, J.W., L.D. Christenson, and G.O. Barr. 1956. Effect of gamma rays on immature stages of the Oriental fruit fly *(Dacas dorsalis* Hendel*)* and possible application to commodity treatment problems. Proc. Hawaii Acad. Sci. 31:18.

3. Benschoter, C.A. 1979. Fumigation of grapefruit with methyl bromide for control of *Anastrepha suspensa.* J. Econ. Entomol. 72:201–402.

4. Benschoter, C.A. 1982. Methyl bromide fumigation followed by cold storage as a treatment for *Anastrepha suspensa* in grapefruit. J. Econ. Entomol. 75:860–862.

5. Benschoter, C.A. 1983. Lethal effects of cold storage temperatures on Caribbean fruit fly in grapefruit. Proc. Fla. State Hort. Soc. 96:318–319.

6. Benschoter, C.A., J.R. King and P.C. Witherell. 1984. Large chamber fumigations with methyl bromide to destroy Caribbean fruit fly in grapefruit. Proc. Fla. State Hort. Soc. 97:123–125.

7. Beraha, L., G.B. Ramsey, M.A. Smith, and W.R. Wright. 1959. Factors influencing the use of gamma radiation to control decay of lemons and oranges. Phytopathology 49:91–96.

8. Burditt, A.K. Jr., M.G. Moshonas, T.T. Hatton, D.H. Spalding, D. L. von Windeguth and P.E. Shaw. 1981. Low-dose irradiation as a treatment for grapefruit and mangoes infested with Caribbean fruit fly larvae. USDA, ARS, ARR–S–10. 9 p.

9. Chalutz, E., J. Waks and Mina Schiffman-Nadel. 1985. Reducing susceptibility of grapefruit to chilling injury during cold treatment. Hort. Science 20 (2): 226–228.

10. Davis, P.L. 1973. Intermittent warming of grapefruit to avoid rind injury during storage. Proc. Fla. State Hort. Soc. 86:280–283.

11. Dennison, R.A., W. Grierson, and E.M. Ahmed. 1966. Irradiation of Duncan grapefruit, Pineapple and Valencia oranges and Temples. Proc. Fla. State Hort. Soc. 79: 285–292.

12. Dollar, A.M., M. Hanaoka, G.A. McClish, and J.H. Mog. 1971. Semicommercial-scale studies on irradiated papaya, p. 137–156. In: Disinfestation of fruit by irradiation. Proc. panel on the use of irradiation to solve quarantine problems in the Intl. Fruit Trade, Honolulu. 1970. Intl. Atomic Energy Agency, Vienna.

13. Farooqi, W.A., M. Ahmed, A. Hussain and M.H. Naqvi. 1974. Effect of gamma irradiation on Kinnow mandarin during storage. The Nucleus 11:25–29.

14. Grierson, W. 1971. Chilling injury in tropical and subtropical fruit IV. The role of packaging and waxing in minimizing chilling injury of grapefruit. Proc. Trop. Reg. Amer. Soc. Hort. Sci. 15:76–88.

15. Grierson, W. 1974. Chilling injury in tropical and subtropical fruits V. Effect of harvest date, degreening, delayed storage and peel color on chilling injury of grapefruit. Proc. Trop. Reg. Amer. Soc. Hort. Sci. 18: 66–73.

16. Grierson, W. and T.T. Hatton. 1977. Factors involved in storage of citrus fruits: a new evaluation. Proc. Int. Soc. Citriculture 1:227–231.

17. Hatton, T.T. and R.H. Cubbedge. 1979. Phytotoxicity of methyl bromide as a fumigant for Florida citrus fruit. Proc. Fla. State Hort. Soc. 92:167–169.

18. Hatton, T.T. and R.H. Cubbedge. 1981. Effects of ethylene on chilling injury and subsequent decay of conditioned early 'Marsh' grapefruit during low-temperature storage. HortScience 16(6):783–784.

19. Hatton, T.T. and R.H. Cubbedge. 1982. Conditioning Florida grapefruit to reduce chilling injury during low-temperature storage. J. Amer. Soc. Hort. Sci. 107: 57–60.

20. Hatton, T.T. and R.H. Cubbedge. 1982. Reducing chilling injury in grapefruit by prestorage conditioning. USDA, ARS, AAT–S–25. 6 p.

21. Hatton, T.T. and R.H. Cubbedge. 1983. Preferred temperature for prestorage conditioning of 'Marsh' grapefruit to prevent chilling injury at low temperatures. HortScience 18:721–722.

22. Hatton, T.T., L. Beraha and W.R. Wright. 1961. Preliminary trials of gamma radiation on mature Irwin and Sensation mangoes. Proc. 21 Fla. Mango Forum Ann. Meet. p. 15–17.

23. Hatton, T.T., R.H. Cubbedge, and W. Grierson. 1975. Effects of prestorage carbon dioxide treatments and delayed storage on chilling injury of 'Marsh' grapefruit. Proc. Fla. State Hort. Soc. 88:335–338.

24. Hatton, T.T., R.H. Cubbedge, L.A. Risse, and P.W. Hale. 1982. Phytotoxicity of gamma irradiation on Florida grapefruit. Proc. Fla. State Hort. Soc. 95:232–234.

25. Hatton, T.T., R.H. Cubbedge, L.A. Risse, P.W. Hale, D.H. Spalding, D.von Windeguth and V. Chew. 1984. Phytotoxic responses of Florida grapefruit to low-dose irradiation. J. Amer. Soc. Hort. Sci. 109(5):607–610.

26. Hatton, T.T., R.H. Cubbedge, D.L. von Windeguth and D.H. Spalding. 1982. Control of the Caribbean fruit fly in Florida grapefruit by phosphine fumigation. Proc. Fla. State Hort. Soc. 95:221–224.

27. Hatton, T.T., P.L. Davis, R.H. Cubbedge and K.A. Munroe. 1981. Temperature management and carbon dioxide treatments that reduce chilling injury in grapefruit stored at low temperatures. Proc. Int. Soc. Citriculture 2:728–731.

28. Houck, L.G. and R.T. Hinsch. 1983. Evaluation of van containers for cold treatment of citrus fruit for quarantine purposes. Proc. Fla. State Hort. Soc. 96:340–344.

29. Lindgren, D.L. and W.B. Sinclair. 1951. Tolerance of citrus and avocado fruits to fumigants effective against the Oriental fruit fly. J. Econ. Entomol 44(6):980–990.

30. Moshonas, M.G. and P.E. Shaw. 1984. Effects of low-dose gamma irradiation on grapefruit products. J. Agr. & Food Chem. 32(5)1098–1101.

31. Pantastico, E.B., J. Soule, and W. Grierson, 1968. Chilling injury in tropical and subtropical fruits II. Limes and grapefruit. Proc. Trop. Reg. Amer. Soc. Hort. Sci. 12:171–183.

32. Purvis, Albert C. 1985. Relationship between chilling injury of grapefruit and moisture loss during storage: amelioration of polyethylene shrink film. J. Amer. Soc. Hort. Sci., 110 (3) 385 - 388.

33. Purvis, A.C., K. Kawada, and W. Grierson. 1979. Relationship between midseason resistance to chilling injury and reducing sugar level in grapefruit peel. HortScience 14: 227 – 229.

34. Schiffman-Nadel, M.E. Chalutz, J. Waks and M. Dagan. 1975. Reduction of chilling injury in grapefruit by Thiabendazole and benomyl during long-term storage. J. Amer. Soc. Hort. Sci. 100:270–272.

35. Seo. S.T., E.K. Akamine, T.T. S. Goo, E.J. Harris and C. Y. Lee. 1979. Oriental and Mediterranean fruit flies: Fumigation of papaya, avacado, tomato, bell pepper, eggplant, and banana with phosphine. J. Econ. Entomol. 72:354–359.

36. von Windeguth, D.L. 1982. Effects of gamma irradiation on the mortality of Caribbean fruit fly in grapefruit. Proc. Fla. State Hort. Soc. 95:235–237.

37. von Windeguth, D.L., A. Arner, A.K. Burditt, Jr. and D. H. Spalding. 1977. Phosphine as a fumigant for grapefruit infested by Caribbean fruit fly larvae. Proc. Fla. State Hort. Soc. 90: 144 – 147.

38. von Windeguth, D.L., A.K. Burditt, Jr. and D.H. Spalding. 1976. Phosphine as a fumigant for grapefruit infested by Caribbean fruit fly larvae. Fla. Entomol. 59:285–286.

39. von Windeguth, J.R. King and V. Chew. 1984. Low-dose ethylene dibromide fumigation for quarantine control of Caribbean fruit fly in grapefruit. Proc. Fla. State Hort. Soc. 97: 120–122.

40. Wardowski, W.F., W. Grierson and G.J. Edwards. 1973. Chilling injury of stored limes and grapefruit as affected by differentially permeable packaging films. HortScience 8:173–175.

41. Wardowski, W.F., L.G. Albrigo, W. Grierson, C.R. Barmore and T.A. Wheaton. 1975. Chilling injury and decay of grapefruit as affected by thiabendazole, benomyl and CO_2. HortScience 10:381–383.

THE PLANT PROTECTION PROGRAMME OF IICA IN THE CARIBBEAN

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ABSTRACT

The IICA Plant Protection Programme for the Caribbean seeks to promote and support the efforts of the countries of the Caribbean to prevent and reduce crop losses caused by pests, diseases and weeds. The programme, which was started in 1981, has as a fundamental strategy of reciprocal technical cooperation where the experiences and technical information of some countries are used in a transfer of technology to others utilising human resources, information exchange and mechanisms for communication. The establishment of a Society for Plant Protection in the Caribbean, the establishment of a Regional Plant Protection Newsletter and annual meetings of Heads of Plant Protection represent the major mechanisms in this technical cooperation package.

Attempts to harmonize pesticide legislation and the training and certification of Plant Quarantine Inspectors represent approaches to standardize the legislative aspects of Plant Protection in the region.

Initiatives have also been focused on survey and eradication studies and proposals are imminent to set up a data base of Plant Protection information for the Caribbean.

RESUMEN

El programa de la protección de plantas de la IICA en el Caribe, aspira a promoveer y ayudar los esfuerzos de las islas del Caribe, para prevenir y reducir las peridadas de cultivos, causadas por plagas, enfermedades y hierbas malas. El programa, el cual se inició en el año 1981, tiene como una estratégia fundamental la cooperación técnica y recíproca, en la cual las experiencias e información técnica de algunos paises es utilizada para transferir la información técnica, a otros, haciendo uso de: recursos humanos, intercambio de información y mecanismos de comunicacion. Los mecanismos mas importantes de este paquete técnico son, el establecimiento de una sociedad para la Protección de Plantas en el Caribe, el establecimiento de un Boletín Regional sobre la Protección de Plantas y de reuniones anuales de Directores de Protección de Plantas.

Los atentados para poder armonizar la legislación sobre el uso de pesticidas y el entrenamiento y certificación de Inspectores de Cuarentena de Plantas, representan los esfuerzos para poder reglamentar los aspectos legislativos de la Protección de Plantas en esta región.

Iniciativas tambien, se han enfocados en los estudios de investigación e irradicación y, las propuestas de establecer una base de datos de Información de la Protección de Plantas para el Caribe, son inminentes.

The Ministers of Agriculture attending the VII Inter-American Conference of Agriculture held in Honduras in 1977 expressed their concern regarding the disease problems of plants and animals throughout the Western Hemisphere. Two of the ten recommendations made at this conference refer to this subject. The Special Committee of the Eighteenth Annual Meeting of IICA Board of Directors held in October, 1978 recommended that the Director General of IICA study a proposal aimed at the establishment of a mechanism for the coordination of efforts to fight pests and disease problems affecting animals and plants and which are the cause of significant losses in the Hemisphere.

As a result of these directives, IICA has established a Hemispheric Plant Protection Programme designed to prevent, control and, if possible, eradicate diseases and pests which cause economic damage to crops in the Hemisphere and which threaten to spread to other regions.

The programme is made up of a Programme Director stationed at IICA headquarters in San Jose, Costa Rica and four Plant Protection Specialists, one stationed in each of the four regions of the Hemisphere. The Plant Protection Specialist for the Caribbean is Chelston W.D. Brathwaite, Plant Pathologist stationed in the IICA Office in Trinidad and Tobago.

In accordance with IICA's basic strategy, this programme is directed towards strengthening national and regional efforts being carried out by other organizaions. It is designed to support, coordinate and collaborate with other International, regional and subregional institutions working in this area and in no case will duplicate or replace existing institutions.

The programme recognises that the spread of pests, diseases, and weeds that affect basic food and export crops aggravate the food, foreign exchange and energy needs of the Latin American and Caribbean countries. Coordinated international action can contribute to reducing the spreading and incidence of these pests, weeds and diseases, since the individual capabilities of national plant protection institutions are usually limited by low levels of physical, human and financial resources with which to attain their objectives.

General objective of the programme

To promote and support the efforts of the countries to prevent and reduce crop losses caused by pests, diseases and weeds.

Specific objectives of the programme

To cooperate with the countries in expanding and improving their institutional capability to:

(a) Update and standardize national and international legal provisions and regulations governing plant protection.

(b) Identify, detect and estimate the damage caused by the main crop pests, diseases and weeds.

(c) Plan, coordinate and implement programmes for reducing the incidence and preventing the spread of the main crop pests, diseases and weeds.

(d) Plan, coordinate and implement research and technical exchange programmes on crop pests, diseases and weeds.

(e) Generate mechanisms for upgrading the physical, human and financial resources of plant protect institutions, according to the levels of responsbility that have been assigned them.

Strategy of the programme

To promote and support:

(a) The updating and standardization of national and international legal provisions and regulations governing plant protection (quarantine and pesticides).

(b) The formulation, implementation and evaluation of multinational projects that involve economically important pests and diseases of mutual interest to several countries.

(c) The formulation, implementation and evaluation of high-priority projects at the national level.

(d) The use of technical and human resources from other IICA programs, from CATIE, and from national and international institutions with experience in this field.

(e) The operational and technical reinforcement of national and international institutions working in this field (OIRSA, FAO, CIP, NAPPO, CIAT, CIMMYT).

(f) Coordination with other international agencies.

(g) The organization and promotion of meetings, seminars and other events for consultation and orientation to establish working guidelines and priorities for action.

(h) The organization of scientific associations for plant protection, that can provide a forum for studying plant health problems in the countries, the subregions and the hemisphere.

(i) The participation of farmers' organizations, field workers and the rural population in campaigns to control pests and diseases, as well as in quarantine measures.

The Heads of Plant Protection of IICA Member States in the Caribbean met in San José, Costa Rica from 15 – 17 August 1979, and again from July 27 – 29 1980 in Barbados. The objectives of these Meetings were to formulate a plan of action for the Caribbean within the Hemispheric Plant Protection Programme.

The Meeting in Barbados had as its objectives:

1. To analyse the programme objectives to make them more precise, more limited in scope and more realistic in relation to the financial resources of IICA.

2. To establish lines of priority from among the various proposals made at the Meeting in Costa Rica.

3. To establish mechanisms for coordination with Regional and International Plant Protection Organizations.

The result of this Meeting formed the basis for the orientation of the Programme at the Regional level.

The priorities identified included:

1. Training courses in Plant Quarantine and General Plant Protection.
2. Strengthening post entry Quarantine facilities.
3. Control and eradication of new pests and diseases.
4. Establishment of a Society for Plant Protection in the Caribbean.
5. Establishment of a Regional Newsletter.

The programme recognised the existence of several institutions concerned with plant protection in the Caribbean.

The Commonwealth Institute of Biological Control, with its track record in the biological control of pests.

The Caribbean Agricultural Research and Development Institute (CARDI), with its work in research and its outreach activities in several of the Islands.

The Faculty of Agriculture of the University of the West Indies, with its research and teaching capabilities and

Plant Protection divisions of the various Ministries of Agriculture.

The programme, however, recognized that there was no agency that provided a formal mechanism for coordination and cooperation in plant protection and that reciprocal, technical cooperation, which is so vital in the region because of the lack of plant protection capability in some of the smaller territories and the limited human and financial resources available, was not being fostered.

The programme also responded to: the need for information on pest and disease control; lack of professional stimulation among professionals in Ministries of Agriculture; lack of access to Scientific journals and lack of trained sub-professionals in plant protection and plant quarantine.

In recognition of these challenges, the following are some of the achievements of the programme to date.

Training

The programme recognises that the improvement of human resources represents one of the most important mechanisms for the enhancement of agricultural development. Consequently, training was given high priority in the actions which were carried out. There were three types of training provided:

a. Plant Quarantine Training
b. Training in Integrated Pest Management and
c. Specialized Training for various Officers of Ministries of Agriculture.

a. Plant Quarantine Training

Effective Plant Quarantine is necessary for the safe movement of agriculture produce in Regional and International trade. The Heads of Plant Protection in the Caribbean recognized that there is an urgent need for trained plant quarantine inspectors in the Region.

Consequently, a Regional Plant Quarantine Training Course was established. The course was held in Trinidad and Tobago in 1982 and in Barbados in 1983.

The course objectives were as follows:

1. To develop and foster among Plant Quarantine Inspectors of the Region an awareness of their mutual responsibility to keep the Caribbean free from foreign pests and diseases.
2. To improve the skills of Plant Quarantine Inspectors in the detection and treatment of Plant pests and diseases which pose a threat to Caribbean Agriculture from either Regional or extra-regional sources.
3. To improve communication between Plant Quarantine Inspectors of various territories of the Region.
4. To form the basis for the preparation of a Caribbean Plant Quarantine Training Manual.

The course was designed primarily for inexperienced Plant Quarantine Inspectors and dealt with the general principles of plant quarantine and the duties, responsibilities and requirements of Plant Quarantine Inspectors.

Twenty-one Plant Quarantine Inspectors have been trained so far. These include six from Barbados, two from Dominica, two from Grenada, two from Guyana, one from Haiti, two from Jamaica, one from St. Kitts, one from St. Lucia, two from Suriname and six from Trinidad and Tobago.

b. Integrated Pest Management

In collaboration with the Caribbean Agricultural Research and Development Institute (CARDI), the University of the West Indies, Faculty of Agriculture and the Consortium for International Crop Protection (CICP), a two week training programme on Integrated Pest Management was held at the Faculty of Agriculture, University of the West Indies, St. Augustine, Trinidad and Tobago on 10th - 21st, 1981. The seminar was attended by twenty-one participants from thirteen countries in the Region and, together with participants from Trinidad and Tobago, there was an average daily attendance of thirty-five persons. Lecturers were drawn from the Consortium for International Crop Protection, the University of the West Indies, Ministry of Agriculture of Trinidad and Tobago, the Commonwealth Institute of Biological Control, the Caribbean Agricultural Research and Development Institute, Caroni Limited and IICA.

The course dealt with the basic concepts of integrated pest management and their application to the solution of pest and disease problems of crops grown in the Caribbean. While most participants expressed a high level of satisfaction with the training programme, it was the opinion of all that a more sustained effort and long-term training in this area was necessary. Certificates were presented at the end of the course.

c. Specialized Training

1. Training for the detection of pests in containerized cargo –

   Two officers of the Ministry of Agriculture, Lands and Food Production, Trinidad and Tobago, were trained in this subject area.
2. Training in Acarology – An officer of the Ministry of Agriculture, Lands and Food Production, Trinidad and Tobago, was trained in Acarology.
3. Training in postharvest losses has been provided to an officer of a Research Institute in Trinidad and Tobago and in seed pathology for officers in Jamaica.

Information

In several of the Islands, access to current scientific literature is lacking. The programme introduced, in 1981, The Caribbean Plant Protection Newsletter.

The Newsletter, which is distributed annually, collects relevant information from scientific journals and from research in the region and makes it available in the form of abstracts to plant protection personnel throughout the region.

The newsletter publishes information on the following:

1. New research findings in the Caribbean.
2. New research findings elsewhere which are relevant to the region.
3. Abstracts of relevant literature.
4. Information on conferences and meetings.
5. Activities of plant protection personnel and institutions in the Caribbean.
6. IICA's Regional Plant Protection Programme.
7. Information on new equipment, pesticides, etc.
8. Feature articles on regional plant protection matters.

A new feature has recently been introduced where readers of the newsletter can obtain photocopies of the original articles from the editor.

In addition to the newsletter, the programme has published a document entitled "A Bibliography of Plant Disease Investigations in the Caribbean from 1880 – 1980". This publication, which contains references to over 3,000 publications on plant disease work in the Caribbean, is intended to serve as a reference source for Plant Pathologists, Nematologists, Agronomists, Research students and other persons interested in Agriculture in the Caribbean.

The Bibliography covers all aspects of plant diseases and their control, including diseases caused by fungi, bacteria, viruses and nematodes. The geographic area covered by the references includes all the territories of the Commonwealth Caribbean. The material covered by the Bibliography dates from the 1880 s to 1980.

The entries were complied mainly from primary sources, many of which have not been indexed previously. It would be impossible to list all the titles searched; however, the main sources of information were Agricultural News, Tropical Agriculture, West Indian Bulletin, the Journal of the Jamaica Agricul-

tural Society, the Journal of Agricultural Society of Trinidad and Tobago, and the Annual Reports and Publications of the Departments and Ministries of Agriculture throughout the Region. The Secondary sources included Regional bibliographies on agriculture and related topics and computerised literature searches of the Commonwealth Agricultural Bureau data bases. Copies of this bibliography have been sent to all plant protection personnel in the Caribbean.

A book on Plant Disease Diagnosis was prepared by the Specialist to provide plant protection personnel with an introductory handbook for the practical study of plant diseases. The book outlines the basic steps, facilities and procedures which are necessary for the accurate diagnosis of plant diseases.

This publication is especially valuable to laboratory assistants who are being introduced to Plant Pathology for the first time, to give them the rudimentary principles and techniques which are required for plant disease diagnosis.

The Establishment of a Mechanism for Professional Stimulation

The establishemnt of a society for plant protection in the Caribbean in 1981 responded to the needs of the region for a professional body to give professional stimulation and also to act as a mechanism for communication and coordination of plant protection activities. The society which now has some 121 members throughout the region has as its objectives the following:

- to strengthen inter-governmental and inter-institutional cooperation in plant protection in the Caribbean.
- to establish a forum for the discussion of plant protection issues affecting Caribbean Agriculture;
- to act as a forum for the exchange of ideas and information among plant protection personnel in the Caribbean;
- to promote and stimulate research and teaching in plant protection subjects, viz., Entomology, Plant Pathology, Weed Science, etc. and to ensure that these are integrated into the discipline of plant protection;
- to stimulate discussion and actions to ensure that the Caribbean environment remains free from contamination by pesticides;
- to carry out all other activities which may be associated with preserving the plant genetic resources of the Caribbean from destruction by pests and diseases as may be defined by the Executive Committee.

IICA assisted in the establishment of the Society for Plant Protection in the Caribbean at the Second Regional Meeting of Plant Protection in Latin America and the Caribbean held in Mexico City in October, 1980.

The Society has held two meetings so far. In 1981 it met in Jamaica and discussed urgent plant pest and disease problems in the Caribbean. In 1983, it met in Trinidad and Tobago and discussed the harmonization of pesticide legislation in the Caribbean. A document describing the Society has been prepared and is available.

Technical Support

This involves the direct use of the Specialist expertise in the assistance to the Member States. It involves answers given to questions of a plant protection nature and the provision of a resource person to assist in the solution of Regional problems. Examples of this would be the assistance given to the Barbados Ministry of Agriculture in the preparation of a Plant Quarantine facility for Cocoa, the advice given to Jamaica on the re-organization of the Plant Quarantine System, and on the design and analysis of plant protection experiments; suggestions for strengthening Plant Quarantine in Guyana; Diagnosis of diseases of sugarcane in Haiti and; suggestions for studies on yellow spot disease of sugarcane, Caroni Limited Trinidad and Tobago.

In addition to these specific areas of work a number of studies have been carried out in collaboration with regional and extra-regional institutions.

The following are examples of studies carried out:

a. An analysis of Plant Quarantine Systems in the Caribbean in collaboration with Animal and Plant Health Inspection Services (APHIS)

b. Training and Research needs in seed pathology in the Caribbean in collaboration with the Danish Institute for Seed Pathology in developing countries, located in Copenhagen, Denmark.

c. Study of the pest risks associated with the movement of agricultural produce between St. Vincent, Grenada and Trinidad and Tobago, (in collaboration with Dr. G.V. Pollard of the University of the West Indies).

d. Study on the economic impact of Moko disease on the economy of Grenada, (in collaboration with Dr. G.V. Pollard of the University of the West Indies).

These studies were designed to generate new information necessary for the implementation of plans within the programme.

Reciprocal Technical Cooperation means using the technical skills of some countries to benefit others, through IICA's action as a means of reciprocal transfer of know-how, and the exchange of technical personnel and useful experience.

Basically using the technical skills available in some countries to benefit others. The International Agency acts only to facilitate and finance in the relationship. This was used successfully during the programme in the following activities.

1. *Assistance to Grenada in the Control of Thrips of Cocoa*

   Thrips have been recognized as a severe problem in cocoa production in Grenada. The Government sought the assistance of IICA and Dr. Eslie Alleyne, Entomologist, Ministry of Agriculture, Barbados was contracted by IICA to provide technical assistance in Grenada. Dr. Alleyne's recommendations for the control of thrips in Grenada have been taken seriously by the Ministry of Agriculture authorities and the Chief Plant Protection Officer has now been seconded to the Grenada Cocoa Association to manage the thrips problem on a full-time basis.

2. *Assistance to the Food and Agriculture Corporation of Trinidad and Tobago in the Assessment of Pest Problems of Banana at Orange Grove*

The Food and Agriculture Corporation of Trinidad and Tobago, an Agency set up for corporate action in the agriculture sector under the aegis of the Ministry of Finance and Planning is cooperating with the Orange Grove National Sugar Company of Trinidad and Tobago in the development of a banana enterprise geared to the production of green banana either for the fruit market or use as a basic carbohydrate food item to partially displace rice and other wheat-derived staples. Based on discussions with the Inter-American Institute for Cooperation on Agriculture (IICA) for close cooperation on technical matters, the Corporation sought the assistance of IICA through its national office in Trinidad and Tobago to evaluate the incidence of pests and diseases in the existing plantings of banana at the estate and to develop a strategy for management of these pests and diseases in the future. The study was carried out during the month of May, 1983. Mr. Frank McDonald, Ministry of Agriculture, Guyana, was contracted to look at the Moko disease aspects of the problem.

Harmonization of Pesticides Legislation in the Region

There has been a dramatic increase in pesticide usage in the Caribbean during the last decade and, as in many parts of the world, there is concern with respect to the potential human and environmental hazards of pesticide use. The concept of the harmonization of pesticide legislation and registration requirements in the region stemmed from the initiatives developed by the FAO in 1977 to seek to harmonize the legislative aspects of pesticide use throughout the world. A meeting to consider the harmonization of pesticide legislation and the registration process in the region was held in Trinidad and Tobago under the auspices of IICA and with financial assistance from the National Agricultural Chemical Association (NACA) and GIFAP.

The meeting considered the status of pesticide legislation in the region and established guidelines for harmonization. The meeting had as its objectives:

- to examine and analyse the status of pesticide legislation in the Caribbean.
- to become familiar with measures currently in operation and to recommend others for standardizing the diverse requirements for pesticide use;
- to prove guidelines to those countries that need to enact legislation to regulate the use of guidelines, norms and technical procedures (chemical, analytical, biological, toxicological);
- to examine the status of establishment or acceptance of the maximum residue levels of pesticide (tolerance) in food in each country;
- to analyse the environmental impact of the large scale application of pesticides in the Caribbean;
- to stimulate training in pesticide registration procedures and in the safe and efficient use of pesticides.

Forty-five delegates from throughout the Caribbean and from Regional and International Organizations attended the meeting.

The meeting recommended, among other things, that the Pesticide and Toxic Chemicals Act of Trinidad and Tobago should be used as a model in the formulation of Regional pesticide legislative actions. Follow-up action to this is now being taken in the development of a Regional Training Programme in pesticide safety in collaboration with the World Bank and the University of Miami, School of Medicine. A 263 page document has been prepared as a result of the meeting.

A Mechanism for Coordination and Cooperation – The Heads of Plant Protection Meeting

The Heads of Plant Protection Meeting which has been held annually since 1981 provided an excellent mechanism for consultation, cooperation and communication in plant protection in the region.

The meetings which are held in a different country each year provide opportunities for the Heads of Plant Protection to visit the countries of the region and to observe the programmes and facilities which exist in the region.

The meetings contribute to:

1. Reduction in the possibilities for duplication of efforts.
2. Establishment of bilateral cooperative programmes in the region.
3. Establishment of a fraternity of plant protection which can be a very important asset in problem solving.
4. Providing guidance to the region programme.
5. Providing a forum for coordination of all technical assistance programmes in the region.

Deepening of the Scope of the Programme by Direct Assistance to National Systems

The scope of the programme has now been deepened by the establishment of national professionals in plant protection in the IICA offices in Dominica, St. Lucia and Grenada. In addition, in collaboration with USAID and USDA/APHIS there are proposals to set up a pest management unit in Grenada. This initiative responds to the need for an effective plant protection capability in the small island states of the region which are embarking on a major thrust in the development of fruits and vegetables for the export markets of North America and Europe. The initiative also responds to the following situation, and I quote from a recent document: "Although chemical pesticides - - particularly insecticides and herbicides - - are being utilized in increasing levels, the pest problems actually seem to be worsening. Annual pest losses in cocoa now approach an estimated $1 million (U.S.). Leaf spot disease, Moko disease, and root knot nematodes cause crippling losses in banana if expensive chemical treatments are not applied. GCA and GBCS together annually spend $450,000 - - about 25 percent of their total budget - - for control of cocoa and banana pest". It also responds to the need to have in place a

point of contact for the delivery of technical cooperation in plant protection from International agencies.

In Suriname, a specialist in coconut pests and diseases has been located in the IICA Office in that country to attend to the pressing problems of coconut mainly "Hart Rot disease" and *Castnia* spp. It is hoped that with assistance from other agencies and friendly governments that these initiatives will result in the development of a regional centre for investigations on coconut and oil-palms.

Future Initiatives

1. Preparation of project proposals for a survey of fruitflies in the Caribbean.
2. Preparation of field guides to plant pests and diseases of importance in the Caribbean and bibliography of pests.
3. Development of Third Regional Plant Quarantine Training Course.
4. Survey of the incidence of mango seed weevil in the Caribbean.
5. Workshop on the detection of pests and diseases of fruits in the Caribbean.
6. Establishment of Regional Training Programme in Pesticide Safety.
7. Establishment of a Data Base in Plant Protection for the Caribbean.

Bibliography

Alleyne, E. (1981) *A report on a visit to Grenada to advise on the control of cocoa thrips (Solenothrips rubrocinitus) on cocoa.* Mimeo 16 pp.

Anon (1983) *An investigation of the incidence of pest and disease at Orange Grove National Sugar Company,* IICA Office, Port-of-Spain, Trinidad and Tobago, 12 pp.

Anon (1982) *The Society for Plant Protection in the Caribean: It origin, constitution and current membership.* IICA Office. Port-of-Spain, Trinidad and Tobago. 19 pp.

Brathwaite, C.W.D. (1981) *An introduction to the diagnosis of plant disease.* Inter-American Institute for Cooperation on Agriculture. Series Book and Education Materials No. **47**, 49 pp.

Brathwaite, C.W.D. (1981) *Perspectives for plant protection in the Caribbean.* IICA Office. Port-of-Spain, Trinidad and Tobago.

Brathwaite, C.W.D. (1981) Crop Protection in the 1980s. An analysis of present alternative technologies. *New Technologies in Food Production.* Port-of-Spain, Trinidad and Tobago. **12**, 32–36.

Brathwaite, C.W.D. (1982) The challenge for Plant Protection in the Caribbean in the 1980 s and beyond. In C.W.D. Brathwaite and G. Pollard (eds) *Urgent Plant Pest and Disease Problems in the Caribbean.* Inter-American Institue for Cooperation on Agriculture. Miscellaneous Publication No. **378**. pp. 7–19.

Brathwaite, C.W.D. (1983) Pest and diseases of onion. *In Workshop on Onion Production and Research for the Eighties.* Bridgetown, Barbados, 1983. Proceedings. Inter-American Institute for Cooperation on Agriculture Miscellaneous Publication.

Brathwaite, C.W.D. (1983) *IICA's activities in the Caribbean.* IICA Office, Port-of-Spain, Trinidad and Tobago. 6 pp.

Brathwaite, C.W.D. (ed.) (1984) *Proc. Mtg. on the Harmonization of Pesticide Legislation in the Caribbean,* Port-of-Spain Trinidad and Tobago, 1983. Inter-American Institute for Cooperation on Agriculture Miscellaneous Publication No. **379.** 253 pp.

Brathwaite, C.W.D. (ed.) Caribbean Plant Protection Newsletter. Vol. I. Nos. 1–4, 1981-1984. IICA Office, Port-of-Spain, Trinidad and Tobago.

Brathwaite, C.W.D., Alcock, M. and Soodeen, R. (1981) *A bibliography of plant disease investigations in the Commonwealth Caribbean 1880-1980.* Inter-American Institute for Cooperation on Agriculture Miscellaneous Publication No. **328.** 1981. 280 pp (ISSN–0534-5391).

Brathwaite, C.W.D. and Pollard, G.V. (1981) The essential role of pest and disease control in crop production in the Caribbean. *Agriculture Extension Newsletter (Trinidad and Tobago).* **12**, 32.

Brathwaite, C.W.D. and Pollard G.V. (eds.) (1981) Ist Meeting of the Society for Plant Protection in the Caribbean, Kingston, Jamaica, 1981. *Urgent Plant Pest and Disease Problems in the Caribbean.* Inter-American Institute for Cooperation on Agriculture Miscellaneous Publication No. **378.** 260 pp.

Pollard, G.V. (1983) The economic impact of Moko disease on the economy of Grenada. IICA Office, Port-of-Spain, Trinidad and Tobago, 14 pp.

Pollard, G.V. (1983) Report on a visit to Grenada, St. Vincent and St. Lucia to investigate the potential pest risks associated with the movement of agricultural produce via the inter-island schooner trade. Report to IICA, Port-of-Spain, Trinidad, November 1983. 23 pp.

Small, L.W., *The legal framework of plant quarantine systems in the Caribbean.*

PLANT PARASITIC NEMATODES ASSOCIATED WITH SUGARCANE IN ST. KITTS

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ABSTRACT

In 1982, an evaluation was undertaken of the plant parasitic nematodes associated with sugarcane in St. Kitts. Eleven plant parasitic nematode genera were found, viz., *Pratylenchus, Helicotylenchus, Macropsthonia, Xiphinema, Meloidogyne, Paratylenchus, Tylenchorhynchus, Paratricodorus, Hemicriconemoides, Longidorus* and *Hoplolaimus*. The average number of nematodes per 200 c c soil sample ranged from 210 to 680 with an overall average of 406. Nematode population densities were influenced by varieties, the number of ratoons and the nematicide.

RESUMEN

En el año 1982, se llevó a cabo una evaluación de los nemátodos asociados con la caña de azucar, en St. Kitts. Once géneros de nemátodos fitoparasíticos, se encontraron, como ser: *Pratylenchus, Helicotylenchus, Macropsthonia, Xiphinema, Meloidogyne, Paratylenchus, Tylenchorhynchus, Paratricodorus, Hemicriconemoides, Longidorus* y *Hoplolaimus*. La cantidad media de nemátodos por 200 cc de suelo fué de los 210 a 680 con un total medio de 406. La densidad de nemátodos fué influenciada por: las variedades, el número de retoños y el nematocída.

Within recent times, there has been increased interest in the study of plant nematodes associated with sugarcane in St. Kitts. Such knowledge is an essential step in the evaluation of the role of nematodes in the soil. Sugarcane is an important crop in terms of the number of people employed, its contribution to the island GDP and value of export earnings.

Sugarcane is usually grown in monoculture in the Caribbean and this practice usually results in the build up of disease organisms. It is known that nematodes cause damage to sugarcane roots and that the amount of damage depends upon the nematode population density. This damage results in the reduction in the quality and quantity of harvested cane. To ensure a good crop it has become the standard practice in St. Kitts to apply nematicides to all plant canes without reference to the nematode population density. This has resulted in an increase in the cost of production. With the depressed international sugar prices at the moment, sugarcane has become, at best, a break-even business.

In 1982, the Government of St. Kitts requested CARDI to make an assessment of the general economic importance of nematodes on sugarcane.

The purpose of this study, therefore, was to evaluate the plant parasitic nematodes associated with sugarcane in St. Kitts.

Background

There are approximately 10,000 acres under sugarcane production in St. Kitts. A significant portion of the total sugar product (32,000 tons) is used for local consumption. Soil and climatic conditions are suitable for the growing of sugarcane in St. Kitts. Sugarcane yields are among the highest obtained in the Caribbean, averaging about 38 tons per acre.

During the past decade, the main research emphasis has been on varietal selection. However, with the appearance of the smut disease in 1978, varietal testing for resistance was initiated and some emphasis was given to minimum tillage. There has been no major insect pest problem except for the moth borer, *Diatraea saccharalis*, for which biological control is used.

Materials and methods

Soil samples were collected from sixteen sugar estates in St. Kitts. The samples were taken with a 1.5 cm borer to a depth of 15 to 17 cm. Each sample was made up of about one litre of soil collected around the sugarcane roots in 15 to 20 locations. A subsample of 200 cm^3 was processed by modified Cobb's decanting and sieving method (3). Ten percent of each nematode suspension recovered was examined under the stereo-microscope and generic counts made. Specific identifications were done under the compound microscope. In a few cases, samples were sent to the Commonwealth Institute of Parasitology for species identification.

Field data on cultivation and crop husbandry were recorded at the time of soil sampling.

Results and discussion

Data from soil samples collected from 16 districts in St. Kitts are shown in Table 1. Eleven plant parasitic nematode genera were found associated with sugarcane, namely, *Pratylenchus, Helicotylenchus, Macroposthonia, Xiphinema, Meloidogyne, Paratylenchus, Tylenchorhynchus, Paratricodorus, Hemicrinomoides, Longidorus* and *Hoplolaimus*. The last four named plant nematode genera were grouped under "Other Tylenchida" because they were found in low numbers in a few samples. The average number of nematodes per 200 c c soil sample ranged from 210 to 680, with an overall average of 406.

Species of nematodes identified were *Macroposthonia sphaerocephala, Hemicriconemoides mangiferae, Xiphinema vulgare, Longidorus laevicapitatus, Pratylenchus brachyurus, Helicotylenchus dihystera, Hoplolaimus columbus* and *Tylenchorhynchus ammulatus*.

Populations of *Pratylenchus* and *Helicotylenchus* were high and were widely distributed throughout the sugarcane growing areas. These nematode population

densities are more than two times higher than those reported for sugarcane from Barbados and Trinidad by Brathwaite (1, 2). Furthermore, the population density of *Pratylenchus* was far above the economic threshold level reported for this crop by Persad (4).

Macroposthonia was frequently encountered, but its economic importance in sugarcane is not known. Of particular importance also is the occurrence of *Xiphinema, Meloidogyne* and *Tylenchorhynchus.* These genera include some of the most damaging nematode pests to sugarcane (4, 5).

The data showed that the varieties, B59136, B63118 and B5970 harbour a higher nematode population than B63371 (Table 2). This may be due to differences in susceptibility of the varieties.

It is noteworthy that the nematode population densities increased markedly with every subsequent ratoon (Table 3). Plant cane had a lower nematode population density, as compared with the first ratoon or the seond ratoon. Correspondingly, sugarcane yield usually declines progressively with every ratoon until after the fourth or fifth ratoon, when the cummulative loss in tonnage is usually greater than the revenue obtained from the cane. At that point sugarcane becomes uneconomical and the land is usually treated before replanting is done. It is interesting to note that in Jamaica the highest yield is obtained in the first ratoon and not in the plant cane, as in the case of St. Kitts. This may be due to the effect of the nematicide that is generally applied to all plant cane in St. Kitts.

The data showed that soil application of Carbofuran reduced markedly the nematode populations below those of the control (Table 4). Other workers (4, 5) also found the Carbofuran was effective in reducing the nematode population in sugarcane. It was difficult to correlate the nematode population with yield in the absence of yield data. Not withstanding the high yield obtained in St. Kitts, however, it could be said that nematodes may be partly responsible for yield losses.

Further work into a number of crop husbandry problems should be undertaken, e.g., an evaluation of the economics of the nematicide, an investigation to find resistant sugarcane varieties.

Acknowledgement

The author wishes to thank Dr. David Hunt of the Commonwealth Institute of Parasitology, England for the identification of some of the nematode species; Mr. Conrad Kelly and Mr. J. Thomas of the Ministry of Agriculture, St. Kitts for their assistance in collecting the soil samples and Mr. K. M. Farrell for technical assistance.

References

1. Brathwaite, C.W.D. 1976 Plant parasitic nematodes associated with sugar-cane in Barbados. Plant Dis. Rept. 60, 294–295.

2. Brathwaite, C.W.D. 1980 Plant parastic nematodes associated with sugar-cane in Trinidad, FAO Plant Prot. Bull., 28, 133–136.

3. S'Jacob, J.J. and J.V. Bezooijen, 1970 A manual for practical work in nematology. Inter. Agr. Centre, Wageningen Holland.

4. Prasad, S.K. 1972 Nematode disease of sugar-cane. In J.M. Webster (ed.) Economic nematology. Academic Press, 144–158.

5. Valle-Lamboy, S. and A. Ayala, A. 1980 Evuluation of four nematicides for the control of phytoparastic nematodes on sugar-cane. J. Agr. Univ, Puerto Rico, 348–355.

6. Winchester, J.A. 1969 Sugar-cane nematodes and their control. Proc. Symp. on Tropical Nematology. Univ. of the West Indies, Trinidad.

Table 1 Mean number and frequency of occurrence of plant parasitic nematode genera in soil samples of sugar cane from various estates in st. Kitts

District	No of samples	Nematode genera per 200cc/soil											
		Pratylenchus	Paratylenchus	Helicotylenchus	Tylenchus	Tylenchorhynchus	Aphelenchus	Macroposthonia	Meloidogyne	Other Tylenchida	Xiphinema	Saprophytic	Total
Ponds Needs-	12	102	50	—	1	4	8	85	0	22	11	56	347
must		(12)	(8)	(0)	(1)	(4)	(0)	(11)	(3)	(10)	(5)	(12)	—
Cranstdun	4	110	—	93	10	15	5	33	—	5	20	40	347
		(4)	(0)	(4)	(3)	(4)	(2)	(3)	(0)	(2)	(2)	(4)	—
Stapleton	2	160	20	150	75	—	20	45	15	15	5	90	595
		(2)	(2)	(2)	(2)	(0)	(2)	(1)	(1)	(1)	(1)	(2)	—
Bourres	2	320	5	70	20	65	—	35	10	35	10	110	680
		(2)	(1)	(2)	(1)	(2)	(0)	(2)	(1)	(2)	(1)	(2)	—
Buckleys	1	60	20	190	20	—	20	40	10	20	—	70	450
Stonefort	1	30	40	90	—	10	—	20	20	40	—	50	300
Winefield	1	40	10	80	30	30	20	90	10	100	70	70	500
Con Phipps	1	10	—	—	—	—	—	90	—	40	50	120	310
Canada	1	80	70	—	10	—	—	40	—	30	10	90	330
Brighton	1	60	—	110	—	60	—	30	30	10	10	90	400
Lodge	1	10	10	160	40	—	—	10	20	10	40	120	420
Lower Bourryeau	1	330	—	20	—	20	—	60	—	30	—	30	490
Molineux	1	30	—	150	50	20	10	—	—	40	—	130	430
Manson	1	230	—	130	10	—	—	—	—	—	—	20	390
Willets	1	30	—	90	10	—	—	—	—	10	—	70	210
Brotherson	1	100	—	360	10	20	—	30	10	—	30	80	640
Overall average		114	25	68	14	13	6	54	0	22	14	68	406
		(32)	(16)	(18)	(15)	(16)	(13)	(26)	(11)	(25)	(16)	(32)	—
Frequency (%)		100	50	56	0	47	50	41	81	34	78	50	100

Table 2 Mean number of plant parasitic nenatode genera in soil samples from sugar cane nurseries grouped according to variety in St. Kitts

Variety	Nematode genera per 200cc soil											
	Pratylenchus	Paratylenchus	Helicotylenchus	Tylenchus	Tylenchorhynchus	Aphelenchus	Macroposthonia	Meloidogyne	Other Tylenchida	Xiphinema	Saprophytic	Total
B59136	220	—	70	30	20	10	—	—	—	—	20	370
B63371	40	—	30		10	10	10	—	—	30	50	180
B63110	90	—	200	10	20	—	10	—	10	20	60	420
B5970	120	—	70	30	10	—	110	—	10	30	30	410

Table 3 Mean number of plant parasitic nematode genera in soil samples from sugar cane variety UCW 54/65 grouped according to plant growth stage in St. Kitts

Cycle	Nematode genera per 200cc soil								
	Prathylenchus	Paratylenchus	Aphelenchus	Macroposthonia	Meloidogyne	Other Tylenchida	Xiphinema	Saprophytic	Total
Plant Cane	80	—	10	30	0	40	—	30	190
1st Ratoon	60	40	10	20	0	40	30	100	300
2nd Ratoon	130	10	10	50	0	50	60	140	450

Table 4 Effect of the nematicide, Carbofuran, on the nematode population of sugar cane in St. Kitts

Nematicide	Nematode genera								
	Pratylenchus	Paratylenchus	Tylenchorhynchus	Macroposthonia	Meloidogyne	Other Tylenchi da	Xiphinema	Saprophytic	Total
Carbofuran (B63118)	180	40	10	0	50	10	0	30	320
Control	260	100	0	50	20	0	0	30	460

EFFECTS OF FOUR CROPPING SYSTEMS ON POPULATION DENSITIES OF *MELOIDOGYNE INCOGNITA* (ROOT–KNOT NEMATODE) ON CARROT

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ABSTRACT

The research was conducted on two farms previously under carrot *(Dacucus carota)* monoculture and intercropped sweet potato *(Ipomoea batatas)* and carrot, respectively, for the past three years. The pre-plant population densities of *Meloidogyne incognita* were highly significantly reduced (P = 0.001) under cabbage-carrot, chives-carrot and onion-carrot, as compared to sole cropping of carrot, after four months' growth. The initial root-knot nematode population densities in both farms combined were increased by 235% when carrot was grown in pure stands. Under the three crop combinations there was also a significant 40–60% reduction in root-knot gall indices of carrots, compared with carrots grown in monoculture. The potential of the three intercropping systems to manage the root-knot nematode on carrot in small farms in St. Vincent is discussed.

RESUMEN

La investigación se llevó a cabo, en dos fincas cultivadas anteriormente con zanahoria *(Daucus carota)* en monocultivo y, con relévo de camote *(Ipomoea batatas)* y zanahoria respectiveamente, durante los últimos tres años. El número de *Meloidogyne incognita* antes del plantío, fué reducido considerablemente (P = 0.001) cuando se plantó, cultivos mixtos de: repollo-zanahoria, cebollino-zanahoria y cebolla-zanahoria, comparados con el monocultivo de zanahoria, despues de cuatro meses de crecimiento. La cantidad inicial del Nodulador, en ambas fincas combinadamente fué incrementada por un 235% cuando zanahoria solamente, fué plantada. Durante el cultivo de las tres combinaciones mencionadas anteriormente se observó, un índice de reducción notable, del 40 al 60%, del Nodulador en la zanahoria, comparado con zanahoria cultivada en monocultivo. En esta presentación discutiremos el potencial de controlar el Nodulador en la zanahoria, que tienen los tres cultivos en asociación en pequenas fincas en la isla de St. Vincent.

Keywords: *Meloidogyne incognita;* Cabbage-carrot, Chives-carrot; Onion-carrot.

Cropping Systems research is assisting small farmers in the developing world to identify low cost, alternative pest management technologies.

Plant parasitic nematodes have been shown to be effectively controlled by crop rotation (Good et al., 1973, Wilson and Caveness, 1980; Hutton et al., 1982; Netscher, 1985), and by short-term fallows and certain cropping sequences (Brodie and Murphy, 1975). However, fallow may have adverse effects on organic matter and structure of soil (Good, 1968; Murphy et al., 1972).

The practice of intercropping or polycultures in traditional agriculture has several advantages. One is the occurrence of less pest damage in polycultures, because of differential susceptibility to pests, pathogens and nematodes (Altieri, 1983). Cropping sequences and intercropping are being researched for different regions of the tropics to identify those which most effectively control plant parasitic nematodes, including the root-knot nematode (Hutton et al., 1982; Netscher, 1985; Rhodes, 1985; Sasser, 1985).

Carrots in St. Vincent are traditionally grown on small farms (0.08 – 0.4 ha), and the rot-knot nematode *(Meloidogye incognita* (Kofoid & White)*)* has been associated with the steep decline in production of the crop over the past nine years (Singh, 1982).

The study reported here sought to identify intercropping systems which could limit population densities of *M. incognita*, and thereby reduce root-knot damage on carrot in St. Vincent.

Materials and methods

The experiment was located on two farms at Belmont (Farm 1) and Schwartz (Farm 2) on the Leeward side of the island. The soil is a loam classified as "Volcanic Ash".

Both farms had a history of root-knot nematode infestations on carrot over the past three years.

The four selected cropping systems were row-intercropping of onion-carrot, chives-carrot, cabbage-carrot, and pure stands of carrot. Plot size was 5.5m x 3.0m, with 30cm separating each plot. There were four ridges per plot. In the row-intercropping plots, each ridge was planted with two rows of carrot and one row of the respective intercrop. In the pure stands, carrot was seeded in three rows per ridge. Cabbage seedlings were planted 45cm apart. Chive setts, onions, and carrots were sown to give an intra-row spacing of 15cm, after the onions and carrots were thinned out as a normal cultural practice.

The treatments were arranged in a randomised complete block design, replicated four times on each farm.

In both farms, 800kg ha^{-1} of the compound fertilizer, 12:8:24, was applied along the ridges in two split applications and incorporated in the soil by trowels. Handweeding was done as needed and a fortnightly application of Decis at 0.003% a.i. was used to control onion thrips *(Thrips tabaci)* and *Plutella xylostella* on cabbage. Three sprays of Trimiltox Forte at 0.31% a.i. concentration were applied to control Early Blight disease *(Alternaria solani)* on carrot.

Preplant soil samples were collected from each plot and a further set of samples taken after four months' of crop growth. In each plot, at each sampling, 10 random cores of 200cc soil to a depth of 20cm were taken. Each plot sample was a composite of 1.5 to 2.0kg of soil. A sub-sample of 200 cc of soil was processed, and extraction of nematodes done using the pie-pan method (Gowen and Edmunds, 1973).

Analysis of variance was done on transformed, pre-plant nematode density counts [$y=\log_{10}(x + 1)$] The population density counts recorded after four months of crop growth were also adjusted for the pre-plant counts, using co-variance analysis.

Yield of marketable carrots and root-galling indices were also statistically analysed.

Results and Discussion

There was no significant difference between the means of the pre-plant population densities of *Meloidogyne incognita* in the two farms (Table 1). The post plant population densities of the two farms were, however, found to be very highly significant (P = 0.001), while the adjusted post-plant population counts for initial counts using co-variance analysis were also very highly significant (Table 1).

The Farms x Treatments interaction was highly significant (P = 0.01), indicating that in Farm 2 the three treatments, onion-carrot, cabbage-carrot, and chives-carrot significantly reduced the root-knot nematode (RKN) population, whereas in Farm 1 only the onion-carrot combination significantly reduced the nematode population (P = 0.05). Where carrots were grown as a monoculture there was a very large increase in nematode counts (Table 1).

Singh (1982) demonstrated the reduction in *M. incognita* population densities in land that was cropped under sweet potato-cassava and sweet potato-tannia, but did not report the corresponding root-knot indices. Population densities of the root-knot nematode *(M. incognita)* were also reduced under onion and chives after four months of growth in a mixed intercropping study (McDonald, 1985). The suitability of the host plant for nematode reproduction is perhaps the major determinant of population densities (Good et al., 1965; Brodie et al., 1970a; Brodie et al., 1970b).

Yields of marketable carrots were not significantly different among the three treatments, when compared with the carrot alone system as control, but reduction in root-knot gall indices of carrots was significant (P = 0.05) under the three di-cultures, as compared to those of carrots grown in single stands (Table 2). Galling of roots was found to increase with increase of nematode population, using co-variance analysis [$y=\log_{10}(x + 1)$].

Seinhorst (1965) found that population damage and yield losses are directly related to pre-plant nematode population densities.

The lack of significant differences in marketable yield of carrots can be explained by the differences in plant populations found in the four cropping systems. The onion-carrot, cabbage-carrot and chives-carrot crop combinations had a third less carrot plants than in the pure stands of carrots. Despite this difference, the chive-carrot cropping system in fact outyielded the single carrot cropping system.

It is intended to follow up this work with further trials, and to use economic analyses to determine the profitability of two of the three tested cropping systems which at the same time would reduce RKN infestations and hence damage.

The findings of this present intercropping study seem to confirm the view of Brodie and Murphy (1975) that other alternatives to chemicals such as relay intercropping, crop rotation, short-term fallow, and non-host crops, when used in combination, can result in greater nematode control and increased crop yields than when used alone.

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Table 1. Effect of four cropping systems on mean soil population densities of *Meloidogyne incognita* [a,b]

Cropping system	Nematadoes per 200cc soil[c]		
	Pre-plant count	Post-plant count	Post-plant count (adjusted for per-plant count)
Onion-Carrot	125 (2.09)	60 (1.78)	69 (1.84)
Cabbage-Carrot	149 (2.17)	104 (2.02)	109 (2.04)
Chive-Carrot	208 (2.32)	129 (2.11)	115 (2.06)
Carrot (alone)	188 (2.27)	445 (2.65)	417 (2.62)
CV	9.5%	9.62%	8.74%
LSD (P=0.05)	NS	- (0.22)	- (0.21)

[a] Data were transformed (log x + 1) for analysis of variance and calculating LSD (0.05) values and were de-transformed for presentation in the table above. Transformed values are given in parentheses.

[b] Based on four replications per farm of four observations (aliquots).

[c] Juveniles only.

[d] Post plant count = counts after 4 months growth of crops.

Table 2 Effect of four cropping systems on marketable yield and root galling of carrot [a]

Cropping system	Wt. of carrot (kg/ha)	Root gall index [b]
Onion-Carrot	6727	1.875 a [+]
Cabbage-Carrot	5515	1.875 a
Chive-Carrot	8866	1.25 a
Carrot (alone)	7091	3.125 b
	CV 36.5%	30.1%
	SE = 4.8	

[a] Based on means of four replications per farm

[b] Mean root gall index based on: 0 = no root infected; 1 = root with a few small galls; 2 = root with many small galls; 3 = root with a few large galls; 4 = root with many large galls; 5 = root with knotted growth

[+] Means followed by a common letter are not significantly different at P = 0.05 as determined by Duncan's multiple range test

References

Altieri, M.A. (1983) *Agroecology*. Division of Biological Control, University of California, Berkeley. p 162.

Brodie, B.B., Good, J.M. and Jaworski, C.A. (1970a) Population dynamics of plant nematodes in cultivated soil: Effects of summer cover crops in old agriculture land, *J. Nematol.* **2**, 147–151.

Brodie, B.B., Good, J.M. and Jaworski, C.A. (1970b) Population dynamics of plant nematodes in cultivated soil: Effects of summer cover crops in newly cleared land, *J. Nematol.* **2**, 217–222.

Brodie, B.B. and Murphy, W.S. (1975) Population dynamics of plant nematodes as affected by combinations of fallow and cropping sequence, *J. Nematol.* **7**, 91–92.

Good, J.M. (1968) Relation of plant parasitic nematodes to soil management practises, In: G.C. Smart Jr. and V.G. Perry (eds.), *Tropical nematology*, University of Florida Press, Gainesville. p. 113–118.

Good, J.M. Minton, N.A. and Jaworski, C.A. (1965) Relative susceptibility of selected cover crops and coastal bermuda grass to plant nematodes. *Phytopathology* **55**, 1026–1030.

Good, J.M. Murphy, W.S. and Brodie, B.B. (1973) Population dynamics of plant nematodes in cultivated soil: Length of rotation in newly cleared and old agricultural land, *J. Nematol.* **5**, 117–122.

Gowen, S.R. and Edmunds, J.E. (1973) An evaluation of some simple extraction techniques and the use of hydrogen peroxide for estimating nematode populations in banana roots, *Plant Dis. Reptr.* **57**, 678–681.

Hutton, D.G., Coates-Beckford, P.L. and Eason-Heath, A.E. (1982) Three-year crop rotation for control of *Meloidogyne incognita* on the South-Central plains of Jamaica (Interim Report), In: *Proceedings of the Third Research and Planning Conference in Root–Knot Nematodes, Meloidogyne spp.*, Panama, 11–15 Jan., 1982. Internal Meloidogyne Project. p. 180.

McDonald, F.D. (1985) The effects of six selected crops on population densities on root-knot, root-lesion and reniform nematodes. *Proceedings of XVII Meeting OTAN/ONTA.* Trinidad, 28 July – 2 Aug., 1985 (in print).

Murphy, W.S., Brodie, B.B. and Good, J.M. (1972) Population dynamics of plant nematodes in cultivated soil: Effect of cropping systems and nematicides, *J. Nematol.* **6**, 103–107.

Netscher, C. (1985) A crop rotation to control root-knot nematode in the tropics, In: *Proceedings of the Third Research and Planning Conference on Root-Knot Nematodes, Meloidogyne* spp. Panama, 11–15 Jan., 1982. International Meloidogyne Project. p. 180.

Rhodes, H.L. (1985) Effects of summer cover crops and fallowing on population of *Belonolaimus longicaudatus* and *Meloidogyne incognita* and yields of subsequent vegetable crops. *Proceedings of XVII Meeting OTAN/ONTA.* Trinidad. 28 July – 2 Aug., 1985. (in print).

Sasser, J.N. (1985) Nematode cropping system research methodology. *Proceedings of XVII Meeting OTAN/ONTA.* Trinidad, 28 July – 2 Aug., 1985 (in print).

Seinhorst, J.E. (1965) The relation between nematode density and damage to plants, *Nematologica* **11**, 137–154.

Singh, N.D. (1982) Root-Knot nematode *(Meloidogyne incognita)* investigation on carrot in St. Vincent, W.I. In: *Proceedings of the Third Research and Planning Conference on Root-Knot Nematodes, Meloidogyne spp.* Panama, 11–15 Jan., 1982. International Meloidogyne Project. p. 180.

Wilson, G.F. and Caveness, F.E. (1980) The effects of rotation crops on the survival of root-knot, root-lesion and spiral nematodes. *Nematropica* **10**, 56–61.

AN APPROACH TO THE INTEGRATED MANAGEMENT OF THE TANNIA RAPID YELLOWING DISEASE

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ABSTRACT

Tannia, *Xanthosoma* spp. (L.) Schott, is a staple root crop in the humid tropics. In the East Caribbean, the crop is also of great survival and economic value to the largely subsistence farming population, amidst the constant threat of hurricanes. The crop is susceptible to Tannia Rapid Yellowing Disease (TRYD), especially in Dominica and St. Lucia. The disease is caused by the fungus, *Pythium myriotylum* Drechsl. It is prevalent in poorly drained locations and particularly affects the desirable, smooth-skinned, white or purple-fleshed cultivars. It is spread through the use of infested planting material and perpetuated in fields with volunteer, diseased host plants. A rough-skinned, white-fleshed tannia cv of limited marketability is tolerant to TRYD. The eddoe, *Colocasia esculenta,* is resistant. The use of fungicides, including metalaxyl, cultural practices, combined with host plant resistance, are suggested for the integrated management of the disease. In the long term, joint efforts with existing breeding programmes for resistance to the disease are recommended.

RESUMEN

El ocumo, *Xanthosoma* spp (L.) Schott, es un tubérculo alimenticio de importancia en el trópico humedo. En el Caribe Oriental, este cultivo es tambien de gran valor económico y de sobrevivencia para la población agrícola marginal, la cual se encuentra en constante amenaza de incidencia de huracanes. El cultivo es susceptible a la enfermedad del Amarillamiento Rapido del *Xanthosoma* spp. (TRYD) especialmente en la isla de Dominica y en la de St. Lucia. La enfermedad es causada por el hongo *Pythium myriotylum* Drechsl. Este es predominante en lugares con pobre drenaje y afecta particularmente a los cultivares de cáscara lisa y de color blanco o morado, los cuales tienen mayor demanda. La enfermedad se disemina mediante el uso de material de plantío infectado y perpetuado en campos con plantas voluntarias-huespedes. La *Xanthosoma* spp cv, blanca y con cascara rugosa y de mercadeo limitado, es tolerante a la enfermedad TRYD. La *colocasia esculenta,* es resistente a dicha enfermedad. El uso de fungicídas, incluyendo el metalaxyl, y las formas de cultivo combinadas con plantas huespedes, son las practicas sugeridas para el manejo integrado de la enfermedad. A largo plazo se recomienda, la practica de esfuerzos mutuos con programas exsistentes de mejoramiento genético.

Tannia *(Xanthosoma* spp. (L.) Schott)*)* originated in tropical America, but is now widely grown as a subsistence food crop in Africa, Asia and Polynesia (Kay, 1973).

Whilst it is rarely grown as a sole crop in subsistence farming systems, it is no longer a "poor man's crop", but rather a crop with economic value (Adams et al., 1985; I.I.T.A., 1981). Under high level management, cormel yields of 25 – 37.5 t/ha have been reported, whereas, with peasant agriculture, yields as low as 5 – 7.5 t/ha (Kay, 1973) are common. However, the lower peasant yield is generally related to intensive, mixed cropping and poor management practices.

In the 1960's there was an upward trend in exports of tannia from the Carihbean to the UK (Kay, 1973), but by the 1970's the trend had begun to drop, due to a 'burning' disease. An apparently similar disease is known to be severe in the Americas, especially in the Caribbean and West Africa (Ghana and Cameroon). It is currently the subject of investigations in Nigeria and Cameroon (I.I.T.A., 1981; Nzietcheung, 1983), Costa Rica (Salazar, 1985), Florida (O'Hair, 1984) and in the Eastern Caribbean (Adams and Pattanjalidial, 1983).

In the Eastern Caribbean, this tannia disease was originally described as tannia leaf burning disease (CARDI-Windward Islands, 1982) and tannia burning disease (Clarendon, 1982; Demarque and Auguste, 1982). Hereafter, in this presentation, the disease will be referred to as tannia rapid yellowing disease (TRYD). This name conveys the most obvious symptom of the disease as we have observed it in the field. It is distinct from bacterial leaf spots (Berniac, 1974) and mineral deficiences or nutrient disorders that cause yellowing and root rots (Spence and Ahmad, 1967), but it is similar to the *Pythium*-induced root rot of cocoyam in Cameroon (Nzietcheung, 1983); Martinique and Guadeloupe (Messiaen and Hotoundji, 1984). The symptoms of cocoyam root rot blight or 'mal seco' of *Xanthosoma* spp. in Costa Rica (Laguna *et al.,* 1983; Salazar, 1985) appears to be similar to TRYD. Earlier reports suggested that 'mal seco' of *Xanthosoma* spp. in Puerto Rico is similar, but Rodriguez (1984) indicated a different array of symptoms and the causal organism was described as *Rhizoctonia solani* Kuhn.

Economic importance of the T R Y Disease in the Eastern Caribbean

Subsistence farmers depend on tannia both as a staple food and cash crop. In addition, the tannia represents food security in times of hurricane and high winds.

The gross annual value of the cormel yield from an estimated area of 2111 ha (Adams and Pattanjalidial, 1983) in the Eastern English-speaking) Caribbean has been estimated to be US$ 6M (Adams *et. al.,* 1985).

However, it was estimated that approximately 65 and 80 per cent of the crop is lost due to the disease in Dominica (Clarendon, 1982) and in St. Lucia (Demarque and Auguste, 1982), respectively. Estimates of losses in St. Vincent and Grenada are not available, but observations by the authors indicate that tannia crops in these two islands are similarly plagued by the disease. Plants observed with bacterial leaf spots, viruses and nutrient disorders produced marketable cormels, whereas the TRY-diseased plants often produce no edible cormels.

Characteristics of the Tannia Rapid Yellowing Disease (TRYD)

TRYD is characterized by a successive. rapid yellowing and early senescence of the outer leaves from as early as 3 weeks after planting, and it may affect plants as old as 24 weeks (CARDI/EDF: Aroids & Arrowroot, 1984). The yellowed leaves are without necrotic spots and successive leaves are smaller than those in the normal, healthy plants. The net result is a severe dwarfing of the plant in the case of early infection. With late infection at 20–24 weeks, a sudden yellowing of the leaves preceded by root rotting, results in an abrupt termination of growth of cormels. Several roots may appear watersoaked and/or semi-decorticated at any point or all along the longitudinal axis of the root to the stele. The fungus, *Pythium myriotylum* Drechsl, an Oomycete, has been isolated from the infested roots and its pathogenicity was proven (CARDI/EDF: Aroids & Arrowroot, 1984).

The disease tends to be associated with poor drainage or water-logged conditions and residual inoculum from volunteer host plants. The susceptible cultivars are the commercially acceptable cultivars, having smooth-skins, with either white or pink-fleshed cormels. Planting material with infested roots provides a source of inoculum (CARDI/EDF: Aroids & Arrowroot, 1985).

Factors Affecting Integrated Management Strategies

Tannia is a preferred staple, and is naturally adapted to the wetter regions of the Windward Islands (Domica, St. Lucia, St. Vincent and Grenada). It requires high rainfall, but cannot tolerate poor drainage or waterlogged conditions. Drainage is generally poor on new plantings, usually after a fallow or newly cleared forest holding, particularly in the seasons of heavy torrential rains experienced in these countries.

The predominant farming systems in these countries, especially where the incidence of the disease is high, is characterised by small farm sizes, multiple farm parcels, mixed cropping and limited crop rotation (Adams *et al.*, 1985). The practice of shifting cultivation is common, but the tannia plants in the intercrop are left and harvested for food. Ultimately, a farmer ends up with volunteer tannia crops on several parcels of land. In this process, "volunteer", diseased plants are often used as the source of planting material for the next crop. Alternatively, diseased tannia planting material from nearby, infected farm parcels is used.

Since the price of tannia is fairly attractive and some storage may be obtained in or out of the ground, the farmer tends to grow the crop as a second cash crop to banana, the latter being the principal export and cash crop of three East Caribbean countries except Grenada.

In general, it is evident that the total tannia production and interest in tannia production are on the increase (Sorhaindo, 1985; Thomas, 1985) and thus underlines the importance of disease management. The principal factors affecting disease management are farm size, farm location and farming system.

Integrated Management Options

Use of fungicides

Calculations by the authors suggest that the income status of the majority of farmers does not presently permit an economic level of control of *Pythium* to be achieved using the fungicide, metalaxyl. Any appropriate fungicide for the management of *Pythium* and, hence, of the disease will have to be effective over a minimum of 24 weeks. The period of planting and early infection coincides with the rainy season which is also favourable for the rapid development of *Pythium* spp., and, therefore, the fungicidal application(s) must be effective under heavy rains.

Use of the fungicide, metalaxyl, has been demonstrated to induce fungal resistance in other crops and, therefore, any sustained fungicidal application for management of TRYD must be such that the induction of fungal resistance is nil or low. Besides, fungicide formulations other than granular are of little practical value for tannias grown at altitudes of 1000–1500 m and on slopes of 10–20°, because of limited access to water and increased labour input. Metalaxyl is systemic, both up and down, and therefore may be used as a dip treatment of planting material in the predominant small farms. Additional dosages of metalaxyl may be applied as granules, especially for its slow releasing property.

Genetic

A few tolerant, tannia cultivars have been identified in the East Caribbean (CARDI/EDF: Aroids & Arrowroot, 1984 and 1985) and will provide an interim option at least for food on farm and limited local and regional markets. Eddoe *(Colocasia antiquorum)*, which bears tannia-like, smooth-skinned, white-fleshed cormels is also known to be resistant to the disease (CARDI/EDF: Aroids & Arrowroot, 1984).

It is imperative, therefore, that any integrated management of TRYD be based on the interactions between cultural measures and host plant resistance.

Cultural Practices

Cultural practices relevant to the management of the tannia disease revolve around measures to exclude the pathogen, avoid build up of inoculum, maintain field sanitation and ensure adequate plant nurtients in the soil.

Exclusion of the pathogen

Measures for the exclusion of the pathogen include the legislative regulatory functions to restrict or ban the importation of any planting material, unless it is produced in tissue culture, between islands where the disease is present. Though the actual implementation of an embargo is not guaranteed, due to the ease of movement of farm produce, it certainly guarantees an awareness of the severe dangers of the problem and should restrict any movement to a low level. This is currently in operation in all the tannia producing islands in the Eastern Caribbean. However, a practical option may be to permit the movement of plants that are free of soil, de-rooted and with

corms that are surface sterilized. The principal incitant, *P. myriotylum*, a soil 'liver; has been isolated only on infested roots. No evidence of the fungus has been found either in or on the tannia corm EDF: Aroids & Arrowroot, 1985). A further step in the exclusion of the pathogen may be to cut or trim the corm after roots have been severed. Should this latter method be the preferred means, material from Grenada and Trinidad would have to be prohibited, due to the possibility of transferring the banana 'moko' disease bacterium, *Pseudomonas solanacearum*.

Avoiding build up of the inoculum

P. myriotylum is a soil-borne fungus, apart from being carried on the tannia roots. Therefore, a manipulation of factors in the soil avoiding the build-up of inoculum is desirable. Observations in diseased fields of both farmers and the CARDI field station (CARDI/EDF: Aroids and Arrowroot, 1984) indicate that poor drainage results in more rapid and certain disease build-up.

Hence, good drainage is a necessary first step to enhance better management of the disease. This is substantiated by the successful tannia cultivations in naturally free-draining soils and by those with artificial drainage. Particular evidence of the latter has been achieved in 3 experimental tannia plots in Dominica, where adeqate drainage coupled with disinfested planting material kept the disease to a low level. When compared to adjacent plots planted with similar quality of planting material but having poor drainage, 100% plants were diseased within 12 weeks of planting (CARDI/EDF: Aroids & Arrowroot, 1984).

Secondly, crop rotations may reduce build-up of inoculum, but since *Pythium* spp. are a typical group of organisms whose inoculum can increase markedly in the presence of susceptible tannia and host roots, this is a risk. *Pythium* spp. also have the ability to function as saprophytes in the presence of readily available, decaying tannia and other host roots and organic matter, and to efficiently maintain an inoculum potential indefinitely without dependence on the presence of a host plant, by forming metabolically inactive sporangia, chlamydospores or oospores (Mitchell, 1979).

Crop rotation however, tends to be incompatible with farmers' production needs and the limited availability of arable land. Therefore, it appears that emphasis should be placed on adequate drainage to avoid a build-up of active inoculum.

Finally, diseased plants may be rouged at about 3–4 weeks after planting and continually thereafter to avoid a build-up of inoculum.

Sanitation

The presence of the fungus, *P. myriotylum*, on the roots of tannia planting material and other known host plants, eg., turmeric and ginger rhizomes and rotting dasheen corms suggests the following sanitary measures at harvest, post-harvest and pre-planting.

At Harvest

Cutting, gathering and burying, in one or more locations, of all tannia corms (including roots) that are below-ground.

Post-harvest

- Removal and destruction of all volunteer tannia plants, especially corms with roots, in early growth.
- Removal of all potential hosts which are not important crops.
- Production of, or ensuring the availability of disease-free plants, using the methods in practice in Grenada byT.W. Beddoe, UNDP/FAO–Minag and this project (Benjamin, 1985). Simpler field methods develop by the authors for use by the small farmers include the improved sprouting of corms, headsetts and cormels.

Fertilizer application

In an apparently similarly diseased situation in the Cameroon, soil fertility studies indicated that up to a 40% increase in cormels may be obtained with the application of fertilizers. Phosphorus at 60–120 kg P_2O_5 per hectare increased the cormel yield in a diseased field (IRA – Cameroon, 1982). In Puerto Rico, in fields where the disease was not present, best yields were obtained following the application of 125 kg N/ha, 15 kg P/ha and 156 kg K/ha, 48 kg Mg/ha and 25 kg Ca/ha (Vincente-Chandler *et al.*, 1982). In Ghana, 1000 kg /ha of 10–5–15–3 proved optimal (Karikari, 1974). Farmers in the Windward Islands (East Caribbean) tend to use the easily available 16–8–24–4 banana fertilizer for their tannia crops at 625–1250 kg/ha.

However, these recommendations are merely expressing a fertilizer need and should be taken against the background of induced root rotting by Ca, Mg and K-deficient plants in pot studies conducted by Spence and Ahmad (1967).

Host Plant Resistance

Observations in the field indicated about two types of resistance to TRYD. Firstly, there is the hypersensitive response of the host, complete with rapid yellowing and root rotting, eg., the susceptible cv. Rabess Dominica (smooth skinned-white fleshed) (CARDI/EDF: Aroids & Arrowroot, 1984).

Secondly, rotting of roots due to *P. myriotylum* was found associated with rough-skinned, white-fleshed cormels, descridbed by Adams *et al.*(1985), and on a wild type with yellow flesh cv Jabba (Dominica) (CARDI/EDF: Aroids & Arrowroot, 1984). No rapid yellowing of leaves, as in the first type, occurs.

Whatever the type or nature of resistance, the following may be considered for management of the tannia disease: since eddoe, *Colocasia antiquorum*, is not susceptible to the disease even under the most severely diseased conditions, this crop should be encouraged in severely diseased fields. In moderately diseased

locations, the rough-skinned, white-fleshed types and the eddoe are the best alternative, both for food and market. In mildly infected fields, the rough-skinned, white-fleshed cultivars should be judiciously mixed with the smooth-skinned, white or pink-fleshed types, taking care to put these susceptible types on the best drained sites.

Present trends in regional marketing indicate that the rough-skinned, white-fleshed types are marketable to a moderate extent. Eddoes are established in regional trade.

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Bibliography

Adams, H. and Pattanjalidial, (1983). An overview of the Aroid Industry in the Eastern Caribbean Is. of Dominica, St. Lucia, St. Vincent and Grenada. Proc. of Conference on "Taro and other Aroids for Food, Feed and Fuel". CATIE, Costa Rica. 35 pp.

Adams, H., Pattanjalidial, Browne, G., Cooper, B., and Clarke, A. (1985). Aroid Improvement in the Eastern Caribbean: An update of the Aroid/Arrowroot Project. Paper presented at the VIIth Symposium of the Int'l Soc. for Trop. Root Crops (ISTRC) 1-6 July, 1985, INRA, G'loupe, F.W.I. *in press* . 24 pp. cyclostyled.

Berniac, M. (1974). Une maldie bacterienne de *Xanthosoma sagittifolium* (L). Schott. *Annale Phytopathologie* 6 (2), 197–202.

CARDI/EDF: Ariods & Arrowroot. (1984). Annual Report for the sub-project "Increased Production of Aroids and Arrowroot" - Project Year II. CARDI–Dominica, Botanic Gardens, Roseau, 77 pp.cyclostyled.

CARDI/EDF: Aroids & Arrowroot. (1985). Annual Report for the sub-project "Increased Production of Aroids and Arrowroot" Project Year III. CARDI–Dominica, Botanic Gardens, Roseau *in press.*

CARDI - Windward Islands (1982). Annual Report for 1980 of the Windward Is. Unit. CARDI - St. Lucia, Castries, St. Lucia 16–17.

Clarendon, H. (1982). Situation of plant health in member countries. *Biannual Bull. of the Carib. Plant Prot. Comm.* Vol. XI No. 1 Jan - June, 1982,30.

Demarque and Auguste (1982). Situation of plant health in member countries. *Biannual Bull. of the Carib. Plant Prot. Comm.* Vol. XI No. 1 Jan - June, 1982,36–37.

IRA–Cameroon (1982). Annual Report - 200: for the year 1981-82. Doula, Cameroon.

IITA. (1981). Annual Report for 1980. IITA, Ibadan, Nigeria. 185 pp.

Karikari, S.K. (1974) The effect of nitrogen and potassium on yield and leaf area in cocoyam *(Xanthosoma sagittifolium). Ghana J. of Agri. Sci.* 7, 3–6 Accra, Ghana Univ. Press.

Kay, D.E. (1973). TPI Crop and Product Digest - No. 2 Root Crops. TPI, London, 245 pp.

Laguna, I.G., Salazar, L.G. and Lopez, J.F. (1983). Fungal and bacterial diseases of Aroids: *Xanthosoma* spp and *Colocasia esculenta* (L.) Schott, in Costa Rica. *Tech. Bull* 10 Trop. Agri. Res. and Training Center, CATIE, Turrialba, Costa Rica. 30 pp.

Messiaen, C.M. and Houtoundji, A. (1984). Tannia diseases in Matinique and Guadeloupe *Proc. of a Workshop;"Aroid Improvement with Particular Reference to the Tannia Disease".* CARDI, St. Augustine, Trinidad. 65 pp.

Nzietcheung, S. (1983). La pourriture racinaire du macabo *(Xanthosoma sagittifolium)* au Cameroun: 1 - symptomatologie et etiologie de la maladie. *L'Agronomie Tropicale* 38 (4), 321–325.

O'Hair, S. (1984). Tannia breeding, *Proc. of a Workshop on "Aroid Improvement with Particular Reference to the tannia Disease".* CARDI, St. Augustine, Trinidad. 65 pp.

Sorhaindo, T.C. (1985). Root crops research in Dominica. Country Paper presented to Regional Network on Tropical Root Crops, INRA 9–10 July, 1985.

Spence, J., and Ahmad, N. (1967). Plant nutrient deficiencies and related tissue composition of tannia *Int. Symp. on Trop. Root Crops* Vol I: Section II, 61–69.

Thomas, M. (1985). Review Meeting August 1985 on Root Crops Marketing, MINAG, Botanic Gdns., Roseau, Dominica.

Vincente - Chandler, J. *et al.,* (1982). Nutrient uptake by taniers as related to stage of growth and effect of age on yields of the morada variety. *Jnl of the Univ. of P. Rico,* **LXVI** (1).

EFFET DE L'INCORPORATION DANS LE SOL DE DIFFERENTS SUBSTRATS A BASE DE BAGASSE PRECOLONISEE OU NON PAR *TRICHODERMA VIRIDE* PERS. SUR L'INCIDENCE DE *SCLEROTIUM ROLFSII* Sacc.

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ABSTRACT

A study in pots was conducted to determine the efficacy, against *Sclerotium rolfsii*, of the amendment of an ultisol with different bagasse substrates colonized or not by *Trichoderma viride* isolates antagonistic to the pathogen. The bagasse substrates were: sterilized bagasse; nonsterilized bagasse alone or with propionic acid, sodium propionate or the nematicide ethoprop. All substrates induced a progressive decrease of the population of germinating sclerotia and of the disease incidence on Lentil *(Lens esculenta* Moench) seedlings. Particular differences between the treatments are discussed in order to suggest pratical use.

RESUMÉ

Une étude en pots a été conduite dans le but de déterminer l'efficacité, contre le *Sclerotium rolfsii*, de l'incorporation dans un ultisol d'une bagasse pre-colonisée ou non par des isolats de *Trichoderma viride* antagonistes du parasite. Différents substrats-bagasse ont été utilisés : bagasse stérilisée ; bagasse non stérilisé, seule ou additionnée d'acide propionique, de propionate de sodium ou d'ethoprophos. Tous les substrats induisent une réduction progressive des populations de sclérotes viables et de l'incidence de la maladie chez les plantules de Lentille *(Lens esculenta* Moench). Les differences particulieres entre les traitements sont discutees en vue d'une utilisation pratique.

En Guadeloupe, les ultisols occupent plus de la moitié des terres cultivées. Leur fertilité diminue assez rapidement mais peutêtre maintenue à un bon niveau ou rétablie par des amendements organiques fréquents (Clairon *et al.*, 1980). Sur place, des quantités importantes de matériaux organiques (résidus végétaux, boues des stations d'epuration des eaux, composts d'ordures ménagères...) sont disponibles et/ou font déjà l'objet d'une utilisation agronomique (Clairon & et Nagou, 1978: Clairon *et al.* , 1982).

L'incorporation dans le sol de ces matériaux entraine une modification de la biocénose tellurique qui peut être favorable à certains champignons phytopathogènes. C'est ainsi que de nombreux résidus de cultures enfouis dans le sol engendrent, dans un premier temps, une augmentation importante des populations de sclérotes de *Sclerotium rolfsii* Sacc., champignon très redoutable en milieu tropical, du fait de sa grande polyphagie. L'agent pathogène puise dans ces résidus les éléments nutritifs nécessaires à son développement (Boyle, 1961) et/ou est favorisé par certains produits libérés par la dégradation de ces matériaux (Beute et Rodriguez-Kabana, 1979a : 1979b ; Linderman et Gilbert, 1973 ; Punja et Grogan, 1981). Les dégâts qui s'ensuivent sont souvent très importants. Par la suite, les attaques diminuent. La période de flambée des dégâts est plus ou moins longue selon le type de matériau organique utilisé. Pour la bagasse, par exemple, la réduction de la gravité des attaques de *S. rolfsii* n'est pas immédiate. Cependant, elle coninci-de avec la prolifération dans le sol d'une microflore dont certains éléments-appartenant pour la plupart aux genres *Aspergillus, Gliocladium, Penicillium* et *Trichoderma* - manifestent une activité antagoniste vis à vis du parasite (données non publiées).

La présente étude a été entreprise dans le but de detérminer comment l'incidence du *S. rolfsii* peutelle être réduite dans un ultisol amendé avec de la bagasse pré-colonisée ou non par des isolats de *Trichoderma viride* antagonistes du parasite.

Materiels Et Methodes

Le sol

Un ultisol prélevé dans une parcelle expérimentale au Centre INRA Antilles-Guyane, Duclos, Petit-Bourg (Guadeloupe) a été utilisé dans cette étude. Il avait un pH (H_2O) de 5, 1 et pour 100 g : 60, 7 g d'argile, 2,8 g de matière organique, 1,66 g C, O, 12 g N, 6, O mg Ca, 1, 2 mg Mg, O, 23 mg K, O, 14 mg Na et O, 9 mg Al. Après désséchement à l'air à la temperature du laboratoire (20–23°C) pendant 24 h, il a été passé au tamis de mailles 2, 5 mm.

L'agent pathogène

Sclerotium rolfsii. L'isolat utilisé provenait du collet de Haricot *(Phaseolus vulgaris* L.) cultivé à Duclos. Les sclérotes servant d'inoculum, ont été produits à partir d'une culture du champignon sur grains de riz paddy. Des rondelles de culture du champignon sur milieu S (Messiaen & Lafon, 1970) sont introduites dans des fioles contenant du riz paddy autoclavé. Après 10–15 jours d'incubation à 30°C, les grains de riz sont transférés dans des petites chambres humides (boîtes de pétri contenant au fond du papier filtre humide). Après une nouvelle période de 7 jours d'incubation à 30°C, dont 3 à l'obscurite, les nouveaux sclérotes produits sont désséchés a l'air et maintenus secs jusqu'à utilisation.

L'antagoniste

Trichoderma Parmi plusieurs espèces de *Trichoderma* collectées dans différentes régions de Guadeloupe, 3 isolats de *Trichoderma viride* Pers. manifestant *in vitro* une activité antagoniste vis-à-vis du *S. rolfsii*

ont été choisis pour leur meilleure croissance à 25°C (température optimale) que *S. rolfsii*, leur croissance encore bonne entre 25 et 35°C (températures fréquentes dans la couche 0-10 cm de sol à Duclos) et leur importante activité cellulolytique. Ces isolats ont été maintenus sur milieu S à patir duquel des disques de mycélium ont été prélevés pour la colonisation des substrats-bagasse.

Préparation des substrats-bagasse

La bagasse utilisée provenait de la sucrerie de Grosse-Montagne, Lamentin (Guadeloupe). Après broyage et tamisage pour obtenir des fragments de taille moyenne inférieure à 0,5 cm, differents substrats ont été considérés:

- bagasse stérilisée : en autoclave pendant une heure à 100°C 2 jours consécutifs;
- bagasse non stérilisée;
- bagasse non stérilisée additionnée de propionate de sodium ou d'acide propionique (1.6% en poids) afin d'éviter la colonisation du substrat par des microorganismes indésirables (Lacey, 1974) ;
- bagasse non stérilisée additionnée d'éthoprophos, de dithiophosphate de O-éthyle et de S,S-dipropyle (29 mg de Mocap 10 G par gramme de bagasse) ; ce nematicide n'a pas d'effet marqué sur les *Trichoderma* (Rodriguez–Kabana *et al.*, 1976) et son emploi ici répondait au souci de limiter le développement d'éventuels nématodes mycophages susceptibles d'affecter l'antagoniste.

Les différents substrats ont été distribués dans des sacs plastuques, humidifiés, inoculés avec les 3 isolats de *T. viride* utilisés en mélange puis mis à incuber dans une chambre climatique (25 ± 2°C) pendant 30 jours avant leur incorporation dans les sol. Des substrats non inocules constituaient les temoins.

Application des traitements et appréciation du potentiel infectieux du sol.

Chaque substrat-bagasse a été mélangé au sol à la concentration de 5% (en poids). Le jour de la réalisation du mélange et après 7, 14, 21, 21 et 28 jours d'incubation, le potentiel infectieux dû sol du au *S. rolfsii* a été apprécié par la détermination de l'incidence de la maladie et l'énumération de sclérotes viables (germants).

Détermination de l'incidence de la maladie

Dans des pots plastiques (7 x 7 x 6 cm) remplis aux deux tiers avec du sable de rivière, la terre amendée additionnée de 15 sclérotes de *S. rolfsii* est apportée sur une épaisseur de 0,8 cm afin de bien permettre l'extériorisation du mycélium issu de la germination de ces sclérotes. Après arrosage de la terre à sa capacité de rétention, les pots sont mis à incuber dans des miniserres disposées dans une chambre climatique (températures de 30 + 2°C et éclairement fourni par 6 lampes de 400 watts 12h/24h). A la fin de chaque période d'incubation, 9 graines prégermées de Lentille (*Lens esculenta* Moench) sont semées dans chaque pot. Sept jours plus tard, on décompte les plantules demurées saines (les plantules infectées sont éliminées progressivement de façon à éviter qu'elles ne servent de sources d'inoculum supplémentaires). Cinq répétitions ont été effectuées pour chaque terre amendée.

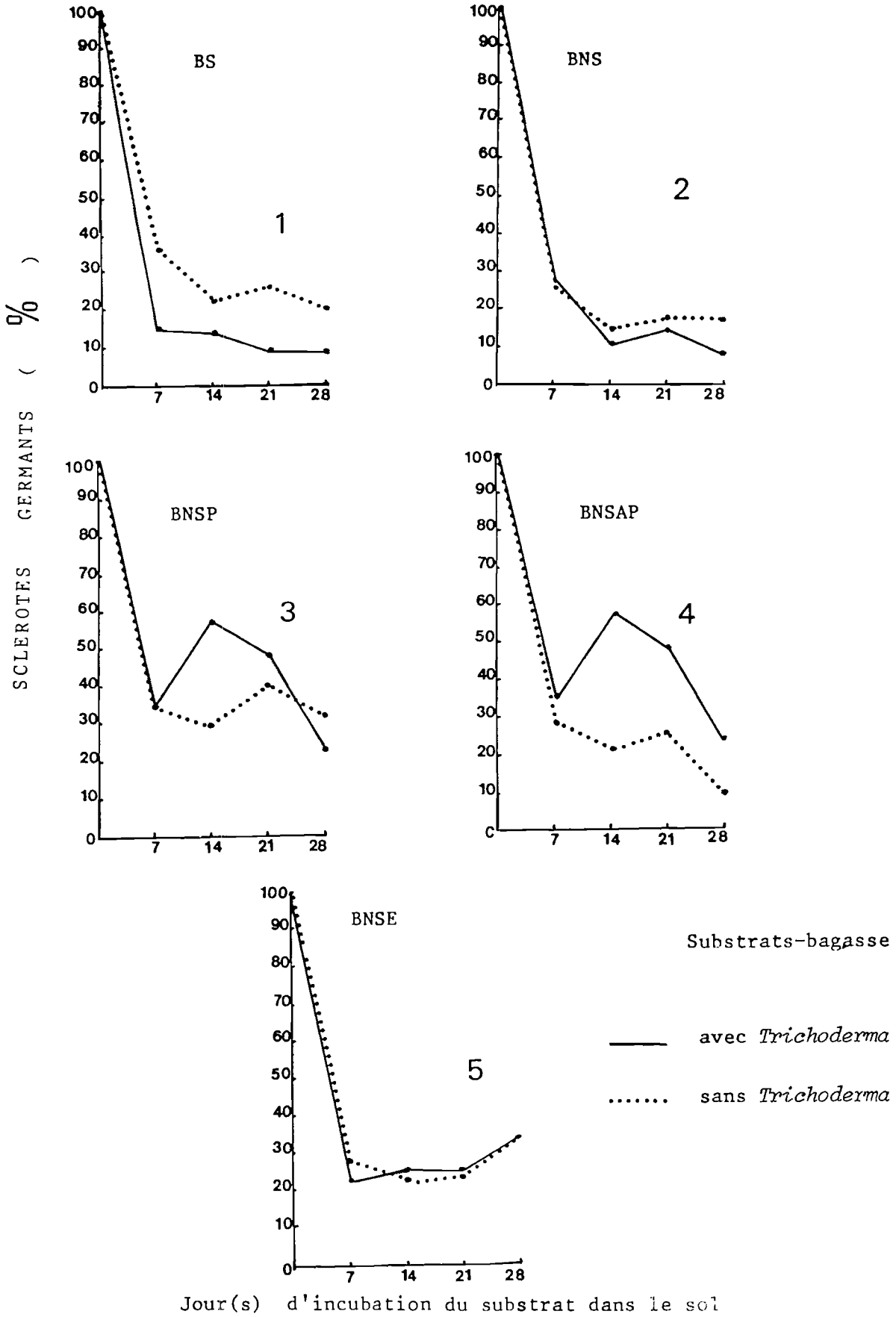
Dénombrement des sclérotes viables

Nous avons utilisé une adaptation de la technique de Toribio (1977). Les différentes terres amendées auxquelles on a ajouté 15 sclérotes sont distribuées en boîtes de pétri sur une épaisseur de 0,8 cm, humidifiées et mises à incuber dans les mêmes conditions que ci-dessus. A l'issue de chaque période d'incubation, la terre est déssèchée a l'air, répartie en couches minces (1,5 mm d'épaisseur) dans d'autres boîtes puis réhumidifiée et mise à incuber a 30°C pendant 48 h au bout desquelles on compte les sclérotes ayant germé. Cinq répétitions ont également été effectuées pour chaque terre.

Resultats Et Discussion

Le rôle des résidus végétaux utilisés en amendements organiques du sol dans le contrôle des agents phytopathogènes telluriques est reconnu, étudié et parfois mis en pratique depuis de nombreuses années (Baker et Cook, 1974 ; Papavizas, 1975). La variabilité des résultats obtenus est liée, de façon importante, aux interactions entre microorganismes pour la colonisation d'un résidu donné (Bruehl, 1975). Ainsi, on peut enfouir l'amendement et attendre que l'induction de la prolifération d'une flore antagoniste s'opère. On peut également introduire dans le sol un substrat minéral ou organique déjà colonisé par un antagoniste du germe que l'on veut combattre (Backman et Rodriguez–Kabana, 1975 ; Davet *et al.* 1981 ; Elad *et al.*, 1980 ; 1983 ; Hadar *et al.*, 1979 ; Kelley, 1976). Dans cette dernière optique, nous avons étudié l'effet d'une bagasse précolonisée ou non par *T. viride* sur l'incidence du *S. rolfsii*. Afin de faciliter la colonisation de cette bagasse par le *Trichoderma* nous y avons ajouté quelques produits signales comme inhibiteurs de microorganismes jugés indésirables (Lacey, 1971, 1974; Pepys, 1969; Rodriguez-Kabana et Backman, 1974, 1976).

Les figures 1 à 5 représentent les courbes d'évolution, dans le temps, des populations de sclérotes germants. De façon générale, on note une réduction brutale des populations de départ après 7 jours d'incubation des substrats dans le sol. Cette réduction est vraisemblablement la conséquence d'une germination normale des sclérotes placés dans un milieu non absolument inhibiteur. Son niveau est sensiblement le même chez un susbstrat donné sauf pour la bagasse stérilisée où un effet net de *Trichoderma* est observé : on obtient 15% de sclérotes germants contre 35% lorsque l'antagoniste est absent. L'évolution ultérieure des populations de sclérotes dépend du traitement considéré. Pour la bagasse stérilisée, la diminution est faible entre 14 et 28 jours d'incubation, avec un pourcentage de sclérotes germants de l'ordre de 10–15% pour le substrat traité avec *Trichoderma* et 18–25% pour le substrat non traité (Fig. 1 et 2, respectivement). Dans le cas de la bagasse additionnée de propionate de sodium (fig. 3) ou d'acide propionique (fig. 4), entre 7 et 21 jours, le pourcentage de sclérotes germants est plus important pour le substrat traité avec *Trichoderma* que pour le substrat non traite. Comparativement au comportement de las bagasse stérilisée ou non, cette observation suggère que: 1) les



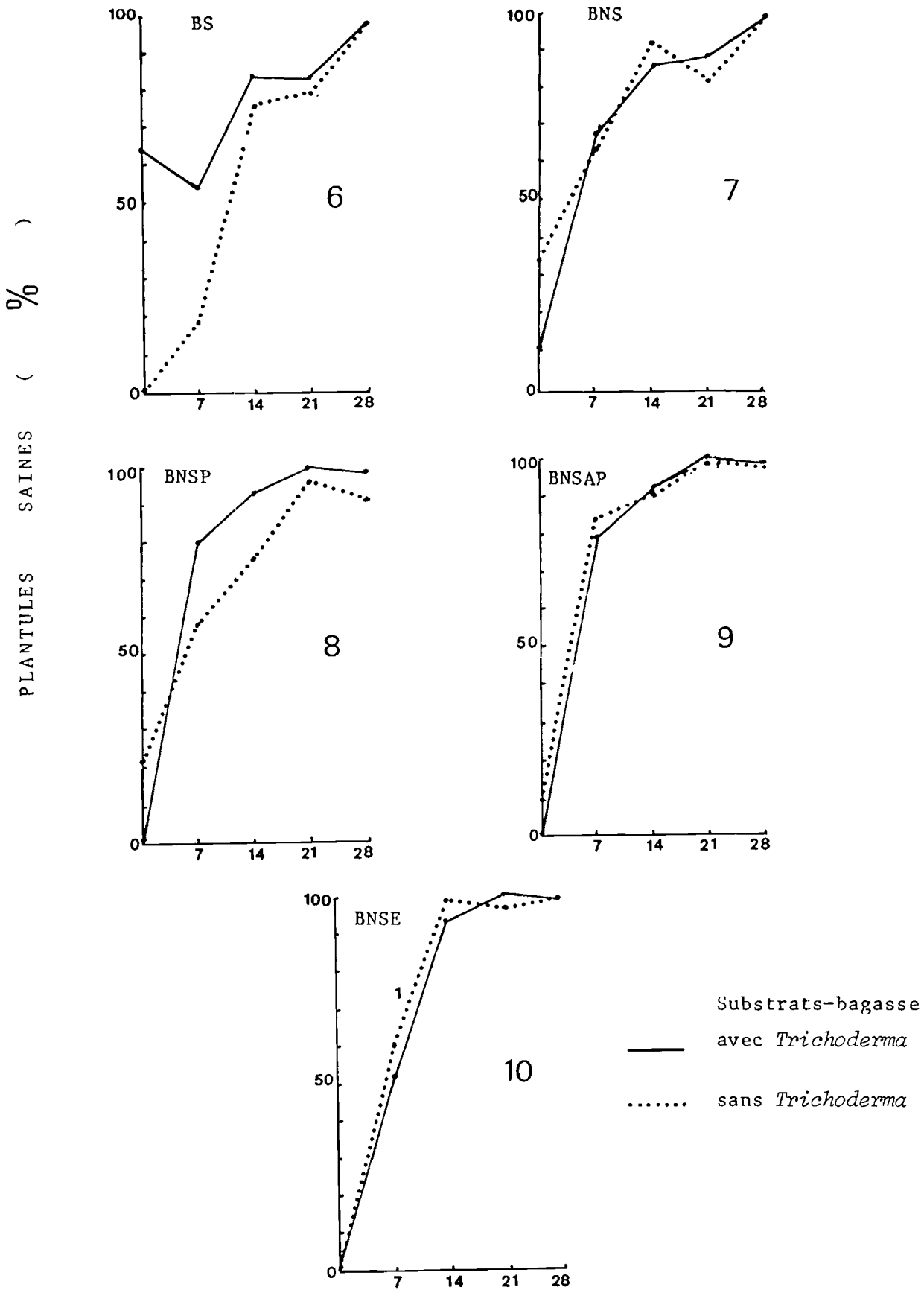
Figs 1-5- Evolution des populations de sclérotes germants, dans le sol amendé avec différents substrats à base de bagasse : stérilisée (BS) ; non stérilisée (BNS) ; non stérilisée mais additionnée de propionate de sodium (BNSP), d'acide propionique (BNSAP) ou d'ethoprophos (BNSE).

Figs 1-5 - Evolution of germinating sclerotium populations in the soil amended with different bagasse substrates : sterilized (BS) ; non sterilized (BNS) : non sterilized with Na propionate (BNSP), propionic acid (BNSAP) or ethoprop (BNSE).

Trichoderma du substrat ne sont pas les seuls microorganismes responsables de l'inhibition de la germination des sclérotes de *S. rolfsii;* 2) la présence d'acide propionique ou de propionate de sodium, aux concentrations introduites dans le sol, combinée à celle des *Trichoderma,* gène ces autres microorganismes dans leur action antagoniste vis-à-vis du parasite. Parmi ces microorganismes, *Aspergillus fumigatus* pourrait occuper une place de choix. En effet, c'est un constituant normal de la flore de la bagasse ainsi que d'autres résidus végétaux de nature cellulosique, et il peut aussi être isolé dans les sols amendés avec de tels substrats. Certains isolats d'*A. fumigatus* provenant de composts d'herbes diverses (entre autres *Axonopus* et *Paspalum)* sont également des antagonistes de *S. rolfsii* (Peltier, 1984). Par ailleurs, *A. fumigatus* ne pousse pas quand il est soumis *in vitro* à des concentrations d'acide propionique supérieures à 27 m M (Lord *et al.*, 1981). Pour le substrat traité avec l'ethoprophos, le pourcentage de sclérotes germants est stable entre 7 et 21 jours (de l'ordre de 20–25%) et croît ensuite, sans influence des *Trichoderma* (Fig. 5). On peut penser que l'action fongicide de l'éthoprophos sur le *S. rolfsii* (Rodriguez–Kabana *et al.*, 1976) commence à se dissiper après 21 jours d'incubation dans le sol.

Parallèlement à la diminution du pourcentage de sclérotes germants, on note une augmentation de la survie des plantules de Lentille. Après 21 d'incubation des substrats dans le sol, on obtiententre 80 et 100% de plantules saines (Fig. 7 a 10). Les dégâts résiduels observés ont été occasionnés par *Fusarium solani* et/ou quelques *Pythium.* A partir des courbes des Figures 7 à 10, nous avons établi des droites de régression. Elles sont d'équation générale $Y=a \log_{10} (x + 0,5) + b$, Y étant Arc sin $\sqrt{y}$ (y = pourcentage de plantules saines) et x, le nombre de jours d'incubation du substrat dans le sol. Le tableau 1 résume les valeurs obtenues. La résolution des équations pour 50% de plantules saines donne des "unités d'efficacité des traitements (UET)". L'UET est ici définie comme étant le nombre de jours d'incubation nécessaires et suffisants pour obtenir 50% de plantules saines dans les conditions de l'expérience. Ainsi, un traitement plus efficace que'un autre sera caractérisé par un nombre inférieur d'UET. Le tableau présente les valeurs calculées pour les differents traitements. Le nombre d'UET varie entre 0 et 4 jours. Excepté le cas de l'amendement stérilisé au départ, la colonisation de la bagasse par les isolats de *T. viride* utilisés n'est pas avantageuse. Cette colonisation pourrait, cependant, être valorisée dans les cas de certains semis fragiles en sols très infestés. De la même façon, le traitement de la bagasse avec le propionate de sodium, l'acide propionique ou l'éthoprophos, aux doses employées, n'est pas nécessaire pour aboutir à une bonne protection des plantules de Lentille.

Cette étude, conduite en conditions contrôlées, indique que la bagasse permet de réduire efficacement l'incidence du *S. rolfsii* quand elle est utilisée comme amendement organique dans un sol ferrallitique. La précolonisation de ce substrat par *T. viride* n'améliore pas de façon nette la suppression de l'agent pathogène. Cette supression de *S. rolfsii* semble être induite par l'envahissement de la bagasse par des microorganismes antagonistes associés normalement à ce substrat et/ou intervenant à partir du sol. Afin de limiter les risques de dévelopment de certains agents responsables de bagassose ou d'autres phénomènes allergiques chez l'Homme (Lacey, 1971 ; Pepys, 1969) on peut suggérer l'incorporation de la bagasse dans le sol immediatement à sa sortie de la sucrerie, après traitement préalable avec l'acide propionique (Lacey, 1974) ou encore après un processus de fermentation humide auto-produisant ce composé.



Figs 6.10- Evolution des populations de plantules saines dans le sol amendé avec différents substrats à base de bagasse (voir figure 1-5 pour l'explication des symboles).

Figs 6.10- Evolution of healthy seedling populations in the soil amended with different bagasse substrates (see figures 1-5 for the explanation of symbols).

Tableau 1 Equations des droites de régression exprimant l'évolution dans le temps de la survie des plantules de lentille dans le sol amendé avec différents substrats á base de bagasse

Table 1 Linear regression equations of the evolution during time of lentil seedling survival in the soil amended with different bagasse substrates.

Substrats[a]	Sans (without) *Trichoderma*		Avec (with) *Trichoderma*	
	Equations Y =	r =[b]	Equations Y =	r =
B S	1.161 Log (x + 0.5) + 4.943	0.885	0.415 Log (x + 0.5) +5.827	0.485
B N S	0.735 Log (x + 0.5) + 5.542	0.808	1.016 Log (x + 0.5) + 5.244	0.862
B N S P	0.749 Log (x + 0.5) + 5.378	0.843	1.347 Log (x + 0.5) + 4.997	0.922
B N S A P	1.103 Log (x + 0.5) + 5.278	0.938	1.396 Log (x + 0.5) + 4.953	0.967
B N S E	1.332 Log (x + 0.5) + 4.883	0.899	1.349 Log (x + 0.5) + 4.861	0.928

a : BS = Bagasse stérilisée (sterilized bagasse)
BNS = Bagasse non stérilisée (unsterilized bagasse)
BNSP = Bagasse non stérilisée + propionate de Na (unsterilized bagasse +Na propionate)
BNSAP= Bagasse non stérilisée + acide propionique (unsterilized bagasse + propionic acid)
BNSE = Bagasse non stérilisée + ethoprophos (unsterlized bagasses + ethoprop)
b : Toutes les valeurs de r sont significatives as seuil de 1% (all r values are significant at the 1% level)

Tableau 2 Efficacité des différents traitements, déterminée á partir des droites de régression de survie des plantules en fontion de la durée d'incubation des substrats dans le sol.

Table 2 Efficacy of the different treatments as determined from the linear regression of lentil seedlings survival in relation to time of incubation of the substrates in soil.

	Nbre d'unités d'efficacité de traitement (DET) Substrats				
	BS[a]	BNS	BNSP	BNSAP	BNSE
avec (with) *Trichoderma*	0	2.1	2.7	1.8	3.4
sans (without) *Trichoderma*	4	1	2	2.8	3.5

[a] Voir tableau 1 (See Table 1)

Bibliographie

Backman, P.A. and Rodriguez-Kabana, R (1975). A system for the growth and delivery of biological control agents to the soil. *Phytopathology* 65 819–821.

Baker, K.F. and Cook, R.J. (1974). Biological control of Plant Pathogens-W.H. Freeman & Co, San Francisco.

Beute, M.K. and Rodriguez-Kabana, R. (1979 a). Effect of wetting and the presence of peanut tissues on germination of sclerotia of *Sclerotium rolfsii* produced in soil. *Phytopathology* 69 869-877.

Beute, M.K. and Rodriguez-Kabana, R. (1979 b.) Effect of volatile compounds from remoistened plant tissues on growth and germination of sclerotia of *Sclerotium rolfsii. Phytopathology* 69, 802-805.

Boyle, L.W. (1961) The ecology of *Sclerotium rolfsii* with emphasis on the role of saprophytic media. *Phytopathology* 51 117-119.

Bruehl, G.W. (1975). Systems and mechanisms of residue possession by pioneer fungal colonists. In: G.W. Bruehl. (ed). Biology and control of soil-borne plant pathogens pp. 77-83. The American Phytopathogical Society, St. Paul, Minnesota.

Clairon, M. and Nagou, D. (1978). Emploi de certains résidus urbains en culture intensive sous climat tropical. *Nouv.Agron. Antilles-Guyane* 4, (3-4) 237-246.

Clairon, M., Zinsou, C. and Nagou, D. (1982) Etude des possibilités d'utilisation agronomique des composts d'ordures ménagères en milieu tropical 1) Compostage des ordures ménagères. *Agronomie,* 2 *(3).*

Davet, P. Artigues, M. and Martin, C. (1981) Production en conditions non aseptiques d'inoculum de *Trichoderma harzianum* Rifai. *Agronomie* 1 *(10),* 933-936.

Elad, Y., Chet, I., and Katan, J. (1980) *Trichoderma harzianum:* A biocontrol agent effective against *Sclerotium rolfsii* and *Rhizoctonia solani. Phytopathology* 70 : 119-121.

Elad, Y., Hadar, Y. & Chet, I. (1983). The potential of *Trichoderma harzianum* as a biocontrol agent under field conditions. In: *Les antagonismes microbiens,* **24**e colloque SFP, Bordeaux (Ed. by INRA Publ.) pp. 305-310.

Hadar, Y. Chet, I. & Henis, Y. (1979). Biological control of *Rhizoctonia solani* damping-off with wheat bran culture of *Trichoderma harzianum.Phytopathology* **69**, 64-68.

Kelley, W.D. (1976) Evaluation of *Trichoderma harzianum*-impregnated clay granules as biocontrol for *Phytophthora cinnamomi* causing damping-off of pine seedlings. *Phytopathology* **66**, 1023-1027.

Lacey, J. (1971). *Thermoactinomyces sacchari* sp. nov., a thermophilic actinomycete causing bagassosis. *Journal of General Microbiology* **66**, 327-338.

Lacey, J. (1974) Moulding of sugar-cane bagasse and its prevention. *Annals of Applied Biology* **76**, 63-76.

Linderman, R.G. & Gilbert, R.G. (1973). Influence of volatile compounds from alfalfa hay on microbial activity in soil in relation to growth of *Sclerotium rolfsii. Phytopathology* **63**, 359-362.

Lord, K.A., Lacey, J. Cayley, G.R. & Manlove, R. (1981). Fatty acids as substrates and inhibition of fungi from propionic acid treated hay. *Transaction of the British Mycological Society* 77 (1) 41-45.

Messiaen, C.M. & Lafon, R. (1970) *Les maladies des plante maraicheres.* pp. 387-388, INRA.

Papavizas, G.C. (1975). Crop residues and amendments in relation to survival and control of root-infecting fungi : an introduction. In : G.W. Bruehl (ed). *Biology and control of soil-borne plant pathogens.* The American Phytopathological Society, St. Paul, Minnesota.

Peltier, C. (1984). La microflore thermophile des composts ; études d'antagonismes vis-à-vis de *Sclerotium rolfsii* et *Pythium* sp. *Mémoire de fin d'études, D.A.A. Protection des cultures.Montpellier.*

Pepys, J. (1969). Hypersensitivity disease of the lungs due to fungi and organic dusts. *Monographs in Allergy,* **4**, Basle, S. Karger.

Punja, Z.K. & Grogan, R.G. (1981). Mycelial growth and infection without a food base by eruptively germinating sclerotia of *Sclerotium rolfsii. Phytopathology* **71**, 1099-1103.

Rodriguez-Kabana, R. & Backman, P.A. (1974) Selective activity of two contact nematicides on *Sclerotium rolfsii* and *Trichoderma* spp. (Abstract) *Proceedings of the American Phytopathological Society* **1**, 70.

Rodiguez-Kabana, R., Backman, P.A. & King, P.S. (1976). Antifungal activity of the nematicide ethoprop. *Plant Disease Reporter* **60**, 255-259.

Toribio, J.A. (1977). Une technique simple de dénombrement direct des sclérotes viables de *Sclerotium rolfsii* dans le sol. *Annales de Phytopathologie* **9**, (2), 177-182.

INTEGRATED WEED CONTROL IN TRANSPLANTED TOMATOES

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ABSTRACT

Two field experiments on tomato, *Lycopersicon esculentus* Mill. var. Duke, were carried out in 1985. In the first experiment, the herbicides napropamide, bensulide and metribuzin were used either alone or in conjunction with manual weeding or mechanical cultivation. In addition, mechanical cultivation was also integrated with manual weeding. The highest marketable tomato yield was obtained with the hand-weeded control; other treatments where yields did not differ significantly ($P > 0.05$) from this were metribuzin (1.12 kg ai ha^{-1}) plus manual weeding; napropamide (4.48 kg ai. ha^{-1}) plus manual weeding; and a combination of mechanical, manual, and glyphosate treatments. All sole-herbicide treatments yielded significantly less than the hand-weeded control. In the second experiment, various mulchings with coffee leaves, sugar-cane trash, rice straw and plastic were used either alone or in conjunction with chemical or manual weeding. The highest marketable tomato yield was obtained with rice straw mulching plus manual weeding; sugar-cane trash mulching plus manual weeding; and plastic mulching plus manual weeding gave yields which were not significantly different from this. The treatments involving mulching plus manual weeding gave significantly better yields that those with mulching alone or mulching plus glyphosate.

RESUMEN

Dos experimentos de campo fueron llevados a cabo en el año 1985, utilizando el tomate, *Lycopersicon esculentum* Mill. var. Duke, como el cultivo experimental. En el primer experimento, los herbicidas, napropamide, bensulide y metribuzin, fueron utilizados, ya sea solos, o conjuntamente con el deshierbe manual, o con el cultivo mecánico. Adicionalmente el cultivo mecánico fué tambien integrado con el deshierbe manual. El rendimiento mas alto de tomate para mercadeo, fué obtenido mediante el control del deshierbe manual. Otros tratamientos en los cuales los rendimientos no difirieron significativamente, ($P > 0.05$) del mencionado anteriormente, fueron: metribuzin (1.12 kg ai. ha^{-1}) y el deshierbe manual; napropamide (4.48 kg ai. ha^{-1}) mas el deshierbe manual; y una combinacion de tratamientos mecánicos manuales y de glyphosate. Todos los tratamientos con herbicidas solamente rindieron significativamente menos que ésos con el control manual. En el segundo experimento, varias coberturas de hojas de cafe, hojarascas de caña de azucar, paja del arroz y láminas plásticas, fueron utilisadas ya sean solas o conjuntamente con el deshierbe químico o manual. El rendimiento mas alto de tomate para mercadeo, fué obtenido mediante el uso de la cobertura de paja de arroz en conjunción con el deshierbe manual. Los rendimientos obtenidos con el de hojarasca de caña de azucar en conjunción con el deshierbe manual y el de cobertura con láminas plasticas conjuntamente con el deshierbe manual, fueron muy diferentes al anteriormente mencionado. Los tratamientos involucrando cobertizos y deshierbe manual, dieron mejores rendimientos que aquellos con cobertizos solamente o los con cobertizos mas glyphosate.

Keywords: Tomatoes; Weed control; Mulching.

The use of black polyethylene plastic mulching for weed control in tomatoes was studied locally (Irizarry *et al*,1968). This controlled practically all weeds, with the exception of purple nutsedge (*Cyperus rotundus* L.) but the high cost of plastic material had prevented its adoption for local use. With the introduction of low-cost plastic material in recent years, the use of plastic mulching for weed control in tomatoes and other vegetables has become practical. Burgis (1973a; 1973b) performed two tomato experiments integrating plastic mulching with herbicides (metribuzin and diphenamid) and obtained excellent weed control. In Nigeria, Quinn (1975) used natural materials such as corn cobs, nut shells and grass-straw integrated with hand weeding in tomatoes. The integrated treatments reduced the cost of weeding by 30 percent as compared to that of manual weeding.

A considerable amount of chemical weed control research has been done on tomatoes in Puerto Rico since 1978 (Almodóvar - Vega 1979-84; Jackson and Sierra-Morales, 1979). Consequently, local vegetable growers have relied heavily on herbicide usage and have not fully recognized the potentially harmful effects of herbicides on the environment. It is therefore deemed necessary to evaluate certain integrated forms of weed control as a means to optimize yield with minimal hazard to the environment.

The research reported in this paper was conducted to determine (1) the effects on tomato yield of chemical control alone and of its integration with manual weeding or mechanical control, and of the integration of mechanical control with manual weeding; (2) the effects on tomato yield of different forms of mulching alone or in combination with manual weeding or chemical control.

Materials and methods

Experiment no. 1

The experiment was conducted on a San Antón soil series (30 percent sand, 33 percent silt, 37 percent clay, 1.6 percent organic matter and pH 7.0) at the Fortuna Research and Development Center, Juana Díaz, Puerto Rico. The seed bed was prepared by ploughing followed by disc-harrowing in two directions. It was partitioned into 3.1 m x 3.7 m plots. Each plot consisted of 20 tomato plants arranged in two rows. The experimental layout was a randomized complete block with four replications. Tomato seedlings (var. Duke) were transplanted 20 December, 1984 when they were 28 days old. The drip irrigation system described by Goyal (1983) was used in this study. Napropamide at 4.48 kg ai ha^{-1}, bensulide at 2.34 l ha^{-1} and metribuzin at 1.12 kg ai ha^{-1} were

applied the day before transplanting. These herbicides were applied with a portable CO_2 sprayer calibrated to deliver a spray volume equivalent to 374 l ha^{-1} at a pressure of 2.1 kg cm^{-2} All herbicides were incorporated with a rake immediately after their application. The first mechanical weeding with a rototiller was performed 14 January, 1985, and a second on 4 February. Manual weeding by hoe was performed for the corresponding treatments on 9 and 14 January, 4 February and 3 and 21 March, 1985. All horticultural and pest-management practices were in accordance with the recommendations of the Conjunto Tecnológico para la Producción de Hortalizas (Estación Experimental Agrícola, 1976). Marketable fruits were harvested in four pickings at 14-day intervals.

Experiment no. 2

This experiment was also established on a San Anto series at Fortuna. The same plot size, experimental design, and tomato variety were used. The tomato cultivar Duke was transplanted to the field on the same day as experiment no 1. The plastic mulching was placed on the row before the transplanting. Within two weeks after transplanting, sufficient quantities of rice straw, sugar-cane trash and coffee leaves were placed to cover the ground. Herbicide treatment included the application of glyphosate by a side swipe (roller-wick applicator) on 14 January, 1985. The plots were hand weeded on 5 and 14 January, 2 and 22 February and 15 March for the corresponding treatments. All horticultural and pesticide treatments were similar to those of the first experiment and fruits were similarly harvested in four pickings.

Results and Discussion

Experiment no. 1

The highest marketable tomato yield (39,743 kg ha^{-1}) was obtained from the hand-weeded control treatment (Table 1). Other treatments where yields did not differ significantly ($P > 0.05$) from the hand-weeded control were: metribuzin (1.12 kg ai ha^{-1}) plus hand weeding; napropamide at 4.48 kg ai ha^{-1} plus hand weeding; a combination of mechanical plus manual plus glyphosate; mechanical cultivation (once or twice) plus hand weeding. All sole herbicide treatments, as well as those using herbicide plus mechanical cultivation, yielded significantly less than the hand-weeded control. The number of tomatoes produced from the different treatments followed approximately the same trend as production on a weight basis.

When the yield data were analyzed on a group basis, treatments involving hand-weeding yielded significantly higher than the group using herbicides alone (Table 2). The herbicide plus hand weeding group produced the highest tomato yields.

All integrated weed control treatments involving hand weeding produced high tomato yields. However, as hand weeding is an expensive operation, future trials should be aimed at the reduction of the frequency of hand weeding. Mechanical cultivation appears to be a logical choice in replacing or reducing expensive manual control. However, the cost and benefit aspects of hand weeding versus mechanical cultivation in an integrated weed control system need to be determined.

Experiment no. 2

The highest marketable tomato yield (47,255 kg ha^{-1}) was obtained from rice straw mulching plus hand weeding and in general, mulching in conjunction with manual weeding gave the best results (Table 3). Mulching alone with rice straw or sugar-cane leaves and sheaths also gave tomato yields which did not differ statistically ($P < 0.05$) from their integrated counterparts or the hand-weeded controls. However, tomato yield significantly decreased when mulchings (except with rice straw) were integrated with glyphosate treatment. The low yield could be attributed to the observed tomato injury resulting from glyphosate treatment. The number of tomatoes produced from the different treatments followed approximately the same descending rank as in the case of tomato weights.

When yield data were analyzed on a group basis, the mulching plus manual weeding group gave significantly higher yields than the mulching-alone and the mulching plus glyphosate groups (Table 4).

From the above results, it is evident that the best integrated weed control is achieved using mulches plus hand weeding. Further studies should be directed to determine the economic feasibility of those promising integrated weed control treatments. Special attention should be focused on the use of rice straw in the integrated weed control system since rice staw is a by-product of the island rice industry. It can be incorporated into soil whereas plastic mulching must be removed after harvest.

Acknowledgements

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References

Almodóvar-Vega, L. (1979 - 1984). Annual Progress Reports of Project H-173 Agricultural Experiment Station, University of Puerto Rico.

Burgis, D.D. (1973a). Herbicides for full bed mulch tomato culture system. I. Row middles, *Proc. South. Weed Sci. Soc.* **26** 196 - 199.

Burgis, D.S. (1973b). Herbicides for full bed mulch tomato culture system. II. In the row, *Proc. South. Weed Sci. Soc.* **26** 201 - 204.

Estación Experimental Agrícola (1976). Conjunto Tecnológico para la Producción de Hortalizas, Publicación 102 43 - 46.

Goyal, M.R. (1983). Labor-input requirements for experimental production of summer peppers under drip irrigation, *J. Agric. Univ. P.R.* **67** (1) 22 - 27.

Irizarry, H., Azzam, H. and Woodbury, R. (1968). Evaluation of black polyethylene plastic mulch for tomato production in Puerto Rico, *J. Agric. Univ. P.R.* **51** (1) 52 - 63.

Jackson, G.C. and Sierra-Morales, C. (1979). Tolerance of tomato cultivars to pre-emergence application of metribuzin, *Proc. 16th Ann. Mtg. Caribb. Food Crop Soc.* **16** 113 - 117.

Quinn, J.G. (1975). A further assessment of mulching and staking a rainfed tomato crop in the Northern Nigerian States, *Hort. Res.* **15** 31 - 39.

Table 1 Effect of different herbicides alone or in combination with other non-chemical control methods on the marketable tomato yield

Treatment	Tomato production (ha) Weight (kg)		Number of fruits	
Napropamide 4.48 kg ai/ha	26,013	c[1]	155,849	[1]e
Bensulide 2.34 l/ha	30,712	bc	179,843	cde
Metribuzin 1.12 kg ai/ha	32,230	bc	183,207	bcde
Napropamide + Mechanical cultivation (rototiller)	32,567	bc	189,934	bcde
Bensulide + Mechanical cultivation (rototiller)	30,018	bc	172,219	de
Metribuzin + Mechanical cultivation (rototiller)	34,442	b	199,577	abcd
Napropamide + Hand weeding	36,807	ab	209,667	abcd
Bensulide + Hand weeding	31,843	bc	193,522	bcde
Metribuzin + Hand weeding	39,447	a	221,552	ab
Mechanical cultivation (rototiller) once + Hand weeding	35,400	ab	216,395	abc
Mechanical cultivation (rototiller) twice + Hand weeding	35,635	ab	208,322	abcd
Mechanical cultivation (rototiller) twice + Hand weeding + glyphosate	36,532	ab	205,855	abcd
Mechanical cultivation only	30,518	bc	174,237	de
Hand-weeded check	39,743	a	236,352	a

[1] Means followed by the same letter or letters do not differ significantly at the 0.05 level of probability

Table 2 Effect of various types of weed control on tomato yield

Treatment	Tomato production (ha^{-1}) Weight (kg)		Number	
Herbicides alone	29,651	c[1]	172,963	c[1]
Herbicides + Mechanical cultivation	32,342	abc	187,243	bc
Herbicides + Hand weeding	36,032	a	206,250	ab
Mechanical cultivation + Hand weeding	32,856	ab	210,188	ab

[1] Means followed by the same letter or letters do not differ significantly at 0.05 level of probability

Table 3 Effect of different mulchings alone or in combination with other weed control methods on the marketable tomato yield

Treatment	Tomato production (ha^{-1}) Weight (kg)		Number	
Rice straw	44,594	ab	288,376	ab
Coffee leaves	29,304	cde	179,619	d
Sugar cane leaves and sheathes	36,173	abcd	228,055	bcd
Silver-coated black plastic + Hand weeding	44,727	ab	278,286	abc
Rice straw + Hand weeding	47,255	a	303,625	a
Coffee leaves + Hand weeding	41,496	ab	266,401	abc
Sugar cane leaves and sheathes + Hand weeding	45,186	ab	293,310	ab
Hand-weeded check (1)	39,641	abc	247,040	abc
Silver-coated black plastic + glyphosate (side swipe)	27,908	def	182,310	d
Rice straw + glyphosate (side swipe)	40,150	ab	251,601	abc
Coffee leaves + glyphosate (side swipe)	25,646	e	172,667	d
Sugar cane leaves and sheathes + glyphosate (side swipe)	34,452	bcde	214,825	cd
Hand-weeded check (2)	41,689	ab	251,825	abc

[1] Means followed by the same letter or letters do not differ significantly at the 0.05 level of probability

Table 4 Effect of various combinations of weed control methods on tomato yield

Treatment	Tomato production (ha^{-1}) Weight (kg)		Number	
Mulching alone	36,746	bc[1]	227,724	b[1]
Mulching + hand weeding	44,666	a	285,408	a
Mulching + glyphosate	32,037	c	218,357	b

[1] Means followed by the same letter or letters do not differ significantly at 0.05 level of probality.

WEED COMPETITION IN TRANSPLANTED TOMATOES

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ABSTRACT

Four field experiments were conducted in 1983 and 1984 at the Fortuna Research and Development Center, Juana Díaz, Puerto Rico, to determine the economic threshold of pigweed *(Amaranthus dubius)*, jungle rice *(Echinochloa colonum)* and horse purslane *(Trianthema portulacastrum)* and their critical period of competition in drip irrigated tomatoes *(Lycopersicon esculentum* Mill. var. Duke*)*. Tomato seedlings were 28 days old at transplanting. In the economic threshold study, weed populations were adjusted to 2, 5, 10, 20, 40 and 80 plants m^{-2}. In the critical period study, mixed weeds were allowed to compete for 0, 12, 24, 36, 48 or 60 days after transplanting and then were kept weed-free until harvest. The economic threshold was found to be 5 plants m^{-2} for pigweed; 40 plants m^{-2} for jungle rice; and 20 plants m^{-2} for horse purslane. This result suggests that pigweed would cause the greatest economic loss to vegetable growers. Pigweed was followed by horse purslane and jungle rice in descending order of causing economic losses. The critical period of weed competition was determined to be 0 to 36 days in 1983 and 0 to 48 days in 1984.

RESUMEN

Cuatro investigaciones del campo fueron conducidos en 1983 y 1984 en el Fortuna Research and Development Center, Juana Díaz, Puerto Rico, para determinar los niveles económicos de *Amaranthus dubius, Echinochloa colonum, Trianthema portulacastrum* y sus periods críticos de competicion en tomate *(Lycopersicon esculentum* Mill. 'Duke') regado por goteo. Al trasplantar, las plantas de tomate de semillero tenían 28 días de edad. En el estudio de niveles económicos, poblaciones de las malezas eran de 2, 5, 10, 20, 40 y 80 plantas m^{-2}. En el estudio de periodo crítico, mezclas de yerbas malas fueron permitidas competir por 0, 12, 24, 36, 48 o 60 días después de transplantar, y entonces, mantenido libre de yerbas malas hasta cosechar. Se encontró que el nivel económico era 5 plantas m^{-2} para *A. dubius;* 40 plantas m^{-2} para *E. colonum;* y 20 plantas m^{-2} para *T. portulacastrum.* El resultado sugiere que *A. dubius* causaría la major pérdida económica a cultivadores de hortalizas. *A. dubius* fue seguido por *T. portulacastrum* y entonces *E. colonum* en orden descendiente de causar pérdidas económicas. Se determinó que el periodo crítico de competición por malezas fue entre 0 y 36 días en 1983, y entre 0 y 48 días en 1984.

Keywords: Tomatoes; Weeds; Competition; Economic threshold; Critical period; Drip/trickle irrigation.

Tomatoes rank first among all vegetables of economic importance in Puerto Rico. According to 1982 Census of Agriculture (Anonymous, 1982) tomato growers contributed $3.5 million to the island economy. The unique mild weather of Puerto Rico enables us to produce a bumper crop of tomatoes during the winter season. Thus, tomato production in Puerto Rico has its great potential not only for self-sufficiency but also for exporting to the United States and Europe. One of the major factors limiting local tomato production has been the high cost of labor required to control weeds. Different weed control methods have been employed in attempts to reduce production costs. An integrated approach to weed control seems to be particularly attractive. Considerable baseline information has been accumulated with regard to the critical period of weed competion (Friesen, 1979; Weaver *et al*, 1983) and population densities effect of weeds on tomatoes yield (Monaco *et al*, 1981) in the United States and Canada. The above-mentioned research was conducted under climatic and edaphic conditions unlike those of Puerto Rico. It is highly imperative that information be gathered under local conditions in order to be valid.

Four field experiments on transplanted tomatoes were thus conducted at the Fortuna Research and Development Center during 1983 and 1984 to determine (1) the economic threshold of horse purslane, jungle rice and pigweed in tomatoes; and (2) the critical period of weed competition in the same crop. Information of this nature could be used as a guideline for establishing an integrated weed control program in tomatoes.

Materials and Methods

1983 Experiment

The experiment was conducted on a San Antón soil (30% sand, 33% silt, 37% clay, 1.6% organic matter; pH 7.0) at the Fortuna Research and Development Center, Juana Díaz, Puerto Rico which is located on the semiarid southern coast. The field was prepared by one plowing and two harrowings and partitioned into 3.3 m x 5.5 m plots. Each plot consisted of 30 tomato plants arranged in three rows. Plant spacing was 30 cm within the row. The layout of the experiment was a randomized complete block design with four replications. Twenty-eight-day-old tomato seedlings (var. 'Duke') were transplanted December 15, 1983, on the left side of a biwall drip line. The drip irrigation system described by Goyal (1983) was used in this study. The tomato plants received fertilizer (10-10-8) application at the rate of 1,198 kg ha^{-1} the second week after transplanting and a second one, at the same rate, at the initiation of flowering. Insects diseases and nematodes were controlled with recommended rates of oxamyl, methamidiphos, maneb, chlorothalonil, methomyl and diazinon during the course of the experiment (Acín *et al.* 1984). Marketable tomatoes were harvested in four pickings for all field experiments.

In the economic threshold experiment the same size of plot and experimental design as described previously was adopted. Individual weeds (horse purslane, jungle rice and pigweed) were adjusted to 2, 5, 10, 20, and 40 plants m^{-2} by hand within 21 days of transplanting. The different weed population densities were maintained until final harvest. In the

critical period , mixed weed populations were removed by hoe at 0, 12, 24, 36, 48 or 60 days after transplanting. The plots were kept weed-free thereafter. Tomato plants were staked and supported by nylon strings from the fourth week onward. All horticultural practices were in accordance with the recommendations developed by the Experiment Station (1976). The yield of marketable tomatoes from four pickings was recorded. Gross income was obtained by multiplying the total weight by a price of 73 cents kg^{-1}. The net income for different treatments was calculated by deducting the cost of production as described by Lloren *et al.* (1984).

1984 Experiment

The 1983 experiments were repeated on the same site during the winter of 1984. The same experimental design and planting distances were used, though an additional treatment of 80 plants m^{-2} density for the three weeds was added. The twenty-eight day old tomato seedlings (var. Duke) were transplanted 20 December, 1984. The same weed adjustment and removal methods were adopted as in the previous experiments. The tomato plants received one application of fertilizer, at the same rate as in 1983, in mid-February 1985. The pest control program was essentially the same as in the previous experiments. Marketable tomatoes were harvested four times. The gross income was calculated based on a price of 80 cents kg^{-1}. The net return of different treatments was calculated as in previous experiments.

Results and Discussion

Economic threshold study

Table 1 shows the net return of tomatoes derived from the different population densities of the three weeds. Statistical comparisons were made between individual weed densities and the control (0 plants m^{-2}) using Duncan's Multiple Range Test. The economic threshold of pigweed was 5 plants m^{-2} in both 1983 and 1984; that of jungle rice was over 40 plants m^{-2} in 1983, and 40 plants m^{-2} in 1984; that of horse purslane was not tested in 1983, and was 20 plants m^{-2} in 1984. According to Llorens *et al.* (1984), the cost for producing 'Duke' tomatoes in Puerto Rico amounted to an average of $17,671 ha^{-1}. The results of the present study indicate that a pigweed density of 5 plants m^{-2} in 1983 and 20 plants m^{-2} in 1984 would leave farmers with no net return in tomatoes. However, the highest density of either jungle rice or horse purslane has not resulted in negative earnings. Thus, our findings suggest that pigweed would cause the greatest economic loss to growers. Pigweed was followed by horse purslane and jungle rice in descending order of economic importance. In the United States, Monaco (1981) reported that tomato yield was reduced by Jimson weed *(Datura stramonium)*, tall morning glory *(Ipomoea purpurea)* and common cocklebur *(Xanthium pensylvanicum)* at densities of 11, 43 and 86 m^{-2}. Other experiments found that tomato yield was reduced at densities even lower than those mentioned above. Large crabgrass *(Digitaria sanguinalis)* reduced tomato yield at densities of 55, 215 and 430 m^{-2} or somewhat lower. Since none of these weeds were studied in the present investigation, no valid comparison can be made.

Critical period of weed competition study

The predominant weed species in experimental plots listed in decreasing order of abundance were: pigweed *(Amaranthus dubius)*, horse purslane *(Trianthema portulacastrum)*, jungle rice *(Echinochloa colonum)*, goose grass *(Eleusine indica)*, crabgrass *(Digitaria sanguinalis)*, spider flower *(Cleome gynandra)* and Jimson weed *(Datura stramonium)*. Table 2 shows that tomato yield was significantly reduced after 36 days of weed competition in 1983. Weed competition was less severe in 1984 than in 1983. Tomato yield was significantly reduced after 48 days of competition with weeds. Friesen (1979) reported that tomato yield was significantly reduced if weeds were allowed to compete with the crop for more than 24 to 36 days after transplanting. Similarly, Weaver and Tan (1983) found that the critical period of weed competition in transplanted tomatoes was from 28 to 35 days. Both findings are in general agreement with our results of 1983. However, the result of 1984 indicates that weed interference in tomatoes could be extended to 48 days. The slightly lower maximum and minimum temperatures recorded in 1984 compared to 1983 might have caused weed growth to be less rapid thus necessitating a longer period of competition in order to affect tomato yield (Table 3). Since irrigation was used, tomato plants received sufficient water, so precipitation was probably not a factor which delayed the critical period of weed competition under the specific conditions of this experiment.

Table 1 The net return of tomatoes derived from different population densities of three weeds

Population density	Net return per hectare (dollars)					
	Horse purslane		Jungle rice		Pigweed	
(plants/m²)	1983	1984	1983	1984	1983	1984
0 (control)	—[1]	14,651 a[2]	13,257 a	12,600 a	9,955 a	10,891 a
2	—	14,504 ab	12,437 a	9,915 ab	4,816 ab	10,159 a
5	—	11,266 ab	10,692 a	10,061 ab	−888 bc	2,835 b
10	—	10,843 ab	13,825 a	8,499 ab	1,783 bc	2,542 b
20	—	8,434 b	10,952 a	5,765 ab	−1,833 bc	−110 b
40	—	8,255 b	9,903 a	3,682 b	−5,409 c	−544 b
80	—	7,295 b	—	2,933 b	—	−1,396 b

[1] Horse purslane was not included in 1983 experiment because of the low infestation level of this weed.

[2] Means followed by the same letter or letters do not differ significantly at the 0.05 level of probability.

Table 2 Effect of time of weed removal on yield of tomatoes grown on a San Antón soil

Duration of weed competition (days)	Yield of tomatoes (kg/ha) 1983	1984
0	35,526 a[1]	35,943 a
12	33,379 a	40,768 a
24	31,702 ab	39,222 a
36	22,163 bc	31,467 ab
48	12,260 cd	24,388 bc
60	10,670 cd	23,338 bc
All the time infested	6,298 d	15,599 a

[1] Means followed by the same letter or letters do not differ significantly at 0.05 level of probability.

Table 3 Maximum and minimum temperatures recorded at the Fortuna Research and Development Center during the 1983 and 1984 tomato growing seasons

	Average maximum temperature (°C)		Average minimum temperature (°C)	
Months	Experiment 1983	Experiment 1984	Experiment 1983	Experiment 1984
December	30.7	27.4	19.4	18.9
January	30.6	28.9	19.5	16.6
February	29.7	29.9	19.0	18.4
March	30.3	29.5	19.0	18.8
April	30.8	30.4	20.3	18.9
Average	30.4	29.2	19.4	18.3

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References

Acín-Díaz, N., O'Farrill-Nieves, H. and Montalvo-Zapata, R. (1984) *Plaguicidas al Día* 5 1 - 103, University of Puerto Rico.

Anonymous (1976) Conjunto tecnológico para la produccion de hortalizas. Estación Experimental Agrícola, Univ. de P.R. 1 - 126.

Anonymous (1982) *Census of agriculture.* United States Department Agriculture.

Friesen, G.H. (1979) Weed interference in transplanted tomatoes *(Lycopersicon esculentum). Weed Science* 27 11 - 13.

Goyal, Megh R. (1983) Labor-input requirements for experimental production of summer peppers under drip irrigation, *J. Agric. Univ. P.R.* 67 (11) 20 - 27.

Llorens, E.A., González-Villafane, C. and Vargas, D. (1984) Gastos e ingresos en la producción de hortalizas en la costa dur de Puerto Rico. Estación Experimental Agrícola, Univ. P.R. Bol. 274 1 - 28.

Monaco, J.J., Garson, A.S. and Sanders, D.C. (1981) Influence of four weed species on the growth, yield and quality of direct-seeded tomatoes *(Lycopersicon esculentum* L.), *Weed Science* 29 394 - 97.

Weaver, S.E. and Tan. C.S. (1983) Critical period of weed interference in transplanted tomatoes. *Weed Science* 31 476 81.

DESHERBAGE DE L'OIGNON EN MARTINIQUE

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ABSTRACT

Many active ingredients were tested against weeds in onion crops. The trials evaluated different cultural practices. In intensive cultivation of vegetable crops, the results indicate the use of a nursery, with chemical weeding - propachlor + ethofumesate as pre-emergence, and propachlor as post-emergence.

After transplantation, the use of other chemicals - nitrofene, oxadiazon, ioxynil - allows production of fresh bulbs in good condition.

RESUMÉ

Plusieurs matières actives sont testées contre les adventices dans les cultures d'oignons. Les essais sont faits suivant différentes méthodes de culture. En culture intensive maraîchère, les tendances sont l'utilisation d'une pépinière avec désherbage chimique - propachlore + ethofumesate en prélevée et propachlore en post-levée.

Après transplantation, l'utilisation d'autres produits chimiques - nitrofène, oxadiazon, ioxynil - permettent d'avoir une production en bonnes conditions de bulbes frais.

Keywords: Oignon, Désherbage Chimique; Méthodes de culture, Martinique.

Dans le programme adopté par L'IRAT en Martinique pour développer la culture de l'oignon, l'un des thèmes principaux est le contrôle des adventices (de Bon, 1985). La maîtrise des mauvaises herbes peut etre faite par:

- l'emploi de substances herbicides,
- des pratiques agronomiques adaptées.

L'amélioration des techniques de culture se fait par:

- le choix des meilleures techniques de production pour un itinéraire techniuqe donné,
- une modification de l'itinéraire technique en partie ou complètement.

Dans la littérature, les principales matières actives recommandées en zones tropicales sont pour une culture avec un semis direct:
pendimethaline 1500g ha^{-1} + linuron 250g ha^{-1} (Bhalla, 1982),
pendimethaline 1120g ha^{-1}(Alspaugh, 1982), oryzaline 1120g ha^{-1} oxyfluorfène 60 à 280g ha^{-1} (Alspaugh, 1982).

Dans une culture utilisant la pépinière, les matières actives recommandées sont:

en préémergence

alachlore 2000g ha^{-1} + sarclage manuel (Gajraj Singh *et al*, 1984), linuron 1000g ha^{-1}, prometryne 1200g ha^{-1}, chlorbromuron 1250g ha^{-1} (Deuber *et al*, 1977), fluorodifen 2160g ha^{-1} (McIntyre, 1978), oxadiazon 1080g ha^{-1} (McIntyre, 1978), 1000g ha^{-1} (Ferreira *et al*, 1977), 1120g ha^{-1} (Alspaugh, *et al*, 1982), metolachlor 1680g ha^{-1} + oxyfluorfen 1350g ha^{-1} (Alspaugh, *et al*, 1982), oxadiazon 1500g ha^{-1} (Malik, *et al*, 1981).

en post-émergence

linuron 1000g ha^{-1} (Deuber *et al*, 1977), oxadiazon 2200g ha^{-1} (Menges, et Tamez, 1981), fluchloralin à 1500g ha^{-1} (Singh et Singh, 1980), bentazone, 460 à 960g ha^{-1} (Mascarenhas et Lara, 1980).

sur une culture à partir de bulbilles, diuron a 1600g ha^{-1} en pré et post-émergence et prometryne 1000g ha^{-1} en préémergence sont recommandées (Horino, *et al*, 1977).

En Martinique, la mission I.R.A.T. a commencé les premiers essais en 1974, en même temps que débuté les expérimentations agronomiques sur la culture de l'oignon. L'utilisation du methabenzthiazuron, du chlorprophame (ou CIPC) n'avait pas permis alors de mener à terme la culture.

A partir de 1976, puis surtout de 1982, des essais plus systèmatiques ont été réalisés pour trier le maximum de matières actives et arriver à une culture en semis direct dans la région la plus favorable de la Martinique, le sud, sans intervention mécanique. On verra quels en ont ete les resultats et l'influence qu'ils ont eu sur les principes de développement de cette culture en Martinique.

La démarche est résumée dans le schéma de la Figure 1.

Methodes et materiel

La liste des matières actives testées dans les neuf essais réalisés de 1976 à 1985 est la suivante (Tableau 1).

Les moments d'applications des matières actives en post émergence seront indiqués au fur et à mesure dans le cours de l'exposé. Les herbicides de préémergence (pré) sont appliqués le lendemain du semis sur sol humide.

Au total, neuf essais ont été réalisés. Les évaluations ont été faites soit à l'aide de l'échelle logarithmique recommandée par EWRS (European Weed Research Society) soit à l'aide d'une échelle linéaire en pourcentage. La surface des parcelles varient de 3 à 10m^2 suivant l'objet de l'essai. On utilise une bande témoin adjacente non traitée pour les premiers essais. Ensuite la comparaison des herbicides est faite entre les differents traitements ou à un témoin sarclé manuellement.

Pour les huit premiers essais, la culture est faite en semis direct à la dose de 8kg ha^{-1} de semences. Ils sont tous réalisés sauf un sur les vertisols magnésiens dans le sud de l'île, à Sainte-Anne. (voir Tableau 2).

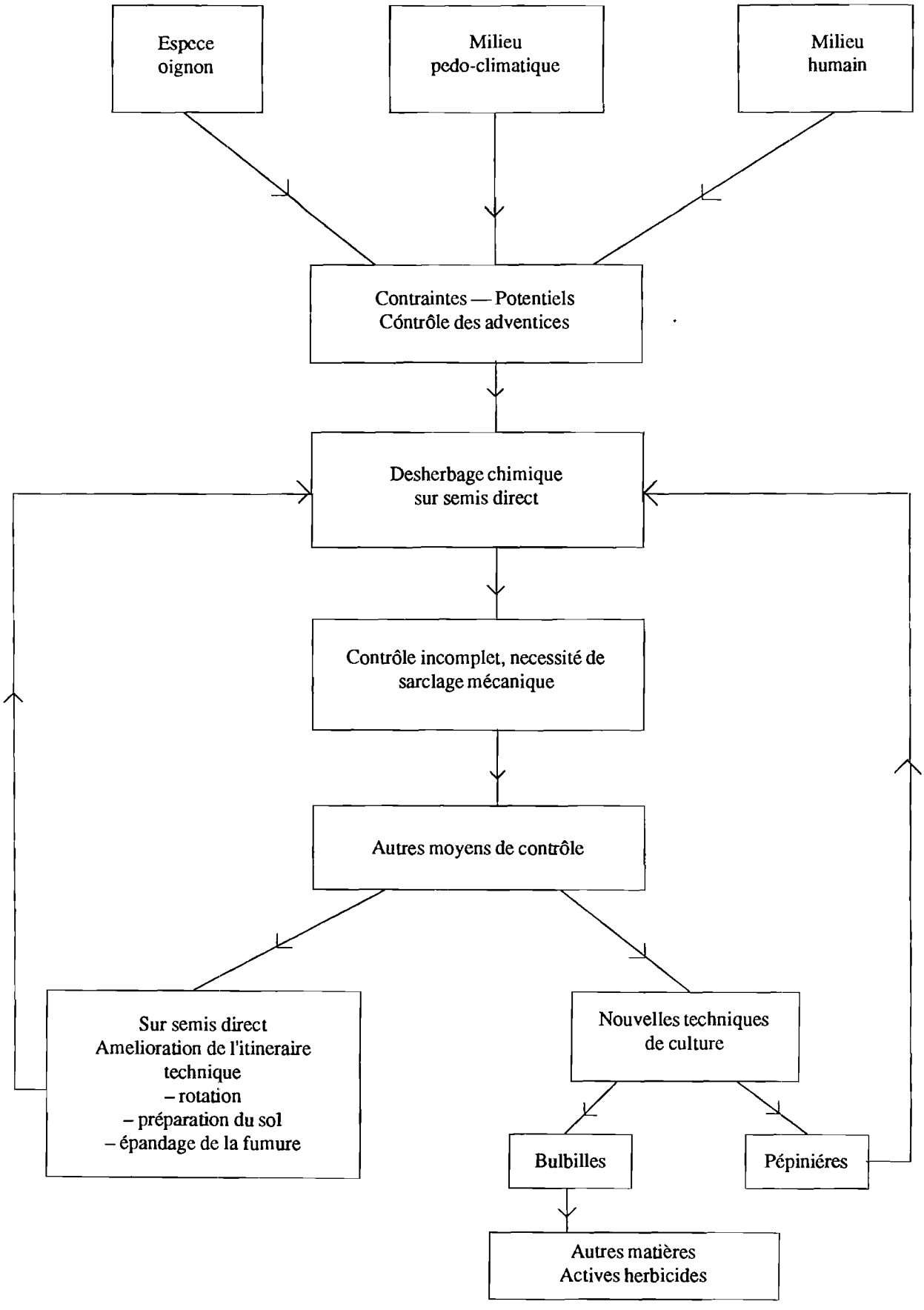

Fig. 1. Démarche pour assurer le contrôle des adventices sur oignon en Martinique

Tableau 1 Liste des matières actives herbicides testées

Matières actives	Doses de matières activées en g/ha
pré émergence (pré)	
alachlore	2000(*)
butraline	1200(*), 2400(*), 3000, 4500, 7200
chloridazone	1300(*)
chlorthal	6000, 9000, 13500, 18000
CIPC	2000(*), 2400(*), 6000
éthofumesate	600, 1000(*)
linuron	350(*), 1000, 2000
methabenzthiazuron	1000(*), 2800, 4200, 5600
pendimethaline	870(*), 1300, 2600
propachlore	2400(*), 3000(*), 4000(*), 4500
post émergence (post)	
butraline	3000(*)
chloridazone	1300(*)
diclofop-méthyl	900
éthofumesate	1000(*)
fluazifop-butyl	750
ioxynil	200(*), 300(*), 550, 940, 1250
linuron	600
méthabenz thiazuron	1000 (*)
oxadiazon	700,1500,2250
propachlore	4000,4500
propyzamide	1500

(*) Les quantités suives d'une astérisque ont été utilisées avec d'autres matières actives.

Tableau 2 Caractéristiques physiques, chimiques, minéralogiques du sol (0-2 mm) de l'horizon de surface. Valeurs moyennes (Communication personnelle, C. Feller, 1985)

Analyse mécanique (%)					minéraux argileux dominants	Teneur en eau (%) à pF		Is
A	LF	LG	SF	SG		2.5	4.2	
65	12	5	13	6	smectite	48	39	0.63

pH		C	N	C/N	P_2O_5		Complexe d'échange (meq/100g)					
H_2O	KC1	(%)	(%)		(%)							
					t	ass	Ca^{++}	Mg^{++}	K^+	Na^+	CEC	$\frac{S}{CEC} \times 100$
6.2	5.2	15.7	1.45	10.8	0.80	0.26	20.5	13.1	1.1	1.8	42.0	87

Is: Indice d'instabilité structurale

Pour se rapprocher le plus possible des conditions réelles, les essais sont faits sur des parcelles maraîchères de culture intensive. Le précédent est une solanacée ou une cucurbitacée.

L'évaluation des herbicides de post-levée est toujours faite après un épandage des herbicides de pré-levée. L'interaction herbicide prélevée X herbicide post-levée est inévitable dans les conditions de culture chez le producteur. Il est apparu nécessaire d'utiliser cette façon de procéder; elle est empirique et ne permet pas de dissocier vraiment les actions pré-et post-mais donne un résultat immédiatement vulgarisable.

Resultats

Adventices

La liste des adventices rencontrées lors des essais est:

	Nom-vernaculaire
Cyperus rotundus L.	Coco chat
Cleome viscosa L.	Mouzambé à fleurs jaunes
Cleome spp.	
Amaranthus dubius Mart.	épinard
Amaranthus spinosus L.	
Cassia sp.	
Echinochloa colonum (L.) link	herbe à riz
Eleusine indica (L.) Gaertn.	pied-poule
Rottbeolia sp.	
Commelina diffusa Burm.	herbe grasse
Portulaca oleracea L.	pourpier
Phyllanthus amarus	en bas feuille
Physalis sp	herbe à claque
Geophila repens (L.) I.M. Johston	liane-terre
Merremia hederacea (Burm.) Hall	
Ipomoea spp.	
Euphorbia hirta L.	
Euphorbia spp.	
Eclipta prostata L.	
Leptochloa sp.	
Acanthospermum sp.	
Acalypha sp.	
Argemone mexicana L.	

Toutes ces espèces ont été rencontrées dans les parcelles où sont faites les expérimentations d'herbicides. La multiplication de ces espèces se fait par graines. Mais on observe fréquemment dans des parcelles intensives des fragments de tiges de pourpier ou de talles d'Echinochloa. Dans ces derniers cas, le développement de l'adventice est beaucoup plus rapide et vigoureux que pour une germination à partir de graines.

Très vite, il apparaît que les adventices les plus difficiles à combattre sont: *Cyperus rotundus L., Cleome spp., Echinochloa sp., Rottboelia sp., Commelina sp., Portulaca oleracea L., Phyllanthus amarus* et *Eleusine sp.* dans le nord de l'ile.

Efficacité herbicide

En préémergence, deux associations ont donné un bon contrôle de l'enherbement:

pendimethaline 870g ha^{-1} + propachlore 2400g ha^{-1}

ethofumesate 1000g ha^{-1} + propachlore 2400g ha^{-1}

– Pendimethaline + propachlore a une efficacité bonne sur *Cleome, Ipomoea, A. dubius,* moyenne sur *P. oleracea, Phyllanthus, E. colonum, Ipomoea, Physalis,* nulle sur *C. rotundus, Rottboelia, Geophila repens.*

– Ethofumesate + propachlore a une efficacité bonne sur *Rottboelia, Cleome, Ipomoea* et *Phyllanthus,* moyenne sur *Echinochloa colonum,* nulle sur *C. rotundus.*

La durée de la rémanence n'a pu être appréciée car les traitements de post-levée sont effectués très rapidement après le semis, et d'autre part, les adventices non touchées envahissent rapidement les parcelles.

Chlorthal, CIPC, propachlore seul, méthabenzthiazuron ont des contrôles des adventices très insuffisants. Alachlore butraline, linuron et méthabenzthiazuron sont phytotoxiques auu doses où ils contrôlent l'enherbement.

En post-levée, il s'agit de trouver un produit qui puisse être utilisé sur la culture dès le stade 1 feuille, en moyenne entre 16 et 20 jours après le semis. Les premiers essais ont porté sur l'utilisation du nitrofène et de l'ioxynil au stade 3 feuilles. Dans ces cas, les adventices non contôlées par les traitements pré étaient tdop développées (30 jours après semis); il n'était pas possible d'avoir une efficacité d'un herbicide chimique sur ces plantes.

Au stade 1 feuille, 15 à 20 jours apres le semis,

– fluazifop-butyl combat efficacement toutes les graminées présentes *Rottboelia, E. colonum, E. indica* jusqu'au stade épiaison.

– propyzamide 1500g ha^{-1} et propachlore 4000g ha^{-1} complète l'action des herbicides "pre" en ayant une bonne efficacité contre *Cleome, Phyllanthus, Ipomoea.*

CIPC n'a pas apporté de contrôle supplémentaire après une pulvérisation pré par rapport à l'absence de traitement.

Au stade 2 feuilles, une seul matière active est retenue le nitrofène à 2000 ou 400g ha^{-1}.

– bonne efficacité contre *Physalis* et *Commelina.*

– efficacité moyenne contre *G. repens, Phyllanthus, C. viscosa, A. dubius, P. oleracea.*

– le passage de 2000 a 4000g ha^{-1} améliore l'efficacité sur *Cleome* et *Phyllanthus,* mais elle reste moyenne.

Au stade 2-3 feuilles, ioxynil à 200g ha^{-1} en association avec la butraline 3000g ha^{-1} ou le méthabenzthiazuron à 1500g ha^{-1}, ou l'ioxynil à 300g ha^{-1} permettent de prolonger l'action des herbicides pré et post stade 1 feuille en maintenant les peuplements *Phyllanthus, Cleome* et *P. oleracea* a des densités faibles. L'efficacité est moyenne sur *Cleome, E. colonum, P. oleracea.*

Au stade 4 feuilles, ioxynil à 500g ha^{-1} a une bonne efficacité contre *Physalis* (3-9 feuilles), *C. viscosa* (4-6 feuilles), *G. repens* (2-8 feuilles), efficacité moyenne sur *P. oleracea, A. dubius, C. diffusa,* efficacité nulle sur *Phyllanthus.* Oxadiazon (700g ha^{-1}), linuron (600g ha^{-1}) ont montré une bonne efficacité contre *Cleome, Phyllanthus, A. dubius, Cassia* après un traitement pré et deux traitements post.

Tableau 3 Fréquence des adventices sur quatre essais

Stade de la culture	1 - 2 feuilles	2 - 3 feuilles	2 - 3 feuilles	3 feuilles
Traitements herbicides *	pré	pré + sarclage manuel	pré	pré + nitrofene 4000
Infestation globale des parcelles en % recouvrement du sol	20	30	40	25
Nombre de jours aprés semis	20	30	29	38
Adventices: frequence (%)				
Cyperus rotundus	60	52	33	79
Cleome spp.	20	24	12	5
Phyllanthus sp.	10	14	35	2
Echinochloa colonum	10	4	15	14
Portulaca oleracea	10	3	15	14
Divers	10	3	5	1

pré: traitement herbicide de préémergence

Tableau 4 Efficacité de traitements herbicides de prélevée (Résultats 1985)

Produits	*Echinochloa colonum*	*Rottboelia* sp.	*Cleome* spp.	*Ipomoea*	*Phyllanthus* spp.
pendiméthaline + propachlore	5	5	1.5	1.5	1
ethofumesate + propachlore	5	1	1	1	1
CIPC + propachlore	5.5	4	1.5	3.5	1.5
chloridazone + propachlore	5	1	2.5	2.5	1

Phytotoxicite pour l'oignon

- Traitements de préémergence

Les deux associations retenues pendiméthaline + propachlore et pendimethaline + ethofumesate montrent respectivement 29 et 11% de phytotoxicité qui se traduisent par un manque à la levée. (voir Tableau 5).

La phytotoxicité de matières actives efficaces à des doses élevées (voir Tableau 5) n'a pas permis de les retenir comme il a été dit.

Tableau 5 Phytotoxicité pour l'oignon de quelques produits de préémergence (Echelle linéaire).

Produits	linuron		butraline		chlorthal		pendimethaline		propachlore
Dose	1000	2000	1000	2000	6000	12000	13000	2600	3600
Phytotoxicité en %	60	100	80	90	0	0	40	80	20

Produits et dose	pendimethaline +propachlore	870 2400	ethofumesate +propachlore	1000 2400	chloridazone +propachlore	1300 1400
phytotoxicité en %	29		11		21	

• Post-émergence

Les references dans la littérature sont nombreuses. Les matières actives ont toutes été essayées a des stades plus précoces que ceux cités usuellement. Le nitrofène est appliqué à partir du stade 2 feuilles sans dommage sur la culture. On a diminué les doses d'ioxynil pour pouvoir l'utiliser plus rapidement seul ou en association avec d'autres matières actives. Tous les autres produits sont utilisés de la même façon que dans les autres pays.

Discussion - Conclusion

L'ensemble de ces essais tente de proposer un programme de 4 pulvérisations d'herbicides chimiques pour mener à terme une production de bulbes sans intervention mécanique.

Dans le dernier essai, on a en moyenne:

– 17% des parcelles conduites à la récolte sans intervention mécanique.

– 54% des parcelles menées avec un sarclage léger consistant à arracher les adventices bien développées vers le 60ème jour.

– 4% des parcelles nécessitant une intervention mécanique sérieuse vers le 60ème jour.

– 25% des parcelles éliminées.

Le programme de traitement proposé comprend en pré-levée, pendiméthaline 870g ha^{-1} + propachlore 2400g ha^{-1}

ou éthofumesate 1000g ha^{-1} + propachlore 2400g ha^{-1}

Stade 1 feuille, fluazifop-butyl 250 à 700g ha^{-1}

+ propyzamide 1500g ha^{-1} ou propachlore 4000g ha^{-1}

Stade 2 feuille, nitrofene 2000g ha^{-1}

Stade 3 feuilles et plus, ioxynil ou ioxynil + methabenzthiazuron ou ioxynil + butraline ou linuron ou oxadiazon.

Ce programme reprend des produits déjà recommandés dans d'autres zones tropicales, notamment en Guadeloupe (Gautier, 1984).

Jusqu'a présent, il n'est donc pas possible de proposer au développement une lutte chimique contre les adventices puisqu'au moins 80% des surfaces demandent une intervention mécanique.

Le fait que de nombreuses zone favorables à la culture de l'oignon par leur températures soient aussi très pluvieuses (plus de 2000mm) confirme les limites du sarclage chimique et conduit à recherche d'autres solutions.

Aussi, dans le programme de developpment del'oignon en Martinique, l'IRAT propose de lutter contre les adventices d'autres facons:

- en ameliorant l'itinéraire technique: choix d'un bon précédent nettoyant comme la canne à sucre à Barbade, utilisation d'une fumure de couverture uniquement, préparation du sol améliorée pour faciliter la germination de l'oignon.

– en utilisant une autre technique de culture soit la pépinière soit les bulbilles.

Pour ces techniques, la lutte contre les adventices est à assurer dans les pépinières puis dans la culture.

En pépinière, les résultats obtenus précédemment sont utilisés, l'intervention mécanique qui sera manuelle est réduite et peut-être meme nulle. Il est sûre que la phytotoxicité des herbicides conduira à augmenter de 10 a 30% les quantités de semences nécessaires.

Ensuite à la transplantation des plants ou à la plantation des bulbilles, il sera possible d'utiliser des herbicides plus efficaces contre les adventices présentes. Ce sont notamment ceux de post-levée.

Cette orientation est actuellement prise par les producteurs en Martinique. Elle conduit à un coût élevé de l'oignon, mais permet d'obtenir une production avec une main-d'oeuvre relativement limitée. Ces spéculations se développent dans des zones de 1300 à 2500mm de pluviométrie par an.

Le producteur maraîcher assure une bonne valorisation de sa culture en proposant un légume different du bulbe importé.

A partir d'un schéma initial, d'une production à partir d'un semis direct pour obtenir des bulbes secs, on arrive à une culture très intensive donnant un produit différent du bulbe de garde mais permettant une production martiniquaise et valorisante pour l'agriculteur.

Bibliographie

Alsphaugh, K.R. et al (1982). Efficacy of oxyfluorfen in West Texas onions. *Proc. 35th Annual Meeting Southern Weed Sci. Soc. 136.*

Bhalla, P.L. and Dubey, M.L. (1982). Study of the efficacy of certain herbicide treatments in onion (*Allium cepa* L), *Abstracts of Papers, Annual Conference of India Soc. of Weed Science.*

Ciba-Geigy (1981). *Manuel pour essais de plein champ. Protection des végétaux.* CIBA GEIGY S.A., Bale, Suisse,Division Agriculture 205 pp.

De Bon, H. (1985). Opérations de recherche - développement sur carottes, oignons et haricots à grains rouges en Martinique Colloque: *Systèmes de Productions Agicoles Caribéens et Alternative de Dévelopment.* Université Antilles-Guyane, DAC, Fort-de-France, Martinique.

Deuber, R. *et al* (1977). *Herbicidas em culturas de cebola,* Instituto Agronomico, Etat de Sao Paulo, boletim technico n° **47**, 20 pp.

Ferreira, F.A. *et al* (1977). Efeitos de diferentes herbicidas na cultura de cebola (*A. cepa* L.), transplantada na regiao sul do estado de minas gerais. Proj. Olericultura relat. Anual. 75/76, Belo Horizonte.

Gajraj Singh,Pandey, U.C. and Singh, G.P. (1984). Chemical control of weeds in onion. *Haryana J. of Hort. Sc.,* **11** (162), 85 - 91.

Gantier, J. and Anais, G. (1984). Conseils pour la culture de l'oignon. *Bulletin agronomique Antilles-Guyane,* n° **3**, decembre, pp 13 - 17.

Horino, Y. *et al* (1977). Ensaio de herbicida na cultura da cebola (*A. cepa* L.) pelo sistema de bulbinho. *Coop. Agricola Cotia,* EMBRAPA., 4 p.

McIntyre, G. (1978). Essai d'herbicides, en culture de l'ail et de l'oignon. *Rev. Agric. et Sucr. de l'Ile Maurice,* **57** (1), 21 - 22.

Malik, Y.S., Singh, K.P. and Pandita, M. (1981). Chemical weed control studies on onion. *Abstracts of Papers Annual Conf. of Indian Soc. of Weed Science,* (in *Weed Abs. 1984,* **33** (7) 2162).

Mascarenhas, M.H.T. and Lara J.F.R. (1980). Effect of doses and time of application of bentazone on the yield of two onion cultivars, *Plantas Daninhas* **3** (2) 75 - 84.

Menges, R.M. and Tamez, S. (1981). Response of onion to annual weeds and post-emergence herbicides. *Weed Science* **29** (1), 74 - 79.

Singh, B. and Singh, R.P. (1980). Studies on chemical weeding in onion. *Vegetable Science* **7** (1), 14 - 17.

ASSURE – A NEW SELECTIVE HERBICIDE FOR THE CONTROL OF ANNUAL AND PERENNIAL GRASS WEEDS IN BROADLEAVED CROPS

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ABSTRACT

Assure [2-[4-[(6-chloro-2-quinoxalinyl)oxy]-phenoxy]- propionic acid, ethyl ester], (formerly DPX-Y6202) is a new post-emergence herbicide for the selective control of annual and perennial grasses in broadleaved crops. It was evaluated in a wide range of broadleaved field crops, including vegetables, on different soil types and seasons in Trinidad and showed excellent activity against grass weeds including *Brachiaria* spp., *Cynodon dactylon, Digitaria* spp., *Eleusine indica,* and *Paspalum* spp. None of the herbicide treatments caused any apparent damage to crops or significant taints in crop products. Annual and perennial grasses were controlled by rates between 0.05 to 0.1kg a.i ha^{-1}.

RESUMEN

Un nuevo herbicída de post-brote-Assure- [2-[4-[(6-cloro-2-quinoxalinyl) oxy]-phenoxy]-acido propiónico, ester etilíco], (anteriormente, DPX-Y6202), sirve para el control selectivo de hierbas anuales y perennes, en cultivos de hojas anchas incluyendo, verduras y en una variedad de suelos y estaciones, a la vez mostrando tener una potencia excelente contra las hierbas de pasto, incluyendo entre ellas la *Brachiaria* spp., *Cynodon dactylon, Digitaria* spp., *Eleusine indica* y *Paspalum* spp. Ninguno de los tratamientos con herbicídas, causó daños apparentes a los cultivos o descoloraciones en los productos de cultivo. Los pastos anuales y perennes fueron controlados por tazas entre los 0.05 a 0.1kg a.i. ha^{-1}.

Keywords: Selective herbicide, Grass weeds, Broadleaved crops.

One of the major constraints limiting the production of field crops in Trinidad and Tobago is the control of weeds. Farmers still rely on manual methods which are tedious, expensive, and frequently ineffective. Weed growth can be rapid and severe, especially in the wet season (June to December), with grass weeds frequently the most common species (Brathwaite, 1978a, b; 1979a, b; 1981; 1982; 1985). Although safe and economic pre-plant and pre-emergence herbicide treatments which can contribute to adequate weed control have been identified (e.g. Brathwaite, 1979a, b; 1981) their adoption by farmers has been slow and limited. Farmers still prefer to wait until weeds are in evidence before applying a herbicide treatment. The recently developed selective post-emergence herbicides for control of grass weeds in broadleaved crops (see for example Plowman *et al,* 1980; Slater and Hirst,1980; Schumacher *et al.*, 1982) offer considerable potential for safe and effective weed control in broadleaved crops. Results of a study with fluazifop-butyl in Trinidad were reported by Brathwaite and Martin (1982). This paper summarizes data from trials carried out since 1983 with DPX-Y6202 (Annexes 1, 2 and 3) for the control of grass weeds and volunteer corn in selected broadleaved crops in Trinidad.

Materials and Methods

All experiments were field trials carried out on loam soils at different locations in Trinidad. Sixty per cent of the trials were on River Estate loam (fluventic eutropept); the pH (water) of the surface 15cm of this soil ranged from 5.2 to 6.5, organic matter from 1.0 to 2.3 per cent, cation exchange capacity from 7.2 to 10.8 meq. 100 g^{-1} and the clay content from 20 to 21 percent. Experimental sites were normally disc ploughed and rotavated before sowing or transplanting the crops. Plot size varied with crop and the minimum plot size used in the study was 1.5m x 0.9m in cabbage. The experimental design was a randomized block with at least four replications. The cultivars of the different crops tested are shown in Table 1. Crops were rainfed or received sprinkler irrigation. All cultural practices except grass weed control followed the normal local recommendations.

All treatments were applied over-the-top when weeds were growing actively with seedlings of annual grass weeds having about four to eight leaves and perennial grass weeds having about six leaves per shoot. Treatments were applied with a CP3 knapsack sprayer at a volume of 200 to 350 litres of clean water per ha using a flat fan Tee Jet nozzle at a pressure of 1.6 to 2.1 bars. Standard treatments in many trials included either appropriate commercially available products, e.g. fluazifop-butyl, alloxydim-sodium, or controls, one of which was maintained weed-free throughout the season and the other an unweeded check. The research chemical, HOE 33171, was included in some trials. Agral 90 at a rate of 0.1 per cent of spray volume was included in all herbicide treatments except HOE 33171. No early weed control was done in any of the crops.

Visual assessments of the crop condition and weed control were made using a scale of 0 to 10 where 0 represented no crop injury or no weed control while 10 represented complete destruction of the crop or 100 per cent weed control. Weed counts, observations on plant stand and the dates of flowering and maturity were made. Many of the trials were harvested and the yields recorded. Cabbage heads and tomato fruits were taken for residue analysis. Analysis of variance was computed on the data.

Results

Crop tolerance

A number of broadleaved crops (Table 1) showed tolerance to DPX-Y6202 at rates at least twice those required for effective grass weed control. In general, there was no visable crop injury nor any effects on date to blooming and maturity, plant height, branching and plant stand in the study. Good crop yields were obtained with DPX-Y6202 treatments which did not affect grade qualitv of harvested products.

Grass weed control

Table 2 presents a list of grass weeds susceptible to DPX-Y6202 applied post-emergence. The rates of DPX-Y6202 indicated are required to provide 90 per cent or more weed control.

The excellent activity of DPX-Y6202 against grass weeds in selected crops under cropping conditions in Trinidad is shown in Table 3 (tomato), Table 4 (cabbage), Table 5 (bodie bean - *Vigna unguiculata*) and Table 6 (bodie bean/sweet potato intercrop).

In three trials DPU-Y6202 at rates of 0.05 - 0.1kg a.i. ha^{-1} gave excellent control of established stands of *Cynodon dactylon*. At one location a repeat application of 0.1kg a.i. ha^{-1} DPX-Y6202 was necessary because of regrowth.

DPX-Y6202 gave excellent control of *Sorghum halepense* in pigeon pea with a single application of 0.1kg a.i. ha^{-1}. In another trial at a different location regrowth occurred and a second application of DPX-Y6202 at 0.1kg a.i. ha^{-1} was necessary for full season control of the perennial weed.

Rainfastness

A trial was conducted during the 1984 dry season to study the effect of rain-washing at 0.5, 1, 2, 3, and 4 hours after DPX-Y6202 at 0.05kg a.i. ha^{-1} treatment to *Eleusine indica* and *Echinochloa colonum*. A sprinkler irrigation system was employed to simulate rain applied at 30mm. Results showed that rainfall 0.5 hours after treatment decreased the control of both grasses, an average of 42 per cent control, but that rainfall after at least 1 hour had no effect on the DPX-Y6202 activity. The average ratings were 100, 95, 100, and 98 per cent after 1, 2, 3, and 4 hours for DPX-Y6202 applied at 0.05kg a.i. ha^{-1}.

Discussion

The considerable potential of DPX-Y6202 for the selective post-emergence control of annual and perennial grass weeds was clearly demonstrated in the many trials. DPX-Y6202 exhibits excellent selectivity to a range of broadleaved crops and compares very favourably with the already commercially available post-emergence grass weed herbicides. The rate advisable for the crop/weed situations studied appears to be 0.05 to 0.1kg a.i. ha^{-1} dependent on the grass weed flora, the higher rate being employed where perennial weeds are predominant. Users must be advised that, as with the already commercially available post-emergence grass weed herbicides, a suitable broad-leaved herbicide or other form of broadleaved weed control must be included in the cropping programme when implementing the adoption of the chemical, particularly if the control of problem weeds, e.g. *Parthenium hysterophorus*, is to be efficient.

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The author gratefully thanks the farmers who supplied the land used in many of the trials, Mrs. Christine Commissiong and Ms. Arlene Vieira for typing the manuscript, Messrs. Sarran Harryram, Ronald Sheppard, and Oscar Brathwaite for technical assistance, Messrs. Floyd Homer and Anthony Applewhite for assistance with some aspects of the work, Geo. F. Huggins & Co. Ltd. for supplying the samples of fluazifop-butyl, Goellnicht and Stollmeyer Ltd. for supplying the samples of HOE 33171, Caribbean Chemicals and Agencies Ltd. for supplying some agrochemicals, and E.I. du Pont de Nemours & Co. (Inc.) (Dupont Latin America) for supplying the samples and technical information for DPX-Y6202.

Table 1 Crops tolerant to the herbicide DPX–Y6202

Crop	Cultivar
Bean	Contender, Harvester, Top Crop
Cabbage	Bravo, Greenboy, Kono Cross, Summer Queen
Cowpea	California Blackeye No 5, Kanhai, Laura B, Los Baños Bush Sitao No. 1, Vita 5
Cucumber	Chipper, Local, Tempo
Eggplant	Early Long Purple, Local
Hot pepper	Red Hot Local
Okra	Clemson Spineless, Lee, Local, Puerto Rico Dwarf
Pigeon pea	Chaguaramas Pearl, Tobago, UW17
Sorrel	Dwarf Early Red
Soya bean	Hsi-hsi, Jupiter
Sweet pepper	California Wonder, Jupiter, Skipper, Starr
Sweet potato	A28/7, Local, 049
Tomato	Calypso, Duke, Early Cascade, Floradel, President, Roma
Watermelon	Charleston Grey, Gloria, Sweet Princess.

Table 2 Grass weeds susceptible to the herbicide DPX–Y6202[a]

A. DPX–Y6202 at 0.02 - 0.05 kg a.i. ha^{-1}
Brachiaria spp.
Digitaria sanguinalis
Echinochloa colonum
Eleusine indica
Leptochloa spp.
Panicum spp.
Rottboellia exaltata
Sorghum bicolor (volunteer sorghum)
Zea mays (volunteer corn)

B. DPX–Y6202 at 0.05 - 0.01 kg a.i. ha^{-1}
Cynodon dactylon
Paspalum fasciculatum
Sorghum halapense

[a] At least 90% control of the weeds

Table 3 Grass control at 5 weeks after application of herbicidal treatments in tomato[a]

Treatment	Rate (kg a.i. ha^{-1})	Grass control (%) *E. colonum*	*E. indica*	*B platyphylla*	*P. fasciulatum*
DPX–Y6202	0.02	92	95	90	86
DPX–Y6202	0.05	95	100	98	92
DPX–Y6202	0.1	98	100	100	96
Fluazifop-butyl	0.5	95	100	100	92

[a]Summary data from four trials. In one trial where *Sorghum halepense* occurred it was controlled by DPX–Y6202 at 0.1 kg a.i ha^{-1} only. *Cyperus rotundus* frequently showed some bronzing but was not controlled by any of the treatments.

Table 4 Grass control at 5 weeks after application of herbicidal treatments in cabbage[a]

Treatment	Rate (kg a.i. ha^{-1})	Grass control (%) *E. colonum*	*E. indica*	*B. platyphylla*	*P. fasciulatum*	*L. scabra*
DPX–Y6202	0.02	93	100	98	85	90
DPX–Y6202	0.05	98	100	100	98	94
DPX–Y6202	0.1	100	100	100	100	100
Fluazifop-butyl	0.5	98	100	95	90	92
Alloxydium-sodium	1.0	82	86	84	75	86
Alloxydim-sodium	1.5	86	96	82	82	90
HOE 33171	0.24	94	98	100	94	93
HOE 33171	0.36	100	100	100	98	96
HOE 33171	0.48	100	100	96	100	100

[a] Sumary data from three trials

Table 5 Grass control at 6 weeks after application of herbicidal treatments in bodie bean (*Vigna unguiculata*)[a]

Treatment	Rate (kg a.i. ha^{-1})	Grass control (%) *E. colonum*	*E. indica*	*B. platyphylla*	*Digitaria* spp.
DPX–Y6202	0.02	100	100	95	98
DPX–Y6202	0.05	100	100	100	96
DPX–Y6202	0.1	100	100	100	100
Fluazifop-butyl	0.5	100	95	98	95

[a] Summary data from four trials

Table 6 Grass control at 56 days after treatment in a bodie bean/sweet potato intercrop[a]

Treatment	Rate (kg a.i. ha^{-1})	Grass control (%) *E. colonum*	*E. indica*	*B. platyphylla*	*P. fasciulatum*
DPX–Y6202	0.05	98	100	98	95
DPX–Y6202	0.1	100	100	100	98
Fluazifop-butyl	0.5	98	100	94	95
Alloxydim-sodium	1.5	90	92	86	86
HOE 33171	0.36	95	98	98	92
HOE 33171	0.48	100	100	98	98

[a] Summary data from two trials. In both *Cyperus rotundus* showed some bronzing but was not controlled by any of the treatments.

References

Anon. (1983). Assure - experimental grass herbicide (formerly DPX-Y6202). E.I. du Pont de Nemours & Co. (Inc.). U.S.A., Technical Bulletin, 5 pp.

Brathwaite, R.A.I. (1978a). Chemical weed control in bodie bean. *PANS* 24 (2) 177 - 180.

Brathwaite, R.A.I. (1978b). Effects of herbicides on weed control, yield and quality of eggplant (*Solanum melongena* L.) in Trinidad. *Weed Research* 18 (4) 243 - 246.

Brathwaite, R.A.I. (1979a). Herbicide performance in rainfed cabbage. *PANS* 25 (1) 50 - 55.

Brathwaite, R.A.I. (1979b). Weed control in grain legumes, *Proc. Regional Workshop on Tropical Grain Legumes, 1979.* The University of the West Indies, Trinidad (In Press).

Brathwaite, R.A.I. (1981). Weed control in production of okra in Trinidad. *Agron. J.* 73 (4) 690 - 692.

Brathwaite, R.A.I. (1985). Weed management in intercropping systems, *Proc. Scientific Colloquium on Caribbean Farming Systems and Alternatives for Development, 1985.* The University of the French West Indies and Guiana, Martinique, French West Indies (In Press).

Brathwaite, R.A.I. and Martin, D.C. (1982). Evaluation of a new grass killer in selected vegetables. *Proc. 18th Ann. Mtg. Caribb. Food Crops Soc.* 18 244 - 253.

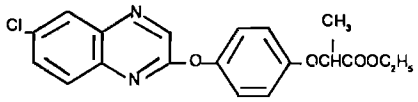
Plowman, R.F., Stonebridge, W.C. and Hawtree, J.N. (1980). Fluazifopbutyl - a new selective herbicide for the control of annual and perennial grass weeds, *Proc. British Crop Protection Conference - Weeds,* 1 29 - 37.

Schumacher, W., Rottele, M. and Marrese, R.J. (1982). Grass weed control in soybeans with HOE 33171. *Proc. British Crop Protection Conference - Weeds* 1 703 - 708.

Slater, A.E. and Hirst, R.H. (1980). Alloxydim-sodium potential in vegetable crops. *Proc. British Crop Protection Conference - Weeds* 1 99 - 106.

Annex 1

Chemical and physical properties of DPX–Y6202

Chemical name	2-[4-[(6-chloro-2-quinoxalinyl) oxy] -phenoxy]-propionic acid, ethyl ester	
Structure		
Physical form	White crystalline solid	
Molecular weight	372.81	
Melting point	91°C	
Solubility at 20°C	water	0.3 x 10^{-4} g 100 ml^{-1}
	n-hexane	0.26 g 100 ml^{-1}
	xylene	12.1 g 100 ml^{-1}
	acetone	11.1 g 100 ml^{-1}
Vapour pressure	3×10^{-7} mm Hg at 20°C	
Formulation	DPX–Y6202 is formulated as an amber coloured emulsifiable concentrate with petroleum odour containing 95.8 g l^{-1} of active ingredient.	

Source: Anon. (1983).

Annex 2

Toxicology of DPX–Y6202

The acute oral LD_{50} values to male and female rats are 1,670 and 1,480 mg kg^{-1}, respectively, for the active ingredient and above 5,000 mg kg^{-1} for the formulated product. The acute skin LD_{50} values to the mouse and rat are over 10,000 and 5,000 mg kg^{-1} for absorption and subcutaneous treatments, respectively with the active ingredient. The acute skin LD_{50} value to the rabbit is greater than 2,000 mg kg^{-1} with the formulated product.

The active ingredient is not a skin sensitizer to either rabbit or guinea pig. The formulated product is an irritant but not classified as a primary skin irritant to rabbit, and is a mild skin irritant but non-sensitizer to guinea pig. The active ingredient is a mild eye irritant and the formulated product is a severe eye irritant to rabbit.

DPX–Y6202 is non-mutagenic in the Ames test. It is non teratogenic at 300 mg kg^{-1} day^{-1}. The acute oral LD_{50} value to mallard ducks is greater than 2,000 mg kg^{-1} with the active ingredient. The LC_{50} at 96 hours for rainbow trout is 10.7 ppm.

Source: Anon. (1983).

Annex 3

Mode of action of DPX–Y6202

DPX–Y6202 is primarily absorbed through the leaves and readily translocated throughout the plant (Anon., 1983). The first visible symptom is a cessation of growth which was frequently observed within 48 hours of application under Trinidad conditions. Chlorosis and necrosis begins on the young leaves and then spreads to the older leaves and shoots. Death usually occurs within 2 to 4 weeks of application. Effective control of root system regrowth of some perennial grasses has been observed. The effectiveness of DPX–Y6202 is enhanced when the chemical is applied to actively growing weeds. Rainfall 1 hour after application did not reduce the effectiveness of DPX–Y6202.

PRACTICAL EXPERIENCE WITH SOLAR CROP DRIERS IN THE CARIBBEAN

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ABSTRACT

Solar crop driers have been used in the Caribbean territories for the past twelve years. Crops dried have included sorrel, bananas, grass, nutmegs, ginger and screw pine. Several types of drier have been employed, varying from the simple wood-and-plastic wire basket drier to the metal-and-glass rock bed drier with chimney-assisted air circulation. Practical experience indicates that the most cost effective design is the wire basket drier with a plastic cover of UV stabilised polyethylene. For crops which require higher or more stable temperatures, the open cycle natural convection rock bed drier may be used. Rock-bed driers have been built in Barbados, Jamaica, Dominica, Grenada and Trinidad & Tobago, wire basket driers have been used in St. Lucia, Dominica, Guyana and Trinidad and Tobago. Simple cabinet driers have also been used, but they lack the simplicity of the wire basket drier and the heat storage capacity of the rock bed driers.

RESUMEN

Durante los últimos doce años, se ha utilizado secadores solares en el Caribe para secar cultivos tales como la acedera, los bananos, la hierba, la nuez moscada, el jengibre y la pandánea. Se ha empleado varias clases de secadores, del sencillo secador de madera y plástico con red de alambre hasta el secador de vidrio y metal con lecho de piedras y circulación de aire por chimenea. La experiencia práctica indica que el diseño más rentable es la red de alambre con una tapa de plástico hecha de polietileno estabilizado contra los rayos UV. Para los cultivos que necesitan temperaturas más altas o estables, se puede utilizar el secador de lecho de piedras de ciclo abierto y convección natural. Se ha construido secadores de lecho de piedras en Barbados, Jamaica, Dominica, Granada, y Trinidad y Tobago. Se ha utilizado también los secadores sencillos en forma de gabiente, pero éstos son más complejos que la red de alambre y no tienen la capacidad de almacenamiento calorifico de los secadores de lecho de piedras.

Keywords: Solar Crop Driers, Caribbean

The solar energy available in the Caribbean region varies from about 25 MJ m^{-2} day^{-1} during the dry season to about 10 MJ m^{-2} day^{-1} during the rainy season. Crops which ripen during the dry season are therefore ideally suited for solar drying since about 2.5 MJ are required to remove 1kg of water from the drying crops.

Solar dryers may vary in complexity from the very simple, such as the drying floor, to highly complicated systems using pumps, heat exchangers and microprocessor controls. Over the past 12 years, experiments have been conducted on a large variety of driers (Headley and Springer, 1973; Headley, Bryan and Hoogmoed, 1976; Headley and Singh, 1979; Harvey et al., 1985) whose design has depended on the type of crop and the economic cost which can be incurred during its drying.

A wide variety of crop materials have also been dried such as grass *(Panicum maximum)*, nutmeg *(Myristica fragrans)*, sorrel *(Hibiscus sabdariffa)* and yam *(Dioscorea alata)*. In terms of cost effectiveness, the simplest driers have been the most suitable.

Drier Types

The following types of solar drier have been tested in the territories listed after them.

(a) The closed-cycle natural convention drier - Trinidad and Tobago.

(b) The rock bed drier - Barbados, Dominica, Grenada, Jamaica, Trinidad and Tobago.

(c) The wire basket drier - Dominica, Guyana, St. Lucia, Trinidad and Tobago.

(d) The cabinet drier - Trinidad.

The closed-cycle natural convention drier

Work on solar driers was begun using the closed cycle natural convention drier. This design was chosen because it did not require fans for air circulation. Tests were conducted on root crops to see if they could be dried by farmers for incorporation into animal feeds. To maximise air circulation rates, a high temperature difference between the top of the solar collector and the bottom of the dehumidifier was required. With a doubly glazed collector, one could reach 110°C at the top of the collector with the dehumidifier at 65°C. This gave a maximum air velocity of about 50cm $sec.^{-1}$ when the unit was unloaded.

Because air at over 90°C was admitted to the drying chamber, this unit was only used to dry root crops such as cassava *(Manihot esculenta)* sweet potato *(Ipomoea batatas)* and yam *(Dioscorea alata)*. Because of the presence of muco-polysaccharides (Santo, 1967), yams had to be sliced to about 3mm thick before they could be dried satisfactorily. Partial cooking of the dried product was not a disadvantage.

During the rainy season, the insolation available was inadequate to maintain suitable air circulation, so the dryer gave problems such as fungal infestation due to the presence of spaces in the drying chamber where the relative humidity reached 100 per cent. During the dry season, drying times varied from 20 hours for yam to 8 hours for grass.

The rock bed drier

The rock bed drier was developed from the closed cycle natural convection drier by removing the dehumidifier and allowing the air from the solar collector to move through the drying chamber before being exhausted to the ambient air. Air was not recycled so humidity control was much easier. The rock bed was in series or parallel with the drying chamber and reduced the air temperature from the 105°C at which it left the doubly glazed solar collector to about 65°C in the drying chamber. Figure 1 shows the efficiency curve for a rock bed drier (Singh, 1979). The heat storage capacity of the rock bed drier is an advantage in that it keeps the drier above ambient temperature during cloudy or rainy periods and allows the drier to continue to operate after sunset. Examples of this drier have been built in Barbados, Dominica, Grenada, Jamaica and Trinidad. Figure 2 shows a cross section of the Grenadian drier which has 7.8m² of collector area and is used to dry spices while Plate 1 shows the Jamaican drier which has 2.2m² of collector and a chimney. This drier is used as a demonstration unit. The chimney aids air circulation.

The Barbados drier is 21m² and was originally designed to dry sugar-cane pith. Its rock bed contains 1600kg. of rocks of 5 to 7cm in diameter. The Trinidad rock bed drier was usually operated in tandem with a wire basket drier which is described in the following section.

The wire basket drier

This is the simplest of the movable driers. It consists of a wooden frame covered in wire mesh to retain the crop over which is draped a transparent cover of of UV-resistant polyethylene. Alternatively, one may use a removable cover to keep the polyethylene over the crop. This transparent cover keeps the rain off and the open wire mesh sides allow free access of ambient air so air circulation is excellent and fungal contamination of the drying crop is usually absent. A mosquito mesh liner keeps out insects.

Figure 3 shows the dimensions of the wire basket drier while Plate 2 shows one being loaded with sorrel. Figure 4 is a drying curve for sorrel which shows that one can get moisture contents as low as 0.13 kg. moisture kg^{-1} of dry matter after three sunny days.

However, it was usually the custom to remove the sorrel from the wire basket dryer after the moisture content dropped below 2kg water kg^{-1} of dry matter and transfer it to a rock-bed drier where drying conditions are much better controlled.

During drying trials on sorrel, three wire basket driers with a total area of 5 m² were used to feed a 3.3 m² rock-bed drier. This allowed much better utilisation of the higher-cost rock-bed drier since the large amounts of water that have to be removed during the initial stages (sorrel is about 90% moisture, wet basis) were removed in the cheaper wire basket dryer. A 2.2 m² wire basket drier can be built for as little as $50 US if the farmer builds it himself.

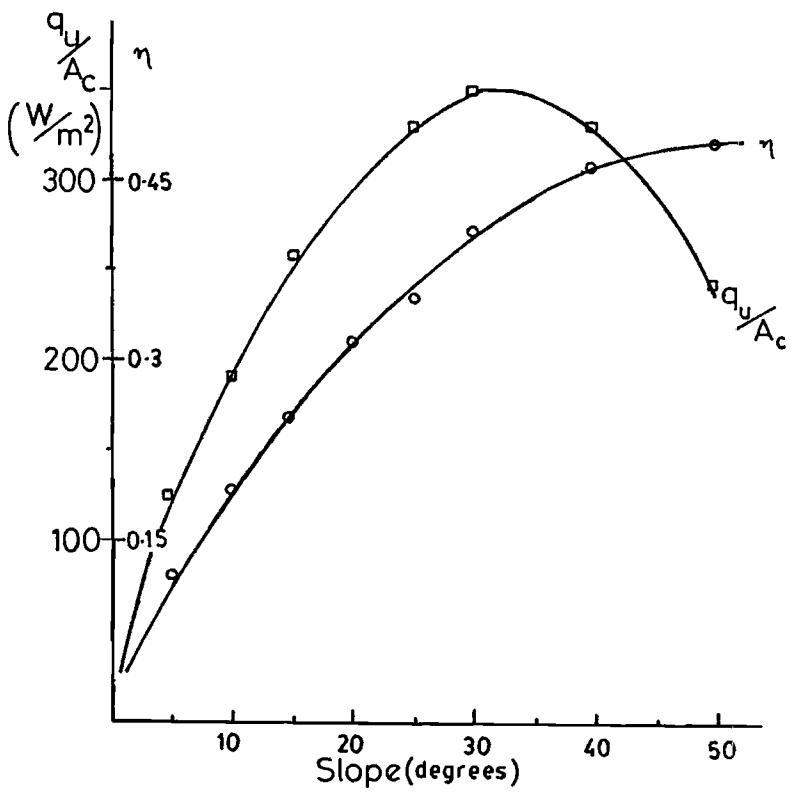

Figure 1 : The Efficiency Curve of a Rock Bed Dryer (After Singh, 1979)
q_u = useful power (watts)
A_c = area of collector (m²)

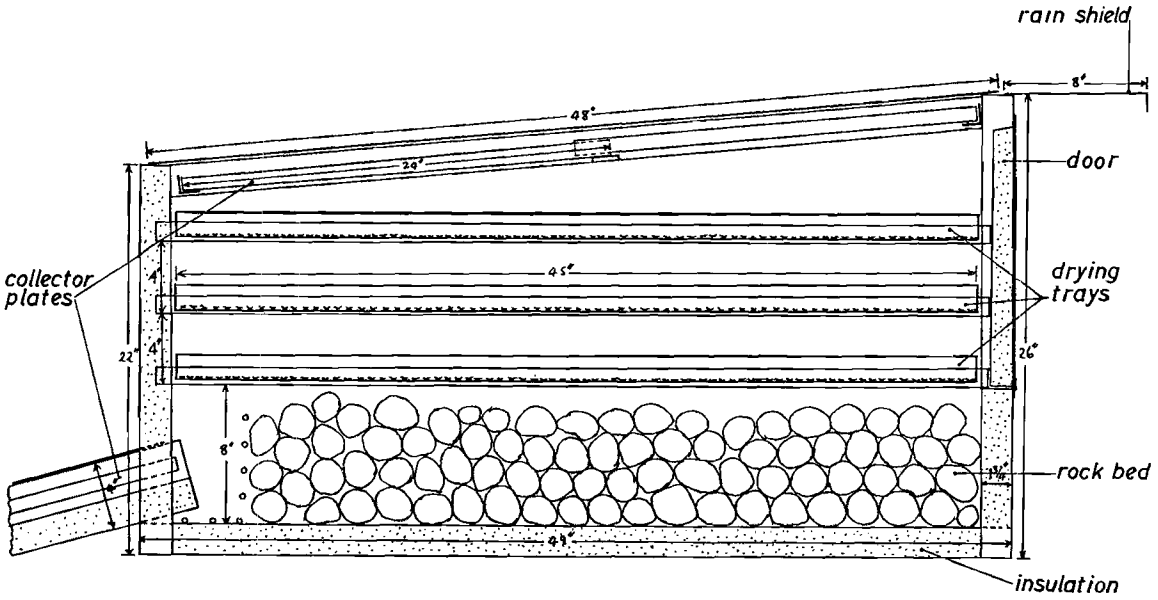

Figure 2 : Cross Section of the Drying Chamber of a 7.8 m2 Rock Bed Dryer in Grenada

The cabinet drier

This design is very suitable for housewives and other small-scale users. It is usually built of wood and plastic to reduce cost (Lawand, 1975) although metal-and-glass units have a longer life expectancy. Plate 3 shows a 2.2 m² metal-and-glass cabinet drier which has been used to dry ripe bananas and pomeracs for use in cake making. These dried fruits may be used as substitutes for imported products such as raisins, currants, prunes etc.

Plate 1: The 2.2m² Rock Bed Dryer with Chimney Assisted Air Circulation at CAST in Jamaica.

Plate 2: Loading Sorrel into a Wire Basket Dryer

The cabinet drier illustrated in Plate 3 also has provision for a 300 kg rock bed which enables much more steady drying conditions to be maintained in the drier. This drier also has metal collector vanes in its roof underneath the glass cover so that the material to be dried is not exposed to the bleaching effect of direct solar radiation.

Plate 3: A 2.2m² Solar Cabinet Dryer

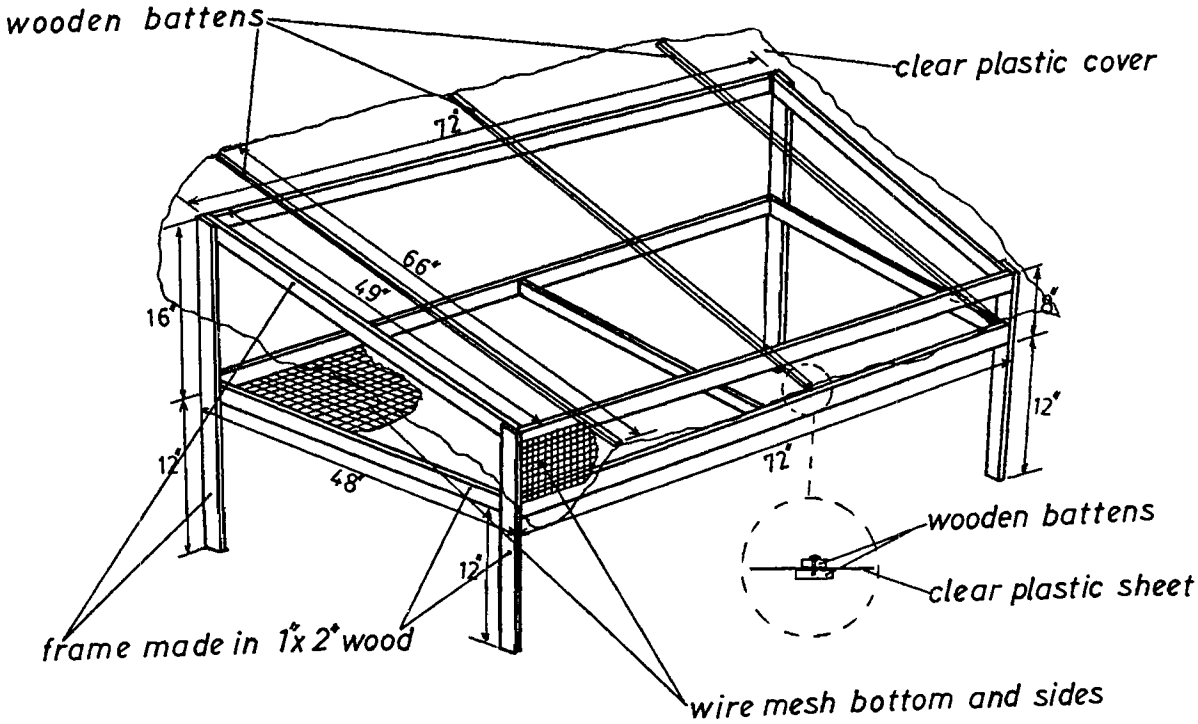

Figure 3 : The Wire Basket Dryer

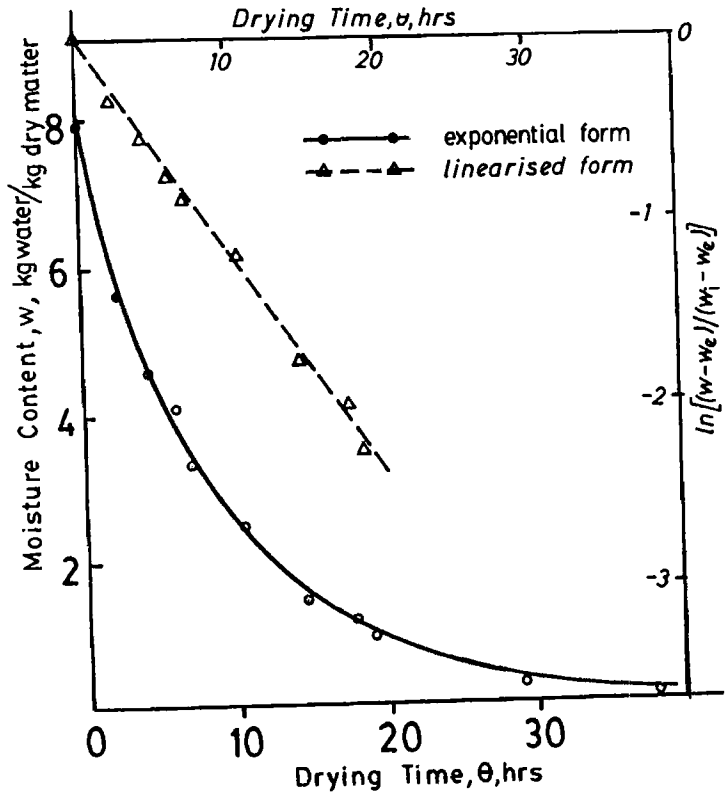

Figure 4 : Drying Curve for Sorrel

The roof air preheater

This is usually designed for large scale usage. A false ceiling in an existing farm building is used to create a hot-air chamber in the space just beneath the roof and a suitable extractor fan pumps air from this space into a drying bin where crop material is dried. It is a design which is very suitable for mixed-mode operation where one can use solar heat from the roof as well as fossil fuel burners or electric resistance heaters. The Brace Research Institute of McGill University and the University of the West Indies are currently designing one of these units for a cocoa drier in Trinidad (Papadopoli *et al.*, 1984).

Performance

The average daily efficiency of a solar drier may be evaluated from the following equation:

$$n = \frac{M_w H_v \times 100}{I_H A} \quad \text{.....} \quad (1)$$

Where n is the efficiency expressed as a percentage, M_w is the mass of water removed in kg.
H_v is the latent heat of vapourisation of water in MJ kg^{-1}.
I_H is the insolation on the horizontal surface in MJ m^2 and A is the area of the solar collector in m^2.

With glass or plactic covered solar collectors, the heat and mass transfer relationships and the optical characteristics of the solar collector may be used to derive a series of equations to give the instantaneous efficiency. Textbooks on solar engineering (see for example Kreith and Kreider, 1978) cover these topics in the required detail.

Of more immediate interest to the farmer is how much drier area he will require to dry crops at a given rate. For most solar crop driers, n is between 15 and 40% with 25% being a reasonable figure. Knowing M_w, I_H and H_v, A is readily calculated.

For certain crops, the drying rate and temperature may be critical. For example, nutmegs should not be taken above 45°C or loss of some of the aromatic volatile compounds may result. The crop is therefore dried under laboratory conditions and its fundamental drying characteristics determined. The type of solar drier which is suitable can then be decided. Most crops show an exponential curve when the fractional moisture content (dry basis) is plotted against the drying time. McGaw (1979) obtained this type of curve for nutmegs and a similar one has been obtained for sorrel. The relevant equation is:

$$(W - We) / (Wi - We) = a \exp(-k\,\Theta) \quad \text{.....} \quad (2)$$

Where W is the moisture content, dry basis, at time Θ. W_i is the initial moisture content, dry basis, W_e is the equilibrium moisture content, dry basis, with a and k being constants.

The drying rate usually increases when one increases the temperature, hence a family of drying curves is obtained, one for each temperature.

Most crops have an equilibrium moisture content under ambient conditions and if they are dried beyond this point they resorb water from the atmosphere until they regain equilibrium. For sorrel, this is about 10 to 12% under Trinidadian conditions i.e. 60-90% relative humidity, 25 to 30°C.

Conclusion

Solar crop dryers may be used successfully in the Caribbean territories so long as their cost and complexity are not beyond the ability of the average farmer. Of all the dryers tested, the wire basket dryer meets these criteria best (Headley, McGaw and Sankat, 1985). This dryer is therefore being deployed in the rural areas of the Caribbean for use as a total drying system or as a pre-dryer where moisture contents of less than about 12% are required for safe storage.

References

Harvey, W.O'N., Headley, O.St. C. and Osuji, P.O. (1985). Simple solar crop dryers for rural areas. *Proc. International Solar Energy Soc. Conf.*, INTERSOL, 1985, Montreal, Canada, In Press.

Headley, O.St.C., Bryan, V. and Hoogmoed, W. (1976). Flat plate collectors for solar dryers. In: M.A. Kettani and J. E. Soussou (eds.) *Heliotechnique and development.* D.A.A. Cambridge, Mass., Vol. 2 pp. 300-306.

Headley, O.St.C., McGaw, D.R. and Sankat, C.K. (1985). *Utilisation of solar energy for crop drying.* Report on O.A.S. Special Project No. 99, University of the West Indies, St. Agustine, Trinidad & Tobago.

Headley, O.St.C. and Singh, U. (1979). Solar drying of crops. In: G. Best, and M. Martinez (eds.), *Proc. Symposium on Technology Applied to Solar Energy Systems.* Universidad Nacional Autonoma de México, pp. 237 – 246.
246.

Headley, O.St.C. and Springer, B.G.F. (1973). A natural convection solar crop drier. *Proc. UNESCO Congress 'The Sun in the Service of Mankind'* Paris, France. Paper No. V. 26.

Kreith, F. and Kreider, J.F. (1978). *Principles of solar engineering.* Hemisphere, Washington D.C.

Lawand, T.A. (1975). Solar cabinet dryer. In *A survey of solar agricultural dryers,* Brace Research Institute, McGill University, Technical Report No. T 99, Case Study EC–E.

McGaw, D.R. (1979). The drying characteristics of nutmegs, *Trop. Agric.* (Trinidad) 56, 301 – 310.

Papadopoli, N., Lawand, T.A. and Headley, O.St.C. (1984). *Solar crop dryers for Grenada.* A report prepared for McGill International and the Royal Bank of Canada. Brace Research Institute, McGill University.

Sato, T. (1967) Constitution and structure of the sticky substance in *Dioscorea batas forma Icho* (especially on the features of the mannans). *Chem. Soc. of Japan.* 88, 982–985.

Singh, U. (1979). *Natural convection solar crop dryers.* M. Phil Thesis, University of the West Indies, St. Augustine, Trinidad and Tobago.

THE CRUDE PROTEIN AND MINERAL COMPOSITION OF SOME TROPICAL GRASSES IN TRINIDAD

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ABSTRACT

One hundred and six grasses grown in plots 2.4m x 1.2m at the University Field Station, Valsayn, Trinidad were cut twice at six weeks of regrowth, in the rainy season. They were analysed for crude protein (CP), Ca, P, Mg, K, Na, Cu, Fe, Mn and Zn content. The ranges of CP, Ca, P, Mg, K and Na (g kg^{-1} dry matter DM) were 58-141, 2.8 - 12.6, 1-3, 0.7-4.4, 1.1-6.4 and 0-16-6.90, respectively, and for Cu, Fe, Mn and Zn (mg kg^{-1} DM) were 2.2-11.9, 90-1473, 63-983 and 11-59, respectively. The percentages of grasses having concentrations of CP, Ca, P, Mg, K and Na below (g kg^{-1} DM) 100, 3, 2, 2, 5 and 1 were 68.9, 0.9, 71.7, 41.5, 88.7 and 41.5, respectively, and the corresponding values of Cu, Fe, Mn and Zn below (mg kg^{-1} DM) 10, 100, 100 and 30 were 98.1, 0.9, 1.9 and 52.8, respectively. The results are discussed in the light of the requirements of grazing beef and dairy cattle, sheep and goats.

RESUMEN

Se cultivó ciento seis tipos de hierba en semilleros de 2,4m x 1,2m en la Estación Experimental Universitaria en Valsayn, Trinidad y se las cortó dos veces a unas seis semanas del nuevo crecimiento durante la estación lluviosa. Se las analizó para determinar su contenido de proteinas crudas (CP), Ca, P, Mg, K, Na, Cu, F, Mn y Zn. Los valores de CP, Ca, P, Mg, K y Na (g/kg de DM – materia seca) eran de 58 - 141; 2,8 - 12,6; 1 - 3; 0,7 - 4,0; 1,1 - 6,4 y 0,16 - 6,90 respectivamente. Los de Cu, Fe, Mn y Zn (mg/kg DM) eran de 2,2 - 11,9; 90 - 1473; 92 - 983 y 11 - 59, respectivamente. Los porcentajes de hierbas con concentraciones de CP, Ca, P, Mg, K y Na inferiores a 100, 3, 3, 2, 8 y 1 (g/kg DM) eran de 68,9; 0,9; 41,5; 34,9; 100 y 41,5 respectivamente. Los valores de Cu, Fe, Mn, y Zn inferiores a 10, 100, 40, y 50 (mg/kg DM) eran de 98,1; 0,9; 0,0 y 99,1 respectivamente. Se examina los resultados, teniendo en cuenta los requistos para el apacentamiento de gando vacuno, tano de engorde como lechero, así como de ovejas y cabras.

Keywords: Tropical grasses; Crude protein; Macro-minerals; Micro-minerals.

The profitability of an agricultural enterprise, whether it is crop or livestock, depends largely on the provision of the nutrient requirements for optimal productivity. To graze livestock, a knowledge of the nutrient composition of forages, i.e. energy, protein, minerals and vitamins, is clearly important for proper supplementation if the desired economical level of productivity is to be achieved.

In Trinidad and, indeed, in all the Commonwealth Caribbean countries, research on tropical forages, in the past three decades, has concentrated on energy and protein utilization (e.g. Butterworth, 1965; Butterworth and Butterworth, 1965; Grieve and Osbourn, 1965). However, information on the mineral composition of forages in the Caribbean, excepting calcium and phosphorus, is very limited (Devendra, 1977; Poland and Schnabel, 1980). Two recent studies in Trinidad have indicated varying degrees of macro- and micro-mineral deficiencies in cattle, sheep and goats; Mohammed (1981) found copper to be deficient as a result of an analysis of blood and liver of cattle and Youssef (1984), analysing blood from sheep and goats, showed possible deficiencies in Ca, P, Mg, K, Na, Cu and Zn.

This paper gives the crude protein (CP), Ca, P, Mg, K, Na, Cu, Fe, Mn, and Zn contents of 106 tropical grasses when cut at six weeks of regrowth.

Material and Methods

Grasses

One hundred and six tropical grasses (See Table 1) were established and maintained over a number of years in plots 2.4m x 1.2m on River Estate loam at the University Field Station, Valsayn, Trinidad. The plots received a top-dressing of 40 kg ha^{-1} of N as sulphate of ammonia approximately 4 weeks before they were cut. The grasses were cut twice at 6 weeks of regrowth to approximately 7 cm above the ground, using a grass knife, on 17 November and 29 December, 1983. Representative samples of the grasses were placed in polyethylene bags and at the laboratory they were given a rapid wash with tap water followed by glass-distilled water. This washing procedure was sometimes found necessary in order to remove soil contamination, particularly in the wet season.

Chemical analysis

Grasses were dried at 60°C in a forced-draught oven to a constant weight, and hammer milled in a stainless steel mill to pass through a 1 mm sieve. Total N was determined by the Kjeldahl method so that g N kg^{-1} dry matter (DM) x 6.25 gives gCP kg^{-1}DM. Ca, Mg, K, Na, Cu, Fe, Mn and Zn were determined according to Fick *et al.* (1979) using a Pye Unicam SP 2900 Atomic Absorption Spectrophotometer equipped with a PU 9090 Data Graphics System. P was determined by the method of Cavell (1955) using a Pye Unicam PU 8600 UV/ Visible Spectrophotometer. National Bureau of Standards, Washington, D.C., U.S.A., Standard Reference Materials 1571 (orchard leaves) and 1573 (tomato leaves) were used as controls for all minerals analysed. All samples were analysed in duplicate and, therefore, 4240 analyses were carried out.

Results and discussion

Table 1 shows the average CP and macro-mineral contents for each of the 106 grasses investigated, and Table 2 presents the average micro-mineral contents for each grass. It can be seen that there were variations among grasses in the concentrations of the ten nutrients studied when they were grown on the same soil and cut at the 6-week stage of regrowth. In Kenya, 58 grasses grown on a single soil type showed wide ranges of 0.9-5.5 and 0.5-3.7g kg^{-1}DM for Ca and P, respectively (Dougall and Bogdon, 1958). The corresponding ranges in the present study were 2.2-12.6 and 1.0-3.0 g kg^{-1} DM.

Table 1 The crude protein and macro-mineral content (g/kg dry matter) of some tropical grasses

Botanical name	Common name	Crude Protein	Ca	P	Mg	K	Na
Acroceras macrum	Nyle grass	138	4.1	1.5	2.0	2.1	6.90
Andropogon gayanus (SR. 593) G. Coast	Gamba grass	64	4.5	1.1	1.9	2.6	0.16
Bothriochloa intermedia (SR. 955) U.S.D.A.		78	5.3	1.1	1.5	1.7	0.76
Brachiaria brizantha	Ceylon Sheep grass	86	8.4	1.6	1.7	3.6	1.09
Brachiaria decumbens	Kenya Sheep grass	86	7.6	1.7	2.2	4.1	1.24
Brachiaria dictyoneura	Sheep grass	88	5.8	1.9	1.4	3.1	3.15
Brachiaria platyphylla	Wild Para grass	81	4.5	1.5	3.3	5.0	1.25
Brachiaria ruziziensis (SR.879) Kenya		91	7.2	1.7	1.6	2.2	1.42
Brachiaria sp (SR. 1237 -2) U.S.D.A		103	4.8	2.1	1.8	3.8	4.02
Brachiaria subquadripara	Lawn Brachiaria	96	5.3	1.5	1.5	3.6	3.15
Chloris gayana (SR.1011) Kenya	Masaba Rhodes grass	66	6.6	1.0	3.6	2.1	0.20
Chloris gayana (SR.1012) Kenya	Mpwapwa Rhodes grass	91	6.9	1.5	3.7	2.1	0.83
Chloris gayana (SR.1013) Kenya	Mbarara Rhodes grass	86	6.2	2.1	1.4	5.5	4.01
Chloris gayana (SR.1036) S. Rhodesia	Katambora Rhodes grass	128	6.6	1.7	2.9	6.4	0.48
Cenchrus ciliaris	Buffel grass	119	3.3	1.5	1.5	2.6	5.50
Cenchrus ciliaris (SR.942) U.S.D.A.		86	4.3	1.5	1.7	2.3	4.14
Cymbopogon citratus	Lemon grass	108	10.5	1.5	2.1	3.0	0.27
Cymbopogon nardus	Citronella grass	120	6.3	1.2	1.5	1.7	0.48
Cynodon dactylon	Bermuda or Bahamas grass	116	8.2	2.6	2.6	3.8	6.79
Cynodon dactylon (SR.615) Tanganyika	Star grass	129	6.6	1.8	2.2	2.2	5.64
Cynodon dactylon (SR.792) Florida	Coastal Bermuda grass	138	7.6	1.8	2.3	1.8	4.77
Cynodon dactylon (SR.948) Kenya	Giant type Star grass	136	7.0	1.6	2.2	2.0	4.28
Cynodon dactylon (SR.952) Kenya	Medium type Star grass	139	6.5	1.7	2.4	2.1	4.03
Cynodon dactylon (SR.954) Kenya	Fine type Star grass	116	5.3	1.5	2.0	2.0	4.56
Cynodon dactylon (SR.999) Puerto-Rico	Tifgreen Bermuda grass	121	8.3	2.3	3.0	2.4	3.32
Cynodon plectostachyus (SR.955) Tanganyika	Naivasha Star grass	121	6.0	1.7	1.9	2.4	4.74
Digitaria chevalieri (SR.1242-1) U.S.D.A		85	5.3	2.0	1.5	2.6	3.85
Digitaria decumbens (SR.633) Surinam	Pangola	77	6.6	1.5	1.7	2.2	3.43
Digitaria decumbens ch.27 (SR.974) St. Croix	Pangola	101	6.5	1.7	1.7	2.1	3.55
Digitaria decumbens ch.30 (SR.975) St. Croix	Pangola	96	5.1	1.5	1.6	1.5	3.48
Digitaria decumbens (SR.1028) Taiwan	Pangola A.24	77	6.5	1.7	2.0	2.5	3.46
Digitaria decumbens (SR.1228-5) U.S.D.A	Pangola selection	95	4.6	1.6	1.6	1.4	3.01
Digitaria decumbens (SR.1228-6) U.S.D.A	Pangola selection	81	5.8	1.7	1.8	2.1	3.67
Digitaria decumbens (SR.1228-7) U.S.D.A	Pangola selection	81	5.1	1.8	1.7	2.6	4.68
Digitaria decumbens (SR.1228-13) U.S.D.A	Pangola selection	89	4.7	1.6	1.6	1.7	3.68
Digitaria eriantha (SR.1229-5) U.S.D.A		79	4.9	1.7	2.8	3.3	2.91
Digitaria grazensis (SR.1248-2) U.S.D.A		98	5.0	1.8	2.6	1.9	2.85
Digitaria longiflora (SR.1232-1) U.S.D.A		83	4.8	2.4	1.3	3.3	3.14
Digitaria macroglossa (SR.1236-1) U.S.D.A		118	4.3	1.5	1.6	2.3	3.73
Digitaria milanjiana (SR.1225-4) U.S.D.A		127	6.5	2.1	4.2	4.9	0.53
Digitaria milanjiana (SR.1225-8) U.S.D.A		109	7.2	2.0	4.0	4.3	0.64
Digitaria milanjiana var *eyesiana* (SR.1226-4) U.S.D.A		98	5.6	1.8	3.4	2.7	0.65

Table 1 continued

Botanical name	Common name	Crude Protein	Ca	P	Mg	K	Na
Digitaria milanjiana var *eyesiana* (SR.1226-7) U.S.D.A		84	7.1	2.0	3.9	2.7	0.95
Digitaria pentsii (SR.908/1) Pretoria		96	6.0	1.8	2.5	2.0	2.18
Digitaria pentsii (SR.989) Pretoria		93	5.9	1.7	3.5	2.1	1.13
Digitaria pentsii (SR.1231-2) U.S.D.A		99	6.6	2.0	2.8	2.5	1.98
Digitaria pentsii (SR.1231-10) U.S.D.A		111	4.6	1.5	1.7	2.3	3.38
Digitaria polevansii (SR.1234-1) U.S.D.A		68	3.3	1.2	1.4	2.8	5.90
Digitaria scalarum (SR.1243-1) U.S.D.A		86	4.6	1.7	1.7	2.2	3.37
Digitaria setivalva (SR.1227-2) U.S.D.A		81	5.1	1.7	1.4	2.2	3.84
Digitaria setivalva (SR.1227-5) U.S.D.A		72	4.5	1.3	1.3	2.5	3.34
Digitaria smutsii (SR.903/3) Pretoria		133	7.9	1.8	4.4	1.1	2.00
Digitaria smutsii (SR.934) Guncon S.A.		118	5.8	1.6	4.0	2.4	1.88
Digitaria smutsii (SR.1224-1) U.S.D.A		111	7.1	1.7	4.4	3.0	3.99
Digitaria sp ((296210) SR.1253-1) U.S.D.A		91	5.1	2.1	1.7	2.4	4.91
Digitaria swazilandensis (SR.1233-1) U.S.D.A		96	5.0	2.1	1.4	2.1	3.23
Digitaria valida (SR.976) St.Croix		97	5.3	1.8	1.9	5.1	4.36
Digitaria valida (SR.983) Pretoria		83	6.1	2.1	1.9	3.5	3.34
Digitaria valida (SR.1230-8) U.S.D.A.		86	5.1	1.9	1.8	2.3	2.63
Digitaria valida (SR.1230-15) U.S.D.A.		74	6.9	2.0	1.9	2.6	4.03
Digitaria valida (SR.1230-16) U.S.D.A.		81	7.9	2.1	2.3	3.0	5.08
Echinochloa pyramidalis (SR.602) Pretoria		95	6.4	1.6	1.9	3.7	5.67
Echinochloa pyramidalis (SR.847) Uganda		93	7.1	1.8	2.9	4.4	4.24
Eriochloa polystachya	Malojilla grass	129	5.0	1.7	2.7	4.7	5.82
Eragrostis curvula (SR.935) Gunson	Weeping Love grass (Am. leafy)	76	3.1	1.1	0.9	2.4	0.33
Eragrostis curvula (SR.951A) Pretoria	Weeping Love grass (wide leaf sel.)	64	2.8	1.4	0.7	2.4	1.94
Hemarthria altissima (SR.1238 -a) U.S.D.A.		58	3.9	1.5	1.1	2.7	0.64
Hyparrhenia rufa	Jaragua grass	82	7.7	1.5	2.5	1.9	0.21
Ischaemum aristatum	Toco grass	99	6.9	2.0	1.9	2.8	4.67
Ischaemum aristatum Fiji	Batiki grass	86	7.0	1.5	3.6	3.0	0.33
Ixophorus unisetus	Mexican grass	74	7.4	1.9	2.9	3.0	0.26
Leptocoryphium lanatum		108	3.7	1.4	2.5	4.2	0.36
Melinis minutiflora	Molasses grass	98	3.9	1.9	2.3	4.1	0.18
Panicum antidotale		101	12.6	2.3	3.9	2.1	1.10
Panicum coloratum (SR.899) Kenya	Coloured Guinea grass	69	6.5	1.1	1.9	2.0	3.06
Panicum maximum	Colonial Guinea grass	96	9.0	1.5	3.8	2.2	0.58
Panicum maximum (SR.890) Jamaica	Cow Guinea grass	95	9.8	1.7	3.9	2.3	0.40
Panicum maximum (SR.891) Jamaica	Silk Guinea grass	97	9.2	1.3	3.5	2.0	0.58
Panicum purpurascens		107	5.4	1.5	1.9	4.5	6.07
Panicum maximum var. *trichoglume* (SR.892) Kenya	Slender Guinea grass	78	9.6	1.5	2.9	2.1	0.76
Paspalum commersonii (SR.1041) Australia		81	5.0	2.3	2.1	4.7	0.23
Paspalum dilatatum	Dallis grass	81	4.8	2.3	2.6	4.4	0.16
Paspalum notatum	Bahia grass	99	6.9	2.1	1.8	4.6	0.30
Paspalum notatum (SR.926) U.S.D.A.	Argentina grass	110	6.5	2.4	2.1	5.0	0.34
Paspalum notatum (SR.927) Maryland	Tifhi	111	5.4	2.5	2.1	5.0	0.26
Paspalum notatum (SR.928)	Wilmington	109	7.4	2.4	2.3	4.2	0.34
Paspalum paniculatum		94	9.2	3.0	3.2	5.8	0.45
Paspalum plicatulum	Crown Land grass	81	9.1	2.3	2.7	5.3	0.41

Table 1 continued

Botanical name	Common name	Crude Protein	Ca	P	Mg	K	Na
Paspalum plicatulum (SR. 851) Australia	Crown Land grass	83	8.0	2.2	3.0	5.3	0.30
Paspalum ragassi (SR.1038) S. Rhodesia		84	4.7	2.2	2.1	4.2	0.38
Paspalum urvillei (Sr,981) B.G	Vasey grass	81	7.1	1.8	1.6	5.5	0.49
Paspalum vaginatum	Sand Couch grass	79	6.8	2.1	2.4	6.3	0.36
Paspalum virgatum	Razor grass	83	4.8	2.3	2.2	4.9	0.34
Pennisetum polystachyon	Kyasuwa grass	81	7.8	1.6	3.8	2.3	0.33
Pennisetum purpureum var *merkeri*	Merker grass	87	7.9	1.7	3.4	3.0	0.16
Pennisetum purpureum	Uganda grass	100	8.2	1.6	3.0	2.4	0.20
Pennisetum setosum		94	4.8	1.5	2.2	2.4	3.83
Rottboellia exaltata	Corn grass	76	6.2	2.8	2.9	2.6	0.39
Saccharum ciliare	Montserrat	78	3.6	1.3	1.5	3.9	0.19
Setaria anceps (SR.856) S. Rhodesia	Golden Timothy (Kazungula)	88	4.8	1.6	2.0	3.4	3.96
Setaria anceps (SR.1006) Kenya	Golden Timothy (Nandi)	106	4.9	1.5	2.1	3.3	3.51
Sporobolus indicus	Tapia grass	79	4.1	1.6	1.5	2.2	2.07
Themeda triandra (SR.911) Pretoria		69	7.0	1.7	2.8	3.0	0.30
Tripsacum latiflora		141	3.8	1.8	2.5	3.9	0.32
Tripsacum laxum	Guatemala	134	3.2	1.3	2.2	2.6	0.26
Vetiveria zizanoides	Khus Khus grass	88	4.4	1.3	2.5	5.6	0.32

Table 2 The trace mineral content (mg/kg dry matter) of some tropical grasses

Botanical name	Common name	Cu	Fe	Mn	Zn
Acroceras macrum	Nyle grass	11.9	1333	360	59
Andropogon gayanus (SR. 593) G. Coast	Gamba grass	2.2	263	300	34
Bothriochloa intermedia (SR. 955) U.S.D.A.		3.2	630	408	23
Brachiaria brizantha	Ceylon Sheep grass	2.7	450	534	34
Brachiaria decumbens	Kenya Sheep grass	3.5	444	389	35
Brachiaria dictyoneura	Sheep grass	3.4	657	828	33
Brachiaria platyphylla	Wild Para grass	4.6	503	114	24
Brachiaria ruziziensis (SR.879) Kenya		2.9	477	812	36
Brachiaria sp (SR. 1237 -2) U.S.D.A		3.6	670	629	34
Brachiaria subquadripara	Lawn Brachiaria	3.2	548	501	27
Chloris gayana (SR.1011) Kenya	Masaba Rhodes grass	2.7	142	166	27
Chloris gayana (SR.1012) Kenya	Mpwapwa Rhodes grass	4.8	377	155	18
Chloris gayana (SR.1013) Kenya	Mbarara Rhodes grass	3.1	204	355	26
Chloris gayana (SR.1036) S. Rhodesia	Katambora Rhodes grass	6.0	246	145	23
Cenchrus ciliaris	Buffel grass	4.7	487	533	38
Cenchrus ciliaris (SR.942) U.S.D.A.		3.7	350	576	30
Cymbopogon citratus	Lemon grass	4.8	279	359	31
Cymbopogon nardus	Citronella grass	5.1	281	471	20
Cynodon dactylon	Bermuda or Bahamas grass	7.6	531	425	53
Cynodon dactylon (SR.615) Tanganyika	Star grass	7.3	688	308	40
Cynodon dactylon (SR.792) Florida	Coastal Bermuda grass	8.3	1084	416	38

Table 2 continued

Botanical name	Common name	Cu	Fe	Mn	Zn
Cynodon dactylon (SR.948) Kenya	Giant type Star grass	8.2	879	255	38
Cynodon dactylon (SR.952) Kenya	Medium type Star grass	8.6	1157	255	38
Cynodon dactylon (SR.954) Kenya	Fine type Star grass	6.2	536	270	35
Cynodon dactylon (SR.999) Puerto-Rico	Tifgreen Bermuda grass	7.1	490	278	40
Cynodon plectostachyus (SR.955) Tanganyika	Naivasha Star grass	5.4	522	374	32
Digitaria chevalieri (SR.1242-1) U.S.D.A		5.2	658	564	33
Digitaria decumbens (SR.633) Surinam	Pangola	5.2	488	409	37
Digitaria decumbens ch.27 (SR.974) St. Croix	Pangola	5.8	665	475	38
Digitaria decumbens ch.30 (SR.975) St. Croix	Pangola	5.7	572	428	38
Digitaria decumbens (SR.1028) Taiwan	Pangola A.24	5.2	499	445	38
Digitaria decumbens (SR.1228-5) U.S.D.A	Pangola selection	4.8	399	394	35
Digitaria decumbens (SR.1228-6) U.S.D.A	Pangola selection	5.0	508	410	34
Digitaria decumbens (SR.1228-7) U.S.D.A	Pangola selection	4.3	404	309	32
Digitaria decumbens (SR.1228-13) U.S.D.A	Pangola selection	5.3	290	337	34
Digitaria eriantha (SR.1229-5) U.S.D.A		5.1	618	266	22
Digitaria grazensis (SR.1248-2) U.S.D.A		5.4	870	387	27
Digitaria longiflora (SR.1232-1) U.S.D.A		3.1	520	335	26
Digitaria macroglossa (SR.1236-1) U.S.D.A		6.3	599	361	30
Digitaria milanjiana (SR.1225-4) U.S.D.A		6.0	513	336	24
Digitaria milanjiana (SR.1225-8) U.S.D.A		6.9	983	539	31
Digitaria milanjiana var *eyesiana* (SR.1226-4) U.S.D.A		4.9	635	318	22
Digitaria milanjiana var *eyesiana* (SR.1226-7) U.S.D.A		5.6	1162	579	25
Digitaria pentsii (SR.908/1) Pretoria		6.7	733	443	24
Digitaria pentsii (SR.989) Pretoria		5.3	756	423	31
Digitaria pentsii (SR.1231-2) U.S.D.A		6.4	1473	412	34
Digitaria pentsii (SR.1231-10) U.S.D.A		5.5	627	347	33
Digitaria polevansii (SR.1234-1) U.S.D.A		9.9	627	347	35
Digitaria scalarum (SR.1243-1) U.S.D.A		4.3	551	424	25
Digitaria setivalva (SR.1227-2) U.S.D.A		4.5	656	348	26
Digitaria setivalva (SR.1227-5) U.S.D.A		2.6	611	284	12
Digitaria smutsii (SR.903/3) Pretoria		11.2	875	329	41
Digitaria smutsii (SR.934) Guncon S.A.		7.9	750	396	33
Digitaria smutsii (SR.1224-1) U.S.D.A		8.0	1465	390	29
Digitaria sp ((296210) SR.1253-1) U.S.D.A		4.3	429	298	29
Digitaria swazilandensis (SR.1233-1) U.S.D.A		5.1	430	490	26
Digitaria valida (SR.976) St.Croix		4.7	587	470	35
Digitaria valida (SR.983) Pretoria		4.8	554	445	34
Digitaria valida (SR.1230-8) U.S.D.A.		5.3	267	379	43
Digitaria valida (SR.1230-15) U.S.D.A.		4.3	635	437	24
Digitaria valida (SR.1230-16) U.S.D.A.		4.6	570	314	25
Echinochloa pyramidalis (SR.602) Pretoria		5.8	314	379	20
Echinochloa pyramidalis (SR.847) Uganda		6.2	297	282	22
Eriochloa polystachya	Malojilla grass	8.4	557	145	39
Eragrostis curvula (SR.935) Gunson	Weeping Love grass (Am. leafy)	2.9	288	193	16
Eragrostis curvula (SR.951A) Pretoria	Weeping Love grass (wide leaf sel.)	2.4	158	115	11
Hemarthria altissima (SR.1238 -a) U.S.D.A.		3.9	266	214	25
Hyparrhenia rufa	Jaragua grass	3.5	476	481	29
Ischaemum aristatum	Toco grass	4.2	90	347	18

Table 2 continued

Botanical name	Common name	Cu	Fe	Mn	Zn
Ischaemum aristatum Fiji	Batiki Grass	4.1	102	207	29
Ixophorus unisetus	Mexican grass	3.0	346	269	33
Leptocoryphium lanatum		4.3	392	253	28
Melinis minutiflora	Molasses grass	3.2	190	837	18
Panicum antidotale		5.5	271	153	20
Panicum coloratum (SR.899) Kenya	Coloured Guinea grass	5.4	270	194	25
Panicum maximum	Colonial Guinea grass	4.7	409	418	24
Panicum maximum (SR.890) Jamaica	Cow Guinea grass	4.6	440	393	30
Panicum maximum (SR.891) Jamaica	Silk Guinea grass	5.0	520	444	28
Panicum purpurascens		9.5	338	118	34
Panicum maximum var. *trichoglume* (SR.892) Kenya	Slender Guinea grass	4.3	404	374	25
Paspalum commersonii (SR.1041) Australia		4.6	271	197	14
Paspalum dilatatum	Dallis grass	5.4	300	229	16
Paspalum notatum	Bahia grass	5.6	648	287	27
Paspalum notatum (SR.926) U.S.D.A.	Argentina grass	5.5	564	194	29
Paspalum notatum (SR.927) Maryland	Tifhi	6.0	601	130	31
Paspalum notatum (SR.928)	Wilmington	6.0	974	292	21
Paspalum paniculatum		8.9	702	115	24
Paspalum plicatulum	Crown land grass	6.1	668	879	33
Paspalum plicatulum (SR. 851) Australia	Crown land grass	6.4	805	983	36
Paspalum ragassi (SR.1038) S. Rhodesia		4.9	321	171	14
Paspalum urvillei (Sr,981) B.G	Vasey grass	5.2	447	267	20
Paspalum vaginatum	Sand couch grass	4.9	466	204	22
Paspalum virgatum	Razor grass	4.6	272	161	15
Pennisetum polystachyon	Kyasuwa grass	3.7	310	437	32
Pennisetum purpureum var *merkeri*	Merker grass	3.7	316	340	29
Pennisetum purpureum	Uganda grass	4.3	418	354	29
Pennisetum setosum		4.0	252	514	35
Rottboellia exaltata	Corn grass	4.2	442	63	30
Saccharum ciliare	Montserrat	4.2	135	92	14
Setaria anceps (SR.856) S. Rhodesia	Golden Timothy (Kazungula)	5.7	373	408	45
Setaria anceps (SR.1006) Kenya	Golden Timothy (Nandi)	6.1	117	287	44
Sporobolus indicus	Tapia grass	2.9	332	778	24
Themeda triandra (SR.911) Pretoria		2.9	248	149	23
Tripsacum latiflora		4.7	205	211	25
Tripsacum laxum	Guatemala	4.0	190	136	18
Vetiveria zizanoides	Khus Khus grass	4.8	137	279	12

Devendra (1977) reported Ca, P and Mg concentrations of 101 grasses of unknown age of regrowth collected mainly from Trinidad; the Ca levels were clearly lower and those of Mg were very much higher than the respective levels reported in the present study. Also P values were higher than those presently reported. The high levels of 5-8g kg^{-1}DM in the majority of the grasses reported by Devendra (1977) could not be confirmed from the analysis of more than 2,000 grass samples collected from Trinidad (F. G. Youssef, unpublished data).

The concentration of K in most of the grasses studied was low when compared with other values reported for tropical grasses (Long *et al.*, 1969; Poland and Schnabel, 1980). As the level of P was also low in most of the grasses, there is a possibility that the application of P and K fertilizers would raise their P and K levels. The values of Na varied greatly with a range of 0.16-6.90 g kg^{-1}DM. Griffith and Walters (1966) indicated that the level of Na in grasses can establish differences between species more than any other constituent.

In the Caribbean there is very little information on the trace mineral content of forages. In the present study the Cu and Zn levels were lower, and those of Fe and Mn higher than the corresponding values of Latin American forages (McDowell *et al.*, 1977). In Jamaica, Poland and Schnabel (1980) found that the ranges for Cu, Fe, Mn and Zn were 2.9-8.4, 98-144, 41-344 and 25-125 mg kg^{-1}DM, respectively, in *Digitaria decumbens and Brachiaria decumbens.*

Crude protein

The CP values of the grasses confirm earlier results from this University (Grieve and Osbourn, 1965). The range was 58-141 g CP kg^{-1} DM. The level of 100g CP kg^{-1}DM would satisfy the maintenance requirements of beef and dairy cattle, and sheep and goats, and produce some beef, milk and mutton respectively. Sixty-nine per cent of the grasses had CP concentrations below 100g kg^{-1} DM and for 19 per cent it was below 80g kg^{-1} DM.

Calcium

The range of the Ca content was 2.8 – 12.6 g kg^{-1} DM, and only *Eragrostis curvula* (SR. 950A) had a concentration below 3g Ca kg^{-1}. The ranges for the requirements of beef cattle, dairy cattle and sheep are 1.8 - 5.3, 4.3 - 6.0 and 2.1 - 5.2 g kg^{-1}DM, respectively (National Research Council, 1984; 1978; 1975). It is clear that the Ca content of most of the grasses would satisfy the requirements of these three classes of livestock.

Phosphorus

P values ranged from 1 to 3g kg^{-1}DM, and the percentage of grasses having a level below 2g P kg^{-1} was 71.7. The P requirements of beef and dairy cattle and sheep are 1.8-4.7, 3.1 - 4.0 and 1.6 - 3.7g kg^{-1}DM, respectively (National Research Council, 1984; 1978; 1975). Thus P content of 75 percent of the grasses would at least provide the maintenance requirements of the three classes of ruminants.

Magnesium

The range for Mg was 0.7 - 4.4g kg^{-1}DM, and the percentage of grasses having concentration below 2g Mg kg^{-1} was 41.5. The beef and dairy cattle and sheep requirements of Mg are 0.5 - 2.5, 2 and 0.4 - 0.8g kg^{-1}DM, respectively (National Research Council 1984; 1978; 1975). Therefore, the Mg content of the majority of the grasses would satisfy the requirements of beef and dairy cattle and sheep.

Potassium

The K level in the majority of the grasses was low with a range of 1.1 - 6.4g kg^{-1}DM. The percentage of grasses which contained below 5g K kg^{-1}DM was 88.7. The K requirements of beef and dairy cattle and sheep are 5-7, 8-12 and 5g kg^{-1} DM, respectively (National Research Council 1984, 1978, 1975). Clearly the majority of the grasses would not satisfy the requirements of these animals.

Sodium

The concentration of Na in the grasses varied from 0.16 to 6.90g kg^{-1}DM. The percentage of grasses with a level below 1g Na kg^{-1} was 41.5. The beef and dairy cattle and sheep requirements of Na are 0.6 - 1.0, 1.8 and 0.4 - 1.0g kg^{-1}DM, respectively (National Research Council 1984; 1978; 1975). Approximately 51 percent of the grasses would provide the dairy cattle requirement of Na, whilst, about 75 percent would satisfy the beef cattle and sheep in this respect.

Copper

The range of Cu in the grasses was 2.2 -11.9mg kg^{-1}DM, and the percentage of grasses with a concentration below 10mg Cu kg^{-1} was 98. The Cu requirements of beef and dairy cattle and sheep are 4-10, 10 and 5 mg kg^{-1}DM, respectively (National Research Council, 1984; 1978; 1975). Accepting the requirement of beef cattle to be 8mg Cu kg^{-1} DM (McDowell *et al.*, 1983), approximately 9 percent of the grasses would be satisfactory. In the case of dairy cattle all the grasses except *Acroceras macrum, Digitaria smutsii* (SR. 903/3) and *Panicum purpurascens* would be considered deficient in Cu. As for sheep, 49 percent of the grasses would provide their Cu reqirements.

Iron

The concentration of Fe in the grasses ranged from 90 to 1473mg kg^{-1}DM, and only *Ischaemum aristatum* grass had a level below 100 mg kg^{-1} . As the requirement for Fe of ruminant livestock is below 100mg kg^{-1}DM, all the grasses are considered adequate. The maximum tolerable levels of dietary Fe are 1000mg kg^{-1} for cattle and possibly 500mg kg^{-1} for sheep (National Research Council, 1980). The high Fe content of some of the grasses would be detrimental to cattle and sheep. Indeed, the very high levels of Fe might interfere with Cu metabolism.

Manganese

The range of Mn found in the grasses was 63-983mg kg^{-1}DM, and only *Rottboellia exaltata* and *Saccharum ciliare* had levels below 100mg kg^{-1}. All had adequate levels of Mn for ruminants.

Zinc

The level of Zn in the grasses studied varied from 11 to 59mg kg^{-1}DM. The percentage of grasses with a concentration below 30mg kg^{-1} was 53. The Zn requirements of beef and dairy cattle and sheep are 20-40, 40 and 35-50mg kg^{-1}DM, respectively (National Research Council, 1984, 1978, 1975). If the Zn requirement of beef cattle is taken as 30 mg kg^{-1} DM (McDowell *et al.*, 1983), 48 percent of the grasses would provide their requirement. However, only about 20 percent of the grasses would satisfy the requirement of dairy cattle and sheep.

Conclusion

Variations existed among the grasses in the concentrations of the ten nutrients studied. Values of P, Mg, and K were generally lower and those of Ca higher than those previously reported, Levels of trace elements Cu and Zn were lower and those of Fe and Mn higher than the values cited in the literature. The data reported are a useful guide for the proper supplementation of forages to desired and economic levels of productivity in different species of livestock. The effects of fertilizer, stage of regrowth and date of harvesting on the mineral profile of some of the grass species are currently under study.

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References

Butterworth, M.H., (1965) Some aspects of the utilization of tropical forages 1. Green elephant grass at various stages of growth, *J. Agric. Sci., Camb.* 65 233-239.

Butterworth, M.H. and Butterworth, J.P. (1965) Some aspects of the utilization of tropical forages 2. Pangola and coastal Bermuda hays, *J. Agric. Sci., Camb.* 65 389-395.

Cavell, A.J. (1955) The colorimetric determination of phosphorus in plant materials, *J.Sci. Fd Agric.* 6 253-256.

Devendra, C. (1977) The mineral content of Caribbean feedingstuffs. *Trop. Agric. (Trinidad)* 54 29-38.

Dougall, H.W. and Bogdon, A.V. (1958) The chemical composition of the grasses of Kenya. *E. Afr. Agric. For. J.* 24 17-23.

Fick, K.R, Mcdowell, L.R., Miles, P.H., Wilkinson, N.S., Funk, J.D. and Conrad, J.H. (1979) *Methods of mineral analysis for plant and animal tissues,* 2nd edn., University of Florida, Gainsville, USA.

Grieve, C.M. and Osbourn, D.F. (1965) The nutritional value of some tropical grasses. *J. Agri. Sci., Camb.* 65 411-417.

Griffith G. and Walters, R.J.K. (1966) The sodium and potassium content of some grass genera, species and varieties. *J. Agric. Sci., Camb.* 67 81-89.

Long, M.I.E. Ndyanabo, W.K., Marshall, B. and Thornton, D.D. (1969) Nutritive value of grasses in Ankola and the Queen Elizabeth National Park. Uganda IV - Mineral content, *Trop. Agric. (Trinidad)* 46 201-209.

McDowell, L.R., Conrad, J.H., Ellis, G.L. and Loosli, J.K. (1983) *Minerals for grazing ruminants in tropical regions,* Bulletin, University of Florida, Gainesville, USA.

McDowell, L.R., Conrad, J.H., Thomas, J.E. and Harris, L.E. (1977) Nutritional composition of Latin American forages. *Trop. Anim. Prod.* 2 273-279.

Mohammed, R. (1981) *The status of certain trace elements in cattle in Trinidad,* M.Sc. Thesis, University of the West Indies Library, (Unpubl.)

National Research Council (1975) *Nutrient requirements of sheep, 5th edn.,* National Academy of Sciences Washington, D.C.

National Research Council (1978) *Nutrient requirements of dairy cattle 5th edn.,* National Academy of Sciences Washington, D.C.

National Research Council (1980) *Mineral tolerance of domestic animals,* National Academy of Sciences Washington, D.C..

National Research Council (1984) *Nutrient requirements of domestic animals. Nutrient requirements of beef cattle 6th edn.,* National Academy of Sciences Washington, D.C.

Poland, J.P. and Schnabel, J.A. (1980) Mineral composition of *Digitaria decumbens* and *Brachiaria decumbens* in Jamaica. *Trop. Agric. (Trinidad)* 57 259-264.

Youssef, F.G. (1985) A preliminary mineral blood profile of tropical goats and sheep in Trinidad. In C.F. Mills, I. Bremner and J.K. Chester (eds)., *Trace elements in man and animals* TEMA5. Commonwealth Agricultural Bureaux. Farnham Royal pp 857-859.

POSTHARVEST STUDIES OF THE WHITE CALLA LILY, *ZANTEDESCHIA AETHIOPICA*

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ABSTRACT

Inflorescences of *Zantedeschia aethiopica* Spreng (calla lily) were placed in various holding solutions for postharvest life comparisons. Solutions containing deionized water (DI), 200 ppm eight-hydroxyquinoline citrate (8-HQC), 200 ppm 8-HQC + 0.025 M sucrose, 200 ppm 8-HQC + 0.025 M sucrose + 50 ppm dithiothreitol (DTE), or 50 ppm DTE did not significantly increase the vase life of *Z. aethiopica;* all lasted 6 to 7 days. Removal of spadices prior to placement in the solutions also did not increase the vase life. Holding solutions buffered to pH's of 3, 5, or 7 did not affect spathe longevity. A steady decrease in weight of spathes was observed with time, whereas an increase in weight was observed in the scapes and spadices. It is suspected that a greater percentage of water was translocated and transpired through the scape than through the spathes. Scanning electron micrographs showed no obstructions or disjuction of water conduction tissue from the scape to the spathes and spadices.

RESUMEN

Infloresencias de *Zantedeschia aethiopica* Spreng (calla lily) fueron metidas en varias soluciones para comparar la duración de vida pos-cosecha. Soluciones de agua deionizada, 200 ppm ocho-hydroxyquinoline citrate (8-HQC), 200 ppm 8-HQC + 0.025 M sucrosa, 200 ppm 8-HQC + 0.025 M sucrosa + 50 ppm dithiothreitol (DTE), o 50 ppm DTE no aumentaron significativamente la vida pos-cosecha de *Z. aethiopica;* todas duraron 6 o 7 días. Eliminación de espadices antes de poner las infloresencias en solución tampoco aumentó la vida pos-cosecha. El ajuste de las soluciones al pH de 3, 5, o 7 no afectó la longevidad de las espatas. Con tiempo, una diminución constante del peso de las espatas fue observado, mientras se notó un aumento en peso en los escapos y las espadices. Se sospecha que un mayor porcentaje de agua fue translocada y transpirada por el escapo que por las espatas. Examinación con electromicroscopio no reveló obstrucciones o disyunción en tejidos de conducir agua desde el escapo a las espatas y espadices.

Additional index words: 8-hydroxy quinoline citrate, flower preservative, dithiothreitol.

Limited investigations have been conducted on the keeping quality of *Zantedeschia aethiopica* (calla lily) inflorescences. Several commercially available preservatives were reported to not increase vase life of *Zantedeschia* and to decrease keeping quality by causing accelerated dehydration and browning of spathes (1). The lack of data on the beneficial effect of present day preservatives on *Zantedeschia* inflorescences prompted this study, designed to determine if preservatives or water with increasing alkalinity would increase the keeping quality of *Zantedeschia* and to investigate if the vascular tissue from the scape connects to the spathes and spadices.

Materials and Methods

Experiment 1. Inflorescences from field grown *Zantedeschia aethiopica* were harvested during late afternoon and transported to the Plant Health and Horticulture laboratories at Massey University, Palmerston North, New Zealand, and scapes recut to uniform 40-cm lengths, measured from the bottom of the spathe. They were then placed in a pulsing solution containing 0.1 M sucrose and 0.5 g iprodione for 12 hours to prevent splitting of scapes and alternaria flower spot from developing (2). Following pulse treatment, the scapes were wiped clean and placed in either deionized water (DI), 200 ppm eight hydroxy quinoline citrate (8-HQC), 8-HQC + 0.025 M sucrose, 8-HQC + 0.025 M sucrose + 50 ppm dithiothreitol (DTE) or 50 ppm DTE. Each treatment consisted of 6 flowers. Laboratory conditions where flowers were placed were as follows: relative humidity 55-65%, temperature 20-24°C, and fluorescent lights were turned on from 0700 to 1700 hours. Flowers were discarded when either the spathe began to wilt or edges began to show signs of browning.

Experiment 2. Another set of 108 flowers were pulsed the same way as in Experiment 1. Each flower served as a replicate. The spadices on half of them were carefully removed with a sharp razor blade and all flowers were then placed in DI water. Each day spathes of flowers with spadices intact and 6 flowers which had the spadices removed were cut. Weights of spathes were expressed as percentages of the total inflorescence weight.

Experiment 3. Another set of *Zantedeschia* inflorescences were harvested and pulsed as in Experiment 1 and then placed in a phosphate buffer solution adjusted to pH of 3, 5, or 7. Each day, for 7 days, 6 inflorescences were cut into scapes, spathes, and spadices and weighed separately. Weights of scapes, spathes, and spadices were expressed as percentages of the total inflorescence weight.

Experiment 4. For electron micrograph studies, *Zantedeschia* flowers were held in DI water for 1 day. Then scape tissue samples were taken 35 cm below the spathe, at the base of spadix and spathe, and at the junction of spathe and scape (longitudinal section). Three- to 4-mm slices of tissue were fixed overnight in 3% glutaraldehyde, plus 2% formaldehyde in 0.1 M phosphate buffer at pH 7.2. They were vacuum infiltrated to remove air pockets. The pieces were sliced with a razor blade into 1-mm slices and left in the primary fixative for 2-3 hours, followed by 4 buffer washes

and an ethanol dehydration series. Samples were critical point dried by liquid CO_2 in a Polaron E-3000 critical point drier. The dried specimens were glued to aluminum stubs with conducting silver paint, sputter coated with 100-200 A° of gold, and viewed in a Cwikscan 100 field emission scanning electron microscope wing at 16 Kv acceleration voltage.

Results and Discussion

Placing inflorescences of *Zantedeschia* in various holding solutions did not increase vase life (Table 1), which suggests that the lack of respiratory substrates may not be the main cause for decline. All inflorescences in the various holding solutions eventually dry out at the same time, which caused a gradual shrivelling and brown necrotic spots on margins of spathes. The desiccation may have been due to reduced water supply caused by increased resistance of water flow in the scape.

When spathes with intact inflorescence fresh weights were compared to inflorescences with spadices removed prior to placement in the vase solution, there were no differences in weight change (Fig.1). This means that there is no advantage in removing spadices of *Zantedeschia* prior to placement in the vase to retain higher fresh weight of spathes.

Placement of inflorescences in solutions with increasing alkalinity (pH 3, 5, or 7) did not increase the vase life. When spathes, scapes, and spadices were separated and weighed, solution pH did not cause differences with respect to weight distribution patterns over the 7 days. Spathe weight as a percent of total inflorescence weight gradually decreased with time (Fig. 2) in all 3 pH solutions, but percentages increased on scapes (Fig. 3) and spadices (Fig. 4).

Previous observations on the presence and distribution of stomates revealed smaller numbers of stomates per unit area on the upper and lower side of spathes, compared to scapes (3). This suggests that most water loss was through the scapes. However, transverse and longitudinal sections taken at the junction of scapes and spathes revealed water conducting tissue to continue all the way to the spathes and spadices (Fig. 5).

In conclusion *Zantedeschia* did not show any increase in postharvest life when placed in solutions containing preservatives or preservatives with sucrose. Removal of spadices prior to placement in holding solutions also did not increase postharvest life. Inflorescences lasted 6 to 7 days. Scapes and spadices gradually increased in fresh weight with time, whereas spathes gradually decreased. The conducting tissue of *Zantedeschia* was found to be continuous from the scapes to the spathes and spadices.

Literature Cited

1. Bakker, J., and H. Stephen. 1961. Hondbaarheidsproeven met snybloemen. Jversl. Proefst. Bloem. Aalsmeer: 133-135.

2. Tjia, B. and K.A. Funnell. 1985. *Zantedeschia aethiopica* control of stem split and alternaria flower spot following harvest. New Zealand Horticulture, April: 28-29.

3. Tjia, B. and K.K. Funnell. 1985. Postharvest studies of cut *Zantedeschia* inflorescences. Proceedings. Intl. Post Harvest Symposium Noordwykerhout, Netherlands, July 1-4 (in press).

Table 1 Post-harvest life of *Zantedeschia aethiopica* held in various holding solutions.

Treatment	Average vase life [z] (days)
DI water	7.0 a
200 ppm 8-HQC	6.8 a
200 ppm 8- HQC + 0.025 M sucrose	6.0 a
50 ppm DTE	7.6 a
200 ppm 8 HQC[x] + 50 ppm DTE[y]	6.7 a
200 ppm 8 - HQC + ppm DTE + 0.025 M Sucrose	7.3 a

[x] 8-hydroxy quinoline citrate (8 HQC)

[y] dithiothreitol (DTE)

[z] Duncan's multiple range test, 5% level. Means with the same letter are not significantly different.

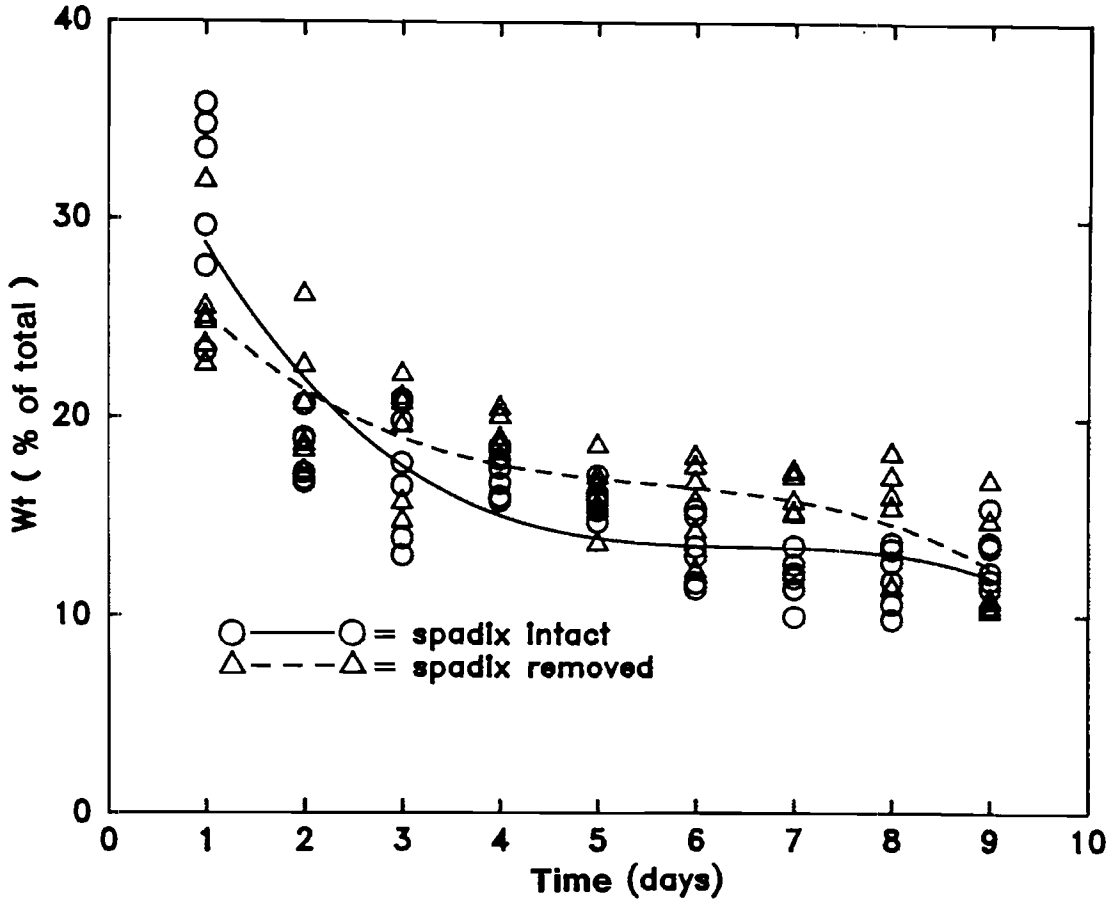

Fig. 1. Comparison of weight distribution of *Zantedeschia aethiopica* intact spathes placed in DI water ($y = 38.537 - 11.407x + 1.741x^2 - 0.089x^3$) with those that had the spadices removed ($y = 31.029 - 6.813x + 1.138x^2 - 0.068x^3$).

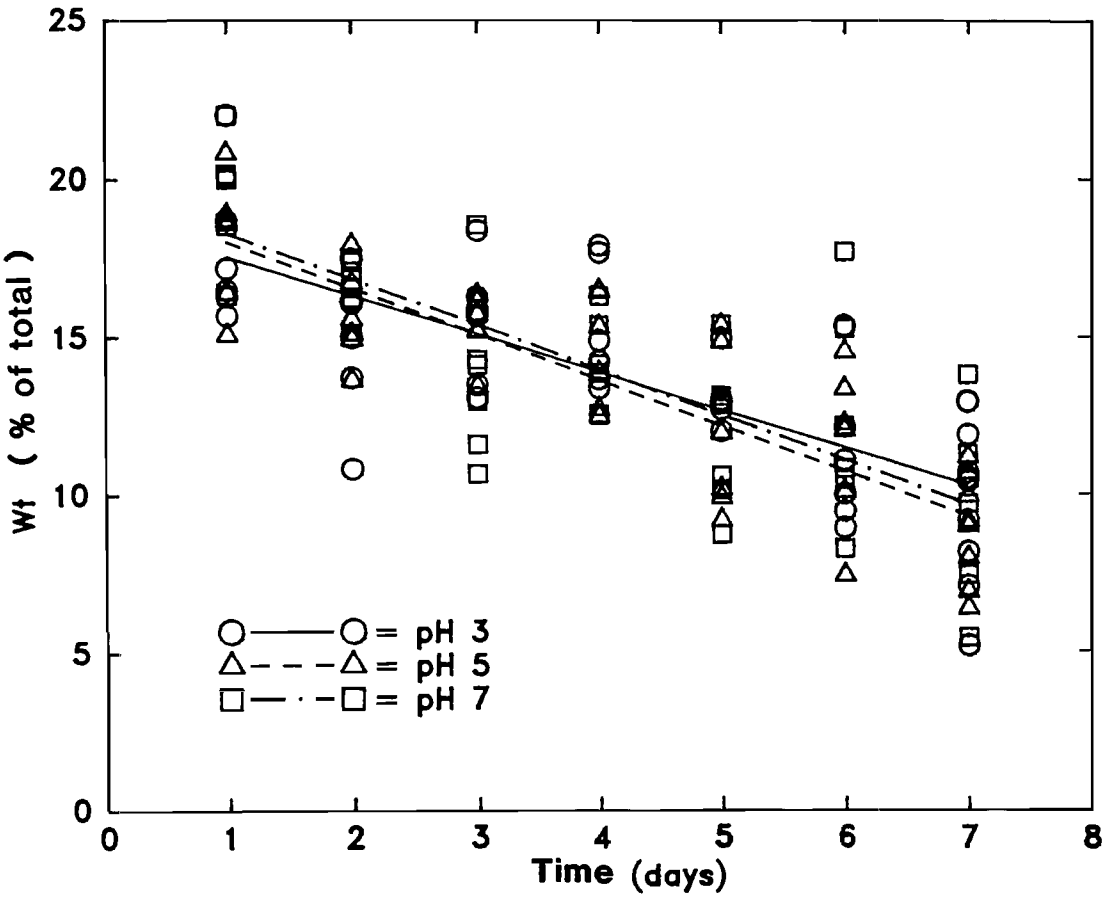

Fig. 2. Effect of phosphate buffer adjusted to pH 3, 5, and 7 on weight distribution of *Zantedeschia aethiopica* spathes. Spathes placed at pH 3 ($y = 18.746 - 1.209x$), pH 5 ($y = 19.464x$) or pH ($y = 19.724 - 1.438x$) did not show any appreciable differences.

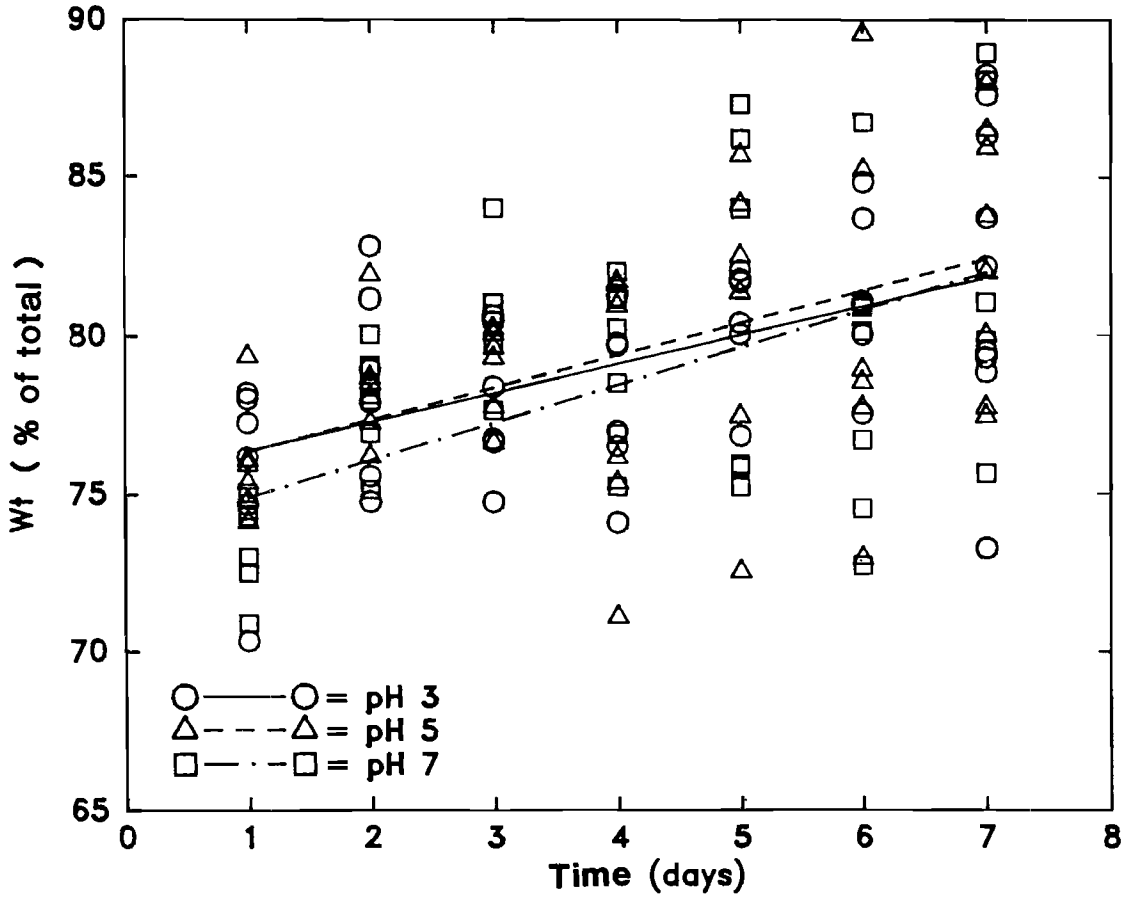

Fig. 3. Effect of phosphate buffer adjusted to pH 3, 5, 7 on weight increase of *Zantedeschia aethiopica* scapes. pH 3 (y = 75.482 + 0.904x), pH 5 (y = 75.370x + 1.004x) or pH (y = 73.728 + 1.178x).

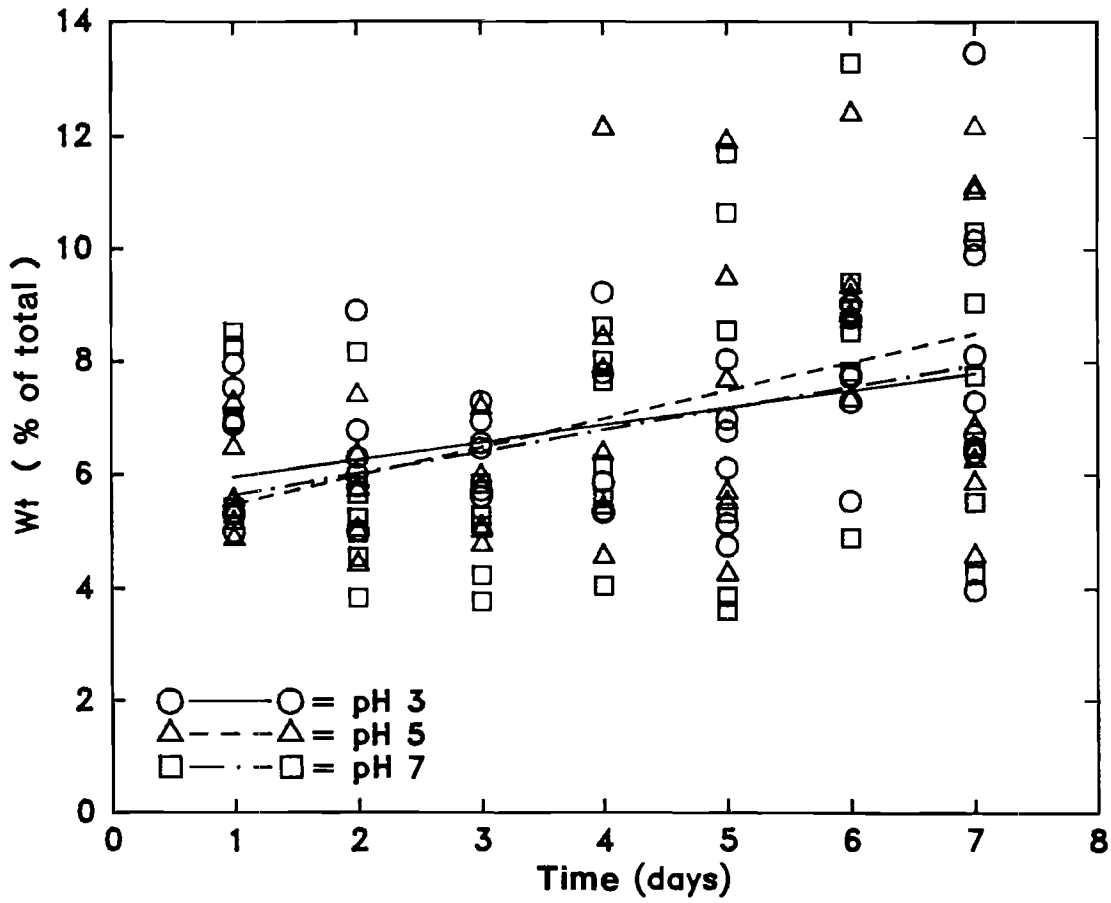

Fig. 4. Effect of phosphate buffer adjusted to pH 3, 5, and 7 on weight distrubution of *Zantedeschia aethiopica* spadices. pH 3 (y = 5.655 + 0.306x), pH 5 (y = 1.00x), pH 7 (y = 5.260 + 0.385x).

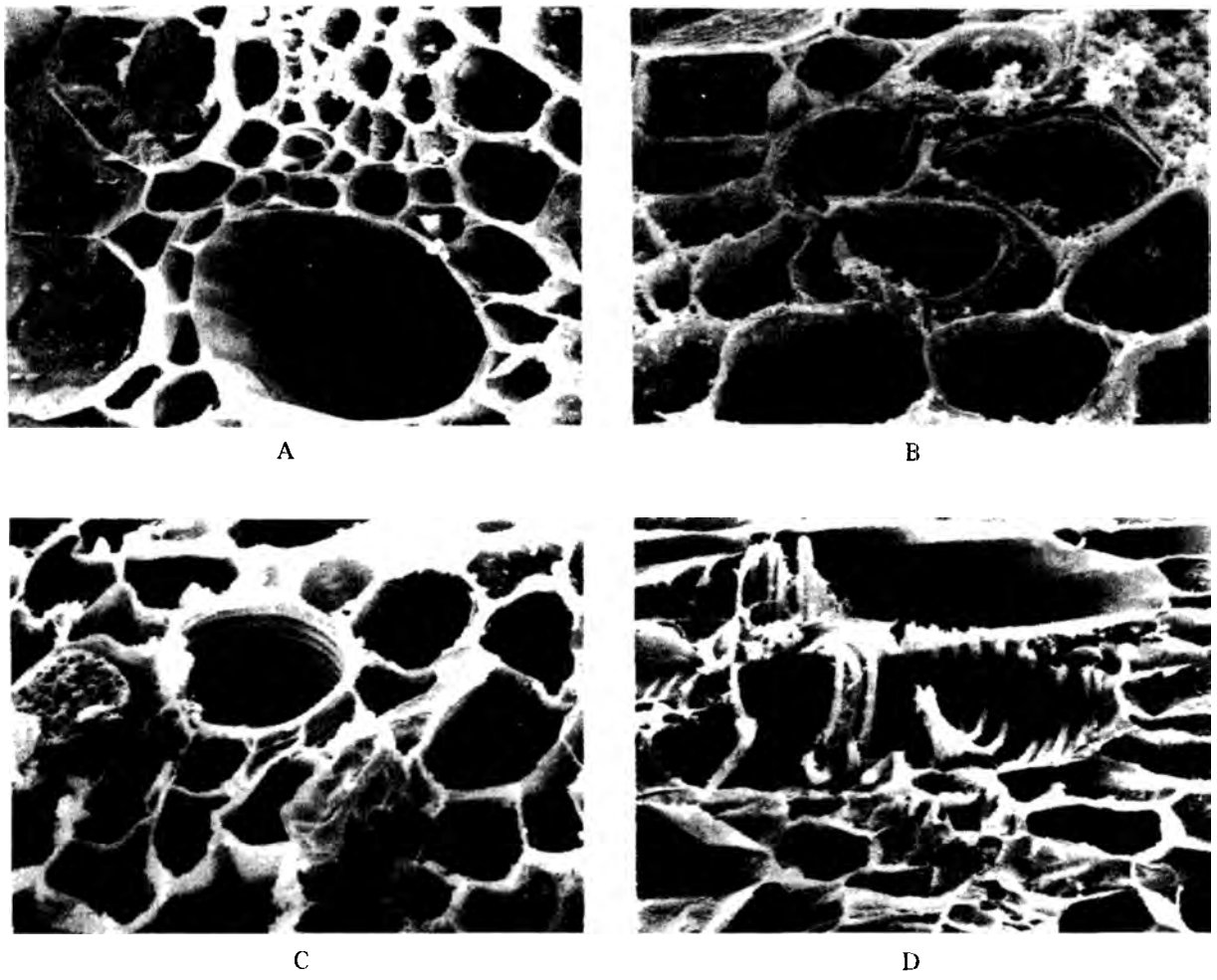

Fig. 5. SEM photomicrograph of *Zantedeschia aethiopica* water conducting tissue.

A. Scape 35cm from the base of the spathe (transverse section)

B. Scape below the spathe (transverse section)

C. Junction of spathe and scape (longitudinal section)

D. Base of spadix (transverse section)