CARIBBEAN
FOOD
CROPS SOCIETY

23

Twenty Third
Annual Meeting 1987

Antigua

Vol. XXIII

CARIBBEAN FOOD CROPS SOCIETY

Crop Diversification:
New Horizions for Agricultural Development

PROCEEDINGS

of the 23rd Annual Meeting

Held jointly with the Caribbean Agro Economics Society

St. John's, Antigua

August 23 - 28, 1987

Edited By:

Brian R. Cooper
and
Robert Paterson

Published by
The Caribbean Food Crops Society
P. O. Box 506, Isabela, Puerto Rico

CFCS

Board of Directors 1986/1987

Officers

President	Francis Henry	Antigua
Vice-President	Brian Cooper	Antigua
Secretary	Carlos Cruz	Puerto Rico
Treasurer	Aurora Lugo-Lopez	Puerto Rico

Members

Rodrigue Aristide	Guadeloupe
Ronald Baines	Barbados
Gerry Dupuy	Dominican Republic
Freddy Leal	Venezuela
Darshan S. Padda	U. S. Virgin Islands

Local Organizing Committee for the 23rd Annual Meetings

Francis Henry (Chairman)

Iftekhar Ameen	St. Clair Barker
Joe Campbell	Brian Cooper
Lennox Daisley	Charles Douglas
Lesroy Grant	Cavelle John
Florita Kentish	John Livingstone
Jennifer Maynard	Rob Paterson
Joseph Samuel	Hayden Thomas

CONTENTS

Presidential Welcome

Francis A. Henry

President, Caribbean Food Crops Society

Mr. Chairman, Your Excellencies, Honourable Minister, President of the Caribbean Agro-Economic Society, Our Guest Speaker, Members of the CFCS and CAES, Participants, Guests, Ladies and Gentlemen:

On behalf of the Caribbean Food Crops Society, it gives me great pleasure to welcome you to this, the Twenty-third Meeting of the Society, which is held jointly with the Nineteenth Meeting of the Caribbean Agro-Economic Society.

In welcoming you here this morning, I recognised three groups of people; those of you who are visiting for the first time, those of you have visited us before and those who live here. To those of you who are here for the first time, let me warn you that a single visit is seldom adequate to give a fair idea of our weather at any one time in the year. You should come again. Do not conclude from the lush vegetation you see, that the island is usually green at this time. The main rainy season has not yet begun. Antigua is indeed an island of low and erratic rainfall; however, we had unusually heavy rains in May.

To those of you who have visited us before, do not be surprised if you are told that we have 366 beaches instead of 365. We claim to have as many beaches as days in the year. The fact that we are preparing for a leap year may be the reason for the adjustment. To all our visitors, you should disregard the numbers but take this opportunity to learn more about our country and appreciate some of the beauty that sometimes we Antiguans take for granted. A special welcome to 'All Visitors'.

To those of you who live here, I must inform you that this is the largest group of agricultural scientists, and practising farmers likely to be assembled in Antigua and Barbuda in this decade. This large group of knowledgeable people will discuss a wide range of important and interesting topics. Your participation in this meeting will be most rewarding. Do register and participate.

The CFCS was delighted to respond to the invitation by the Government of Antigua and Barbuda to host this meeting, especially as it is the first time that CFCS is meeting in Antigua. The CFCS responded positively to the idea of making this joint meeting with CAES, thus allowing the Caribbean Agro-Economic Society to return to Antigua for its second meeting here. This is the first joint meeting of CFCS and CAES. We hope it will mark the beginning of a closer working relationship between the two societies which have a common interest agricultural development activities.

The theme of this meeting " Crop Diversification: New Horizons for Agricultural Development" was chosen because of the importance attached to nontraditional crop production. There is increasing awareness that the region's agriculture is too dependent on a few crops. Export crop domination and monoculture have been features of our agricultural production systems for a long time. Most countries are pursuing agricultural development as a policy objective and have set out programmes to widen the agricultural base. Strategies have been developed to introduce new crops and to develop and expand production of minor crops already under production.

Widening the range of crops which can be produced economically and marketed successfully is a common objective in the region. However, increasing local food production and creation of economic linkages may also be pursued. In the case of Antigua - diversification efforts are not concerned with reduction in production of traditional export crops as there is little of these produced.

The application of science and technology to crop production, increases to possibilities of commercially viable enterprises. Successful results are more likely to be achieved through regional co-operation which allows for the sharing of experiences and the information exchange necessary to allow technology development and transfer. In this way it can contribute to the improvement in the standard of living of people engaged in agricultural production.

The programme which has been prepared around the theme will allow for discussion on a wide range of issues. The topics of more general interest include:

- Problems Facing Agricultural Diversification
- Diversification Issues
- Commercial Experiences in Diversification
- Role of Agro-Processing in Agriculture Diversification

Topics of more specific interest include:-

- Vegetable Production Technology
- Crop Protection
- Post Harvest and Processing Technology
- Forages
- Economics of Diversification
- Marketing, and Trade Issues in Diversification

We expect a high level of participation and expression of points of view, in keeping with the professionalism and friendly atmosphere which have become a part of these meetings.

The annual meetings of CFCS continue to be the main activity of the society. The attendance here is testimony to a high level of interest. The Newsletter is yet another feature. I wish to compliment the editor on the fine job he is doing and to urge members of the society to provide support by submitting articles for inclusion.

Ladies, and Gentlemen, I wish on behalf of the society to express appreciation to the Government of Antigua and Barbuda for their invitation to host the meeting and for their financial support. We in Antigua and Barbuda have grown accustomed to expressions of encouragement in agriculture pursuits. We are delighted when such expressions are accompanied by tangible support. We therefore record our gratitude to the many sponsors and wish to announce that we have found a section of the community which we can call friends of agriculture. We will call on our friends for assistance in practical implementation of Diversification in the form of support for the Farmers Annual Plot to Plot Competition. Your generous support will mark a New Horizon.

Finally, Ladies and Gentlemen, we view your presence here as a symbol of support for the Society. We look forward to a beneficial meeting. Thank you!

Formal Opening and Address

The Hon. Mr. Hilroy Humphries

Minister of Agriculture, Lands, Fisheries and Housing
Antigua and Barbuda

Mr. Chairman, Dr. Yankey, Members of CFCS and CAES, Ladies and Gentlemen:

I am indeed happy to be invited to address this joint meeting and to declare the discussions open. It cannot be gainsaid how prestigious this gathering is with most of the leading agricultural researchers, planners production and marketing specialists and economists from both within and outside of the region gathering in one conference to exchange ideas, knowledge and experiences with each other. There is no doubt that your exchange of experiences and knowledge, as well as the resultant actions from these discussions will benefit agricultural development in general and food production in particular throughout the region.

From your timetable of activities, I have noticed that this conference will not be all work, but that some time has been allocated for social events, and a tour of the country. I trust that you will enjoy your stay here, enjoying the full pleasures of all that this island has to offer.

This meeting is taking place at a time when the development theorists have begun to reject industrialization as the requisite path on which under-developed countries have to tread to become developed. The development theorists have instead turned their attention back to agriculture as the means by which development for Third World countries, including the Caribbean, is most likely to occur. This joint meeting is also taking place at a time when the call for immediate agriculture diversification has gained tremendous momentum. In fact, it has reached the point where most countries in the region have accepted the need for agricultural diversification as the only strategic alternative.

Today, the focus of attention, even in a heavily tourism based country such as ours, is on the integrative capacity of the agricultural sector, in terms of its ability to develop linkages with several other sectors, thereby increasing the local value added, while simultaneously reducing the foreign currency requirements and strengthening the internal resilience of the economy. Added to this, it is felt that only agriculture can meet the absolute requirements of increasing goods and services to the point at which a significant input is made on reducing the level of unemployed and raising the levels of income from a regional perspective.

The fact that today the structure of agriculture within the region is similar to what it was over a hundred years ago, with one or two crops dominating agricultural production and employment, makes the task of diversifying the sector an especially difficult one. This becomes even more complicated with the present trends, and structural changes occurring in the world commodity markets.

The problems of over production on the world market and contraction of traditional trading markets as deficit countries overnight become surplus producers, the tendency for trade protection, and the weakening of preferential trading arrangements are all known to us.

We also recognise the problems in our national economies, where unemployment, balance of payment difficulties and fiscal shortfalls, create the urgent need to realise the benefits of any new development thrust.

Agricultural diversification is this new thrust, and as such it must be successfully implemented within the context of the above conditions both locally and internationally and within a constrained time frame.

It is in this context, that this joint meeting takes on an added significance. Since, while the projected benefits of diversification are fairly well known, in terms of its beneficial impact on food security, foreign exchange savings and earnings, employment generation, creation of economic linkages and utilisation of underutilised resources,there are only a few concrete plans and programmes to operationalise the diversification strategy.

Members of both these bodies gathered here for this joint conference are ideally placed to come up with implementation plans and carry out the actual diversification work. For all studies on the diversification process have identified that economically viable, new or adjusted technologies and organizational arrangements within an appropriate macro-economic framework, will be the motor of any successful diversification efforts.

Examination of the three elements of this perceived motor of diversification will reveal that they lie within the specialities of this joint group.

In terms of the need for new organizational structure, it should be clear by now that our traditional small farmers cannot be expected to carry the weight of the diversification effort in the manner in which they are presently organised. Development of high-value nontraditional crops, requires penetration of markets which are highly competitive and therefore requires the highest standards in terms of consistency of supplies and product quality.

The necessity for highly technical, fully commercialized farms to produce the quality and consistency of supplies required, seems to indicate the need for a new type of farmer and for investment in the agriculture sector not yet seen.

Here in Antigua, the Government has not been afraid of stimulating the tourism sector, with several bold Government investment projects, which assisted in the consolidation and advancement of the momentum of expansion in the sector. This confidence displayed by the Government, among other factors, has led to the rapid development of the tourism sector with the occurrence of attendant social benefits such as employment generation and increased income.

It is possible that similar stimulation can occur in the agricultural sector, if the pace and level of private investments are not sufficient or suitable. Your role in this process of designing and managing the new organizational structure will be pivotal, especially against the back ground of a history of part-time small farmers and mono-crop plantation systems.

The issue of technology is also critical, especially with the present conditions in the global commodity markets. In the context of declining prices, subsidization and over production, the identification of economically viable, new and adapted technologies becomes paramount in this situation of cost price squeeze.

The production of new crops alone gives rise to the need for adjusted technological packages. The pressure of the cost price squeeze will also require the development or adjustment of technologies which not only utilise an acre of land or annual unit more intensely, but also reduce costs as much as possible. If, as seems to be the case, product and input prices are by and large given, then technology along with organization and management of the farm, become some of the few controllable variables at the farmers' disposal and as such must be focused on in any successful diversification efforts.

Convincing macro-economic policy recommendations must be made, based not only on their perceived effect on the agricultural sector, but also on their expected impact on the economy as a whole. Here in Antigua this is a critical requirement of any proposed policy change since we must be mindful of avoiding, as much as possible, any policy options which would significantly damage the tourism sector. In this context, the assumptions on which policy is based must be carefully examined to ensure that they apply when making predictions about the impact of a policy instrument. Otherwise, planners might be faced with a credibility crisis if implemented policy options fail to bring the expected benefits.

I am looking forward to the outcome of this meeting, especially in terms of any new light and direction it can give to the diversification effort. During your field trip you will see the first effort of our Government to provide pump priming in our diversification effort when you visit the Antigua Sugar Industry Vegetable Farm. This is an indication of how serious the Antiguan Government is, even within its limited resources and present heavy investment programme, to start the ball rolling in the agriculture sector in some significant way. Governments throughout the region are looking towards this joint body for some significant outputs from your week long deliberation, and so I wish you a fruitful week of discussions, and it gives me great pleasure in declaring this conference open.

Keynote Address

Crop Diversification:
New Horizons for Agricultural Development

Dr. Bernard Yankey

Caribbean Development Bank, Barbados

Mr. Chairman, Honourable Minister of Agriculture: Crop diversification as distinct from agricultural diversification is limited to a discussion of the combination of cropping possibilities which are available to a country in order to improve the performance of the agricultural sector and correspondingly, increase its contribution to national development. It creates demands on other sectors of the economy for support services and can also, both provide and strengthen vital growth linkages. In its broadest sense, crop diversification in the Caribbean runs closely to agricultural diversification. It involves a combination of sector activities which include product intensification/rehabilitation of export crops, commercialisation and increased production of existing non market crops, increased production of crops to satisfy local consumption and the tourist market and the introduction of new crops or new market varieties of existing crops.

Crop diversification has been widely discussed and proposed by a variety of professionals - many not directly involved in agriculture - ranging from public officials, agriculturalists, national organisations, regional institutions, and of course, the news media. The subject has also been studied a few times, without any concern for implementation of the recommendations. The subject is also very topical at this point in time as some major export crops appear in trouble, but crop diversification is itself as old as the emergence of the small farm system. The concern which undoubtedly has been growing over the need to harness both human resources and financial resources to sustain and strengthen crop diversification in any, or all of our agricultural economies, goes as far back as the early 1960s. It is a concern that spans over a quarter of a century. But where are we?

In all this, very seldom have we been hearing the voices of the farmers - the entrepreneurs who are daily at work in the agricultural sector - but they are constantly making decisions in a variety of ways; and are taking action to diversify their cropping systems in an almost unnoticed fashion.

In this whole debate, what seems to me to be a relatively weak area is the involvement of professionals and technicians in actively designing and implementing, either collectively as groups, or as individuals in positions of employment, both research activities and projects/programmes geared to facilitate crop diversification. As professionals present here today, you belong to this group that I am referring to and it is very important that you enter the forefront of this debate - not for the purpose of talking but to ensure that only realistic and practical alternatives are put forward to decision-makers in the national system, and that careful consideration is given to implementation. Remember, in agriculture, we are dealing with people who must be persuaded and convinced to act, before things can happen. Very often, it is this process that frustrates decision-makers, planners and implementation agencies. But this will remain so until the relatively high degree of risk in agriculture is progressively reduced. Since our agricultural professionals and technicians have the knowledge, experience and the gut feelings over what can work and what will not work; and because they have a wealth of insights into the working of the agricultural sector and both understand and appreciate the nuances of the farmer and farm family, it is my view that they should take some leadership role and should be strongly influential as we look for new horizons for agricultural developments.

Agriculture is a major economic sector for many CARICOM countries. Where it is not the dominant sector, it is significant in terms of employment, contribution to foreign earnings and its stimulative linkage effect on other economic sectors. However, the performance of this sector, which so many countries depend upon, has from time to time, been mixed and shows increasing weakness. This situation emerges from the over dominance of the major export crop on which the economy relies heavily. The problem is the susceptibility of that major export crop - be it sugar, bananas, cocoa, nutmeg, citrus, arrowroot - to a variety of market conditions i.e., strict quality requirements, slow growth in demand, supply allocations and depressed world prices. The collapse of any dominant export crop which fuels an economy, can mean negative economic growth, unbearable levels of unemployment, low foreign earnings with its effect on limiting import capacity and debt repayment, poor fiscal performance of the public sector with its effect on limiting public sector investment programmes and so on. Crop diversification, or better yet, agricultural diversification, is a means to eliminate the prospects of such a situation. The objectives of crop diversification are varied, but essentially, they are to minimise the adverse impact of the world market place on an economy; to improve the living standards of the rural population, in particular, farm families; to improve the level of foreign savings from import reduction of foods which are locally in demand and can be produced at comparable costs at home and in the region; and to provide a component of food security for the population against natural and international crises.

Crop Diversification: some essential features

Before we examine the scope and potential for crop diversification, a discussion of some leading facts of importance on the subject is necessary. These will help us to appreciate how far and how fast we can move in this direction.

The first fact is that the logical and financially sound way to pursue a programme of crop diversification is to adopt a market-led diversification approach. In other words, let the real market opportunities dictate what crops must be emphasised and in what form in the production systems.

The second fact is that crop diversification must be a cautious and programmed activity, supported extensively by both technical and market research. It must follow a pattern of adjustment within the farming system - one that is flexible and adaptable to the perception and capabilities of the farmer. The farmer or the farm corporation, if this is feasible, must undertake the pivotal role.

The third fact is that crop diversification does not necessarily mean the cutting back of a crop with market difficulties to move completely into something new - how would the farmer live? It is a shift in crop relationships, with expansion of productivity, or improvements in an existing crop or new variety through a reallocation of farmland or use of higher levels of cultural practices.

The fourth fact is that the relatively limited good quality land resources of most CARICOM countries mitigate against crop diversification through expansion. However, in many countries, underutilized lands are generally those which have limited alternative uses and these could therefore be properly cultivated in a suitable crop with good market prospects.

The fifth fact is that relatively good quality lands which are generally scarce should not be completely tied up with a permanent crop - for example, tree crops like coconuts, cocoa, nutmeg - in a programme of crop diversification. If a permanent crop provides a useful source of permanent income then an appropriate ratio of crop to land should be developed to accommodate the production of arable crops. Since market conditions vary in time, the more long-term the tree crop, the more risky the proposed change. Demand and price forecasts are not useful beyond three to four years. Hence, the market condition for a long-term tree crop that will come into full economic production by year six to eight will be anybody's guess. This can be a high risk gamble.

The sixth fact is that crop diversification should hardly be supported by input subsidies unless the crop has a wider economic role to play - preservation of hillsides for control of soil erosion, first source supply of raw material for agro-industry or for strategic reasons, e.g. food security. In any case, how many subsidies can the relatively weak Caribbean economies provide to agriculture, given their unstable fiscal situations? In recent time, subsidy packages have been going through the dismantling process.

The seventh fact is that crop diversification should be carefully planned to time implementation when the prospective market crop is in the trough of market performance, particularly biennials and tree crops, so that output comes into full production when the cycle is projected to be on the upswing.

The eighth fact is that crop diversification should be a dynamic process. Once an additional crop is given predominance in the agricultural system, it should be subject to regular market surveillance through aggressive market salesmanship which focuses on important quality characteristics of Caribbean agricultural products. For example, if Caribbean grapefruit have permanent marks but have sweeter and juicier characteristics, we should relate both features in a positive way in advertising. In other words, we should not be apologetic abut the permanent marks which are merely physiological in nature. In addition, both production and marketing technology should be modernised and continuously improved to ensure cost effectiveness and high quality standards. Crop diversification therefore should be supported by appropriate institutional mechanisms and the support services required to provide the necessary reliable and accurate information on which decisions can be effectively made. The role of the public sector in crop diversification is very crucial and important, but it does not have to bear the overriding burden. It has a well defined position in terms of scope and design implementation but at the same time, it should be far from the sole actor on this stage. The conceptualisation, preparation, implementation and management of any crop diversification programme should be the function of research, credit and market institutions, commodity associations and farmer organisations, with the public sector providing the initiatives, incentives, the support services where necessary, and the appropriate legislation.

The ninth fact is that for crop diversification to be effective and self-sustaining - which is the sensible and economic approach - it must be backed up by some measure of market diversity. By this, I mean access of output to local, regional and extra-regional markets should be both initiated and strengthened to achieve optimum income to the sector. At the same time, diversification programmes through this approach, should enable agro-processing to obtain independent supplies of raw material to operate above break-even levels. This scenario obviously envisages an agricultural sector with large volumes of production. Whereas experiences do not support this type of development, it is useful to add that herein lies the opportunity for fostering joint production and marketing activities, with selective areas for agro-processing within the framework of CARICOM or the OECS countries.

The tenth fact which we should appreciate is that any crop diversification programme that focuses on the introduction of new crops, or even new varieties of crops is very expensive both in terms of financial resources and the human resources required at the technical and management levels. Who can meet that bill? Are there historical experiences which can serve as a guide? Yes, small farmers have been doing this over a considerable period of time.

The eleventh fact is that crop diversification is not synonymous with the re-introduction of the 'plantation' or 'estate' large-scale agricultural systems of the past. Small and medium scale farming is the dominant agricultural systems in many CARICOM countries and has developed for many sensible reasons over time. It is therefore here to stay. It is more efficient in the use of land, labour and credit. Also, it generates more economic activities for rural people who constitute the majority of the population in many of the countries. It therefore ensures greater distribution of wealth and employment. For these reasons, crop diversification should pursue a path with small and medium-scale farming; with a cadre of special focus farms which could set the leadership role in being the '*innovators*'.

The twelfth fact is that, if we are to seriously engage in crop diversification to improve the marketable range of crops, research will have to focus seriously on the development of cost effective technology packages for the farmer, with continuing operational research on the farm to determine the best crop combinations to achieve a level of income to the farmer that will provide him with the 'real incentive' to sustain any national programme of crop diversification on his farm. The totality of this commitment by farmers is what will make any crop diversification programme succeed. Research programmes therefore will have to be developed on a priority basis and tailored to meet specifically defined objectives if crop diversification is a serious component of national agricultural policy and is subject to annual budgetary evaluations.

The final and thirteenth fact is that crop diversification has been going on for a considerable period of time and mainly in the small and medium-scale family farms. These farmers, historically part of the lower income sectors of society, have been adjusting their production systems against many risks. This they have been doing with the support of extension services and availability of new technology (particularly in its quantitative forms). Currently, they have advanced the level of crop diversification in a number of CARICOM countries. Their perceptions and experiences could provide planners with some of the unwritten considerations which should be taken into account as we attempt, in our very modern times, to develop investment projects in crop diversification.

But should crop diversification always mean the addition of new crops to the agricultural production system? No - it need not. For cost reasons as outlined, it is better if it does not.

I would argue seriously that the most economical solution to the problem of a dominant export crop agricultural sector which requires adjustment through crop diversification, is a process of undertaking serious market investigations, with aggressive salesmanship in the market place, to obtain reliable, medium-term and reasonably remunerative market orders for some of the commercial crops already in production but which are currently confined to small local markets, sometimes going to waste and with unnecessarily high levels of on-farm consumption. What then are the horizons for agricultural development for the period 1990 onwards, through the process of crop diversification?

A major consideration in crop diversification is the need to pay particular attention to the minimisation of risks to individuals or groups of farmers. Secondly, organisation and management structures and capabilities, whilst avoiding any duplication and overlap, need to be put in place to achieve the desired cost/benefit results from the diversification process.

Initiating and implementing sustained crop diversification

The objectives tend to be very national and economy centered, but any failure bears heavily on the farm family. This particular dilemma therefore, should sensitise our approach to the development strategy. I wish to propose that three methods of initiating and implementing sustained crop diversification which I will outline, have some merit and could be pursued in the future.

Firstly, priority should be given to a detailed examination of the crops which are grown on farms and determination made of how any or all of these respond to market tests (local, regional and extra-regional), and to what extent, commercialisation can progress within existing market time frames.

Secondly, based on historical evidence of the previous cropping systems which existed in the country, which are for medium-term crops with reasonably good market prospects and can be securely re-introduced?

Thirdly, which crops already being grown by farmers - even on a piecemeal basis - can be expanded satisfactorily on lands with very limited alternative use, to an above break-even volume of output for the principal purpose of agro-processing. The design for agro-processing in most CARICOM countries should involve the utilisation of efficient small/medium-scale plant - given each country's relatively low volume potential. The production objective should be to satisfy demand for products which can effectively compete within local and regional markets. But more important, such products should start with an appropriate capital structure for financing the operation as well as experienced project management and plant operation technicians. The HIAMP project of USAID with its venture capital component could pay considerable attention to addressing this particular urgent need. I have deliberately excluded extra-regional markets because we have consistently seen measures introduced to limit entry of our products.

Areas with diversification potential

I see our horizons, therefore, in three categories of crops:

- fruits:
- food crops; and
- spices, condiments and essential oils.

The market potential for flowers and ornamentals exists but because of world-wide competitiveness, particularly from our Latin American neighbours, I would give this category of crops only moderate priority rating.

Fruits

Caribbean countries presently produce a large variety of fruits, some of which go to waste. Through appropriate varietal selection of those which can be processed into fruit chunks, segments and juices, we could harness available supplies, and through a judicious process of expansion - particularly on underutilized lands which have limited alternative use - produce the raw material for small to medium-scale agro-processing. This does not exclude the fresh fruit market which is always a prime target area. However, significant spoilage rate in marketing, high per unit transportation costs and seasonality which produce gluts, favour an emphasis on agro-processing.

Undoubtedly, this would require a package of extension and research in varietal selection, plant propagation and crop expansion, as well as expertise in the selection, management and operation of plant and processing technology. But in addition to this, and very important too, will be the need for selection of appropriate packaging geared to consumer acceptance, as well as market programmes to improve and sustain demand.

The potential for production and marketing of processed fruit products from the wide variety of Caribbean grown fruits presents a challenge for Caribbean agriculture. A carefully designed fruit crop diversification programme should include, among other things, varietal selection for processing.

Food Crops

What about our food crops? With the present and projected growth of tourism in the Caribbean, food crops should have a guaranteed local and regional market. But this is not generally the case. Why then is it so difficult for our farmers to tap this potential demand, which would, at the same time, progressively reduce the large food import bill? It seems to me that this market will not come to the farming community, unless we are determined to penetrate it.

When confronted, the hotel industry stresses the problems of poor presentation, handling difficulties because of variable sizes and striking varietal differences, among others. In addition, there is the issue of price competitiveness. Are these problems too difficult to tackle in terms of our research and organisational capabilities? There is no doubt, that additional resources will be required to make the necessary breakthrough, but it is an investment in which the benefits should far outweigh costs.

Linkages with Tourism Sector: Those of us who stay at hotels know fully well that there are a range of food items which we could comfortably produce and/or process for the hotel table. Concerted national efforts could therefore be undertaken, along the following lines, to increase the tourist consumption of food crops and fruits:

- Detailed consultation with the management of hotels on the types and quality of food crops and fruits which can be served to tourists and how they should be presented for sale:

- Designing and implementing a package of research, based on the selection of crops arrived at through consultation, to deal with:

  (a) appropriate varietal selection and adoption;

  (b) the development of improved technology to increase productivity and to facilitate efficient harvesting;

  (c) standardisation, processing, packaging and pricing for fresh marketing; and

  (d) the development of a range of differentiated consumer products for wider utilisation of the foods selected.

- Wide-scale education of the population by the National Home Economics and Nutrition Institution on the choice, preparation and nutritional value of foods produced, including demonstration of the preparation of various recipes to hotel kitchens;

- Addition to the fiscal incentive package normally available to hotels of a provision for eligibility that would require a significant utilisation of local food crops and fruits in feeding tourists.

Promotion of local foods to the indigenous population: The increasing consumption of local food crops and fruits by tourists would undoubtedly have a positive demonstration effect on the local population. This could be strengthened by a local foods consumption education campaign, improved standardisation and promotion of variable pricing of food items at local markets, and an appropriate school meals programme among others.

This approach to generate increased consumption of local food crops and fruits could be tied up with a national food consumption policy which sets targets for reducing certain imports for which there are good substitutes. These targets could be related to certain criteria such as the quality of the substitutes, price competitiveness and the growth of local food production. This by itself, is a tall order for implementation. There is no doubt that for achievement of this aspect of crop diversification, appropriate existing institutions will have to be identified and strengthened to undertake the various tasks. This will require sound and effective organisation and management and could put a serious strain on both human and financial resources. Time constraints will also be a limiting factor and in the final analysis, decisions will have to be taken on the basis of priority.

Spices, condiments and essential oils

Any serious attempt at crop diversification, must of necessity examine areas in which CARICOM countries have certain comparative and competitive advantages for expanding production. The sub-sector of spices, condiments and essential oils provides the raw materials for both local and regional agro-based industries.

Ecological conditions are generally suitable in many countries for the production of a range of spices and condiments. However, the technology, research and extension support, as well as the infrastructural requirements (nursery and propagation facilities) are only available to a limited extent in a few countries. The same may be said of the essential oils such as bay and lime oil. However, except for nutmeg, lime and bay, these are mainly minor crops which have not been subjected to serious market promotion tests.

What seems feasible for this sub-sector is the identification and development of joint ventures among local, regional and extra-regional entrepreneurs in the processing of spices, condiments and essential oils into a variety of consumer products for extra-regional export. This could be pursued through national policies which provide specific incentives for the development of this sub-sector by the private sector, where the potential exists. The incentives could be based on the hoped for export provided by such trade initiatives as the Caribbean Basin Initiative (CBI). This is the only significant area in the CBI that, in my view, Caribbean agriculture can take advantage of without the frustrations of marketing primary products such as mangoes or processed commodities such as grapefruit juice.

There are marketing opportunities provided by international trade arrangements such as the Home Convention, the CBI, and others, of which greater advantage could be taken. However, to do so, we will have to invest heavily in the development of marketing infrastructure to provide the products which meet the phytosanitary, standardization and quality tests of these variable markets.

Transportation links will have to be carefully worked out and synchronized to limit, as much as possible, transit times and undue handling.

This is not an easy task for the relatively small economies within CARICOM. This is undoubtedly an area for tourist marketing initiatives which will become a necessity for the OECS Countries if they are to make any significant break-through in extra-regional exports. In addition to this, we will need a firm and permanent presence in the market place to provide the vital, reliable, market intelligence promptly to the domestic agricultural sector, as well as to monitor the products on entry and their performance in the market.

The investment required in this area may be merely marginal, since, in my view, we may only have to request the various High Commissions and Embassies of individual CARICOM countries to undertake trade specific functions for their respective countries.

Summary

The prospect exists for crop diversification which can broaden the horizon for agricultural development, improve the income position of the farming community and of investors in agricultural enterprises, and contribute to national development. To achieve any measurable gains in this direction will require a combination of purposeful national policies, specific identification and appropriate strengthening of organisational structure and capabilities to undertake these many tasks.

The supply of adequate human and financial resources to plan and implement a market-led crop diversification programme will limit what can be done and must force each country to seriously select what is financially and economically feasible on a priority basis. The process will require, among other things, the undertaking of essential research as promptly as possible; the assessment, selection and application of adaptable technology and the provision of appropriate credit, extension and marketing services which are geared to the particular stage of development.

Above all, any crop diversification programme must be subject to constant monitoring and evaluation and, based on cost/benefit impacts as assessed at regular intervals, adjustments to the programme.

Thank you.

TECHNICAL PAPERS

The role of agroprocessing in the regional diversification thrust

Desmond A. Ali, BSc, PhD

Deputy Director, CARIRI, University Campus, St. Augustine

Introduction

"Now if the capital sector produces no food, its expansion increases the demand for food, raises the price of food in terms of capitalist products and so reduces profits. This is one of the senses in which industrialisation is dependent upon agricultural improvement; it is not profitable to produce a growing volume of manufactures unless agricultural production is growing simultaneously. This is also why industrial and agrarian revolutions always go together and why economies in which agriculture is stagnant do not show industrial development". (W. Arthur Lewis 1954)

Agribusiness is enormous business and agroprocessing, which is an important component of agribusiness, is one of the world's principal industrial activities. Agroprocessing is the application of technology to the transformation of agricultural raw materials to produce various goods and services. Agroprocessing is popularly held to be synonymous with food and beverage processing but in fact this is a limitation in definition with which we ought not to be constrained. It is certainly true to say that food and beverage processing constitute important and significant elements of agroprocessing. There are, however, major areas of agroprocessing that are concerned with products unrelated to the food and beverage subsectors and which we must consider if we are to provide a true and accurate perspective of the potential of agribusiness.

Once the search for gold and silver in the Caribbean Region by the colonial powers in the 16th and 17th centuries proved to be an exercise in futility, the true El Dorado of the region was found in agriculture and primary agroprocessing. The productive potential of the land to lock up solar energy in various cash crops - sugarcane, cocoa, coffee, bananas, coconuts, spices, and timber - and the equable year round climate produced wealth of enormous proportions to the metropolis. This wealth fueled industrialisation in the metropolitan countries and the technology was developed to further process these tropical raw materials to a plethora of high value end products, much of which ended up in the very countries that produced the raw material in the first place. And so was born a pattern of agroprocessing that was to become established and that dominates agribusiness in the region to this very day. In a real sense, the region produced what it did not consume and consumed what it did not produce. Now in the dying years of the twentieth century, attempts are being made to link production with consumption and to use agroprocessing as the tool to achieve this fundamental transformation with the objective of socio-economic development.

Agroprocessing - technological considerations

Agroprocessing refers to transformation after harvesting and so constitutes a major element of postharvest technology. Such technological transformation ranges from the simple to the complex depending on the level of the technology applied and on the degree of transformation that occurs. Thus, simple drying or the removal of water using various types of dryers will result in a product not too different from the raw material, whereas molecular transformation by microbial fermentation will produce something totally unrelated to the original raw material. One economic fact is clear and that is that the amount of value added and hence wealth and employment created will be directly proportional to the level of agroprocessing. Processing trees to lumber is simple and hence little value is added but processing this to veneered cupboard elements will ensure major value added.

Agroprocessing is concerned with manufacturing consumer products but the imperatives of agroprocessing deal with preservation and presentation. On the one hand, preservation is a natural development of the fact that consumer markets have become distal in time and space from production and since agricultural raw materials have an inbuilt characteristic to degrade and recycle, methods must be used to halt or retard this process. On the other hand, presentation has to do with consumer tastes and preferences and the natural specialisation that accompanies civilization as we understand it.

In agroprocessing, therefore, a terminology has arisen that pertains directly to the level of transformation of the agricultural raw material. The processing may be:

Primary
Secondary
Tertiary or higher

Primary processing refers to an elementary conversion of the raw material, e.g. conversion of sugarcane to raw sugar, molasses and bagasse; logs to timber, aloe vera to stabilized gel, live animals to chilled/frozen carcasses. As the level of transformation increases, one progresses through to secondary, tertiary and even higher and at each stage more technology comes into play. As mentioned earlier, during the processing, wealth created and employment generated increase proportionally to the level of processing, leading to products of increasing value.

Agroprocessing and diversification - some policy considerations

Given the relatively large internal market for processed agricultural products; given that the export market for processed agricultural "exotics" beckons temptingly and given that agroprocessing appears to hold significant potential for generating both wealth and employment, one can easily be led to believe that agroprocessing holds the key to the Pandora's box of development. Our experiences to date should warn us against what appears easy and obvious and must inform our future actions.

If we examine the development of the foods and feeds industries in the region through the 1960s to the present, we will see that what started off with the good intentions of backward linkages into agricultural production and opportunities for export in fact never materialised. With considerable assistance from the taxpayer, these industries commenced in the 1960s and 1970s in practically every territory, initially as import substitution exercises, using imported preprocessed material with the hope that over time, linkages would develop with the primary production sector and products with export potential would be developed. Today, in some of these industries, the import component in terms of raw material continues to approach 100%, linkages into primary production are often zero (except in a few notable instances like Frozen Concentrate Orange Juice in Belize) and extra-regional exports are insignificant. In the period, quality has been variable, prices to the consumer have been high and taxpayer subsidy has continued.

If agroprocessing is to be a real option with developmental potential, the objectives must be explicitly and quantitatively set out. These objectives need to be constantly re-examined and re-evaluated in the context of performance. There is need for careful investigations and detailed feasibility studies as the industry is charting a course into new and unfamiliar areas.

Agroprocessing as an element in agricultural diversification must be considered within the following policy framework:

- to create remunerative, permanent and gainful employment opportunities
- to develop a vibrant agricultural and agro-industrial sector to strengthen the economic base of our economies
- to increase our ability to produce more of our food needs and to increase self reliance, as opposed to self-sufficiency, and strengthen food security
- to effect meaningful and immediate reductions in the huge regional food import bill, thereby reducing foreign exchange outflows for imported food
- to transform a backward, traditional agricultural sector, into a modern technological oriented sector
- to earn foreign exchange through creating and filling niches in the export market.
- to generate R&D into new products, new technologies and new market opportunities
- to create a demand for new goods and services

Within the above policy framework, the following guidelines will be considered in selecting projects:

(a) technical feasibility and financial viability

(b) meaningful relationships must be established with the existing, or soon to be developed, primary production sub-sector

(c) to minimize risk, one ought to look at possibilities as close as possible to our own markets using established technology

(d) significant linkages must be developed with other sectors, e.g. engineering, R&D, packaging, etc.

(e) products must not significantly increase the cost of living to the consumer

(f) there must be maximal utilisation of wastes and by-products

(g) the processing sub-sector must create and sustain an indigenous capital goods sector

Opportunities in agroprocessing

In the light of the above, it would be informative to examine regional opportunities in agroprocessing. For convenience, this examination will commence with existing agriculture.

Sugar

Any discussion on regional agroprocessing must commence with sugar, which for so long has been king in the region and continues to be important to Barbados, Belize, Guyana, Jamaica, St.Kitts/Nevis and Trinidad and Tobago. Regional production has declined by 18% in the period 1980-84 to 748,000 tonnes, with export sales declining in the same period by 11% to 638,000 tonnes. In 1985, sugar prices fell to their lowest level in 14 years against a backdrop of large stocks, failure to negotiate a new International Sugar Agreement and competition from other sweeteners. The long term outlook for sugar prices is grim, so too are the opportunities for export sales. The acreage under sugarcane has remained more or less stable since 1980 at about 125,000 ha. This represents the single largest use of our land resource. Sugarcane thus constitutes a prime situation for agroprocessing since abandonment of sugarcane is not really an option. Any agroprocessing thrust must therefore be two-pronged involving better utilization of sugar and its by-products; and alternative uses of the sugarcane plant.

Utilization of sugar and by-products: Appendix I summarises the range of possible processed products from the various outputs of the existing sugar industry. The list is formidable and becomes even moreso when one considers that it is possible to make more than 10,000 chemical products from sucrose. These range from low volume, high value products like pharmaceuticals and pesticides to high volume low priced products like feeds and alcohol (Thomas 1985, Paturau 1982).

Alternative uses of sugarcane: Much of this work is going on at the Sugar Industry Research Institute in Jamaica where the approach is to treat the sugarcane plant as having the following useful components:

- hard outer rind capable of being cut into strips to produce structural board, decorative board and fuel briquettes (22% of cane)

- the sugar rich pith (75% of the cane) from which the juice can be extracted to leave a material that can be made into animal feed. The pure juice, uncontaminated by rind elements, can be made into specialty syrups and sugars.

- a thin protective layer of wax covering the rind (2% of cane). When extracted this yields a high quality, hard wax.

A commercial facility using this technology is now being constructed at Bernard Lodge in Jamaica.

Cocoa

Cocoa is produced in eight territories in the region with production having declined by some 27% in the period 1980-1984 to 6,856 tonnes. Both Trinidad and Tobago and Jamaica cultivate the fine-flavoured "Trinitario" clones and seedlings. These produce a bean that carries a premium price on the world market. Cocoa is primary processed in the region by fermenting and drying to produce the dried beans of the international trade.

Secondary and tertiary processing of cheaper imported beans are carried out in Barbados, Trinidad and Tobago and Jamaica to produce sweets and chocolate bars as well as chocolate drink bases.

If regionally produced beans, which are in high demand, could only be secondarily processed into cocoa mass, paste, powder and butter, we could increase income ten-fold as compared to the export price for the raw beans. Further processing using indigenous sugars and spices could lead to a range of exquisite high value products.

Coffee

Production occurs in four territories with output having fallen by 50% in the period 1981-84 to 3,044 tonnes. Much of the coffee in the region is already being processed to ground coffee, instant coffee and high value coffee liqueurs.

Bananas

Banana production by the six major producers averaged 220,000 tonnes in the 1980-84 period, with exports accounting for some 65-70% of the total. Because of the demands in metropolitan markets for blemish-free and well-shaped fingers, there is much wastage due to culling and rejects. Processing in the region is negligible, though it is possible to produce chips of various types, purees and frozen bananas.

Coconuts

Regional production of copra has declined by 16% in 1980-85 to 16,700 tonnes. Part of this goes into the production of edible oils and part into non-edible oils for manufacturing purposes. Total regional production of coconut oil now supplies less than 10% of the demand for edible oils (Caricom, 1986) with the bulk of the deficit made up by importing soya and corn oil. Despite this, countries have been experiencing difficulties in disposing of coconut oil. Some coconut oil is used to make toilet soap, other soaps, margarine and shortenings. Because of health concerns and an apparent preference for soft unsaturated oils, more coconut oil will be available for processing.

A major project is now under way to develop a range of high value cosmetic products based on coconut oil. The region continues to import coconut cream and desiccated coconut for the baking industry in significant quantities. Manufacture of these products is based on well-known simple technology and there is no reason why such products cannot be produced in the region.

Other products for coconut include use of the milk for vinegars and the wood from culled and diseased trees. The wood is extremely hard and damaging to ordinary saws, but in countries like Sri Lanka, much of the rafter material for supporting roofs is coconut wood.

Timber and forestry products

The region is rich in exotic, quality, tropical hard-woods, much of it centered in Guyana, Belize, Trinidad and Tobago and Jamaica, but even for ordinary construction timber, the region is dominated by imports. The furniture and woodworking industries are in their infancy and have enormous potential for development given adequate design and marketing support. In fact it is true to say that the potential of our tropical woods, both the well-known species as well as the lesser-known, has not been touched.

It is particularly important to consider the market for well-designed CKD furniture, wooden carvings and objects d'art, wooden toys and games and other wooden articles like cutting boards, cheese boards, wall holders, etc. The growing market for veneers is another area worthy of investigation.

Agroprocessing of non-traditional crops

Fruits and vegetables: The region already has significant installed capacity for processing fruits and vegetables but apart from a few exceptions, much of the raw material used is imported as pre-processed raw material. Thus, in Trinidad and Tobago alone, imports of tomato paste primarily for tomato ketchup exceeds US$2.4 million p.a. and yet it is possible to make perfectly good catsup equivalent to tomato ketchup from pumpkins as anyone who has been to the Philippines and parts of Latin America will know.

A fruit which I want to mention as having great potential, especially for the drier parts of the Caribbean is cashew. This crop can be processed to the nut (the third most expensive consumer nut after macadamia and pistachio) and cashew nut shell liquid which is a material of enormous industrial importance.

One must also mention the growing market for dried fruits. Raisins and prunes are well-known imports but dried products in may cases superior to raisins and prunes can be made from papaya, pineapples, five fingers (Carambola), pommerac (rose fruit) and others.

Meats: Certain of the territories in the region now have an over production of chicken, yet the secondary and tertiary processing of chicken has barely started. Some chicken burgers and sausages are produced, but chicken can be canned or frozen in a number of ways to produce attractive, consumer and institutional products. Much of the necessary technology for these operations is already installed in the region and it would be but a short step to move in this direction.

Fisheries: The region continues to be a net importer of fish and fish products. Practically all of the fresh fish and shrimp catch, except for shrimp exports, is consumed as fresh or frozen raw material. But the shrimping industry especially during trawler operations, catches large quantities of fish which are simply dumped back into the ocean. Much of this dumped fish can be processed to perfectly acceptable products even using such simple technology as salting.

Natural products: The use of aloe vera exudate for skin ailments in the Caribbean is a traditional medicine (Seaforth, Adams and Sylvester 1985). Yet, though we have in our midst an established sector that produces creams and lotions, aloe vera in commercial skin and hair preparations had to come to us via the imported route. Essential oils can be extracted from our spices by simple distillation or solvent extraction. After standardization, such high priced extracts are vital to the food and cosmetic industries.

Fermentation biotechnology: The region has a well-established fermentation technology, i.e. rum, and to our regret, this was not used to build capability and knowledge in fermentation technology. With our sugarcane base, we could easily have moved to citric acid, vinegars, fruit wines, yeast, bacterial gums and polysaccharides and other fermentation alcohols, acids and esters. Rum as a base for other potable products including liqueurs is an infant industry and yet is an industry with a potential for enormous value added.

Realising agroprocessing potential

Agroprocessing has the potential to revolutionize the agricultural sector in the Region as it has done in other parts of the world. The agribusiness sector consists of the raw material producers (primary producers) working together with the agroprocessors to produce a vibrant and profitable industry that is the foundation of real and lasting socio-economic development. To realise this potential, the following are some of the constraints that need to be addressed:

Raw material supply

A processing sub-sector cannot be built around a raw material supply that is variable in respect of quality, quantity and/or price. Experience in the region to date, especially in respect of fruits and vegetables for processing, has fully demonstrated the unreliability of raw material supply. Contract farming has not lived up to its name, the terms of the contract being broken on occasion by both processor and producer.

Pre-processing facilities

The reality of the situation in the region is that there are established processing facilities based on using pre-processed materials. These processors do not want to handle agricultural raw materials and adequate pre-processing facilities need to be established. There may be a role here for producer cooperatives. Such facilities must be so organised and managed that their outputs are standardised in respect of acceptable quality criteria.

Harvest and immediate post-harvest technology

Harvesting of agricultural raw material and the immediate post-harvest handling will play a significant role in determining the utility of that material for processing. This applies whether one is harvesting logs, fruits, flowers or root crops. When to harvest, how to harvest and how to handle are all important considerations to be addressed. Agricultural raw material is living material and is susceptible to major deterioration after harvest.

Processing technology

Practically all of the processing technology now in use is imported, usually from a limited range of sources. The region needs to broaden its net in the search for more appropriate technology, especially from the Far East and our colleagues in the Third World. We also need to develop our own capital goods sector so that we can supply some of our needs in technology. CARIRI is already pioneering work in this area.

Packaging

The packaging industry must be broadened and deepened. The range of packaging now available is too limited and far too expensive to support an aggressive agroprocessing sector. New packaging materials, better designs, more attractive colours, better labels, new technology - all these and more are important especially to an export-led sector.

Marketing know how and information

This area must drive the processing sector into the most relevant areas and along the most appropriate directions. Such information must be derived internally and externally. The products of processing must satisfy real consumer needs. For exporters there are enormous obstacles,barriers and the ugly head of protectionism in the metropolitan markets. The processors must satisfy all legal and other criteria, must understand marketing channels and must be prepared to work assiduously and patiently to achieve success.

Training

Training at every level is a must for success in this area. Such training will be both formal and non-formal and must cover handlers, factory workers, technicians and professionals. Training programmes need to be on-going and must be aimed at having adequate knowledge about raw material, the product, the process and the technology.

Entrepreneurship

I feel that the sector and the system need to encourage, develop and breed a new kind of entrepreneur, now coming out of the technical and professional class rather than the trading community. This would provide a new industrial attitude based on innovation and technical expertise. The region's technical and professional people need to think of themselves as employers rather than as employees.

Collaboration

Collaboration amongst ourselves and with other countries of the South is essential to survival. We must be prepared to share R&D, information, experiences, expertise and to collaborate in joint training exercises. Maintenance of equipment has plagued our societies at every level. This is a problem area that can be solved through collaboration.

Research and development (R&D)

All of the above need to be supported by an adequate level of R&D in all areas. Such R&D must collaborative and must address the real problems of the industry. A vibrant industry cannot be built without a quality and quantity of R&D that is the driving force of new ideas, new products, new processes and information. Such R&D must be multi-faceted in approach and multi-disciplinary in execution. The linkages between R&D and the industry must be close and profound if the results of R&D are to be translated into productive activities.

Summary

Agroprocessing has been responsible for transforming agricultural production and for catalysing the development of agribusiness into a major international activity. It is only through agroprocessing that the real and the full potential of the agricultural sector can be realized. Agroprocessing is the driving force behind agricultural diversification creating wealth, generating employment and leading socio-economic development. In the Caribbean Region, our agroprocessing as now occurs is really only marginal except for a few notable areas. Governments must take the lead to provide the conditions that would encourage agroprocessing, linked to agricultural production, to develop and prosper. The sector must be supported be a high level of collaborative R&D that is closely linked to indentifiable policies for industrial development.

References

Caricom Secretariat (1986) Agricultural and Commodity Review Doc. ASP (0) 86/1/2. Meeting of Agricultural Officials to discuss Agricultural Sector Programme, 10-12 December 1986

Lewis, W.A. (1954)· Economic Development with Unlimited Supplies of Labour, The Manchester School, May, 1954

Paturau, J.M. (1982) By Products of the Cane Sugar Industry, Elsevier, Amsterdam

Seaforth, C.D., Adams, C.D. and Sylvester, Y. (1985) A Guide to the Medicinal Plants of Trinidad and Tobago, Commonwealth Secretariat, London

Thomas, C.Y. (1985) Sugar: Threat or Challenge, IDRC, Ottawa.

Wilson, L. (1986) Background Paper on Cocoa and Coffee, Doc. ASP (0) 86/1/6, Meeting of Agriculture Officials to discuss Agricultural Sector Programme, 10-12 December 1986

Appendix 1

Range of possible diversification products

1. **Based on Sugar**

    (a) Traditional Products
    - Refined sugar products, e.g. white sugar, castor sugar
    - Syrups, including invert syrups
    - Non-alcoholic drinks, including carbonated soft drinks, cordials, non-carbonated drinks
    - Alcoholic drinks
    - Bakery Products
    - Confectionery Powdered drink mixes
    - Food Products

    (b) Non-Conventional Products
    - Fermentation products including organic acids, xanthan gums, antibiotics, dextrans, gluconates
    - Sucroesters, sorbital (thence to Vitamin C) Alcoholic beverages
    - Animal feeds - pelleted for non-ruminants
    - Sugar charcoal
    - Caramel

2. **Based on Molasses**

    Alcoholic drinks including rum, neutral blending spirits
    Other fermentation products, e.g. organic acids, flavour enhancers, bakers yeast, single-cell protein
    Invert syrup
    Animal feeds for both ruminants and non-ruminants

3. **Based on Bagasse**

    Fuel
    Pulp and Paper
    Cellulose
    Board and building materials
    Bagasse-molasses
    Animal feeds

4. **Based on Filter Press Mud**

    Fertilizers and soil conditioners
    Waxes
    Building materials extender
    Animal feeds

5. **Based on Fly Ash**

    Building materials

6. **Based on Cane Juice**

    Fermentation products, e.g. alcohol, vinegar, dextrans, flavour enhancers
    Drinks (alcohol and non-alcoholic)

7. **Based on Cane Tops/Trash**

    Animal feed (ruminants)

CROPS

DIVERSIFICATION ISSUES AND EXPERIENCES

Crop diversification in the Eastern Caribbean: Will it help arrest declines in agriculture?

Klaus de Albuquerque

Department of Sociology and Anthropology, College of Charleston Charleston, South Carolina, USA 29424

This paper attempts to address the central issue of the future of agriculture in many small Caribbean islands, especially given long run declines for various agricultural products, including livestock, the declining contribution of agriculture to the GNP, the annual loss of arable land and the progressive deterioration in the agricultural production/consumption ratio. Forecasts are made with respect to the latter three. Given the dismal picture that emerges from these forecasts, numerous policy measures are suggested to arrest agricultural decline, including land reform, strict ordinances to prevent agricultural land from being taken out of use and crop diversification. Problems (transportation, marketing, economies of scale, etc.) associated with the latter are highlighted.

Keywords: Crop diversification; Small farm systems; Island economies; Agricultural development

Introduction

The decline of agriculture in the OECS, particularly in the Leeward Islands, has been persistent and thoroughgoing, due largely to the emergence of modern growth-intensive sectors, such as light manufacturing, tourism and government employment. These relatively high wage sectors, especially labour intensive tourism, have captured land and labour away from agriculture (de Albuquerque and McElroy, 1983; Richards, 1983), but have failed to truly diversify the insular economies. One of the more pernicious effects of sectoral wage imbalances has been the steady erosion of the small farm sector, which accounts for over 90 percent of all farms and produces most of the domestic fruit and vegetables in the region.

There have been scores of studies, task forces, and inquiries into the state of agriculture in the OECS, initiated by the respective governments, aid donor agencies, non-governmental organizations, and regional and international organizations. The reports, assessments, white papers, and policy pronouncements that have ensued, have all called for, in one way or another, the revitalization of agriculture. They have all pointed to the importance of agriculture in the region by stressing the following:

1. Although overall agricultural production has either stagnated or declined, the agricultural sector is still the dominant sector in a majority of OECS countries.

2. Agriculture provides employment and subsistence to a large number of people in the region.

3. Agriculture is still the major foreign exchange earner in the Windward Islands.

A concerted effort has therefore been made, particularly in the Windward Islands, to commercialize, modernize, and diversify the agricultural sector, and since 1975 there have been in excess of 200 agricultural development projects in the OECS that have had one or more of these major components as their objective. Despite the expenditure of millions of dollars and the many successes, the major structural problems affecting agriculture still remain, and their continued existence raises important policy questions regarding the whole issue of agricultural viability, and consequently food security, in small islands undergoing tourism related economic restructuring.

The state of agriculture in the OECS

Table 1 shows changes in the percentage contribution of agriculture to the gross domestic product (GDP) over a 20 year period. Although the various islands vary considerably in size, resource endowment, climate, and level of development, they have all experienced major declines in the sectoral contribution of agriculture to the GDP.

Table 1 Percentage contribution of agricultural sector to Gross Domestic Product at factor cost for OECS countries: 1961 - 1986[1]

	Country [2]						
Year	Antigua/ Barbuda	Dominica	Grenada	Montserrat	St. Kitts/ Nevis	St. Lucia	St. Vincent/ Grenadines
1961	19.5	32.2	38.9	-	45.8	-	40.3
1962	15.9	32.3	37.8	38.8	43.5	-	38.2
1963	18.2	35.4	34.8	35.4	41.4	33.9	32.5
1964	14.7	35.7	33.5	31.4	40.2	33.9	31.6
1965	-	29.2	38.8	24.0	40.6	-	31.5
1966	4.9	29.2	34.7	19.9	39.3	-	29.4
1967	2.7	29.2	34.6	15.1	39.3	-	30.0
1968	-	28.2	33.1	17.3	37.8	-	28.1
1969	-	27.2	31.7	17.8	35.0	28.1	27.9
1970	-	26.4	21.4	16.9	29.7	22.0	25.0
1971	-	26.4	20.8	16.1	24.4	23.2	24.8
1972	-	28.8	21.3	13.7	24.6	17.2	22.2
1973	-	31.1	23.5	12.8	22.2	18.3	25.0
1974	-	-	24.9	-	-	-	-
1975	-	-	-	5.0	-	-	-
1976	-	-	-	5.1	-	-	-
1977	-	31.8	-	4.7	-	15.6	16.8
1978	-	34.1	-	4.6	-	17.4	18.0
1979	8.1	28.4	-	5.2	19.0	14.7	15.6
1980	7.5	25.5	22.1	4.0	20.4	11.6	13.8
1981	6.4	25.3	22.9	4.5	15.6	9.8	16.8
1982	6.7	24.0	19.1	4.6	20.0	12.6	15.7
1983	7.5	23.1	22.0	-	17.0	13.8	15.4
1984	6.5	22.7	21.3	-	17.2	-	-
1985	5.0	27.9	18.0	5.0	9.5	15.0	19.8
1986	4.6	30.2	18.2	4.5	9.8	16.6	19.5

1) Includes livestock, forestry and fishing. In current prices.

2) Sources: Chernick, (1978), World Bank, (1985), Government of Montserrat, (1985) United Nations, (1988).

As might be expected, the sharpest declines are observable for Antigua/Barbuda with its drier climate, and for Montserrat and St. Kitts/Nevis, the latter plagued by limited available arable land and steep topography. These declines coincided with the phase out of sugar in Antigua and large-scale emigration in the 1960s and tourism growth of the 1970s, which affected all three island states. For the larger and wetter Windwards, these trends were less marked, but equally persistent. By 1986, agriculture's contribution for Grenada, St. Lucia, and St. Vincent/Grenadines had declined to slightly less than half the 1961 level (see Table 1). Only in Dominica, has agriculture's contribution to the GDP remained roughly the same.

Despite declines in Grenada, St. Lucia, and St. Vincent/Grenadines, agriculture still accounts for nearly 20 percent of GDP in the Windwards, mainly because of the continuing importance of traditional export crops.

Corresponding declines in the percent of the population working in agriculture are observable in Table 2.

Table 2 Percent of economically active population working in agriculture(1) in OECS States: 1960 - 1980

Country	Year(2) 1960	1970	1980
Antigua-Barbuda	35.3	10.7	9.3
Dominica	54.5	39.2	35.1(3)
Grenada	43.3	33.3	28.7(3)
Montserrat	50.0	20.1	13.6
St. Kitts-Nevis	48.0	34.1	28.8
St. Lucia	53.1	39.3	30.9
St. Vincent-Grenadines	42.7	29.0	31.8

1) By industrial group
2) Sources: Axline, 1986; Commonwealth Caribbean Census, 1970, 1980-81
3) Census was conducted in 1981.

I have argued earlier that sectoral imbalances in wages have had the net effect of siphoning off labour from the agricultural sector, and that this direct displacement is the single most important factor in the decline of agriculture in the OECS. Declines in the percent of the population working in agriculture were greatest for Antigua/Barbuda and Montserrat. Recent estimates for Antigua, place the economically active population in agriculture at less than 5 percent. While agriculture in the Windwards remains one of the principal sources of livelihood, trends in employment and other data suggest that agriculture might soon be eclipsed by other forms of economic activity such as trade and commerce, construction, or government employment.

Table 3 shows changes in arable and permanent crop land. The greatest changes between 1960-80 occurred in Antigua/Barbuda, Montserrat, and St. Lucia, the more heavily penetrated tourist destinations. Projected declines (1990 and 2000) in per capita arable and permanent crop land are a function of increased population growth, particularly in the face of declining opportunities for emigration. In addition, it should be noted that a lot of arable land, especially in the Leewards, is being diverted to residential and other non-agricultural uses. However, an estimated one third of the arable land in the OECS is not being used or is underutilized, so from the strict standpoint of land availability the potential to expand agricultural production exists.

Table 3 Arable and permanent crop land (hectares per capita) for member OECS Countries, 1960 - 2000[1][2]

	Arable Land and Permanent Crop Land									
	Hectares Per Capita					Percent Change				
Country	1960	1970	1980	1990	2000	1960-80	1970-80	1980-90	1960-2000	1980-200
Antigua-Barbuda	.15	.12	.11	.09	.08	-26.7	-8.3	-18.2	-46.7	-27.2
Dominica	.27	.24	.24	.20	.19	-11.1	0.0	-16.7	-29.6	-20.8
Grenada	.18	.17	.15	.14	.13	-16.7	-11.8	- 0.7	-27.8	-13.3
Montserrat	.25	.17	.09	-	-	-64.0	-47.1	-	-	-
St. Kitts-Nevis	.31	.31	.32	.31	.29	3.2	3.2	-3.2	-6.5	-9.4
St. Lucia	.24	.21	.14	.12	.11	-41.7	-33.3	14.2	-54.2	-21.4
St. Vincent/ Grenadines	.21	.21	.17	.15	.13	-19.0	-19.0	-11.8	-38.1	-23.5
Average	.23	.20	.17	.17	.16	-25.1	-16.6	10.8	-33.8	-19.3

1) Sources: Bouvier (1984), FAO, Production Yearbook (1966, 1970, 1982 & 1984)
2) Comments: Arable and permanent crop land was assumed to remain at 1983 levels for 1990 and the year 2000. Since most of the OECS member countries have recently recorded declines in arable and permanent crop land and will continue to do so, such an assumption yields extremely conservative estimates. There is little hope of reversing the downward trend as the OECS countries have exhausted their ability to develop new agricultural lands. If at all, population increases will have the net effect of diverting arable and permanent crop land to non-agricultural use. Actual and projected declines in per capita arable and permanent crop land are due to increases in population.

Population projections were made by the Population Reference Bureau using the FIV FIV/SIN Sin projection package. For assumptions underlying the particular scenarios see Bouvier (1984). Data for 1990 and the year 2000 were based on scenario "A" for Antigua-Barbuda, "C" for Grenada, and "B" for Dominica, St. Kitts-Nevis, St. Lucia and St. Vincent. In all cases these scenarios assumed declining fertility and emigration.

Although crop diversification has long been proposed as one way to rehabilitate agriculture in the OECS, and there have been major thrusts in this direction, the data in Table 4 indicate that the traditional export crops remain dominant, and in fact, have been reasserting themselves. For example, banana production in the Windwards began to decline in the mid 1960s, but continued to dominate exports until the late 1970s when production began to fall more rapidly (some of this due to the temporary effects of hurricanes David and Allen). Since 1983/84, the Windwards have experienced a banana boom, stimulated by protected and price-supported markets in the United Kingdom and an increase in the real international price of bananas. So, from 1984 onwards, we have seen an increasing shift of productive resources into bananas, or in the case of Grenada, nutmeg. Indeed, farmers in the Windwards did not need much encouragement to increase their plantings of bananas or go back into bananas, as they have always shown a preference for proven cash crops for which well developed extension and marketing systems exist. The dominance of agriculture and of the traditional export crops, in the export picture of the Windwards, is apparent in Table 4. Seventy percent or more of Grenada's and St. Lucia's domestic exports are accounted for by agriculture, and over 90 percent for Dominica. The picture is very different in the Leewards. In Antigua/Barbuda and Montserrat, agriculture's contribution to domestic exports is marginal and all indications are that this will be further eroded. St. Kitts, on the other hand, is experiencing a gradual phase out of sugar production and a boom in tourism, such as occurred in Antigua in the 1960s and

1970s. Labour shortages in the St. Kitts sugar industry, because of sectoral wage imbalances, have necessitated the importation of cane cutters and the use of mechanical harvesters, and at times, a significant portion of the sugar crop has been left unharvested.

Table 4 Value of total and leading exports for OECS member countries, 1976 - 1986 (% of all domestic exports)[1]

Country	Year										
	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986
Antigua-Barbuda											
Total Ag. Exp.				6.7	4.3	4.2	3.1	4.7	5.4	3.7	-
Leading Ag. Exp.											
Dominica											
Total Ag. Exp.	96.2	88.9	83.1	73.7	43.3	55.5	56.0	56.5	56.6	61.1	73.5
Leading Ag. Exp. (Bananas)	61.7	59.0	57.5	46.3	30.9	47.2	47.2	41.3	44.6	50.8	64.8
Grenada											
Total Ag. Exp.				93.4	89.0	80.1	76.5	83.8	92.1	91.7	95.8
Leading Ag. Exp. (Cocoa to 1983 then spices)				48.6	40.1	37.9	25.9	22.0	23.7	25.6	44.3
Montserrat											
Total Ag. Exp.	85.4	35.6	19.1	53.5	25.1	21.5	17.2				
Leading Ag. Exp.											
St. Kitts-Nevis											
Total Ag. Exp.			77.2	71.3	63.0	64.5	66.7	59.9	56.9	44.8	45.5
Leading Ag. Exp. (Sugar)[2]			77.2	70.7	62.6	64.1	66.1	59.9	56.8	44.8	45.5
St. Lucia											
Total Ag. Exp.[3]		57.2	58.7	60.1	41.1	47.9	50.5	57.5	59.7[5]	67.0	74.1
Leading Ag. Exp. (Bananas)		45.9	48.8	48.3	31.2	39.9	41.5	49.8	52.2	63.5	69.7
St. Vincent-Grenadines											
Total Ag. Exp.[4]		66.0	72.4	74.1	76.2	72.3	56.5	54.0[5]	41.2	48.3	48.4
Leading Ag. Exp.		56.0	42.0	31.9	31.2	34.9	27.0	24.4	22.4	27.2	27.4

1) Sources: Government of Montserrat, (1984 & 1987), World Bank (1985 & 1988)
2) Includes molasses.
3) Includes unrefined and refined coconut oil.
4) Includes flour and mill feed.
5) Preliminary estimates.

The ratio of the value of imports to exports (Table 5) provides some rough measure of food security. OECS countries like Antigua/Barbuda and Montserrat, with ratios greater than 1.0, are importing more agricultural products than they are exporting, and the level of dependence on food imports in these two territories appears to be increasing.

Table 5 Ratio of value of agricultural imports to agricultural exports for OECS member countries, 1969 - 1986[(1)(2)]

Year	Country						
	Antigua/ Barbuda	Dominica	Grenada	Montserrat	St. Kitts/ Nevis	St. Lucia	St. Vincent/ Grenadines
1969	38.4	0.3	0.7	52.0	0.5	0.4	0.9
1970	3.7	0.4	1.0	61.0	0.8	1.0	0.9
1971	2.8	0.4	1.5	39.5	1.0	1.0	1.2
1972	30.2	0.5	1.3	49.0	0.8	0.9	1.3
1973	28.1	0.6	1.1	26.8	0.7	1.0	1.6
1974	30.4	0.7	1.2	32.5	0.5	0.9	1.8
1975	13.8	1.1	0.8	11.6	0.4	1.1	1.3
1976	24.3	1.1	0.7	8.7	0.4	1.1	1.0
1977	23.1	1.0	0.6	193.0	0.5	1.2	1.1
1978[(3)]							
1979	24.1	1.0	.7	222.0	0.6	1.0	1.3
1980	29.5	2.9	1.0	264.0	0.5	1.2	1.4
1981	19.0	1.4	1.0	46.9	0.6	1.3	0.9
1982	29.2	0.9	1.3	277.0	0.7	1.1	0.9
1983	29.7	0.7	1.1	277.0	0.9	1.0	0.7
1984	29.4	0.8	1.3	284.0	0.8	0.8	0.7
1985	59.3	0.8	1.3	-	1.3	0.9	0.5
1986	46.6	0.5	1.0	-	1.0	0.6	0.4

(1) Sources: FAO, (1971, 1977, 1984, & 1987)
(2) Imports and exports of total agricultural products (food and animals, beverages and tobacco, crude materials, animal/vegetable oil, fish and fishery products, forest products, and agricultural requisites). A ratio greater than 1.0 indicates that a country is importing more agricultural products that it is exporting.
(3) Data for 1978 are not comparable.

The banana producing Windwards, by contrast, have seen recent declines in this ratio to below 1.0, primarily because they are flush from the so called "green gold" windfall. The eventual loss of the protected UK market will leave these islands extremely vulnerable, since they will be unable to compete with more efficient banana producers. One cannot think of a greater impetus towards agricultural diversification, and especially non-traditional export crops, than the threatened loss of the protected UK market for bananas, yet all indications are, that farmers are still rushing to cash in on the windfall. Clearly, the uncertainty associated with agriculture as a livelihood in the OECS, is prompting farmers to invest in short term quick cash crops as opposed to long term non-traditional crops of unproven market value.

With the rapid modernization of the OECS economies, food imports as a percentage of total imports are decreasing (Table 6), mainly because of the increasing importance of high value imports such as consumer durables and automobiles. Yet until the mid 1980s, food imports remained the single largest item in the import bill for Dominica, Grenada, and St. Vincent and the Grenadines. However, the absolute value of food imports in the OECS is growing every year and this drain on the treasury of the individual governments, has prompted periodic calls for food import substitution policies. Such policies can only be based on comprehensive and successful agricultural diversification programmes. However, as I have observed in this paper, Antigua/Barbuda, Montserrat, and St. Kitts/Nevis have been diversifying out of agriculture into tourism and to a lesser extent assembly type manufacturing, while in the Windwards there has been a greater concentration of effort in the production of the traditional export crop.

Table 6 Percentage of food imports in the total import bill for OECS member countries, 1976 - 1986[1][2]

	Country						
Year	Antigua/ Barbuda	Dominica	Grenada[3]	Montserrat	St. Kitts/ Nevis	St. Lucia	St. Vincent/ Grenadines
1976		36.3	32.3	25.0			
1977		32.9		27.3		22.1	30.7
1978		34.0		23.2	24.4	20.7	37.9
1979	35.0	17.5	30.6	21.3	20.9	19.1	36.9
1980	19.9	21.5	28.9	20.9	18.9	18.9	35.0
1981	23.0	25.2	28.2	19.7	19.5	20.4	31.8
1982	19.6	26.5	27.5	18.5	19.6	21.1	32.4
1983	22.4	24.4	24.2	19.9	19.6	22.8	29.0
1984	15.1	25.1		24.3	20.5	20.9	28.3
1985	13.8	21.9	24.8	20.8	21.4	24.8	26.5
1986	11.8	25.1	21.9	20.5	17.9	23.1	22.6

(1) Sources: Gov't of Grenada, (1981); Gov't of Montserrat, (1984); World Bank, (1985 & 1988)
(2) Includes beverages and tobacco for Dominica and St. Vincent, and for St. Lucia for 1985-86.
(3) Food imports represented the single largest item in the import bill, but have been supplanted by manufactured goods since the mid 1980s.

Further evidence of the progressive marginalization of agriculture in the OECS can be gleaned by comparing selected indicators from the various agricultural censuses (the 1946 and 1961 West Indies Census of Agriculture, the 1972 and 1985/86 census for St. Vincent/Grenadines, the 1975 and 1986 census for St. Kitts/Nevis, the 1972 Montserrat census, the 1981 Grenada census, the 1976/77 Dominica census, the 1984 Antigua/Barbuda census, and the 1986 St. Lucia census). Invariably, comparisons across time of various indices, demonstrate the declining importance of agriculture as a livelihood: the increasing fragmentation of holdings, increases in the percentage of holdings without land, a greater percentage of part-time farmers (69% of all farmers in Antigua in 1984 reported themselves as part-time farmers), a greater number of days spent annually on off-farm labour, diversification into less labour intensive activities (livestock and tree crops), the increasing median age of farmers (in Grenada in 1981, 22 percent of the farmers were above age 65), and so on.

Constraints facing agriculture in the OECS

How do we explain the relatively poor performance of the agricultural sector in the OECS and the progressive marginalization of agriculture in the Leewards? Any explanation must inevitably adumbrate the structural/institutional and other constraints facing agriculture in the OECS. It is a familiar litany: the Moyne Commission Report (1938 -39), O'Loughlin (1968), and the First World Bank survey (Chernick, 1978).

I have attempted to outline these constraints below, but in reviewing them one must keep in mind that these constraints are not discrete or isolated from each other, but interact and affect each other in numerous ways.

Resource constraints

These include steep topography, heavily deforested hillsides, eroded soils, shallow soils, limited arable land (Leewards), problems related to rainfall reliability (droughts are common in the Leewards), long dry seasons in the Leewards (effects availability of forage for livestock), inadequate surface and ground water, etc.

Land constraints

Problems relating to secure tenure, excessive fragmentation of holdings, small uneconomic holdings, land distribution, the rising cost of land as it is competed away to other uses (residential developments and tourism), etc.

Demographic constraints

These include the increasing average age of farmers and the corrosive impact of external migration and rural to urban migration.

Agricultural and socio-economic constraints

Low yields, high cost of production because of high cost of inputs, declining government expenditure on agriculture, overburdened and underfunded extension services, poor availability of subsidized inputs (seeds, fertilizers, tractor services, etc.), little involvement of farmers in the planning process, rudimentary marketing structures for non-traditional crops, marketing boards that have become inefficient or unviable, lack of adequate storage, processing and packaging facilities, predominance of small farms making mechanization and diversification difficult, the increasingly part-time nature of farming, poor to non-existent agricultural reporting systems, inadequate market information, poor transportation services, inadequate rural infrastructure (feeder roads etc.), economies of scale problems, competition from low cost imports, increasing resource competition from more profitable higher wage sectors, uneconomic pricing policies, limited access to capital markets, etc.

Political constraints

Political considerations in the distribution of government land, politicians who are less responsive to farmers than they are to other occupational groups (taxi drivers, teachers, government employees), lack of truly coordinated local and regional agricultural policies, little control over external markets, nepotistic and highly personalistic politics, etc.

Is crop diversification the answer?

Given the above constraints, which have historically plagued caribbean agriculture, is crop diversification the answer? Crop diversification is nothing new, indeed inter-cropping has been widely practiced in the Windwards and the whole structure of production is quite diversified. What is perhaps more correct to say, however, is that diversification has taken on a new urgency, and that it often means different things in different OECS countries. Currently (1987), there are three generally agreed upon definitions of diversification in the OECS. The first involves intensification/rehabilitation of traditional export crops. The second sets as its goal, production for local consumption including the growing tourist market. The third, focuses on the production of non-traditional exports.

If diversification is not new, has it really helped? The data presented in this paper would indicate not. Practitioners in the field would argue that this is because diversification has been approached the wrong way. The arguments are familiar: efforts have concentrated on the production rather than on the marketing side; projects have not been implemented in a consistent manner and; the appropriate political commitments have not been made. Apart from these arguments, there are some even more fundamental problems that take us back to the aforementioned constraints on agriculture in the OECS.

First, most diversification schemes have been based on the mistaken assumption that all that was necessary was the provision of a critical quantum of inputs and farmers would do the rest. In the absence of the necessary structural/institutional changes for diversification to succeed, farmers have been unwilling to give up traditional cash crops for crops with untried market potential. This is not to suggest that farmers in the OECS are not responsive to diversification efforts, since they would like to distribute their market exposure, but as realists, they are concerned about the future of agriculture in the region. Accordingly, they have been diversifying out of agriculture.

Second, the economies of scale problem, the bane of the OECS countries, is exacerbated by diversification.

Third, the predominance of small farms makes diversification doubly difficult, as there is a lack of concentration in certain crops in certain areas.

Fourth, many of the nontraditional crops that are being tried, do not enjoy captive markets, and in some cases may encounter restrictions (mangoes) or stiff resistance from local growers (flowers) in metropolitan markets.

Fifth, most diversification schemes have generally been short term donor driven projects. Each new project adds an additional drain on the already overburdened personnel and other resources of Ministries of Agriculture, etc. In addition, when a project is completed, there is seldom any follow-up since most of the effort is now devoted to new projects.

Sixth, there has been a general inability to marry successfully the various stages/processes (transportation, storage, packaging, processing, marketing) that are necessary to move agricultural produce from farmer to consumer, higglers and agricultural marketing boards notwithstanding.

Undoubtedly, there are many more reasons that might explain the general failure of diversification to redress some of the fundamental issues concerning the long-term viability of agriculture in small tropical islands. These reasons aside, the search for technological and production/marketing solutions should not blind us to the consideration of such public policy initiatives as restrictive legislation to promote rural retention, the permanent zoning of prime agricultural land, rural protection legislation, tax benefits for farmers, higher tax rates for unproductive/idle farm land, import substitution for selected food items, etc., since fundamentally, agriculture in the OECS will have to be retained on other than commercial profitability criteria.

References

Axline, A. (1986) *Agricultural Policy and Collective Self-Sufficiency in the Caribbean*, Boulder, Colorado, Westview Press

Bouvier, L., (1984) *Antigua/Barbuda, Dominica, Grenada, St. Kitts/Nevis, St. Lucia, and St. Vincent/Grenadines*, Occasional Series: The Caribbean, Washington, D.C.: Population Reference Bureau

Chernick, S., (1978) *The Commonwealth Caribbean: Report of a Mission Sent to the Commonwealth Caribbean by the World Bank*, Baltimore, Johns Hopkins University

Commonwealth Caribbean Census Regional Project, (1970) Volume 4

Commonwealth Caribbean Census Regional Project, (1980-81) Volume 3 OECS countries, Kingston, Jamaica, Statistical Institute of Jamaica.

de Albuquerque, K. and McElroy, J. (1983) "Agricultural Resurgence in the U.S. Virgin Islands," *Caribbean Geography* 1(3) 121-132

FAO, (1966, 1970, 1982, & 1984) *Production Yearbook*, Rome, Italy, Food and Agricultural Organization

FAO, (1971, 1977, 1984, & 1987) *Trade Yearbook*, Rome, Italy, Food and Agricultural Organization

Government of Grenada, (1981) *Annual Abstract of Statistics, 1979*, St. Georges, Statistical Department, Ministry of Finance

Government of Montserrat, (1985) *Statistical Digest, 1984*, Plymouth, Statistics Department

______, (1987) *Trade Statistics, 1987*, Plymouth, Statistics Department

O'Loughlin, C., (1968) *Economic and Political Change in the Leeward and Windward Islands*, New Haven, Yale University Press

Richards, V., (1983) "Decolonization in Antigua: Its Impact on Agriculture and Tourism," in: *The Newer Caribbean* (Ed. Henry, P. and Stone, C.) Philadelphia, Institute for the Study of Human Issues.

United Nations, (1988) *Agricultural Statistics, Caribbean Countries*, Vol. VIII, Port of Spain, Trinidad, ECLAC

World Bank, (1985) *Country Economic Reports for Antigua-Barbuda, Dominica, Grenada, Montserrat, St. Kitts-Nevis, St. Lucia, St. Vincent-Grenadines*, Washington, D.C., World Bank

How Jamaican Small Farmers view crop diversification

John Rashford

Department of Sociology and Anthropology, College of Charleston
Charleston, South Carolina 29492

There are many ways to look at the idea of crop diversification, and one perspective that should not be omitted is the traditional view of the farmers who are the object of various programmes aimed at agricultural development. The way Jamaican farmers traditionally think about crop diversification is primarily expressed in relationship to the practice of intercropping-the simultaneous growing of two or more crops in the same field. This paper looks at the cultural concept of crop diversification that is implicit in the practice of intercropping. For Jamaican farmers, the basic objective of this method of cultivation is not only efficient production but social independence.

Keywords: Crop diversification; Intercropping; Jamaica

Introduction

There are many ways to look at the idea of crop diversification, and one important perspective that should not be omitted is the traditional view of the farmers who are the object of various programs aimed at agricultural development. The way Jamaican small farmers think about crop diversification is primarily expressed in relationship to the practice of intercropping - the simultaneous growing of two or more crops in the same field. Today, a great variety of vines, herbs, shrubs and trees are intercropped in yards and fields throughout Jamaica and the majority of these plants have come to the island over the past five hundred years from all parts of the world. This paper looks at the cultural concept of crop diversification that is implicit in the practice of intercropping. For Jamaican farmers, the basic objective of this method of cultivation is not only efficient production but social independence.

For many Jamaican farmers, the cultural concept of crop diversification that is implicit in the kind of intercropping they practice, often results in what is referred to as a "food forest". According to the 1973 Agricultural Census (Vol 1, Part B), food forest was:

> *"The definition given to cases where a canopy of tall economic trees existed (breadfruit, star-apples, mango, avocado pear, etc.) in association with or without a lower canopy of cocoa, coffee, citrus and other small trees and crops, and in spaces where the light permits crops such as kale or calaloo".*

This food forest which is characteristic of the wetter parts of the island and is especially associated with the land around dwellings has also been identified in a number of other ways. Adams (1971) described it as an "artificial woodland" and an "arboretum" while Money (1971) saw it as a "tangle of productive vegetation". Clarke (1974) referred to it as a "polyculture" and as "mixed planting" and in a (Jamaica) Daily News article (Anon, 1976) it was identified as a "tropical jungle garden".

The basis for traditional mixed crop farming

If the cultural attititude toward crop diversification is ideally expressed in the traditional practice of food forest intercropping, then we must ask ourselves why Jamaican small farmers engage in this particular form of cultivation. In this paper I shall argue that food forest intercropping (especially in the form of food forest) is important to Jamaican farmers precisely because it allows them to accomplish many objectives simultaneously. These objectives can be divided into two basic types: (1) to produce efficiently and without interruption, a diversity of products for household use and for sale by growing different species and varieties of wild and domesticated vines, herbs, shrubs and trees and (2) to do this as the basis for a relatively independent way of life, free from forced labor and from dependence on charity and state welfare.

Much of the discussion of why Jamaica small farmers practice crop diversification through food forest intercropping has focused on the various ways in which it is efficient as a system of cultivation and not on its social and cultural value (Edwards, 1961). Here let me list quickly the reasons associated with efficiency that are usually given.

Efficiency in production identifies considerations such as the most productive use of labour; the intensive use of available space and the best use of the soil and other natural resources such as light, water and various topographical and microclimatic conditions; maintaining the fertility of the soil and preventing its erosion; insuring against risks resulting from pest, disease, theft, hurricane, drought, strong winds and fluctuating market demands; maintaining a favourable level of continuous harvest; the control by natural means of weeds and pests and other competing species that greatly reduces or eliminates the need for expensive and dangerous insecticides, herbicides and other highly poisonous chemicals; and the production of a diversity of medicinal, spice, beverage, food and timber crops for household use and for sale. This aspect of intercropping has long been recognized by researchers such as Mintz (1955), Edwards (1961), Blaut et al (1959), Miracle (1967) and others. Here the concern is largely with the ecology of intercropping and the techniques, technology and economics that are applicable to this kind of cultivation.

Social, political considerations

While it is easy to understand the various ways in which food forest intercropping is an efficient system of cultivation, the cultural, political and historical context of this traditional practice has not been as well appreciated; yet, it is clear that tradition and politics viewed in an historic framework are especially important in understanding the motivations of Jamaican farmers. In describing the history of small cultivators in the Caribbean, Marshall (1972) provides us with the appropriate context within which we can better understand the cultural basis of food forest intercropping as the traditional form of crop diversification practiced by many Jamaican farmers and by small farmers elsewhere in the Caribbean:

> *"In the main the peasantry's development has been characterized by economic activity-persistent efforts, both on an individual and co-operative basis, to secure an independent existence through cultivation of the soil outside of the dominant plantation society and sugar economy".*

In studies dealing with the history of small farming in Jamaica, it has long been recognized that owning land meant more than just food; it meant above all, economic independence and the possibility of a dignified social life. Land, through crop diversification, meant the ability to produce a wide variety of one's needs which would in turn "free" one from complete dependence on an unsure market or on hostile social relationships. Food forest as a system of crop diversification meant a choice for a direct relationship to nature through self-provisioning.

I have been studying cropping patterns in rural Jamaica since 1975. At fist, when I asked small farmers why they practiced forest cropping, I expected them to mention only the things related to efficiency described earlier. It was surprising to hear many of them say that they practiced food forest intercropping not only for these reasons, but for other reasons that are not often mentioned in the literature. They wanted to be free of the market so they would only have to "buy a few things"; they wanted to be able to "save money" to help themselves, and to "be independent". In fact many farmers did not see themselves as practicing a system of food forest cultivation. Some were unsure of such terms as intercropping, mixed cropping and multiple cropping and did not fully understand what I meant until I asked why they planted all the different plants all "mixed up" in the same field.

In my effort to understand the traditional perspective of Jamaican small farmers, I found it more useful to ask them why a particular plant - say a guava tree - was planted just where it was and not somewhere else. When the question was put to them this way, the answers were always precise and very enlightening. Some trees like pimento, mango and various timber trees grew where they did because they were volunteers and the seedlings were protected. June plum trees were planted so that the ripe fruits would fall on soft soil rather than on hard limestone rock which would make them worthless for marketing. Yams were planted around trees so that poles on which the vines could climb would be rested against the tree trunk. Dasheen were planted in wet areas. Other crops were planted in areas because the soil was good or bad or because the location was sunny or shady or because they were less likely to be destroyed by animals or stolen by people passing by, or damaged in the harvesting of other crops. There were many reasons why individual plants were located in particular areas but the overall reason for practicing this form of crop diversification was always related to the broader picture of social and economic independence.

Crop diversification and cultural orientation

Let me conclude by saying that a comprehensive approach to crop diversification, as an important component of a policy aimed at agricultural development, must take into account the cultural orientation of the farmers involved. I hasten to add that this is clearly not a new idea. In fact, it is by now a well recognized concept that has long been accepted. For example, Oliver, who was very familiar with Jamaican agriculture, expressed this point well, as early as 1929, when he wrote (Oliver, 1929):

> *"The Government of Jamaica began its attempts to improve the African peasant agriculture of the island by direct methods: setting up demonstration plots, sending Kew-trained gardeners to lecture; distributing pamphlets. Such measures were as ineffectual as the like have been when attempted by the Board of Agriculture in this country for the improvement of British farming. The contempt of the negro planter for all this kind of "buckra foolishness" was hardly less complete than is that of the British farmer for Whitehall agriculture. It is a mistake to suppose that British-trained*

agriculturists can see at a glance what is wrong and what is right with African methods, the product of long traditional experience. Instructors had to be found who did not appear as officers of the State or agents of the employing class, but were men who understood and sympathized with the lives of the people and loved to work with them. They proceeded experimentally, not on Government demonstration plots, which to the negroes meant nothing, but by inducing them on their own grounds to try methods of improving things good and useful for themselves".

The idea that the farmer's culture must be taken into account is well known and generally accepted but it is not as widely applied as I think many people believe. That is why in his review of David Edward's classic study of Jamaican small farmers, Augelli (1962:372) wrote:

"Edwards focuses on items which are generally given a cavalier treatment by geographers. These include such potentially important criteria as farmers' life histories, their social positions and relations, the ways in which the farmer learned his farming techniques, the influence on managerial decisions exerted by the farmer's wife and the community in which he lives, the financing schemes involved in production, and the psychological reaction of farmers to given economic conditions and to potential change".

Of the many ways to look at crop diversification, the cultural view of Jamaican farmers which is expressed through the traditional practice of food forest intercropping is one perspective that should not be omitted. It is certainly an important aspect of our concern with crop diversification from a national point of view, especially when our concern is linked, as it usually is, to a preoccupation with broadening the basis of export production. Small farmers are already major contributors in this regard, they are capable of doing a great deal more.

References

Adams, D.C. (1971) The Blue Mahoe and Other Bush: An Introduction to Plant Life in Jamaica, McGraw Hill Far Eastern Publishers, Ltd., Singapore

Anon., (1976) "Praedial Larceny - One of the Most Difficult Problems of Farming", Daily News, Jamaica, Jan. 14, 1976

Augelli, J. P. (1962) Review of 'An Economic Study of Small Farming in Jamaica, *Economic Geography*, 38(4) 372-373

Blaut, J.M. (1959) The Ecology of Tropical Farming Systems of the New World, Pam American Union, Washington

Clarke, C. (1974) Jamaica in Maps, University of London Press, U.K.

Marshall, W. K. (1972) "Peasant Movements and Agrarian Problems in the West Indies: Aspects of the Development of the Peasantry". *Caribbean Quarterly* 18(1) 36-46.

Mintz, S. (1955) The Jamaican Internal Marketing Pattern: Some Notes and Hypothesis, *Social and Economic Studies*, 1 273-281.

Miracle, M. (1967) Agriculture in the Congo, University of Wisconsin Press, Wisc. USA.

Money, D. C. (1972) Patterns of Settlement: Human Geography in Color. - Evan Brothers Ltd., London

Olivier, Lord (1929) The Improvement of Negro Agriculture, *Journal ofthe Royal Society of Arts*, 77(3980) 396-419

Extension implications of agricultural diversification in the OECS States

Dunstan A. C. Campbell

Caribbean Agricultural Extension Project (CAEP), Ministry of Agriculture, Castries, St. Lucia

The unstable economic situation of monoculture due to markets and weather conditions has pushed and is pushing the policy makers of the OECS States to adopt a new strategy of agricultural development - crop diversification. The programme of crop diversification varies from island to island and at times crop diversification and import substitution are viewed in the same light. As a result of this new thrust, extension programmes are being oriented to meet this need. However, the implementation of these programmes is hindered by: (a) the high price currently received for bananas; (b) the unavailability of a technological package with a strong economic component; (c) the unsuitability of the programme to meet family goals of a continuous cash flow; (d) the unwillingness of farmers, especially the young farmers, to invest in crops with long gestation periods; (e) the inability of extension workers to fully internalize the economics of crops with long gestation periods, i.e., discounting techniques, and thus to deliver an effective programme; (f) the goals of most crop diversification programmes - e.g. to have a certain number of trees planted within a certain time - conflict at times with land capability and land use policy. There is need for a re-examination of crop diversification programmes given their importance to the economy of the islands.

Keywords: Diversification; Extension services; Farmer goals.

Introduction

The economies of the Organization of Eastern Caribbean States (OECS) are based on agriculture which not only provides the greatest share of GDP but also employs the highest percentage of the labour force. In these states, agriculture must also be seen as an important contributor to the socio-cultural life, because the majority of people engaged in agriculture regard it not only as a business, but also as a way of life.

All OECS states are now developing and implementing agricultural diversification projects because they see a threat to their economies which for the most part are based on a few commodities that have unpredictable markets. This new project direction is especially true in states that practice a monoculture which is susceptible not only to market fluctuations but also to the vagaries of the weather. If the threats to these economies were to materialize, the consequences would be economic as well as social - destroying the very social fabric of the societies. Hence, the importance of agricultural diversification cannot be over-emphasized.

Participation of two groups of people is critical for successful implementation of any diversification project. This paper presents a sampling of such projects, highlighting the participation of the two groups in terms of their abilities to understand project goals, to be convinced, to deliver and to implement the recommendations.

Agricultural diversification projects

There is a clear difference between diversification projects in the Windward and Leeward islands. The Windward islands are mainly tree crop oriented (for example, coconut, coffee, and non-traditional fruits such as soursop, pawpaw, mangoes, avocado, and passion fruit) whereas the Leeward islands are livestock oriented. One reason for this difference is climate. The climate in the Leewards is much drier than that in the Windwards and readily supports a livestock production system.

Agricultural diversification programmes are also either export oriented or import substitution oriented. In the Windwards for instance, vegetable and livestock production are primarily import substitution projects, while tree crops are for the export market. In the Leewards however, vegetable and livestock production are both for export and home consumption (import substitution). The projects with export orientation as their major goal are funded mainly by foreign sources (Table 1). The main funding agencies are the British Development Division (BDD), European Development Fund (EDF), United States Agency for International Development (USAID), Organization of American States (OAS), Canadian International Development Agency (CIDA), International Bank for Reconstruction and Development (IDBRD) and Caribbean Development Bank (CDB).

Each of the above funding agencies has its own agenda and vision of development and as this paper will point out later, the agenda and/or vision does not always fit into farmers' goals and visions. This is often a dilemma for these well intentioned programmes. Following are some examples of diversification projects in the Windwards and the Leewards.

Grenada

Agricultural rehabilitation and crop diversification project: This project is aimed at revitalizing the agricultural sector through: (a) rehabilitation of the existing major export crops - nutmeg, bananas, sugar cane and; (b) introduction of new crops for export - mainly non-traditional fruits such as mango, avocado, soursop.

The project was developed without consultation with the farming community and as a result, the implementation is proving to be more difficult than expected. Although there is island wide increase in activity in the production of the crops targeted for rehabilitation and revitalization under this project, this increase cannot be said to be as a result of the project. The price of nutmeg went up, making it more profitable to harvest and maintain nutmeg trees. Also the price of bananas is now regarded by farmers as attractive, thus farmers are going into banana production, regardless of the threat of moko disease on the island.

Sugar cane, however, has been experiencing problems. The farmers are being asked to grow sugar cane but the infra-structure for production is not in place. For example, roads, land and tractor service. The extension officer is placed in the predicament of convincing the farmer to go (once again) into the production of a crop although the necessary support is lacking. In some cases, the extension officer is asked to explain the land tenure situation - answering the question, "why is the Government encouraging us to go into sugar cane production when it is not willing to regularize our land situation?" In most cases the extension officer is unable to provide answers because these decisions are not taken at his level or, as is so often the case, the decisions are not communicated to him.

Table I List of some agricultural diversification projects in the OECS (CIDA 1987)

Country	Project	Funding (Executing) Agency
Antigua/Barbuda	Livestock Improvement 1984 - 1987	USAID
	Income Generation (Production of sheep, goats and rabbits)	OAS
	Bethesda Vegetable Production	BDD
	Vegetable Production	Taiwan Govt.
St.Kitts/Nevis	Yam Multiplication	BDD (CARDI)
	Livestock Improvement	BDD
Montserrat	Separate Irrigation projects at various locations (i.e.):	
	Lees	CIDA
	Trans Farms	EDF
	Rodericks' Small Farms Irrigation Scheme	USAID
Dominica	Tree Crop Diversification Programme Phases I, II & III	BDD
	Coffee Development - Phase I	BDD
	Coconut Rehabilitation and Expansion	CIDA
	Lime Rehabilitation	EC
St. Lucia	Tree Crop Diversification Programme Phases I & II	BDD
	Cocoa Rehabilitation Programme	USAID
	Black Bay Vegetable Project	UNDP (CARDATS)
St. Vincent	Mango Top Working, Phases I & II	BDD
	Livestock Development (Diamond Estate)	EC
Grenada	Agricultural Rehabilitation and Crop Diversification	IBRD/CDB
	Cocoa Rehabilitation	CIDA

On the other hand, the introduction of the non-traditional fruits for export - mango, avocado, soursop - is being implemented without much setback. This is so, because of the lucrative Trinidad market (although this market is now dwindling). In fact, without any campaign from the Ministry of Agriculture the hucksters generated such a thriving trade that in 1985 the export of these fruits was the largest contributor to agricultural export earnings of EC$17 million. This was a dramatic increase over the EC$3.8 million earned in 1982.

The extension worker's task was made easy because of the available market for fruit crops. There is however, the problem of farmers planting these fruit trees on lands which are better suited for another crop. This problem goes beyond the extension worker's control because he has no jurisdiction over the farmer's private property. The situation is more controllable when a subsidy is involved. (This was not the case in Grenada.) For instance, if the farmer does not follow the recommendation, then the subsidy would not be given. It is important to stress here that subsidy is not a panacea. It is known that farmers on receiving subsidy either neglect the plants or remove them to other areas.

The cocoa rehabilitation project: Grenada's cocoa rehabilitation is aimed at reintroducing new vigour into the cocoa industry. The project is island wide and is run separately from activities of the other cocoa organization - the Cocoa Growers Association.

To qualify as a participant in this project, the farmer has to destroy all his cocoa plants in the specified area to be rehabilitated. Clonal plants along with fertilizer and other inputs are then supplied to him. The rehabilitation project has its own extension officers. These officers perform both regulatory and educational functions.

So far, the project has had its setbacks. Farmers are resisting the total destruction of all plants in the project area. These farmers do not get their supply of plants. In fact, the situation got out of control because while the farmers were asking for plants and were finding them difficult to obtain, the project propagation station was dumping overgrown plants because extension workers claimed that farmers were not ready to receive them. This can clearly be seen as a conflict between goals and agenda of project administrators and farmers. The situation also created conflict between farmer and extension worker.

Dominica

Tree crop diversification programme: This programme, like Grenada's Agricultural Rehabilitation and Crop Diversification project has national implications. The programme is aimed at the introduction of non-traditional fruit trees to farmers' holdings. The project has a target acreage and as such, the number of plants in the ground or distributed becomes an important consideration for project success. Although other factors like proper site selection, correct spacing and maintenance are part of the project staff responsibility, these factors become difficult to control once the plants are issued to the farmers. In fact, preliminary results from this project indicate that farmers are doing the minimum to obtain whatever subsidy is provided. At the end of the subsidy, most of the recommended practices are discontinued. The project extension staff is finding it difficult to convince farmers to continue maintaining their orchards. The problem here is a question of conviction on the part of the farmers. Apparently, farmers entered the programme for the subsidy provided, especially the cash subsidy. This cash subsidy provides an important source of working capital for the farm.

Antigua

Bethesda Vegetable Production Project: This project is aimed at using irrigation techniques in the production of vegetables for the export and local markets. The project has important diversification implications for Antigua because of the strong dependence on the livestock sector. The success of this project, like any other diversification project, depends heavily on the market. Extension workers' involvement as a catalyst to the production of these crops is therefore critical because of the uncertainties of markets.

The above examples describe diversification initiatives that were developed outside of the farming community and the farmers' system. Diversification also occurs within the farming community without outside intervention. An example of this can be seen in Grenada, where there is a definite shift in cropping systems among farmers.

Young farmers are more prone to accepting short term crops - for example, vegetables and bananas. As farmers grow older they shift their cropping system to more permanent crops such as cocoa and nutmeg; the reason being greater security in their old age.

Implications for Extension

Because of the different types of diversification in the OECS states, the implications are obviously different. In general though, initiatives from within are more easily handled by extension agents when the farmers have themselves already taken the decision to diversify. The task then is one of guiding the farmers to make the best possible use of the land and return to capital investment.

Diversification initiatives from the outside are fraught with problems. In the Windwards, selling diversification today is extremely difficult if the crop involved is not bananas. In St. Lucia, where banana is the main crop, tree crop diversification programmes are proceeding at snail's pace, even though subsidies are given out. Farmers are more interested in the immediate benefit that can be derived for an enterprise. Many, if not all, of the crops introduced do not satisfy the farmer's objective of a steady cash flow. From the farmer's point of view, the substituted crop must provide that steady cash flow. The longer the gestation period of the substituted crop, the more difficult it will be for farmers' acceptance.

Further, extension officers are not adept in discounting techniques, a tool necessary for analysing crops with long gestation periods. The Caribbean Agricultural Extension Project (CAEP) has been emphasizing these techniques during its annual in-service training programme in the Windwards and more recently during its Farm and Home Management Training. However, to date, one can say that only the surface has been touched. The problem therefore is that extension agents have not fully internalized the economics of crops with long gestation periods. In fact, the economic component is seldom, if at all, highlighted for extension workers.

A review of most diversification initiatives in the OECS states would indicate that the economic benefits to the farmer are left out. None of the project promoters are giving extension workers clear indications of cost and benefits. The projects are being sold as "something good for the nation". Such a project marketing pitch is not enough and is creating serious implementing problems. In some instances, not even the markets for the introduced crops are clearly worked out for example:

- where would the Windward islands sell their mangoes and avocados? or, the Leeward islands their vegetables?
- who will be responsible for the organization of the market?

These are some questions that farmers are asking in response to tree crop diversification initiatives.

Finally, one observes that most tree crop diversification projects are creating land use problems which go beyond extension. The fact is, that numbers of plants and acres are the main objectives of the project. Extension officers are therefore motivated to distribute as many plants as possible, thus giving an indication of acreage planted. It is not uncommon to find that these plants either end up in a storage place or are planted at incorrect spacing and incorrect location. At the same time, the project can be seen as successful in terms of desired project output - acreage to be planted was attained. Yet, serious long term effects on national development are likely as most of the more arable flat land will be taken up by tree crops and the slopes will be left to be farmed.

Conclusions

Agricultural diversification initiatives should continue to be an important agenda item in agricultural development in the OECS states. The aim of these initiatives is to establish economic stability within the region. However, development and implementation of projects should take into consideration the local socio-economic and cultural dynamics within the various states. The differences are sufficient to justify separate considerations.

There should be dialogue among farmers, extension workers and policy makers before and during project development and implementation. A training programme should be mounted to allow for sensitization and internalization of the technical and economic ramifications of these programmes. Finally, diversification projects should be designed so as not to create a burden for the existing extension organization at the completion of the project. Project staff should be easily absorbed into existing extension organizations.

Reference

CIDA, (1987) Review of Agricultural Diversification in the OECS, Vol. 2. Published by Canadian International Development Agency, Ottawa

Crop Diversification: Some possibilities and some problems

Lawrence W. Lewis

Agricultural Missions, 475 Riverside Drive, NY 10115, USA

Modern technology has moved so fast that most of the agricultural commodities produced during colonial times are no longer economically produced in the Caribbean. People have neither been prepared for non-traditional economic activity within a post-colonial Caribbean, nor is there infrastructure or economic surplus to encourage meaningful diversification - agricultural or industrial. However, crop diversification shows some promise. Promising areas include production for national self-sufficiency in food and increasing consumption of locally produced food in industries such as tourism and food preservation. The potential of bio-genetic engineering for the Third World bring both promise and risk. A definite problem is the inability of the region to coordinate production of crops in a way that would favour regional economic growth and cooperation. These topics along with others are discussed in this paper.

Keywords: Crop diversification; Import substitution; Biotechnology

The development of modern technologies has moved so fast that most agricultural commodities produced during colonial times are no longer economically produced in the Caribbean today. "King Sugar" started its exodus even before most of the countries achieved independence. Sucrose from beet (*Beta vulgaris*), high fructose corn syrup from corn (*Zea mais*) and immobilized enzymes, as well as the non-sugar sweeteners such as saccharin and the bio-engineered "nutrasweet" all significantly reduced the need for labour intensively produced cane sugar.

For example, U.S. consumption of high fructose corn syrup grew from 1.3 million tons in 1978 to 4.3 million tons in 1984 while U.S. sugar imports dropped from 6.1 million tons in 1977 to 1.5 million tons in 1985-86. And this is not all. One of the most promising sweeteners, the protein thaumatin, is extracted from the fruit of the West African plant *Thaumatoccus daneillii*(Anon,1987b). Thaumatin is 100,000 times sweeter than cane sugar and is sold at $1,000.00 per lb (or $2,500.00 per kg) by Tate and Lyle of Britain. The fruits are not produced outside of their natural habitat. However, International Genetic Engineering Inc. (Ingene) of Santa Monica California (USA), has been working under contract for Beatrice Foods (Chicago) since 1982 on the development of genetically engineered thaumatin protein. Ingene holds a patent of the regulatory genetic sequences it developed to produce the thaumatin protein. Its product may be on the market by 1988-89. Unilever, a Dutch multinational, DNA Plant Technology Corporation, and Cinnaminson of New Jersey (all collaborating with Monsanto Corp. of St. Louis Missouri) are all working on engineering techniques which would produce non-sugar sweeteners.

In economic terms, Caribbean exports of sugar to the USA dropped from $686 million in 1981 to about $250 million in 1985. In 1986 and 1987, the US import quotas for sugar were further reduced, notwithstanding the continued depressed prices for cane sugar on the world market.

Cotton, the other king of colonial times, has been an off-and-on mini economic activity in the Caribbean in recent times. Even countries such as the Sudan which grows 1M hectares of cotton are concerned with innovations in biological engineering which would have impact on world cotton production. Chances for a comeback of cotton production in the Caribbean as a significant economic activity, are close to zero.

Fruit production for export has mostly concentrated on one crop - Bananas. Monopoly control of the marketing of bananas has resulted in many rejects of peasants' fruits and often unfavourable prices for exported bananas. At the world level, the FAO has predicted that demand for bananas will remain stagnant up to 1990. In fact, growth in demand for bananas in Western Europe declined by 0.2% up to 1982 and is expected to increase annually by only 0.1% from 1983 to 1990. Western Europe - especially Britain (which pays preferential prices in some cases) is the prime market for Caribbean bananas.

Except for the prospects of citrus production by Minute Maid, Coco Cola's subsidiary in Belize, there is little hope for other export fruit production. In recent times, Cocoa and Coffee have not been factors and the spice market is saturated. The words - Arrowroot, Ginger, Dyes and Timber are referred to with historical significance.

Rice production in Guyana has been declining either as a direct result of farmers' protest at the political-economic policies of the Government or as a result of reduced inputs of fertilizers etc. These inputs affect higher yield. It has been suggested that Guyana lacks the ability to generate the foreign exchange necessary to purchase these inputs. One must also raise the question of how much green-revolution rice (IRRI strains dependent on fertilizer) is currently grown in Guyana and Trinidad. Without fertilizers and pesticides, many of these new rice types are inefficient yielders. This review of agro-economic crops of the Caribbean just serves to identify the importance of diversification.

Diversification opportunities

Politicians generally think of diversifying the economy. Tourism has provided the biggest diversification success yet, and in the case of Antigua, diversification efforts have moved from the two crop sugar-cotton economy to the one-legged Tourist Economy. The refinery was at one time the second leg. It is difficult to balance on one leg. Light assembly industries are seen by many politicians as the alternative. These activities are riddled with abuses of workers (overworking and sexism) and disrespect for national objectives. Many companies pack and leave when fair labour practices are enforced.

The first job of any government is said to be that of feeding, clothing and sheltering its people. Concentration on the production of food crops is therefore one area, relevant to feeding its people, that Caribbean governments could look to as an answer within the diversification context.

Within this context an even bigger task lies ahead. The colonial policy of importing, rather than growing food (Belize), the extensive use of wheat flour, rice and corn (maize) meal as staple sources of carbohydrates in the diet and the influence of the media (especially of U.S. television) on food preferences has taught us to prefer that which most of us can not produce economically. Therefore, if Caribbean people are to eat more of what they produce, an ongoing education on economic realities, nutrition and pride in eating locally produced food should take place.

In addition, Caribbean foods should be standard to the everyday menus of hotels and restaurants rather than the one-night-per-week-local-food situation that typifies the Caribbean tourist hotel scene.

In places where cash crops still remain the major pillars of the economy, there has always been a systemic obstacle to diversification. Cultivation of cash crops has been in direct competition with food crop production. Both crops have been cultivated in the same rainy season and this prevents workers (peasants) from giving the necessary time to both crops. To remove this obstacle, clear, deliberate choices and strategies must be made by policy makers.

With the demise of sugar cooperatives, coupled with the reduced production and utilization of Jamaican bauxite and alumina, Jamaica has been seeking alternatives in addition to tourism. Agro 21 is one initiative. The objective has been to produce vegetables for the North American winter vegetable market. It has been substantially successful. However, some reports suggest that it has further exacerbated poor human nutrition in Jamaica, since peasants sell all of their nutritious vegetables for cash and leave themselves undone.

Essential components of diversification strategies

It has been suggested (Lewis, 1987) that availability of fertile lands, clear identification of what to produce, identifying markets for products, refrigerated storage and processing, adequate orientation of producers to export marketing, attitudes to foods, the need for extension education, agricultural credit, government and university expertise and assistance were essential for agricultural development. Moreover, these inputs must be undergirded by a clear philosophy of development and an approach which soundly addresses the needs of the small Caribbean farmer within his cultural context. Care for the natural resource base (including land) is as important as the other factors listed above.

Biotechnology - promise or threat?

In examining the sugar economy, I referred to the role of bio-engineering in the production of Nutrasweet and thaumatin. Further examination of biotechnology will help to focus on parameters necessary in considering the future of food production in the Caribbean. Plant tissue culture, as well as recombinant DNA techniques or gene splicing (i.e. incorporating genetic characteristics from one plant or animal in to a virus and thereafter into another plant or tissue which normally does not carry that characteristic) make it possible to revolutionize the production of food and consequently change many industries in the foreseeable future.

Cary Fowler of the Rural Advancement Fund International (RAFI), an organization which keeps a close watch on the manipulation of plant genetic materials, suggests that biotechnology will influence every other industry and has enormous economic implications (Fowler, 1987). Within the past five years, patent applications to the US Patent Office for bio-engineering procedures have increased from none to over 5000. Biotechnology companies have been able to generate great activity in the U.S. and other stock markets. Genentec Inc. of South San Francisco, California, has an annual revenue of US$100 million, which is predicted to increase to $10 billion by the early 1990's. Genentec Inc. has bioengineered an anti-blood clotting agent (relevant to heart attacks) called Activase.

David Michael & Co., a flavour manufacturing company of Philadelphia, PA. USA, is currently supporting a three year research project on tissue culture to improve the genetics of natural vanilla in order to make possible a consistent supply of vanilla beans at a reasonable price. (Anon, 1987a) They are using tissue culture to develop new, hardy, disease resistant vanilla plants *which could be grown outside of traditional vanilla growing areas* and they are experimenting with production of natural vanilla flavour using plant cell technology. The possible impact is up to $67 million in the annual export earnings of Madagascar, Reunion, Indonesia and Comoros Islands.

Another example: American Cyanimid, Eli Lilly, Monsanto, Upjon and Sanofi (France), all cooperated on the production of Bovine Growth Hormone (BGH) or Bovine Sonatotropin (BST). This hormone is designated to dramatically increase milk production in dairy cattle (Anon, 1986). The impact would be a drop in milk prices and loss of 23-30% of US dairy farms (predictably the small farms which cannot pay for the BGH shots). Changes in cropping patterns will also occur and a narrowing of the genetic base of diary cattle (i.e. those strains that best respond to BGH will be selected). In the Third World, people would be further encouraged to import cheap diary products rather than produce their own. Chances of directly increasing Third World milk production depend on the ability to buy the new cattle and the BGH. The U.S. and Europe already has a surplus of diary products.

On April 17, 1987, the US Patent and Trademark Office announced its intention to allow patenting of new forms of animal life (Anon, 1987c). In one experiment, human genes have been successfully incorporated into pigs. However, this new development raises serious ethical questions for many.

The point being made here is that, as we consider the question of diversification both at the level of agricultural production and in industry, we must note that there is an energetic move by multinational companies to change not only production patterns but also to control by monopoly the means of production through pricing and patenting. In addition, most of these new technologies keep human participation and human labour input at a minimum. Bio-technology will eliminate the need for certain crops or transfer production from the field to the factory. Producers will not have to deal with labour and political problems.

When we stop to consider that of the 1500 plants used in formal agriculture, 95% of our global nutritional requirements are derived from a mere 30 plant kinds and a full 75% of the diet of Europeans and North Americans is based upon only 8 crops; and to further consider the implications of bio-engineering and bio-technology, we must conclude that the Caribbean, as a region, must either be highly innovative at finding ways to be among the top runners in research, or forever be welfare recipients.

The need for cooperative action

It is therefore necessary for universities and governments to coordinate and cooperate in production, research and marketing so that resources are shared, profits distributed and counter productive duplications eliminated. The idea of a federated Caribbean is not such a bad one even if the most recent advances in this direction were ill conceived.

Festa (1987) noted that U.S. producers of agricultural products were already blaming transfer of agricultural technology to the Third World as the reason for a reduced U.S. market share of export agriculture. He refers to a paper presented by Robert Evenson of the Yale Growth Centre at the meeting of the American Association for the Advancement of Science (AAAS) in which Evenson said: "*The most transferable technology is not a specific item or techniques, but rather the capacity to perform research*", *what Evenson calls a kind of "intellectual germplasm. It is clear,*" he says, "*that while the U.S. played a role in building these research institutions in developing countries, it has very little power to influence them today.*" It seems clear that there are those who see fair trade as no competition!

References

Anon. (1986) Bovine Growth Hormone, Bio Communique, Rural Advancement Fund International, Pittsboro, NC. USA 27312

Anon. (1987a) Vanilla and Biotechnology, Bio Communique, Rural Advancement Fund International, Pittsboro NC. USA 27312

Anon. (1987b) Biotechnology and Natural Sweeteners - Thaumatin, Communique, Rural Advancement Fund International, Pittsboro, NC USA. 27312.

Anon. (1987c) Animal Patents, Communique, Rural Advancement Fund International, Pittsboro NC. USA. 27312.

Festa, D. (1987) Technology: The U.S. Threat to Shut off the Flow, South, August 1987, London.

Lewis, L. W. (1987) Bottlenecks in Agricultural Production which pose meaningful challenges to small producers, XII Ann. Meeting of Caribbean Studies Association, Belize Agricultural Missions NCCC/USA, NY, 10115

Agricultural crop diversification in Belize

Azucena Quan

Belize Agri-business Company (BABCO), Ltd. P.O. Box 92, Orange Walk Town, Belize, Central America.

Belize has a narrow range of traditional export crops - namely sugarcane, citrus and bananas. The Belizean economy is highly dependent on foreign exchange earnings from sugar. The cutbacks in the US preferential quota and the deterioration in the price for sugar on the international market have resulted in sugar's contribution to export earnings declining steadily from 60% in 1978 to only 43% in 1986. Given the need to diversify Belize's agricultural base, a Commercialization of Alternative Crops Project (CAC) was initiated in June, 1986 by the Ministry of Agriculture and the United States Agency for International Development. The Belize Agri-Business Company (BABCO) is the nonprofit organisation responsible for administering the CAC Project until June, 1990. BABCO's agricultural crop diversification strategy has both export oriented and import substitution components.

Keywords: Agricultural diversification; Sugar; Belize

Sugar and its importance to the economy

The agricultural sector in Belize provides approximately 17% of the Gross Domestic Product (GDP), 30% of its national employment and 70% of all domestic exports. (Tables 1 - 3). The sugar industry plays an important role in the economy. Sugarcane is grown on about 60,000 acres by some 4,400 farmers. The industry alone employs one third of the agricultural labour force and, from 1978 to 1986 contributed 51%, of Belize's domestic exports. Sugar's contribution to export earnings, however, has declined from 60% in 1978 to only 43% in 1986.

On a macro-economic scale, sugar's impact on Belize's balance of trade can be traced to its preferential markets in the European Economic Community (EEC) and the United States (US). Much of the decline in Belize's export earnings due to sugar can be attributed to the cutbacks in the U.S. quota and the deterioration in the worldwide price for sugar. In 1983, approximately 65% of Belize's sugar was sold in preferential markets - 41,200 tons to the EEC and 24,000 tons to the US. Since 1983, the US quota has been cut back from 24,000 tons to 16,200 tons effective December 1, 1985. The U.S. quota was further cutback to 8,600 tons effective December, 1986. The reduction in the US quota alone means approximately 50% of Belizean sugar will be sold in international markets at the prevailing market prices.

On a micro-economic scale, the gradual loss of the US preferential quota along with depressed world market prices forced the Belize Sugar Industry Ltd. to close one of its two sugar factories in June, 1985. Milling capacity was reduced by 20%. Approximately 700 factory workers were laid off. Direct effects on sugarcane farmers have been an increase in their production costs accompanied by a decrease in their revenues. Costs of transporting cane to the remaining factory have increased for some 50% of farmers. The 1986 quota reduction translates at farmer level to an estimated loss of US$0.75 to US$1.00 per ton of cane. The farmers are responding to the cost/price squeeze by reducing agricultural inputs in sugarcane and expanding subsistence plots.

Table 1 Structure of employment by economic sector - 1983/84

Sector	Employment (percent)
Agriculture	30.0
Forestry	0.8
Fishing	1.3
Quarrying	0.2
Manufacturing	10.3
Electricity and Water	1.5
Construction	4.9
Commerce	11.2
Transport	5.0
Banking and Insurance	1.4
Government	15.4
Community and other services	18.0
Total Employment	100.0

Source: Central Statistical Office, Ministry of Economic Development

Table 2 Gross domestic product by industrial origin, for the period 1983 - 1985 (current prices)

Industry/Sector	Value			Percentage Breakdown		
	1983	1984 ('000 US $)	1985	1983 (%)	1984 (%)	1985 (%)
Primary						
Agriculture	25,265	27,831	24,384	17.0	17.1	14.9
Forestry and Logging	3,053	3,141	2,833	2.0	1.9	1.7
Fishing	4,959	5,019	5,284	3.3	3.1	3.2
Mining & Quarrying	380	380	380	0.3	0.2	0.2
Subtotal:	33,656	36,370	32,880	22.6	22.3	20.1
Secondary						
Manufacturing	16,409	18,000	17,343	11.0	11.0	10.6
Electricity/water	384	4,754	5,170	0.3	2.9	3.2
Construction	8,335	9,384	9,020	5.6	5.8	5.5
Subtotal:	25,128	32,137	31,532	16.9	19.7	19.3
Tertiary						
Public Administration	18,607	18,667	18,759	12.5	11.4	11.5
Services	74,068	80,370	83,667	49.7	49.3	51.2
Subtotal:	92,675	99,037	102,426	62.2	60.7	62.6
Less imputed banking charges	2,446	4,503	3,323	1.6	2.8	2.0
Gross Domestic Product	149,012	163,041	163,515	100.0	100.0	100.0

Source: Central Statistical Office

Table 3 Belize: Major domestic exports, 1978 - 1986

	1978	1979	1980	1981	1982	1983	1984	1985	1986
TOTAL VALUE US M$ - (Current Prices)	55.3	60.8	81.9	74.8	59.8	65.1	71.2	64.4	72.8
PRODUCTS					Percentages				
Traditional agricultural exports (total)	72	68	72	71	72	68	66	61	66
Sugar	60	52	58	57	55	52	46	36	43
Molasses	2	3	2	2	2	1	2	1	1
Citrus products	8	7	8	9	12	11	14	19	16
Bananas	2	6	4	3	3	4	4	5	6
Other agricultural exports (non-traditional crops and livestock products)	na	2	2	2	2	2	na	1	1
Total agricultural exports	72	70	74	73	74	70	66	62	67
Fish products	3	7	5	9	10	11	8	12	7
Timber	2	3	1	2	3	2	1	1	1
Garments	17	18	18	14	11	13	21	24	22
Miscellaneous	6	2	2	2	2	4	4	1	3
Total	100	100	100	100	100	100	100	100	100

Source: Central Statistical Office

With this background, the need for agricultural diversification in Belize has been recognized by the government of Belize and the United States Agency for International Development . The Commercialisation of Alternative Crops (CAC) Project was initiated in June, 1986 and will last four years.

Agricultural crop diversification in Belize

Belize has a narrow range of traditional export crops - sugarcane, citrus and bananas - which comprise 65 % of domestic exports. Non-traditional export crops and livestock only comprise 2 % of the gross domestic exports. Historically, limited national resources have concentrated on these few traditional export crops. Agricultural crop diversification, in the Belize context, specifically refers to commercialisation of existing and non-traditional crops for the export and domestic markets.

The major objective of Belize's diversification strategy is to reduce, not replace, economic dependency on sugar. Previous attempts by different groups have been made to enter export production of vegetables and fruits. Crops that have been tried include cucumbers, squash, watermelon, papayas, hot peppers, okra, tomatoes and cantaloupes. Most attempts have not been successful to date because of a number of institutional and economic constraints.

BABCO's approach has been to start with the market linkage. American packers/shippers were subcontracted to grow selected crops which they marketed and which they thought had potential. These subcontractors were to provide fieldmen to develop the production technology for these crops. The first phase of work was research and development on the crops. Once the technical package was refined, shipping and marketing trials would be done on semi-commercial acreages. The final phase would be commercialisation. The project focuses on the financial feasibility of the crops.

BABCO's crop diversification strategy has both export oriented and import substitution components. First is diversification into non-traditional export crops (i.e. winter vegetables for the U.S. market, and tropical fruit orchard crops). Second is commercializing grain crops and oilseeds for import substitution (i.e. the domestic livestock and poultry markets).

Constraints to agricultural diversification

There are many constraints to commercializing non-traditional crops in Belize. There is limited infrastructure for processing, packaging and storage for non-traditional crops. Export transportation, especially for perishable foodstuffs, is very unreliable since the volumes of production have not justified regular, timely schedules. Adequate information on production technology for Belizean growing conditions is not fully developed. Similarly, information and expertise on post harvest handling technologies are also not readily available. At present, the costs of production for most Belizean diversified crops evaluated thus far are uncompetitively high, primarily due to the high costs of inputs. Important indirect constraints on the diversification process thus far are the lack of credit for non-traditional crops, and the lack of sufficient market intelligence.

In addition, some government policies have negatively affected incentives for diversifying agriculture. One of these is the failure to implement or enforce restrictions on imports of food products which crowd out the small domestic market. This has been one of the primary reasons discouraging off-season production of vegetables. Another policy is placing ceilings on domestic marketing margins which discourages development of a competitive marketing system for local produce, and may even favour imports over local produce. Another policy with negative impact is that of granting exclusive importing privileges to importers of agricultural inputs which raises costs and decreases the produce's cost-competitiveness. A recent policy aimed at controlling the flow of aliens into the country has affected seriously the agricultural labour supply. Casual workers from Mexico, Guatemala, El Salvador and Honduras have regularly supplemented labour needs in the sugar and citrus industries, for example. Many of the crops being considered and worked with are labour intensive.

BABCO - its role in Agricultural Diversification

The Belize Agri-Business Company (BABCO) is the nonprofit organisation established to administer the production oriented aspect of the CAC Project. BABCO is responsible for generating information on production alternatives to attract entrepreneurs to invest in the export marketing and/or domestic processing of non-traditional commodities. Non-traditional export crops under consideration are winter vegetables for the US market and tropical fruit crops for the US, European and Canadian markets. Import substitution crops are oilseeds and grains. The target is to replace 50% of edible oil and fats imports and to produce enough meal to satisfy the present protein animal feed requirements.

BABCO is conducting all crop production work through on-farm trials to facilitate the transfer of technology from the project to the target group of farmers. These crop trials are managed by farmers following technical recommendations from project personnel. The project provides the capital equipment and agri-chemical inputs required for the trials.

Regarding exportable crops, the first season of on-farm trials were conducted on sweet corn, hot and sweet peppers, snapbean, squash, cucumber, eggplant and cantaloupe for the US winter market. Long term production trials were also initiated on tropical fruits including papayas, pineapples, mangoes, starfruit, passion fruit, lychee and rambutan. Regarding import substitution crops, on-farm trials were done with hybrid corn, hybrid sorghum, soybean, and sesame. A total of thirty-three trials totaling 50 acres were attempted with nineteen cooperating farmers.

Several difficulties were experienced in the first round of trials, mostly related to basic agronomic problems (ie. suitable water availability and quality for irrigation during the dry winter season) and socio-economic considerations (e.g. the labor requirements for many diversified crops peaked during the sugarcane harvesting season, resulting in competition for scarce labor resources).

For the second round of crops for the US winter market, marketing and shipping trials will be done for squash, cucumber and papayas. Research and development will continue on snapbean, pickled cucumber, melons, hot pepper, orchard crops and the grains and oilseeds.

Conclusions

Many of the operational difficulties experienced by BABCO in the first year of diversified crop trials are not uncommon, and have highlighted several important factors. Crop diversification is a multidisciplinary exercise, requiring adequate institutional support as well as appropriate government policies to enable farmers to respond to favorable market opportunities.

The importance of establishing linkages between the producers and the marketer is essential. However, although the market linkage is important, the production technology for the crop is essential. In BABCO, the market links were established. However, the production technology was not satisfactorily developed in the first year of on-farm trials. A successful commercial operation requires adequate crop production and market technology.

Understanding farmer attitudes, their constraints, the farming system and how commercialisation fits into their context are critical considerations for maximizing successful farmer participation. Changing a cropping pattern may also entail changes in the farmer's lifestyle. Moving from a relatively labour extensive crop like sugarcane to labour intensive, high risk crops like vegetables requires long-term attitudinal and socio-economic adjustments by the farmer. The exchange of information on work being done in agricultural diversification in regional countries can facilitate the process by avoiding duplication of efforts and concentrating scarce resources in other aspects.

References

Anonymous (1984) Economic Survey, Belize 1984, Office of Economic Development, Belize

Anonymous (1985) Trade Report 1985, Central Statistical Office, Belize

Anonymous (1986) Abstract of Statistics 1986, Central Statistical Office,Belize

Anonymous (1986) Food and Agricultural Policy of the Government of Belize, Ministry of Agriculture, Belize

PRODUCTION SYSTEMS

Preliminary investigations into the development of two pigeon pea production systems for Barbados

Frances L. Chandler and John R. Leach*

CARDI, P.O. Box 64, Cave Hill Campus, St. Michael, Barbados

Barbados imports a considerable volume of canned and dried peas and beans. In keeping with the import substitution thrust of the Barbados diversification programme, CARDI is investigating the possibility of substituting locally produced pigeon peas for some of this imported product. The major constraints to the development of large scale pigeon pea production are harvesting and shelling of pods which are costly, labour intensive operations. The growth habit of the newer dwarf varieties like ICPL 289, UWI 17, and UWI 10 lend themselves to mechanization. The results of investigations into the development of mechanized green pea and dry pea production systems are described. Mechanized planting has been successfully accomplished using a Stanhay seed drill, while efforts at mechanical harvesting and threshing of dry peas have been only partially successful.

Keywords: Pigeon Pea; *Cajanus cajan*; Mechanization; Commercial production systems.

Introduction

Barbados imports a considerable volume of canned and dried peas of various types. The volume and value of imports over the past 5 years are shown in Table 1. As can be seen from the table, the import figure for dry pigeon peas alone was 177,919 kg in 1986, with a CIF value of BDS$ 241,235. In addition, a considerable volume of canned pigeon peas is included under the general heading of Canned Peas. There is also a large market for fresh green pigeon peas and a potential unexploited market, both local and export, for frozen green pigeon peas. In keeping with the import substitution thrust of the Barbados Diversification Programme, CARDI is investigating the possibility of substituting locally produced pigeon peas for some of the imported product. The recent imposition by Government, of a 15% consumption tax on pigeon peas imported from extra-regional sources, should assist in the development of a local industry.

Traditional production methods

Pigeon peas have been grown in Barbados for many years, both on small farms and on sugar estates. However, all the varieties used in the past are affected by photoperiod, thereby limiting availability to the Christmas season. These cultivars are tall, highly branched and indeterminate and have traditionally been grown around the borders of canefields and not in pure stands on a commercial basis. In recent years, production has decreased drastically due to the leveling of headlands to accommodate mechanization of sugar cane and the increase in the use of herbicides, which have caused considerable damage to the plants. The large habit of the old varieties has led to difficulties in harvesting the crop, and this, coupled with the unavailability or high cost of labour, has prohibited the development of an "industry".

---

*Present address: CARDI, c/o Ministry of Agriculture, P. O. Box 479, Basseterre, St. Kitts.

Table 1 Imports of dried and canned peas into Barbados, 1982 - 1986(1)

Commodity	Year									
	1982		1983		1984		1985		1986	
	Volume (kg)	Value (BDS$)	Volume (kg)	Value (BDS$)	Volume (kg)	Value (BDS$)	Volume (kg)	Value (BDS$)	Volume (kg)	Value (BDS$)
Dry Peas										
Red Kidney Beans	35291	69783	34031	54487	27343	59935	25456	48827	21188	35777
Other Beans	66519	139828	25299	53383	40402	94183	19876	35277	5386	10515
Pigeon Peas	168876	13864	184148	240350	61042	99064	138710	207477	177919	241235
Split Peas	606852	782142	589389	712937	534827	609854	581727	671926	580142	736191
Black Eyes	210893	390107	227343	379582	187990	332666	180994	275592	178641	256033
Other Peas	284877	45022	354298	467875	317812	412751	319175	421105	233542	256774
Canned Peas	204855	483817	202301	473679	255210	557899	242615	534990	326823	676986

1) Source: Barbados Government Statistical Department

New pigeon pea cultivars

In recent years, the development of new pigeon pea cultivars which are relatively insensitive to day length would appear to make all year round production possible. Some of these cultivars are dwarf and determinate in their growth, lending themselves to mechanization, which is a crucial factor in the development of an economic system of production.

Over the past four years, CARDI has carried out evaluation trials in an effort to select an early maturing, high yielding variety acceptable to the local consumer which is suitable for mechanization. A number of varieties has been tested, of which the following four show the most promise: UWI 17 and UWI 10, from the University of the West Indies; and ICPL 87 and ICPL 289 from ICRISAT in India. Some characteristics of these varieties are shown in Table 2.

Development of production systems

We have concentrated our efforts on ICPL 289 in the development of two pigeon pea production systems, one for green pea production, and a second for dry pea production.

Green pea production systems

This consists of three components: all-year-round production for small farmers; pick-your-own; and production for freezing.

All-year-round production: In investigating all-year-round production, three demonstration plots ranging from 1100 to 1650 sq. ft. were established. Two were in low rainfall areas and one in a high rainfall area. Green pea yields were monitored on these plots for a period of one year. Plants in these plots were allowed to grow continuously without ratooning over this period. In the high rainfall area, yields were greater and production was sustained throughout the year, while in the low rainfall areas flowering was severely reduced during the intense dry months. The variety UWI 17 appeared to flush during the drier months, when the other varieties produced no significant flush. All four varieties produced similar cumulative yields, but the distribution of yield varied. (See Figures 1 and 2).

Table 2 Varietal characteristics of four cultivars of pigeon pea when grown in Barbados

Variety	Time of planting (month)	Average height of plant (m)	Time to 1st green pea harvest (days)	Dry seed size(1) (g/100 seeds)	Average No. peas per pod(1)
UWI 17	June	1.26	-	13.4	3.3
	Sept.	0.95	116		
	Oct.	1.10	112		
	Dec.	1.80	89		
	March	1.25	170		
UWI 10	Jan.	1.25	95	10.5	N/A(2)
ICPL 289	March	0.82	165	9.1	4.0
	July	1.16	105		
	Oct.	0.95	93		
	Dec.	0.60	86		
ICPL 87	Jan.	1.05	86	9.4	N/A

1) General characteristic, not specific to month of planting
2) = not available

General Observations:

UWI 17 - appears able to set pods during dry spells, and of making three flushes/year. Pods of UWI 17 and UWI 10 are scattered throughout plant canopy.

UWI 10 - has large pods , which are easy to shell. Green peas are large.

ICPL 289 - pods are borne in clusters at terminal apices of branches. 95% pod maturity attained over a short period. Early maturing variety capable of two heavy flushes/year.

ICPL 87 - is an early maturing variety with acceptable pod distribution and size.

ICPL 289 came into full bearing earlier than UWI 17 both in the first and second flushes at Bath Plantation but the yield of UWI 17 during the third flush - which occurred in the dry season - was substantially higher than that of ICPL 289. Yield of green pods (per plant) over a period of one year at the lowest rainfall site (1066mm/annum) was 0.18 kg for UWI 17, compared to 0.17 kg for ICPL 289. Yield will be looked at again on the pilot commercial plots being established this season.

Pick Your own: In recent years, the "pick-your-own" method of marketing has become popular with large vegetable growers in Barbados. This marketing method is ideally suited to pigeon peas, since harvesting is labour intensive and extremely costly. The limited height and desirable growth habit of ICPL 289 make it an obvious choice for this marketing system. Height varies slightly according to planting date, ranging between 0.60 and 1.16 m. Pods are borne in clusters at the ends of branches, facilitating picking. Furthermore, pods mature evenly so that the majority of pods in a cluster can usually be picked at one time. Farmers in Barbados have shown great interest in developing this system and to date approximately 1.2 hectares have been planted, and a further 1.2 ha are planned.

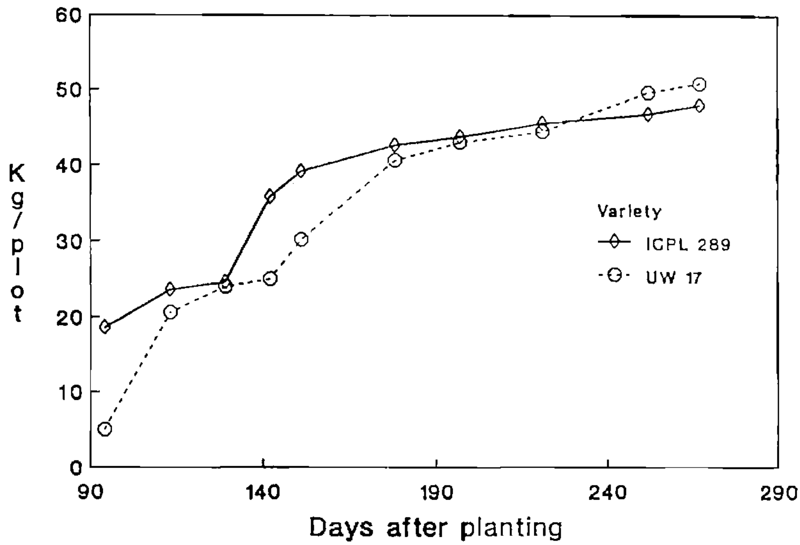

Figure 1 Cumulative yields of green pods versus time for two varieties, at Bath Plantation, St. John

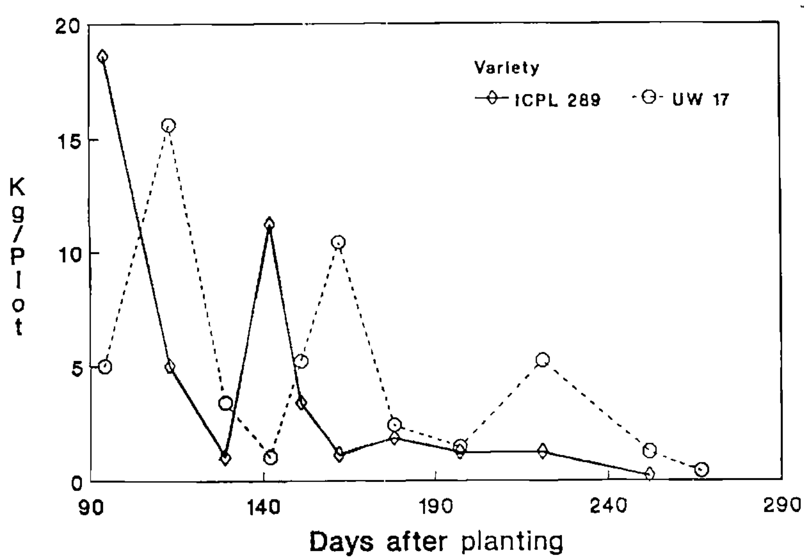

Figure 2 Distribution over time of green pod yield, for two varieties at Bath Plantation, St. John

Recent information from CARIRI indicates that a Dixie Pea and Bean Huller is being successfully used in Trinidad to shell green pigeon peas. The availability of this machine should be an added incentive to large growers who could either shell themselves, or offer the service to their "pick-your-own" customers.

Frozen Pigeon Peas: There appears to be a large, unexploited market for frozen pigeon peas, both in the region and in the metropolitan countries. Again, the advent of mechanized shelling should be a step towards making this feasible.

Dry pea production

Over the past 2 years, CARDI has been attempting to develop a fully mechanized system for large scale, dry pea production. To date we have successfully planted 1.2 ha, using a tractor-mounted Stanhay precision seed drill. Two rows, 45 cm apart are planted on each 168 cm bed. A ribbed #19 belt, with 24 holes, is used on the D pulley, with a D2 spring base and an X choke, to space seeds approximately 20 cm apart in the row.

Plant protection measures: Insecticide was applied with a mist blower. Control has been adequate when Diazinon has been alternated with cypermethrin (*Sherpa*), using the latter compound as harvesting approaches. Weekly monitoring from onset of flowering of pest population levels is essential if cost efficient spraying is to be carried out. The major problems which we have encountered have been the pod borers *Heliothis virescens*, *Ancylostomia stercorea* and *Fundella cistipennis* during fruiting and the defoliator *Anticarcia gemmatalis*, during the early stages of growth.

Chemical weed control using prometryne (Gesagard) at 2.2 kg/ha has been carried out on these demonstration plots, but a herbicide trial to evaluate a number of alternatives is planned.

Harvesting: To date, the major constraint to developing this system has been mechanization of harvesting. The system presently being investigated is the removal of plant tops from the field, followed by threshing of the material. During 1985, the Carib sugar cane "reaping aid" base cutter, mounted on a tractor was used to cut 2 rows at a time on a 0.4 ha plot. The plants were then windrowed in the field for 4 days before being collected by a sugar cane loader and placed in a trailer for transport to the thresher.

Although the "reaping aid" did a reasonable job of cutting the plants, the action was too rough, and since the peas were matured, unacceptable losses due to shattering, as well as loss of pods occurred. In addition, the clearance of the tractor was low, and this resulted in some dragging of plants along the bed after cutting. The further handling with the sugar cane loader during the gathering operation compounded the shattering and pod loss problem.

During 1987, a Carib Agro Industry Ltd. prototype "Cotton Destroyer" which was designed to remove cotton plants from the field in preparation for the cotton close season was tested in pigeon peas. This implement has the capability of not only cutting but also collecting plants in a bin. However, the cutting action was not gentle enough for the harvesting of peas and plants tended to be chopped into small pieces. In addition, a large proportion of pods and peas were destroyed in the process. Despite this, the machine has potential if pigeon pea is being harvested for the production of silage, or for the cutting and removal of old plants when ratooning a field.

There is scepticism over using a tractor mounted sickle bar, but we feel that a machine with a similar mode of action would do an adequate job. We have tested, with some measure of success, a hand-held motorised grass trimmer fitted with a rotating serrated blade. Of course on a large scale, this method would be very time consuming and therefore costly.

Ratooning: Ratooning is an important component of this production system. We have successfully ratooned a crop of ICPL 289 twice during a period of 1 year before ploughing out. The variety has reacted favourably to ratooning when plants were cut back to 45 cm above soil level. Die back was minimal.

Ratooning a pigeon pea crop has three advantages:

- It allows the harvesting of up to three crops from an area before recultivation.
- It assists with pest control by reducing infestation levels.
- It allows for the production of silage.

ICPL 289 is capable of producing in the vicinity of 9600 kg/ha of foliage per ratoon. CARDI has successfully produced silage from pigeon pea foliage on a small scale. This production could be a beneficial "spin-off" from dry pea production.

Threshing: We have tested an Alvin Blanch Minorette P.T.O. driven thresher on the dry pigeon pea crop. The plants, after being cut with the motorized trimmer are passed through the machine. Although the throughput has not been accurately measured, it appears to be adequate and we have obtained a reasonably clean product. Further testing is necessary to improve the adjustment and efficiency of the machine.

Packaging: Peas collected from the thresher were sun dried to approximately 14% moisture content and were further cleaned by sieving. Packaging was done in transparent plastic bags using a small packaging machine. The packages were labeled and distributed to consumers. Evaluation forms requesting views on size, colour, taste and cooking time accompanied the packages. The replies are being evaluated, but indications are that the product is generally acceptable.

Conclusion

Further information on yields of dry and green peas will be collected from the pilot commercial plots being established this year. These plots will also assist in compiling production costs for the crop when grown on a commercial scale. As additional varieties are tested, and found promising as regards yield, growth habit and consumer acceptance, these will be incorporated into the production system.

Since out-crossing in pigeon peas may be as high as 40%, problems will no doubt arise with maintaining the characteristics of the introduced dwarf varieties. Consideration will have to be given to maintaining a source of pure seed for distribution to growers.

Les Cultures sans sol sous abri en climat tropical humide; atouts et contraintes pour leur developpement

P. Rault

IRAT, B.P.427, 97204 Fort de France Cedex, Martinique

Les surfaces couvertes en vue de produire des especes vegetales (maraicheres et horticoles) sont en augmentation aux Antilles-Guyane. On assiste a une adoption de techniques, materiels et equipements tres divers et varies. Partant d'une constatation des atouts et contraintes qu'offre le climat tropical de basse altitude, l'auteur analyse graduellement les avantages mais aussi les exigences induites par des niveaux de technologie croissante : Passage de l'agriculture saisonniere de plein champs a la culture continue sous abri serre, puis evolution vers les cultures sans sol dites "hydroponiques". A aucun moment le producteur ne doit negliger dans son evolution technique de se resituer dans le contexte commercial. Seule la consideration realiste de tous les parametres evoques permettra un developpement durable des cultures abritees sans sol en zone tropicale humide.

Mots clefs: Cultures sous abri; Hydropiniques; Zone tropicale humide

Areas for protected crop production are increasing in the French West Indies and Guyana. Techniques, materials and equipment used are large and diversified. By establishing the assets and constraints associated with the low altitude, humid tropical climate, the author has derived the advantages and requirements resulting from these increased levels of technology: Passage from seasonal outdoor agriculture to continuous production in greenhouse and progression to soilless cultivation or "hydroponics". At all stages in this technical evolution the grower must take into account the changing financial and commercial context. Only when all these aspects are fully considered, will the development of protected soilless culture in humid tropics become effective and durable.

Keywords: Protected culture; Hydroponics; Humid tropics

Introduction

En 1966, l'IRAT demarre ses premiers travaux de recherche concernant les cultures abritees, sans sol, en Guyane. Aujourd'hui une dizaine de serristes y produisent des legumes sur pres de 3 hectares, entierement hors-sol, de maniere simple et efficace. Dans les annes 80, la serriculture prend un essor marque en Martinique pour atteindre, de nos jours, une surface de 4 hectares (1/3 en plein sol, 2/3 en hors sol).

Une vingtaine de producteurs font pour la majorite du maraichage (tomate, melon, laitue), mais la production de fleurs semble s'affirmer (rose, chrysantheme). L'IRAT est present et assure le volet recherche et experimentation au travers de sa base terrain equipee de 1000 m^2 d'abris plastique hors-sol. En Guadeloupe, cette technique est moins developpee, avec un producteur pour 6000 m^2 de legumes hors-sol.

Actuellement en Martinique, on assiste a un reel engouement qui aboutit a l'adoption de techniques, materiels et equipements tres divers et varies, parfois onereux et sophistiques : Nutrient Film Technic, cooling-system, serre a double paroi gonflable, ventilation dynamique, ordinateur de gestion de la ferti-irrigation, fog system.

Il nous semble essentiel, a ce stade d'evolution, de situer clairement le systems "culture protegee" dans le contexte "zone tropicale humide".

Parametres du climat tropical des Antilles exemple de la Martinique

Avec moins de 2900 heures d'insolation totale annuelle, les durees d'insolation, mensuelles, sont peu variables aux Antilles. Elles oscillent, pour la Martinique, entre des durees journalieres moyennes de 7,3 heures en octobre et 8,3 heures en avril.

L'energie recue par le rayonnement solaire global atteint 1920 joule/cm^2/mois en moyenne (periode 1967-1985, poste meteorologique aeroport du Lamentin). Le minimum d'energie est recu en decembre (1600 J/cm^2) et le maximum en avril (2150 J/cm^2).

Les temperatures moyennes observees sont elevees toute l'annee (24,5°C en janvier, fevrier et 27°C en juin, juillet et aout). Les moyennes minimales vont de 21°C en janvier, fevrier a 24°C en juin, juillet. 29,4 jours/an ou la temperature minimale est inferieure a 20°C. Les moyennes maximales vont de 28°C en janvier, fevrier a 30,5°C de mai a septembre. On compte en moyenne 148,1 jours/an ou la temperature maximale est superieure a 30°C. Quel que soit le mois considere l'amplitude quotidienne maximale est de 11°C et se reduit au minimum a 4°C. Elle n'est en moyenne que de 6°C.

L'humidite relative de l'air est en moyenne de 79% avec une moyenne des maxis a 94% et une moyenne des minis de 65% (60% en mars - 82% en septembre et octobre).

La pluviometrie moyenne annuelle est variable du Nord au Sud de l'ile : 5 metres d'eau sur les reliefs du Nord (climat de type tropical de montagne); moins d'un metre pres des cotes du Sud (climat de type semi aride a aride). Sur l'ensemble de l'ile, les precipitations avoisinnent les 2 metres avec des moyennes mensuelles de 70 mm en mars et de 250 mm en aout (climat de type tropical humide).

Les vents. L'alize constitue l'essentiel du regime des vents avec 33% de vent d'Est et 28% E.N.E., 20% de ces vents ont une vitesse comprise entre 20 et 40 km/h. Le cyclone tropical (vent de 117 km/h) constitue un risque majeur tous les 9 ans en moyenne.

Pour resumer, l'agriculteur antillais evolue dans une situation climatique caracterisee par des longueurs de jours de 11 h (decembre) a 13 heures (juin) sans excedent ni d'insolation, ni d'energie dolaire rayonnee. Les pluies sont abondantes de juillet a novembre. L'humidite relative de l'air est constamment forte, les temperatures sont peu variables, elevees et d'amplitude journaliere faible. La contrainte climatique majeure est la pluviometrie. Elle reste defavorable a la culture de pleine terre de juillet a novembre. Produire des legumes, d'une facon fiable, pendant la saison des pluies, necessite l'emploi d'un abri.

Consequences du passage d'une agriculture saisonniere de plein champ a la culture en continu sous abri serre

Les ameliorations engendrees

L'abri serre etant avant tout un parapluie, tous les inconvenients lies aux precipitations sont evites. La recolte a un meilleur aspect, une bonne presentation commerciale car la culture n'est plus endommagee par l'effet mecanique des pluies. L'environnement racinaire est preserve du point de vue agronomique car la structure du sol n'est plus detruite par les pluies violentes. L'environnement sanitaire est ameliore. De nombreux sites privilegies de proliferation des maladies et ravageurs disparaissent. L'organisation et le suivi du planning des travaux est facilite. La continuite du travail pendant la periode des pluies est assuree. Il y a absence de contrariete de certains travaux autant a l'echelle journaliere que saisonniere. Il est desormais possible de gerer de maniere rigoureuse le calendrier de lutte chimique. Les applications de produits phytosanitaires peuvent etre decidees sans avoir le souci de pluies potentielles qui pourraient annuler leur efficacite.

L'abri serre induit de nouvelles contraintes

D'Ordre climatique: La serre est en elle-meme un agent de modification du climat. Le climat spontane qui s'etablit sous abri ne repond generalement pas a la totalite des exigences des cultures.

Les films polyethylene transparent employes pour la couverture des tunnels ne transmettent que 70% du rayonnement solaire en particulier pour les radiations physiologiquement efficaces du visible. En periode de jours courts ou d'ennuagement important, la quantite d'energie lumineuse recue sous abri peut-etre limitante.

Meme si "l'effet serre" avec une couverture polyethylene est de l'ordre du 1/5eme de celui du verre, il provoque une montee en temperature a l'interieur de l'abri. C'est ainsi qu'aux mois d'avril et juin sur 19 journees de mesure en continu effectuees sous tunnel parapluie plante en tomates; nous avons observe une augmentation de la temperature diurne moyenne variant de 0,5^{0}C a 4^{0}C par rapport a la temperature exterieure. L'effet serre se faisant sentir de 7 h 30 a 17 h 30. Les maximums sont majores de 1 a 6^{0}C (en moyenne de 3^{0}C). L'amplitude diurne sous abri est de 9^{0}C alors qu'elle n'est que de 5,5^{0}C a l'exterieur.

Cet excedent d'energie du climat spontane sous abri eloine un peu plus la culture de ses optimums thermiques. Il pourrait des lors etre juge necessaire d'associer a la serre une climatisation. Ceci dans le but de permettre aux cultures d'exterioriser leurs potentialites et d'ameliorer l'efficience des facteurs de production mis en jeu. Il s'agit avant tout d'en cerner la rentabilite economique.

D'Ordre economique: L'investissement de base se revele important pour une duree d'amortissement de 5 annees (2 annees pour la couverture polyethylene) le cout annuel de l'investissement est de l'ordre de 18 a 21 F/m^2 couvert.

Tableau 1. Cout d'un abri serre tunnel parapluie de 9,2 m x 55 m (500 m^2) (IRAT, Martinique, 1987)

Elements de l'investissement	Francs francais	
	Global	par m^2 couvert
Armature charpente + couverture plastique (+ fret maritime + dedouanement + transport terrestre)	de 28000 a 33000	de 56 a 66
Nivellement et preparation de la plate forme terrain	4500	9
Montage et mise en oeuvre (main d'oeuvre)	5000	10
Total sans equipement d'arrosage	37500 a 42500	75 a 85
Materiel d'irrigation		
aspersion	1000	2
irrigation localisee	3500	7
Cout total d'un abri Parapluie equipe pour la culture	38500 a 46000	77 a 92

D'Ordre technique: Au-dela des modifications climatiques et compte tenu de l'investissement de base, dans une optique de rentabilite, le serriste devra desormais raisonner en terme de productivite. Il devra produire de maniere intensive en limitant les temps morts; obtenir des rendements eleves; produire de la qualite; ne pas se disperser, mais plutot s'astreindre sinon a la monoculture ou plus a une rotation de 2 especes. Cette specialisation lui permettra de fournir avec efficacite et constance son marche.

Pour y parvenir, il devra maitriser toutes les etapes et les facteurs de la production: produire des plants sains et forts, prets au moment opportun a un stade optimal de plantation; maintenir et ameliorer le niveau de fertilite de son sol; conserver un bon etat sanitaire de la couche de sol cultivee par des desinfections; maitriser les doses et frequences d'irrigation; asurer un suivi phytosanitaire strict de ses cultures.

Toutes ces exigences, ces efforts continus devront se concretiser par une valorisation du produit au travers d'un circuit commercial fiable.

D'Ordre commercial: Si le serriste offre, avec regularite, une quantite donnee d'un produit de qualite, il doit pouvoir echapper peu a peu aux fluctuations saisonnieres tres amples du marche local. Il ne doit plus et ne peut plus se contenter de speculer et de tenter des "coups". Il doit faire appel a un circuit commercial qui puisse, tout au long de l'annee, absorber l'ensemble de sa production a un prix d'un bon niveau moyen determine au prealable.

Nous ne pouvons que constater le niveau des diverses exigences induites par l'adoption de la technique de culture sous serre et ceci parce que le serriste doit faire face en priorite a un investissement d'environ 85 F/m^2 couvert. L'outil serre peut au depart venir en complement du plein champ sur une surface moderee, et motiver l'installation des jeunes. L'abri serre rassemble assez d'atouts pour que son extension se fasse de maniere progressive et raisonnable.

Pourtant, il arrive que certains serristes preferent, soit des le depart, soit par evolution, adopter une technique d'apparence plus sophistiquee: La technique hors-sol dite aussi "hydroponique".

Le passage de la culture en sol sous serre a la technique hors-sol sur substrat

Motifs de cette evolution

C'est avant tout la nature et l'etat du sol qui motivent ce choix. La culture intensive en pleine terre sous abri, sous climat tropical humide, peut voir sa rentabilite fortement reduite du fait: de l'implantation sur des sols peu fertiles ou desequilibres ou pauvres en matiere organique; d'une infestation rapide et quasi irreversible par des maladies et parasites des plantes.

Le serriste peut pallier le premier inconvenient en irrigant ses cultures, en permanence ou de facon episodique, avec une solution nutritive complete ou en n'apportant que quelques elements. Si par contre il doit faire face au second probleme, en general il opte pour un abandon radical du sol. La desinfection des maladies (*Pythium spp., Fusarium spp., Pseudomonas solanacearum, Corynebacterium spp.*) et des nematodes, notamment du genre *Meloidogynes* demeure imparfaite dans le cas d'infestations soutenues et surtout est couteuse.

Le "plus" de la culture sans sol

Tous les inconvenients lies au sol sont elimines, a condition bien sur que toute voie de contamination exterieure par des germes pathogenes soit definitivement muselee. Quoi qu'il en soit, le substrat peut-etre facilement lave, desinfecte ou meme renouvelle. Il est en theorie possible d'approcher au mieux les besoins reels en eau et en elements mineraux des especes cultivees. La culture hors sol, reunit les conditions optimales pour l'obtention de rendement eleves.

Redoubler d'attention!

De par l'investissement necessaire: Sans tomber dans une grande sophistication, adopter la technique de l'hydroponie signifie mettre en oeuvre des parametres essentiels tels que un substrat dans un conteneur, isole du sol; une solution nutritive et un equipement pour son injection; un minimum d'automatismes pour le bon fractionnement des irrigations.

De par la fragilite du systeme: L'outil est couteux, mais de qualite. Le systeme, s'il est bien conduit, sera performant mais il est fragile et ne supporte aucune negligence telle que: une carence de l'irrigation (faible reserve hydrique du substrat de par sa nature et le volume par plante); un manque de controle de la solution nutritive (erreur de fabrication, mauvais fonctionnement des materiels d'injection, inadequation de la concentration); mauvais suivi sanitaire; mauvaises conditions d'hygiene de l'environnement immediat des abris.

Conditions necessaires

Une bonne technicite du serriste: Le serriste en plus d'une solide experience de culture en pleine terre, sous abri ou non, devra avoir recu une formation "hydroponie" adequate. Il est necessaire qu'il ait une maitrise correcte de facon a pouvoir lui meme intervenir, controler et modifier certains aspects de sa conduite des cultures sur substrat.

Tableau 2. Cout specifique de l'amenagement d'un abri serre de 500 m^2 pour la culture sur substrat. (IRAT, Martinique, 1987)

Elements d'amenagement	francs francais	
	global	par m^2 couvert
Substrat ponce (30 m^3)	4500	9
Bacs de culture en polypropylene (600 metres lineaires)	10000	20
Emplacement des bacs de culture (en ciment)	2000	4
Pompes doseuses (2 injecteurs proportionnels)	6000	12
Filtre + petit equipement divers	2000	4
Unite de programmation d'arrosage	3000	6
Main d'oeuvre	2500	5
Cout total des equipements	30000	60

12 F/m^2/an pour 1 amortissement sur 5 annees

Un bon encadrement technique des professionnels: Il serait souhaitable qu'il se compose: d'un conseiller technique competent, assurant la liaison entre d'une part, les producteurs et d'autre part, la recherche, les laboratoires et la commercialisation; d'une unite de recherche et d'experimentation permettant de progresser et d'adapter rapidement des techniques mises au point sous d'autres climats; des laboratoires de determination (protection des cultures et analyse d'eau et de solutions nutritives); des sessions de sensibilisation, formation et vulgarisation pour les producteurs mais aussi au niveau des techniciens de developpement, des formateurs de l'enseignement agricole.

Les intrants doivent etre disponibles localement: Le serriste doit pouvoir s'approvisionner a tout moment en engrais solubles, materiel de micro-irrigation, produits phytosanitaires chez des fournisseurs locaux - sa dependance vis a vis de source lointaines doit etre reduite.

Une differenciation du produit: Un produit issu de culture hydroponique se doit d'etre de qualite. Cette qualite a elle seule justifie un prix de vente majore. Encore faut-il que le produit soit differencie et mis en valeur (emballage, etiquetage avec mention "hydroponie"). Le serriste, au travers de son reseau commercial, doit faire preuve d'innovation, d'originalite; il doit promotionner son produit.

Une option agricole d'avenir

Le concept de l'hydroponie vehicule des atouts certains, mais il faut etre pleinement conscient des exigences qu'il engendre. Aux Antilles l'urbanisation gele progressivement nombre de terres de qualite et facilement cultivables. Il s'ensuit une speculation inevitable. Les grands secteurs de la production vegetale (banane, canne, ananas, avocat, agrumes) necessitent des surfaces importantes; d'autre part leur extension semble incertaine sinon aleatoire.

Face a cette situation beaucoup de jeunes diplomes de l'enseignement agricole voient dans les cultures hors-sol une possibilite d'installation sur une surface reduite (1000 m^2 a 1500 m^2) voire totalement inculte avec un rapport rapide. Quelques jeunes agriculteurs ont deja concretise leur projet et sont en bonne voie de reussite.

Conclusion

En zone tropicale humide, les prix a la production, pour certaines especes vegetales, selon les circuits de commercialisation, autorisent des investissements de l'ordre de 150 F/m^2 courvert sous abri serre. Pour que l'equilibre financier de l'unite de production ne puisse etre remis en cause, le serriste devra faire face a l'ensemble des contraintes evoquees et etre accompagne par un bon encadrement technique.

L'abri serre avec un equipement modeste mais fonctionnel devrait pouvoir s'adapter aux petites exploitations. Le recours a des "serres" disposant d'un equipement perfectionne et necessitant une tres bonne technicite de la part de l'agriculteur ne peut concerner qu'un nombre tres restreint d'exploitations. (En Martinique une unite maraichere a investi plus de 1100 F/m^2 sur une surface de 2000 m^2, une Societe horticole atteint un cout superieur a 700 F/m^2 pour 5000 m^2 d'installations).

L'insularite (Antilles), ou les faibles densites de population (Guyane) posent le probleme de la saturation des marches locaux. Il faudra, a moyen terme, que certains serristes, envisagent la diversification des productions en vue de creneaux commerciaux locaux specifiques, que d'autres se concertent afin d'organiser des debouches a des periodes bien definies de certains produits vers l'exportation.

Tissue Culture in the Eastern Caribbean - The experience of a production laboratory in Barbados

R. D. Bancroft

CARDI, Cave Hill Campus, P. O. Box 64, St. Michael, Barbados, W.I.

In the past decade much has been said and written concerning the various ways in which tissue culture technology may contribute to agricultural production and crop diversification within the Caribbean. There have been successes, but in many respects, the true potential of this technology still remains untapped. The present paper briefly restates the rationale behind the use of tissue culture and examines the experience of the CARDI laboratory in Barbados. The case is put that, should countries within the region wish to benefit from the increasing availability of germplasm, resources should be allocated for the establishment of simple yet productive reception centres that are capable of handling tissue culture products imported from overseas.

Keywords: Tissue Culture; Germplasm; Root crops; Barbados

Introduction

In recent years there has been much discussion throughout the Caribbean region about the need of agricultural and horticultural enterprises to strengthen and develop the production and marketing of a wide variety of products. At the highest levels, policy makers see the wisdom of encouraging farmers to grow crops not only for export but also to contribute towards import substitution. Fundamental to the success of such projects is the provision of suitable planting material which has not only the potential of producing good yields of high quality but will also provide a satisfactory return on the farmers' investment.

The marketing of certified 'true seed' is well established in the region and has given growers the opportunity of raising a wide variety of vegetables. There are, however, many major crop species such as the root crops and other staples that are generally only regenerated vegetatively. Within the Caribbean basin and worldwide there is a great diversity of these crops, many of which would no doubt yield well on the islands of the Eastern Caribbean. However, the threat of introducing new and potentially devastating diseases and plant parasites from one territory or locality to another, severely restricts the exchange of any vegetative planting material. It is in this context that micro-propagation or tissue culture techniques and the facilities available at the production laboratories of the Caribbean Agricultural Research and Development Institute (CARDI), in Barbados and Dominica are likely to make a significant contribution to the regional crop diversification programme in the years ahead.

Tissue culture techniques

Traditional propagating methods rely on the use of seed, cuttings, grafting, budding and divisions, etc. Tissue culture techniques represent a refinement of these age old practices, for under aseptic laboratory conditions, fragments of tissue or bundles of cells, when placed in a suitable nutrient medium and held under appropriate environmental conditions, may be encouraged to regenerate into entire miniature plants which are genetically identical to that of the parent material.

While tissue culture can serve a diverse number of purposes, in terms of rapidly improving the production of designated crops, the technique may be used for:

1) The derivation of disease free germplasm from valuable parent material
2) The maintenance and conservation of these genetic resources
3) The mass propagation and distribution of economically important clones.

Germplasm may be maintained in a disease free environment. When required, clones may be regenerated at any time of the year and in many instances the rate of propagation is far more rapid than by the alternative conventional methods. The ability to maintain large numbers of plantlets in relatively small growth rooms also obviates the need to service extensive museum plots in the field. On the debit side, tissue culture techniques are not a universal panacea, micro-propagation technology brings with it its own problems, laboratories are expensive to run and are not immune from disasters. However, within limits, micro-propagation will no doubt play an increasingly important role in agricultural research and development.

The micro-propagation of yams

To illustrate how tissue culture techniques are able to contribute to the development of agriculture in the Caribbean, I would like to refer to the process by which CARDI personnel developed the virus-tested yam material which is now widely available throughout the region (see Figure 1).

CARDI's involvement with aspects of tissue culture technology may be traced back to the work already in progress when the organisation was established. In the early 1970's, surveys undertaken by the 'Yam Virus Research Project' (Scheme No. R2672) funded by the British Ministry of Overseas Development (ODM), indicated that virus diseases were widespread in all five major yam species found in the Commonwealth Caribbean (i.e. *Dioscorea alata, D. cayenensis, D. esculenta, D. rotundata and D. trifida*) (Haque and Mantell, 1980). Although the intensity of infection was often low, field studies revealed that the virus particles present were associated with gross reductions in tuber yields and in the case of *D. alata* at least, a bacilliform virus was also implicated as the cause of the condition known as 'Internal Brown Spot' (IBS) which had adversely affected the sale and export of yams since the mid-1960's (Mantell, 1978; Mantell and Haque 1978 & 1979b).

Research work by CARDI in conjunction with the University of the West Indies (UWI) resulted in the development of an apical meristem technique which, when combined with thermotherapy, was able to produce what is believed to be, virus free cultures of 'White Lisbon' and 'Oriental'. Both are popular cultivars of *D. alata* (Mantell, et al 1980). Towards the close of the 'Yam Virus Project', micro-propagation techniques were developed to facilitate the rapid multiplication of 'virus-tested' yam material from the original meristem-tip cultures (Mantell et al, 1978 & 1979, Mantell and Haque, 1979a) and in 1979 a proposal was put forward for the establishment of a yam seed propagation scheme in Barbados to ensure the future availability of disease free yam material to growers in the region.

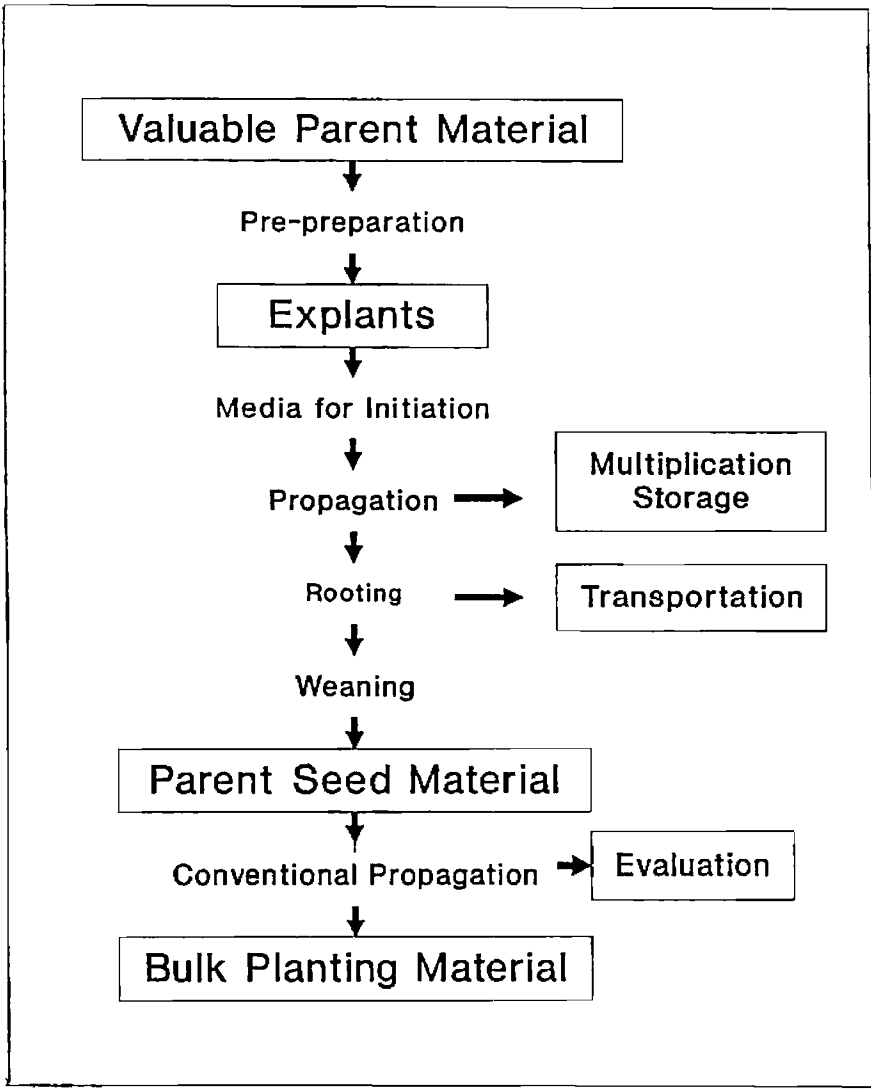

Figure 1 Essentials of micro-propagation process

With the support of the European Development Fund (EDF), CARDI was able to put this project into effect and between the years 1980 and 1984, the present 'Tissue Culture and Yam Propagation Centre' was constructed and made operational (CARDI, 1984). By the end of the project, the propagation unit had produced and made available over two million pounds of virus-tested yam tubers to farmers in eleven countries of the Caribbean. On more developed farms, the use of the virus tested plant material was found to increase the yield of tubers by some 35% (Mantell, 1979a). Under conditions of low technology and among many small farmers, yield increases, without extra inputs were estimated at over 90% (George and Pilgrim, 1982).

Today, the work on *D. alata* continues. The germplasm of the original virus-tested material is maintained in the laboratory. The fields of those registered growers involved in the conventional propagation of the improved yam lines are rogued annually to remove virus infected plants, and in the coming seasons it is planned that once again new stocks of parent material regenerated from cultures will be bulked up for release to the same registered growers and ultimately to the general farming public in Barbados and elsewhere to improve the planting material.

Other root crops

In the last two years the Barbados tissue culture unit has also been supporting the 'Cassava Production Project' (CARDI/USAID/FSRD-538-0099) funded by the USAID. In early 1986, ten 'elite' .cassava (*Manihot esculenta* Crantz) varieties were imported from CIAT in Columbia. In much the same way as the yams, these cultures have been micro-propagated and mature plantlets have been released to nursery plots. Sufficient material has now been produced to enable extensive agronomic trials to be undertaken. The results of these trials will help the agronomic staff of the CARDI unit in Barbados to determine which cassava varieties are best suited to the local environment. It is hoped that the cassava varieties now available will find a market for human consumption as well as on the farms where the entire plant may be processed for livestock and poultry feed.

In the latter part of 1986 and early 1987, the Barbados unit took delivery of a number of sweet potato (*Ipomoea batatas* L.) cultivars developed by the breeders associated with Clemson University in South Carolina, USA. These lines have now been propagated *in vitro* and certain cultivars have already been distributed to Antigua and St. Lucia. Cultures are also due to be released to Dominica in the next few weeks. Over a period of time, it is envisaged that a cooperative exchange of sweet potato germplasm will develop between South Carolina and the states of the Commonwealth Caribbean. To facilitate this work, the tissue culture unit will act as a 'staging post' for material entering or leaving the region.

Propagation of ornamentals

Although root crops have been and will remain a major component of the tissue culture work carried out in Barbados, it is recognised that exotic tropical pot-plants and cut flowers of high quality are additional horticultural products of potential importance and great commercial value. The ornamentals of enduring popularity that appear eminently suited to exploitation are *Anthurium andraeanum* Lind., a member of the *Araceae* and various *Heliconia* spp. Under the correct growing conditions both these plant species will produce spectacular blooms throughout the year. At the request of an ornamental grower in Barbados, CARDI has already started to micro-propagate Anthurium plantlets. It is envisaged that the project will expand and develop in the next few years.

Germplasm transfer and storage

Looking to the future, a major component of the laboratory's work will be the implementation of the recently endorsed 'Yam and Cassava Development Project' (TCP/RLA/6768) which is to be funded by the FAO. Under the terms of this sub-regional project, it is proposed that the Barbados tissue culture laboratory will become one of the regional centres dedicated to the intensive micro-propagation and distribution of improved and disease free root and tuber crop germplasm. Essentially, by building on the experience of the past, the Barbados unit will develop and expand existing projects with a view to fulfilling the following objectives:

1) To assemble and maintain *in vivo* and *in vitro*, the major germplasm groups of yam, cassava, tannia and sweet potato clones of the region.

2) To micro-propagate and distribute to participating countries, selected disease-free cultivars of yam, cassava and sweet potato.

In order to achieve the first objective, the tissue culturalists involved in this proposed project require not only the thoughts and ideas, but also the active participation of the region's agriculturalists. In the CARICOM countries, although tissue culture facilities are available on the U.W.I. campuses of Jamaica and Trinidad, most of the production work will be based in the laboratories in Barbados and Dominica. Our resources and manpower are limited. We cannot at present hope to store, maintain and propagate vast numbers of different root crop cultivars. Thus to do the job well, the staff of CARDI will have to concentrate on a limited number of cultivars of each of the major crop species already mentioned. In order to make a valid judgment about which cultivars should be selected, we need to know what types of germplasm are already available in the region and also which products would be most acceptable to the consumer. Armed with this information, it should be possible to identify and select superior germplasm from both collections overseas and from material within the region and hence propagate those cultures best suited to the needs of the farmer and the market place.

The Caribbean states in general are well placed to take advantage of the tissue culture technology available both within the region and worldwide. It is not necessary for each small territory to develop elaborate laboratory facilities, for international research centres and private companies have increasingly large collections of the economically important plant species which are potentially available to both the development agencies and individual growers. Unlike true seed, however, such material is transported as miniature plantlets in culture. This poses something of a problem, for although the process of transferring plantlets from culture to a soil based medium is relatively simple, rough handling, inadequate moisture and exposure to harsh environmental conditions at this critical stage can lead to high rates of loss. To minimise such wastage, some forms of reception centre are called for.

On a number of islands certain agencies, ministries or even private growers are able to provide greenhouse or screenhouse facilities to overcome the problems of weaning valuable plant material. On other islands such facilities may be poor or absent. Under the auspices of the FAO project, it is hoped that a small number of reception centres may be established where they are most needed. Once operational, such centres would be able to receive germplasm from whichever sources proved most appropriate.

The international exchange of germplasm is essential for the further development of many crop species worldwide. The ultimate provision of suitable reception centres in all of the territories of the region will facilitate the distribution of those crops that may not be available in the form of certified 'true seed'.

References

CARDI (1984) Virus-Tested Yam Tuber Multiplication Project, Final Report 1980-84.

George, C. and Pilgrim, R.(1982) Evaluation of recommended virus-tested Yam - *Dioscorea alata* cv. White Lisbon ex Barbados on small farms in St. Lucia, Proc. 18th Meeting Caribbean Food Crops Society, Barbados

Haque, S. Q. and Mantell, S. H. (1980) Status of the virus diseases of Yams (*Dioscorea* spp.) in the Commonwealth Caribbean, Proc. Int'l Symposium on Yams, Guadeloupe,

Mantell, S. H. (1978) Studies on the Internal Brown Spot disease of White Lisbon yams (*Dioscorea alata* L.), Ph.D. Thesis, University of the West Indies, Trinidad

Mantell, S. H. and Haque, S. Q. (1978) Incidence of Internal Brown Spot Disease in White Lisbon Yams (*Dioscorea alata*) during storage, Exptl. Agric. **14** 167-172

Mantell, S. H. and Haque, S. Q. (1979a) Disease-free yams - Their production, maintenance and performance, CARDI, Yam Bulletin, No: 2, 22 pp.

Mantell, S. H. and Haque, S. Q. (1979b). Internal Brown Spot disease of yams, CARDI, Yam Virus Project Bull. No:3, 16 pp.

Mantell, S. H. and Haque, S. Q. and Whitehall, A. P. (1978). Clonal multiplication of *Dioscorea alata* L. and *Dioscorea rotundata* Poir. Yams by Tissue Culture, J. Hort. Sci. **53** 95-98

Mantell, S. H., Haque, S. Q. and Whitehall, A. P. (1979). A rapid propagation system for yams, CARDI, Yam Project Bull. No:1, 19 pp.

Mantell, S. H., Haque, S. Q. and Whitehall, A. P. (1980) Apical meristem tip culture for eradication of flexuous rod viruses in yams (*Dioscorea alata*), Tropical Pest Management, 26(2) 170-179.

Crop management trials using the Continuous Variable Design

G. L. Spain and W. I. Lugo

Department of Agronomy and Soils, Agricultural Experiment Station, University of Puerto Rico, Mayaguez, P. R. 00708

The literature concerning crop management experimentation using continuous variable designs (CVD) is reviewed. Some modifications and advantages and disadvantages of the CVD are discussed based on field trials with vegetable, grain, and root crops. The results for three experiments with cassava in Puerto Rico using the CVD are discussed. In the first, on a Udic Chromustert, the yield response to nitrogen levels was linear up to approximately 30 kg N/ha. In the second and third, on a Cumulic Haplustoll, there was little or no discernible response to nitrogen levels from 0 to 44 kg N/ha or to phosphorus levels from 0 to 37 kg P/ha. The CVD appears to be an efficient but underutilized technique that has merit for use in management trials for various crops, especially where space and funding are limiting factors.

Keywords: Experimental design; Cassava; N and P fertilizers

Introduction and Literature Review

This paper has two purposes: 1) to present the concept of the continuous variable technique and some advantages and disadvantages inherent in the CVD when applied to crop management experimentation and 2) to discuss the results of three fertilizer trials with cassava using the CVD at Lajas, Puerto Rico. Nature almost always confronts the ecologist with continuous variables in the field. Ecologists therefore have to devise methods of handling this data. However, most agronomists and horticulturists have for many reasons avoided continuous variable designs in favor of field designs employing selected discrete levels of the chosen variable(s). Very few researchers have employed continuous variable designs in fertilizer rate or other crop management studies.

Fox (1973) determined leaf N and grain yield of sweet corn treated with 40 levels of N applied sequentially down the row to single-plant plots and recommended the use of continuous function experimental designs in agronomic investigations. Treatments were replicated four times and occupied an area of less than 50 m^2. Fresh corn yield was highly correlated with leaf N and increased with each increment of N; yield response was nearly linear throughout the range of applied N.

This was the first of only six papers in English (none in Spanish or German) on CVD application to fertilizer trials found in the literature since 1970. Fox suggested the use of a CVD for studying interactions in two- and three-variable experiments and Hundtoft et al. (1974) used it in a two-variable experiment varying one factor in one direction and a second at 90 degrees. More recently Shoulders and Tiarks (1983) modified Fox's design to accommodate experimentation with N and P as continuous variables applied to young pine plantations. They are testing 11 levels each of N and P from 10 to 1000 and 5 to 500 kg/ha, respectively, with rates increasing on a logarithmic scale. The N levels are applied sequentially in one direction and the P levels are superimposed at 90 degrees.

Bauder et al. (1975) compared response surfaces generated using a CVD with response surfaces developed from a randomized complete block, split plot design on two soils with soil water and fertilizer N as variables applied to field corn. In the CVD both water and N treatments were applied as continuous variables, one at 90 degrees to the other. The two designs gave yield functions that, when used to predict yield values, led to the same conclusions. Although the authors recommended caution in drawing conclusions from the application of statistical analysis, their results suggest that the lack of randomization in the CVD is not always a serious limitation. A major advantage of the CVD was that more treatments were possible on less land while a disadvantage was that the small plot size led to large variation between replications and it was necessary to smooth the data by pooling treatments. Experiments using a similar design and with the same variables, water and N, applied to field corn were conducted at Isabela, Puerto Rico (Beinroth, 1982).

In the two experiments by Bauder et al., as well as those in Puerto Rico, water was applied to the CVD plots using a drip irrigation system with the amount of water delivered varying sequentially from row to row; nitrogen levels were applied across the rows. The drip system gave good control of the water treatments but was expensive and required considerable manpower. Hanks et al. (1976) improved the method of applying water treatments by developing a line source sprinkler system for continuously variable irrigation-crop production studies. This system uses a single row of closely spaced sprinklers down the center of the plot. This method applies a uniform water gradient varying from highest next to the line source to zero at the outer margins on both sides of the line. It is a relatively simple design that has stimulated interest in continuous variable designs and proven useful in studies involving soil water management (Hanks et al., 1976; Miller and Hang, 1980), leaching (Stark et al., 1982, 1983), continuously variable N levels applied through the line source sprinkler (Lauer, 1983), cultivation timing (Sorensen et al, 1980), and cultivars (Beinroth, 1982; Hanks et al., 1980).

Hanks et al. (1980) present data from an experiment with three winter wheat cultivars as influenced by irrigation using the line source sprinkler system. With the cultivars randomly assigned to strips across the line source a statistical analysis was valid and showed a significant irrigation-cultivar interaction as well as differences in yields among cultivars.

Stark et al. (1982, 1983) described a modified line source sprinkler system for use in leaching studies and conducted experiments with water as the continuous variable and N sources as a second variable applied randomly at 90 degrees to the sprinkler line to determine the effect of N sources and irrigation rate on celery yield and to determine the effect of these variables on NO3 - leaching. Lauer (1983) further modified the design to facilitate the application of N as the continuous variable through the line source sprinklers while maintaining the water applied at a uniform level. He employed three laterals spaced 13.8 m apart, one sprinkler wetted radius, with an in-line sprinkler spacing of 4.5 m, one-third the wetted radius. By injecting nitrogen fertilizer into the irrigation water entering either the central or the two side laterals, uniformity of application of N throughout the desired range of the N variable was produced. This design also gave uniform application of the water over the experimental.area.

Possibly the most important advantage of the CVD is the conservation of space, material and equipment, labor and the technician's time. The small size of each experiment reduces the labor and other resource requirements, so multiple sites can be installed and because a large number of levels of the variable can be applied it is possible to include extreme levels, thus obtaining more information (Shoulders and Tiarks, 1983). The continuous variable technique is also considered by most of the authors cited above to be useful for the study of possible treatment interactions.

The most serious disadvantage associated with continuous variable designs is a consequence of the nonrandom arrangement of the treatment levels. A method of statistical analysis of data from experiments using the line source sprinkler system was described by Hanks et al. (1980) and could apply to other CVD layouts as well. They conclude that the influence of irrigation using the line source sprinkler system cannot be assigned a probability level because of the nonrandom application of the water, but that irrigation effects are usually large and statistical analysis is not critical. It was recommended that the line source sprinkler design not be used where irrigation effects are expected to be small. Treatments imposed on randomized and replicated plots laid out at right angles to the irrigation variable could be tested statistically for treatment and treatment - irrigation interaction effects.

In Puerto Rico, food crops are grown on a wide range of soil types in various parts of the island and the fertilizer recommendations developed at the Agricultural Experiment Substations are not always applicable to farmers' conditions. Techniques need to be developed for conducting more fertilizer trials on sites more representative of farmers' field conditions and in more agroecological zones, but with limited funds. Because of this need and considering the apparent potential of the CVD, in spite of obvious inherent limitations, fertilizer trials have been conducted with varying degrees of success with sweet corn, okra, cabbage, green bean, sweet pepper, pumpkin, sweet potato and cassava (Spain, 1984 - 1987) in Puerto Rico using modifications of the technique advanced by Fox (1973). The results of three fertilizer experiments with cassava are reported in this paper.

Materials and Methods

One experiment with cassava (*Manihot esculenta*) was planted August 9, 1984 and harvested June 27 - 28, 1985 on a Fraternidad clay (Udic Chromustert) on the Agricultural Experiment Substation, Lajas, Puerto Rico to test a modified CVD with single-plant-plots for measuring crop response to applied N. On a San Anton clay (Cumulic Haplustoll), also on the Lajas Substation, experiments with N and P were planted to cassava on June 25, 1986 and harvested April 22 - 23, 1987. Stem cuttings of about 2.5 cm in diameter and 18 - 20 cm long with three or more buds were positioned at a 45 degree incline in the same hole where the fertilizer was placed but separated from the fertilizer by about 5 cm of soil and covered to within 2 - 3 cm of the upper end. Plant spacing was 1 x 1 m. All plots were flood irrigated at planting and thereafter as needed. Nitrogen rates in 1984 - 1985 were 0 - 30 g/plant of ammonium sulfate applied sequentially in 1 g increments down the treatment row and replicated three times, reversing the gradient with each replication. In 1986 - 87, N and P rates were 0 - 17.5 and 0 - 15 g/plant of ammonium sulfate and triple superphosphate, respectively, applied in the same manner, but in 0.5 g increments and not replicated. The nutrient not varied was applied uniformly to all plots at the highest level. Reference rows with the zero level of the nutrient under study were included along side the treatment rows to detect possible natural gradients already existing in the field. Treatment - reference -row assignments were random.

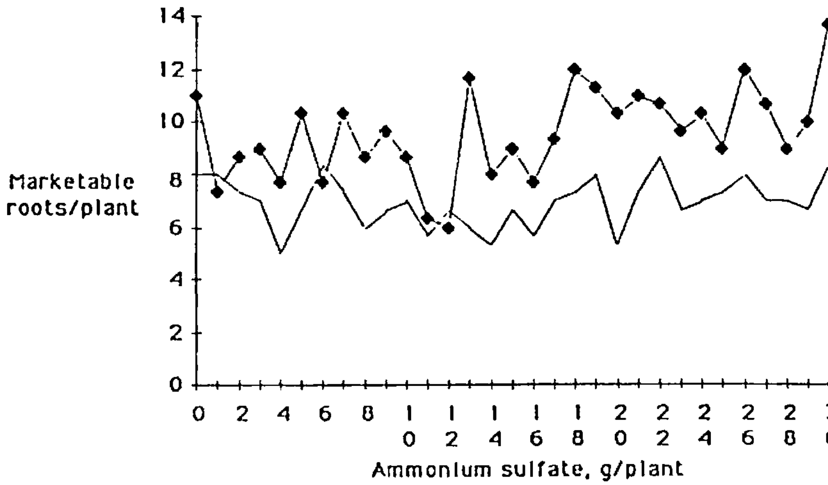

Figure 1 Marketable cassava roots per plant, treatment row ( ) vs. reference row, Fraternidad clay soil, Lajas, P.R., 1985

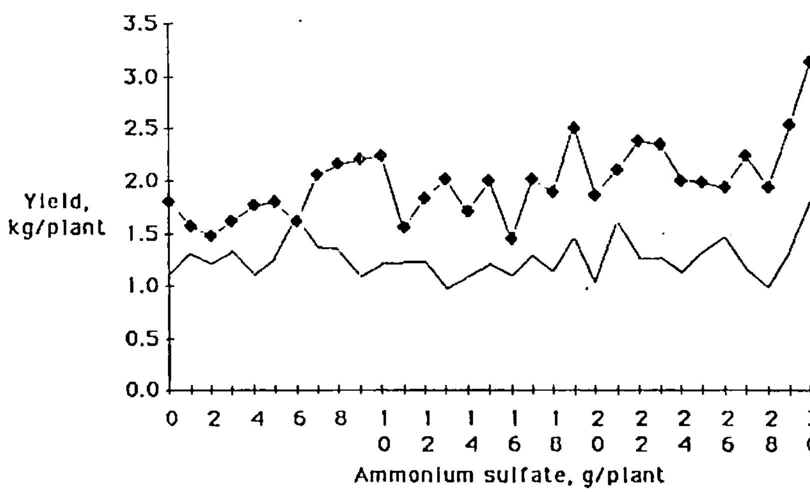

Figure 2 Mean Yields of cassava roots, treatment row ( ) vs. reference row, Fraternidad clay soil, Lajas, P.R., 1985

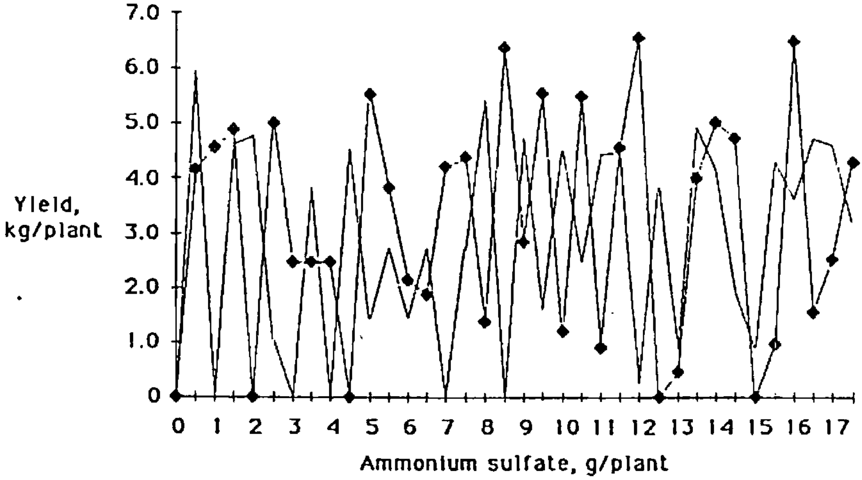

Figure 3 Cassava root yields, ammonium sulphate treatment row ( ) vs reference row, San Anton clay soil, Lajas, P.R. 1987

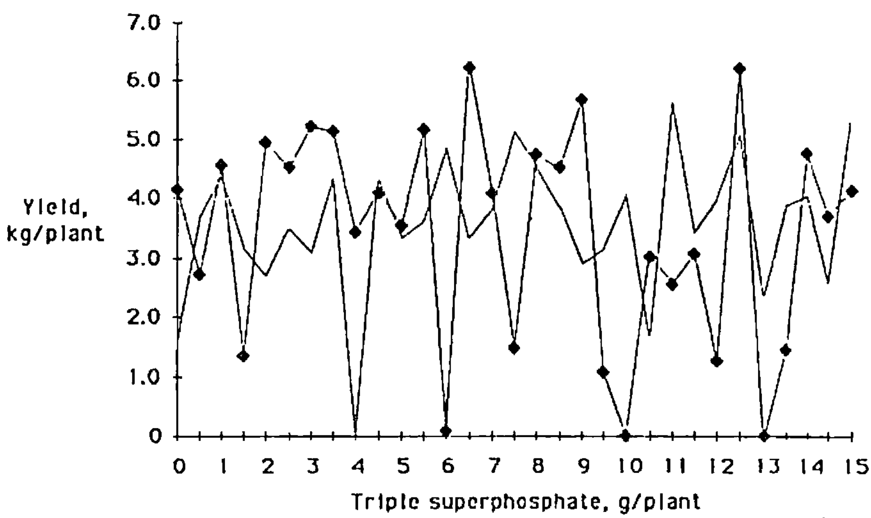

Figure 4 Cassava root yields, tripple superphosphate treatment row ( ) vs reference row, San Anton clay soil, Lajas, P.R. 1987

One early hand weeding and two passes with the line weeder gave only moderately acceptable weed control in 1984 - 85. Good weed control was obtained in 1986 - 87 by one application of paraquat between the rows 20 days after planting, and subsequent hand weeding and wick applied glyphosate to control Johnsongrass. Dicofol (*Kelthane*) was applied occasionally during both years when red spider mites were numerous.

The weight and number of marketable roots were recorded for the 1984 - 85 trial. Weights of all remaining above ground biomass at harvest time and of all marketable roots were recorded in 1987.

Results and discussion

In the 1984 - 85 trial on Fraternidad clay soil, cassava response to increasing N applications was inconsistent (Figures 1 & 2), and correlation coefficient values were small ($r = 0.31$ and 0.33 for tuber number and marketable yield respectively). However, number and weight of tubers were higher overall in N treatments than in reference rows. Number of tubers ranged from 5 to 17 with a mean of 9.55/plant among N levels versus 2 to 13 with a mean of 6.97 /plant for the reference rows. Weight of marketable tubers ranged from 0.88 to 3.24 with a mean of 1.94 kg/plant among N levels in contrast with 0.42 to 2.14 with a mean of 1.27 kg/plant for the reference rows. The mean yield of plants receiving 10 or more g of ammonium sulfate was 19,933 kg/ha, while the mean yield of reference rows (without N) was 12,700 kg/ha.

During the 1986 - 87 experiment on the San Anton clay soil there were no apparent differences in plant size as a result of either the N or P treatments. Likewise no tuber yield response was seen within the range of either N or P treatments as shown in Figures 3 and 4 which compare treatment rows with reference rows. When the differences between yield values of treatment row and reference row plant pairs were plotted with missing plants and their pair values deleted. The same lack of response was evident.

The modified continuous variable design employed in these experiments would appear effective and inexpensive for use with cassava. Two 38 m rows, with plants spaced one meter apart are adequate for testing 36 levels (a convenient number, if pooled data from 2, 3, 4 or 6 adjacent plants are desired for smoothing the response curve) of a nutrient with each extreme level duplicated to provide a buffer zone at each end of the treatment row. One more row on either side as borders would bring the total experimental area to 152 m_2, about one fifth of that required by conventional techniques for only five levels of one variable replicated four times. Materials required were almost negligible and labor during the establishment, maintenance and harvest of the experiment was minimal. These are essential features of techniques for increasing the number of experiments to include on-farm trials on various sites with limited funding.

References

Bauder, J. W., Hanks, R. J. and James, D. W. (1975) Crop production function determinations as influenced by irrigation and nitrogen fertilization using a continuous variable design, Soil Sci. Amer. Proc. 39 1187 - 1192

Beinroth, F. H. (1982) Final Report of the Puerto Rico Benchmark Soils Project 1975 - 1981, Dept. of Agron. and Soils, College of Agricultural Sciences, University of Puerto Rico, Mayaguez, P. R.

Fox, R. L. (1973) Agronomic investigations using continuous function experimental designs -Nitrogen fertilization of sweet corn. Agron. J. 65 454 - 456

Hanks, R. J., Keller, J., Rasmussen, V. P. and Wilson, G. D. (1976) Line source sprinkler for continuous variable irrigation - crop production studies, Soil Sci. Soc. Am. J. 40 426 - 429

Hanks, R. J., Sisson, D. V. Hurst, R. L. and Hubbard, K. G. (1980) Statistical analysis of results from irrigation experiments using the line - source sprinkler system, Soil Sci. Am. J. 44 886-888

Hundtoft, E. G. and Wu, I-Pai (1974) Continuous function designs for demonstration and research, University of Hawaii, Cooperative Extension Service, Misc. Publ. 115

Lauer, D. A. (1983) Line-source sprinkler systems for experimentation with sprinkler - applied nitrogen fertilizers, Soil Sci. Soc. Am. J. 47 124 - 128

Miller, D. E. and Hang-An N. (1980) Deficit, high-frequency irrigation of sugarbeets with the line source technique, Soil Sci. Soc. Am. J. 44 1295 - 1298

Shoulders, E. and Tiarks, A. E. (1983) A continuous function design for fertilizer rate trials in young pine plantations, USDA Forest Service, Gen. Tech. Rep. SE. pp 352 - 356

Sorensen, V. M., Hanks, R. J. and Cartee, R. L. (1980) Cultivation during early season and irrigation influences on corn production, Agron. J. 72 266 - 270

Spain, G. L. (1984 - 87) Annual Reports, Agricultural Experiment Sta., College of Agric. Sci., University of Puerto Rico, Mayaguez, P. R.

Stark, J. C., Jarrell, W. M. and Letey, J. (1982) A modified line source sprinkler technique for continuous-variable leaching studies, Soil Sci. Soc. Am. J. 46 441 - 443

Stark, J. C. Jarrell, W. M. and Letey, J. (1983) Evaluation of irrigation - nitrogen management practices for celery using continuous - variable irrigation, Soil Sci. Soc. Am. J. 47 95 - 98

VEGETABLE PRODUCTION TECHNOLOGY

Response of five corn genotypes to daylength in Puerto Rico

A. Sotomayor-Rios, S. Torres-Cardona, P. Hepperly

*USDA, ARS, Tropical Agriculture Research Station
Mayaguez, Puerto Rico 00709*

P. Maderal

*Agronomy and Soils Department, University of Puerto Rico,
Mayaguez Campus, Mayaguez, Puerto Rico.*

Response of corn (Zea mays L.) to daylength has not been investigated in Puerto Rico. Five genotypes, two temperate (Ohio S9 and Ohio S10), two local (Mayorbela and Diente de Caballo), and hybrid X304C (PBH304C) were evaluated every 90 days during a 2-year period at Mayaguez and Isabela, Puerto Rico. Planting dates were March 21, June 21, September 21 and December 21. Daylight hours (DL) for the first 60-day growth periods corresponding to the four planting dates were: 746, 771, 687 and 669 hours, respectively. Significant effects of location (L), planting date (PD) and genotype (G) and significant interactions (L x PD and PD x G) were observed for grain yield (GY) and most traits studied. The genotype overall response was higher at Mayaguez compared to the Isabela location. Genotypes showed a quadratic response to PD. Genotypes responded to increases in daylength up to the June planting (771 light hours). The highest GYs, 5971 and 5469 kg/ha, were obtained by PBH304C at Mayaguez and Isabela, respectively. Diente de Callo showed the strongest response to PD and the best yields were obtained by planting before the initiation of long days.

Keywords: Corn; *Zea mays*; Daylength

Introduction

Although corn is not grown commercially in Puerto Rico, it is an important component for animal feed with imports over $50 million yearly (Vicente-Chandler, 1984). Research on corn breeding and management at Mayaguez indicate that Puerto Rico could reduce imports of cereals if at least 50,000 hectares of mechanizable land were utilized to cultivate corn and/or sorghum intensively (Quiles-Belen, et al, 1985; Quiles, 1983 and Sotomayor-Rios, 1979). At present, corn and sorghum are grown in Puerto Rico as rotation crops with sweet potatoes and vegetables in the southern part of the island.

Limited research has been done in the tropics to study the response of corn to daylength (Domenech et al, 1977; Mangual-Crespo, 1977; Quiles, 1983; SotoMayor-Rios, 1979; Sotomayor Rios et al, 1980, Spain, 1982; Torres-Cardona et al, 1984; Vicente-chandler, 1984), although numerous studies have been conducted on management and cultivar response to soil and climatic conditions (Badillo-Feliciano et al. 1979; Brown et al. 1970; Fox et al. 1970; Quiles. 1983; Sotomayor-Rios, 1980 and 1983; Spain et al. 1982; Talleyrand et al. 1976; Torres-Cardona et al. 1984; Vazquez, 1961; Webster et al. 1977). However, reports indicate that agronomic performance of the crop may be affected by photoperiod (Allison et al. 1979; Keun et al. 1982; Kiniry et al. 1983a & b; Rood et al. 1980; Russel et al. 1983).

This study was carried out to evaluate the effects of daylength on the agronomic performance of four selections (from a reciprocal recurrent selection program) and a commercial hybrid, Pioneer X304C, at two locations in Puerto Rico.

Materials and methods

The experiment was conducted at the experimental farms of the USDA, ARS, Tropical Agriculture Research Station (TARS) in Isabela and Mayaguez, Puerto Rico. The soil at the Isabela location is an Oxisol (Tropeptic Haplorthox), whereas at Mayaguez it is an Ultisol (Dystropeptic Tropudult).

General characteristics of the experimental sites were as follows:

	Isabela	Mayaguez
Location	Northwestern PR	Western PR
Latitude	18°30'N	18°7'N
Longitude	67°W	67°W
Temperature range (°C)	18.8-29.4	22.2-26.1
Elevation (m)	128 m	10 m
Annual rainfall (mm)	1,675	2,158
Soil - name	Coto clay	Consumo clay
- type	(Oxisol)	(Ultisol)
Organic matter content	2.5%	3.2%
Exchange capacity (meq./100 g soil)	23	23
pH	5.0	4.8
P (ppm)	53	3
K (ppm)	140	194
NO_3 (ppm)	10	8

The planting dates at both locations were March 21, June 21, September 21 and December 21, 1985. Total light hours for the first 60-day growth period were: 746, 771, 687 and 669 for the four planting dates, respectively. The genotypes used were Mayorbela, Diente de Caballo, Ohio S9 and Ohio S10 from the third reciprocal recurrent selection cycle program at TARS, and the commercial hybrid Pioneer Brand Hybrid 304C (PBH304C). The experimental design was a complete randomized block replicated four times. Each plot consisted of 4 rows, 6 m long and 0.75 m apart; plants were collected from the two inner rows, 7.5 m^2 in area.

Two weeks after planting, 560 kg/ha of a complete 15-5-10 fertilizer was applied to all plots. An additional application of N was applied as $(NH_4)_2$ SO_4 at the rate of 60 kg/ha, four weeks after planting. Weeds were controlled with propazine pre-emergent herbicide, at a rate of 2.5 kg ai/ha, and by hand-weeding. For the control of soil-borne insects and nematodes, carbofuran was applied at planting at a rate of 30 kg ai/ha. Methomyl was applied at a rate of 0.5 kg ai/ha to control foliar insects.. Supplemental overhead irrigation was applied to all plots as needed.

Prior to harvest, plant height (soil surface to tip of the tassel), ear height (soil surface to topmost ear-bearing node), leaf area (by a portable area meter, model LI-3000, Lambda Instruments Corporation), root and stem lodging, days to midbloom, and severity of southern rust (*Puccinia polysora*) southern leaf blight (*Helminthosporium maydis*) and corn bushy stunt (Spiroplasma) were measured. Harvested ears were dried to a uniform moisture content; ear length and ear diameter were measured on 10 ears/plot at random. Test weight (TW) was measured and grain yield (GY) was adjusted to 15.5% moisture. All data were subjected to analysis of variance (ANOV) and regression, and significant differences identified with Duncan's multiple range test.

Results and discussion

Table 1 shows the combined ANOV for 14 traits of corn during four planting dates at two locations in Puerto Rico. Significant effects of location, planting date, genotype, location-x-planting date and planting date-x-genotype interactions were observed for most traits. Grain yield responded significantly to increases in total accumulative light hours.

Table 1 Combined analysis of variance for 14 traits of corn during four plating dates at two locations in Puerto Rico

Traits	C.V. (%)	Source [1]						
		L	PD	LxPD	G	LxG	PDxG	LxPDxG
Days to midbloom	1.3	**	**	**	**		* [3]	
Ear height	9.2		**		**		*	
Plant height	9.0		**	*	**			
Ear length	6.0		**	**	*			
Ear diameter	4.9	**	**	**	**			
Leaf area	73.0		**	**				
Root lodging	41.0	**	**	**	**	**	**	**
Stem lodging	112.0	**	**	**	**			
Grain yield	21.0	**	**	**	**	*	**	
Test weight	3.2	**	**	**	**	*		
Northern leaf blight	49.6	**	**	**	**			*
Southern leaf blight	77.1	*	**	**	**		**	
Corn bushy stunt	73.6	**	**	**	**		**	
Southern rust	42.0	**	**	**	**		*	

L = location, PD = planting date, F = genotype,
CV = coefficient of variance
* = significant at the 0.05 probability level
** = significant at the 0.01 probability level

Table 2 compares means between locations for 14 traits of five genotypes across four planting dates. The overall agronomic performance of genotypes (grain yield, ear length, ear diameter and leaf area) were higher at Mayaguez than at Isabela. Genotypes took two additional days to reach midbloom at Mayaguez (61 days) as compared to Isabela (59 days). While the severity of northern leaf blight was significantly higher at Mayaguez than at Isabela, the southern leaf blight, southern rust and corn bushy stunt diseases were higher at Isabela than at Mayaguez.

Tables 3a & b compare means among planting dates and locations for 14 traits of five corn genotypes. Days to midbloom were significantly different for planting dates at both locations, except for the June and September plantings at the Isabela location. Days to midbloom ranged from 54 to 66 (Isabela) and 58 to 64 (Mayaguez). The effect of daylength on midbloom on corn has been studied in the tropics. In general, the reports indicate that plants take longer to reach midbloom when planted during short days (less than 12 hours) as compared to plantings made during long days (over 12 hours) (Allison and Daynard, 1979; Kiniry et al. 1983a & b; Rood et al. 1980; Russel et al. 1983).

Table 2 Comparison of means between locations for 14 traits of five corn genotypes across four planting dates

Traits	Locations	
	Isabela	Mayaguez
Days to midbloom (days)	59b	61a
Ear height (cm)	107a	112a
Plant height (cm)	237a	247a
Ear length (cm)	16.2a	16.5a
Ear diameter (cm)	4.1b	4.2a
Leaf area (cm^2)	6805a	6953a
Root lodging (%)	24a	17b
Stem lodging (%)	5a	2b
Grain yield (kg/ha)	3069b	3631a
Test weight (kg/ha)	77a	73b
Northern leaf blight	0.7b	1.4a
Southern leaf blight	0.9a	0.7b
Corn bushy stunt	18a	4b
Southern rust	1.4a	0.8b

Horizontal means followed by the same letter do not differ significantly at the 0.05 probability level.

Ear height of genotypes was similar at both locations, but differed significantly among planting dates. The best plant, ear height and ear length increases were observed in the March and June plantings at both locations. Ear length was significantly higher when genotypes were planted in March (Mayaguez) and June (Isabela). At both locations, ear diameter and leaf area were higher during the March planting.

The leaf area results are in agreement with those obtained by Allison and Daynard (1979). Root lodging of genotypes was significantly higher during the September planting at both locations. Stem lodging was significantly higher in the June (Mayaguez and Isabela) and September (Mayaguez) plantings, corresponding to the rainy season at both locations. Grain yield was significantly higher when genotypes were planted in March at both locations, in agreement with Keun Jong et al. (1982), who found that corn yields in the tropics increase as daylength increases.

The northern leaf blight incidence was significantly higher when genotypes were planted in December at Mayaguez, and for the March and June plantings at Isabela. A higher southern leaf blight incidence was observed when genotypes were planted during September (Mayaguez) and June and September (Isabela), corresponding to periods of higher rainfall and humidity. There was no incidence of corn bushy stunt when genotypes were planted prior to the initiation of the long day period (over 12 hours) at either location, while for southern rust severity, the opposite was observed.

Table 3a Effect of planting date at Isabela on 14 traits of corn (Means of five genotypes)

Traits	Date of planting			
	Mar.	Jun.	Sep.	Dec.
Days to midbloom (days)	54 c	59 b	58 b	66 a
Ear height (cm)	136 a	116 b	84 c	91 c
Plant height (cm)	277 a	240 b	203 c	228 b
Ear length (cm)	16.3 b	16.9 a	16.0 bc	15.8 c
Ear diameter (cm)	4.3 a	4.0 b	4.1 b	4.1 a
Leaf area (cm2)	7,693 a	----	6,797 b	5,925 c
Root lodging (%)	4.9 b	4.9 b	85.0 a	3.1 b
Stem lodging (%)	4.5 b	12.2 a	2.1 b	2.6 b
Grain yield (kg/ha)	3,766 a	2,440 c	2,971 b	3,101 b
Test weight (kg/ha)	79 a	75 c	79 a	77 b
Northern leaf blight	1.4 a	1.1 a	0.2 b	0.2 b
Southern leaf blight	0.3 b	1.4 a	1.6 b	0.1 b
Corn bushy stunt	0.0 d	41.2 a	21.6 b	8.5 c
Southern rust	1.9 a	1.8 a	1.3 b	0.5 c

Figures within rows, followed by the same letter, do not differ significantly at the 0.05 probability level.

Table 3b Effect of planting date at Mayaguez on 14 traits of corn (Means of five genotypes)

Traits	Date of planting			
	Mar.	Jun.	Sep.	Dec.
Days to midbloom (days)	64 a	58 c	61 b	62 a
Ear height (cm)	127 a	124 a	93 b	106 b
Plant height (cm)	260 ab	273 a	214 c	240 bc
Ear length (cm)	18.2 a	16.1 b	16.0 b	15.6 b
Ear diameter (cm)	4.7 b	4.1 b	4.1 b	4.0 b
Leaf area (cm^2)	9,136 a	6,704 b	6,366 bc	5,605 c
Root lodging (%)	5.8 b	13.6 b	44.8 a	4.4 b
Stem lodging (%)	0.3 b	3.7 a	3.9 a	1.3 b
Grain yield (kg/ha)	5,737 a	3,176 b	2,674 b	2,939 b
Test weight (kg/ha)	72 b	70 c	75 a	74 a
Northern leaf blight	0.2 c	1.0 b	1.0 b	3.3 a
Southern leaf blight	0.1 c	0.5 b	1.7 a	0.3 bc
Corn bushy stunt	0.0 c	0.0 c	10.9 a	6.4 b
Southern rust	1.0 b	1.4 a	0.5 c	0.4 c

Figures within rows, followed by the same letter, do not differ significantly at the 0.05 probability level.

Comparisons among genotypes and locations for 14 traits of five corn genotypes is shown in Tables 4a & b. Pioneer hybrid 304C required an average of one day more to reach midbloom, compared to the remaining genotypes at both locations. Ear height for Diente de Caballo was significantly higher than for other genotypes at both locations. Genotypes exhibited similar plant heights at both locations, except Ohio S9 which was shorter at Isabela. Genotypes produced similar ear lengths, except Ohio S9, which was significantly shorter at both locations. Pioneer hybrid 304C produced the highest grain yield and ear diameter and showed the lowest northern leaf blight and root lodging. Leaf area was similar for all genotypes at both locations. Stem lodging of genotypes was similar at both locations, except for Ohio S9, which lodged significantly more at Isabela. Mayorbela showed the highest test weight at both locations as compared to the remaining genotypes. The incidence of southern leaf blight in Ohio S9 and Ohio S10 at both locations was significantly higher than that of the other genotypes. The genotypes most susceptible to the southern rust were PBH304C, Ohio S9 and Ohio S10.

Table 4a Effect of genotype on 14 traits of corn at Isabela (Means of 4 planting dates)

Traits	Corn genotype				
	X304C	Caballo	Mayorbela	OH S9	OH S10
Days to midbloom (days)	60 a	59 b	59 b	59 b	59 b
Ear height (cm)	107 ab	113 a	108 ab	100 b	105 ab
Plant height (cm)	251 a	243 ab	234 b	216 c	238 ab
Ear length (cm)	16.6 a	16.4 a	16.6 a	15.4 b	16.0 a
Ear diameter (cm)	4.4 a	4.0 c	3.7 d	4.2 ab	4.2 ab
Leaf area (cm2)	7,123 a	7,174 a	6,452 b	6,903 ab	6,790 ab
Root Lodging (%)	19.7 b	27.3 a	25.5 a	23.6 ab	26.3 a
Stem lodging (%)	3.1 b	4.0 b	3.5 b	10.0 a	6.0 b
Grain Yield (kg/ha)	4,335 a	3,173 b	3,222 b	2,219 c	2,299 c
Test weight (kg/ha)	76 c	78 b	81 a	76 c	75 c
North leaf blight	0.4 b	0.7 ab	0.8 ab	0.8 ab	0.9 a
Southern leaf blight	0.5 b	0.4 b	0.5 b	1.3 a	1.6 a
Corn busy stunt	11.6 c	16.8 abc	15.0 bc	23.1 a	22.3 ab
Southern rust	1.6 a	1.0 b	0.8 b	1.7 a	1.7 a

Figures within rows, followed by the same letter do not differ significantly according to Duncan's multiple range test (p=0.05).

Table 4b Effect of genotype on 14 traits of corn at Mayaguez (Means of 4 planting dates)

Traits	Corn genotype				
	X304C	Caballo	Mayorbela	OHS9	OHS10
Days to midbloom	62 a	61 b	61 b	61 b	61 b
Ear height (cm)	110 c	126 a	117 b	103 d	107 cd
Plant height (cm)	253 a	258 a	245 ab	235 b	245 ab
Ear length (cm)	16.9 a	16.7 ab	17.0 a	15.7 c	16.0 bc
Ear diameter (cm)	4.6 a	4.1 c	3.8 d	4.3 b	4.3 b
Leaf area (cm2)	7,181 a	7,116 a	6,638 a	7,037 a	6,792 a
Root Lodging (%)	5.3	25.3 a	28.0 a	8.7 c	17.5 b
Stem lodging (%)	2.0 a	2.0 a	2.2 a	3.4 a	1.7 a
Grain Yield (kg/ha)	4,735 a	3,740 b	3,299 bc	3,117 c	3,266 bc
Test weight (kg/ha)	69 d	74 b	77 a	71 c	72 bc
North leaf blight	0.7 a	1.4 a	1.5 a	1.7 a	1.6 a
Southern leaf blight	0.3 b	0.7 a	0.3 b	0.9 a	1.0 a
Corn busy stunt	2.0 a	6.1 a	3.9 a	5.7 a	3.7 a
Southern rust	1.0 a	0.4 b	0.5 b	1.0 a	1.0 a

Figures within rows, followed by the same letter do not differ significantly according to Duncan's multiple range test (p=0.05).

Figure 1 shows the relationship between daylight hours during the first 60-days growth period for the four planting dates and grain yield of the five corn genotypes at the two locations. In most cases genotypes showed a quadratic response over planting dates at both locations. Significant increases in grain yields up to the March planting were obtained at both locations. The strongest effect of plating date was observed for Diente de Caballo at Mayaguez. The highest grain yields were obtained with PBH304C giving 5,971 (Mayaguez) and 5,469 kg/ha (Isabela) in the March planting. Even though the highest grain yields were obtained by planting in March, prior to the initiation of the long day period, a potential exists to develop genotypes insensitive to daylength which could be grown all year round.

References

Allison, J. C., and Daynard (1979). Effect of change in time of flowering, induced by altering photoperiod or temperature, on attributes related to yield in maize. Crop Sci. 19(1):1-4.

Badillo-Feliciano, J., Lugo-Lopez, M. A. and Scott, T. W. (1979) Influence of cultivars, N levels and time of N application on plant characters, leaf composition, and yield of corn grown on an Oxisol, J. Agric. Univ. P. R. 63 (3):273-80.

Brown, R. H., Beaty, R. H., Ethredge, W. J., and Hayes, D. D. (1970). Influence of row width and plant population on yield of two varieties of corn (Zea mays). Agron. J. 62 (6):767-770.

Domenech, J. O., and Mangual - Crespo, G. (1977) Performance of sweet corn varieties and their response to planting season, J. Agic. Univ. P. R. 61(2):170-174.

Fox, R. H., Talleyrand, H., and Bouldin, D. R. (1970). Nitrogen fertilization of corn and sorghum grown in oxisols and vertisols in Puerto Rico. Agron. J. 66(4):534-540.

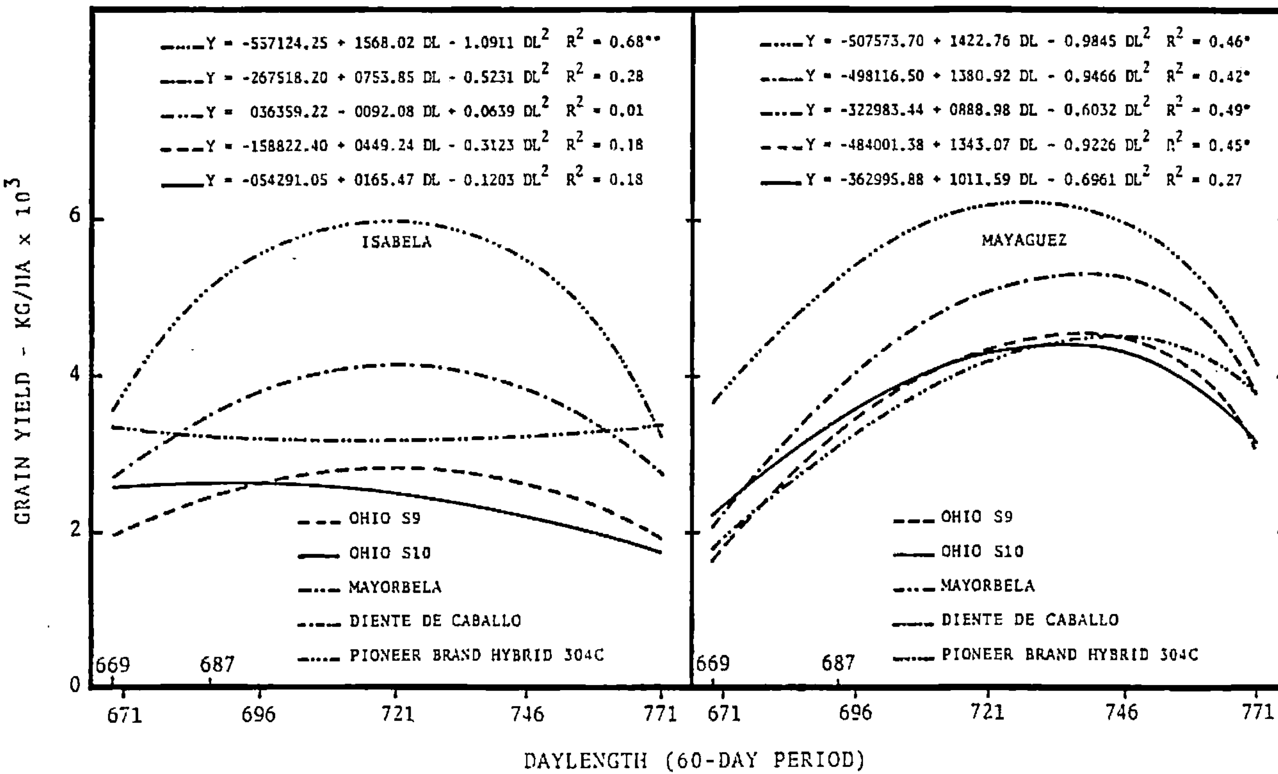

Fig. 1 Accumulative light hours for the first 60-day growth of five corn genotypes during four planting dates.

Keun. J. S., Brewbaker, J. L. and Lee, C. H. (1982). Effects of solar radiation on the performance of maize in 41 successive monthly plantings in Hawaii. Crop. Sci. 22(1):13-18.

Kiniry, J. R., Ritchie, J. T. and Musser R. L. (1983). Dynamic nature of the photoperiod response in maize. Agron. J. 75:700-703.

Kiniry. J. R., Ritchie, J. T., Musser, R. L., Flint, E. P. and Iwig, W. C.(1983) The photoperiod sensitive interval in maize. Agron. J. 75:687-690.

Mangual-Crespo, G. (1977) Yield performance of two sweet corn varieties and two hybrids in the Isabela areas. J. Agric. Univ. P. R. 61(2):175-181

Quiles-Belen, A., Sotomayor-Rios, A. and Torres-Cardona, S. (1985) Breeding and agronomic performance of corn cultivars and hybrids during the past five years in Puerto Rico. In: Proc. of the Annual Meeting, Carib. Food Crops Soc., Trinidad, Tobago.

Quiles, A. (1983). Response del maiz a la fertilizacion nitrogenada y a densidades poblacionales en dos localidades de Puerto Rico. M.S. Thesis, Univ. P.R., Mayaguez Campus, Mayaguez, P.R.

Rood, S. B. and Mayor, D. J. (1980) Response of early corn inbreds to photoperiod. Crop. Sci. 20(1):679-682.

Russell, W. K. and Stuber, C. W. (1983). Effects of photoperiod and temperatures on the duration of vegetative growth in maize. Crop. Sci. 23(5):847-850.

Sotomayor-Rios, A. (1979). Performance of twelve corn hybrids and selection in three consecutive crops on the same site in the same year. J. Agric. Univ. P.R. 63(2):170-179.

Sotomayor-Rios, A., Torres, C. and Ellis, M. (1980). Effect of plant density on yield and plant characters of twelve corn hybrids and selections.. J. Agric. Univ. P.R. 64(4):407-413.

Sotomayor-Rios, A., and Weibel, D. (1983). Grain Crops. In: Martin, F. W. (Editor), Handbook of Tropical Food Crops. CRC Press. Boca Raton, Florida.

Spain, G. L., Nightengale, S., and Badillo-Feliciano, J. (1982) Corn variety trials in an Eutrustox in Puerto Rico. J. Agric, Univ. P. R. 66(3):223-234.

Talleyrand, H. M. and Lugo-Lopez, M. A. (1976) Performance of high yielding corn hybrid Pioneer X-306 B and Funk's G795W at high levels of fertilization in the acid and relatively infertile soils (ultisols and oxisols) of Puerto Rico. J. Agric. Univ. P. R. 60(10:132-134

Torres-Cardona, S.M. and Sotomayor-Rios, A. (1984). Response of corn (Zea mays L.) to planting dates in Puerto Rico. Proc. 19th Ann. Meeting Carib. Food Crops Soc. pp. 112-125.

United States Department of Agriculture (1986) Agricultural Statistics, United States Government Printing Office, Washington. p. 35.

Vazquez, R. (1961). Effects of irrigation at different growth stages and of nitrogen levels on corn yields in Lajas Valley, Puerto Rico, J. Agric. Univ. P. R. 45(2):85-105.

Vicente-Chandler, J. (1984) Comentarios sobre una agricultura productiva para Puerto Rico. Revista Colegio de Agronomos de Puerto Rico, Oct.-Dec. pp. 7-8.

Webster, O. J., and Walker, D. W. (1977) A field test of corn cultivars for insect and disease resistance, J. Agic. Univ. P. R. 61(3):319-325

Yearbook of Agriculture (1985) U.S. Agriculture in a global economy, U.S. Government Printing Office, Washington, D.C. pp. 152-156.

Introductions de varietes d'oignons en Martinique

H. De Bon

IRAT-CIRAD, Martinique, BP 427, 97204 Fort-France Cedex, Martinique, French West Indies

Depuis 1984 des introductions d'oignons sont faites en Martinique en provenance de toutes les zones tropicales. Les criteres de selection sont l'aptitude a bulbifier, une bonne conservation et la possibilite de produire des graines dans les conditions de la Martinique. Au total, en 1984, 93 varietes ont ete introduites. A la fin de la conservation, nous en avons retenu 41, soit 44%. Des graines ont ete obtenues sur 14 varietes soit 39% du nombre de porte-graines mis en place, ou 15% des varietes introduites. Elles proviennent d'Israel (2), des Etats-Unis (3), du Bresil (2), d'Afrique (8). Elles feront l'objet d'une selection massale per se pendant deux cycles de culture avant d'etre utilisees dans un programme d'amelioration.

Onions from various tropical and subtropical regions were tested in Martinique during 1984. The criteria used for selection were good bulbing ability, good storage and ability to set seeds under Martinquan conditions. In all, 93 varieties were introduced, of which 44% were selected. Seeds were obtained from 15 varieties when bulbs were replanted after 45 days cold treatment at 7 to 11 degrees Centigrade. Origins of these varieties were: Israel, 2; United States, 3; Brazil, 2; Africa, 8. Further improvement will be made by two cycles of mass selection followed by a breeding programme.

Keywords: Onions; Varietal selection; Seed production

Introduction

Les oignons en Martinique representent le deuxieme legume le plus importe a raison de 2500 tonnes par an environ. Le developpement de la culture de l'oignon peut se faire avec des varietes des Etats-Unis (De Bon, 1985). Elles presentent des potentialites moyennes car les rendements depassent rarement 30 t/ha en parcelles experimentales. La conservation, de faible duree est de 2 mois environ. La floraison est difficile a obtenir et souvent impossible dans les conditions des petites Antilles pour plusieurs raisons. Les temperatures minimales qui ne descendent jamais en dessous de 19^{o}C, sont trop elevees pour permettre l'initiation de la plupart des varietes. Les temperatures maximales sont trop chaudes (30 a 32 ^{o}C) et peuvent entrainer l'avortement des hampes florales et une mauvaise nouaison.

En Guadeloupe, des 1973, Anais avait mis en evidence les possibilites de culture et de reproduction de l'oignon avec l'utilisation des varietes du Niger. En 1978, Anais et Schweisguth avaient fait des hybrides entre Violet de Galmi, originaire du Niger, et des lignees d'origine europeennes pour creer des varietes hybrides adaptees aux conditions antillaises. Ils ont obtenu des lignees males steriles, des lignees mainteneuses de sterilite et des parents males. En 1984, Gautier et Anais ameliorent les techniques de culture de l'oignon pour la Grande-Terre et Marie-Galante. Le choix varietal est fait en fonction des dates de semis. Plusieurs varietes du Japon (King Star, Tropic Ace, Senshu Yellow), des Etats-Unis (Texas Grano, Granex) et Jaune Hatif de Valencia "Babosa" du Sud de la France, sont

L'IRAT a commence un programme d'amelioration de l'oignon pour les regions tropicales. Dans un premier temps, il s'agit d'evaluer le materiel susceptible d'etre utilise dans un programme de selection. Ce tri a commence en Martinique en 1984. Le choix a ete relativement large. Les varietes courantes commerciales de jours courts proviennent d'une base etroite (Peters, 1984). Il etait preferable d'elargir le materiel initial afin que le rendement et la vigueur ne soient pas sacrifies par des problemes de consanguinite risquant d'apparaitre rapidement dans les generations ulterieures.

Materiel & methodes

122 varietes sont introduites sous forme de graines. Le choix se fait en tenant compte dans la mesure du possible, de certains criteres: la resistance aux maladies *Alternaria sp.*, *Pyrenochaeta terrestris*, la resistance a *Thrips tabaci*, une bonne aptitude a la conservation et une origine tropicale entre des latitudes de 5 a 35 degrees.

Les origines des varietes sont les suivantes:

Moyen-Orient: Afghanistan (1); Iran (5);
Asie: Inde (10); Pakistan (7);
Afrique tropicale: Burkina-Faso (1); Cameroun (2); Ethiopie (1); Ghana (3); Niger (3); Soudan (7);
Bassin mediteraneen: Bulgarie (1); Egypte (5); Espagne (1); Israel (12); Portugal (1); Turquie (7); Syrie (1);
Afrique du Sud (4);
Ocean indien: Ile Maurice (1); Ile de la Reunion (1);
Amerique du Nord: Etats-Unis (10);
Amerique du Sud: Bresil (13);
Asie extreme-orientale: Chine (1); Taiwan (2); Japon (8);
Europe Temperee: France (1); Pays-Bas (1);
Oceanie: Australie (8); Nouvelle-Zelande (4);

(Le nombre entre parentheses indique le nombre de varietes testees dans l'origine geographique)

Les collections sont testees par rapport a Yellow Granex et Violet de Galmi. Les parcelles elementaires sont de 1 a 3 m_2 environ. Nous evaluons leur aptitude a bulbifier, les differentes caracteristiques du bulbe (forme, couleur, fermete, taille, division), l'homogeneite du materiel, la sensibilite aux maladies du feuillage, le comportement pendant la conservation et l'aptitude a fleurir dans les conditions des Antilles pendant la 2eme partie d'un cycle de culture bisannuel.

L'aptitude a la floraison est determinee apres un passage des bulbes porte-graines dans une chambre froide pendant 45 jours a une temperature variant entre 7 et 11 degrees Centigrade. Les bulbes-meres sont plantes au champ en octobre pour que la floraison se fasse au moment ou les temperatures sont les plus fraiches entre la fin de decembre et fevrier.

Les collections sont mises en place dans le sud, a Sainte-Anne, et dans le centre, au Lamentin, de la Martinique. Les principales caracteristiques agro-climatiques de ces implantations sont:

Sainte-Anne: Vertisols magnesiens, pluviometrie annuelle totale de 1500 mm, saison seche marquee de janvier a juin; la culture se fait en semis direct; une irrigation de complement est apportee pendant toute la duree de la culture;

Lamentin: Sols ferralitiques, pluviometrie annuelle totale de 2200 mm, saison seche peu marquee de fevrier a mai; la culture se fait avec un semis en pepinieres et une transplantation au champ; les conditions d'humidite et de temperature y sont tres favorables au developpement des maladies des feuilles et du bulbe.

Resultats

Mise en place des collections

Quatre collections sont semees, 2 pendant la saison 1984 - 1985, et 2 pendant la saison 1985 - 1986 (Tableau 1). Au Lamentin (1), la transplantation est faite le 29-Dec-1984; la recolte commence le 18-Mars-1985 et se prolonge jusqu'au 29-Avr-1985; A Sainte-Anne (2), la recolte a lieu entre les 6 et 20-Mai-1985; A Sainte-Anne (4), le 15-Mai-1986, 9 d'entre elles, avaient ete observees l'annee precedente au Lamentin, en zone plus pluvieuse et y avaient eu un bon comportement.

Tableau 1 Caracteristiques des collections testees

Numero de la collection	Localite	Date de semis	Nombre de varietes	Mode de semis	Temoin utilise
1	Lamentin	19-11-84	79	Pepin.	VG & YG
2	Sainte-Anne	23-01-85	13	Semis	VG
3	Lamentin	25-11-85	29	Pepin.	YG
4	Sainte-Anne	15-05-86	19	Semis	VG

Pepin.: semis fait en pepinieres suivi d'une transplantation au champ; Semis: semis direct au champ; VG: Violet de Galmi; YG: Yellow Granex.

Collection 1 (Lamentin): Le choix est large. 23 varietes sont interessantes; elles figurent dans le Tableau 2. Elles sont retenues essentiellement sur leur bonne aptitude a bulbifier dans les conditions de la Martinique.

Tableau 2 Liste des varietes retenues de l'essai 1

Origine geographique	Varietes
Bresil	Amarela globular, Baia piriforme, Pera baia sintese n 13, Jubileu, Norte 14, Empasc 351, Pera IPA-1, Pera IPA-2, CEPEG 27
Afrique du Sud	De Wildt, Atjar, Rowcliffe brown
Afrique	Soudan: Red onion (2), Yellow onion (2)
Israel	Nissan, H-39, H-23, Ori, Galil
Asie	Local white (Pakistan), NVRS 3503
Australie	Early Lockyer Brown

Collection 2 (Sainte-Anne): Elle permet de retenir Superex venant du Japon, Hybrid Texstar 80 PRR des Etats-Unis et CEPEG 27 hybride experimental bresilien. Ces varietes presentent une bonne productivite en bulbes de qualite homogene. Nous y ajoutons Violet de Garango (IRAT 72) et Violet de Soumarana (IRAT 295) qui ont de bonnes aptitudes a la conservation. Pour ces 2 premieres collections, 28 varietes apparaissent interessantes soit 30% de celles observees en culture. Elles sont mises en conservation. Un 2eme choix de 11 varietes moins satisfaisantes est effectue. Elles presentent une bonne vigueur en vegetation due a un feuillage peu attaque par les maladies fongiques et *Thrips tabaci*; mais, les bulbes sont de mauvaise qualite et arrivent difficilement a maturite. Ils sont mis aussi en conservation (Annexe 2).

Collection 3 (Lamentin): Nous retenons HA-55, Anak, Moab, Beth Alpha Autumn, Ori, Galadalan White, Early Lockyer White et Golden Brown. Parmi cellesci, Ori avait eu un bon comportement l'annee precedente. Ces 8 varietes ont un cycle court et une production de bulbes homogenes et reguliers.

Collection 4 (Sainte-Anne): Onze varietes presentent une bublbification homogene et de forme reguliere: Galil, HA-55, H-60, HA-23, Pera IPA 1, Baia piriforme, Jubileu, Pusa Red, Goudami, Pusa White Flat et Pusa White Round. La variete HA-55 a un bon comportement au Lamentin et a Sainte-Anne a des dates de semis differentes. Galil, H-23, Pera IPA-1, Baia piriforme, Jubileu avaient ete retenues l'annee precedente. Au total, pour ces deux collections 3 et 4, 18 varietes sont mises en conservation soit 38% de celles observees en culture.

Floraison des introductions

Introductions du cycle 1984 - 1985: Ces varietes ont ete observees sur un cycle de culture en 1984-1985. Les bulbes obtenus sont mis en conservation entre mai et septembre. Apres un passage au froid de 45 jours a 7 - 11 degrees Centigrade, en octobre - novembre 1985, ils sont plantes pour en observer la floraison. 41 varietes sont plantees; 15 d'entre elles emettent des hampes florales et donnent des graines. Elles representent 15% des varietes introduites. Ce sont suivant le pays d'origine:

1) Deux varietes d'Israel: Nissan (6%) et H-39 (39%);

2) Trois des Etats-Unis: Red Creole, Golden Hybrid (39%), Hybrid Texstar 80 PRR (21%);

3) Deux du Bresil: Amarela globular (100%) et Baia piriforme (33%)

4) Une d'Afrique du Sud: De Wildt (43%);

5) Sept d'Afrique tropicale et de la Reunion: Red onion (40%), Yellow onion (50%) et Soudan-IRAT (100%) du Soudan; Violet de Galmi (56%) et Violet de Soumarana (29%) du Niger; Chateauvieux (22%) de la Reunion et Local Red (28%) de l'Ile Maurice.

Les varietes qui fleurissent proviennent principalement des Etats-Unis et d'Afrique. Les floraisons observees sont partielles et varient de 6 a 100% des plants en culture. Le pourcentage de plants fleuris est indique entre parentheses apres chaque variete.

Introductions du cycle 1985 - 1986

Ces varietes ont ete observees sur un cycle de culture en 1985-1986. La conservation et le passage au froid sont identiques a ceux de l'annee precedente. 28 varietes sont plantees en novembre 1986. Il n'apparait des hampes florales que sur 11 d'entre elles. La floraison exprimee en nombre de plants avec au moins une hampe florale apparue, varie de 4 a 66%. Ce sont suivant le pays d'origine:

1) Quatre varietes d'Asie: Pusa Red (62%), Pusa White Round (38%) et Pusa White Flat (58%) venant d'Inde, ainsi que Tainan selection n 2 (10%) de Taiwan;

2) Trois du Bresil: Pera IPA-1 (5%), Baia piriforme (4%),Jubileu;

3) Deux d'Afrique: Gebake (54%), Goudami (66%);

4) Deux d'Australie: Early Lockyer White (4%), Golden Brown (7%).

Au total sur ce cycle d'introductions, 48 varietes ont ete testees; 27 d'entre elles sont mises en place pour une production de semences; 11 emettent des hampes florales soit 23% du nombre initial.

Bilan

En rassemblant l'ensemble des resultats, nous avons pu trier 25 varietes qui fleurissaient plus ou moins bien dans le climat de la Martinique avec les conditions de vernalisation que nous etions imposes au depart. Elles peuvent etre classees en 2 grands groupes. Le premier comprend le materiel venant d'Inde, d'Afrique tropicale et de la Reunion: les bulbes sont de couleur blanche ou rouge, a forme aplatie, avec une tres forte tendance a la division, a gout piquant; les pourcentages de floraison sont eleves. Le second comprend les varietes a bulbes jaunes, gros, de forme globe a plat-epais; ce sont celles du Bresil, D'Afrique du Sud, d'Israel, d'Australie et des Etats-Unis. La variete de Taiwan est une amelioration d'une population originaire d'Australie.

Discussion-Conclusion

Si on reprend par pays d'origine les differentes introductions, on obtient le Tableau 3 des varietes retenues. Ce programme de selection de l'oignon debute en Martinique en est a sa troisieme annee. En Martinique, nous realisons un travail d'amelioration de l'oignon, destine a la zone tropicale humide. Il peut meme etre considere comme destine aux climate insulaires. Cependant, etant donne que le tri tient compte des exigences photoperiodiques de la plante et de son aptitude a supporter des temperatures elevees, une partie des resultats peut zones plus seches comme la zone soudano-sahelienne.

Dans les conditions des petites Antilles, le nombre de varietes fleurissant apres les conditions de vernalisation que nous sommes imposees, est faible. La floraison y est souvent partielle sans doute inhibee par les hautes temperatures. Le determinisme de la floraison n'est pas connu sur l'oignon. Mais, il est vraisemblable de penser que des croisements entre des varietes fleurissant bien et des varietes fleurissant tres peu, ameliorent le taux de floraison de ces dernieres. Si l'on veut aboutir a une certaine autonomie en matiere d'oignons, il faut en assurer la multiplication. Cela passe par la creation de varietes bulbifiant, mais aussi fleurissant dans nos conditions. Ce tri permet d'orienter precisement les voies de recherches.

Tableau 3 Liste des varietes retenues apres les observations en culture

Origine geographique	Varietes
Bresil	Amarela Globular, Baia Piriforme, Pera Baia Sintese n 13, Jubileu, Norte 14, Empasc 351, Pera IPA-1, Pera IPA-2, CEPEG 27
Afrique du Sud	De Wildt, Atjar, Rowcliffe Brown
Israel	Nissan, H-39, HA-23, Ori, Galil, HA-55, Anak, Moab, Beth Alpha Autumn, H-60,
Australie	Gladalan White, Early Lockyer White, Golden Brown, Early Lockyer Brown,
Afrique	Violet de Soumarana, Violet de Galmi, Goudami, Yellow onion (2), Red onion (2), Violet de Garango
Etats-Unis	Hybrid Texstar 80 PRR, Hybrid Golden, Yellow Granex
Asie	Pusa Red, Pusa White Flat, Pusa White Round, Superex,

Le choix de ces varietes permettra de creer des populations "source" a grande variabilite genetique. Tant que la variabilite sera large nous poursuivrons un schema de selection massale pour l'amelioration des populations en elles-memes (Schweisguth, 1984). Si le rendement et la conservation sont peu ameliores par ce type de selection, nous pouvons esperer des progres simultanes sur la floraison et la bulbification. Deja, apres ce tri un certain nombre de varietes peuvent etre utilisees dans un programme de developpement. A Yellow Granex, Hybrid Golden et Hybrid Texstar 80 PRR, deja connues, on peut ajouter des varietes bresiliennes comme Pera IPA-1 ou Pera IPA-2 et israeliennes comme Galil et Nissan.

Bibliographie

Anais, G. (1973) Possibilities of onion bulb and seed production in the French Caribbean (Guadeloupe, Martinique), 9th Ann. Meeting of Caribbean Food Crop Society, Barbados, July 1973, 471 -473.

Anais, G., Scgweisguth, B. (1978) Comportement en zone tropicale d'hybrides F1 d'oignon (*Allium cepa* L.) entre varietes sensibles a la photoperiode et une variete indifferente, Ann. Amelior. Plantes 28, (2), 223 - 229.

De Bon, H. (1985) Operations de Recherche-Developpement sur carottes, oignons et haricots a grains rouges en Martinique, Actes du colloque des 9 a 11 mai 1985, "Systemes de production agricole caribeen et alternatives de developpement", Universite Antilles-Guyane, Developpement agricole caraibe, p. 215 - 227.

Gautier, J., Anais, G. (1984) Conseils pour la culture de l'oignon, Bulletin Agronomique Antilles-Guyane, 3 13 - 17.

Peters, R. (1984) Hybrids versus open-pollinated cultivars in short day onions, Eucarpia 3rd Allium Symposium, p. 60 - 64.

Schweisguth, B. (1984) Recurrent selection with onion, Eucarpia, 3rd Allium symposium, p. 107.

The effects of two drip irrigation rates and two emitter placements on tomato production

A. Navarro and J. Newman

UVI Agricultural Experiment Station, St. Croix, USVI 00850

The effects of two drip irrigation rates and two emitter placements (surface and subsurface) on the production of tomatoes were investigated in the U.S. Virgin Islands. There was significant ($P<0.05$) difference in yields between irrigation rates but none with emitter placements. Using tomato variety N-69, marketable production of 45 tons/ha was obtained from the treatment which was irrigated at the weekly rate of 5.5 mm while marketable production of 55 tons/ha was obtained from the treatment supplying 10.4 mm water per week. The relationship of production to rainfall and potential evapotranspiration is discussed.

Keywords: Drip Irrigation; Tomato

Introduction

The climate of the US Virgin Islands is characterized by constant wind movement ranging from 5 to 15 miles per hour, by high temperatures, and by low and often erratic rainfall (Jordan, 1975; Rivera et al. 1970). The average yearly rainfall is approximately 44 inches but most of it is lost to the atmosphere by evaporation. It is estimated that only 1-3 inches of the rainfall enters the underground aquifer and about an inch flows overland into the ocean(Bowden, 1968; Rivera et al.,1970).

The limited water resource, aggravated by long periods of dry weather during the year, is one of the most important obstacles in increasing food production in the U.S.Virgin Islands. Without irrigation, it is almost impossible to obtain reasonable yields particularly from vegetable crops. Since water is a limited resource and therefore expensive, its application for irrigation can only be economically justified if it is used efficiently on high value crops.

The drip method of irrigation is the most efficient method known today. It has been reported that with the drip method, irrigation can be reduced by 50% or more without impairing yield or quality of production (Furt et al., 1980). The efficiency of the method can possibly be enhanced by using it in combination with other water conservation methods such as strict monitoring of water application and minimizing evaporation.

This study was conducted to evaluate the influence of two different rates of water application and emitter placement on tomato production in St. Croix, U.S. Virgin Islands.

1) This project was funded by the Tropical and Subtropical Agricultural Research Grant PL 89-808).

Materials and Methods

The study was conducted at the UVI Agricultural Experiment Station in St. Croix. The soil is Fredensborg clay loam. The irrigation system comprised mainlines and submains of 12.7 mm polyethylene tubes. The laterals were 12.7 mm bi-wall tubing, with orifices spaced 46 cm apart.

Tomato seeds (cv. N-69 from Hawaii) were sown on 2.54-cm jiffy pellets on December 29, 1986. Approximately 22 days after sowing, the seedlings were transplanted. Spacing was 46 cm between plants and 91 cm between the rows. Each row was 9 meters long. There were four rows to a treatment. After transplanting, one tensiometer was installed per treatment, approximately 10 cm away from the plant at a depth of approximately 15 cm.

The treatments were two levels of water, low (I1) and high (I2) in the high water level treatment, the tensiometer readings were maintained most of the time between 20-30 centibars. In the low water level treatment, tensiometer readings were maintained most of the time between 40-50 centibars. The other treatments were emitter placement, either surface (S1) or sub-surface (S2). For the S2 treatment, the bi-wall laterals were buried about 8-10 cm under the ground. Under the two levels of irrigation, the amount of water was divided between the two emitter placements. The treatments were arranged in a split-plot design, with water levels as main plots and emitter placements, the subplots. There were three replications.

A week after transplanting, the plants were fertilized with a 20-20-20 mixture at the rate of 1/2 tablespoon per plant. The fertilizers were applied around each plant and covered with soil. When about fifty percent of the plants started to flower, the same fertilizer mixture was applied at the rate of 1 tablespoonful per plant in the same manner as the first application.

The tomatoes were harvested at the ripe and turning stage. Eight harvests were made. The first harvest was on March 4, 1987, approximately 64 days from transplanting and 86 days from sowing. The last harvest was done on April 6, 1987. At harvest, the weight and number of fruits were recorded.

Results and Discussion

The highest amount of irrigation, as shown in Table 1 was applied during the month of January which was 13.4 and 22.4 liters per plant for I1 and I2 treatments respectively. During the first two weeks of January, irrigation was maintained at the highest level permissible under the two treatments in order to help the plants get better established.

Table 1 also shows that during the three-month cropping period, the amount of water applied for the I2 treatment is almost twice the amount that was used for the I1 treatment. During January and February the amount of water used for the I1 treatment was approximately 60% and 53% of the amount used for the I2 treatment respectively. During March, the difference in the amount of irrigation water applied between the two treatments is much greater, the low level treatment using approximately 41% of the high level treatment.

The precipitation which occurred during the period reduced the differences in the amount of water available to the plants between the two treatments (Table 2). In January, February and March, the total amounts of water available to plants in the I1 treatment were respectively, 78%, 72% and 78% of the water available to the plants in the I2 treatment.

The amounts of irrigation applied per plant are shown in Table 3. In the I1 treatment, an average of 5.5 mm of water was used per week during the cropping period. For the same period, water use in the I2 treatment averaged 10.4 mm per week.

Table 1 Frequency and amount (litres/plant) of irrigation supplied during the cropping period.

Date	Cropping period					
	January		February		March	
	Low level	High level	Low level	High level	Low level	High level
1	2.3	4.2	0.0	0.0	0.0	0.0
2	0.0	0.0	0.0	0.0	0.6	3.6
3	0.0	0.0	0.0	0.0	0.0	0.0
4	0.0	0.0	0.0	0.0	0.0	0.0
5	0.0	0.0	1.5	2.3	1.2	1.9
6	0.0	0.0	0.0	0.0	0.0	0.0
7	0.0	0.0	0.0	0.0	0.0	0.0
8	0.0	0.0	0.0	0.0	0.0	0.0
9	0.0	0.0	0.0	0.0	0.0	0.0
10	2.0	3.2	0.9	1.7	0.0	0.0
11	0.0	0.0	0.0	0.0	0.0	0.0
12	3.2	5.0	1.1	1.4	1.8	4.2
13	0.0	0.0	0.0	0.0	0.0	0.0
14	0.0	0.0	0.0	0.0	0.0	0.0
15	0.0	0.0	0.0	0.0	0.0	0.0
16	3.7	5.2	0.0	0.0	0.0	0.0
17	0.0	0.0	0.0	0.0	0.0	0.0
18	0.0	0.0	0.0	0.0	0.0	0.0
19	0.0	0.0	0.0	0.0	0.0	0.0
20	0.0	0.0	0.0	0.0	0.0	0.0
21	0.0	0.0	2.0	1.7	0.0	0.0
22	0.0	0.0	1.2	1.9	0.0	0.0
23	0.0	0.0	0.0	0.0	0.0	0.0
24	0.0	0.0	0.6	2.2	0.0	0.0
25	0.0	0.0	0.0	0.0	0.0	0.0
26	0.0	0.0	1.0	2.5	0.0	0.0
27	0.7	2.2	0.0	0.0	1.9	3.8
28	0.0	0.0	0.9	3.7	0.0	0.0
29	0.5	2.6			0.0	0.0
30	1.0	0.0			0.0	0.0
31	0.0	0.0			0.0	0.0
Total	13.4	22.4	9.2	17.4	5.5	13.5

Crop water use in the present study is slightly lower than in a study done in the same location in 1982 (Navarro,1982). This study involved two field experiments, where weekly irrigation rates of 6.4, 6.6 and 17.3 mm of water were applied to maintain tensiometer suction pressures at 60, 40 and 20 centibars. Best yields were obtained with 6.4 mm of water/ week (Trial 1, cv. Royal Chico) and 14.7 mm/ week (Trial 2, cv. Tropic).

Table 2 Precipitation and sum of precipitation and irrigat during the cropping period (liters/plant)

Date	Precipitation			Precipitation plus irrigation					
	Jan	Feb	Mar	Jan		Feb		Mar	
				Low	High	low	High	low	High
1	0.0	0.0	0.0	2.3	4.2	0.0	0.0	0.0	0.0
2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.6	3.6
3	0.0	0.0	0.4	0.0	0.0	0.0	0.0	0.4	0.4
4	0.0	0.0	0.4	0.0	0.0	0.0	0.0	0.4	0.4
5	2.2	0.4	0.0	2.2	2.2	1.9	2.7	1.2	1.9
6	0.0	0.0	2.3	0.0	0.0	0.0	0.0	2.3	2.3
7	8.3	0.0	0.0	8.3	8.3	0.0	0.0	0.0	0.0
8	0.8	0.0	0.0	0.8	0.8	0.0	0.0	0.0	0.0
9	0.4	0.0	0.4	0.4	0.4	0.0	0.0	0.4	0.4
10	0.0	0.0	0.0	2.0	3.2	0.9	1.7	0.0	0.0
11	0.0	0.0	0.4	0.0	0.0	0.0	0.0	0.4	0.4
12	0.0	0.2	0.4	3.2	5.0	1.3	1.6	2.2	4.6
13	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
14	0.2	6.7	0.0	0.2	0.2	6.7	6.7	0.0	0.0
15	0.0	0.0	6.4	0.0	0.0	0.0	0.0	6.4	6.4
16	0.0	0.0	0.0	3.7	5.2	0.0	0.0	0.0	0.0
17	0.0	0.0	9.5	0.0	0.0	0.0	0.0	9.5	9.5
18	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
19	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
20	2.5	0.0	0.0	2.5	2.5	0.0	0.0	0.0	0.0
21	0.0	0.0	0.0	0.0	0.0	2.0	1.7	0.0	0.0
22	0.0	0.0	0.0	0.0	0.0	1.2	1.9	0.0	0.0
23	0.7	0.2	0.0	0.7	0.7	0.2	0.2	0.0	0.0
24	0.0	0.0	0.0	0.0	0.0	0.6	2.2	0.0	0.0
25	0.0	0.0	2.0	0.0	0.0	0.0	0.0	2.0	2.0
26	0.7	0.0	0.0	0.7	0.7	1.0	2.5	0.0	0.0
27	0.0	0.3	0.0	0.7	2.2	0.3	0.3	1.9	3.8
28	0.2	3.7	0.0	0.2	0.2	4.6	7.4	0.0	0.0
29	0.0		0.0	0.5	2.6			0.0	0.0
30	1.0		0.0	3.5	2.5			0.0	0.0
31	0.0		0.0	0.0	0.0			0.0	0.0
Total	18.5	11.5	22.2	31.9	40.9	20.7	28.9	27.7	35.7

Hoare, et al. (1974) presented a simplified formula for determining the rate of potential evapotranspiration as follows:

$$E_t = f_1 Eo$$

Where E_t = rate of potential evapotranspiration
f_1 = crop coefficient
E_0 = U.S. Class A pan evaporation.

Hoare et al. reported f1 for tomatoes as 1. The authors adjusted f1 in accordance with the fraction of the ground covered by the plants. The formula is as follows:

$$f^1 = f_1 \; [GC + 1/2 \; (1 - GC)]$$

Where f^1= corrected f_1 and GC = fraction of the ground covered by the plants.

Table 3 Average weekly values for applied irrigation, (I) irrigation plus precipitation (I+P) and computed crop potential evapotranspiration (ET) (in mm) for the cropping period[a].

Treatment	January			February			March		
	I	I&P	Et	I	I&P	Et	I	I&P	Et
			12.6			17.1			21.4
I1	7.6	18.0		5.7	12.6		3.1	15.7	
I2	12.7	23.2		10.9	16.2		7.6	20.2	

a) Average weekly U.S. Class A Pan evaporation rates for January, February and March were 28.1, 28.6 and 32.0 mm respectively. Et was calculated by the method of Hoare et al. (1974).

Based on the observation of Fleming (1964), these workers determined E_0 using the following relationship: $E_0 = 0.8\ E_{pan}$. Applying the above method and using GC values of 12%, 50% and 67% for January, February and March, respectively, Et values were computed and are shown in Table 3. It can be seen that, except during the month of January, the Et values are much greater than the amount of water made available by irrigation.

The rainfall during the cropping period contributed substantially to increasing the amount of moisture available to the plants. As a result, the I2 treatment showed only marginal water deficits in February and March. In the low water treatment however, water deficits were 4.5 mm in February and 5.7 mm in March. Surprisingly, in spite of the moisture deficits, the treatment with the lower rate of irrigation still managed to produce reasonable yields (Table 4) This suggests that tomatoes, or at least this particular variety, can tolerate considerable moisture stress and still maintain the capacity to produce reasonable yields. In addition, moisture conditions in the deeper layers of the soil may need to be observed to see if the plants are drawing water from these regions which were not accounted for.

Table 4 shows that yields obtained from the higher rate of irrigation were statistically greater than those obtained from the lower rate of irrigation. Emitter placement however did not show any significant influence on yield. The shallow placement of the emitters may have allowed the moisture to rise to the ground surface. Davis et al. (1985) reported a case in which yield and evapotranspiration rates of tomatoes were not affected by surface or subsurface emitter placement when irrigation frequencies and volumes were the same as in this study. The lack of effect of placement cannot be explained on the assumption that water was not limiting, since in the present study this was not the case.

In order to determine the efficiency of water use in each treatment, the production was expressed as weight of marketable fruit per liter of water applied (Table 5). The I1 treatment was significantly more efficient. A similar observation was made by English (1982), who stated that by under-irrigating a field crop, the yields may be reduced but capital outlay and operating costs associated with irrigation may also be reduced. The net result can be increased income to the farmer.

Table 4 Marketable tomato production (t/ha) as influenced by rate of irrigation and emitter placement

Irrigation Treatment (Average application) (mm/week)	Emitter Placement		Mean[1)]
	Subsurface	Surface	
Low level (5.5)	43.9	46.9	45.4[a]
High level (10.4)	54.3	55.0	54.6[b]
Mean	49.1	51.0	

1) Means with different letter superscripts are significantly different (P = 0.05).

Table 5 Average production of tomatoes (g) per liter of irrigation water applied (Water Use Efficiency)

Irrigation rate	Water Use Efficiency (g/liter)		
	Subsurface	Surface	Mean[1)]
Low level	124	133	128 [a]
High level	81	82	82 [b]
Mean	102	108	

1) Differences between means with different letter superscripts are significant at 1% level.

References

Bowden, M.J. (1968) Water balance on a dry island, Geography publication at Dartmouth, No.6, Clark University, Mass.

Davis K.R., C.J. Phene, R. McCormick, R.B. Hatchmacher and D.W. Meek (1985) Trickle frequency and installation depth effects on tomatoes, Proc. 3rd Intl. Drip/Trickle Irrigation Congress. Am. Soc. Agr. Engineers, Michigan.

English, M.J. (1982) Deficit irrigation frequency on crop yields, Technical conference proceedings of the Irrigation Association. 375 Connecticut Avenue, Silver Springs Maryland.

Fleming, P.M. (1964). Evaporimeter relationships at Griffith, N.S.W. Trans. Int. Ergrs. Aust.

Furt, R.C., D.S. Ross and H.L. Brodie (1980). Economic comparison of trickle and sprinkler irrigation of six fruit crops in Maryland, 1978, Maryland Agricultural Experiment Station, University of Maryland, College Park, Maryland.

Hoare. E.R., K.V. Garzoli and J. Blackwell (1974) Plant water requirements as related to trickle irrigation. Proc. Second International Drip Irrigation Congress. San Diego, California.

Jordan, D.G. (1975) A survey of the water resources of St. Croix, Virgin Islands. U.S. Geological Survey, Government of the U.S. Virgin Islands.

Navarro, A.A. (1982) Summary of vegetable crops research 1980-1981, Virgin Islands Agricultural Station Technical Bull. No.4. St. Croix, U.S. Virgin Islands.

Rivera, L., Wayne, D., Farris, C., Jensen, E., Davis, L., Palmer, C., Jackson, L. and McKinzie, W. (1970) Soil survey of the Virgin Islands of the United States (1970) USDA, Washington, D.C.

Nouveaux Cultivars De *Vigna unguiculata* (L) Walp

H. Touvin

Centre INRA, Antilles-Guyane, Station d'Amelioration des Plantes B.P.1232, 97184 Pointe-a-Pitre CEDEX, Guadeloupe, F.W.I.

Les travaux de selection, poursuivis depuis une dizaine d'annees au Centre de Recherches Agronomiques Antilles-Guyane sur le *Vigna unguiculata* ont conduit a la creation de nouveaux cultivars qui repondent aux exigences suivantes : assurer une recolte de grain durant toute l'annee (non photoperiodique) ; avoir une maturite groupee des gousses permettant une recolte mecanisee (croissance determinee) ; fournir une production elevee et reguliere. Nos lignees ameliorees se repartissent en trois groupes selon leur tulisation: Le groupe 1, destine a l'alimentatiion humaine, comprend des lignees a gros grain rouge dont les gousses peuvent etre recoltees soit a l'etat immature comme pois e ecosser, soit a maturite complete, en sec ; Le groupe 2, destine a une production industrielle en vue d'enrichir en proteine les rations des monogastriques, est constitue par les lignees a haut rendement (18 a 22 Qx/ha) ; le groupe 3, destine a l'affouragement en vert des ruminants et a l'amelioration proteique des ensilages de graminees, comprend les types a grand developpement vegetatif. Par ailleurs, pour faciliter la culture du Vigna en association avec le bananier, il a ete mis au point le desherbage chimique selectif par l'utili-sation du Treflan (Trifluraline) a la dose de 1,5 litre/ha ou de l'Amex 820 (Butraline) a la dose de 7,5 litres/ha.

Mots Cles: *Vigna unguiculata*; Pois z'yeux noirs; Fourrage; Desherbage chimique

Breeding work on Cowpea (*Vigna unguiculata*) at the INRA Antilles-Guyane Research Centre during the last ten years has had three main objectives. These were: 1) To obtain a Vigna with many pods and large red grains as a shelling pea for traditional gardens and polyculture; 2) To increase the grain yield of determinate and non-photoperiodic lines for commercial production destined for supplementing monogastric animals; 3) To select forage types for ruminants, used fresh or to enrich graminaceous silage. Significant results have been obtained in achieving these three objectives by breeding from germplasm of various origins and use of genes favourable to yield increase. Detáils are given of the characteristics of the main parent lines, and the breeding scheme used as well as the performance of lines released to the growers. To facilitate production in association with bananas, a study of selective herbicides was made with Treflan (Trifluraline) at 1.5 litres/hectare, and Amex 820 (Butraline) at 7.5 litres/ha.

Keywords: Cowpea; *Vigna unguiculata*; Breeding; Forage; Herbicides

Introduction

Le *Vigna unguiculata*, communement appele Pois z'yeux noirs, Niebe, Cowpea ou Southernpea, est une plante rustique, bien adaptee aux conditions ecologiques extremes des Antilles (18 degrees a 30 degrees de temperature, zones humides ferralitiques, zones seches calcaires).

La duree de son cycle de developpement permet d'envusager plusieurs productions par an. Peu exigeante en eau, la culture une fois installee, resiste bien a des conditions de secheresse assez severes.

La selection conduite au INRA depuis une diazine d'annees sur cette plante visait trois objectifs principaux:

1) obtenir un Vigna a longues gousses et a gros grain rouge pour une production de pois a ecosser au niveau des jardins traditionnels de polyculture.

2) accroitre le rendement en grain de lignees a croissance determinee et non photoperiodiques en vue d'une production industrielle destinee a enrichir en proteines les rations des monogastriques.

3) selectionner des types fourragers pour l'affouragement en vert des ruminants et l'amelioration proteique d'ensilages de graminees.

Materiel et methodes de selection

Chez cette plante cleistogame ou l'autogamie est quasi-totale, la production industrielle d'hybrides F1 est exclue. La strategie d'amelioration consiste a rechercher de nouvelles associations de genes de haute heritabilite par des croisements diriges. Le premier objectif a ete atteint par la methode genealogique classique appliquee a des croisements reciproques et des backrosses realises entre trois varietes: M53, Blackeye et Vita 3 dont les caracteristiques sont donnes au Tableau 1.

Les deux autres objectifs qui concernent plus particulierement la productivite, ont ete abordes par la constitution d'une population source en utilisant la sterilite male genique de la variete Vita 2S (Rachie et al., 1975). Les plantes male-steriles issues de la F2 de l'hybride (male-sterile x Vita 2S) ont ete croisees par 20 lignees selectionnees pour des caracteristiques agronomiques et physiologiques diverses. Trois backrosses ont ete realises a partir des plantes male-steriles issues de ces hybrides. Ensuite, apres trois generations en "panmixie" durant lesquelles la recolte n'etait faite que sur les plantes male-steriles prealablement marquees, nous avons pratique la technique de recolt en descendance unipare (ssd) durant trois autres generations. Au cours de celles-ci les plantes male-steriles etaient eliminees au fur a mesure de leur apparition.

Par la suite, les plantes qui presentaient des caracteres interessants ont ete suivies en genealogie ligne/plante pendant quatre generations. Les lignees selectionnees ont ete d'abord testees en essais de comportement dans deux stations distinctes (1. Domaine Duclos en Basse-terre: sols ferralitiques acides; pluviometrie 2800 mm/an et; 2. Ferme de May a Saint-Francois an Grande-terre: Vertisols calcaires; pluviometrie <1300 mm/an, saison seche marquee) et a des epoques differentes de l'annee, puis mises en essais comparatifs de rendement.

Resultats

Les croisements reciproques (Blackeye x M53) ont permis de selectionner, a partir de la F5, une cinquantaine de lignees, a grain rouge, et de productivite superieure ou equivalente a celle des parents. Actuellement les meilleures lignees issues de ce premier cycle de selection sont proposees aux agriculteurs. Le recroisement de quelques unes d'entre elles par la variete Vita 3, realise en 1985, produit en F6, des lignees a gros grain rouge qui pourront etre avantageusement exploitees en gousses immatures (Tableau 2).

Tableau 1 Quelques caracteristiques phenotypiques et physiologiques de 3 geniteurs utilises dans la selection du Vigna selon les normes de l'IBPGR

Caracteristiques phenotypiques et Physiologiques	Geniteur					
	M53		Black eye		Vita 3	
	Note	Appreciation	Note	Appreciation	Note	Appreciation
Port de la plante	3	1/2 dresse	2	dresse	2	dresse
Type du port	1	determine	2	indetermine	2	indetermine
Tendance volubile	0	absence	3	faible	5-7	moyen a fort
Forme de la feuille	2	1/2 arrondie	2	1/2 arrondie	2	1/2 arrondie
Nombre d'axes principaux	3		5		4	
Nombre de jours semis-floraison	45		52		66	
Position des racemes	1	au-dessus du feuillage	1	au dessus du feuillage	2	dans le feuillage
Attache des gousses	5	intermediaire	3	pendante	3	pendante
Pigmentation gousses immatures	5	pigmentation uniforme	3	2 cotes pigmentes	5	pigmentation uniforme
Courbure de gousse	0	droite	3	legerement recourbee	0	droite
Couleur gousse	2	marron clair	1	jaune pale a marron	2	marron clair
Longueur de gousse	12		18		22	
Nombre de loges par gousse	12		12		18	
Forme de la graine	1	rognon	1	rognon	2	ovoide
Structure du tegument	1	lisse	9	ride	3-5	lisse a rugueux
Aspect de l'oeil	1	petit	6	entoure le dos du hile	1	petit
Couleur de l'oeil	5	noir	5	noir	3	rouge
Couleur de la graine		rouge		blanc		rouge
Poids de 1000 grains	109,7 (±2,0)		206,3 (±7,6)		203,9 (±15,1)	

La selection conduite a partir de la population-source a permis une amelioration du rendement de l'ordre de 60% par rapport aux varietes commerciales temoins. Le Tableau 3 resume les caracteristiques des lignees selectionnees pour le grain.

En ce qui concerne les types fourragers, le choix a porte en priorite sur les lignees alliant une forte production de tiges et feuilles a une production de gousses elevee. Ce dernier caractere qui ameliore tres nettement la qualite du fourrage, est indispensable pour abaisser le cout de la production de semence. Ces Vigna fourragers, en parcelles de culture pure, juxtaposees a des parcelles de Sorgho, peuvent permettre de realiser des ensilages mixtes sorgho/vigna. Le Tableau 4 montre les avantages de telles associations et plus particulierement au niveau des quantites ingerees et de la teneur en matieres azotees.

Table 2 Quelques observations sur des lignees F5 du recroisement [(Black eye x M53) x Vita 3]

Lignees et Cultivars	Gousses Diametre (mm)	Gousses Longeur (cm)	Nombre de Grain (par gousse)	Poids de 1000 grains (g)
122-4-1 x Vita 3	9,8 (9,0 - 11,4)	20,2 (17,2 - 23,6)	14,7 (12,4 - 16,4)	173,4 (105,6 - 220,5)
133-1 x Vita 3	10,0 (8,2 - 11,0)	20,4 (17,8 - 24,9)	14,7 (12,2 - 17,6)	170,9 (94,4 - 237,8)
245-1 x Vita 3	10,2 (9,0 - 11,0)	19,9 (19,4 - 20,8)	13,8 (13,6 - 14,0)	172,3 (135,5 - 218,1)
413-2 x Vita 3	9,8 (9,2 - 10,5)	18,5 (16,1 - 23,5)	13,2 (8,3 - 16,2)	197,3 (141,4 - 228,4)
133-1	8,2 (+/-0,3)	17,4 (+/-1,2)	13,5 (+/-0,5)	137,9 (+/-11,2)
245-1	8,2 (+/-0,2)	15,7 (+/-0,3)	13,0 (+/-0,3)	136,3 (+/-2,8)
413-2	7,3 (+/-0,2)	15,4 (+/-0,3)	13,5 (+/-0,4)	127,2 (+/-10,7)
122-4-1	7,1 (+/-0,2)	16,4 (+/-3)	14,2 (+/-0,4)	121,8 (+/-6,7)
Vita 3	11,4 (+/-0,4)	23,5 (+/-0,4)	17,8 (+/-0,5)	203,9 (+/-15,1)
Black eye	9,5 (+/-0,3)	18,0 (+/-0,4)	10,9 (+/-0,4)	206,3 (+/-7,5)
M53	7,2 (+/-0,4)	14,8 (+/-0,4)	13,2 (+/-0,6)	109,7 (+/-2,0)

Tableau 3 Caracteristiques de quelques lignees selectionnees de *Vigna unguiculata* (essais a St. Francois, Juin 1982)

Lignees et Cultivars	Rendt (qx/ha)	Poids de 1000 grains (g)	Couleur du grain	Semis a Floraison (jours)	Origine
15-3	21,37	106	marron clair	51	population[a]
82-14	19,50	112	blanc	51	"
CRA-36	19,00	135	marron clair	56	genealogie
13-5	17,87	142	marron mouchete	51	population
245-1-5	16,62	125	rouge vif	45	genealogie
93-13	15,31	143	rouge vif	51	population
104-1	15,18	144	blanc	51	"
9-12	14,81	116	marron clair	56	"
364-1-2	13,87	103	rouge clair	47	"
485-4-5	13,81	101	rouge fonce	47	genealogie
485-8-2	13,75	122	rouge fonce	47	"
122-3-4	13,68	115	rouge clair	47	"
17-16	13,56	100	blanc	56	population
M-53	13,50	105	rouge clair	47	Var. com.[b]
Blackeye	13,43	185	blanc	50	var. com.[c]
9-2	13,37	110	rouge clair	45	genealogie
589-1-5	12,93	110	rouge clair	47	"
V9	12,93	195	blanc	51	var. com.
249-1	12,87	126	rouge clair	47	genealogie
516-1	12,06	111	rouge vif	47	"
314-1-1	11,93	113	rouge fonce	40	"
595-2	11,75	139	rouge clair	43	"
14-7	11,75	91	marron mouchete	51	population
12-1	11,56	128	marron clair	51	"
413-4-1	10,25	93	rouge clair	47	genealogie
36-5	8,18	117	marron mouchete	51	population
ppds 5%	5,17 qx/ha				

a) population constituee a l'aide d'une sterilite-male genique
b) Variete commerciale, precoce (temoin)
c) Variete commerciale a gros grain (temoin)

Tableau 4 Composition d'ensilages Sorgho et Vigna

Fourrages[a]	MS (non corrigee) %	Composition chimique: Cendres	Composition chimique: Matieres azotees	Quantities ingerees (g/MS/Kg P 0.75)	Mo Di (g/Kg P 0.75)	Valeur energetique et azotee: CUD Mo	Valeur energetique et azotee: CUD MAT
Saint Francois							
Sor/Vig	20,6	13,3	14,0	63,0	28,1	51,4	55,0
Sor/Vig/Mel	24,8	12,3	12,9	76,3	38,3	57,3	58,5
Duclos							
Sor/Mel	24,8	7,0	6,8	36,7	17,9	52,6	34,1
Sor/Vig/Mel	21,7	8,7	10,3	51,1	26,3	56,3	54,9
Gardel							
Sudax 1)	30,2	7,9	8,7	43,6	26,7	66,6	51,2
2)	29,0	8,3	8,5	47,8	27,4	62,6	44,3

a) Sor = Sorgho (INRA SB6); Sudax = Sudax SX11 (grain pateux)
Mel = 2% Melasse

Enfin, des essais de desherbage chimique selectif ont montre l'efficacite de deux produits : Treflan (m.a. Trifluraline) et Amex 820 (m.a. Butraline). Ces produits ont ete utilises en inter-rangs de bananiers plantes selon les modalites suivantes: TREFLAN a la dose de 1,5 litre/ha p.c. et AMEX 820 a la dose de 7,5 litres/ha p.c. Pour l'un et l'autre de ces produits il convient de pratiquer deux traitements, l'un en incorporation au sol 8 jours avant le semis du Vigna, l'autre en post-semis, avant la levee.

Conclusion

Le Vigna, par sa rusticite, son cycle de developpement court, la richesse en proteins de ses tiges, feuilles et graines, est une des meilleures sources de proteins vegetales. En alimentation humaine, loin de concurrencer d'autres legumineuses comme le haricot, il doit en etre le relais dans des conditions difficiles de climat et de sols. En alimentation animale, la graine, par sa pauvrete en huile, peut avantageusement se substituer aux tourteaux de soja dans les rations des monogastriques; la plante entiere, par sa richesse en proteines, peut etre utilisee comme l'un des constituants dans les associations de graminees/legumineuses annuelles.

Nos obtentions recentes apportent une amelioration de la productivite globale, de la grosseur de la graine, de la qualite marchande de la gousse immature et la possibilite de mecanisation de la recolte. Ces caracteristiques alliees a la mise au point de desherbage chimique selectif devraient contribuer au developpement de cette espece tant au niveau des jardins de polyculture qu'au niveau de la grande culture.

Bibliographic

Rachie, K.O., Rawal, K., Franckowiak, J.D. and Akinpelu, M.A. (1975) Two out-crossing mechanisms in cowpea (*Vigna unguiculata* L. Walp., *Euphytica* **24** 159 - 163

Response of Tanier to different water regimes

A. I. Lugo, H. Lugo-Mercado, J. Badillo, A. Beale, M. Santiago and L. Rivera

Agronomy, Soils and Horticulture Departments, Agricultural Experiment Station, Box 21360, Rio Piedras, Puerto Rico 00926

An experiment to determine the response of taniers (Xanthosoma sp.) to irrigation was established at three locations in Puerto Rico. Drip-irrigated taniers were grown with different water regimes, where water application was based on tensiometer readings at 15-, 30- and 45-cm depths. Plots were irrigated when soil moisture tension was above 40 cbars. The combined analyses of the data showed that plots receiving the highest amount of water (based on tensiometers at 15-cm depth) yielded significantly higher than plots receiving the intermediate and lowest amounts of water (tensiometers at 30- and 45-cm depths, respectively). At two locations, number of marketable cormels was significantly higher in plots with the high water regime than in the inter immediate treatment. Mean cormel weight was not affected by the irrigation treatments at two locations. Symptoms of dry rot were conspicuous at both locations. The results show that tanier yields can be increased by irrigation even in the presence of dry rot.

Keywords: Tanier; Xanthosoma spp.; Irrigation; Dry rot

Introduction

Tanier (Xanthosoma spp.) is a staple in the diet of many people in tropical counties. A native plant of tropical America, it is now cultivated around the world under tropical and subtropical conditions. Tanier is one of the most important root crops in Puerto Rico. However, production has been steadily declining in the last four decades, from 32, 430 tonnes in 1952-53 to only 5,760 tonnes in 1985-86. Even though yields of 20,000 kg/ha have been reported (Rodriguez-Garcia, 1981,) most farmers are experiencing heavy decreases in yields. One of the main limiting factors is the dry rot condition (mal seco) which affects the root system.

Irizarry et al. (1977) suggested that abnormal rainfall distribution, coupled to the highly selective moisture requirement of taniers, contributes to the erratic yields of the crop. Tanier requires ample moisture throughout the growing season. The importance of water distribution and constant availability has been recognized (Kay, 1973 and Onwueme, 1978). In Puerto Rico, Abruna-Rodriguez et al. (1967) found that moisture availability was an important factor in tanier production. Irizarry et al. (1977) reported a tendency for higher yields when taniers were irrigated. However, differences were not significant, probably because of the wet and short growing season under which the taniers were grown. Most farmers depend solely on rainfall to satisfy the moisture requirements of the crop.

This study was conducted to measure the effect of different water regimes on yield, number, and weight of tanier cormels.

Materials and methods

The experiment was established at three distinct ecological locations (Fortuna, Isabela, and Corozal Substations) varying in rainfall and soil conditions. At Fortuna, on the semiarid southern coast, the soil is classified as San Anton (Cumulic Haplustoll), pH 7.4. Average annual rainfall is about 920 mm. Rainfall during the crop cycle was 520 mm while evaporation was 1690 mm (Fig. 1). At Isabela, on the northwestern coast, the soil was classified as Coto (Tropeptic Haplorthox), pH 6.0. Average annual rainfall is about 1640 mm. Rainfall and pan evaporation during the crop cycle were 1800 and 1370 mm, respectively (Fig. 2). At Corozal, in the humid central uplands, the soil was classified as Corozal (Aquic Tropudults), pH 4.7. Average annual rainfall is about 1650 mm. Rainfall and pan evaporation during the crop cycle were 1160 and 900 mm, respectively (Fig. 3).

In all locations the fields were disc-plowed and harrowed twice. Tanier (cv. Alela) was planted on beds using pregerminated corm pieces. At Isabela and Fortuna, plants were spaced at 1.07 m between rows and 0.61 m between plants. At Corozal, the planting distance was 0.91m x 0.61m. Taniers received a total of 125, 15, 156 and 48 kg/ha of N, P, K and Mg, respectively. At Isabela and Fortuna a commercial micronutrient formula was applied at a rate of 56 kg/ha. Plots were hand weeded when necessary.

Three water regimes (high, intermediate and low), based upon readings of tensiometers installed at 15, 30 and 45 cm depths, were established after planting. Irrigation was applied when moisture tension exceeded 40 cbars. Plots with tensiometers at 15-cm depth were the most frequently irrigated since evapotranspiration is higher at the soil surface. An additional treatment was established at Corozal, where taniers were not irrigated at all to conform with farmers' practices. Treatments at all locations were arranged in a randomized complete block design. Irrigation water was provided through a drip (trickle) system. Main and submain lines consisted of 3.8-cm PVC tubing. A dual chamber drip line with outer spacing of 20.32 cm was used.

The Isabela and Fortuna experiments were harvested approximately ten months after planting. At Corozal the crop was harvested about seven months after planting when maturity symptoms and cormel sprouting were observed. Weight and number of marketable cormels were recorded and mean cormel weights calculated.

Results and discussion

Table 1 presents data on yields by location. The statistical analysis of the data shows that yields of marketable taniers increased with increasing water applications. Plots receiving the greatest amount of water (tensiometers at 15-cm depth) yielded significantly higher than the other treatments at Fortuna and Corozal. At Isabela, yield differences between plots at the highest and intermediate water regimes were not significant. Yields of the intermediate and low moisture regimes were not significantly different at any location.

Significantly lower yields were recorded in the non-irrigated plots at Corozal. Yields were only about 25% of those obtained at the low water regimes, despite a total rainfall of 1160 mm during the crop cycle. Plants without irrigation might have suffered because of monitor stress induced by poorly developed root system coupled with uneven distribution of rainfall. A yield difference of 87% was observed between the non-irrigated and the highest water regime plots.

Table 1 Yield of marketable taniers (kg/ha) as affected by water regimes

Water Regime (tensiometer depth) (cm)	Location		
	Fortuna	Isabela	Corozal
15	13,080 a[1)]	8,860 a	9,260 a
30	7,860 b	6,430 ab	4,840 b
45	6,020 b	4,540 b	4,750 b
Non-irrigated	-	-	1,180 c

1) Values in columns followed by the same letter do not differ significantly at $p = 0.01$.

Little or no dry rot was evident at Fortuna. Dry rot symptoms in the aerial parts of the plant were not observed during the growing period. However, an evaluation of the root system at harvest indicated some root damage, which decreased with increments in the amount of water applied. Low incidence of dry rot could be related to low rainfall and an even distribution of irrigation water (Fig. 1). Where rainfall was higher and unevenly distributed, as at Isabela and Corozal (Figs. 2 & 3), symptoms of dry rot were conspicuous, especially at Corozal. Most farmers claim that dry rot occurs when a dry spell is followed by heavy rainfall. The relationship between moisture regime and occurrence of dry rot was not determined in this study.

A combined analysis of the yield data from all locations indicated that a mean yield of 10,630 kg/ha at the high water regime was significantly greater, at the 1% level, than mean yields of 6, 580 and 5,280 kg/ha obtained at the intermediate and low water regimes, respectively. There were no other significant differences. Thus, irrigation based on tensiometer readings at 15 cm depth resulted in yield increments of about 62% and 101% more than the other two treatments, respectively. The results indicate that growers can attain good commercial tanier yields with adequate crop management practices, specifically those related to irrigation.

Cormel number, one of the most important components of yield, increased as the frequency of irrigation increased (Table 2). A significantly higher number of cormels was produced with the high water regime than with other regimes. The intermediate and low water regimes produced similar amounts of cormels at two locations.

As Isabela and Corozal, mean cormel weight was not significantly affected by the irrigation regime (Table 3). However, there was a tendency for heavier cormels in the most frequently irrigated plots. A significantly lower men Cormels weight was produced at Fortuna at the low water regime. These data suggest that yield differences attributable to treatments can be explained on the basis of cormel number more than cormel weight.

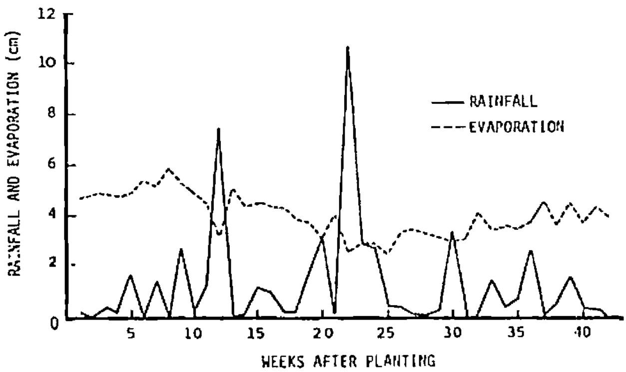

Figure 1 Weekly rainfall and evaporation from 13 June 1986 to 31 March 1987 at the Fortuna Substation

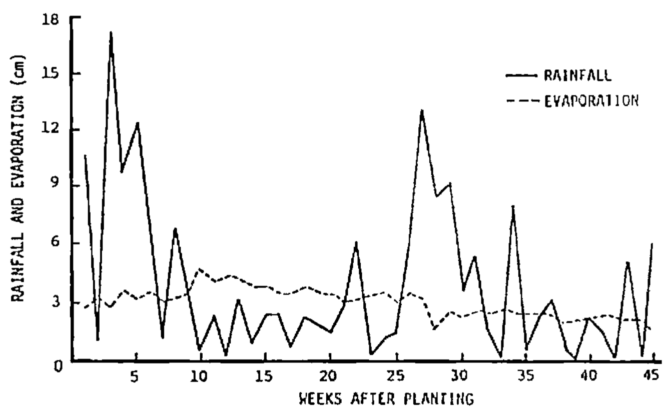

Figure 2 Weekly rainfall and evaporation from 9 April 1986 to 18 February 1987 at the Isabela Substation

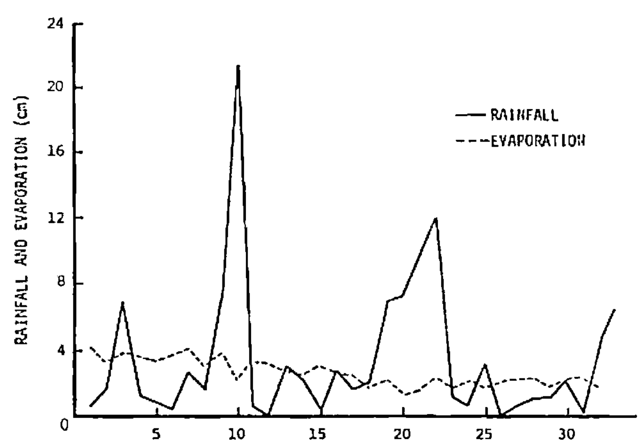

Figure 3 Weekly rainfall and evaporation from 26 June 1986 to 12 February 1987 at the Corozal Substation

Table 2 Number of Cormels (,000/ha) as affected by water regimes

Water Regime (tensiometer depth) (cm)	Location		
	Fortuna	Isabela	Corozal
15	73.6 a[1)]	45.9 a	74.2 a
30	46.8 b	37.6 b	45.7 b
45	46.6 b	26.1 c	42.9 b
Non-irrigated	-	-	10.9 c

1) Values in columns followed by the same letter do not differ significantly at p = 0.05.

Table 3 Mean cormel weight (g) as affected by water regimes

Water Regime (tensiometer depth) (cm)	Location		
	Fortuna	Isabela	Corozal
15	176.4 a[1)]	193.9 a	124.6 a
30	166.7 a	182.2 a	105.0 a
45	129.6 b	170.7 a	110.1 a
Non-irrigated	-	-	112.9 a

1) Values in vertical columns followed by the same letter do not differ significantly at p = 0.01.

References

Abruna-Rodriguez, F., Boneta-Garcia, E.G.,Vicente-Chandler, J. and Silva, S. (1967) Experiments on tanier production with conservation in Puerto Rico's mountain region, J. Agr. Univ. P.R. **51** (2): 167-175

Irizarry, H., Capiel, M. and Acosta-Matienzo A. (1977) Yield of twelve tanier cultivars grown with and without irrigation in east-central Puerto Rico, J. Agr. Univ. P.R. **65** (4): 100-105.

Kay, D E. (1973) Crop and Product Digest No. 2 Root Crops, Tropical Products Institute, Foreign and Commonwealth Office, London.

Onwueme, I. C. (1978) The tropical tuber crops: yams, cassava, sweet potato and cocoyams. John Wiley & Sons, New York

Rodriguez-Garcia, J., Abruna, F. and Diaz N. (1981) Effect on tanier yields of artificial shade levels and of intercropping with plantains. J. Agr. Univ. P.R. **65** (4) 326-330

Gibberellic acid and CCC effects on sugar composition and tuber yield in Yam Bean (*Pachyrhizus erosus*, Urban)

C. Zinsou, G. Vansuyt and A. Venthou-Dumaine

Laboratoire de Physiologie et Biochimie Vegetales, INRA, BP 1232 Pointe-a-Pitre cedex, Guadeloupe, FWI

Yam bean is a tropical tuber and grain legume that needs to be better known as a crop for human consumption and animal feed. The seeds are poisonous but can be used for planting. The tuber is edible and can be eaten as a fresh vegetable or cooked. Large tubers and better fruiting occurred when the growing season coincided with long days, but marketable tubers were produced, especially under short days. In all cases tuber production competes with seed production. Investigations were undertaken to study the effects of foliar application of GA3 and CCC on growth, sugar composition and tuber yield of yam bean under short days. GA3 promoted shoot growth, tuber enlargement, yield increase, sucrose accumulation and starch content increase. CCC did not consistently affect growth, but reduced tuber size, increased starch content, therefore reduced tuber and starch yields per plant. Foliar applications of GA3 might be used to increase tuber and starch yields per plant under short days. This result was obtained because of a partial or total inhibition of flowering and seed set by that growth substance.

Keywords: *Pachyrhizus*; Yam Bean; Growth Regulators; Gibberellic Acid; CCC

Introduction

Mexican Yam bean, (*Pachyrhizus erosus* Urban), is a tropical root crop that deserves to be better known in the Caribbean. It is today widely disseminated in the tropical regions of China, India, Indonesia and the Philippines (Schroeder, 1967; Srivastava et al., 1973). It belongs to the family Papilionaceae and produces tubers and pods. Although the seeds are not suitable for human consumption because they contain rotenone, a respiratory inhibitor (Hansberry et al., 1947), they are used to propagate the plant. The edible tubers are therefore available as food. The chemical composition indicates a well balanced protein content (Marta Evans et al. 1977). The tuber contains 84.5 percent water. Glucose, fructose, sucrose and starch are the main sugars.

As a legume, yam bean can supply its own nitrogen needs by biological dinitrogen fixation and leave in the soil an appreciable amount of nitrogen that is usable by the next crop. In addition the tops are rich in proteins, and can be used for forage or as green manure. (Cortes, 1970).

Tuber yield depends on climatic conditions and cultural practices. The best yields are obtained if vegetative growth occurs under long day conditions. The yield can be increased twofold if the plant is prevented from fruiting by an early pruning (Zepeda, 1971). Tuber size, yield and sugar composition may also be modified by use of growth regulators. This article reports the result of the application of different concentrations of gibberellic acid (GA3) and chlorocholine chloride (CCC) during the growth of yam bean.

Materials and methods

Yam bean seeds (kindly supplied by Dr. Steele of IITA, Ibadan, Nigeria) were sown in October and grown under field conditions. The plants received basic slag containing 70 kg of P_2O_5/ha and potassium sulphate (120 kg K_2O/ha.). The plant did not receive any nitrogen fertilization. The nodulating rhizobium was present and efficient in the soil.

Beginning six weeks after sowing, five applications of growth hormones were made at two week intervals to plots of 200 plants. Treatments were gibberellic acid at 50 ppm (GA 50) and 200 ppm (GA 200), chlorocholine chloride at 1000 ppm (CCC 1000) and 5000 ppm (CCC 5000); control plants were sprayed with water. Ten plants of each set were harvested weekly to follow growth characteristics and carbohydrate content. Only the results at harvest are reported here. Yield of yam bean tubers was taken after 5 months of growth on a sample of 50 plants.

At harvest, plants were individually separated into various constituents; leaves were counted and dry weights of different parts were determined after 48 hours of drying at 80°C.

Tubers of 5 plants randomly harvested were washed, cut into pieces and oven dried at 80°C for 48 hours. The dried material was ground to pass a 0.4mm sieve. Soluble sugars (sucrose and reducing sugars) were extracted in ethanol-water (80:20) (Cerning-Beroard, 1975). Total ethanol-water soluble carbohydrates were estimated in sulfuric acid with orcinol (Tollier and Robin, 1979); sucrose, glucose and fructose according to the enzymatic methods of Bergmeyer (1979). Starch was extracted as described by Thivend et al. (1965) and determined according to Bergmeyer (1979).Starch was extracted as described by Thivend et al. (1965) and determined according to Bergmeyer (1979).

Results

Effect of GA3 and CCC on aerial organs

Leaf number: Gibberellic acid, at both 50 and 200 ppm, increased leaf number compared to the control. The effect was observed from the beginning of the treatment. At harvest, the leaf number for GA 50 treatment was twice that of the control. CCC did not significantly affect leaf number (Table 1).

Leaf Dry Matter: Only GA 50 treatment had a large effect on leaf dry matter accumulation at harvest (Table 1). Although GA 50 and CCC 1000 treatments increased leaf dry matter up to pod set, levels declined thereafter in the CCC 1000 treatment. Other treatments showed little effect.

Stem and Petiole Dry Matter: All treatments showed increased dry matter accumulation over the control (Table 1). The effect was greatest with GA 50 treatment and as with the GA 200 treatment, resulted from increased internode length. CCC increased dry matter by increasing development of floral organs.

Pods and Seeds: Fruiting was completely inhibited by GA 200 as compared to GA 50 and the control (Table 1). CCC had an inverse effect, enhancing pod and seed production.

Effect of GA3 and CCC on tuber yields

Yam bean generally bears one tuber (exceptionally two). In our experiments the application of growth regulators began after the start of tuberization. So our results concerned the tuber development rather than tuberization.

At harvest, tuber dry matter of the GA 50 and GA 200 treatments was respectively, 2.7 and 1.8 times higher than that of the control (Table 1). The opposite effect was found under CCC treatments where the CCC 1000 and CCC 5000 treatments yielded respectively, 78% and 37% that of the control. Tuber fresh weights followed closely the trends in dry weight. On the basis of 200,000 plants per hectare the highest tuber yield was around 70 t/ha (GA 50), while control plots yielded 24 t/ha (Table 1).

Effect of GA3 and CCC on tuber composition.

Soluble carbohydrates: Tuber analysis at harvest showed that sugar composition was affected by applications of the growth regulators (Table 2). As compared to the control plants, GA 200 maintained soluble sugars content but GA 50 and CCC 1000 treatments decreased it. All treatments modified the ratio of soluble sugars analysed. Sucrose was not found in control tubers. Studies are under way to identify the other soluble sugars.

Table 1 Growth characteristics of yam bean at harvest under GA3 and CCC treatments (weights in g/plant).

Growth Characteristics	Treatments				
	Control	GA 50	GA 200	CCC 1000	CCC 5000
Leaf number	31.0	61.0	50.0	34.0	31.0
Dry Weights					
Leaves	28.0	50.8	37.4	31.6	26.6
Stems & Petioles	24.9	48.4	32.1	34.3	30.0
Pods & seeds	93.6	71.0	9.5	162.0	153.0
Tuber	109.0	300.0	200.0	84.5	40.8
Fresh Weight					
Tuber (Mean)	1200	3500	1800	900	430
(Range ±)	200	800	300	250	130
Yield (t/ha)	24.0	70.0	36.0	18.0	8.6

Table 2 Carbohydrate composition of yam bean tuber at harvest under GA3 and CCC treatments. Carbohydrate expressed as % dry matter.

Carbohydrate Composition	Treatments			
	Control	GA 50	GA200	CCC 1000
Soluble sugars	30.2 (0.9)	16.5 (1.0)	31.1 (0.6)	24.8 (0.9)
Glucose	6.7 (0.5)	2.0 (0.2)	10.4 (0.6)	5.7 (0.5)
Fructose	9.8 (0.6)	6.8 (0.5)	13.7 (0.7)	5.7 (0.5)
Sucrose	0	7.6 (0.5)	6.0 (0.5)	6.4 (0.5)
Starch	12.5 (0.5)	18.9 (0.8)	17.2 (0.7)	17.5 (0.5)

Range (±) given in brackets, ( )

Starch: Both GA3 and CCC increased starch content in the tubers, irrespective of concentration used. The improvement varied from 37.5% for GA 200 to 51% for GA 50. GA3 not only improved starch content in the tuber, but also increased starch yield per plant. Taking into account the dry matter produced by each treatment, starch yields were 14, 56, 34 and 15g/plant for control, Ga 50, GA 200, and CCC 1000 treatments, respectively.

Discussion and conclusions

The results generally indicate opposite effects from GA3 and CCC foliar applications to yam bean:

- GA3 promoted shoot growth, whereas CCC had no significant effect.

- GA3 reduced flowering and seed production, whereas CCC improved flowering and increased seeding.

- GA3 promoted tuber enlargement, whereas CCC treatments reduced tuber production.

- Both growth regulators, however, increased starch levels in the tuber generally resulting in increased starch yields per plant.

The promotion of shoot growth by GA3 and the inhibition of flowering for some species has been reported by Sachs and Hackett (1969 and 1977). The antagonistic effects of GA3 and CCC are similar to reports by many authors. Tuber enlargement was not found in other tuber plants (Okazawa, 1960; Kumar and Wareing, 1975). This was attributed to an inhibition of photoassimilate translocation into tubers and the hydrolysis of sucrose into reducing sugars, thus preventing its conversion into starch (Lovell and Booth, 1967).

A full discussion of the results reported on yam bean was given elsewhere (Zinsou et al, 1987a and b). It was suggested that GA3 and CCC activated photosynthesis and increased assimilate production, by inducing a greater top growth (GA3) and improving chlorophyll and carotenoid levels as reported by Prokhorchik and Mashtokov (1972) in El-Abd et al, 1980). Other possible effects of the growth substances were modifications of the distribution pattern between the different sinks. GA3 reduced or suppressed the pod and seed sinks and favoured tuber enlargement, whereas CCC improved seed production by reducing assimilates allocated to the tuber.

Finally, the results are interesting for practical application. Foliar application of GA3 at 50 ppm may triple tuber yield while allowing sufficient seed production for crop propagation.

References

Bergmeyer, H.V. (1979) Principes de l'analyse enzymatique. Technique et documentation Paris, 303 pp.
Cerning-Beroard, J. (1975) The use of invertase for determination of sucrose, application to cereals, cereal products and other plant materials, Cereal Chem., 52 431-438
Cortes, B.P.(1970) Cultivo de la Jicama, Novelas Horticolas, 1531-34.
El-Abd, S.O., El-Beltagy, M.S., Abou-Hussein, M.R., El-Beltagy, A.S., Maksoud, M.A. (1980) Effect of some growth regulators on growth and development of potato plants, Egypt. J. Hort. 7 169-180

Hansberry, R., Clausen, R.T., Norton, L.B. (1947) Variations on the chemical composition and insecticidal properties of the yam bean (*Pachyrhizus*), J. Agric. Res. **74** 55-64

Kumar, D., Wareing, P.F. (1975) Studies on tuberization of *Solanum andigena*, 2 - Growth hormones and tuberization, New Phytol. **73** 833-840.

Lovell, P.H., Booth, A. (1967) Effects of gibberellic acid on growth, tuber formation and carbohydrate distribution in Solanum. New Phytol, **66** 525-537

Marta-Evans, I., Boulter, D., Eaglesham, A.R.J., Dart, P.J. (1977) Protein content and protein quality of tuberous roots of some legumes determined by chemical method, Qual. Plant. PI. Foods Hum. Nutri, **27** 275-285

Okazawa, Y. (1967) Physiological studies on the tuberization of potato plants, J. Fac. Agric. Hokkaido Univ. Sapporo, **55** 267-336

Sachs, R.M., Hackett, W.P. (1977) Chemical control of flowering, Acta Hort, **68** 29-49

Schroeder, C.A. (1967) The Jicama, a rootcrop from Mexico, Proc. Amer. Soc. Hort. Sci., Tropical Region, **11** 65-71

Srivastava, G.S., Shukla, D.S., Aeassthi, D.N. (1973) We can grow sankalu in the plains of Uttar Pradesh, Indian Farming, **33** 3-9

Tollier, M.T., Robin, J.P. (1979) Adaptation de la methode a l'orcinol sulfurique au dosage automatique des glucides neutres totaux. Conditions d'application aux extraits d'origine vegetale, Ann. Technol. Agric., **28** 1-5

Zepeda, A.H. (1971) Efecto de desfloracion de la jicama (*Pachyrhizus erosus*) sobre el rendimiento, Dept. Hort. INIA SAG CIAB celoya GTO, Mexico

Zinsou, C., Venthou-Dumaine, A., Vansuyt, G., (1987) Croissance et developpement du *Pachyrhizus erosus* Urban, 1 - Effets de l' acide gibberellique et du chlorure de chlorocholine en jours courts, Agronomie **7** (10), (in press)

Zinsou, C., Vansuyt, G., Venthou-Dumaine, A.,(1987) Croissance et developpement du *Pachyrhizus erosus* Urban., 2 - Effets de l'acide gibberellique et du chlorure de chlorocholine sur la composition glucidique du tubercule, Agronomie, 7(10): (in press)

NON - TRADITIONAL CROPS

An overview of the Mango industry in Puerto Rico

W. Colon-Guasp and A. Acosta-Rodriguez

USDA-ARS Tropical Research Station, P.O.Box 70, Mayaguez, Puerto Rico, 00709

Puerto Rico has been successfully exporting mangoes to the European market for the past three years. In 1986, 1407 tonnes were exported. Major producers/exporters are: Fruits Int'l Inc.; Huertos del Caribe Inc. and ISPRAC Inc.; with 200, 320 and 69 hectares respectively; each producer marketing their fruits independently. Extending the harvest period from late April to early September could be important, since several mango varieties are available. Management and production technologies vary in each particular case. The Mango industry is characterized by high investment, high level technology and high yields of excellent quality. At present the mango produced in Puerto Rico can enter European markets without restrictions except for Spain. However, they are not permitted to enter the mainland United States markets until an acceptable treatment for fruit fly control is validated under local conditions. During 1986 a shipment of irradiated mangoes from Puerto Rico was permitted to enter the United States at Miami, Florida. Consumer acceptance was monitored. American consumers reacted positively to the irradiated mangoes. The economic feasibility of mango irradiation has yet to be determined.

Keywords: Mango; Varieties; Export; Puerto Rico

Introduction

The Mango (*Mangifera indica* L.), native to Southeastern Asia, was introduced to Puerto Rico about 1750 from Jamaica (Toro, 1987). In the early 1900's the Federal Experiment Station, now the Tropical Agriculture Research Station, initiated a collection of mango varieties (Kinman, 1918). The University of Puerto Rico, Agricultural Experiment Station (UPR-AES), also established a mango collection which was expanded in 1948 by introducing related varieties of large size and excellent quality fruit (Mattern et al., 1972). At present, a collection of 105 related mango varieties from all parts of the world is maintained at the Fortuna Substation of UPR-AES.

The first attempt to export mangoes occurred in 1952 with the shipment of local varieties "Mayaguezano" and "Pasote" to the continental United States, mainly to New York City (Spencer and Kennard, 1955). The next attempt to export better and more attractive mango varieties was made by the UPR-AES in 1970 (Mattern et al., 1972). Fruits were shipped to evaluate market acceptability and determine price fluctuations as affected by season of the year and consumer preferences. In their study, fruits were treated with ethylene-dibromide (EDB) in a sealed chamber for 2 hours. With this treatment, no deterioration or spoilage of fruits occurred. Fruit size, color and appearance, and the attractiveness of packaging were found to be important considerations. According to their results, fruits of large size demanded higher prices. Mango fruits in the U.S. market were reportedly scarce before May and after September. Such cultivars as "Springfels", "Irwin" and "Haden" were considered the best varieties based on criteria of size, early bearing and productivity.

In 1984, the Environmental Protection Agency (EPA) prohibited the use of EDB on mangoes shipped from Puerto Rico to the U.S. market. This decision forced local growers to seek markets outside the U.S. Since then, the production is mainly exported to Europe and some is marketed locally.

Present status of the Mango industry

In 1986, the most important mango growers in Puerto Rico were Fruits International, Inc. (FII), Huertos del Caribe, Inc. (HDC) and ISPRAC, Inc., with 200, 320, and 69 ha, respectively. The three companies are located on the southern coast of Puerto Rico where annual rainfall is less than 150 mm. In addition, the region has a well developed infrastructure where irrigation facilities and deep, fertile calcareous soils are common. Furthermore there is abundant labor. All farms use drip irrigation, fertilizer injectors, intensive pest control and have packing facilities. The average investment amounts to US $15,000-17,500/ha.

The implementation of this technology leads to high yields of excellent quality fruits. Since 1985, Puerto Rico has been exporting appreciable amounts of mango fruits to the European market from early, middle and late season cultivars (Table 1).

Table 1 Production (metric tons) and varieties exported to Europe by Mango producing companies, 1985-1987

	Year			
Grower (Estimated)	1985	1986	1987	Varieties Used
FII	45	878	1500	Irwin, Haden, Parvin, Davis, Haden, Keitt
HDC	25	448	600	Irwin, Haden, Osteen, Parvin, Springfels, Tommy Adkins, Keitt
ISPRAC	NA	79	714	Irwin, Haden, Springfels, Keitt

Production Technology

Recommended Varieties: The commercial varieties grown in Puerto Rico extend the mango producing season from the end of April to the beginning of September. These varieties can be classified as follows:

Early-season	Mid-season	Late-season
Irwin	Davis, Haden	Keitt
Tommy Adkins	Springfels	
Haden	Parvin	
	Osteen	

The fruit weight of these varieties ranged from 0.34 kg for "Irwin" to 0.68 kg for "Springfels" (Anon., 1985). Planting densities are 172, 400 and 335-1000 trees/ha at ISPRAC, FII, and HDC orchards, respectively. Plant populations depend on the growth habit of the varieties grown. "Irwin", which is a semi-dwarf tree, can be planted effectively at the rate of 400 trees/ha. A medium size tree such as "Osteen", "Tommy Adkins", "Davis" and "Haden" should be planted at a density of 350 trees/ha. Large trees, such as "Parvin", "Keitt" and "Springfels" should be planted at 175 trees/ha. Densities of over 400 trees/ha should be avoided.

Intercropping: Intercropping of mangoes with other economic cash crops such as plantains and papaya in order to provide wind breaks and a source of income during the first year is recommended. ISPRAC successfully intercropped their mangoes with plantains. The FII mango orchard was successfully intercropped with Solo papaya, cv. Sunrise.

Irrigation: Each tree is irrigated by drip lines. Two emitters are spaced one meter from the trunk of each tree, providing approximately 8 liters of water/hour. Each tree receives approximately 96 liters of water/week. At the FII farm, tensiometers are distributed uniformly throughout the orchard. Three tensiometers are located at each station at a depth of 0.33m, 0.66m and 1m. The tensiometers are used to monitor the distribution of the water in each section and not to program the water applications. However, at ISPRAC and HDC farms, water applications are made depending on the reading of the tensiometers located throughout the orchard.

At each farm, water applications are cut back preceding flowering. Apparently this practice helps induce a heavy bloom and reduces growth flushes on bearing mango trees. At that time, trees should be left without water for about one month.

Fertilization: The trees are fertilized through the irrigation system. The fertilizer solution is made up of very soluble salts, including potassium nitrate, ammonium sulfate and phosphoric acid. The amount of fertilizer applied depends on the age of the trees. Young, non-bearing trees receive 0.30 kg of N, 0.30 kg of P. and 0.25 kg of K per year. Application rates are doubled each year. Fertilizer applications, are cut off around October-November, depending on the variety. This is done to avoid excessive growth flush and a physiological disorder leading to softnose on the fruits. Fertilization is resumed as soon as all the fruits have been harvested.

Flower Inducement: In each mango orchard, trees are stimulated to flower uniformly by spraying with potassium nitrate. Two applications are made/year at a concentration that varies from 1 to 5%. Applications are made using a 500 gal stainless steel blower. Flower inducement has been shown to be most effective on 7-month old shoots (Raul and Fidel, 1981). For this reason mango growers try to avoid excessive growth flushes during the year.

Pruning: Huertos del Caribe, Inc. and ISPRAC, prune their trees manually, while FII uses a tractor mounted machine. Trees are heavily pruned after the harvesting season to facilitate spraying and picking operations. In the long run, better quality fruit is obtained by this practice.

Harvesting and Packing: Mangoes are harvested manually at the three farms. Fruits are taken to the packing-house in bins. The fruits are cleaned, sorted and weighed mechanically. Hand labor is used to reject malformed or cracked fruits and to pack the fruits in boxes. Boxes can hold 6-18 mangoes each. Each box weighs approximately 10 lbs. FII does all the packing manually, since it lacks an automated packing-house. All companies stack the mango boxes on pallets, which are then placed into refrigerated containers. The temperature in the containers is maintained at 10-12^{o}C (50-55^{o}F), depending on the variety. The capacity of each container is approximately 15 metric tons. Mango production is considered seasonal, since it provides most employment from late April to early September. During the rest of the year, a small group of permanent employees carry out maintenance work on the orchard.

Marketing: Mangoes that are classified as Grade A are neither malformed nor exhibit any anthracnose damage. Grade B mangoes are malformed with anthracnose spots throughout the fruit. Grade C mangoes are those which are slightly over-ripe. Only grade A mangoes are exported to Europe. Shipping the refrigerated containers from Puerto Rico takes approximately 12 days. Once fruits arrive in Europe, brokers, who work on a commission basis, coordinate the distribution and marketing of mangoes throughout Europe, except Spain. This country does not permit mangoes to enter its market because of strict phytosanitary restrictions. From the actual selling price, brokers deduct all expenses including sea freight and commission. The difference is transferred back to the company. Grade B and Grade C mangoes are sold locally and in the US Virgin Islands. A small amount of Grade B and Grade C mangoes are sold to a food processing company for the preparation of fruit cocktail and mango slices. A limited amount is sold to make chutney.

Each company markets their fruit independently. FII markets its Grade A mango under "Pango Mango" brand and its Grade B mango under the "Coqui Mango" brand. HDC markets its mango under the "Mango Rico" brand. ISPRAC markets its mangoes under the "Tropic" brand. The price of mangoes varies in relation to a series of factors such as color, firmness, variety, and size of fruits. The demand for mangoes in the European market is usually high in April and mid-May. Price and demand are depressed by the entry of mexican mangoes in July. In August and September the market demand again increases. Prices obtained so far by FII in Europe range from US$6.00-8.00/10 lbs box (Segal, 1987)

Irradiation of Fruits

In September of 1986, 479 boxes of mangoes from FII were treated to 50 kilorads of gamma rays from a Colbalt-60 irradiation source. This treatment was carried out at Isomedix Inc., a company which sterilizes health care equipment. This company is located at Vega Alta, Puerto Rico. The mangoes were then sold at a produce market in North Miami at about US $1.00/lb (New York Times, 1986). Consumers reacted favorably to the irradiated fruits. This venture provided a valid control of fruitflies, but the price of irradiating the mangoes was extremely high. For this reason the Mayor of Ponce, the largest city near the mango producing area has proposed building a fruit and vegetable irradiation plant. If this can be done at a low cost, Puerto Rico will probably be able to meet the growing demands of the American consumer for imported specialty and tropical fruits and vegetables.

Research

The UPR-AES is currently conducting various research projects which will benefit the mango industry in Puerto Rico. These projects are:

1) Control of the Caribbean fruitfly (*Anastrepha suspensa*) and the West Indian fruitfly (*A. obliqua*) on mango by irradiation and hot water treatment.

2) Biology of the West Indian fruitfly (*A. obliqua*) related to larval population in 16 varieties of mangoes.

3) Evaluation of Bravo 500 fungicide for control of anthracnose (*Colletotrichum gloeosporiodes* Penz)

4) Behavior of mango rootstocks to different pruning systems.

5) Effect of different water regimes, using drip irrigation on mango fruit production.

6) Inducement and retention of flowers in mango trees.

Numerous scientific papers on mangoes have been published in the Journal of Agriculture of the University of Puerto Rico over the last 40 years. In addition, Puerto Rico has an experienced cadre of highly qualified professionals involved in production, processing and marketing of mangoes and other tropical fruits. This can be an important resource in the Caribbean due to the demand for these fruits in U.S. and European markets and their potential as a source of foreign exchange.

References

Anonymous, (1985) Conjunto Technologico para la Produccion de mango, UPR, EEA, Publication 114

Kinman, C.F. (1918) The Mango in Porto Rico, *Porto Rico Agricultural Experiment Station, Bulletin No. 24*, p. 30

Mattern, F., Pennock, W., and Valle-Lamboy, S. (1972) Supplying the New York Market with High-Quality Puerto Rican Mangoes, *J. Agri. Univ. P. R.*,56(1) 1-10

New York Times (1986) Irradiated Fruit on sale in Miami, September 13

Raul, M.V. and Fidel, S.R. (1981) Asperciones de KNO_3 para adelantar e inducir la floracion del mango, cv. Manila, en Mexico, *Proc. Tropical Region. Amer. Soc. Hort. Sci*,25 315

Segal, S. (1987) Pers. Communication

Spencer, J.L. and Kennard, W.C. (1955) Studies on Mango (*Mangifera indica* L.) fruit set in Puerto Rico, *Tropical Agric.* 32 323-330

Toro, E. (1987) Pers. Communication

Heat stress of container-grown tropical fruit and ornamental plants

Dewayne L. Ingram

Ornamental Horticulture Department, Institute of Food & Agricultural Sciences, University of Florida, Gainesville, Florida, USA 32611

Robert Webb, Christopher Ramcharan and Arthur Peterson

University of the Virgin Islands, Kingshill, St. Croix USVI 00850

Effects of 3 plant container types and 3 spacing treatments on plant growth and container temperatures were determined in St. Croix, U.S.V.I. These effects were compared with plant physiological response to supraoptimal root-zone temperatures in controlled environment studies. White rigid plastic plant containers or polyethylene containers placed inside large rigid plastic containers reduced the temperature in containers as compared to single black rigid plastic containers. *Dracaena marginata* 'Tricolor' root and shoot dry weights were greatest in white containers. *Ixora chinensis* 'Maui' height was greatest in white containers but dry weights were not affected by container type. A close pot spacing, also reduced the heat load, but the effect on maximum temperatures was minimal from September to March. Such treatments did not affect 'Carrizo' citrange and 'Barbados Dwarf' papaya growth in containers. 'Grand Naine' banana root weight was significantly greater for plants in close spaced pots, compared to other spacing treatments.

Keywords: Plant containers; Ornamentals; Fruits; Root temperatures

Introduction

Many tropical fruit and ornamental plants destined for landscaping or for planting in the field are started in containers. Although this production method offers many advantages, high growth medium temperatures can reduce plant growth and quality. Temperatures in excess of 50°C have been recorded in growth media in such containers and temperatures about 40°C are commonly maintained for more than 4 hr. daily (Fretz, 1971; Young and Hammet, 1980).

Direct heat injury to plant roots, as described by Levitt (1980), results from a short exposure to an extreme temperature. This lethal temperature for excised roots of various woody and tropical plants exposed for 20 min. ranged from 46.5 $\pm$0.5°C to 53.5 $\pm$0.5°C (Ingram, 1985; Ingram and Buchanan, 1984). Indirect heat injury can result from prolonged exposure to temperatures below those causing direct injury. Some of the postulated mechanisms of indirect injury include plant starvation, biochemical lesions and the accumulation of toxic by-products (Levitt, 1980).

Research has been conducted at the University of the Virgin Islands in Kingshill, St. Croix and the University of Florida, Gainesville, to determine critical supraoptimal root-zone temperatures for selected tropical and subtropical crop plants and to evaluate cultural practices aimed at reducing heat stress to container-grown plants.

This paper reports the results of two experiments conducted in the Virgin Islands and results of experiments conducted in Florida in 1985 and 1986. The objective in the Virgin Islands was to evaluate the effects of container type and container spacing on root-zone temperatures (RZT) and growth of *Dracaena marginata* cv. Tricolor; citrange [*Citrus sinensis* (L.) Osbeck x *Poncirus trifoliata* Raf.] cv. Carrizo; *Ixora chinensis* cv. Maui; banana (*Musa* sp. AAA) cv. Grande Naine and papaya (*Carica papaya* L.) cv. Barbados Dwarf. The objective in the Florida experiments was to determine critical RZTs for the physiological processes and growth in Dracaena, Citrange, Ixora and banana. Results of the studies conducted in Florida have been published previously (Ingram and Ramcharan, 1985; Ingram and Ramcharan, 1986; Ingram, et al., 1986; Ingram, et al., 1987).

Materials and Methods

Container Trials: Uniform rooted cuttings of Ixora and Dracaena and seedlings of Citrange and papaya were transplanted into 3 container types on May 20, 1986. The volume of each container was 7.6 liters. The container types were black rigid plastic containers (C_b) plastic container painted white (C_w) and black polyethylene bags inserted into black rigid plastic containers 7.5 cm greater in diameter than the bags (C_{b+p}). A soilless growth medium (Metro Mix 500, W.R. Grace, Inc., Cambridge, MA., USA) amended with 0.6 kg m^{-3} of Perk (a micronutrient formulation by Estech Inc. Winter Haven, FL, USA) was used in all container types. Plants in containers were placed on a gravel bed in full sun and irrigated daily to container capacity through a low-volume irrigation system. There were six replicates of each species in the 3 container types and species were analyzed as separate experiments.

Plant heights and widths were recorded initially and monthly thereafter. Shoot and root dry weights were determined when the experiment was terminated on November 20, 1986. Diurnal temperature and solar radiation intensity were recorded on 2 representative 24 hr. periods each month using a microdatalogger (Model 21X, Campbell Scientific Inc., Logan, Utah, USA). Welded copper-constantan thermocouples were positioned in the growth medium equidistant from the top and bottom and 1 cm from the container sidewall on the north, east, south, and west coordinates and in the center of the container medium. Temperatures at each location were sensed every 5 min. and 15 min. averages were recorded from before sunrise to sunset.

Spacing Trials: Rooted cuttings of Ixora and Dracaena, Citrange seedlings and established *in vitro* cultured plantlets of 'Grande Naine' banana were transplanted into 7.6 liter, rigid plastic containers in 1986. Three spacing treatments comprised: a) container centers spaced at 46 cm (S1); b) containers touching each other for the entire period (S2) and; c) as (b) until adjacent plants began to touch and then at 46 cm. (S3). A border row was maintained at the same spacing for each group. Plant heights and widths were recorded initially and monthly thereafter. Shoot and root dry weights were determined at termination of the experiment on February 12, 1987. Diurnal temperature and solar radiation intensity were recorded as described above.

Critical temperatures for physiological processes: Plants were transplanted into 7.5 cm dia. x 23 cm tall polyethylene bags that were inserted into electronically controlled heating tubes in a walk-in growth room at Gainesville, Florida. Growth room ambient day/night temperatures were maintained at 28°C/25°C. A 14 hr. photoperiod with an irradiance of approximately 1100 umol m^{-2} s^{-1} at canopy height, 65 to 70% relative humidity and a CO_2 concentration of 300 to 400 $mg.L^{-1}$ were maintained during lighted hours. RZT treatments of 28°, 34°, 40° and 45°C for 6 hr. daily were provided within ±0.3°C of the desired temperatures. Temperature treatments were replicated 6 times in a randomized complete block design.

Midday photosynthesis, leaf conductance and transpiration were determined after 11 weeks using a portable gas analyser (LICOR 6000) and shoot and root dry weights were determined after 12 weeks and root and leaf samples were taken for analysis of soluble and structural carbohydrates. Data from this study were published previously (Ingram, et al., 1987).

Results and discussion

Container types: Dracaena height, root and shoot dry weights were significantly greater (P = 0.05) in plants grown in white containers compared to black containers (Table 1). Treatment C_{b+p} resulted in intermediate height and root dry weight. Citrange and Papaya were not significantly influenced by container type. Ixora final height was less in treatment C_b than C_{b+p} but the shoot and root dry weights were lowest in the white containers.

The mean maximum temperature recorded in black containers on May 23, 1986 was 45.5°C and temperatures above 40°C were maintained for 4 hours (Table 2.). The maximum temperature was recorded on the western side of the container and temperatures in this treatment were generally 5 to 10°C higher than in the other treatments. Temperatures recorded in container media in the Virgin Islands were generally lower than temperatures recorded in Gainesville, Florida, during the same season (Ingram, 1981).

Container spacing: Banana height was greatest at the S3 spacing, while treatment S2 produced greater plant height than the S1 spacing (Table 3.). Shoot dry weights did not reflect these differences in plant height, but root dry weight was greatest for the S2 spacing. A similar trend was noted in Papaya with the tallest plants produced at the S2 spacing, but dry weights were not affected by treatments. Dracaena shoot dry weight, width and height were not influenced by spacing treatment, but plants grown with S1 spacing had slightly greater root dry weight than plants grown at the S3 spacing. Citrange was not affected by spacing treatments. Ixora height was reduced in the S1 spacing but other parameters were not influenced by spacing treatments.

Temperatures during September through February were generally lower than those recorded in May through August. Maximum temperatures were generally found on the southern exposure, and on October 30, 1987 did not exceed 40°C (Table 4.) Maximum temperatures were generally 5 to 8°C higher in containers at the S1 spacing compared to S2 treatments. The same trends in temperatures were noted in data collected during other months (data not shown). Growth medium temperatures were below those causing growth reduction or alterations in measured physiological processes for plants tested (Ingram and Ramcharan, 1985 & 1986; Ingram, et al., 1986 & 1987. Plant response to treatments might have been different if the experiment had been conducted during the summer months because growth medium temperatures recorded in October were generally 8 to 10°C lower than those in the summer.

Table 1 Effects of container type on growth of Ixora, Dracaena, citrus and papaya plants produced in St. Croix, U.S. Virgin Islands.

Container Treatment[1]	Final Height (cm)	Final Width (cm)	Shoot Dry weight (g)	Root Dry weight (g)
Dracaena marginata 'Tricolor'				
C_b	66.5b[2]	61.5a	25.7c	10.2b
C_w	74.5a	55.2a	37.1a	15.2a
C_{b+p}	70.2ab	65.2a	31.1b	12.6a
Ixora chinensis 'Maui'				
C_b	46.3b	49.3a	40.2a	11.2a
C_w	53.2ab	43.0a	26.6b	8.6b
C_{b+p}	59.4a	52.0a	42.7a	12.6a
Citrange cv.'carrizo'				
C_b	130.7a	85.7a	60.8a	54.5a
C_w	131.3a	65.0a	55.2a	36.8a
C_{b+p}	122.0a	74.7a	60.8a	39.9a
Papaya, cv. 'Barbados Dwarf'				
C_b	25.0a	31.0a	31.8a	26.1a
C_w	26.6a	30.3a	36.4a	32.2a
C_{b+p}	27.9a	32.8a	43.8a	32.5a

1) Treatments: Cb = Black plastic containers, Cw = White painted plastic containers, Cb+p = black polyethylene bags inside black plastic containers
2) Means within columns for each species with the same letter are not statistically different at the 5% level

Table 2 Mean temperatures (^oC) at one centimetre from the sidewall in four regions of container media on May 2, 1986 in St. Croix, U.S. Virgin Islands, as influenced by container type.

		Container type[1]											
		C_b				C_w				C_{b+p}			
Time (h:m)	Solar Intensity (KWm^{-2})	North	East	West	South	North	East	West	South	North	East	West	South
7:15	0.37	23.5	24.5	24.3	24.9	23.7	24.6	23.3	23.6	24.5	24.0	23.5	24.3
8:15	0.58	25.3	26.8	26.3	27.8	25.6	27.4	24.8	25.7	25.6	25.0	24.2	26.1
9:15	0.60	27.3	29.3	28.2	29.2	27.0	28.2	26.1	27.0	26.8	26.3	25.4	27.2
10:15	0.59	29.2	31.4	30.2	31.6	28.1	29.6	26.9	28.3	27.8	27.2	26.4	28.4
11:15	1.77	31.1	33.2	32.6	34.5	29.3	31.6	27.8	29.8	29.0	28.4	27.3	30.2
12:15	1.73	34.0	35.5	36.1	36.9	32.0	33.1	30.1	31.5	31.4	30.5	30.0	32.8
13:15	1.45	36.6	37.3	39.3	38.7	33.9	34.3	32.4	33.5	33.6	32.6	32.7	35.0
14:15	1.21	38.5	38.2	42.7	39.2	35.0	34.5	34.6	33.4	35.1	34.1	34.9	36.0
15:15	1.22	39.9	38.6	44.9	39.3	35.3	34.5	35.8	34.5	35.7	34.9	35.7	36.2
16:15	0.75	40.1	38.4	45.2	39.6	35.1	33.9	35.8	34.2	35.7	35.0	35.3	35.8
17:15	0.30	40.2	37.6	45.6	37.6	34.5	33.1	35.5	33.6	35.4	34.9	35.5	35.1

1) Container treatments as Table 1

Table 3 Effect of spacing treatments on growth of container-grown plants in St. Croix, U.S. Virgin Islands.

Spacing Treatment 1)	Height (cm)	Width (cm)	Shoot dry weight (g)	Root dry weight (g)
Banana cv. 'Grand Naine'				
S1	65.2c	76.2b	20.4a	22.2b
S3	85.9a	85.6a	28.1a	16.5a
S2	76.2b	84.9a	31.2a	30.8a
Papaya cv. 'Barbados Dwarf'				
S1	55.0b	74.2	27.8	9.0a
S3	85.5a	82.5a	31.5a	7.8a
S2	62.5b	78.0a	32.2a	11.6a
Ixora chinensis cv. 'Maui'				
S1	53.5b	56.5a	48.0a	34.6a
S3	65.0a	56.6a	47.9a	25.4a
S2	68.1a	61.9a	50.5a	32.0a
Dracaena marginata cv. 'Tricolor'				
S1	64.0a	62.4a	35.0a	22.8a
S3	60.6a	57.9a	32.0a	13.8b
S2	65.1	58.9a	33.8a	18.5ab
Citrange cv. 'Carrizo'				
S1	57.5a	20.0a	11,6a	9.2a
S3	60.6a	18.8a	10.9a	7.5a
S2	61.8a	16.9a	12.1a	8.1a

1) Spacing Treatments: S1 = 46cm, centre-centre; S2 = containers touching; S3 = S2 until plants touched, then as S1
2) Means within columns for each plant with the same letter are not statistically different (P = 0.05)

Table 4 Mean temperatures one centimetre from the sidewall in four regions of container media on May 23, 1986 in St. Croix, as influenced by container spacing (spacing treatments as in Table 3)

		Spacing Treatment											
		S1				S3				S2			
Time (h:m)	Solar Intensity (kWm^{-2})	North	East	West	South	North	East	West	South	North	East	West	South
8:00	0.33	25.4	27.5	24.9	25.2	24.6	26.8	24.9	27.2	24.7	25.0	24.8	24.7
9:00	0.79	26.2	32.0	27.0	29.6	25.7	31.0	26.4	29.0	26.3	26.3	25.6	25.6
10:00	1.20	28.6	34.2	29.6	34.5	27.4	34.0	28.7	30.7	29.1	26.3	25.6	25.6
11:00	1.41	30.9	36.1	31.8	37.5	29.4	34.7	31.2	31.9	31.1	30.2	29.6	29.6
12:00	1.62	32.7	36.7	33.6	38.8	31.1	34.7	33.1	33.1	32.1	31.2	30.3	30.4
13:00	1.62	34.9	36.3	35.2	39.9	32.4	32.5	34.6	33.8	32.5	31.8	32.0	31.4
14:00	1.23	34.5	35.6	34.9	36.8	33.0	33.9	35.8	33.7	32.8	31.9	32.7	32.1
15:00	0.66	33.2	33.2	34.5	31.8	33.0	32.2	34.2	31.8	32.9	32.0	31.6	30.9
16:00	0.86	32.2	31.4	32.1	31.6	31.8	31.4	32.1	21.8	31.1	30.8	31.3	31.4
17:00	0.17	31.4	30.1	32.0	30.3	31.1	30.4	31.2	31.9	30.5	30.0	30.6	31.0

Results from the spacing and container treatments are consistent with growth room and laboratory research on the response of these plants to elevated RZT. Recorded temperatures in all treatments were below those found to cause direct membrane injury to test plants (Ingram, et al., 1986; Ingram, et al., 1987). Dracaena shoot and root dry weights, midday leaf photosynthesis, stomatal conductance and transpiration decreased linearly with increasing RZT from 28^{0} to $45^{0}C$ but shoot dry weight was not affected (Ingram, et al., 1986; Ingram, et al., 1987).

Container types that decreased absorption of solar radiation reduced the maximum temperature in the growth medium. Dracaena growth was enhanced by such treatments during summer months but citrus, ixora and papaya were not influenced by these treatments. Spacing treatments in September through February altered RZTs, but less than container treatments during summer months. Variability in plant response reflects this fact. Alternative cultural practices such as close initial spacings, which are increased as plants grow and imported plant containers with reflective colors and/or textures should be considered.

Acknowledgments

The authors wish to acknowledge that this research was supported in part by the U.S. Department of Agriculture under CSRS Special Grant No. 84-CSRS-12482 managed by the Caribbean Basin Advisory Group (CBAG().

References

Fretz, T.A. (1971) Influence of physical conditions on summer temperatures in nursery containers, Hort. Science 6(14) 400-401

Ingram, D.L. (1981) Characterization of temperature fluctuations and woody plant growth in white poly bags and conventional black containers. Hort. Science **16**(6) 762:763

Ingram, D.L. (1985) Modeling high temperature and exposure time interactions on *Pittosporum tobira* Thunb. root cell membrane thermostability, J. Amer. Soc. Hort. Sci. **109**(2)

Ingram, D.L. and Buchanan, D. W. (1981) Measurement of direct heat injury of roots of three woody plants, Hort. Science **16**(6) 769-771

Ingram, D.L. and Buchanan, D.W. (1984) Lethal high temperatures for roots of three citrus rootstocks, J. Amer. Soc. Hort. Sci. **109**(2) 189-193

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

Ingram, D.L. and Ramcharan, C. (1986) Heat tolerance of 'Carrizo' citrange and *Ixora coccinea* root cell membranes. Fla. State Hort. Soc. **99** 214-217

Ingram, D.L., Ramcharan, C. and Nell, T.A. (1986) Response of container grown banana, ixora, citrus and dracaena to elevated root temperatures, Hort. Science **21** 254-255

Ingram, D.L., Ramcharan, C. and Nell, T.A. (1987) Effect of high root-zone temperatures on physiology and growth of *Dracaena marginata* 'Tricolor' and 'Carrizo' citrange', (In press)

Levitt, J. (1980) Response of plants to environmental stresses, Vol.1. Chilling, freezing and high temperature stresses, Academic Press, New York.

Young, K. and Hammet, D.R.Q. (1980) Temperature patterns in exposed black polyethylene plant containers, Agr. Meterol. 21 165-172

Paclobutrazol increases fruiting in container grown Pummelo and Barbados cherry

Stan Michelini

Fruit Experiment Station for the Caribbean, Lascelles, St. James, Barbados

Louis E. Chinnery

Department of Biology, University of the West Indies, P.O. Box 64 Bridgetown, Barbados

Five concentrations of paclobutrazol ('Cultar') were applied as a soil drench to container grown pummelo (*Citrus grandis*), grafted on either sour orange (*Citrus aurantium*) or alemow (*Citrus macrophylla*), and Barbados cherry (*Malpighia glabra*). The citrus received between 0.03 and 0.5 g and the cherry between 0.005 and 0.5 g a.i. per container. Paclobutrazol had no effect on the increase in caliper of the pummelo scion and sour orange but it reduced it on alemow. On both rootstocks, 70% of the trees bore fruit in the 0.5 g a.i. treatment compared with 30% in the control and less than 1% in field plantings. Barbados cherry produced 171% more fruit in the highest treatment than in the control. It is concluded that paclobutrazol may be useful in tropical situations to induce flowering by simulating drought conditions when rainfall is abundant

Keywords: Plant growth regulators; Paclobutrazol; Pummelo; Barbados cherry

Introduction

Many plant growth regulators (PGRs) have been applied to plants in attempts to exercise greater control over vegetative plant growth, flowering and fruiting. Within recent years, a new Gibberellic acid (GA) biosynthesis inhibitor, paclobutrazol or PP333 ((*2RS*,*3RS*)-1-(4-chlorophenyl)-4,4-dimethyl-2-(*1H*-1,2,4-triazol-1-yl) pentan-3-ol), has been produced by ICI, England under the trade name 'Cultar' (Anon, 1983). It has effectively reduced shoot growth and/or increased fruiting on temperate fruit trees such as apple (Williams and Edgerton, 1983; Richardson *et al*., 1986), peach (Erez, 1984), plum (Webster and Quinlan, 1984) and *Prunus* cherries (Webster et al., 1986) and has been tested on tropical guavas (Mohammed et al., 1984) and citrus (Iwahorl and Tominaga, 1986).

The pummelo or shaddock, *Citrus grandis* (L.) Osbeck, is a lowland tropical citrus native to Southeast Asia (Hodgson, 1976) and commonly cultivated in the West Indies. It is the largest of the commercial citrus, both in tree and fruit size, with fruits weighing up to 2 kg. Flowering is dependent upon moisture conditions and the pummelo may flower at any time of the year in the tropics (Reuther, 1980). PGRs have been used on citrus to change vegetative characteristics by limiting height and reducing suckering (Wilson, 1983). Fruit peel thickness, fruit size, and eating quality can also be affected by PGR application (Monselise & Goren, 1978).

The Barbados cherry, *Malpighia glabra* L. (= *M. punicifolla* L.), is a small shrubby tree native to the West Indies and South America (Martin et al., 1987). It has achieved some commercial success, notably in Puerto Rico, where it is known as acerola. The intrinsically high ascorbic acid (AA or Vitamin C) content of the fruits, typically 1% to 4% by weight, has been its most marketable asset (Asenjo and Friere de Guzman, 1946; Mustard, 1946; Martin et al., 1987). The fruits ripen 19 to 21 days after bloom (Jackson and Pennock, 1958) and the trees can flower repeatedly, with little time delay following fruit ripening (Moscoso, 1956; Ledin, 1958). Fruit set is usually low, from 2 to 12% in Hawaii (Yamane and Nakasone, 1961a), but it has been improved by the application of PGRs (Yamane and Nakasone, 1961b). While young trees may flower and set fruit within one year of propagation, field plantings exhibit vigorous vegetative growth, which is often detrimental to flowering and early fruit production.

Day length and temperature are nearly constant in near equatorial lowland tropical areas and changes in water conditions become important in stimulating fruiting. Under consistently rainy conditions, unrestricted vegetative growth often occurs. The application of GA inhibitors offers the possibility of shifting the carbohydrate sink from vegetative growth to fruiting. This paper reports the results of the application of paclobutrazol to container grown pummelo and Barbados cherry.

Methods

Sour orange and alemow rootstocks were transplanted in late 1985 into 30 cm diameter rigid containers, placed on concrete blocks and drip irrigated using two pressure compensating emitters per container. The media consisted of either 60% well rotted sugarcane bagasse and 40% sand; or 40% bagasse, 20% manure and 40% sand. The trees were grown and grafted to a local selection of pummelo between January and March, 1986. The following November, 42 uniform trees, on each rootstock, were selected from a population of over 400 trees. The remaining trees were field planted. Stem calipers of the container trees were measured two to three centimetres above the graft union. Paclobutrazol was applied on December 16 at concentrations of 0, 0.03, 0.06, 0.125, 0.25 and 0.5 g active ingredient (a.i.) to each of seven trees on each rootstock as a soil drench in 500 cm^3 of water. Approximately 60 g of 24-0-18 NPK fertiliser were applied in December and March. The trees were kept weed free and watered. On April 15, 1987, stem calipers were remeasured and the number of trees in each treatment, and in the field planting which bore fruit in excess of 5 cm diameter were recorded.

Similarly sized, nine month old rooted cuttings of Barbados cherry cv. 'Florida Sweet' were transplanted from 20 cm into 30 cm diameter containers in September, 1986. The media was a 60:40 mixture of bagasse and sand. A single row of containers was placed on concrete blocks and irrigated using polyethylene tubing with one pressure compensating emitter per tree. The trees, which had been randomly assigned to position, were divided into six groups of six trees. Each group of trees was treated with paclobutrazol on November 21, 1986. The concentrations used were 0, 0.005, 0.01, 0.05, 0.1 and 0.5 g a.i. per tree and these were applied as a soil drench in 500 cm^3 of water. The trees were fertilised with approximately 60 g of 24-0-18 NPK fertiliser in September, December and March. Attempts were made to avoid any drought stress, but all trees became wilted occasionally as a result of inadvertent water deprivation. New fruits, on each tree, were recorded seven times between January 8 and April 13, 1987. The fruits were not weighed due to constant bird damage as they were ripening. Due to the vigorous, multi-trunked, spur type growth, attempts to accurately measure shoot growth had to be abandoned. However, visual observations were recorded to assess any major differences between treatments.

Results

Fruiting of pummelo on both rootstocks tended to increase with increasing paclobutrazol concentration (Table 1). The response on sour orange was more marked than that on alemow, but on both rootstocks the proportion of trees bearing fruit was greatest at the highest rate of application. Only three of the 400 non-treated field planted trees produced fruit in the same time period.

Over the four month period there was a significantly greater ($P < 0.001$) percentage increase in stem caliper of pummelo on the sour orange rootstock (Table 2). The paclobutrazol had no apparent effect on radial growth on this rootstock but on alemow there was a tendency for reduced growth with increasing treatment concentration. Shoot extension growth was noticeably restricted only at the 0.5 g a.i. treatment.

Cherry fruiting tended to improve with increasing paclobutrazol concentrations (Table 3). Cherry trees receiving the highest level of paclobutrazol (0.5 g a.i.) fruited earliest, most frequently and produced the greatest numbers of fruit. Fruit number was increased 171% over the control.

Cherry tree growth was noticeably restricted at the highest paclobutrazol rate. The trees did not exhibit any shoot growth until March, about four months after application, and all new growth until then was either leaves on extremely short internodes or flowers produced at available growing points.

Discussion

The increased fruit set, and reduced vegetative growth in Pummelo at 0.5 g a.i. paclobutrazol was expected and parallels the results found with cherries and other fruits (Iwahori and Tominaga, 1986; Webster *et al.*, 1986). Some of the control trees also fruited and the response was similar to that at the lower paclobutrazol treatments (Table 1). In the case of the controls, the fruit set appeared to be drought stress related, with flowering occurring sporadically on the larger trees. Since all the plants were grown in the same size containers, container restriction effects cannot be separated from treatment effects in these data.

Since less than one percent of the field planted trees produced fruit within the same period, it suggests that the fruiting of the control plants in containers was due to root restriction and/or associated water stress. The different patterns of caliper increase obtained while using identical scion varieties and similar cultural conditions, indicate differing rootstock sensitivities to paclobutrazol.

Members of a genus would be expected to have similar capacities for producing GA, and to be affected similarly by GA inhibitors. However, if concentration thresholds varied, then the same reduction in GA production could result in different specific growth responses or different changes in carbohydrate sink activities. Thus, it may be inferred that the sour orange rootstocks' demand for carbohydrate was insensitive to the GA synthesis inhibition while in alemow, these changed with paclobutrazol concentration. In consequence, radial growth of the trunk of the pummelo scion was affected only on the latter rootstock.

Overall, citrus was less sensitive to paclobutrazol than cherries. At the highest rate, citrus trees resumed active growth earlier and the fruiting effects were not as pronounced. However, it appears feasible to apply the chemical to cause a shift towards flower initiation in young vigorous groves and to provide a measure of control over shoot growth.

Table 1 Fruiting response of pummelo to paclobutrazol. The data indicate numbers of trees (out of seven) bearing fruit, four months after treatment.

Treatment (g a.i./ container)	Rootstock		Mean a)
	Sour orange	Alemow	
0.5	5	5	5.0 a
0.25	3	0	1.5 a,b
0.125	2	2	2.0 a,b
0.06	1	1	1.0 b
0.03	1	2	1.5 a,b
0.0	2	2	2.0 a,b.

a) Means followed by the same letter are not significantly different ($P > 0.05$)

Table 2 Increase (mm) and percentage change in caliper of pummelo treated with paclobutrazol. The data are the means of seven trees for each treatment.

Treatment (g a.i./ container)	Rootstock			
	Sour orange		Alemow	
	Increase	% Increase	Increase	% Increase
0.5	5.1	34	1.9	12
0.25	4.9	36	2.3	21
0.125	5.7	51	1.7	13
0.06	4.7	33	3.1	19
0.03	5.4	36	3.6	25
0.0	5.0	33	4.6	30
Mean	5.2	37	2.8	20

The Barbados cherry is an unusual perennial tree crop in that it has a short fruiting cycle. Small changes in carbohydrate allocation, followed by stimulating water and fertiliser application often result in flower flushes. This sensitive carbohydrate shift should be easily manipulated, if not controlled.

The obvious inhibition of growth and concurrent stimulation of fruiting shows a response to paclobutrazol treatment. While the 0.5 g a.i. treatment resulted in substantial control of vegetative growth and increased flowering, the other rates achieved only a mild stimulating effect on fruiting without obvious vegetative effects. Thus, the paclobutrazol may be causing a significant redistribution of carbohydrate only at the highest treatment level.

The means presented in Table 3 may not fully reflect the effect of paclobutrazol. Towards the end of the experiment, there was an increase in fruiting in the control and the lower level treatments which can be attributed, in part, to increasing water stress. Initially, sufficient rooting media existed to allow for rapid growth, resulting in large trees whose roots soon filled the existing container space. This eventually caused water supply to become limiting. Ample water, following this restriction, would have resulted in enhanced flowering.

Table 3 Fruiting response of Barbados cherry to paclobutrazol. The data are the mean number of fruit on six trees average over seven sample dates.

Treatment (g a.i./ container)	Mean number of fruits[a)]
0.5	7.6 a
0.1	4.3 b
0.05	5.5 a,b
0.01	4.1 b
0.005	3.8 b
0.0	2.8 b

a) Means followed by the same letter are not significantly different, ($P > 0.05$).

Similar container grown trees were observed throughout the experimental period in both field plantings and in the experimental containers. The fruiting patterns of all those in containers where root restriction was present showed a tendency toward flower production. However, early stimulation of flowering achieved with paclobutrazol increased flowering without root restriction and may give tropical growers the opportunity to simulate drought conditions when rainfall is abundant.

References

Anon, (1983) Paclobutrazol, top fruit growth regulator. ICI, Plant Protection Division, Technical Data Sheet 2A

Asenjo, C.F. and Friere de Guzman, E.R. (1946) The high ascorbic acid content of the West Indian cherry, Science. N.Y. **103** 2191

Erez, A. (1984) Dwarfing peaches by pruning and paclobutrazol, Acta Hort. **146** 235-241.

Hodgson, R.W. (1967) Horticultural varieties of citrus, In: The Citrus Industry, Vol. I, History, World Distribution, and Varieties, (Eds., Reuther, W., Webber, H.J. and Batchelor, L.D.) Rev. Edn. University of California, Riverside, CA, USA, pp. 431-591.

Iwahorl, S. and Tominaga, S. (1986) Increase in first-flush flowering of 'Meiwa' Kumquat, *Fortunella crassifolia* Swingle, trees by paclobutrazol, Sci. Hort. **28** 347-353.

Jackson, G.C. and Pennock, W. (1958) Fruit and vitamin C production of 5 and 6 year old acerola trees, J. Agric. Univ. Puerto Rico **42** 196-205.

Ledin, R.B. (1958) The Barbados or West Indian cherry, Bull. 594 Univ. Florida Agric. Expt, Stn.

Martin, F.W., Campbell, C.W. and Ruberte, R.W. (1987) Perennial Edible Fruits of the Tropics: an Inventory, U.S.D.A., Handbook # 642

Mohammed, S., Wilson, L. and Prendergast, N. (1984) Guava meadow orchard, effect of ultra high density planting and growth regulators on growth, flowering and fruiting, Trop. Agric., Trin. **61** 297-301

Monselise, S.P. and Goren, R. (1978) The role of internal factors and exogenous control in flowering, peel growth, and abscission in citrus, Hort. Sci. **13** 134-139

Moscoso, C.G. (1956) West Indian cherry - richest known source of natural vitamin C, Econ. Bot. **10** 280-294

Mustard, M.J. (1946) The ascorbic acid content of some *Malpighia* fruits and jellies, Science, N.Y. **104** 203-231

Reuther, W. (1980) Climatic effects and quality of citrus in the tropics, Proc. Am. Soc. Hort. Sci. (Trop. Reg.) **24** 15-28

Richardson, P.J., Webster, A.D. and Quinlan, J.D. (1986) The effect of paclobutrazol sprays with or without the addition of surfactants on the shoot growth, yield and fruit quality of the apple cultivars Cox and Suntan, J. Hort. Sci. **61** 439-446

Webster, A.D. and Quinlan, J.D. (1984) Chemical control of tree growth of plum (*Prunus domestica* L.) I. Preliminary studies with the growth retardant paclobutrazol (PP333), J. Hort. Sci. **59** 367-375.

Webster, A.D., Quinlan, J.D. and Richardson, P.J. (1986) The influence of paclobutrazol on the growth and cropping of sweet cherry cultivars, I. The effect of annual soil treatments on the growth and cropping of cv. Early Rivers, J. Hort. Sci. **61** 471-478

Williams, M.W. and Edgerton, L.J. (1983) Vegetative growth control of apple pear trees with ICI PP333 (paclobutrazol) a chemical analog of Bayleton, Acta Hort. **137** 111-116

Wilson, C. (1983) The use of exogenous plant growth regulators on citrus, In: Plant Growth Regulating Chemicals (Ed. L.G. Nickell,) CRC Press, Boca Raton, Fl, U.S.A. pp. 207-232

Yamane, G.M. and Nakasone, H.Y. (1961a) Pollination and fruit set studies of acerola (*Malpighia glabra*) L. in Hawaii, Proc. Am. Soc. Hort. Sci. **78** 141-148

Yamane, G.M. and Nakasone, H.Y. (1961a) Effects of growth regulators on fruit set and growth on the acerola (Malpighia glabra L). Tech, Bull. #43, Hawaiian Agric. Expt. Stn., Univ. Hawaii

An agro-economic evaluation of fertilization methods for White Potato (*Solanum tuberosum* L.) in Montserrat

R.E. Fletcher, C.S. Weekes

CARDI, P.O. Box 272, Plymouth, Montserrat

C. Douglas

CARDI P.O. Box 766, St. John's Antigua

Eight fertilizer regimes comprising traditional and recommended alternatives were evaluated on three farms during the 1985/86 cropping season. In terms of marketable yield, the currently recommended practice of pen manure with all P_2O_5 and one half N and K_2O at planting, with the remainder at first weeding was significantly better than all other treatments. The alternative, pen manure only, was second best, while the recommended practice without pen manure ranked third. However, in terms of economics, marginal rates of return for these treatments relative to the control were 649, 992 and 429 per cent, respectively. Although the riskiness of the treatments were not explicitly considered, the high marginal rates of return should motivate even risk averse farmers.

Keywords: White potato; *Solanum tuberosum*; fertilization

Introduction

The revived interest in commercialization of white potato (*Solanum tuberosum* L.) in several countries in the English speaking Caribbean has re-emphasised the need for a systematic approach toward developing an appropriate technological production package for the crop, applicable to small farm systems. Small farmers in Jamaica have been producing potato commercially for at least 3 decades (Stone, 1972) while other countries (Dominica, Barbados, Montserrat, St. Kitts, Trinidad and Tobago) have attempted production on a sporadic and rather disorganized basis in the past. (Fletcher and Weekes, 1985). Heavy capitalization costs and the high risk involved in producing the crop make it imperative that all crop husbandry components be suitably "fine-tuned" to ensure optimum returns to the farmer.

Fertilization is considered an important agronomic practice in potato production. The crop is a heavy feeder and highly responsive to balanced fertilizer regimes. Caribbean potato farmers have been taught the basics of potato fertilization which is based on the well known formula: all P plus 1/2 N and K at planting, and the balance at first weeding (3 weeks after germination). (Adams, 1975; Perrenond, 1983). In Montserrat, a study of potato fertilization practices in small farm commercial production brought out several variations which involved both timing and quantities of nutrients. (CARDI, Montserrat, 1984). It was also clear that farmers were modifying recommendations as financial or logistic short cuts in their production package, sometimes without adequate knowledge of the agro-economic

This paper is an output of the CARDI/USAID farming systems research and development project (FSRD #538-0099) and the Ministry of Agriculture, Montserrat.

implications. It was therefore considered necessary to examine the most common fertilizer regimes practised on-farm in order to derive accurate agro-economic parameters for their characterization.

Materials and methods

An on-farm trial was designed to evaluate eight fertilizer regimes on the potato crop in the 1985/86 growing season. The trial comprised a randomised block design with two replications on each of three farms in the Amersham and Rileys districts of Montserrat. Treatments were selected to test the effect of split applications of N and K against a single application at planting at two levels of fertilization. The effect of pen manure (PM) applied under the seed with and without NPK fertilizer was also tested.

Details of the treatments are given in Table 1. Treatments T1, T5, T7 and T8 represented practices used by farmers; T3 and T4 were new recommendations. The soils at all three trial locations are alfisols and mapped as Rileys sandy clay loam (Typic Tropudalf, fine-loamy, mixed). Properties are set out in Table 2. Farm location, altitude, planting and harvesting dates for the three trial locations are set out in Table 3.

The land was ploughed, harrowed and made into ridges 1m apart. Fertilizer treatments were applied before planting seed tubers (cv Desiree) 30cm apart, in single rows to the lower side of each ridge. This resulted in a plant population of approximately 33,000 plants/ha. Cultural practices, including weeding by hoe, hilling up and pest and disease control measures were standard. The second application of fertilizer, where required, was side dressed at the first weeding and hilling up operation, 3 weeks after germination of the tubers. The crop at all three locations was entirely rain-fed.

Harvested tubers were weighed and graded into marketable and unmarketable lots. All tubers below 3.5cm in diameter as well as diseased, cracked and damaged tubers were graded out. For the purposes of this trial, however, green skin (exposed) tubers of marketable size were included in marketable yields.

Activity budgets for each of the eight treatments tested were formulated to describe each technological alternative in terms of

(i) Mean marketable output (kg/ha);
(ii) The demands placed on farm-household resources throughout the production to disposal period;
(iii) The variable costs associated with each input in accordance with the period incurred.
(iv) The net benefit.

Net benefit in the budgets was based on the simplified relationship:

$$\text{Net Benefit (NB)} = P_y.Y_j - (P_j\text{-}X_i)$$

Where P = farm-gate price of output
(assumed to be constant irrespective of the level of output).

Y = the mean yield of the jth treatment (j = 1, 2...8)

P = the price paid by farmers for the i th input (i = 1,2,...N) used in production of the crop.

X = the level of the ith input used (e.g. land, labour, materials, services, etc.)

Table 1 Details of nutrient treatments applied.

Treatment		NPK Fertilizer		Amount of nutrient applied (kg/ha) At planting				At 3 wks		
No	Code	Rate	Timing	N	P_2O_5	K_2O	PM[1)]	N	P_2O_5	K_2O
T1	Fp - PM	Full	At planting	120	96	150	0	0	0	0
T2	Fp + PM	Full	At planting	120	96	150	5000	0	0	0
T3	Fs - PM	Full	Split	58	96	78	0	62	0	0
T4	Fs + PM	Full	Split	58	96	78	5000	62	0	62
T5	Hp + PM	Half	At planting	60	48	75	5000	0	0	0
T6	Hs + PM	Half	Split	29	48	39	5000	31	0	36
T7	Control	None	-	0	0	0	0	0	0	0
T8	PM	None	-	0	0	0	5000	0	0	0

1) Partially decomposed sheep and goat dung (0.5 l/plant)

Table 2 Physical and chemical properties of Rileys sandy clay loam, (after Ahmad, 1983)

Particle size analysis				Chemical Analysis							
C'se sand	Fine sand	Silt	Clay	pH	CEC	Ca	Mg	K	Na	C/N Ratio	P
------- (%) -------					----- (m.e./100 gm) -----						(ppm)
23	19	14	41	6.0	9.81	4.97	3.52	0.12	0.28	11.3	7

Table 3 Details of trial locations, planting and harvesting dates

Detail	Farm 1	Farm 2	Farm 3
Location	Amersham	Rileys	Rileys
Farmer	Fergus	Collins	Osborne
Altitude (m)	250	400	450
No. of Reps.	2	2	2
Planting date	85-12-05	85-12-09	85-12-18
Harvesting date	86-03-20	86-03-14	86-03-20

The total variable cost and net benefits were used to perform dominance analysis on the eight treatments evaluated. This analysis is based on the assumption that dominated technological alternatives would never be chosen by farmers (or recommend by researchers), because there is at least one other alternative, which has a higher, or at least an equal, net benefit and a lower variable cost.

Results and discussion

Agronomic analysis

Table 4 reports yields of marketable tubers from the eight treatments on each of the three farms. The two treatments that yielded significantly higher than the rest were; full dose of NPK-split with pen manure (T4) and 1/2 dose NPK-split with pen manure (T6). Pen manure and splitting of N and K treatments showed the most profound effect on yield.

A comparison of Treatment 8 (PM) with the check (T7) shows a significant yield increase of 8,541 kg/ha. When this comparison is extended across all +PM treatments, the increase due to pen manure was 5,675 kg/ha. Similarly, a comparison of all at-planting vs. splitting treatments shows a yield increase of 3,084 kg/ha marketable potatoes for the split treatment, (Table 5). The yields from the full NPK and 1/2 NPK treatments were not significantly different and further detailed studies will have to be done to determine which of the individual elements or factors are non-responsive and what interactions if any, exist. In fact, the trial results indicate that there is little or no advantage in application of NPK when pen manure is applied, unless the dose is split.

The mean grade-out percent of harvested tubers was 89.8% and no significant difference in the grade-out among treatments was observed. Fertilizer treatments influenced tuber size significantly, the control treatment (T7) producing significantly smaller tubers than other treatments (Table 4). Treatment T4 produced a significantly higher number of tubers than all other treatments. In all cases, splitting the NPK application resulted in an increase in the tuber number per plant. The lowest number of marketable tubers per plant was obtained in the check treatment (T7) and the inclusion of pen manure (T8) significantly improved this figure from 4.19 to 5.93. High initial levels of NPK (T1, T2) appeared to depress tuber number.

Economic analysis

Table 6 presents data on costs and returns for field activities relevant to this trial. Mean yields (kg/ha), gross benefits (EC$/ha) and net benefits are reflected here. When a dominance analysis was performed on the yield data (see Figure 1) results suggested that T1, T2, T5 and T6 were dominated, while T3, T4, T7 and T8 were undominated.

To make recommendations regarding the undominated production opportunities it is important to allow for availability of capital, because scarcity of this resource is a general feature of small farmers. For example T4 would be relevant to farmers who can invest greater than EC$15,000/ha, whereas T3 would be acceptable for farmers who can invest close to EC$13,000/ha, and T8 would be an intermediate position between these two ranges.

Marginal analysis was applied to the net benefit curve of Figure 1 (i.e. to the undominated alternatives (T3, T4, T7 and T8) in order to evaluate the increase in net benefit obtainable from a given increment of investment. Reference to Table 7 shows a marginal rate of return of 649 per cent when the farmer changes from traditional practice (T7) to T3 (Fs-PM). The next change from T3 to T8 (PM) resulted in a marginal rate of return of 922 per cent. Finally, the change from T8 to T4 (Fs+PM) resulted in a marginal rate of return 429 per cent.

The above trend is similar to that depicted by the slope of the net benefit curve in Figure I. First the curve rises steeply, then more steeply and finally rises at the slowest rate.

Table 4 Yield components and marketable yields

Treatment No	Code	Marketable Yield (kg/ha)	Yield components: Mean Tuber Size (g/tuber)	Mean Tuber Number (tuber/plant)
T1	Fp - PM	14,667 c[1)]	96.3 c	4.94 d
T2	Fp + PM	19,083 b	104.8 b	4.79 d
T3	Fs - PM	17,667 b	104.8 b	5.49 c
T4	Fs + PM	22,292 a	109.2 a	6.57 a
T5	Hp + PM	17,208 b	102.8 bc	5.43 c
T6	Hs + PM	20,250 ab	111.8 a	5.75 bc
T7	Control	10,167 d	76.5 d	4.19 c
T8	PM	18,708 b	103.0 bc	5.93 b
LSD (p = 0.05)		2,149	-	-

1) Figures in columns followed by the same letter are not significantly different (P = 0.05) according to multiple range test.

Table 5 Effect of pen manure and splitting fertilizer applications on marketable yields (kg/ha)

	Split application	Pen Manure
With	20,070	19,508
Without	16,986	13,833
Difference	+ 3,084	+ 5,675

The yield response (and consequent net benefit) of the PM treatment relative to T3 and the dominated treatments is somewhat surprising and merits some further investigation.

Conclusions and recommendations

This exploratory trial has confirmed one of the basic general principles of white potato fertilization i.e. the beneficial effects of split applications of N and K on yields. Potts et al (1983), working with potato farmers in the Philippines, found that application of commercial fertilizer to the seed bed prior to planting instead of as a side dressing resulted in a 15% increase in yields generally. This trial however suggests that further beneficial effects are possible if some or all of the N and K are sidedressed at first hilling up after all P has been applied at planting.

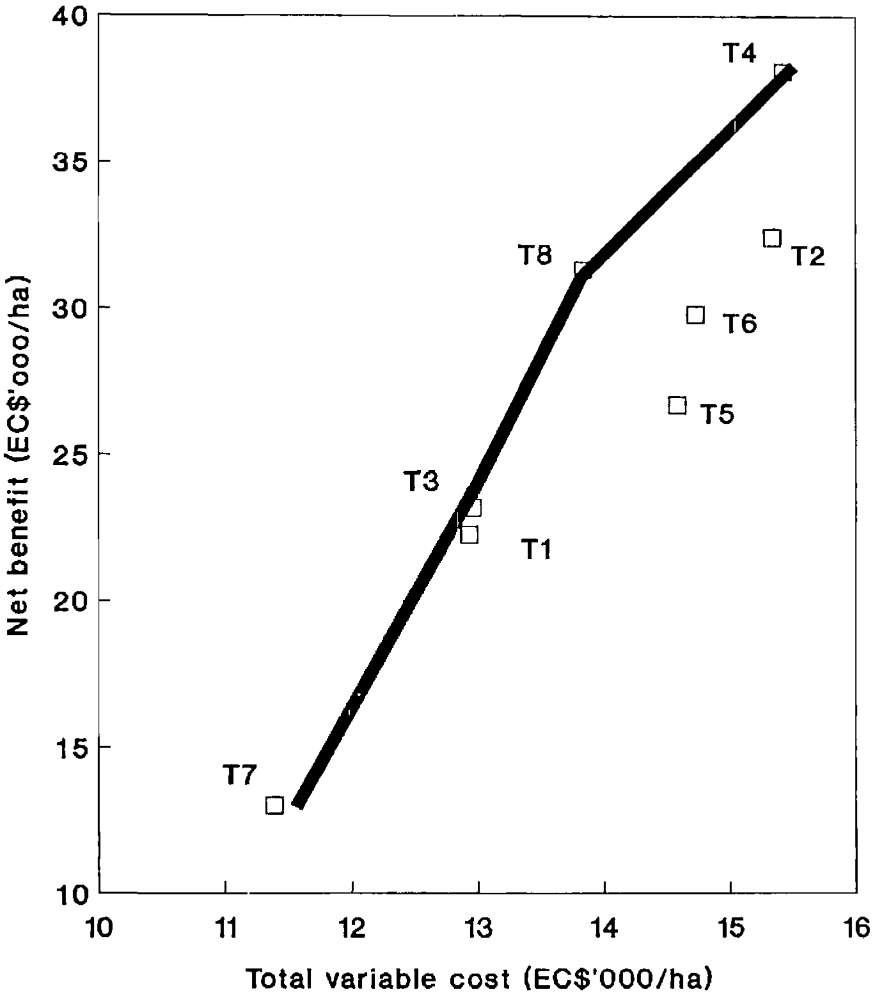

Figure 1 Dominance analysis of alternative fertilization technologies for potato in Montserrat

Pen manure had the most profound effect on yields. It may have exerted several influences which would be difficult to define conclusively in the absence of chemical analysis. It was devoid of straw or other crop residues. The rate of application was similar to the rate applied by farmers in the Philippines (Potts et al., (1983). In the small farmers production practices in the Philippines, the organic matter has had variable effect on yield and this has been attributed to varying soil conditions and climatic factors. In this trial the evidence suggests that pen manure may be influencing a more even and prolonged availability of N and other nutrients, as well as providing trace elements that may have been in short supply.

Table 6 Costs and returns according to treatments

Variables	Treatment costs and returns (EC$/ha							
	T1	T2	T3	T4	T5	T6	T7	T8
Yield (kg/ha)	14,650	19,900	15,050	22,300	17,200	18,550	10,150	18,800
Gross Benefit (kg/ha)	35,160	47,760	36,120	53,520	41,280	44,520	24,360	45,120
Cost of NPK ($/ha)	1,220	1,220	1.220	1,220	609	609	0	0
Cost of PM ($/ha)	0	1,600	0	1,600	1,600	1.600	0	1,600
Cost of applying NPK ($/ha)	248	248	652	628	492	632	0	0
Cost of applying PM ($/ha)	0	384	0	384	384	384	0	384
Total cost of Treatment ($/ha)	1,468	3,452	1,872	3,832	3,085	3,225	0	1,984
Total variable cost ($/ha)	12,929	15,331	12,954	15,420	14,580	14,725	11,385	13,834
Total labour used (hrs/ha)	1,274	1,370	1,292	1,388	1,348	1,383	1,212	1,308
Net Benefit ($/ha)	22,230	32,428	23,165	38,099	26,699	29,794	12,974	31,285

Table 7 Marginal analysis of undominated alternative treatments

Treatment	Net benefit		Variable costs		Incremental marginal rate of return
	Total (EC$)	Incremental (EC$)	Total (EC$)	Incremental (EC$)	(%)
T7(Control)	12,974	--	11,385	--	--
T3	23,165	10,191	12,954	1,569	649
T8	31,285	8,120	13,834	880	922
T4	38,099	6,814	15,420	1,586	429

a) EC$ 1.00 = US$ 0.38

It would seem logical to recommend a reduction in the level of NPK fertilization for farmers who supplement with pen manure and in such a situation the benefit of applying inorganic P and pen manure at planting and all inorganic N and K at the first side dressing needs to the investigated. For farmers not using pen manure, the full dose of NPK treatment may need to be modified to achieve a much lower initial application of N and K and an increase in the sidedress application.

With regard to the economic considerations and implications for the farmer in the use of the tested alternatives, it is probable that he will be influenced by the following five factors: (i) profitability (ii) divisibility (iii) resource requirements (iv) complexity or simplicity (v) riskiness.

The economic evaluation considered profitability using marginal analysis. Aspects of divisibility, resource requirements, and simplicity would be evident from activity budgets. Although the riskiness of the alternatives was not evaluated it is reasonable to argue that the high marginal rates of return could motivate even risk-averse farmers.

References

Adams, B.R. (1975) Farmers' guide to Irish potato production. Department of Agriculture - Montserrat. U.K. Tech. Assistance

Ahmad, N. (1983) "An Investigation of Soil Conditions of Farmers Holdings in Montserrat", USAID/CARDI Small Farms Study, Consultant Report No. 14

CARDI (1986) White potato crop report 1985/86, Montserrat

Fletcher, R.E. and Weekes C.S. (1985) Integration of White Potato (*Solanum tuberosum* L.) into the vegetable production systems of Montserrat. Caribbean Food Crops Soc. Proc. Vol. 21 216 -221

Perrenond, S. (1983) Fertilizing potato for high yields, International Potato Centre, Lima, Peru, Bulletin #8.

Potts *et al* (1983) "An Agro-economic assessment of white potato manurial trials: Benguet and mountain Provinces" On-farm potato research in the Philippines. International Potato Centre.

Stone, D.H. (1972) Irish potato: Assessment of varieties in Jamaica from 1948 onwards, Ministry of Agriculture, Jamaica (unpublished)

POST HARVEST AND PROCESSING TECHNOLOGY

Solar Crop Dryers for the Caribbean

C. K. Sankat, D. R. McGaw and O. Headley

University of the West Indies, St. Augustine, Trinidad.

Crop drying in the Caribbean is carried out mainly by small farmers and estates, the normal technique being by simply spreading the material out in the sun. This method however, suffers from a number of disadvantages which could be alleviated by the use of solar or mechanical dryers. The paper describes an approach which identifies two basic types of simple, natural convection solar dryers well suited for the small farmer situation, where only small quantities would be dried at any time. Experimental results are presented which demonstrate dryer performance for both types. In the case of drying produce from the larger estates where much larger quantities are being harvested, the packed bed dryer is projected. This type of dryer can operate using either solar energy, hydrocarbon fuel or biomass as an energy source or, alternatively, can utilise any convenient combination of these sources. For the drying of timber and forages, greenhouse type solar dryers, working either by natural or forced convection are described.

Keywords: Solar dryers; Tropical crops; Small farmers

Introduction

Sun drying is a traditional method of food preservation practised extensively in the Caribbean. It usually involves the spreading in thin layers of crops, such as paddy, coconuts, coffee and shrimp on concrete floors, large trays, galvanize sheets or simply on pitched roadsides, until the crop moisture content (m.c.) is reduced to a safe level for crop storage. This method of drying has its inherent advantages of no operational energy cost for moisture evaporation, together with a low or negligible initial investment, except for the larger sundrying installations such as those used in Guyana for paddy, or in Grenada for cocoa, which may require as much as 180 m^2 of drying floor space/tonne of paddy (Madramootoo, 1973). This system of drying however, is limited in that,

- during periods of intermittent and particularly during continuous rainfall, crop drying is not possible and the risks of crop losses are high.

- sun drying is slow and weather dependent, compared to other alternative drying systems.

- crop quality may be low, due to contamination by dust, dirt, stones and insects, while direct crop losses from theft and livestock consumption can be high.

The system also suffers from a high labour requirement and excessive crop handling which can result in high costs, crop damage and a loss in quality.

Solar drying systems can offset many of the shortcomings associated with open air, sun drying techniques. Additionally, through appropriate designs and materials of construction, initial costs can be kept very low.

This paper presents the important findings of a research project on "Utilisation of Solar Energy for Crop Drying" funded by the Organisation of American States (OAS) with the participating countries being Antigua and Barbuda, Dominica, St. Lucia and St. Vincent and the Grenadines, with the University of the West Indies (UWI) in Trinidad and Tobago, providing technical assistance.

Non-Traditional crops with drying potential

A number of crops not traditionally dried have been identified as having considerable potential for preservation, marketing (domestic and export) or further processing, using solar drying systems as the principal unit operation. Since many of these crops are produced at the present time by small farmers, simple solar dryers of low initial cost and capacity, may be projected for use. Non-traditional crops which may benefit from solar-drying technology were therefore identified on an island basis.

Antigua and Barbuda

Rootcrops such as sweet potatoes, yam and cassava show considerable potential for slicing and drying from 70% to 8% m.c., before being ground for flour preparation. Drying and curing of whole onions, together with the production of sliced, chopped or powdered onions by drying from 90% to 7% m.c. Drying of peanuts from 36 - 60% at the time of digging to 9% m.c., and sorrel calyces from 88% to 12% m.c. The drying of fresh fruits and/or candied fruits such as cashew, pommerac and five-finger, with fruit leathers also being possible. Drying of gutted, de-boned and salted fish such as barracuda and snapper from an initial m.c. of 65 - 70% to 30%.

Dominica

In the essential oil extraction process for patchouli, the drying of leaves from 85% to 15% m.c. is necessary. The drying of green bananas and plantain slices from 75% to 12% m.c. for chip and/or flour production, together with the drying of ripe bananas to produce "banana raisins" for the baking industry. There is an active interest in the drying of tropical timbers such as gommier (*Decryodes excelsa*), carapite (*Amanoa caribea*) and mahogany (*Swietenia mahogoni*). As in Antigua and Barbuda, drying of root crops. sorrel and fruits are also important.

St. Lucia

While the drying of coconuts, coffee and cocoa are of primary importance, the use of solar energy in the drying of the root crops, particularly cassava, and breadfruit together with reject bananas for flour preparation as well as animal feed ingredients are interesting possibilities. The drying of spices particularly sliced ginger from 70% to 10% m.c., is important.

St. Vincent and the Grenadines

The drying of sorrel for export is of considerable importance. Potential also exists for the slicing, drying and milling of ginger and other spices, as well as improved systems for the drying and curing of onions.

Solar drying systems - The alternatives

Selection considerations

The choice of a solar drying system to meet the needs identified above, as well as for drying the traditional crops such as coconuts, coffee, cocoa and nutmegs, is dependent principally on two factors, viz:-

The crop to be dried: Consideration must be given to the drying air temperature and air flow characteristics required for a particular crop, with these requirements being matched to a particular dryer design.

The intended user: The design of a dryer will to a large extent be determined by the drying capacity (small farmer, co-operative group or estate) required and cost limitations, with such considerations as methods and materials of construction, materials handling and reliability being extremely important.

Solar dryers for small farmers

Using the previously mentioned guidelines, and after a number of dryers were examined, two types of solar dryers are projected for use by small farmers, viz:-

- The wire basket dryer for crops where high ventilation rates and low temperatures are required.

- The cabinet dryer, where higher air temperatures and lower air ventilation rates are appropriate.

In both dryers, capacity is low (a maximum of 50 kg of wet material), initial cost of the materials of construction is approximately US$50, the designs are simple with no mechanical components, and construction is possible by farmers.

Solar dryers for co-operatives and estates

For the larger co-operatives and estates, many drying the traditional crops, the choice of the drying system is more peculiar to the needs and resources available, with each situation requiring careful examination. At the present time however, two types of dryers show considerable potential for such use, viz:-

- The greenhouse type solar dryer, consisting of a bulk drying module within a specially designed greenhouse and providing relatively low drying air temperatures and air flow rates.

- The packed-bed dryer, having a solar air pre-heater and a hydro-carbon fuel or biomass burner i.e. a mixed mode dryer offering considerable adaptability and reliability for the drying of large volumes of perishable crops.

The wire basket dryer

Description: The wire basket dryer (Figure 1) is a simple device consisting essentially of a frame made of 25 mm (1") x 50 mm (2") wooden strips. The bottom and four sides of the dryer are covered with wire mesh having 6 mm square openings. The sloped top, consists of a removable transparent plastic cover on a wooden frame. This

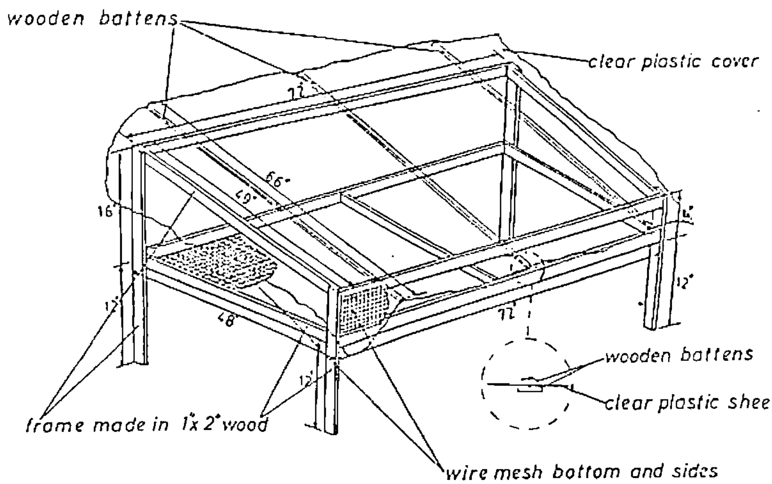

Figure 1 The Wire Basket Dryer

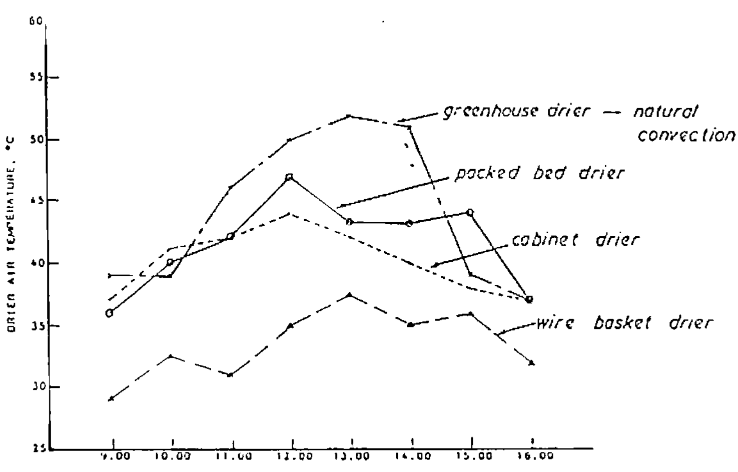

Figure 2 Typical air temperatures in various solar driers

serves to protect the crop from inclement weather and also raises the air temperature in the dryer to about 5 - 7 degrees C above ambient (Figure 2). Higher temperatures are not possible, due to the free access of the wind into the dryer. At such low operating temperatures, radiative heat losses are low, and as long as the relative humidity of the air is below saturation, drying will proceed. A 1.83 m (6') x 1.22 m (4') unit as shown in Figure 1, can be built in two (2) hours by two (2) semi-skilled individuals.

Operation and Performance: In the drying of sorrel for example, the calyces are first separated from the seed pods and placed in the dryer on a 1.5 mm nylon mesh (normally used for mosquito screening). The depth of the sorrel bed is from 5 to 10 cm. The plastic cover is put on the dryer, with the sloped cover facing south, and the dryer left for 3 to 4 days. The sorrel is normally stirred twice per day.

In Figure 3, it is shown that the m.c. of the sorrel is reduced from its initial value of 88% wet basis (800%, dry basis to 11% wet basis (12%, dry basis) in about four (4) days of drying. Also shown is the drying curve (81.4% to 10.6%, wet basis) for sliced ginger in the wire basket dryer, with drying time being about two (2) days. Matthew (1986) working in Antigua, noted that sweet potato slices attained a finial m.c. of 11% within two (2) days, using a loading of 12.3 kg sweet potatoes/m_2 of tray area.

The cabinet dryer

Description: In its simplest form, a natural convection, direct, solar cabinet dryer as shown in Figure 4, is recommended for small farmers. The dryer consists essentially of two parts, viz:-

- A wooden sided cabinet, with a corrugated metal base of 2.4 m (8') x 1.2 m (4'). The height of the wooden sides is 0.3 m (1'), with the base located 0.2 m (8") from the top. Screened, rectangular openings 1.2 m x 0.1 m (4'x 4") along the length of the shorter sides, provide the air inlet and air exit.

- A removable transparent cover, made from a wooden frame and designed to fit snugly over the sides of the cabinet.

When operating, the air exit side is raised and supported above the inlet side to provide a slope of 10 degrees, with the cover facing south. Interior surfaces of the dryer are painted with flat, black paint, and trays may be placed in the dryer, depending upon the product to be dried.

Operation and Performance: The dryer described above was evaluated by drying split, dehusked coconuts. Approximately 150 dehusked coconuts were split, and the split nuts placed directly on the corrugated base, with the meat or kernels facing up. As shown in Figure 5, drying resulted in a m.c. reduction from 37.8% (wet basis) to 10% in five (5) days of drying, with good, white copra resulting. Day time temperatures in this dryer, averaged 8 - 14 degrees C higher than ambient as shown in Figure 2, with a maximum value of 52 degrees C measured at midday. Temperatures may be varied by using flaps at the inlet and exit air ports. Matthew (1986) reported that this dryer was used to dry 10 kg of sweet potato slices from 69% m.c. (wet basis) to 8%, in two (2) days of good sunshine. It was also reported that salted fish i.e. snapper and gromanic dried well in this dryer, as did sorrel.

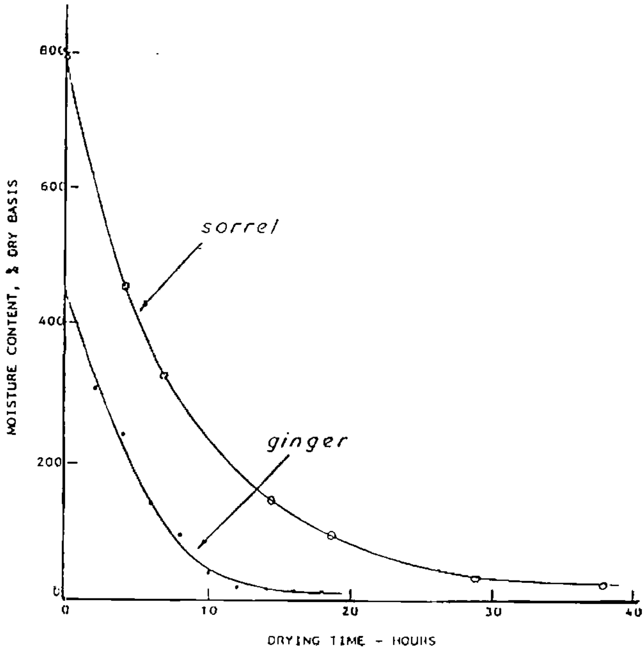

Figure 3 Drying curves for sorrel and ginger in a wire basket dryer

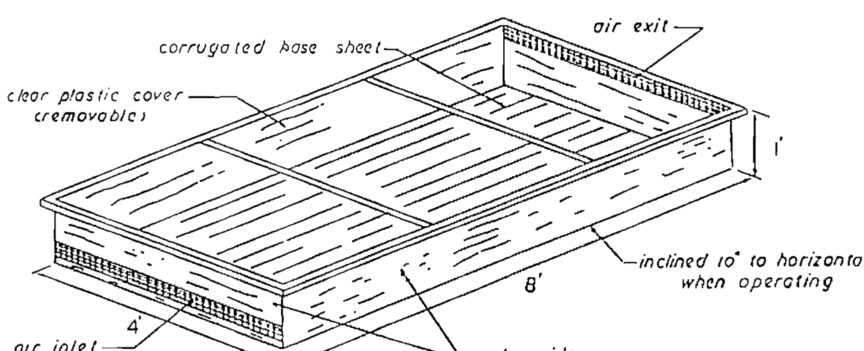

Figure 4 A Solar Drying Cabinet

A solar timber dryer

A solar greenhouse dryer, shown schematically in Figure 6, has been designed for the drying of timber. It is 7.6 m long x 4 m wide, with a sloping, transparent plastic covered roof, 3.5 m high on the northern side to 2.6 m high on the southern side. It has a timber capacity of 18 m_3.

Two axial flow fans, each of 186W, blow air from the plenum chamber into the timber stacks, with the plenum chamber being supplied by hot air pulled from the roof space. Variable vents at the fan inlet, and at the base of the dryer are used to control the air temperature within the greenhouse dryer. Typically, the temperature rise of the air at the fan exit is approximately 5 degrees C above ambient.

Planks 5 cm thick, 30 cm wide and 3 to 4 m in length can be dried from a m.c. of 50 - 60% (wet basis) to 16%, in 3 weeks. If a small wood waste burner is attached to the dryer and used for 6 - 8 hrs. per day, the drying time can be reduced to 12 days (Headley, 1987).

For drying a leafy crop such as patchouli in Dominica, a forced convection greenhouse dryer, as described above and appropriately modified for materials handling (using trays, for example) should prove effective. Smaller greenhouse type dryers, using natural convection only have been built in Antigua for the drying and curing of onions, and fish.

A greenhouse dryer for forage

A simple greenhouse dryer has been designed and evaluated for the drying of forages (Figure 7). This dryer has a base with dimensions 3.04 m (10') x 1,82 m (6'), and the dryer's height varies linearly from 1.52 m (5') to 0.91 m (3') i.e. from north to south. The lower portion of the dryer is made of plywood, and the upper portion from clear plastic sheeting, attached to a wooden frame.

The dryer has four (4) similar trays or drawers for the crop to be dried, with dimensions 1.83 m (6') x 0.76 m (2.5') x 0.15 m (0.5'). The sides of the trays are made of plywood and the base of 1.27 cm (0.5") square, wire mesh. The drawers are supported on runners placed across the dryer i.e. in an east-west direction, and may be pulled from, or pushed into the dryer through a hinged opening on the western side.

There is an exhaust fan installed on the lower, southern panel of the dryer. Drying therefore results from the exposure of the crop to direct solar radiation as well as by the movement of heated air, entering from the top of the northern side and deflecting through the crop in the trays, before being exhausted.

In a natural convection mode, with the fan off, heated air simply rises through the crop bed by natural convection and the air flow direction is reversed.

The dryer was evaluated under natural convection conditions, by drying 22.5 kg leucaena i.e. approximately one quarter the dryer capacity. In Figure 2, the variation of the air temperature with the time of the day in this dryer and averaged over the four (4) days of observations is shown, with the maximum average daily temperature being 52 degrees C.

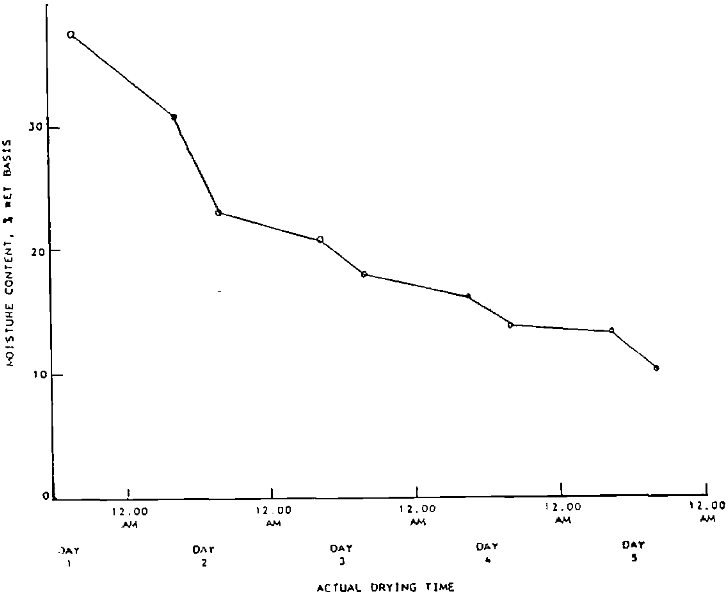

Figure 5 Drying of coconut meat (kernel in shell - half cup)in a solar cabinet dryer.

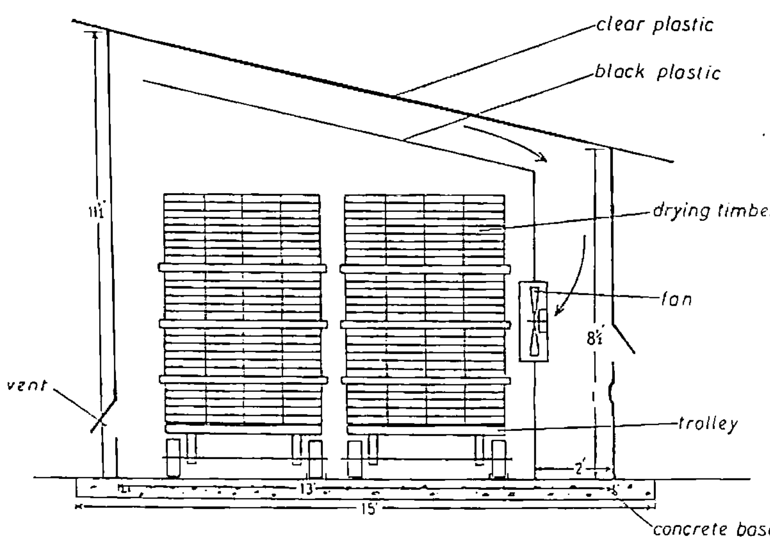

Figure 6 A plastic covered solar timber dryer

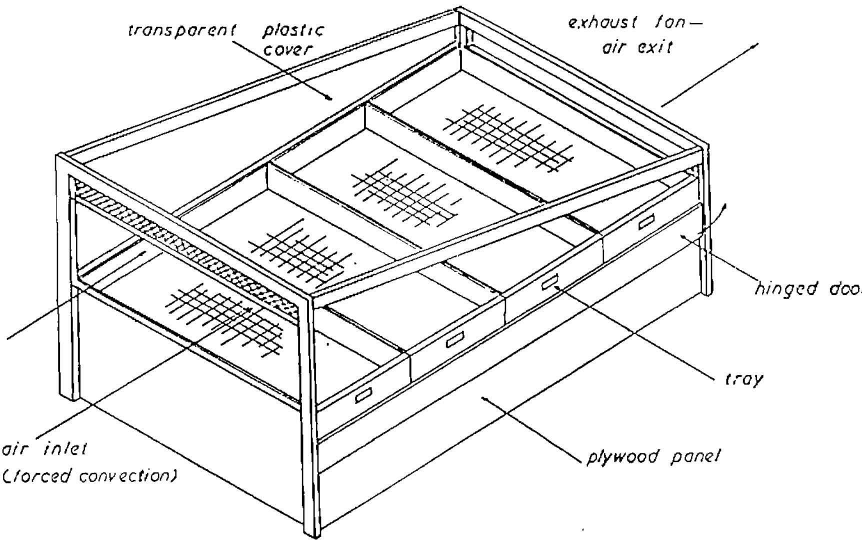

Figure 7 A greenhouse dryer for forages

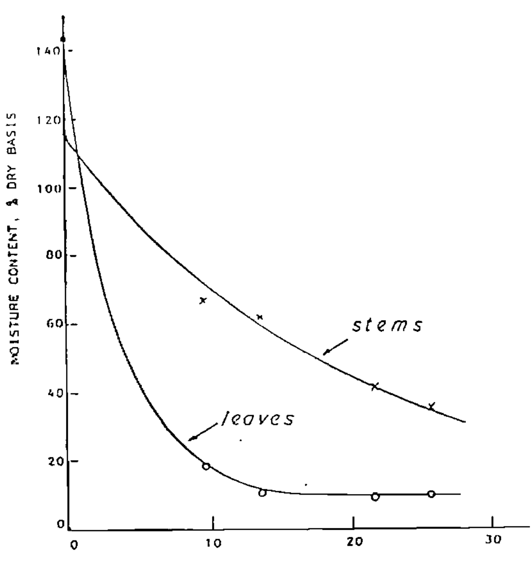

Figure 8 Drying curve for *Leucaena* in a natural convection greenhouse dryer

The drying curve (Figure 8) for the leaves, shows that drying was completed within the first fifteen (15) hours, with the m.c. falling from 58.8% (wet basis) to 8.9%. Thus leaves may be dried in 1.5 days of good sunshine in the dryer. However, the stem m.c. fell slowly, and at the end of the third day had reached 26.1% from an initial value of 53.0% wet basis. This was due to the thickness of the stems, averaging 9 mm in diameter. It is felt that the overall drying rate (leaves and stems) will be improved, by passing the harvested leucaena through a forage chopper.

A packed-bed mixed mode dryer

A packed-bed, mixed mode dryer has been developed through the coupling of the following two main components, viz:-

- A parallel flow, flat plate air heater of 17.6 m_2 area (4.9 m x 3.6 m), together with a wooden support frame which provides a 10 degree slope to the horizontal.

- A packed bed commercial dryer, consisting of a drying bin 1.82 m square, with a maximum possible bed depth of 0.45 m, equipped with a 200 W axial flow fan and a kerosene burner with a maximum fuel consumption rate of 3 litres/hour.

The air heater was placed directly above the drying bin (Figure 9), thus protecting the crop from the weather, and it was coupled to the fan and the kerosene burner inlet, using 0.35 m square, sheet metal ducting.

Preliminary tests have shown that 300 kg of paddy at a bed depth of 11.5 cm (approximately 50% of dryer capacity using a 200 W axial flow fan) can be dried, using solar energy alone from 26% m.c. (wet basis) to 9% m.c. in 1.5 days of good weather (Figure 10). As expected, the bottom layer of paddy dried faster than the top layer, though by the third day of drying, the difference in m.c. between the top and the bottom layer, was small. In this trial, the fan was continuously in operation i.e. including the night, and the maximum air temperature in the plenum averaged 47 degrees C, as shown in Figure 2. At nights, the paddy regained moisture, as illustrated in Figure 10, thus it would have been more useful to have the fan off at nights.

Conclusions

Two simple solar dryers are recommended for use by small farmers in the preservation of their crops. The wire basket dryer, operating at temperatures of 5 - 7 degrees C above ambient is ideally suited for crops which require drying at low drying temperatures such as spices, sorrel and ginger. On the other hand, for crops which require higher drying air temperatures, and lower final moisture contents such as coconuts and root crops, the simple, natural convection dryer appears suitable. Both of these dryers are capable of being built by farmers themselves, and material costs are not expected to exceed $US50. While the rate of drying of some crops in these dryers may not be much faster than open air sun drying, the use of such dryers will improve product quality, an essential element for foods to be consumed directly, reduce the risk of crop re-wetting due to rain and greatly reduce the labour input traditionally required in drying.

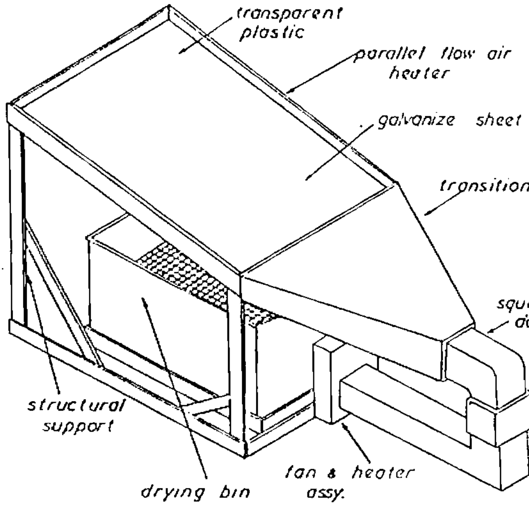

Figure 9 A packed-bed, mixed mode dryer

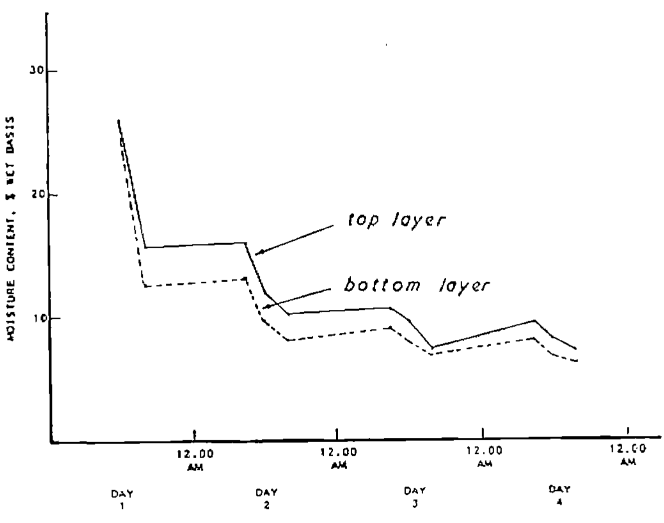

Figure 10 Drying of paddy in a packed-bed dryer using a solar air heater only

For the larger estates and co-operative drying installations, two crop dryers are recommended viz:- the packed bed, mixed mode dryer and the greenhouse dryer. The packed bed, mixed mode dryer uses a solar air heater which may be incorporated directly in the roof of a new or even existing drying installation. Such an air heater may provide sufficient air of the required flow rate and temperature, thus eliminating the need for a supplemental heat source such as wood or diesel oil, except for drying at nights or in periods of inclement weather. The mixed mode solar, packed bed dryer, which can be used for drying of all the traditional crops such as coconuts, cocoa, coffee and paddy, therefore will reduce operational drying costs through solar energy utilisation, without any loss of reliability.

For the drying of cut timber and other materials of low bulk density such as forages, solar greenhouse dryers are recommended. These dryers can operate in a natural convection mode, or in a forced convection mode. The latter is recommended when large volumes of material of initially high moisture content are to be dried.

Acknowledgements

The authors with to thank the Organisation of American States (OAS) in Washington for their financial support, and the participants of the various islands in the "Crop Drying Project" for their continuing interest.

References

Headley, O. (1987). Plastic covered solar dryers for tropical timbers, Paper presented at "Workshop on Materials Science, Energy and Development," UWI, Jamaica

Madramootoo, H. (1973). The Story of rice in Guyana. Guyana Rice Corporation, Georgetown, 52 p

Matthew, H. W. (1986). Progress Report - Solar Drying Experiments at the Chemistry and Food Technology Division. Paper presented at "Co-ordination Meeting on Utilisation of Solar Energy for Crop Drying", St. John's, Antigua, 22 p

The ABRICO controlled solar drying system for Barbados Agricultural Development Corporation

F. H. Krenz,

ABRICO Energy Management Services Ltd., Lakefield, Ontario, Canada

A crop-dryer of 20-tonnes (or 10,000 FBM) capacity has been constructed for the Barbados Agricultural Development Corporation at their Spencer's Estate, based on the ABRICO Controlled Solar Drying concept. The project was a joint effort of BADC and the Canadian International Development Agency. The dryer will be used as a demonstration and production facility by BADC. Crops to be dried include peanuts, onions, cassava and cotton-seed. This paper describes the construction and operation of the dryer and includes a discussion of the economics of drying.

Keywords: Solar drying; vegetable crops

Introduction

In September 1985, at the Caribbean Food Crops Society meeting, held in Port-of-Spain, Trinidad, we introduced our concept of an agro-industrial scale crop dryer using mainly solar heat, specifically designed for use in tropical regions. Since that occasion, we have been encouraged by wide-spread interest in the concept, not only in the Caribbean, but in Africa and Asia, indicating that there is a place in the agro-economies of these countries for solar dryers of large capacity. However, the system was designed on the basis of surveys made in the Caribbean; and we have been pleased to be able to establish a dryer in Barbados as a proof-of-concept for this region.

In March of 1986 an agreement was signed between Barbados Agricultural Development Corporation (BADC), Redma Consultants Limited of Mississauga and ourselves to construct a solar crop dryer of 20-tonnes capacity at BADC's Spencer's Estate adjacent to Grantley Adams airport. BADC contracted with Nehaul Construction Limited of Barbados for the construction of the dryer. The preparation of the site and the construction of the foundation for the dryer were completed by Nehaul in November. After a recess during the month of December, assembly of the dryer itself was resumed in early January and completed in the first week of February. The dryer was immediately put into use to dry cotton-seed, as the ginning process and Spencer's was then in full swing.

BADC assumed financial responsibility for all local components of the project. The Canadian component was financed by the Canadian International Development Agency (CIDA). Redma Consultants Limited were prime consultants for the project and ABRICO was technical consultant, providing all designs and specifications and supervising construction and commissioning.

Design Features

The design of the dryer is exceptionally rugged. BADC stipulated that the structure should be high enough that their existing peanut trailers could be brought under cover for attachment to the drying system. At the same time, the structure was to meet Southern Building

Code standards, since the site is exposed and hurricane force winds are a possibility.

Aside from this characteristic of ruggedness, the design called for the simplest of construction techniques using standard materials of construction. This proved to be a wise decision, for during the construction of the dryer an accident resulted in the breakage of 59 panes of glass imported from Canada for glazing the air-heating solar collectors. Since the panes were of standard patio-door size, replacements were found immediately in Barbados. These replacements were installed without modification to the glazing support structures in any way. The quality of glass did not quite match the quality of the imported "Solatex" panes; however, the difference is slight and the collectors are performing more than adequately.

Division of Responsibilities

BADC assumed overall responsibility for the management of the contracts associated with the project. As client, BADC also undertook to provide the following:

a) A suitable site with unobstructed solar access
b) Access roads, fences, safe storage during construction.
c) A concrete foundation made to ABRICO specifications.
d) A concrete block drying chamber to ABRICO specifications.
e) Services: electrical power (typically 10 KW of 220V, 3-phase) and water (service, fire safety).
f) Staff to operate and maintain the system once it was commissioned.

BADC also paid all local fees, such as: entry-fees, handling and off-loading costs, duties and taxes, permits, insurance and inland transportation costs

ABRICO, as technical consultant, assumed responsibility for the following:

a) Solar Air Heating Array consisting of 36 panels of 5 m^2, each complete with T-175 steel absorber plates, Glasclad insulation and Solatex low-iron, tempered glazing, supported on extruded aluminum I-section beams with pressure plate and snap-cap protection. All metal surfaces coated to resist corrosion. 20 spare panes of glazing included.

b) Solar Array Support Structure consisting of Oricon treated wood trusses bolted to steel headers supported by H-section steel columns bolted in turn to headers and to anchor-bolts in the concrete foundation. This was designed to withstand 177 km/h wind pressures. All surfaces coated against salt corrosion.

c) Industrial Exhauster consisting of radial, standard duty fan rated at 2.4 m^3S^{-1} (5000 cfm) at 7.62 cm (3" W.G.), 10 HP, 220V 60 Hz, 3-phase motor, tropicalized for service in salt air environment. Spare motor belts and spare impeller included. All surfaces given paint finish suitable for tropical service.

d) Air Distribution System consisting of plenum down-comer, dampers, ductwork with adjustable vents, all of galvanized steel, and exhaust duct of 1.27 cm (1/2 in.) Wolmanised plywood.

e) Temperature and Humidity Sensors consisting of air actuated recording hygrometer with wet and dry bulb temperature sensors in the exit air flow; temperature sensors in both inlet and outlet air. Air flow measurement situated at the central control panel. Temperature ranges: 0 to 1000 ^{o}C.

f) Control Panel consisting of a hermetically sealed cabinet with power centre and controls supplying the fan motor and current meter registering current drawn by the motor. Also chart recorder for wet and dry bulb output. The dryer is operator controlled, i.e. the operator makes adjustments to obtain the required operating conditions. Once drying cycle parameters have been established, the process can be made automatic if BADC decides in favour of this step.

g) Roller Door: a rolling steel, overhead door for full opening access to drying chamber. Curved steel slats, galvanized finish, 9 cm deep track, wind-locks on alternate slats. Hand chain hoist with security lock.

Commissioning and performance

Commissioning was completed without difficulty in late February and the drying chamber was used almost immediately to dry cotton-seed preparatory to storage, although the formal opening was not until 1st April. It was at once apparent that, with the insolation being received, temperatures could not be reduced below 40 ^{o}C in the drying chamber by controlling the air-flow through collectors, even at the maximum flow of 2.4 $m^3 S^{-1}$ (5000 cfm.). A simple modification was made to the fan intake which allowed ambient air to be mixed with the solar heated air in any proportion desired. This permitted a range of temperatures between ambient and 50^{o}C to be obtained. Tests have yet to be made to determine the maximum upper temperature which can be obtained with solar heating alone.

Sensors for temperature (RTD) and humidity (capacitance) measurements originally installed were electronic. Although the temperature measurements were reliable, difficulty was experienced with the humidity readings and it was finally concluded that the capacitative sensors were becoming contaminated with salt from the sea air being drawn into the dryer. These sensors have now been replaced by recording wet and dry-bulb thermometers with stainless steel bulbs containing pressurised gas to actuate the recording pens. Ambient, inlet and outlet temperatures are also monitored with thermisters connected to a Cole/Parmer electronic thermometer.

The drying chamber is a simple concrete block room of 60 m^3 capacity. An air distribution duct was supplied with the installation to direct the air-flows in the chamber laterally against the walls. This duct is also provided with an attachment for connection with the peanut trailers. However, it is expected that the duct will not be used for crops such as onions or cassava, since special supports will be developed for these crops to maximise effectiveness of air flows. Timber may also be dried on an experimental basis; and this will require still another drying configuration in the chamber.

Despite considerable research, a complete understanding of the mechanism of drying has yet to be fully developed (Anon., 1985). The system at Spencer's will be used as a development and production facility to establish drying technology for a variety of crops and materials. Users will include the following:

Barbados Agricultural Development Corporation
Barbados Sugar Industries Limited (cotton, onions)
Caribbean Agricultural Research and Development Institute (onions)
Barbados Industrial Development Corporation (timber)

It is also hoped that other organisations will participate in the drying program; e.g. the St. Vincent Organisation for Rural Development, the St. Lucia Banana Growers Association, and the Grenada Cooperative Nutmeg Association.

System Economics

The appropriateness of the drying system for the Caribbean region seems assured in the sense that drying is a major post-harvest requirement, sunshine for heating is "super-abundant' for a good part of the year and, in most countries of the region, conventional heating fuels, if available, place a strain on foreign exchange reserves. However, the final arbiter of appropriateness is the farmer/grower and his market. We have been much influenced by the work of Baynes (1988), in our assessment of our system. The drying system is semi-industrial; that is, it is not suitable for the individual farmer/grower unless he is producing on an agro-industrial scale, but is suitable for cooperatives or organisations collecting the output of a number of individual farmers/growers.

The initial investment is of the order of $ 100,000 Cdn. In the Caribbean, this corresponds to energy costs of about Cdn$ 50 per annual GJ of heat energy collected, a figure which is competitive with conventional energy costs in the Caribbean. However, the cost per unit of energy is only one aspect of a solar installation. The owner is, by definition, insulated against further changes in conventional energy costs. Since the system uses standard building materials, a system life of 20 years is the minimum of expectation and even a 10 year pay-back time gives a period of productivity of another ten years at practically no cost other than the cost of operating the drying fans. As shown below, the pay-back period is considerably shorter than ten years.

The economic performance of the BADC dryer has yet to be determined. However, it has been shown that drying air at temperatures ranging from 35 - 50^{o}C is produced at rates up to 2.4 $m^{3}S^{-1}$ (5000 cfm). Starting with air at 28^{o}C and 80% relative humidity (normal at Spencer's) and drying at 50^{o}C (20% R.H.) using full fan power of 6 KW. to send 5000 cfm through the drying chamber, it can be shown that - with a reasonable "pick-up efficiency" (Anon.,1985), approximately 10 hours of operation are required to remove a tonne of water . This means an expenditure of 60 KWh of electrical energy. At the current rate of B$ 0.26/KWh this works out to:

60 KWh x B$ 0.26/KWh = B$ 15.6/tonne water

Meanwhile, a tonne of water requires at least 2.26 GJ of heat energy to vaporize it for removal by the air stream. At an energy cost in Barbados of B$ 70/GJ, this represents a minimum cost of B$ 158. However, the air stream is only about 50% effective (pick-up efficiency = 0.5) hence the cost will be at least B$ 300, or Cdn$ 215. To achieve a simple pay-back of Cdn$ 100,000 would, at this rate, require the removal of 390 tonnes of water or operation for 3900 hours. Since the dryer is multi-purpose, this might be achieved over a period of 3 - 5 years. Thus the installation would pay for itself in this time.

As noted by Baynes (1985), the appropriateness of the technology for the farmer/grower will depend not only on such things as the simple pay-back time calculated above, but upon whether the out-put from the dryer results in financial gain for him or herself. This can only occur if the increased production made possible by the dryer can be sold on the market at a price bringing a reasonable profit. Where such a market exists, or has been identified, or where the drying process is essential for other reasons (such as in the drying of timber for furniture manufacture) the ABRICO Controlled Solar Dryer System would appear to be a technology whose time has come.

References

Anon. (1985) Solar Dryers, their role in post-harvest processing, Commonwealth Science Council, London, pp. 25-36

Baynes, R. A. (1985) Appropriate technology for agriculture in the Caribbean Region, Joint Meeting CFCS/ASHS, Trinidad, Sept. 1985 (In Press)

Quality control in cucumber for export

Richard A. Graham

Caribbean Agricultural Trading Company (CATCO), P.O. Box 15A, Adams International Airport, Christ Church, Barbados, W.I.

The short shelf life of cucumber (21-24 days) emphasizes the need for proper production, harvest and post-harvest handling procedures. A high quality product is essential to impact upon the export market and to ensure reasonable returns. Some of the problems encountered by CATCO during the 1986 - 1987 season are illustrated, and ways and means of maintaining fruit quality are defined.

Keywords: Cucumber; Post harvest handling

Introduction

Antigua exported approximately 78 tons of cucumber to the USA during the period January to April, 1987. The target for the 1987-1988 export season is 187 tons. To achieve this target those constraints which hampered production during the previous season must be removed. Several problems were encountered in the production, harvest and post-harvest procedures which affect the quality and self-life of the cucumbers. The ability of the Caribbean Agricultural Trading Company (CATCO) to return a good price to growers, depends on the receipt of a high quality product.

Outlined subsequently are details of the major constraints observed during the previous season and recommendations to prevent their recurrence. A set of procedures is suggested which, if adhered to, should ensure procurement of a high quality product for the market.

Quality criteria

Groundspot: This occurs as a yellow-green area where cucumbers are in contact with the soil and away from exposure to the sun. On heavy clay soils and under heavy rainfall conditions the fruit may become embedded in the soil thus increasing the size of the groundspot. Usually, unless the spot covers more than three-quarters of the fruit there is no diminution in quality.

Yellowing: Yellowing is usually an indication of senescence and cucumbers showing this symptom are totally undesirable. Yellowing is accelerated by too low or too high a storage temperature. Below 10^{o}C cucumbers suffer chilling injury and yellow rapidly; above 15^{o}C similar symptoms are exhibited. Exposure to ethylene also promotes yellowing.

Shrivelling: Excessive water loss after harvest causes shrivelling at the blossom end of the fruit. The fruit rapidly goes flaccid afterwards. Flaccidity of fruit was noticeable both in the field prior to harvest and upon arrival at the packhouse. Since the entire cultivated area was rain-fed and undergoing water stress during the period of observation, it appears that fruit was not turgid at harvest and deteriorated further during processing (washing, waxing, grading and packing). shrivelling indicates poor handling or storage practices.

Cottony Leak: A soil-borne fungal pathogen, *Pythium aphinidermatum* is the causal agent. Soft, water-soaked lesions precede the growth of a cottony-type fungus which may cover all of the fruit. Infection is usually evident during prolonged storage and once established, spreads rapidly (McCombs and Winstead, 1963).

Recommendations

Field Cooling: As a hot day progresses, vines lose water by transpiration and the fruit accumulate field heat. Cessation of harvesting by midday on hot days is recommended to prevent the accumulation of a high level of field heat. Cooling immediately after harvest is critical to the maintenance of fruit quality. Fruit should be hydro-cooled by immersion in cold water, preferably in the field.

Disinfection: The removal of soil and other foreign material from the surface of the cucumber is necessary to prevent infection by soil fungi. Washing in chlorinated water is recommended to reduce fungal and bacterial infection (Segall and Smoot, 1962). Cut or broken ends are the most susceptible to being infected: cucumbers in this condition should be discarded during grading and sorting. Infection is rendered even more unlikely if the cucumber is removed from the vine with a small portion of the stem intact.

Waxing: The application of a thin surface coating of a wax slows down moisture loss considerably, thus reducing wilting and shrivelling of fruit. Moisture loss can be reduced by as much as 50% (Mack and Janer, 1942).

Storage: A storage temperature of 12-13^{o}C ensures the longest shelf-life (see Table 1). However, for storage of one to two weeks, 10^{o}C is preferable, because chilling is minimal and yellowing is retarded. High humidity (95%) in storage is also essential to prevent cucumbers from becoming flaccid.

Table 1 Cucumber spoilage after 18 days storage at 20^{o} and 12^{o}C> (after Apeland, 1961)

Post-harvest Problem	Storage Temperature	
	20 (^{o}C	12 (^{o}C)
Marketable (%)	38.0	69.6
Shrivelled (%)	24.5	4.7
Diseased (%)	27.0	18.5
Yellowed (%)	8.5	8.2

Data represent observations on 5 randomly chosen boxes (210lbs) in storage. Fruit were waxed but not washed in chlorinated water.

Summary of Procedures

1. Immediately after harvest, crates containing cucumbers should be immersed for 15 min. in cold water ($5^{0}C$) in field tanks adjacent to the area harvested. After immersion crates should be stored in a cool, shaded area.

2. As soon as possible after harvesting cucumbers should be removed from the field for processing. Transportation should be effected using a covered vehicle to prevent re-exposure to the sun.

3. Washing should be done in water containing 10% sodium hypochlorite (Chlorox). Frequent changes of the chlorinated water are necessary as accumulated soil reduces the effectiveness of the chlorine.

4. Cucumbers should be put into cool storage as soon as possible after processing and packing. Since exposure to ethylene causes yellowing, cucumbers should not be stored, either in transit or in a cold room, with tomatoes, melons, bananas or papaya.

References

Apeland, J. (1961) Factors affecting the keeping quality of cucumbers, International Inst. Refr. Bull. Annex 1 45-48

Mack W.B and Janer, J.R. (1942) Effects of waxing on certain physiological processes of cucumber under different storage conditions, Food Research 7 38-47

McCombs, C.L. and Winstead, N.N (1963) Control of cucumber cottony leak in transit, Proc. Am. Soc. Hort. Sci., 83 538-546

Segall, R.N and Smoot, J.J. (1962) Bacterial black spot of radish, Phytopathology 52 970-973

Post-Harvest Studies and Quality of Yams - A review

L. M. Degras

Plant Breeding Station, INRA Antilles-Guyane, BP 1232, Pointe-a-Pitre CEDEX, Guadeloupe

There have been few studies on factors affecting yam tuber quality. Tuber quality can be approached from several points of view: nutritional value, changes in organoleptic and physico-chemical characteristics during storage and food preparation or the differing responses of the various yam cultivars to these factors. This paper reviews the literature on these aspects of yam quality and reports on work carried out in Guadeloupe to characterize the response of different yam species to storage and cooking. The studies bring out the differing behaviour among and within *Dioscorea* species and the need to take into account post-harvest behaviour when selecting cultivars for a particular food or processing use.

Keywords: Yams; *Dioscorea* spp.; Post-harvest; Tuber quality; Storage losses; Processing

Introduction

The main use of the genus *Dioscorea* is for food. A few species have pharmaceutical use and small amounts of yam food waste are used in animal feed. Among the nearly one hundred edible *Dioscorea* species, which are the true yams (Martin, Degras, 1978), the main cultivated ones have provided the needs of millions of people in the tropics for many centuries, in the following respects:

- high food production per unit area
- good balance of nutritive elements
- significant contribution to socio-cultural traditions.

If we consider the research carried out during the last decades, it has not been demonstrated that yams could perform as well as other staples like cassava, cereals or even sweet potatoes in these respects.

The possibility of attaining high yields still exists, but two constraints may account for today's situation. The economics of the production system and the relevance of post-harvest management systems have not been sufficiently studied. Post-harvest losses are known to account for between 25 and 50 per cent of the gross yield lost to the consumer. Improvements in cultivation cannot compensate for such large losses. Studies and experiments are not lacking in this area, but are far less numerous than conventional field research. They have never considered the whole process from harvest to final consumption. This paper is a modest attempt at providing a comprehensive approach to maintaining the qualitative value of yams after harvest.

Several aspects of the process of post-harvest utilisation of yam have been documented by several authors. We shall review these and also include original data from research conducted at INRA with the assistance of collaborators in the Caribbean and elsewhere.

Post-harvest losses

Losses during storage

Most yams are stored for several months before use. The consequent loss of weight is well documented (Coursey, 1967, 1981, Degras, 1986). Roughly ten per cent of harvest weight is lost per month, which amounts to between 50 and 60 per cent after a six month storage period, the maximum duration for most yam farmers. However, storage for as long as one year has been reported. (Malinowski, 1977).

As Treche and Guion (1979) have pointed out (Table 1), loss of edible portion may not be as great as loss of fresh weight and is also influenced by the cultivar. Losses are also increased by other factors, such as damage from wounds and bruises, nematodes, beetles or caterpillar attacks, and diseases.

Table 1. Effects of storage on nutritional potential of yam in the Cameroon (after Treche and Guion, 1979).

	Fresh		After 7 weeks		After 19 weeks	
	D. cayenensis	*D. rotundata*	*D. cayenensis*	*D. rotundata*	*D. cayenensis*	*D. rotundata*
Gross weight (g)	1000	1000	765	879	430	611
Peel lost (g)	28	20	37	25	49	37
Edible dry matter (g)	170	279	151	256	92	184

D. cayenensis = cv Batibo; *D. rotundata* = cv Oshei, both of Cameroon

Reduction of Post Harvest Losses

To reduce storage losses, various attempts have been made to improve traditional storage methods, such as structural changes to the Nigerian yam barns (Wilson 1979) and replacement of yam houses in the Ivory Coast with storage pits (Sauphanor, 1986) and cribs in Guadeloupe. These changes have been combined with the use of pesticides. However, traditional use of wood ash is still effective although according to Nwankiti (1983), the choice of the wood or burning material is important. Careful curing under natural conditions can assist in providing a significant reduction of pest and disease attack (Degras, 1986).

Only sophisticated physical or chemical procedures can significantly reduce the normal deterioration due to aging, by reducing the rate of metabolism. Cold storage and gamma irradiation have been proposed (Adesuyi, 1978, Demeaux, 1981). The experimental use of gibberellic acid is now being studied at IITA and NRCRI in Nigeria, at IDESSA in Ivory Coast and at INRA in Guadeloupe, following the initial studies of Wickham (1983) in Trinidad. At INRA we have shown that Gibberellic acid is effective on *D. trifida*, which normally has a short dormancy. A report from Ivory Coast indicates the possibility of using a solution of gibberellic acid for as long as a week thus reducing the cost of the dip (Dumont, personal communication).

The characteristics of different cultivars in storage is well known. However, less is known about the effect of pre-harvest crop management practices. A review of the effect of fertilizers on the rate of subsequent post-harvest tuber loss suggested some surprising results (Degras, 1985). Recent experiments in Ivory Coast (Dumont, 1986) suggest that fertilization may increase of the level of post-harvest loss. Treche and Guion (1979) have shown that depending on the cultivar of *D. cayenensis-rotundata* and the duration of storage, greater food yield food could be obtained from harvesting at either seven, eight, nine or ten months.

Losses during food preparation

The edible part of the tuber: The rejection of peel during food preparation leads to losses commonly estimated at 15% - 30% of the weight at harvest. Smaller losses are found with tubers from the primary harvest of *D. cayenensis* ssp. *rotundata* from a crop harvested at five months. In some parts of Nigeria part of the peel can then be incorporated in the part consumed (M. Akoroda, personal communication). In general, the bigger the tuber, the lower is the relative loss of weight from peeling. Finally, the highest relative losses occur with very irregular shaped tubers.

Varieties of some cultivated species (D. alata, D. glabra, D. nummularia) and of protocultivated, or wild species, may sustain a far higher relative loss due to their tuber morphology. For example, the yam head may be large, hard and unpalatable. In this case, losses can reach half of the harvest. In contrast, many cultivars of *D. trifida*, the cush-cush yam, have long slender peduncles between the nodal complex and the storage organ. Here, the ratio of relative loss from peeling can be as low as five percent depending on the cultivar.

Cultivation techniques and ecological conditions can induce wide variations in losses through effects on tuber morphology. One of the best known examples is the variation of the "head" portion in the tuber of some *D. alata* cultivars where late planting of cv Taiti, in August, instead of March or April, suppresses the development of the unpalatable part. The total yield is lower than with early planting, but it is still within the range of good selected cultivars (Degras, 1986).

Yam Composition and Food Value

The chemical composition of the important yams is well known, though the variations within species and in different ecozones needs further study. For instance, analysis of sugar content among cultivars of *D. trifida* (Splittstoesser,1976) and *D. alata* (Bell and Fourier, 1981) provide evidence of a non-sweet cush-cush and of sweet *D. alata* cultivars. Before considering the balance among nutritional elements in yams, it is worth considering the toxicity or poor digestibility factors in some edible yams.

Nutritional acceptibility factors range from actual toxicity of some edible yams (e.g. *D. bulbifera, D. dumetorum, D. hispida*) to the poor digestibility of some *D. alata* cultivars. Such problems can be avoided by choosing the cultivar or by a tedious detoxification process. However, studies done by Martin (1980) suggest that ordinary diets which include yams could contain some toxic components. Traces of an anti-amylase factor could account for the rather low digestibility of yam, when compared to cassava. However, even with the "toxic" species, *D. dumetorum*, non-toxic cultivars exist. Moreover Szylit et al. (1977) have proved that the starch of this species is as digestible as that of cassava. We are not aware of any extensive evaluation of the range of digestibility within a yam species. Such research, as well as the evaluation of the range of toxic components (Eka, 1985) could provide explanations for the different intake levels and traditions of usage which exist.

We have cited already the work of Splittstoesser (1976) showing variation in the levels of sugars among species. He also showed in this paper the inter- and intra-specific variation in amino acid levels within five yam species.

The main nutritive component in yam is starch (50 - 80% of dry matter (D.M.)), which also shows considerable intraspecific variation, not only as proportion of the dry matter content, but also in its structure. The size of starch grains is closely related to the proportion of amylose and amylopectin. In *D. esculenta* such grain size ranges from 1 to 15 microns (Delpeuch et al., 1978). The activity of the amylase enzyme during storage of *D. esculenta* also shows considerable intraspecific variation (Houvet et al., 1982). Size of grain and type of starch affect starch digestibility.

Few studies measure losses of nutrients occurring during cooking. Coursey and Aidoo (1966) studied the loss of ascorbic acid and observed losses of 5 to 35 percent depending on cooking method. The results of Splittstoesser (1976) for the loss of amino-acids during cooking presented in Table 2 compare both inter- and intraspecific differences. Losses of free amino acids can more than double depending on cultivar. The only complete study of the variation in nutritional components during culinary preparation (Bell and Favier, 1981) considers four yam species, but, unfortunately it lacks clear varietal references for D. cayenensis and D. rotundata. Figure 1 shows the different preparations and the resulting variations in protein, fiber, ash and thiamine content for *D. rotundata*. No change in the carbohydrate content was found. The effect of high levels of yam consumption on human health has been studied only indirectly (Martin, 1980).

Table 2 Protein content and amino-acid changes resulting from cooking (Data from Splittstoesser, 1976)

Species	Protein (Nx6.25 % D.M.	Amino-acid content: Before cooking: Proteic % protein	Before cooking: Total a.a. % D.M.	Before cooking: Free % D.M.	Before cooking: Free % Total	After cooking: Total a.a. % D.M.	After cooking: Lost % Total	After cooking: Lost % Free
D. alata:								
cv Forastero	7.3	77	6.6	1.0	15.0	6.1	7.6	50
cv Florido	10.5	78	9.8	1.6	16.3	9.5	3.1	19
D. esculenta:								
cv Papa	8.2	68	7.6	2.0	26.3	7.3	4.0	15
cv Spindle	8.8	82	7.9	0.7	8.9	7.6	3.8	43
D. rotundata:								
cv guinea blanco	8.1	83	7.2	0.5	6.9	6.9	4.2	60
D. trifida:								
cv Cousse-couche violette	6.7	76	6.1	1.0	16.4	5.8	5.0	30
cv INRA 25	7.6	78	7.2	1.3	18.1	6.9	4.2	23

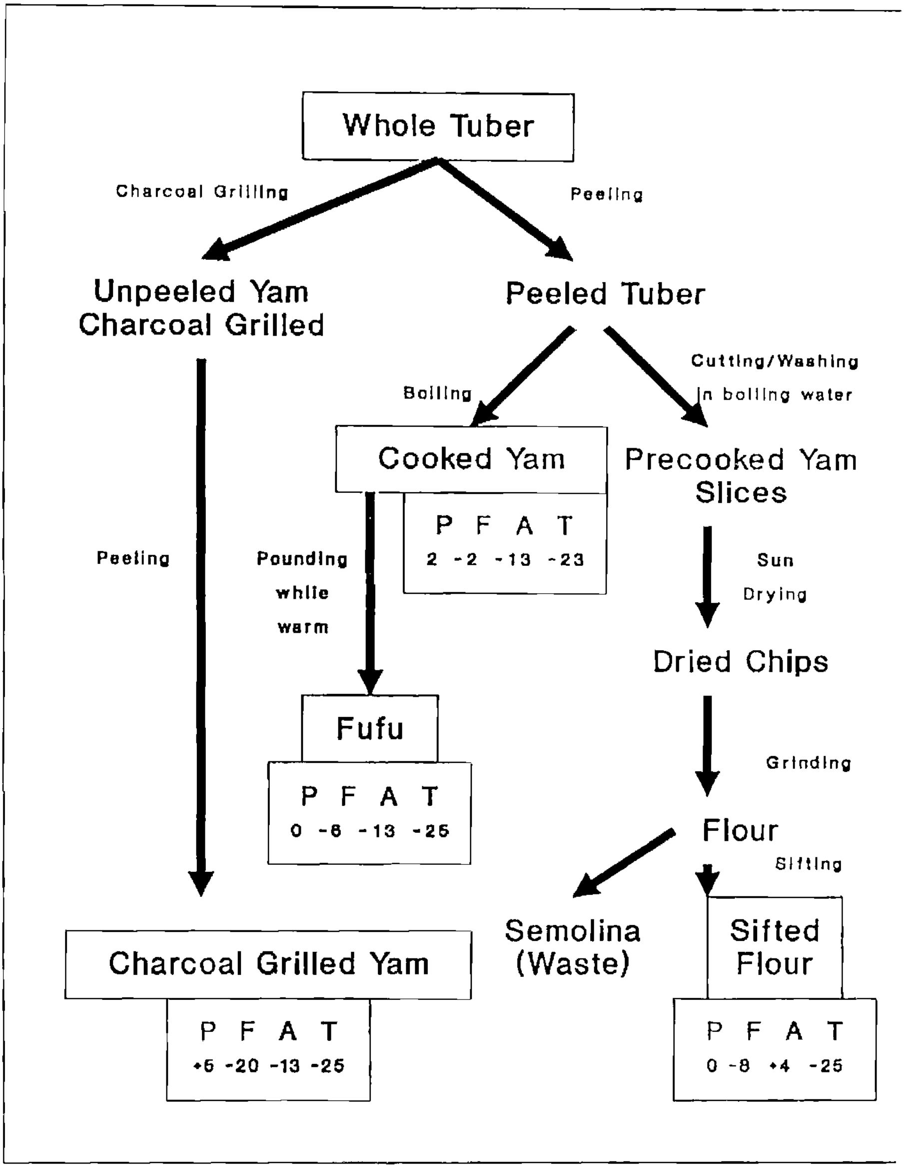

Figure 1 Changes in white yam (D. rotundata) composition after processing into various products after Treche and Guion (1970). Protein (P), Fat (F), Ash (A) and Thiamine (T) changes are given as % DM change from original whole tuber

Evaluation of Cooking Quality

The chemical composition of a food resource does not itself determine attractiveness. Through their preparation processes, foods which are not eaten raw become more attractive. Identifying the factors responsible for this attractiveness is possible through sensory analysis of organoleptic characteristics and sometimes through physico-chemical analysis. Analyses can establish "objective" measures for easier selection of required varieties or for testing the conformity of industrial products to consumer preferences. They also provide socio-cultural data.

The relatively short time since the beginning of experimental selection of yams accounts for the absence of a methodology for determining culinary attributes and characteristics. From preliminary observations over several years and the very limited literature (Martin, 1976; Martin and Ruberte, 1976) we attempted to describe two series of yams for their culinary attributes.

Culinary attributes of two series of yams

One of the main objectives of the study was to establish some basis for varietal characterisation and clonal selection among progenies. Varietal specification was tested with our *D. alata* germplasm collection and clonal selection feasibility was tested with *D. cayenensis-rotundata* material.

Material: Tests were begun on 61 cultivars of *D. alata* (local or introduced) in February, two weeks after harvest. Sixteen of these were still available in June after five months of storage.

Seventy clones of progenies of *D. cayenensis-rotundata* selected from 800 sexual seeds of IITA polycrosses received in 1983, were harvested after full plant senescence in February 1987 and observed the same month. Fifteen clones were also harvested at an early edible stage as a first harvest at five to six months after planting. A second sampling was made two or three months later, according to the traditional system. At the time of testing, the samples harvested early had had four to five months of storage, whereas the later harvested samples or those harvested only once were stored for only a few weeks. Only one tuber of each series of clones was available for study.

Observations and Methods: Weight, length and health of each tuber were noted. After peeling, three slices, one centimeter thick, were cut from top, middle and bottom sections of each tuber. Skin irritation by rubbing on arm, flesh granulation (cell starch and vessel arrangement) and flesh colour were noted for each section. Samples were placed in individually covered petriboxes, without directly adding water, and cooked for eleven minutes in a micro-wave oven provided with a free water surface. Cooking degree and flesh colour were noted, as well as consistency, sweetness and bitterness.

Specific gravity, pH and glucose (using colorimetric paper) were tested for most samples and chemical analysis for sugar was performed on a limited number of samples.

Results

D. alata cultivars: The observations made on the 61 cultivars tested after two weeks of storage as well as the tests on 6 cultivars with five months storage are still being analyzed. The only important result so far is that the traditional cultivars (Pacala group) and good new selections (Belep, Plimbite) can be identified from our assessment, as having medium to weak flesh granulation, no skin irritation, maintenance of pure white flesh after cooking, firm to friable consistency and a score (scale of 0 to 3) of not more than 1 for sweetness and 0 for bitterness.

***D. cayenensis-rotundata* progenies:** The full analyses are not yet completed, but some preliminary results can be selected for discussion.

Skin irritation: Middle sections from 30% of clones were non-irritant, while 15% were very irritating in the sample of 70 single harvest clones. Good correspondence was found between early and late harvested material.

Flesh granulation: Very coarse granulation as seen in some *D. alata* types was not observed in middle sections of the tubers. Of the 70 late harvested clones, 63% was only slightly granulated. The distribution was similar for both systems of harvest.

Cooking quality: About 80 per cent of the middle tuber sections cooked well under the uniform time used. Insufficient or excessive cooking was sometimes associated with infected material.

Flesh colour: Table 3 presents data concerning the colour changes occurring to tuber slices of *D. rotundata* clones during cooking. From the data presented it is possible to conclude that:

- The number of colour combinations is increased by cooking
- Colour combinations are likely to be more diverse from late harvested material than from early harvested material
- The greyish component is always increased by cooking
- The dominance of the white component is obvious in early harvested material after cooking, but is not so clear after cooking late harvested material.

Flesh consistency: Flesh consistency of middle sections varied from pasty (21%) to firm (50%) or very firm (10%) and friable (10%). Some pasty samples appeared to be associated with infection of the tuber.

Sweetness: On a scale of 0 to 3 (3 = cush-cush yam standard) middle sections ranged from 0 to 2.0 with similar frequencies for 0.5 (27%), 1.0 (25%), and 1.5 (24%).

Bitterness: On a scale of 0 to 3 (3 = quite unpalatable) tuber sections ranged from 0 to 2.5 with 20% at 0 level and 44% at 0.5.

Discussion - Conclusion

It is noteworthy that, apart from flesh coloration, which was studied for all three tuber sections, the harvesting systems did not appear to affect tuber quality. It may be that flesh colour is more susceptible than other characters to the duration of storage. If so, the longer storage time after the early harvest would reduce white colour levels. The data of Martin and Ruberte (1976) partly support this view. If the colour difference is due to the younger stage of the early harvested tubers having less developed off-colours, this could account for the traditional use of this material.

Table 3 Coloration of yam slices of *D. rotundata* progenies before and after cooking

Sample	Harvest Date	Frequencies (%) of the Basic Coloration among the Samples								Number of Combinations of the Basic colorations	
		White		Yellow		Purple		Greyish			
		B[1]	A[1]	B	A	B	A	B	A	B	A
Same 15 Clones	Early	98	81	21	30	33	19	2	42	7	14
	Late	85	65	21	53	40	31	31	63	11	14
70 Clones	Late	91	57	46	44	44	16	28	71	17	25

1) B = before, A = after cooking

More characteristics should be considered, especially aroma at cooking. Osinowo (1985) found only slight differences between the aroma of *D. alata* and *D. rotundata*, but differences between cv. Taiti and other *D. alata* cultivars, as well as among the progenies was evident. A more experienced taste panel would have been required to weight the different odour profiles of our yams using the terms such as "sweet, cooked vegetable, aromatic, fragrant, earthy, nutlike, herbal" quoted by Osinowo (1985).

Also, there is need to asses more accurately the correlation between micro-wave oven and conventional cooking methods and to correlate the results of this year with those of future harvests.

As has been said, physico-chemical tests are at too much of an exploratory level for extensive comment. pH appeared somewhat reliable as a clonal character, while specific gravity and glucose levels did not appear to be reliable.

The usefulness of these characteristics of yam quality will be evident in view of developing the quality of yam food required by the consumer by selection or through technological transformation. For instance, "Fufu" is the main way of consuming yam in West Africa and *D. rotundata* is obviously more adapted to traditional culinary recipes. In the Caribbean "fufu" is quite unknown and in many places white *D. alata* cultivars cut in big pieces and cooked in salted water remain the standard, while in Jamaica, yellow yam (*D. cayenensis*) is highly favoured.

These culinary differences require the maintenance of a reasonable level of cultivar diversity. A recent survey conducted in Martinique among 200 homesteads (Palcy, 1987) indicates a desire for a cultivar combining the qualities of the best *D. alata*, *D. rotundata* and *D. trifida* cultivars.

Quality of Yam and Industrial Processing

Experience in the Caribbean, Africa and Asia has shown that yam can be processed either at the village level or in industrial scale plants using technology developed for white potato, to provide modern processed yam products suitable for urban consumption. Such products are "instant yam" and yam chips. Since it soon became obvious that choice of cultivar was important (Martin, Ruberte, 1972), more attention has been paid recently to the effect of cultivar on the quality of "instant yam". At the beginning, only the quality of the different species was stressed, particularly in Barbados, where *D. alata*, *D. cayenensis-rotundata* as well as *D. trifida* were thought good, while D. esculenta was not (Sammy, 1983). There was perhaps little local experience with consumption of the product to provide guidance. The failure in the past of many attempts to produce "instant fufu" in West Africa is clearly related to lack of concern with varietal factors in the industrial processing (Dumont and Hahn, personal communication). Okpokiri's data (Okpokiri,1982) clearly shows the differences between *D. rotundata* cultivars. Recent changes have led to promising products in Ivory Coast and Nigeria.

The successful use of yam mixed with wheat flour, in foods like bread or pastries, has also proved to be dependent on use of suitable varieties (Martin, Ruberte, 1975).

Even products which differ from usual standards can be promoted through publicity or adapted to the new requirements of our changing world. For instance, the low cost, mechanized production of cv. Florido in Ivory Coast could provide suitable material for an industrial "fufu" which could become established, despite its less classical taste, among poor consumers in the urban areas. The use of unpeeled yam as proposed by Akoroda (1987) may be similarly accepted.

The importance of technological and economic policies in determining the future development of yam utilization should also be recognised.

Acknowledgments

The assistance of M. Namory (Station de Biotechnologie des Produits Vegetaux) with the physico-chemical tests and support to our laboratory panel is sincerely acknowledged.

References

Adamson, I., (1985) The dietary fibre of Yam and Cassava. Advances in Yam research, The biochemistry and technology of the Yam tuber, pp.319-342,(Ed. Osuji, G.O.) Anambra State Univ. of Technology, Nigeria.

Adesuyi, S. A., (1978) The application of advanced technology to the improvement of yam storage, Seminaire international sur l'igname, Buea, Cameroun, 1-6 Octobre, Compte Rendu, pp. 387-398. Cf. Miege, Lyonga, 1982, pp. 312-319.

Akoroda, M., (1987) Incorporating tuber peels in white yam flour, Advances in Yam research, The production and post-harvest technologies of the yam tuber, 2nd National Symposium on the yam tuber (8-10 June 1987), Anambra State Univ. of Technology, Nigeria, Summary of papers, p. 4.

Bell, A. and Favier, J. C., (1981) Effect of traditional food processing methods on the nutritional value of yams in Cameroun, in: Terry et al., (1981), 214-226.

Coursey, D.G., (1967) Yams, Longmans, London.

Coursey, D.G., (1981) Yams, in: Handbook of Tropical Foods, (Ed. Chan, H. T.), Marcel Dekker, N. Y. (In press).

Coursey, D.G. and Aidoo, A., (1966) Ascorbic acid levels in Ghanaian yams, J. Sci. Food & Agric., 17 (10), 446-449.

Degras, L., (1976) L'Igname, Maisonneuve et Larose, Paris. 408pp

Delpeuch, F., Jiron-Najou, J. L., Chevalier, P., Dyck, J. L., Frontier-Abou, D., (1982) Consommation alimentaire et etat nutritionnel a la Martinique, ORSTOM, Martinique.

Demeaux, M., (1981) Amelioration de la conservation des ignames en Cote d'Ivoire, Colloque International CENECA, Agriculture et Alimentation, Paris.
Dumont, R., (1986) Programme Igname, Rapp. Anal. (1985) Institut des Savanes (IDESSA), Bouake, Cote d'Ivoire.
Eka, C. U., (1985) The chemical composition of Yam tubers, in: Advances in Yam research, The biochemistry and technology of the yam tuber, pp.49-76, (Ed. Osuji, G.O.) Anambra State Univ. of Technology, Nigeria
Houvet, D., Diopoh, J., Ketekou, F. S. and Marchis-Mouren, G., (1982) Caracterisation et evolution des activites amylasiques des tubercules germes et non germes d'Ignames, Physiol. Veget. **20** (3) 451-457.
Malinowski, B., (1977) Les jardins de corail, Maspero, Paris (reedition).
Martin, F. W., (1976) Selected yam varieties for the tropics, Proceedings of the Fourth Symposium of the International Society for Tropical Root Crops, (Eds. Cock, J. and Intyrf, M.) IDRC-CIAT, Columbia, pp. 44-49.
Martin, F. W., (1980) The question of toxicity of edible yams, in: L'Igname, Seminaire international, Les colloques de l'INRA, 1981, pp. 31-39.
Martin, F. W. and Degras, L., (1978) Tropical yams and their potential, Part 5, *Dioscorea trifida*, No. 522.
Martin, F. W. and Ruberte, R., (1972) Yams (*Dioscorea* spp.) for production of chips and french fries, J. Agric. Univ. Puerto Rico 56(3) 228-234.
Martin, F. W. and Ruberte, R., (1975) Flours made from edible yams (*Dioscorea* spp.) as a substitute for a wheat flour, J. of Agric. Univ. Puerto Rico 59(4) 255-263.
Martin, F. W. and Ruberte, R., (1976) Changes in the quality of yams (*Dioscorea alata*) in storage, Tropical Root and Tuber Crops Newsletter 9 40-51.
Martin, F. W. and Thompson, A. E., (1973) Protein content and amino acid balance of yams, J. Agric. Univ. Puerto Rico 57(1) 78-83.
Nwankiti, A. O. and Ene, L. S. O., (1983) Effect of delayed planting and chemical treatment on the performance of yams grown from minisetts, 7th Congres de la Soc. Intern. Plantes a Tubercules Tropic. (ISTRC), 8 pp., (Ed. INRA), mimeographed (in preparation).
Ochse, J. J. and Bakhuizen-Van Den Brink, R. C., (1977) Vegetables of the Dutch East Indies, A. Asher & Co., B. V., Amsterdam.
Okpokiri, A. O., (1982) Farm gate processing of Yams, Yam cultivars for fufu flour production, Ann. Report, 1982, Nat. Root Crops Res. Inst., Umudike, Nigeria, p. 42-44.
Okpokiri, A. O. (1983) Assessment of yam flour ("elubo") quality based on chemical and rheological factors, Ann. Report 1983, Nat. Root Crop Res. Inst., Umudike, Nigeria, p. 59-60.
Osinowo, F. A. O. (1985) The flavour of edible yam species, in: Advances in Yam research, (p. 233-248) (Adamson, 1985 *loc. sit.*)
Palcy, L. (1987) L'Igname et l'assiette du consommateur, Journees d'information Igname, p18-19 Mars, 1987, Chambre d'Agriculture, Martinique, 8 p. (mimeographed).
Sammy, G. M., (1983) The processing potential of tropical root crops, Proc. Caribbean Regional Workshop on Tropical Root Crops (Ed. Dolly D.) Jamaica, p. 199-206.
Sauphanor, B. (1986) Influence du mode stockage sur le parasitisme des stocks d'Igname, IVe Congres sur la Protection de la Sante humaine et des cultures en milieu tropical, Marseille, 2-4 Juillet 1986. p. 140-145 (mimeographed).
Splittstoesser, W. E., (1976) Protein and total amino acid content before and after cooking of yams, Hort. Sci. 11 611.

Treche, S. and Guion, Ph., (1979) Etude des potentialites nutritionnelles de quelques tubercules tropicaux au Cameroun, 1. Influence de la maturite de la recolte, 2. Aptitude a la conservation des tubercules recoltes apres maturite, 3. Influence de la maturite a la recolte sur l'aptitude a la conservation, Agron. Tropicale, 34(2) 127-156.

Wickham, L. D., (1983) Extension of dormancy in tubers of tropical Yams (*Dioscorea* spp.) Proc. Caribbean Regional Workshop on Tropical Root Crops, p. 171-249 (Ed. Dolly, D.) Jamaica.

Wilson, J. E. (1979) Careful storage of yams - some basic principles to reduce losses, IITA, Ibadan, Nigeria.

Potential for new lightly processed tropical fruit products

Robert E. Berry and Joseph H. Bruemmer

P.O.Box 1909, U. S. Citrus and Subtropical Products Laboratory, U.S.D.A. - A.R.S., Winter Haven, FL., 33883, USA.

The U. S. market for table-ready prepared fruit and vegetable products, such as fruit segments, slices, cut fruit and pieces is expanding. The vacuum infusion technique makes possible protection of cut and peeled surfaces using natural enzymes, edible coatings, antioxidants and/or nutrients to preserve natural quality attributes such as color, texture, nutrients and flavor. Infusion of pectinases has been used to separate peel, albedo and rag from grapefruit and oranges. The technique was also used to add color and nutrients. Applied to mango, papaya, pineapple, peach, apple and carambola slices and peeled fruit pieces, it will help preserve them for marketing.

Keywords: Fruit processing; Vacuum infiltration; Citrus

Introduction

In U. S. markets, demand has been greatly increasing over the past few years for prepared fresh fruit and vegetable or "salad-type" items. Grocery stores and supermarkets now routinely feature delicatessen and garden salad sections where such items are readily available. Many fast-food restaurants feature cut, sliced, prepared fruit and vegetable pieces as part of their salad bar. Limited-menu buffet and cafeteria style restaurants also are proliferating in most towns in the U.S. This creates great demand for this type of product. While such products usually offer good taste, color, nutrients and texture when freshly prepared, these attributes begin to deteriorate immediately. Thus the color either fades, turns brown or darkens; the texture becomes mushy, or soggy, the flavor becomes unbalanced and less intense and nutrients are lost to oxidation or through internal reactions. Such products rarely retain satisfactory fresh quality more than a few days to a week, at most.

A process has been developed which can add protectants to these cut surfaces, or internal structures within the cut piece. This prolongs and enhances the quality by retarding deteriorating reactions, whether at the surface or internal. The process, known as vacuum infusion was initiated at our laboratory about 10 years ago, for the purpose of removing or lowering the amount of the bitter principle, naringin, in grapefruit.

Bruemmer et. al (1978) showed the process could also be applied to removing peel and separating sections in grapefruit with very little hand labor or loss of quality. This paper reviews some of these results and similar studies and also develops some additional potential applications of the vacuum infusion process for other tropical fruits.

Vacuum Infusion for Debittering Grapefruit

Early studies of the grapefruit bitterness problem showed that the factor causing much of the bitterness resided in the albedo portion of the peel, the membranes surrounding and separating the fruit segments, and in the core material, which is also mostly albedo (Sinclair, 1972). Studies by Ting (1958), of grapefruit juice and Olsen and Hill (1964) on grapefruit concentrate, showed bitterness could be reduced by treatment of the respective products with naringinase, which was separated from commercial pectinase preparations. The primary problem was getting the naringinase to penetrate into the albedo material. In studies at our laboratory, Roe and Bruemmer (1976) determined that the best approach to incorporating the enzyme into the albedo was by vacuum infusion. They first scraped, perforated, or thinly peeled off the flavedo. By withdrawing the air from a lab desiccator containing the fruit submerged in a beaker of the solution, and then releasing the vacuum, the solution was able to saturate the albedo.

A medium sized grapefruit soaked up about 100 ml. of solution under these conditions. Using this method, they were able to reduce the naringin content by about 8% to 81% depending on conditions. These results are indicated in Table 1. Naringin content reduction depended on amount of naringinase, and time, as indicated. Best results were obtained with 60 min treatment at 50 ^{0}C, using a solution of 350 Units per liter of a commercial preparation of the enzyme.

Table 1 Reduction of naringin in grapefruit by vacuum infusion with naringinase at 50^{0}C.

Naringinase (U/l)	Time (min)	Naringin (%)	Reduction (%)
0	30	1.03	-
70	30	0.95	8
175	30	0.81	21
350	30	0.51	51
70	60	0.54	48
175	60	0.35	66
350	60	0.20	81

Taste panel results using the triangle taste discrimination of difference method, described by Larmond (1967), indicated a general confirmation of the analytical results. Lower levels of the enzyme or lesser time resulted in products that were not significantly different from the untreated control samples in bitterness. A summary of their most significant flavor results is given in Table 2.

Table 2 Reduction of bitterness in grapefruit vacuum infused with naringinase solution.

Naringinase treatment (U/l)	(min)	Tasters 1	2	3	4	5	6	Sum
350	60	2	1	2	2	2	1	10
175	30	3	3	3	3	3	3	18
350	30	2	2	1	2	1	2	10
350	60	1	1	2	1	2	1	8

Samples 3 & 4 different from 1 & 2 at the 99% confidence level.

Vacuum Infusion Peeling and Sectionizing

Another major problem with fresh grapefruit that seemed amenable to application of the vacuum infusion process was the separation of the peel and individual fruit segments. While grapefruit sections in can and glass have long been a very desirable consumer product, the high cost of hand labor involved in preparing the product has become almost prohibitive in recent years. Whereas there were about 15 Florida citrus processors who produced this product about 12 years ago, now there are only two. Bruemmer et.al (1978) showed vacuum infusion could be used to alleviate the peeling/sectionizing problem in grapefruit. Using this approach the processing costs could be reduced because the 60% loss of fruit flesh and juice which accompanied the conventional cut-fruit, hand method, was virtually eliminated. Quality of the conventionally processed product is comparatively low also because of heat damage from softening peel with steam, and use of hot lye baths to finish the sections (i.e. remove adhering pieces and strings of albedo, peel, core material, etc.). These heat treatments are not required with the enzyme digestion method, thus improving product quality.

They compared 6 different types of commercially available pectinase preparations, using vacuum infusion to get the enzyme to penetrate into the interior of the fruit. As shown in the results summarized in Table 3, all 6 were effective after 30 to 45 minutes at 50 ^{o}C though two of them, B and F achieved this within 15 minutes after incubation. These preparations contained combinations of pectinesterase, cellulase, polygalacturonase (PGA) and polymethylgalacturonase (PMGA). They found effectiveness of the enzymes seemed to correlate best with content of PGA and PMGA.

Table 3 Comparison of 6 commercial pectinases for grapefruit peeling and sectionizing.[1)]

Treatment times	Pectinase brands					
	A	B	C	D	E	F
15 min	10	8	9	11	13	7
30 min	6	6	7	7	8	7
45 min	5	4	4	4	4	4

1) Criteria: peeling ease, lack of adhering albedo, ease in removing sections, appearance; Scores determined by assigning values; 1=good, 2=fair and 3=poor. Avg. sums of 4 scores for 6 fruits. Lower score = more effective.

For treating the fruit, the peel was scored in quadrants, by hand, using a sharp knife, and barely cutting through the flavedo (colored layer of the peel). The fruits were then submerged in a solution of enzyme in water, and the container placed into a heavy-walled desiccator attached to a vacuum pump. A vacuum of 71 cm (28 in.) Hg was drawn on the apparatus for about 5 min. During this time the solution foamed and bubbled as the fruit was being degassed. The vacuum was then released and the interior of the desiccator allowed to resume atmospheric pressure. During this time about 100 ml. of the enzyme solution was drawn into the fruit to replace the gases that had been removed. After removal from the solution, the fruit were placed into individual plastic bags and incubated for 30 minutes at 50 ^{o}C. They were then removed and peeled. At this point the peel fell easily away from the fruit and remaining rag and peel "strings" had been dissolved, or were easily washed away with a gentle stream of water. The segments, thus removed, were packed in plastic bags, either dry, or with juice.

Grapefruit sections prepared by pectinase treatment were dry and intact and had an excellent fresh fruit flavor. They were completely recovered as intact sections whereas those prepared by the conventional method were wet and appeared smaller due to a 30% to 40% loss of the juice vesicles remaining attached to the segment membranes. The cut sections also sustained a drip loss of over 10% after 3 days at 4.4 ^{o}C, whereas the new sections did not have this loss. The enzyme processed sections were unanimously preferred by an experienced taste panel for flavor, texture and appearance.

Some Potential Applications to Tropical Fruit

The discovery that vacuum infusion is an effective way of introducing materials into the interior or onto the surface of cut or peeled fruit suggests some other potential uses of this technique with regard to tropical fruit. The mango is one of the most widely grown fruits around the world, and yet a large portion of the crop is lost each year, due to anthracnose or other surface blemish problems. It is also a difficult fruit to peel due to its diversity of shapes and types. A simple skin-scoring enzyme diffusion process using pectinases or other enzymes might prove as effective for mangoes as for grapefruit. With mangoes, this could lessen the losses due to surface blemishes by providing a lower cost removal of the surface skin, and an easier approach to peeled mango products. This method should also be effective for removing peel from papaya, oranges, tangerines and other mandarin type oranges. Perhaps with lipases or other appropriate enzymes, it would be useful for peeling avocados.

Another potential application is the protection or preservation of color on cut surfaces of tropical fruit. Often the color fades or darkens, (usually turning brown), after fruit are cut and exposed to air, as in mangoes, papayas, peaches, apples, and bananas. The cut surfaces could be infused with substances like bisulfite or benzoate solutions to inhibit browning. With recent moves in the U.S. to disallow sulfite additives in foods however, the infusion of other antioxidant agents or browning inhibitors such as ascorbic acid (Vitamin C) might be more appropriate. The method also allows the incorporation of protective coatings such as gelatins, cellulose derivatives, etc. which are edible and relatively tasteless but form a protective layer over the cut surface. Similarly, protective coatings would retard flavor loss of volatiles and help maintain balanced flavor in delicately flavored tropical fruits, e.g. pineapples, papayas, and mangoes. Likewise, nutrients such as protein from gelatins, vitamins and minerals could be incorporated to enhance the nutritive value, or to prepare new dietary supplements.

Another possibility, already demonstrated in the studies of Bruemmer et. al (1976) is the incorporation of flavored or colored agents to change or enhance the surface color. Different juices could be colored or mixed with other juices of other colors and infused onto the surface and interior of cut fruit. For example, cut pieces of papaya could be infused with a blend of vitamin C to avoid darkening, orange juice (for flavor) and cherry juice (for color). The possibilities are only limited by the imagination and creativity.

Finally, an area where cut tropical fruits suffer as badly as any, the loss of textural quality, also affords an opportunity to apply the infusion method. Infusion of calcium citrate, chloride or other salts can help retain turgidity and crispness in cut surfaces.

The development of "mushiness" or "sogginess" in cut surfaces is a common trait observed with most fruit but is especially notable in papaya, mango, carambola, apples and peaches. Some of the coatings or other protective agents mentioned above could also be effective in this respect.

References

Bruemmer, J. H., Griffin A.W. and Onayemi, O. (1978) Sectionizing grapefruit enzyme digestion, Proc. Fla. State Hort. Soc. **91** 112-114

Larmond, E. (1967) Methods for sensory evaluation of foods, Can. Dept. Agric. Publ. #128A 15-16

Olsen, R. W. and Hill, E.C. (1964) Debittering of concentrated grapefruit juice with naringinase, Proc. Fla. State Hort. Soc. **57** 321-325

Roe, B. and Bruemmer, J.H. (1976) New grapefruit product: debitterizing albedo, Proc. Fla. State Hort. Soc. **89** 191-194

Sinclair, W. B. (1972) The Grapefruit, its composition, physiology, and products, Univ. of California, Div. Ag. Sci., 137

Ting, S. V. (1958) Enzymic hydrolysis of naringin in grapefruit, J. Agric. Fd. Chem. 6 546-549

Control of Southern Bacterial Wilt caused by *Pseudomonas solanacearum* (Smith) on Tomatoes in the Caribbean

G. Anais, J. Manyri and C. Vincent

Centre INRA Antilles-Guyane, Station d'Amelioration des Plantes, B. P. 1232, 97184 - Pointe-a-Pitre - Cedex

Southern bacterial wilt caused by *Pseudomonas solanacearum*, E.F. Smith, a soil borne bacterial pathogen, is one of the most threatening plant diseases in the Caribbean, and elsewhere in the hot humid tropics. The disease affects all solanaceous crops; eggplant, pepper, tomato and tobacco. No one control measure is effective against this disease, but varietal resistance combined with adequate cultural practices is effective. Though some soils were known to be resistant (black clay vertisols), the disease appeared recently in such soils. In 1966, a local wild tomato, CRA 66, was found resistant to the disease in Guadeloupe. CRA 66 was used in breeding for resistance which led to the release of cv. Caraibo, whose resistance has been assessed worldwide. Other resistant sources, such as PI 126408, Hawaii 7996 and introductions from Taiwan (AVRDC) and Japan, are used in our current breeding program to ensure stability of the resistance.

Keywords: Tomato; *Pseudomonas solanacearum*; Cultural practices; Genetic control

Introduction

Of all diseases found on solanaceous crops, and on tomatoes in particular, Southern bacterial wilt is the most widespread and the most threatening in the Caribbean. Yet this disease is still unknown by many growers and often confused with other diseases such as *Fusarium* or *Verticillium* wilts. Due to the extent and severity of *Pseudomonas* it is important to find effective means of control. The only one appears to be varietal resistance associated with appropriate cultural practices. For this reason, research is going on in several countries to breed *Pseudomonas* resistance in various solanaceous crops; the most extensive work being done on tomatoes.

Causal agent of bacterial wilt

Pathogen and hosts

Bacterial wilt was first described by E. F. Smith almost a century ago and the causal agent named as the bacterium *Pseudomonas solanacearum* (Smith, 1896). Three races of *P. solanacearum* are described:

Race 1, which affects solanaceous crops and other plants;
Race 2, which affects bananas and Heliconia and
Race 3, which affects potatoes and tomatoes.

Different pathotypes are known in each race. Differences in reaction to the pathogen according to locations can be attributed to differences in strains of the pathogen; thus, cultivar Floradel is considered as susceptible in Guadeloupe (100% mortality). This susceptibility has been confirmed in Florida by Sonoda (1977), but the variety is moderately resistant in Taiwan. Saturn and Venus, which are resistant in North Carolina, have shown 57% and 60% mortality respectively in Florida.

Infection and symptoms

The soilborne pathogen penetrates the roots during the emergence of young radicles or when the roots are damaged mechanically. The presence of nematodes enhances the penetration. The bacteria can also be propagated from plant to plant by clipping or by any inappropriate cultural practices such as moving of infested plants or infested soil, use of irrigation water, tools or machinery that were in contact with infested soil or plants. Nothing is known regarding the possibility of seed transmission. After penetration, the bacteria multiplies in the xylem vessels producing a browning which can be observed on a section of the stem. The youngest leaves become flaccid and wilt. On the bottom of the stem many protuberances appear. These signs may sometimes be attributed to Fusarium wilt. Diagnosis of the disease can be made by cutting off the stem after uprooting, and by dipping the root in a container full of water. On the cut section of the stem, a bacterial exudate of a white creamish colour will be seen. A sero-agglutination test can be applied directly to this exudate to confirm the diagnosis (Digat and Escudie, 1967).

Control Methods

Cultural practices

Development of the disease is closely related to cultural conditions. In conditions which favour a good physiological state of the plants, the infection remains latent and there are few symptoms. The infected plants constitute at this time a source of inoculum able to spread very rapidly in less favourable conditions. Several factors determine the spread of the disease, (Kelman, 1953).

Ferralitic soils (pH 5.5 - 6.5) are the most easily contaminated; very acid soils (pH 4.5 to 5.5) are less susceptible and calcareous soils (limestone/coral soils as found in Barbados, Grande-Terre in Guadeloupe and Antigua with pH greater than 7) are considered resistant (Berniac & Beramis, 1973). However, pH is not the main factor *per se*, but its association with varying calcium levels. The disease is increased by high temperature, rainfall and humidity.

Repetitive planting of solanaceous crops on the same soil leads to soil exhaustion and accumulation of inoculum in the soil to the point where even resistant varieties can be affected. Chemical control of *Pseudomonas* is difficult, costly and not very effective. The most effective means of control is crop rotation in association with soil improvement through mineral liming and organic amendments. Grafting tomatoes onto resistant solanaceous rootstocks is also effective. However, none of these means of control are fully satisfactory. It is necessary to associate them with resistant varieties.

Genetic control

Attempts in Florida to find resistant varieties of tomato date back to 1898 (Rolphs, 1898). In many areas of the world, including North Carolina, Florida, Guadeloupe, Martinique, Puerto Rico, Taiwan, Japan, South Africa and Australia, breeding work is going on to obtain resistant varieties (Anais, 1986; Kaan, 1977). Some have already been successful. The most common procedure is inoculation with the bacteria and testing in the field.

The genetic type of resistance most commonly found is a polygenic additive type such as in Caraibo derived from CRA66. However, dominant resistance is suspected in the Hawaii 7996 line.

Conclusion

With the breeding work going on, more and more resistant tomato varieties will be made available to the grower, but to ensure success good cultural practices must be employed.

References

Anais, G., (1986) Utilisation de la resistance varietale dans la lutte contre le fletrissement bacterien de la tomate. *Pseudomonas solanacearum* E.F. Smith, Bull. Tech. d'Inf. No. 4099/411, 439-448

Berniac, M., and Beramis, M., (1973) Etude des relations entre nature physico-chimique des sols en Guadeloupe et installation de *Pseudomonas solanacearum*, Nouvelles Maraicheres et Vivrieres de l'INRA aux Antilles No. 6 p. 54-62

Digat, B., and Escudie, A., (1967) Reconnaissance du fletrissement bacterien des solanacees aux Antilles Francaises, Phytiatrie-Phytopharmacie 16 189-197

Kaan, F., (1977) Etat actuel et perspectives d'utilisation de la resistance varietale au fletrissement bacterien *Pseudomonas solanacearum* E. F. Smith, Proc. XIVth Ann. Meeting CFCS p. 5

Kelman, A., (1953) The bacterial wilt caused by *Pseudomonas solanacearum* E. F. Smith. Tech. Bul. 99, North Carolina Agricultural Experiment Station

Rolphs, P. H., (1898) Bacterial tomato blight (*Bacillus solanacearum S.*), Report of the biologist and horticulturist, Bul. Agr. Exp. Sta. Ann. Report p. 30 - 31

Smith, E. F., (1896) A bacterial disease of the tomato, eggplant and irish potato, *Bacillus solanacearum* nov. sp., USDA Div. Veg. Phys. and Path. Bul. 12 128

Sonoda, R. M., (1977) Behaviour of tomato lines selected for resistance to southern bacterial wilt in a field naturally infested with the pathogen, Res. Rep. Agric., Research Center, Fact. Science, In: Hort. Abstr. 1978 48(9) Abstr. 8245

Diamondback Moth, *Plutella xylostella* (L.), control studies on cabbage in St. Kitts

G.C.. Yencho, T. Blanchette and E. Dolphin

SSMC/CARDI Integrated Pest Control Unit, P.O. Box 96, Basseterre, St. Kitts

Diamondback moth (DBM) (*Plutella xylostella* (L.)) insecticide efficacy and population dynamics studies were conducted in St. Kitts 1985 - 1987. Experiment station and "on-farm" trials were conducted in addition to monitoring small farmers cabbage crops for DBM and *Apanteles plutellae* population levels. Permethrin, *Bacillus thuringiensis* (Berliner), and pirimiphos-methyl, controlled DBM adequately. Peaks in A. *plutellae* parasitism coincided with a predominance of 4th instar larvae. The presence of high parasite populations delayed the time to first spray. A relative growth rate analysis of DBM populations indicated that growth rates are correlated to percent A. *plutellae* parasitism. It is hypothesized that parasitism levels exceeding 25-35% may control DBM populations.

Keywords: *Plutella xylostella;* Cabbage; *Apanteles plutellae;* St. Kitts; Population dynamics.

Introduction

The diamondback moth (DBM), *Plutella xylostella* (L.) is a cosmopolitan pest of crucifers. (Talekar et al., 1985). In the Caribbean, the DBM is well distributed and is a particularly serious pest of cabbage (Cook 1985). Alleyne (1978) reports that the DBM is the chief pest of cabbage in Barbados, while Yaseen et al. (1977) reported a similar situation in Trinidad. It is not unusual for an entire crop of cabbage to be destroyed by this insect in St. Kitts/Nevis.

Alam (1982 a & b) reports annual percent *A. plutellae* parasitism levels ranging from 17.9 - 68.9% in Barbados during the years 1971 - 1982. Van Driesche (1983) has determined that, percent parasitism alone, serves as a poor indicator of actual parasite impact unless host and parasite phenologies are described at the time of sampling. Yaseen et al. (1977) report *A. plutellae* parasitism levels of DBM feeding on cauliflower in Trinidad, increasing from zero to a maximum of 22.2% over a 3 week period after a release of 100 *A. plutellae*.

Much research still needs to be conducted on the dynamics of A. *plutellae* and DBM in integrated pest management programmes for cabbage. The authors are unaware of any Caribbean studies that have actually monitored a cabbage crop and its associated pest complex from seedling to harvest. The dynamics of the DBM/parasite system are complex and the effects of spray treatments compound problems when one intends to assess the ability of a *A. plutellae* to control DBM populations.

For the past two years, the St. Kitts Manufacturing Corporation/Caribbean Agricultural Research and Development Institute, Integrated Pest Control Unit (SSMC/CARDI-IPCU), has been conducting

DBM control studies "on-farm" and at CARDI's experiment station in St. Kitts. The objectives of these studies have been to determine:

1) The efficacy of selected insecticides for control of the St. Kitts DBM biotype;
2) The population dynamics of the DBM during the course of a typical cabbage crop
3) The pest/parasite interactions of the DBM and *A. plutellae*.

We believe that the DBM is regulated by *A. plutellae* under certain conditions. However, an integrated pest management approach must provide a suitable environment and enhance the parasite's ability to regulate DBM levels.

Materials and Methods

Three DBM control experiments were conducted during 1985 -1987. In addition, several small farmers' cabbage plots were monitored for DBM and parasite levels during the course of an entire crop. Experiments 1 and 2 were conducted at CARDI's experiment station. Both experiments consisted of 3 treatments replicated 4 times in a RCB design. Plot sizes were 2.3m x 3.2m and 2.3m x 2m for Experiments 1 and 2, and contained 35 and 25 plants respectively. Experiment 3 was conducted "on-farm" using a 4 x 4 RCB design. Plots were 3.7m x 3.2m and contained 56 plants each.

Diamondback moth and *A. plutellae* populations were monitored weekly for the entire cabbage crop in all experiments. Population estimates were derived from 10 randomly selected whole-plant counts in each plot. At each count, all stages of the DBM were recorded. Percent parasitism (%PA) was calculated using Van Driesche's (1983) formula:

$$\%PA = P/(H + P),$$

where P = number live *A plutellae* cocoons and
H = number DBM larvae (all stages)

Insecticides were applied by knapsack sprayer when populations averaged 2-3 DBM/head. In addition, in Experiment 3, a blanket treatment of malathion was used to control cabbage aphids, *Brevicoryne brassicae* (L). Yield measurements were taken for all experiments and in Experiment 2, a visual damage assessment was performed by an unbiased observer.

Regular monitoring was conducted in three commercial cabbage crops to gather additional data on pest/parasite interactions. At each site, 45 cabbage plants were randomly selected and pest/parasite levels recorded from approximately 1 - 2 weeks post-transplant, until harvest.

Results

Table 1 provides summarized results of average post-spray DBM/head counts for all experiments. In Experiment 1, insecticide treatments were applied twice. Pirimiphos-methyl, *Bacillus thuringiensis* (Berliner) and permethrin gave the best control, with post-spray counts of 0.8. 1.2 and 2.0 DBM/head, respectively. Diazinon was also selected for further evaluation.

The top performing insecticides from Experiment 1 plus cartap and PP-321 (Karate) were evaluated in Experiment 2. A total of three spray treatments were applied in this experiment. Pirimiphos-methyl, *B. thuringiensis* and permethrin were again top performers, with average post-spray counts of 0.5, 1.7, and 2.1 DBM/head, respectively. Cartap also provided excellent control with a post-spray average of 0.4 DBM/head. Karate, did not give good control.

Pirimiphos-methyl, *B. thuringiensis* and permethrin were retested "on-farm" in Experiment 3. Average post-spray populations were 0.8, 0.3 and 1.2 DBM/head, respectively, while Carbaryl, the standard "on-farm" control treatment, had a significantly higher post-spray average of 1.7 DBM/head.

Table I Efficacy of various insecticides for the control of *Plutella xylostella* diamondback moth on cabbage. Average of post application pest levels.

Compound	Rate (kg. ai/ha)	DBM population (counts/head)		
		Expt 1	Expt 2	Expt 3
Bacillus thuringiensis (var. Berliner) (3.2% wp)	0.84	1.2(±0.1)[1]a[2]	1.7(±0.5)ab	0.3(±0.04)a
Carbaryl 80% SP	2.2	-	-	1.7[3](±0.4)b
Cartap 50% SP	0.5	-	0.4(±0.1)a	-
Deltamethrin 2.5 EC	0.017	3.1(±0.3)b	-	-
Diazinon 60 EC	1.4	2.4(±0.2)ab	3.0(±0.2)bc	-
Fenvalerate 2.4 EC	0.2	2.1(±0.2)ab	-	-
Karate 70% w/v	0.35	-	9.4(±2.1)d	-
Malathion 5 EC	2.1	2.0(±0.4)ab	-	-
Permethrin 50% w/v	0.2	2.0(±0.4)ab	2.1(±0.4)ab	1.2(±0.3)ab
Pirimiphos-methyl	0.5	0.8(±0.2)a	0.5(±0.1)a	0.8(±0.2)ab
Control (no insecticide)	-	3.3(±0.4)b	4.3(±0.7)c	-

1) S.E. given in ( )
2) Means in same column followed by different letters are significantly different (Fisher's Protected LSD Test, P <0.05).
3) Control for "on-farm" trial

DBM pest/parasite population dynamics

Experiments 1 - 3: Populations of *A. plutellae* and DBM were present early in Experiments 1 and 3 (Figs. 1 and 3 respectively). Maximum percent parasitism was observed in these experiments 3 to 4 weeks after transplanting. In Experiment 2, *A. plutellae* was not recorded until 5 weeks after transplanting (Fig. 2) when DBM populations were beginning to increase rapidly and insecticide treatments were initiated. DBM populations were kept in check by *A. plutellae* up to 6 weeks in Experiment 1. The relatively high percent *A. plutellae* parasitism levels in Experiments 1 and 3 kept DBM populations under control for a longer period and delayed the time to first spray for up to seven weeks.

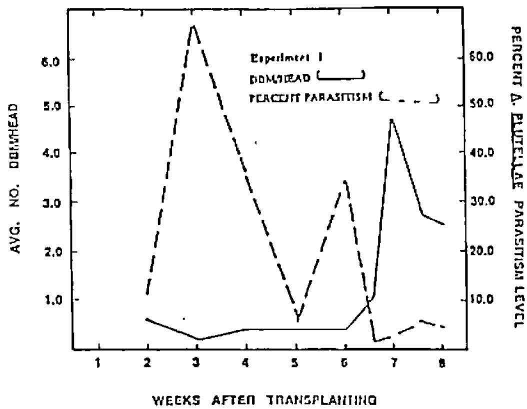

Figure 1 Percent parasitism and DBM/Head populations for insecticide-free control plots in Experiment 1

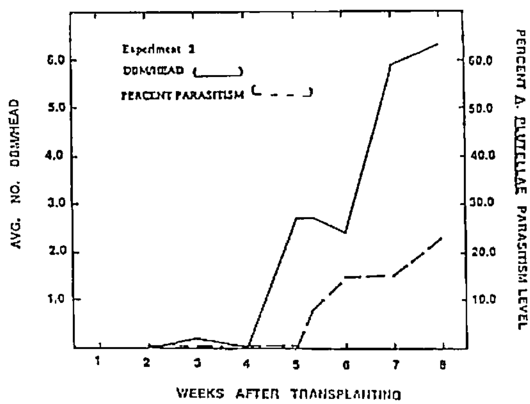

Figure 2 Percent parasitism and DBM/Head populations for insecticide-free control plots in Experiment 2

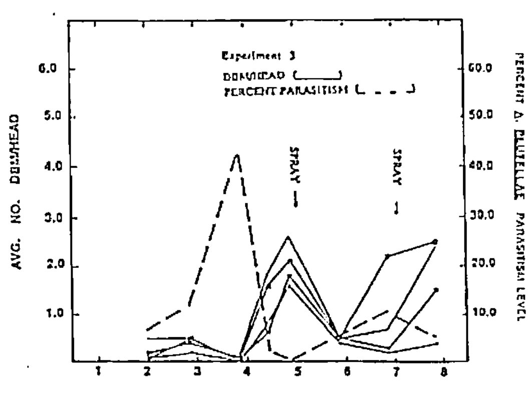

Figure 3 Percent parasitism and DBM/Head populations for all treatments in Experiment 3

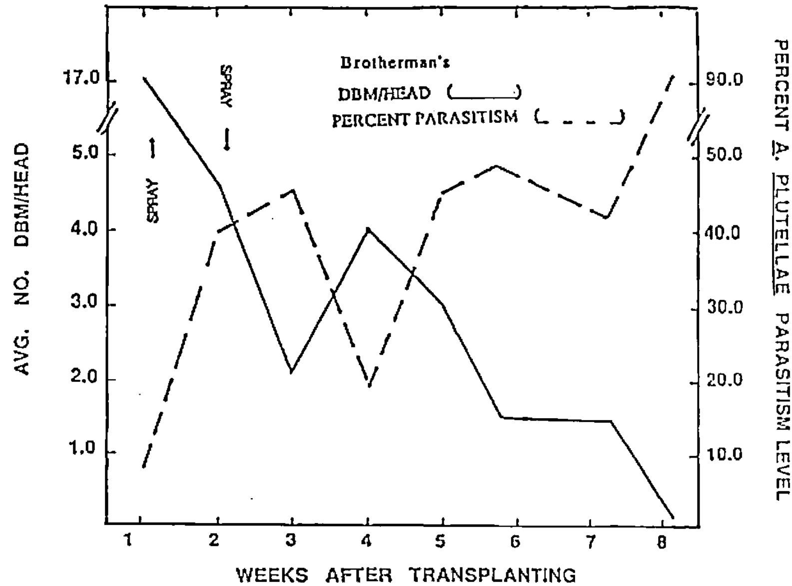

Figure 4 Percent parasitism and DBM/Head population levels at Brotherman's Farm, Green Acres, St. Kitts

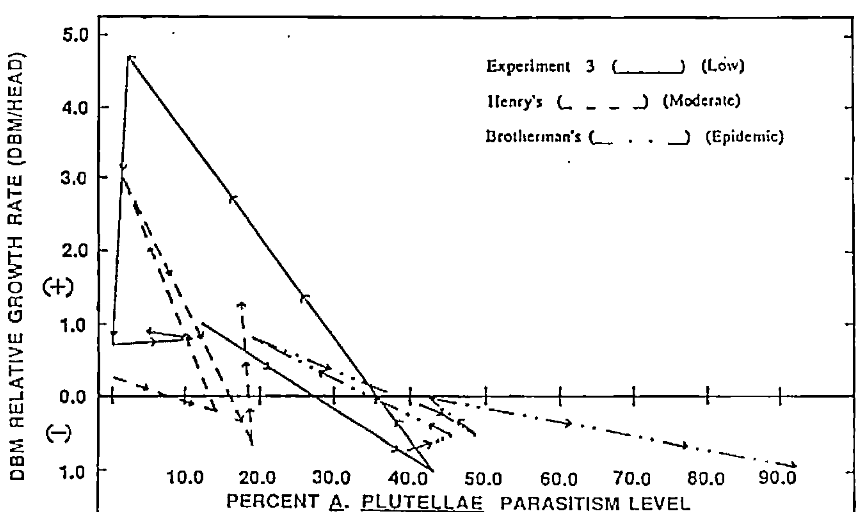

Figure 5 Results of a DBM relative growth rate analysis vs. percent *A. plutellae* parasitism. Analyses calculated for 3 sites. Points above the zero line represent increasing populations while those below are decreasing

Peaks in parasitism typically coincided with a predominance of 4th instar DBM larvae and fresh pupae since it is during this stage that *A. plutellae* larvae emerge from their host to pupate. Percent parasitism levels were highest when DBM populations were low (Figs 1 and 3) where a single *A. plutellae* pupa significantly affects the parasitism level. After the initial peak, parasitism levels generally declined due to a gradual increase in DBM numbers. As a second 4th instar DBM cohort began to appear, percent parasitism increased once again (Fig 1 - Week 6). Spray treatments in Experiment 3 may have prevented a similar occurrence in this trial. The decline in percent parasitism toward the end of Experiment 1 (Fig. 1) was probably due to a combination of similar factors since spray treatments were initiated in surrounding plots on 18 March (Week 7).

On-farm Studies: DBM and *A. plutellae* populations in commercial cabbage crops typically behaved in a manner similar to those in Experiments 1-3. Peaks in *A. plutellae* parasitism coincided with 4th instar DBM larvae, and populations that had low *A. plutellae* populations at the initiation of the crop, typically developed greater pest populations.

At one site (Brotherman's, Fig. 4), DBM populations were high approximately 3 weeks after transplanting, while parasitism was less than 10%. Two sprays of permethrin were applied within a 10-day period to reduce DBM levels, which were suppressed to approximately 2.2 DBM/head. Parasitism subsequently rose to ca. 45% 1 week after sprays were concluded. This peak in parasitism coincided with a flush of 4th instar DBM larvae. Parasitism subsequently averaged 48.2% and peaked at 92.0% during the next 5 weeks of the cabbage crop, while population declined to less than 1.0 DBM/head. Yield from this crop was unfortunately, very low due to the severe damage inflicted during the first few weeks of the crop.

DBM relative growth rate analyses

Berryman (1985) indicates that populations of two different species coexisting within the same geographic area (e.g. the DBM and *A. plutellae* in a cabbage field) may be viewed as two separate population systems which interact with each other, so that the numbers of one population modify the favourability of the environment for the other. By analyzing the growth rates of the competing populations, it is possible to determine the negative effects that each has upon the other and to estimate the equilibrium positions about which the populations fluctuate. These techniques can be used to determine the approximate parasitism levels that are required to maintain a pest population in check.

Percent parasitism plotted against the DBM relative growth rate (RGR) (= rate of DBM increase per capita) yields an additional measure of the significance of *A. plutellae* in regulating DBM populations. Figure 5 contains a plot of the DBM RGR vs. % parasitism for 2 farmer's cabbage plots and Experiment 3. The RGR was calculated as:

$$RGR = H_t - H_{(t-1)}/H_{(t-1)} \quad \text{(Berryman, 1985)}$$

where H is the DBM population/head at times t and (t-1),

The magnitude of the RGR determines the rate of increase or decrease of the DBM population. By plotting RGR vs. percent *A. plutellae* parasitism at time t, one obtains an estimate of the parasitism level that is required to maintain DBM populations at a zero growth rate (RGR = 0).

A visual, "best fit" line for Figure 5, suggests zero RGR is attained at approximately 30% parasitism by *A. plutellae*. Figures 1-4 support this value as they show that percent parasitism levels exceeding 30% typically resulted in a decline in DBM populations. The results therefore suggest that if *A. plutellae* parasitism levels can be maintained above 25 - 35%, adequate DBM control will result.

Conclusions

Our studies have shown that *B. thuringiensis*, cartap, permethrin and pirimiphos-methyl provide adequate control of the DBM in St. Kitts/Nevis. However, it is likely that persistent use of these compounds will lead to the development of insecticide resistance in the near future. Already, we have lost a number of insecticides for the control of DBM in the Caribbean and continued use of these compounds will contaminate our fragile environments further.

A. plutellae is distributed throughout the Caribbean, can readily establish itself and is easy to rear and release. Our studies indicate that sustained percent parasitism levels of 25-35% can control DBM populations. The Asian Vegetable Research and Development Center (AVRDC) has reported similar results in Taiwan where releases of *A. plutellae*, *Diadegma eucerophage* (Hortsman), and *B. thuringiensis*, gave effective DBM control without the use of chemical insecticides in cabbage (AVRDC, 1985). Further, DBM control studies should be conducted in the region to test the hypotheses needed for establishing an effective biological control program that incorporates *B. thuringiensis*, limited use of chemical insecticides at reduced rates, and parasites for the control of the DBM.

Acknowledgments

The staff of the SSMC/CARDI-IPCU Integrated Pest Control Unit wish to acknowledge the farmers Dudrige Huggins, Arthur Henry and Ben Phipps for their cooperation and support with these studies.

References

Alam, M.M. (1982a) Cabbage pests and their natural enemies in Barbados, W.I.. Paper presented at the 18th Meeting of the Caribbean Food Crops Society, August 1982, 30p

Alam, M.M. (1982b) Integrated Pest Control Unit (CARDI/BSIL/BBIL) annual report, (Unpublished), 67p

Alleyne, E.H. (1978) Effect of selected insecticides on cabbage insects in Barbados. Min. of Agric., Food & Consumer Affairs, 15p

AVRDC (1985) Progress Report Summaries, Asian Vegetable Research and Development Centre, Taiwan

Berryman, A.A. (1985) Population systems, a general introduction, Plenum Press, N.Y. 222p

Cook, M.J.W. (1985) A review of biological control of pests in the Commonwealth Caribbean and Bermuda up 1982. Commonwealth Agricultural Bureaux, Slough, United Kingdom, 218p.

Talekar, N.S., Yang, H.C., Lee, S.L., Chen, B.S. and Sun L.Y. (1985) Annotated bibliography of diamondback moth. The Asian Vegetable Research and Development Center, Taiwan.

Van Driesche, R.G. (1983) Meaning of percent parasitism in studies of insect parasitoids, Environ. Entomol. 12 1611-1622.

Yaseen, M., Barrow, R.M. and Katwary G.S., (1977) Preliminary studies of the development of a pest management programme for cruciferous crops in Trinidad and Tobago, Paper presented at the 14th Meeting of the Caribbean Food Crops Society, June 1977, 12p

Arrowroot Leaf-Roller - a serious pest of Arrowroot in St. Vincent

M. M. Alam

CARDI, P. O. Box 64, Cave Hill Campus, Barbados

In St. Vincent, arrowroot leaf-roller *Calpodes ethlius* (Cramer) is the major pest of arrowroot (*Maranta arundinacea*), and causes a reduction in the starch yield of the rhizomes. During the period 1982 - 1984, it was found that the pest was more numerous between July and November, the infestation was slightly lower in the North of Dry River and the two varieties "Banana" and "Creole" grown in the island were equally susceptible to the pest. The two larval parasites, *Ardalus (=Elachertus)* sp. and *Bracon* sp., (despite their secondary parasites) are the most important biocontrol agents which keep the pest under reasonable control. The "Jack Spaniard" *Polistes cinctus cinctus*, *Polybia occidentalis grenadensis*, *Anoplius* sp. and *Prionyx thomae* play a significant role in the reduction of the pest populations, particularly during outbreaks and should be encouraged.

Keywords: *Calpodes ethlius*; Arrowroot; Biocontrol; St. Vincent

Introduction

In the Lesser Antilles, arrowroot (*Maranta arundinacea* L.) is grown on a large scale only in St. Vincent, where a high quality starch is extracted from the rhizomes. The most important pest of the crop is the "arrowroot leaf-roller" *Calpodes ethlius* Cramer. The larvae feed on the leaves, eating all but the mid-ribs. During severe outbreaks, the crop is completely defoliated and such damage reduces the starch reserves in the rhizomes. Heavy infestations necessitate the use of pesticides, which apart from killing a large number of natural enemies also increase the cost of production.

The female lays milky-white eggs, singly, on the upper surface of the leaves, which hatch in 5 to 6 days. The dull-green larvae, with head distinctly marked off from the body, feed for a short time on the leaf-surface and then fold over the edge of the leaf to form a shelter under which they continue to feed. As the larvae grow in size, they enlarge the leaf-folds. The larvae become fully grown in 15 to 20 days. Pupation occurs in the leaf-fold or in litter. The pupal stage lasts for 9 to 12 days.

The pest is found in the Greater and Lesser Antilles and also feeds on Indian shoot (*Canna coccinea*) and other *Canna* spp.

Background

At the start of the *C. ethlius* project in St. Vincent, a search for its natural enemies was made in the Eastern Caribbean islands (Table I). Generally, it was found that the pest preferred to lay more eggs on *Canna* spp., even when arrowroot was growing close by. Also parasitism both on eggs and larvae was higher on *Canna* than on arrowroot. It might therefore be concluded that if *Canna* is a preferred host plant for arrowroot leaf-roller, and if levels of parasitism are also higher, it is worth planting *Canna* round arrowroot fields, to encourage high parasitism and also to keep the parasite populations fairly high during the arrowroot crop time.

Table 1 List of natural enemies of *Calpodes ethlius* recorded in Trinidad, Barbados, Guyana, Puerto Rico, St. Vincent and Cuba.

	Parasite	Stage Attacked	Host Plant
Trinidad			
Trichogrammatidae	*Xenufens ruskini* Girault	Eggs	*Canna* spp.
Encyrtidae	*Ooencyrtus* spp. (2)	Eggs	*Canna* spp.
Eulophidae	*Ascrysocharis* sp.	Eggs	*Canna* spp.
	Ardalus (=*Elachertus*) sp.	Young larvae	
	Horismenus sp.	Secondary parasite of *Ardalus* sp.	*Canna* spp.
Scelionidae	*Telenomus* sp.	Eggs	*Canna* spp.
Braconidae	*Alphomelon* (=*Apanteles*) sp.	Young to medium stage larvae (solitary para.)	*Canna* spp.
	Apanteles marginiventris Cresson	Young to medium stage larvae (solitary para.)	*Canna* spp.
	Apanteles talidicida Wilkinson	Young to medium stage larvae (gregarious para.) Also attacks *Quinte* sp. (*Hesperidae*)	*Canna* spp.
	Apanteles ruficollis (Cameron)	Young to medium stage larvae (gregarious para.)	*Canna* spp.
	Microbracon sp.	Medium to full-grown larvae	Arrowroot
Elasmidae	*Elasmus maculatus* Howard	Secondary parasite of *A. ruficollis*	
Eupelmidae	*Anastatus* sp.	Eggs	*Canna* spp.
Chalcididae	*Brachymeria annulata* (F.)	Pupae	Arrowroot
Tachinidae	*Achaetoneura nigripalpis* Ald.	Pupae	Arrowroot
	Exoristoides urichi Ald.	Pupae	Arrowroot
Barbados			
Encyrtidae	*Ooencyrtus* sp.	Eggs	*Canna* spp.
Aphelinidae	*Marietta* sp.	Secondary parasite of *Ooencyrtus* sp.	
Eulophidae	**Ardalus* (=*Elachertus*) sp.	Young larvae (introduced from St. Vincent). Well established against *C. ethlius*.	*Canna* spp.
Guyana			
Trichogrammatidae	*Trichogramma* sp.	Eggs of a Hesperid	*Canna* spp.
Dominica			
Encyrtidae	*Ooencyrtus* sp.	Eggs	*Canna* spp.
Eulophidae	*Horismenus* sp.	Young larvae. Probably a primary parasite	*Canna* spp.
Puerto Rico			
Chalcididae	*Brachymeria incerta* Cresson	Pupae	*Canna* spp.
Eulophidae	*Euplectrus* sp.	Young larvae	*Canna* spp.
Trichogrammatidae	*Xenufens ruskini* Girault	Eggs	*Canna* spp.

Table 1 (ctd.)

	Parasite	Stage Attacked	Host Plant
St. Vincent			
Trichogrammatidae	*Trichogramma* sp.	Eggs	Arrowroot
Scelionidae	*Telenomus* sp.	Eggs	Arrowroot
Eulophidae	*Ardalus* (=*Elachertus*) sp.	Young larvae	Arrowroot
	Horismenus sp. nr. *fraternus* (Fitch)	Secondary parasite of *Ardalus* sp.	
Braconidae	*Alphomelon* (=*Apanteles*) sp.	Young to medium stage larvae (solitary para.)	Arrowroot
	Bracon sp.	Medium to full-grown larvae (solitary para.)	Arrowroot
Ceraphronidae	*Aphanogmus* (=*Ceraphron*) sp. prob. *fijiensis* (Ferriere)	Secondary parasite of *Alphomelon* and *Bracon*	
Chalcididae	*Brachymeria annulata* (Fab.)	Pupae	Arrowroot
	Spilochalcis sp.	Secondary parasite of *Alphomelon*, *Tachinids* and *Sarcophagids*	
Tachinidae	*Eucelatoria* sp. (*armigera* group)	Larval-pupal parasite	Arrowroot
	Sporgosia (=*Phorocera*) *floridensis* (Townsend)	Larval-pupal parasite	Arrowroot
Sarcophagidae	*Sarcodexia innotata* (Walk.)	Larval-pupal parasite	Arrowroot
	Sarcophaga lambens Wiedemann	Larval-pupal parasite	Arrowroot
Vespidae	*Polistes* (=*Aphanilopterus*) *cinctus cinctus* (Lepeletier)	Larvae (predator)	Arrowroot
	Polybia (=*Myraptera*) *occidentalis grenadensis* Richards	Larvae (predator)	Arrowroot
Pompilidae	*Anoplius* sp.	Larvae (predator)	Arrowroot
Sphecidae	*Prionyx thomae* (Fab.)	Larvae (predator)	Arrowroot
Reduviidae	*Arilus gallus* (Stal)	Eggs (predator)	Arrowroot
	Zelus longipes (L.)	Eggs (predator)	Arrowroot
Formicidae	Unidentified ants	Eggs (predator)	Arrowroot
Virus	Polyhedral virus	Puparia of *Tachinids* and *Sarcophagids*	Arrowroot
Cuba			
Eulophidae	*Euplectrus* sp.	Larval parasite	Arrowroot
Trichogrammatidae	*Xenufens ruskini* Girault	Egg parasite	Arrowroot

In St. Vincent, egg-parasitism by *Telenomus* sp. and *Trichogramma* sp. is moderate. In Barbados, Trinidad and Dominica, *Ooencyrtus* spp. are quite common, attacking a high percentage of eggs, and are therefore good candidates for introduction into St. Vincent. Amongst the larval parasites, *Ardalus* (=*Elachertus*) sp. and *Bracon* sp. play a significant role in the control of *Calpodes* in St. Vincent. These are sometimes attacked by secondary parasites, the population of which may be fairly high in individual fields, and so restrict the populations of the primary parasites. To overcome this problem, the primary parasites were bred in the laboratory, and releases were made in heavily infested fields, with satisfactory results.

A number of *Apanteles* spp. recorded in Trinidad were considered for introduction into St. Vincent, but due to very low populations of these parasites in Trinidad and also due to the presence of secondary/hyperparasites in St. Vincent, these were not found suitable.

The populations of Tachinids (*Eucelatoria* sp. [*armigera* group] and *Spoggosia floridensis*); and Sarcophagids (*Sarcodexia innotata* and *Sarcophaga lambens*), were not high in St. Vincent. This was probably due to the high incidence of a Polyhedral virus infecting the puparia of these insects. In Trinidad also, the parasitism levels of Tachinid flies, *Achaetoneura nigripalpis* and *Lxoristoides urichi*, were not encouraging.

Survey Findings

Levels of infestation recorded during the year 1983 are given in Table 2. From January to November, the monthly range of leaf infestations was 4 to 29 percent, (average 14 percent). The time of highest infestation was between July and November. Individual field plant infestation ranged from 1 to 29 percent, the lowest being in February and the highest in November. Observations in different arrowroot growing areas were also taken. Details are given in Table 3, which shows that the lowest level of infestation was in the area north of Dry River, while there was no significant difference in the other three areas.

Table 2 Percentage leaves damaged by *Calpodes ethlius* during 1983 in St. Vincent

Month	No. fields examined	No. plants examined	Percent leaf infestation
January	1	50	6
February	12	600	4
March	17	850	10
April	7	350	10
May	20	1,000	11
June	12	600	9
July	7	350	17
August	7	350	10
September	22	1,100	19
October	16	800	29
November	11	550	28
Total	132	6,600	14

Table 3 Percent leaf infestation in different arrowroot growing areas in St. Vincent

Area	No. fields examined	No. plants examined	Average % leaf damage/field
North of Dry River	23	1,150	7
Mt. Grennon to Dry River	67	3,350	18
Windward up to Mt. Grennon	38	1,900	17
Leeward	4	200	14

Varietal susceptibility

There are only two arrowroot varieties - "Banana" and "Creole" -grown in St. Vincent. Of these, "Creole" produces some 1,500 lbs. tubers per acre and "Banana" 2,000 lbs. per acre. The higher weight of Banana is due mainly to the higher water content of the tubers, but they are equal in starch content. The levels of leaf infestation by *C. ethlius* on "Creole" and "Banana" varieties in St. Vincent during 1983 is given in Table 4. The data shows that there was no significant difference in the levels of infestation on these two' varieties.

Biological control

Simmonds (1950, unpublished report) listed a number of parasites and predators attacking eggs, larvae and pupae of *C. ethlius* in St. Vincent. He also reported some natural enemies from other Caribbean territories.

Table 4 Percent leaf infestation by C. ethlius on variety "Creole" and "Banana", in St. Vincent

Variety	No. fields examined	No. plants examined	Average No. leaves/plant	Percent leaf infestation
Creole	82	4,100	5.5	13
Banana	17	850	5.9	19

During the studies carried out between August 1982 and February 1984, a large number of parasites and predators were recorded in St. Vincent. Observations were taken on their abundance, levels of parasitism during different times of the year and their impact on the pest populations. Records of secondary parasites attacking these natural enemies were also kept. Collections of egg and larval parasites in other Caribbean islands were also made. (Table 1). The natural enemies recorded in St. Vincent, and their level of parasitism are discussed below.

Egg parasites

Telenomus sp. and *Trichogramma* sp. were the two egg-parasites recorded. Between January and December 1983, out of 1,935 eggs collected, 146 (7.5 percent) were parasitised. The former species was more consistent and the parasitism was relatively higher than by *Trichogramma* sp.

Larval parasites

The larvae of *C. ethlius* are parasitised by *Alphomelon (=Apanteles)* sp., *Ardalus (=Elachertus)* sp. and *Bracon* sp.; and the pupae by *Brachymeria annulata* Fab., *Eucelatoria* sp. (*armigera* group) *Spoggosia (=Phorocera) floridensis* (Townsend), *Sarcodexia innotata* (Walk.) and *Sarcophaga lambens* Wiedemann. *Alphomelon (=Apanteles)* sp. - a solitary larval parasite - attacked 2 to 5 percent larvae in individual fields. Some 5 percent cocoons of *Alphomelon* sp. were parasitised by *Aphanogmus* sp. prob. *fijiensis* and *Spilochalcis* sp. *Ardalus (=Elachertus)* sp. - a gregarious ecto-larval parasite -

attacks first and second instar larvae of *C. ethlius*. During 1983, out of 1,770 larvae collected from different parts of the island, 661 or 37.3 percent, were parasitised. The range of parasitism was 0 - 40 percent. Some 13 percent pupae of *Ardalus* sp. were attacked by a secondary parasite, *Horismenus* sp. nr. *fraternus*.

Bracon sp. - a solitary larval parasite - attacks medium sized *Calpodes* larvae. Out of 1,770 larvae collected, 1,062 or 60 percent, were parasitised by *Bracon* sp. Some 15 percent of cocoons of *Bracon* sp. were attacked by *Aphanogmus (=Ceraphron)* sp. prob. *fijiensis* (Ferriere). *Brachymeria annulata* Fab. - a pupal parasite - was not very common in the field. Occasionally one to two percent of pupae were found parasitised. *E.* sp. (armigera group) and *S. (=P.) floridensis* - The parasitism by these two Tachinids was erratic. Between August 1982 and February 1984, from 272 pupae collected, 7 were parasitised by the two species. *S. innotata* and *S. lambens*: of 272 field-collected pupae 25, or 9.2 percent were parasitised.

One percent pupariae of the Tachinids and Sarcophagids were attacked by a secondary parasite *Spilochalcis* sp. During August and September 1983, 7 percent pupariae of Sarcophagids and 35 percent of Tachinids were infected by a Polyhedral virus. From August to December 1982, the total parasitism by Hymenoptera and Diptera ranged from 11.8 - 57.5 percent, averaging 33.7; from January to December 1983, 6.7 - 60.1 percent, averaging 23.4, and during January and February 1984, 23.7 - 60 percent, averaging 34.

Predators

The Jack Spaniard wasp *Polistes (=Aphanilopterus) cinctus cinctus* (Lepeletier), and *Polybia (=Myraptera) occidentalis grenadensis* Richards become very active during heavy attacks of *C. ethlius*. The wasps attack the larger larvae in their leaf-rolls, biting their heads off after a struggle and gnawing off only a small part to take away. The wasps tend to congregate where infestations are highest and are more efficient as control agents under these circumstances than when the larval population is low. Thus, although they help in diminishing an attack once started, they do little to prevent its occurrence. However, it would certainly be an advantage to encourage the wasps by providing nest-building sites. This has been done in the past, but is offset by the stings sustained by field workers who destroy the nests. The other predatory wasps recorded in the fields were *Anoplius* sp. and *Prionyx thomae* (Fab.). In the field, some of the eggs were eaten by ants, probably also by some predaceous bugs, viz. *Arilus gallus* (Stal) and *Zelus longipes* (L.) (Reduviidae).

Brachymeria ovata Say, a pupal parasite of cabbage white butterfly *Ascia monuste* L. was bred in the laboratory in Barbados on the pupae of arrowroot leaf-roller, and releases were made in arrowroot fields in St. Vincent, but the parasite was not recovered. During heavy attack the farmers were advised to spray the crop with Decis (R) 1 tsp/41 (US gal.) or Ambush (R) 1 tsp/41 (US gal).

Acknowledgments

I wish to thank Drs. F. J. Simmonds and F. D. Bennett, of the Commonwealth Institute of Biological Control, Trinidad, for the list of natural enemies recorded in Trinidad and Puerto Rico, and Dr. Lloyd Knutson, United States Department of Agriculture, Maryland, for the identification of parasites and predators recorded in St. Vincent, Barbados, Guyana, and Dominica. I also thank Mr. I. H. Gibbs and Mr. B. Cox (Peace Corps Volunteer) for collecting the data in the field.

Management of the root-knot nematode (*Meloidogyne incognita*) in carrots by intercropping

Frank D. Mc Donald

CARDI, Arrowroot Association Building, Kingstown St. Vincent, W.I.

Bernard Francois

CARDI, P.O. Box 971, Castries, St. Lucia, W.I.

The management of root-knot nematode (*Meloidogyne incognita*) in carrot was studied over a three-year period in St. Vincent. Onion (*Allium cepa*), chive (*Allium schoenoprassum*), corn (Zea mais) and eddoe (*Colocasia esculenta* var. *antiquorum*) were found effective in reducing root-knot nematode population densities in the soil. Cropping systems were then designed and tested for their effectiveness in reducing nematode population densities and galling damage in carrot (*Daucus carota*). Cabbage-carrot, chive-carrot and onion-carrot were found to be the most effective. Cabbage-carrot and chive-carrot significantly reduced unmarketable yields and root damage in carrots as compared to carrot monoculture. Root gall index was positively correlated with unmarketable yields. Economic analysis showed that the two intercropping systems were more efficient in the use of land, labour and capital resources than carrot monoculture, and that the overall farm income is greatly increased by intercropping carrot with cabbage or chive.

Keywords: Carrot; *Meloidogyne incognita*; Intercropping; Chive; Cabbage

Introduction

Crop rotation has long been identified as an efficient means of controlling several important nematode pests (Hutton et al., 1982; Netscher, 1985). More recently, intercropping or multiple cropping as a means of managing nematode pests has attracted the attention of researchers world-wide, (Adams et al., 1971; Perrin, 1977). Trembath (1976) produced the first evidence from Australia that nematodes and diseases may be impeded when both hosts and non-hosts are grown in mixtures. Several other workers (Brodie & Murphy, 1975; Mc Donald, 1985b) have shown that multiple cropping harbours significantly fewer nematodes than monocultures. This has been attributed to a differential susceptibility to pests, pathogens and nematodes (Altieri, 1983). Work has included studies in the tropics to identify those systems which most effectively control plant nematodes, including the root-knot nematode (Egunjobi, 1985; Rhodes, 1985).

Carrot production in St. Vincent has been on the decline since 1976. Losses during the period 1976-1978 were estimated to be between 55% and 60% (Barker & Henderson, 1985), which reduced annual revenue by over EC$ 500,000 (Sing,1979). This resulted in a significant reduction in foreign exchange earnings, and at the regional level, disrupted production of a major carrot producer and led to increased importation of carrots from extra-regional sources. This decline in

This paper is an output of the CARDI/USAID Farming Systems Research and Development Project #538-0099

production was attributed to the root-knot nematode (RKN) (*Meloidogyne incognita* (Kofoid & White, Chitwood), and to the fungal pathogen *Sclerotium rolfsii*. Singh (1982) subsequently confirmed *M. incognita* as the major contributor to the decline in carrot yield and quality in St. Vincent. This paper presents results of a 3-year study, using a systems approach, to manage the root-knot nematode in carrots in St. Vincent including an economic analysis of the carrot intercropping systems investigated.

Materials and methods

Studies were conducted on farms in the Leeward and Windward districts of St. Vincent over 3 years, using a farming systems methodology developed by CARDI (CARDI, 1983). The objective of the first year's experiment was to identify crops which reduce *M. incognita* populations in the soil. Two farms were selected in Rosehall, North Leeward, a major carrot producing region. The two farms had a similar history of heavy RKN infestations, and were in the same agro-ecological zone. The soils were both Belmont gravelly, sandy loams (Typic Hapludolls, loamy, skeletal, mixed) (Ahmad, 1981).

Six crops; Onion (*Allium cepa* L. cv. Texas Yellow Grano), chive (*Allium schoenoprassum* L.), corn (*Zea mays* L.), eddoe (*Colocasia esculenta* (L.)Schott cv. *antiquorum*), bean (*Phaseolus vulgaris* L. cv. Kentucky Wonder), and carrot (*Daucus carota* L., cv. Danvers Half Long) were planted in individual plots 3m x 6m with 0.5m pathways separating each plot. There were four rows per plot. The six treatments were arranged as randomized complete blocks (RCBs) with three replicates per farm.

In the second year, the objective was to test the influence of four cropping systems, including pure stands of carrot on the suppression of the RKN populations. On the same two farms, three intercrop systems; onion-carrot, chive-carrot and cabbage-carrot, were established on plots 5.5m x 3.0m. There were four ridges per plot. In the intercropped plots, each ridge had two rows of carrot, and one row of the intercrop. In the purestand plots, there were three rows of carrots per ridge. Cabbage seedlings were planted 45 cm apart. Chive setts, onion and carrot were sown to give an intra-row spacing of 15 cm, after the onions and carrots were thinned. The four treatments were replicated four times in a RCB design on each farm.

Five farms were used in the third year. Four were in the North Leeward district and the other at Biabou, Windward. All five farms were plagued with RKN damage in carrots. The soil at Biabou was a Greggs loam and clay loam (Typic Dystrandept, Ahmad 1981). Two selected intercropping systems, cabbage-carrot and chive-carrot were tested and compared with purestand carrot. Plot size was 6m x 5m with 60cm separating each plot. There were five ridges per plot. The cabbage and chive intercrops were planted two weeks before seeding the carrots. Planting was completed between November 1985 and mid-January, 1986. Crop management included fertilizing, manual weed control and insect pest control, as required (Mc Donald, 1985a). The procedures for nematode sampling and processing (Mc Donald (1985a) and extraction (Gowen and Edmunds, 1973) were the same in all experiments.

Analyses of variance were performed on transformed [$Y = \log_{10}(x+1)$] pre-plant density counts. Population density counts after four months of crop growth were adjusted for the pre-plant counts, using co-variance analysis. Standard procedures for analysis of variance were used. Correlation co-efficients between un-marketable carrot yields and mean root gall indices and between marketable carrot yields and mean root gall indices were calculated. The economics of the intercropping systems was analysed and compared with carrot monoculture using partial budgeting.

Table 1 Mean soil populations of *M. incognita* juveniles, after four month's growth of six selected crops in 1984[1)]

Farm	Crops											
	Onion		Chive		Corn		Eddoe		Beans		Carrots	
	Preplant	4Mo[2)]	Preplant	4Mo	Preplant	4Mo	Preplant	4Mo	Preplant	4Mo	Preplant	4Mo
1	67	27	10	3	40	22	40	25	30	72	47	125
2	60	12	50	30	30	27	17	7	73	140	33	142
Means	64	20	30	17	35	25	29	16	52	106	40	184
L.S.D.(P=0.05) = ±0.9												

1) Data were transformed ($\log_{10}(x+1)$) for analysis of variance and calculating LSD values. Population density counts were based on means of three replicates per farm. Soil sample size = 200 cm^3.
2) 4Mo = sampling after 4 months of crop growth

Table 2 Effects of four cropping systems on mean soil population densities of *M. incognita* juveniles, per 200cm^3 of soil in 1985[1)]

Cropping system	Nematode counts		
	Preplant	Postplant[2)] (Unadjusted)	Postplant[2)] (Adjusted for preplant count)
Onion-Carrot	125	60	69
Cabbage-Carrot	149	104	109
Chive-Carrot	208	129	115
Carrot (purestand)	188	445	417
C.V.(%)	9.5	9.62	8.74
L.S.D (P = 0.05)	N.S	0.22	0.20

1) See notes for Table 1 regarding statistical treatment. Means based on 4 replications/farm with 4 observations
2) Post-plant count after 4 months' growth of crops.

Results

In 1984 and 1985 there were significant differences ($P = 0.05$) among means of post-plant population densities of *M. incognita* with highest levels in carrot and bean (Table 1). The differences among mean post-plant population counts adjusted for initial counts were also highly significant ($P = 0.01$) (Table 2). In 1985, yields of marketable carrots under the four cropping systems were not significantly different, but reductions in the root gall index (RGI) under the intercrops were significant (Table 3). In 1986, there were no significant differences among cropping systems in marketable carrot yield, but treatment differences were significant for unmarketable yield (Table 4). Unmarketable yields for the chive-carrot, cabbage-carrot and sole-carrot systems were respectively, 19.2%, 21.8% and 22.3% of the total carrot yield

Table 3 Effect of four cropping systems on marketable yield and root galling of carrot at four farms in 1985

Cropping System	Yield of Carrots (t/ha)	Root Gall Index[1]
Onion-Carrot	6.73	1.9a[2]
Cabbage-Carrot	5.52	1.9a
Chive-Carrot	8.87	1.3a
Carrot (alone)	7.09	3.1b
C.V. (%)	36.5	30.1

1) Mean root gall index based on: 0 = no root infected; 1 = few small galls; 2 = many small galls; 3 = a few large galls; 4 = root with many large galls; 5 = root with knotted growth.
2) Means followed by a common letter are not significantly different (at $P = 0.05$) as determined by Duncan's Multiple Range Test.

Table 4 Effect of cropping systems on yields and root galling of carrot. Mean of five farms in 1986 (after Mc Donald, 1986).

Cropping system	Yield of carrots (t/ha)			Root Gall Index[1]
	Total	Marketable	Unmarketable	
Cabbage-Carrot	11.58	9.05	2.53	2.1
Chive-Carrot	11.58	9.35	2.23	1.8
Carrot (purestand)	14.05	10.91	3.14	2.8
C.V. (%)	21.1	25.4	26.1	

1) Mean root gall index as for Table 3.

Significant positive correlations were observed between the mean RGI and unmarketable yield ($r = 0.59^*$) but RGI was not significantly correlated with marketable yield. The RGI ranged from 1.7 to 2.8 among the five farms.

The mean costs and returns per hectare in cabbage-carrot, chive-carrot and purestand carrot systems are presented in Table 5. The returns to land, risk and management per unit labour and capital were compared. The highest returns to these two factors were EC$23,447 per ha from the cabbage-carrot treatment, followed by EC$13,342 per ha for the chive-carrot treatment. Purestand carrots gave the lowest returns with $9,350 per ha. Although there was a 33% reduction in the carrot population in the two intercrop systems compared to purestand carrots, the reduction in the income derived from carrots in the cabbage-carrot and chive-carrot systems was only (18% and 13%, respectively. A comparison of costs and returns from the intercrops themselves is presented in Table 6.

The intercropping systems of cabbage-carrot and chive-carrot provided higher returns per unit of all resources than purestand carrot. Thus, the intercropping systems are more efficient utilizers of these resources. Edje (1970) also showed that mixed cropping is more efficient than monocropping in terms of total productivity per unit area of land and utilization in the ecosystem. The analysis also shows that the benefits from the intercrops more than covered the cost of establishing and maintaining them in the system and that the overall farm income is increased by intercropping carrot with cabbage or chive.

Table 5 Mean costs and returns per hectare in three carrot cropping systems in 1986

	Cropping system		
	Cabbage/ Carrot	Chives/ Carrot	Purestand Carrot
Gross returns[1]			
Carrot	19,800	21,120	24,200
Cabbage	19,717	-	-
Chives	-	8,469	-
Total returns	39,517	29,589	24,200
Materials costs	891	858	776
Returns to land, labour, risk and management	38,626	28,731	23,424
Labour costs	15,179	15,389	14,074
Returns to land, etc.			
Land ($/ha)	23,447	13,342	9,350
Labour ($/hr)	3.7	2.1	1.6
Capital ($/$)	26.3	15.6	12.0

1) Farm gate prices (EC$ per Kg) for carrot, cabbage and chive were respectively: $1.76, $3.30 and $1.65.

Acknowledgments

The authors wish to thank Dr. J.L. Hammerton for his guidance in completing the manuscript; Mr. F.B. Lauckner, Biometrician, CARDI, for assistance with the statistical analysis. We would also like to express our sincere appreciation for the assistance of Miss. D. Smart who typed the manuscript.

Table 6 Costs and returns from intercrops in carrot-intercrop systems

	Intercrop	
	Cabbage	Chive
Costs[1)]	4,613	4,794
Returns		
Gross	19,717	8,469
Net	15,104	3,675
% Returns to costs	327	77

1) 1/3 of the cost of fertilizer, fertilizer application, and weeding is borne by the intercrop in addition to costs solely attributed to the intercrop.

References

Adams, N.W., Ellingboe, A.H. and Rossman, E.C. (1971) Biological uniformity and disease epidemics, Bioscience, 21 1067-1070

Ahmad, N. (1981) An investigation of soil conditions of farmers' holdings in St. Vincent. Consultant Report No. 8, CARDI, Contract No. 81-0003 pp. 80.

Altieri, M.A., (1983) Agroecology, Division of Biological Control, University of California, Berkeley, pp. 162.

Barker, St. Clair P. and Henderson, T.H. (1985) Factors influencing the diffusion and adoption of recommended cultural practices among carrot farmers in St. Vincent In: Caribbean Farming Systems and Alternatives for Development, Acts du Colloque, Martinique, pp. 93-104

Brodie, B.B and Murphy, W.S. (1975) Population dynamics of plant nematodes as affected by combinations of fallow and cropping sequence. J. Nematology 7 91-92

CARDI, (1983) Farming Systems Research and Development Methodology, Project Paper, July 1983.

Edje, O.T. (1979) Response of maize and groundnuts in monoculture and in association, Paper presented at the Symposium on Grain Legume Improvement in East Africa, Nairobi, Kenya, August 20-24, 1979.

Egunjobi, O.A. (1975) Cropping Systems and Pest Control: The nematode story, Int. Nematology Network Newsletter 2 28-40

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: Proc. 3rd Res. and Planning Conf. in root-knot nematodes, *Meloidogyne* spp., Panama, Jan, 1982. Internat. Meloidogyne Project, pp. 180.

Mc Donald, F.D., (1985a) The effects of six selected crops on the population densities of root-knot, root-lesion and reniform nematodes, Nematropica 15 119-120

Mc. Donald, F.D., (1985b) Effects of four cropping systems on population densities of *Meloidogyne incognita* (Root-Knot nematode). Proc. 21st Meeting Caribbean Food Crops Soc. Trinidad and Tobago, pp. 264 -266

Mc. Donald, F.D., (1986) Effects of two selected intercropping systems on the yield of carrots in St. Vincent, Proc. 22nd Meeting Caribbean Food Crops Soc. St. Lucia, (In press).

Netscher, C. (1985) A crop rotation to control root-knot nematode in the tropics, In: Proc. 3rd Res. and Planning Conf. on Root-knot nematodes, Meloidogyne spp. Panama, Int'l. Meloidogyne Project 99, pp. 180

Perrin, R.M., (1977) Pest management in multiple cropping systems. Agro-Ecosystems 3 93-118

Rhoades, H.L., (1985) Effects of summer crops and following on populations of *Belonolaimus longicaudatus* and *Meloidogyne incognita* and yields of subsequent vegetable crops, Nematropica **15** 123

Singh, N.D., (1979) Control of root-knot nematodes in St. Vincent. CARDI Report, 1979, p. 4.

Singh, N.D., (1982) Root-knot nematode (*Meloidogyne incognita*) investigation of carrot in St. Vincent, W.I. In: Proc. 3rd Res. and Planning Conf. on Root-knot nematodes, *Meloidogyne* spp. Panama, 11-15 January, 1982, Int'l. Meloidogyne Project, pp.180.

Trembath, B.R., (1976) Plant interactions in mixed crop communities, In: Multiple Cropping (Eds. R.J. Paperdick, P.A, Sanchez and G.B. Triplett, Amer. Soc. Agron. Spec., Publ., Madison, Wisconsin, pp. 377

The registration and labeling of agricultural pesticides for use in Puerto Rico (IR-4 Program)

R. Montalvo-Zapata, N.M. Acin-Diaz

Puerto Rico Agricultural Research Station, P.O.Box 21360, Rio Piedras, P.R. 00928

C.W. Meister

Pesticide Research Laboratory, University of Florida, Gainesville, FL

The Inter-Regional Research Project, No. 4 (IR-4) is a USDA-CSRS and ARS sponsored program to develop data required by the EPA for pesticide, biorational and drug labels for minor or speciality uses. In Puerto Rico, IR-4 pesticide research efforts have been directed towards determining efficacy, effect on yield, residues and phytotoxicity data to obtain tolerances for the pesticide/crop combinations: ametryn/yam, tanier and cassava; prometryn and metribuzin/pigeon pea; paraquat and glyphosate/acerola; chloramben and paraquat/pigeon pea. Most of the data has resulted in Federal or Special Local Need registrations. Field and residue work has also been completed for fluvalinate and captafol/coffee; methomyl/sugar cane; acephate and esfenvalerate/ pineapple; paraquat/cassava, tanier and yam and; fluazifop-p-butyl, fenamiphos and oxamyl/cooking peppers. With IR-4 collaboration, tolerances and exemptions established for pesticide residues on bananas have been extended to plantains, from sweet potatoes to yam and from peas to pigeon pea. The inclusion of specific crops grown in Puerto Rico and the Caribbean Basin into EPA's crop groupings has also been achieved. Problems affecting tolerance approvals and label development by EPA are discussed.

Keywords: Pesticides; Registration, Puerto Rico

Introduction

General considerations

The use of a pesticide in the United States of America, its territories and possessions, must be registered with the Environmental Protection Agency (EPA) in Washington D.C. Types of pesticide registration such as a full federal label, a label restricted to a state or region and an experimental use permit can be obtained by following the requirements of the Federal Insecticide, Fungicide and Rodenticide Act (FIFRA), as established in Sections 3 and 5 (USEPA 1985). In addition, pesticides can be registered for one year under the following types of exemptions: specific, crisis and quarantine-public health (Section 18 of FIFRA).

The Commonwealth of Puerto Rico, through the Departments of Agriculture and Health, regulates the registration and use of pesticides through the provisions of Acts #49 and #132 (DAPR 1980 and DSPR 1966). Under section 24(c) of FIFRA, the Commonwealth of Puerto Rico can register additional uses of federally registered pesticides to meet special local needs. In 1977-1987, over 45 Special Local Need (SLN) registrations were approved by the Puerto Rico Department of Agriculture.

Pesticide manufacturers allocate human resources, time and funds to research and develop new pesticides registered for major commodities such as grains (wheat, rice, corn), soybean, cotton and tobacco. Experience indicates that about 8 to 10 years and more than US$ 20M are necessary to fulfill all EPA requirements to obtain the first pesticide registration. Manufacturers will develop data for major uses only when the volume of sales exceeds research and development costs. A minor use of a pesticide is a use on a crop which is limited such that the potential market volume of the agrochemical for that particular use is inherently small. Pesticide needs on tropical crops grown in Puerto Rico and other countries in the Caribbean Basin are usually not addressed by manufacturers, simply because potential sales volume is too small. The IR-4 project was established by the USDA to develop data for securing pesticide labels for minor and specialty crops to aid small farmers in the continental US, Hawaii, Guam, Puerto Rico and the US Virgin Islands.

The Inter-regional Research Project No. 4 (IR-4), "Clearances of Safe Animal Drugs, Biorationals (Microbials and Biochemicals) and Pesticides for Minor or Speciality Uses" is a national agricultural program for the clearance of chemical and biologicals for minor uses on food crops, ornamentals, forages and animals. The IR-4 project was initiated by the State Agricultural Experiment Stations (SAES) in 1963 and is a joint effort of the United States Department of Agriculture (Agricultural Research Service and Cooperative State Research Service), (EPA), the Food and Drug Administration (FDA), SAES, individual researchers, animal drug and pesticide manufacturers, and growers. In 1980-1986, IR-4 completed the data for documenting and obtaining positive action on 485 tolerances or exemptions of pesticides on several commodities.

The program has about $5 million available from federal and state entities and agricultural experiment stations in four USA regions. The Southern Region includes Puerto Rico, the US Virgin Islands, and 12 other states. The IR-4 regional office is at the University of Florida in Gainesville, Florida and sends data and information to National Headquarters at Rutgers University in New Brunswick, New Jersey.

Procedure for Tolerance for Commodities

Pesticide needs are identified by the Puerto Rico IR-4 Liaison Representative with the help of researchers, specialists and extension agents of the College of Agricultural Sciences of the University of Puerto Rico - Mayaguez Campus; growers; members of state agricultural agencies and grower associations and local representatives of pesticide manufacturers. Once the needs are considered by the administration of the Puerto Rico Agricultural Experiment Station, an IR-4 pesticide clearance request (PCR) is prepared and submitted through the regional office to National Headquarters. Information required for a PCR includes: chemical needed, site/commodity where needed, parts of commodity consumed, reasons for need, alternative treatments, importance of proposed use and proposed labeling (formulation, active ingredient, method of application, directions for use, and others).

Each PCR undergoes careful screening, both at the regional office and at National Headquarters to be sure that it meets certain specific criteria. These include the verification of the need for the pesticide, the chemicals already labeled for the requested pest control but which do not satisfy the need, availability of a full registration on a major commodity for the pesticide selected, whether the manufacturer is unwilling to perform the field research but willing to support registration, lack of major data gaps in EPA and, verification that there are no other EPA constraints impeding the potential use permit.

A research test protocol is developed by IR-4 to generate performance data (efficacy, residues and effect on yield and quality of the commodity) through two or three years of field work. Pesticide manufacturers, state and IR-4 regional laboratories perform the residue analyses.

All field and laboratory data are developed, compiled and evaluated by the IR-4 regional and main offices. The pesticide tolerance data packaging and proposed label are sent to the manufacturer for comments. Several months later, the final package and tolerance petition is submitted to EPA's Office of Pesticide Programs (OPP). The petition is assessed by several divisions of the EPA-OPP. After approval, either the pesticide manufacturer or a third party applies for a pesticide registration for the selected commodity (NACA 1984).

For the last nine years, efforts in Puerto Rico have been directed to securing tolerances for sub-tropical and tropical crops also grown in other Caribbean Basin countries. Pesticide clearance requests and research test protocols have been developed for pineapple, acerola, mango, avocado, mango, papaya, root and tuber crops (yam, tanier, cassava and arracacha), legumes (pigeon pea), plantain, banana, coffee, sugarcane and vegetables (tomato, pepper, eggplant, pumpkin, etc.).

Results and discussion

Pesticide Clearance Requests, Tolerances and Labels

About 263 pesticide clearance requests have been submitted by Puerto Rico (Table 1). A large number have been for pesticides needed on pineapple (16), mango (14), acerola (7), papaya (6), yam (22), tanier (14), coffee (10), plantain and banana (21), pigeon pea (27), and rice (8). Lack of sufficient research funds and trained personnel to collect performance data and low priority in terms of acreage and farm value have hindered the initiation of most of the required work. It has been difficult to combine work with the US Virgin Islands, Hawaii and Florida, in order to obtain data for pesticide tolerances and to develop the label for crops of common interest.

In spite of the difficulties, tolerances have been obtained and uses approved for the following herbicides: ametryn on yams, tanier, and cassava; prometryn, metribuzin, chloramben and paraquat on pigeon pea; glyphosate and paraquat on acerola; and also for the insecticide methomyl on pigeon pea. Several SLN registrations, following Section 24(c) of FIFRA and Commonwealth requirements, were obtained for pigeon pea, yam, tanier, cassava, and acerola (Table 2). Manufacturers have also secured EPA importation tolerances for several pesticides on pineapple, plantain and banana.

For vegetables, data from Puerto Rico and other states was collected by IR-4, evaluated and submitted to EPA in order to secure the tolerance. After tolerance approval, most of the pesticide manufacturers obtained full or restricted federal labels.

Table 1 Information on Pesticide Clearance Requests Submitted by Puerto Rico

Commodity	Number of Pesticide Clearance Requests
Tropical Fruits	20
Root and Tuber Vegetables	54
Sugarcane	11
Plantains and Bananas	21
Coffee	10
Pigeon Pea	27
Rice	8
Pastures and Forages	8
Solanaceous	45
Cucurbits	35
Others	24
Total	263

Field and residue data have already been completed for fluvalinate and captafol on coffee; methomyl and acephate on sugarcane; ametryn on arracacha; acephate and esfenvalerate on pineapple; paraquat on cassava, tanier and yam; fluazifop-p-butyl, fenamiphos and oxamyl on cooking pepper; chlorothalonil on pigeon pea, and *Bacillus thuringiensis* on pineapple. Label petitions have been sent to manufacturers and EPA. The pesticide clearance requests shown in Table 3 are active IR-4 projects that could be completed within the next five years.

A glance at EPA's approved tolerances for citrus and tropical fruits (FCN 1987) reveals that only a few tolerances are available for tropical crops grown in the Caribbean Basin. The number of tolerances available include only passion fruit (2), acerola (2), guava (17), papaya (17), mango (21), avocado (29), and pineapple (44). The Puerto Rico Department of Agriculture has intensified efforts for crop diversification and emphasized the cultivation of tropical fruits for export. Therefore, efforts should be continued to develop field and residue data on tropical crops grown in Puerto Rico and other countries of the Caribbean Basin. Several pesticide manufacturers have indicated interest in securing tolerances and labels for crops shown in Table 4.

Expansion of tolerances

Although most manufacturers consider pesticides used on most crops grown in the Caribbean Basin and Central America as minor uses, with IR-4 and EPA assistance, Puerto Rico has been successful in expanding tolerances and exemptions for pesticide chemicals in the general category of raw agricultural commodities to the corresponding specific raw agricultural commodity (USEPA, 1985).

After many years of work, Puerto Rico has been successful in applying the rulings of Section 40CFR 180.1(h) for banana to plantain; for sweet potato to yam, and for pea to pigeon pea. More information has been requested by EPA to complete the request to apply the tolerances and exemptions for pepper to bell pepper, cooking pepper and sweet pepper (known in Puerto Rico as ajies dulces). These new rulings will facilitate obtaining the use permit for thiabendazole to

Table 2 Examples of Special Local Needs registered in Puerto Rico

Commodity	Pest/Treatment	Formulation
Pigeon Pea	Weeds/pre-emergence	Caparol 80W[a]
	Weeds/pre-emergence	Lexone DF
	Pod borers/foliar sprays	Lannate L
	Pod borers/dust sprays	Thiodan 4D
Yam, tanier, cassava	Weeds/pre-emergence	Evik 80W
Yam	Nematode/foliar sprays	Vydate L
	Anthracnose/foliar sprays	Benlate 50WP
Acerola	Weeds/post-emergence	Round-up
	Weeds/post-emergence	Gramoxone CL
Avocado	Anthracnose/foliar sprays	Benlate 50WP
	Root rot/soil drench application	Terrazole 4E
Pineapple	Weeds/post-emergence	Gramoxone CL[a]
	Nematode/foliar sprays	Vydate L[a]
	Weeds/pre and post	Karmex 80WP
	Reproduction of planting material	Maintain CP-125
Plantain & Banana	Yellow Sigatoka/foliar sprays	3055 Spray Oil
	Yellow Sigatoka/foliar sprays	Orchex 796
	Yellow Sigatoka/foliar sprays	Excel Ortalex
	Yellow Sigatoka/foliar sprays	Bravo 500
	Nematodes/spot gun	Vydate L
	Nematodes and banana weevil/ soil surface application	Furadan 10G
	Nematodes and banana weevil/ soil surface application	Temik 10G
	Weeds/post-emergence	Round-up[c]
Coffee	Weeds/post-emergence	Dowpon M
	Anthracnose/foliar sprays	Bravo 500
	Nematodes, leafminers, scales/soil surface application	Furadan 10G
	Weeds/post-emergence	Round-up[a]
Rice	Weevil/broadcast application	Furadan 3G & 5G
	Weeds/pre and post	Bolero EC
Sugarcane	Pineapple disease/Seed piece dip	Benlate 50WP
	Diaprepes abbreviatus/ foliar sprays	Furadan 4F
Tomato	Insects/foliar sprays	Monitor 4S
Tomato and pepper	Weeds/post-emergence	Gramoxone CL
Cucumber and melon	Insects/foliar sprays	Monitor 4S[a]

a) Registration now included in full or supplemental label control soil-borne and foliar diseases; methomyl and carbaryl for adult *Diaprepes abbreviatus* control on yam; captan for canker control on pigeon pea; and benomyl for powdery mildew control.

The IR-4 Technical Committee has requested that 40CFR 180.1(h) be amended to define Annona and include raw agricultural commodities such as atemoya, cherimoya, sugar apple, sweetsop, soursop, custard apple, ilama, and their hybrids. The establishment of the definition requested would facilitate establishing tolerances or exemptions of pesticides on many similar crops of the genus Annona.

Table 3 Pesticide clearance requests to be completed before 1992

Pesticide	Pest	Crop
Acephate	Diaprepes root weevil Pod borer	Yam
Carbaryl	Diaprepes root weevil	Pigeon pea
Oxyfluorfen	Weeds	Pigeon pea
Bacillus thuringiensis	Pod borer	Pigeon pea
Permethrin	Pod borers Various insects	Pigeon pea Mango and papaya
Esfenvalerate	Various insects	Mango and papaya
Metalaxyl	Root rots and blights	Papaya
Fluazifop-p-butyl	Grass weeds (post)	Yam, tanier and cassava Pigeon pea Mango and papaya
Glyphosate	Weeds (post directed)	Pineapple
Methomyl	*Diaprepes* root weevil	Yam
Fenamiphos	Nematodes	Acerola
Benomyl	Powdery mildew	Peppers
Triadimefon	Powdery mildew	Peppers
Chlorothalonil	Anthracnose	Mango
Chlorothalonil	Rust	Pigeon pea
Thiabendazole	Seed Diseases	Yam

Use of Crop Groupings

The concept of establishing maximum pesticide residues for a group of related crops was first used in 1962 and was significantly modified in 1967 when tolerances for negligible residues were initiated.

Table 4 Potential pesticides for pest control in tropical crops

Formulation	Active Ingredient	Pest	Crop
Spotless 25 WP	Dinixazole	Yellow and Black Sigatoka	Plantain and Banana
Tilt 3.6E	Propiconizole	Yellow and Black Sigatoka	Plantain and Banana
Punch 40EC	Flusilazol	Yellow and Black Sigatoka	Plantain and Banana
		Rust,	Coffee
		Mycena citricolor, and	Coffee
		Anthracnosis	Coffee
Summit EC	Triadimenol	Yellow and Black Sigatoka	Plantain and Banana
Rugby 10G	Butylfos	Nematodes & banana weevil	Plantain and Banana
Goal 2E	Oxyfluorfen	Weeds (Pre & Post)	Rice
Bravo 500	Chlorothalonil	Anthracnose	Mango
		Rust	Pigeon pea
Marshal EC	Carbosulfan	Scales & mites	Mango and Citrus

Since 1969 it had been evident that there was an increasing problem with this system. Throughout the 1970's and early 1980's, EPA explored the possibility of further expanding the 14 crop groupings in order to allow a more extensive use of related crops and to minimize the burden of establishing pesticide residue tolerances. By re-grouping crops in at least 18 categories, pesticide tolerances could be established for all members of the group on the basis of those established for representative commodities within each group.

Puerto Rico submitted a substantial number of comments, suggestions and recommendations through the IR-4 Program and directly to the EPA main office. Arracacha, cassava, celeriac, tanier, taro, and yam were included in the root and tuber vegetables; pigeon pea in the legume vegetables; sweet and cooking pepper in the fruiting vegetables; and citron in the citrus fruit groups.

Problems with tolerance approval and labeling

The EPA is in the process of re-registering about 35,000 pesticide formulations. Because of data gaps for active ingredients, many formulations will not be available for minor and specialty crops. Neither will EPA grant additional tolerances for active ingredients lacking complete toxicological data. Re-registration could become one of the major obstacles in labeling pesticides for use on tropical crops.

Serious problems involving legal, economic, cultural practice and diet aspects are affecting the development of pesticide tolerances and labels for tropical crops in USA, Puerto Rico and other countries (PCR 1986).

After IR-4 secures a tolerance for a pesticide use, some agency or group must apply for a label or it will not be available to the grower. Usually the manufacturer will apply for a label. In rare cases, fear of potential crop injury and resulting liability will stifle interest. EPA may, however, allow a third party (grower, grower group or State Department of Agriculture) to apply for the label.

Up to the present, the acreage of commercial plantings of tropical fruits such as mango, papaya, avocado, passion fruit and others is rather small compared to coffee, plantain and banana. In addition, very few reliable technical publications on cultural practices and processing technology for tropical crops are available. The Puerto Rico Agricultural Experiment Station had publications on technological practices for cultivation and production of sugarcane, pineapple, coffee, vegetables, pigeon pea, papaya, mango, plantain, banana, and root and tuber crops. Some of this information is considered by EPA's Branch of Residue Chemistry and Toxicology for tolerance and use permit requests. The publication "Food and Feed Crops of the United States" needs to be updated and cleared of confusing information regarding cultivation practices as well as edible parts of agricultural commodities (Magness 1971).

The allowable daily intake (ADI) is the maximum theoretical intake of a pesticide through a calculated diet based on maximum residue levels (established tolerances) in all commodities. The registration of a pesticide for numerous crops, such as vegetables, tends to use up the EPA's Allowable Daily Intake for the pesticide of interest (BOA 1987). Pesticide manufacturers are highly reluctant to expend an ADI through a profusion of limited marketing's like root and tuber crops, tropical fruits and others.

The information obtained through IR-4 and the Program's achievements can be useful throughout the entire Caribbean Region. Utilization of this information can significantly decrease health and environmental hazards. Furthermore, it can pave the way for opening new markets for agricultural export crops to the U.S. mainland, Puerto Rico and the Virgin Islands. This will indeed be fitting within the framework of the Caribbean Basin Initiative.

References

Board on Agriculture (BOA) (1987) Regulating Pesticides in Food, The Delaney Paradox, Committee on Scientific and Regulatory Issues Underlying Pesticide Use Patterns and Agricultural Innovator, National Research Council, National Academy Press.

Departamento de Agricultura de Puerto Rico (DAPR) (1980) Ley Num. 49, Ley de Plaguicidas de Puerto Rico, 10 de junio, segun enmendada

Departamento de Salud de Puerto Rico (DSPR) (1966) Ley Num. 132, Ley para Reglamentar la Aplicacion Commercial de Insecticidas y/o Venenos Comerciales en Puerto Rico, 28 de junio

Duggan, R.E. and Duggan, P.D. (Eds.)(1987) Food Chemical News Inc. Pesticide Chemical News Guide

Magness, J.R., Markle, G. M., and Compton, C. C. (1971) Food and Feed Crops of the United States, Interregional Research Project IR-4, IR Bulletin No. 1.

National Agricultural Chemical Association, (NACA) (1984) Agricultural Chemicals: From Laboratory to Commercial Label
Peer Review Committee (PRC) on IR-4, (1986) A review of Interregional Project 4 (IR-4), Submitted to the Committee of Nine and the Cooperative State Research Service, United States Department of Agriculture through Iowa State University
United States Environmental Protection Agency (1985) The Federal Insecticide, Fungicide and Rodenticide Act as Amended, Office of Public Affairs (A-107), Washington, D. C. 10460, Revised
United States Environmental Protection Agency (1985) Code of Federal Regulations, Volume 40, Parts 150 to 189, revised July 1, 1985

Economic importance of White Top (*Parthenium hysterophorous* L. [f]) under intense vegetable production in Trinidad

Puran Bridgemohan

Crop Research Division, C E S, Ministry of Food Production, Marine Exploitation, Forestry and the Environment, Centeno, Trinidad

Richard A.I. Brathwaite

Department of Crop Science, University of the West Indies, St. Augustine, Trinidad and Tobago.

A weed survey conducted to determine the incidence of *Parthenium hysterophorous* L. (f) in vegetable crops during the wet and dry seasons in Trinidad indicated that the plant is a predominant noxious weed. It has shown the ability to survive bipyridylium herbicide treatments, and biological and cultural control was insignificant in reducing the population of the weed. The weed reduced crop yield in tomato (*Lycopersicon esculentum* Mill.) cv. Calypso by 100% and crop quality in Cauliflower (*Brassica oleracea* var. *botrytis* L.) by 75-100% due to its competitive ability and allelopathic potential. The plant served as a suitable 'resting site' for the adult insect pest *Plutella xylostella* (L.) (Lepidoptera: Yponomenitidae) which attacks cruciferous crops.

Keywords: *Parthenium hysterophorous*; White top; Vegetables

Introduction

Parthenium (*Parthenium hysterophorous* L. (f) # PTNNY)[1] commonly called barley flower (Adams et al., 1972) and white-head or white-top (Hammerton, 1980) in the Caribbean is considered a noxious weed. The plant exhibits wide ecological amplitude, and invades and competes with all types of crops, especially vegetables, with substantial losses in yield (Gupta and Sharma, 1977).

The weed displays characteristics of profuse seedling ability, photothermal insensitivity, non-dormancy, high growth rate, and low photo-respiratory rate (Bridgemohan and Brathwaite, 1987). Hammerton (1980) reported that it has spread within the last few years to all Commonwealth Caribbean countries.

Brathwaite (1978) noted the frequent presence of the weed in the major vegetable growing areas of Trinidad, and reported that it was effectively controlled by dinitroanilines, e.g., butralin [4-(1,1-Dimethylethyl)-N-(1-methylpropyl)-2,6-dinitro-benzenamine] in eggplant (*Solanum melongena* L.), and by the amide herbicide, diphenamid [N,N-Dimethyl-2,2-diphenyl-acetamide] in cabbage (*Brassica oleracea* var. *capitata* L.).

1) Letter: following this symbol are a WSSA approved computer code from *Important Weeds of the World*, 3rd. ed., 1983. Available from WSSA, 309, West Clark St., Campaign, IL 61820, USA

The weed is difficult to control physically. It has shown resistance to bipyridylium herbicides in Trinidad, and has become dominant on lands where these chemicals are used intensively (Brathwaite, 1978; Hammerton, 1980; Bridgemohan, 1987). The plant has the ability to survive carbohydrate depletion approach to control (Bridgemohan, 1987).

Parthenium is deemed a noxious weed in Australia (Haseler, 1976), and India (Gupta and Sharma, 1977). In India it causes severe skin allergies (Krishnamurthy et al., 1975) fever and asthma, and often death among the population (Mani et al., 1975). No cases of allergies or death have been reported in Trinidad (R.A.I. Brathwaite, Unpublished data, 1986).

In the Aranguez district, the major producer of the country's fresh vegetables, the weed was identified as early as 1956. However, it was not of any significance until the 1960's when the use of paraquat [1,1'- dimethyl-4-4'-bipyridinium ion] and diquat [6,7-dihydrodipyrido (1,2- a: 2,1-c) pyrazinedium ion]) became widespread.

The objective of this paper is to provide quantitative data on the levels of infestation of *Parthenium* in vegetable crops in the Aranguez district for both wet and dry seasons. Such information is essential for herbicide benefit analysis. The level of losses due to the presence of the weed in vegetable crops is also assessed in the paper.

Materials and methods

Two statistically designed surveys were conducted in the Aranguez District, where the soil type is River Estate Loam (pH 5-6). The first survey was made in the late wet season, October-December, 1986 and the second, in mid-dry season, February-March, 1987.

A random selection of the farms to be surveyed was made with the assistance of the local Agricultural Extension District Office. Apart from conducting counts of *Parthenium* in the crops, the farmers were interviewed with emphasis on the management of the crop, particularly the methods of weed control and their efficacy.

The survey and weed counts were conducted using a modification of the notional square system used by Phillipson (1974). A quadrat of $0.25m^2$ and 10 list counts for each farm were made. The weed number, height, physiological stage of growth, and basal area were recorded.

The data were summarized using seven quantitative measures as previously used and described by Ashby (1948), Misra (1973), Tiwari and Bisen (1981), and Thomas (1985), and modified by Bridgemohan (1987). Visual estimates (VE), Abundance (Ap), Density (DP), Percentage frequency (Fp), Relative dominance (RDi), Relative density (RDp), and Relative frequency (RFp) were determined. These were used to compute the Importance Value Index (IVI).

$$IVI = RDi + RDp + RFp$$

The IVI allowed for comparisons between seasons and years, and among crops. However, it does not necessarily represent losses in crop production caused by the weed as crops vary in their competitive ability. The level of losses due to the presence of the weed in various vegetable crops was assessed, and the economic importance of the weed determined.

Results and discussion

Incidence of *P. hysterophorous* in several crops

Irrespective of the visual estimate (VE) of parthenium infestations in the wet season (Table 1) and dry season (Table 2), the frequency (Fp) in both seasons was greater than 50%.

Table 1 Incidence of P. hysterophorous in the Aranguez District in various vegetables during the wet season (October - December 1986).

Crop	VE	Fp	IVI
Cauliflower 1)	50	90	417.1
Cauliflower 2)	10	70	262.5
Tomato 3)	25	100	274.1
Tomato 4)	50	90	430.0
Tomato 5)	75	100	562.5
Cabbage 6)	40	100	379.9
Cabbage 7)	50	100	974.7
Patchoi	40	100	382.2
Sweet pepper	25	50	265.4
Hot pepper	25	50	273.5
Spinach	30	90	358.0
Okra	100	100	880.0
Fallow field	100	100	910.0
Mean	48	87.5	489.9
S.E.±	7.85	5.2	72.17

1) 2 hand weedings and no herbicides; 2) 1 hand weeding and 1 herbicide application; 3) 2 hand weedings and 1 herbicide application; 4) 3 hand weedings and no herbicides; 5) 2 hand weedings and no herbicides; 6) 2 hand weedings; 7) 1 hand weeding

Table 2 Incidence of *P. hysterophorous* in the Aranguez District in various vegetables during the dry season (February - March 1987)

Crop	VE	Fp	IVI
Squash	90	100	674.9
Tomatoes	75	100	836.4
Cabbage	10	50	360.0
Spinach	25	100	365.6
Bodie bean	10	100	207.8
Cauliflower	10	50	215.8
Mean	36	83	443.4
S.E.±	2.45	2.07	6.5

There was no variation in the mean Importance Value Index (IVI) for parthenium for the wet (489.1) and dry (437.6) seasons. Also, variations between seasons were minimal under similar levels of weed management; cabbage in the wet season had an IVI of 379.9 and in dry season 360.0, cauliflower 262.5 (wet) and 215.8 (dry), and spinach 358.0 (wet) and 365.6)dry).

In the wet season (Table 1), there were variations within the same crops due to different levels of weed management, eg. cauliflower with two hand weedings and no herbicides had a higher IVI (417.1) than a crop of similar age with treatments of one hand weeding and pre-emergence herbicide (262.5). Similar trends for tomato and cabbage were observed at the same growth stage, but under different levels of weed management. The application of pre-emergence herbicides reduced the IVI for parthenium by 40 to 50% over one or two hand weedings.

Crops with shrub-type architecture, eg. hot and sweet peppers, had no competitive plant height advantage over leafy vegetable crops under similar levels of weed management. Both types of crops had an IVI below the mean recorded for the wet season.

In both wet and dry seasons, the IVI for leafy vegetable crops was lower than the mean IVI. This is due mainly to the close spacing used at planting, and the intensity and thoroughness of the hand weeding operations practised by the farmers.

A field prepared for planting, but subsequently abandoned, showed an IVI of 910 (wet season) and gives an indication of the weed's dominance. The high IVI (880) for okra in the wet season was due to the wide spacing as well as the absence of any weed management operations. The *Parthenium* seedlings were the same height as the crop (15-20 cm).

In the fields surveyed, adequate irrigation facilities were available to all farmers during the dry season. Adequate water supply was the main factor determining the lack of shift in *Parthenium* populations between seasons.

Incidence of *P. hysterophorous* during different seasons

There was no significant difference between visual estimates (VE) for *Parthenium* in the wet and dry seasons in the Aranguez District (Table 3), or for the major vegetable growing areas of Trinidad (Table 4). Visual estimates in the range of 25 to 60% can be considered as moderate infestations (Phillipson, 1974).

There were no changes in abundance (Ap) between seasons. *Cyperus rotundus* (L.) #CYPRO, "the world's worst weed" (Holm et al., 1977), is a serious weed in vegetable crops in India with an abundance of 2.7 to 9.6 (Tiwari and Bisen, 1981). The Ap for *Parthenium* in Aranguez fell well within this range in both seasons.

Wet season density (Dp) in Aranguez (5.77) did not differ significantly from that of other vegetable growing areas (7.46). Dexter et al (1981), reported that wild oats (*Avega fatua* (L.) #AVEFA) had an average of 2.0 to 2.5 plants per 0.25 m^2, and Thomas (1985) noted that green foxtail (*Setaria viridis* (L.) Beau #SETVI) had a density of 32 plants per m^2. These are serious weeds in cereals and oilseeds, respectively. The Dp for *Parthenium* emphasizes the predominance of this weed in Aranguez in both seasons.

Frequency (Fp) was over 80% in both seasons. Thomas (1985) indicated that weeds occurring in the frequency levels 76 to 100 are serious weeds that require some level of control. He found green foxtail and wild oats with frequency levels of 63.3 to 94% during his survey.

The RFp values for both seasons were over 60%. Chancellor (1971) observed that *Sinapsis arvenis* (L.) #SINAR, and *Chenopodium album* (L.) #CHEAL, had relative frequency levels of 60 and 44%, respectively, and both are widespread weeds in arable lands in Britain.

The IVI indicated that there were no shifts in *Parthenium* population between seasons (Table 3). Also there was no significant difference between IVI for Aranguez wet season and that for other vegetable growing areas of Trinidad (Table 4.) These findings indicate that *Parthenium* is a serious problem in all the major vegetable growing areas in Trinidad, especially in Aranguez, where the IVI is even greater for the dry season.

Crop loss assessment

Results from the surveys indicated that *Parthenium* caused significant losses to vegetable production in both seasons. Most farmers reported that the weed had no effect on the yield of solanaceous crops, if it was effectively controlled while the crop was in the early vegetative stage or prior to flower initiation. However, if weed control was poor, they observed yield reductions between 25 to 30% for the wet season, and 20 to 25% for the dry season.

All farmers found that the presence of the weed within or around the field can result in a reduction of the marketable yield of cabbage and cauliflower. The authors observed a 75 to 100% damage to marketable curds of cauliflower caused by the larvae of *Plutella xylostella* (L.) (Lepidoptera: yponomentidae). Apparently, the adult pest found *Parthenium* to be a suitable "resting site" (Mona Jones, Pers. Comm., 1987).

On nursery beds, failure to remove *Parthenium* seedlings at 3 to 5 day intervals on a regular schedule resulted in a 75 to 100% loss of healthy and vigorous vegetable transplants.

Table 3 Incidence of *P. hysterophorous* in the Aranguez District during wet and dry seasons of 1986-87

Parameters	Season	
	Wet (October-November)	Dry (February-April)
Visual Estimates (%) (VE)	47.69	36.66
Abundance (Ap)	5.77	5.25
Density (Dp)	5.24	3.99
Frequency (Fp)	87.69	83.3
Relative Dominance (RDi)	58.88	56.8
Relative Frequency (RDp)	415.61	340.0
Relative Frequency (F4RFp)	66.31	61.36
Importance Value Index (IVI)	489.99	443.43

Table 4 Incidence of *P. hysterophorous* for the major vegetable growing areas of Trinidad in 1986-1987

Parameters	Seasons			
	Wet (Oct. - Dec.)		Dry (Feb. - Apr.)	
	Mean	S.E.	Mean	S.E.
Visual Estimates (VE)	43.87	1.78	35.58	1.23
Abundance (Ap)	7.46	1.11	15.50	1.67
Density (Dp)	5.6	0.66	15.04	1.68
Frequency (Fp)	65.32	14.96	88.4	1.15
Relative Dominance (RDi)	53.02	9.04	44.4	1.81
Relative Density (RDp)	412.0	37.46	284.73	4.51
Relative Frequency (RFp)	58.43	5.9	59.48	1.03
Importance Value Index (IVI)	491.19	37.92	378.5	4.76

The authors noted the total loss of one tomato crop, (cv. Calypso) where the farmer had failed to remove the weed up to flower initiation stage. The weed had a V.E. of 100% and an IVI of 836.4 (Table 2). *Parthenium*, the only weed present in the field at the time of the survey, was 75 to 100 cm tall and flowering profusely. The farmer had applied paraquat at the pre-plant stage of the crop.

Failure to plant lettuce and celery on *Parthenium* free plots led to 50 to 60% mortality of the transplants. When early hand weeding at 10 to 14 day intervals was not done, mortality in excess of 75% was observed.

No significant reduction in yield was reported by farmers for vining crops, eg. pumpkin, squash, or cucumber and staked bodie bean withstood the weed competition. However, early hand weeding was essential for bush type cow peas to prevent yield reductions of 25 to 50%.

The reduction in crop yield and quality is probably due to the competitive ability and allelopathic potential of *Parthenium*. Rajendra and Rama Das (1981) noted that although the weed was a C3 plant, a low carbon dioxide compensation concentration and photorespiratory rate were observed. This was attributed to the activity of PEP carboxylase. The authors described the weed as having a luxurious growth and high survival potential. Sukhada and Jayachandra (1984) reported that *Parthenium* produced allelopathic compounds that influenced pollen germination and tube growth in solanaceous and bean crops where yield reductions between 27 to 73% were observed.

Conclusions

The survey provided quantitative data on the incidence of *Parthenium* infestation on vegetable crops for the main vegetable production area in Trinidad, the Aranguez District, over two seasons. It can be concluded that the weed is a more significant weed in the commonly grown vegetable crops in Aranguez than nutgrass. *Parthenium* is a predominant and pernicious plant in both wet and dry seasons.

From an earlier survey, the authors concluded that under systems of intensive vegetable production and where the use of bipyridyliums is widespread, the weed has shown the ability to survive herbicide treatments, except at the seedling stage, regardless of the season and crop or management practices. Also, biological and cultural control was insignificant in reducing parthenium populations. The weed can significantly reduce crop yields and quality due to its aggressive growth habit; competitiveness and allelopathic interference.

Acknowledgments

The authors wish to thank Dr. Ronald Barrow, Director of Research, Central Experiment Station, for his interest and encouragement in the work; Devika and Ria-Shanare Bridgemohan for their patience and understanding, Sarran Harryram for technical assistance during the study and Ms. Ann Marie Jacobs for typing the manuscript.

References

Adams, C.D. (1972) Flowering plants of Jamaica. The University of the West Indies, Mona, Jamaica 151pp

Ashby, E. (1948) Statistical Ecology - A reassessment, Bot. Rev., 222-224.

Brathwaite, R.A.I. (1978) Effect of herbicides on weed control, yield and quality of eggplant (*Solanum melongena* L.) in Trinidad Weed Research 18 245-246

Bridgemohan, P. (1987) A survey of the incidence of *Parthenium hysterophorous* L. in vegetable crops in Trinidad, Department of Crop Science, U.W.I., St. Augustine, Trinidad and Tobago 104 pp.

Bridgemohan, P. and Brathwaite, R.A.I. (1987) A review of whitetop (*Parthenium hysterophorous*) its biology and control, Department of Crop Science, UWI, St. Augustine 71 pp

Chancellor, R.J. (1977) A preliminary survey of arable weeds in Britain, Weed Research 17 283-287

Dexter, A.G., Nalewaja, J.D, Ramsusson, D.D., and Suchii, J. (1981) Survey of wild oats and other weeds in North Dakota 1978 and 1979, North Dakota Agric. Exp. Sta. Research Report 79.

Gupta, O.P. and Sharma, J.J. (1977) Parthenium menace in India and possible control measures, FAO, Plant Protection Bulletin 25 (3) 112-117.

Hammerton, J.L. (1980) Weed problems and weed control in the Commonwealth Caribbean, Pest and Pesticide Management in the Caribbean, Proceedings of a Seminar, 1980 II 87-97

Haseler, W.H. (1976) *Parthenium hysterophorous* L. in Australia, Pest Articles and News Summaries 22 (4) 515-517

Krishnamurthy, K., Ramachandra Pasad, T.V., and Muniyappa, T.V. (1975) Agricultural and health hazards of parthenium, Current Research 4 169-171

Mani, V.S., Guatam, K.C., and Gita Kulshreshtha, (1977) Some observations on the biology and control of parthenium, Weed Abstracts (1979), 28(1) 327

Misra, R. (1973) Ecology work book, Oxford and I.B.H. Publishing Company, New Delhi, India, p 31-50

Phillipson, A. (1974) Survey of the presence of wild oat and blackgrass in parts of the United Kingdom, Weed Research **14** 123-135

Rajendra, G. and Rama Das, V.S. (1981) *P. hysterophorous* exhibiting low photorespiration, Current Science **50**(13) 529-593

Sukhada, D.K., and Jayachandra (1980) . Pollen allelopathy - A new phenomenon, New Phytologist **85**(4) 739-746

Tiwari, J.P. and Bisen, C.R. (1981) The weeds of rabi vegetables, Proc. 8th Asian Pacific Weed Sci. Soc. Conf., 191-196

Thomas, A.G. (1985) Weed survey system used in Saskatchewan for cereals and oilseed crops, Weed Sci. 33 34-43

Viny weeds of the Eastern Caribbean

John L. Hammerton

CARDI, P.O. Box 971, Castries, St. Lucia, W.I.

There are at least forty-two viny weed species found in the Eastern Caribbean, belonging to twelve botanical families. The *Convolvulaceae* has fifteen species from five genera, and the *Fabaceae* has twelve species from ten genera. These viny weeds are known by a variety of vernacular names, though two, including a very striking common weed, appear to have no recognized and accepted names. A simple key is presented, but it does not claim to be inclusive of all viny species. Simple brief descriptions are given.

Keywords: Weeds; Vines; *Convolvulaceae; Fabaceae;* Identification

Introduction

A weed is "a plant in the wrong place": "a plant that needs to be controlled". A vine is "a plant that climbs or trails. So a viny weed is "a climbing or trailing plant in the wrong place". All weeds compete with crop plants for water, light, and mineral nutrients. Viny weeds are no exception, but are particularly effective in competing for light, not infrequently overwhelming crop plants, especially shrubs and trees, cutting off most of the light to the crop plant. Those wavelengths needed for photosynthesis are filtered out by the leaves of the viny weeds. The vine foliage can comprise several layers of leaves, so that the filtering and light attenuation effect can be considerable. This "smothering" can be so effective as to result in severe or total defoliation of the crop plants, leading unless some control measures are taken, to eventual death.

The Viny Weeds

The literature on the plants and flora of the Eastern Caribbean which for the purposes of this paper comprises Grenada, St. Vincent, Barbados, St. Lucia, Martinique, Dominica, Guadeloupe, Antigua, Montserrat, and St. Kitts and Nevis, (Adams et al., 1970; Fournet, 1978; Gooding, Loveless & Proctor, 1965; Honychurch, 1986), and other sources (primarily the author's trip reports), indicates that there are at least forty-two viny species that are weeds of agricultural land (Table 1). These species belong to twelve families. Of these, the Convolvulaceae accounts for 15 viny weed species, and the Fabaceae for 12 viny weed species. A few species not listed may occur occasionally as weeds. *Macfadyena uncata* ("cat's claw creeper", yellow shower", "griffe a chatte"), of the Bignonaceae family, an attractive ornamental vine, may sometimes run amok over fruit trees for example, and *Stigmaphyllon cordifolium* ("liane a ravet", "mariebouya"), a member of the Malpighiaceae, often found on fences and hedges, can invade crop land and become a weed.

Several of the viny weed species of the Fabaceae are used as forage legumes, but can be found as weeds of cropped land. The status of "weediness" is a variable one: a weed in one island or crop may be almost unknown as a weed in another island or crop.

This paper is an output of the CARDI/USAID Farming Systems Research and Development Project 538-0099

Seven of the viny weeds listed in Table 1, are "tendril climbers". These include the *Cucurbitaceae*, and *Passiflora foetida*, *Antigonon leptopus*, *Cissus sicyoides*, *Cardiospermum microcarpum*, and *Paullinia, cururu*. Tendrilled plants normally climb, but if there are no tall plants to climb, they will attach to any and every thing - other weeds, crop plants and debris - making it very difficult to weed, and causing much uprooting and damage to the crop.

Vernacular Names

These are listed in Table 1, though the list may be incomplete, and there are no doubt many local unpublished names in common use. Spellings are sometimes phonetic, and variations in spelling are common. In some cases, the same name is used for two or more different species, even within the same island. As far as possible, the vernacular names given in the Table, which includes French, Patois, and English names, are those most commonly used and published. Many of these names are very descriptive and poetic: "black-eyed Susan", "Liane sans fin", "concombre diable", for instance. Two species only *Prestonia quinquangularis* and *Coccinea grandis* apparently have no recognized vernacular names.

Descriptions

The descriptions of the species listed in Table 1 given below are not precise botanical descriptions, but outline a few significant features of each species. Table 2 comprises a simple dichotomous key to the species listed in Table 1. This uses a few simple features to aid identification, but does not necessarily go to species level. Nor is it, of course, inclusive of all viny plant species found in the Eastern Caribbean only of those most commonly found as weeds.

The **Acanthaceae** family includes several vines grown as ornamentals, and several non viny weedy species. The two viny weeds listed, *Thunbergia alata* and *T. fragans*, have opposite leaves, cordate in shape. *T. alata* has orange yellow flowers with a purple brown centre, while the latter has attractive white flowers. Both species occur on fences and hedges, sometimes invading cropland, especially orchards. They are more common in wetter areas.

The **Apocynaceae** family includes some well known ornamentals, such as periwinkle and oleander. Leaves are usually opposite. *Echites umbellata* has tubular greenish white flowers in clusters. In spite of its vernacular name, there are no reports of its being poisonous but it does have poisonous relatives. *Prestonia quangularis* has red veined leaves and greenish flowers, and may not occur in all the islands. *Urechites lutea* has pale yellow flowers 3 to 5 cm long. All three species contain sap.

Only one viny species of the **Asteraceae** family is common as a weed in the Eastern Caribbean. *Mikania micrantha* and possibly other *Mikania* species, are found mainly in bananas, but may occur in other crops. *M. micrantha* has opposite leaves, and small whitish flower heads.

The **Convolvulaceae** family includes three parasitic Cuscuta species which are not easy to separate. They share the same vernacular names. They occur very widely on a wide range of host plants both useful plants and weeds. They are leafless and the stems are typically orange or yellow. A piece of the vine thrown on to a plant allegedly establishes very rapidly. *C. indecora* has smaller flowers and capsules.

The Ipomoea genus has several weedy species that differ in leaf shape and flower colour. The flowers are bell-shaped, and usually 3 to 4 cm across. These species have a white latex and are often trailing, but can twine up trees to a height of several metres, where they can smother the tree, unless controlled. They root easily from stem fragments, which makes control by chopping with a machete, or by hoeing, of doubtful effectiveness, especially in wet weather. *I. nil* has blue or white flowers, while *I. triloba* and *I. tiliacea* have mauve or purple flower sometimes white in the latter species. *I. pes-caprae* spp. *brasiliensis* is more robust than the above, with larger, purple, flowers,. It is typically found on sandy seaside soils above beaches, but sometimes invades agricultural land near a beach. The *Merremia* species are also common as weeds. *M. umbellata* has clusters of yellow flowers, and simple cordate leaves. The dried clusters of seed capsules are conspicuous, and are sometimes used in dry floral arrangements. The other three *Merremia* species listed, have larger flowers which usually open singly. These flowers are white, but may have a coloured centre. *M. aegyptia* and *M. quinquifolia* have compound leaves, but *M. dissecta* has deeply dissected simple leaves. M. umbellata in particular is a serious problem of tree crops, often growing over them, and smothering them unless controlled. *Quamoclit hederifolia* has beautiful tubular scarlet flowers, about 3 cm long, and 3 lobed leaves, though leaf shape is variable. *Q. pinnata* is a charming viny weed, with finely dissected leaves, and smallish scarlet flowers about 4 cm long. *Turbina corymbosa* has cordate leaves and clusters of white bell-shaped flowers. It is commoner in wet areas.

Weeds of the **Cucurbitaceae** family are tendrilled climbers and trailers. *Coccinea grandis* is recorded only from Barbados. It has cucumber like leaves, white flowers, and elongated oval fruits about 5 cm long. These turn red on ripening. Monkeys are apparently fond of the fruits, and probably birds also. *Cucumis anguria* looks even more like a cucumber plant, but the edible fruits are only about 6 cm long and are spiny. *Melothria guadelupensis* also has cucumber like leaves, with yellow flowers and small, purple black fruits. *Momordica charantia* is the best known, and most common, of the Cucurbitaceae weeds. The palmate leaves are lobes, the flowers are yellow, and the fruits, at first green, turn orange and split open to reveal the seeds, which are covered with a red pulp. The vine is used for medicinal teas, and children suck the red pulp off the seeds. This is an extremely common and well-known viny weed.

Only one member of the **Euphorbiaceae** family is a climbing weed. *Tragia volubilis* is armed with stiff stinging hairs. The male and female flowers are small and inconspicuous, occurring in slender racemes. The capsules are covered with stiff white hairs. This viny weed is not common and occurs mainly in hedgerows and fences, occasionally invading cropped land, orchards, or pastures.

Only two of the viny weeds of the **Fabaceae** family have pinnate leaves: *Abrus precatorius*, and *Clitoria ternatea*. The former has 10 to 20 pairs of small oblong leaflets, and racemes of pinkish flowers, while the latter has 5 to 7 elliptical leaflets, and single flowers, usually blue, and occasionally white. *A. precatorius* has very conspicuous seeds red with a black "eye" as the pods open and twist back, but the seeds remain attached. The seeds are used in jewellery, but are poisonous. *A. Precatorius* is mainly found as a weed of neglected orchards. *C. ternatea* has large flowers about 4 cm 'across and pods about 10 cm long. This species is used as a forage plant, and is a weed of only minor importance. The other viny weed species in the Fabaceae family all have trifoliolate leaves. *Centrosema pubescens* and *C. virginianum* have elliptical leaflets, those of the latter being narrower. Flowers occur in clusters of 2 or 3: the standard petal is about 3 cm across, and whitish with purple stripes in *C. pubescens*, and blue or white in *C. virginianum*. The pods are up to 10 cm long with small seeds. Both these species occur as weeds in cultivated land and in orchards. *Macroptilium atropurpureum* is a twining forage legume but sometimes becomes a weed, mainly in drier areas. The leaflets are narrowly ovate or elliptical, and the flowers are usually a deep red, but sometimes pink. *Mucuna pruriens* is well-known as "cowitch". The pods are densely covered with stinging hairs. Leaflets are rhombic or broadly ovate in shape, with silky hairs on the under-surface: the flowers are purple and occur two or three together. Pods are up to 7 cm long. This species is widely distributed and is common in sugar-cane in Barbados, and in tree crops occasionally. *Phaseolus adenanthus* is a perennial twiner, somewhat woody, found in sugar-cane and other crops. The leaflets are narrowly elliptical, and the flowers are variable in colour, from mauve to white or yellow. *Pueraria phaseoloides*, kudzu, is well known as an aggressive cover crop that easily gets out of hand and becomes a weed. It is extremely effective at smothering tree crops. Leaflets are ovate-triangular, up to 12 cm long. The mauve or purple flowers are in racemes 10 to 20 cm long, and the pods are up to 8 cm long. *Rhyncosia minima* and *R. phaseoloides* are both woody twiners. Leaflets are broadly ovate or rhombic in shape. The former has leaflets up to 10 cm long and nearly as wide: the latter has leaflets only 2 to 3 cm long and wide. *R. minima* leaves are often blotched yellow due to viral or mycoplasmal infection. Flowers are yellowish or brownish yellow in many flowered racemes. *R. minima* is perhaps more common as a weed of crops, but both are found in hedgerows and fences. *Teramnus labialis* has ovate or elliptical leaflets and small white flowers in racemes and clusters. The pods are slightly curved. *T. labialis* is a forage legume, but sometimes occurs as a weed of cultivated land and of tree crops.

Two species of *Jasminum*, of the **Oleaceae** family, are not uncommon in the Eastern Caribbean. *J. fluminense* is more common than *J. multiflorum*, and has trifoliolate leaves, whereas *J. multiflorum* has simple leaves, small white flowers and blue black berries . It is a climbing (perennial) shrub, which tolerates shade, and is sometimes found in orchards as a weed. More than one *Jasminum* species is cultivated as an ornamental in the Caribbean.

The **Passifloraceae** family comprises mainly tendrilled climbers. Only one species is common as a weed - *Passiflora foetida*. This has three lobed leaves, softly hairy stems, and filamentous flowers, white and purple in colour and very striking. The fruit is an oval berry. This species can be found growing over shrubs and trees, and trailing on the ground, mainly in perennial crops. *Passiflora edulis* is the passion fruit.

The **Polygonaceae** family has one of the most attractive of the viny weeds. *Antigonon leptopus* has light green cordate leaves, with crenated margins, and tendrils. The flowers grow in clusters on trailing racemes. The bracts are bright pink, or occasionally white. There are small tubers on the roots, which are not easy to extract, making the plant difficult to eradicate. This species rapidly grows over large trees, or trails over the ground. An extremely beautiful vine.

The **Sapindaceae** family includes a number of tendrilled climbers. Two of these are fairly common in the Eastern Caribbean -*Cardiospermum microcarpum* and *Paullinia cururu*. The former has deeply lobed bipinnate leaves, resembling those of parsley, and giving rise to some of the vernacular names. The flowers are small, but the capsule is inflated, 3 angled and heart shaped. It occurs in cultivated lands, usually in low growing crops, but sometimes in tree crops. *P. cururu* has trifoliolate glossy leaves, with winged petioles. The flowers are small, in pendulous racemes, and the fruit is a red flask shaped capsule, about 2 cm long. *Cissus sicyoides*, of the Vitaceae family, can grown to a height of many metres or may trail over the ground. The leaves are ovate or cordate, and up to 10 cm long. The flowers are small, varying in colour from red to pink to greenish yellow, but occur in spreading cymes up to 10 cm across. These are very striking and attractive. This vine can smother large trees.

It is hoped that this account will enable readers to identify, with some confidence, some of the many viny weeds that occur in the Eastern Caribbean. Some of them are very beautiful, and easy to identify from a distance.

References

Adams, C. D., Kassasian, L. & Seeyave, J. (1970) Common weeds of the West Indies, University of the West Indies, St. Augustine, Trinidad

Fournet, J. (1978) Flore illustree des Phanerogames de Guadeloupe et de Martinique, INRA, Paris

Gooding, E. G. B., Loveless, A. R. & Proctor, G. R. (1965) Flora of Barbados, H. M. S. O., London

Honychurch, P. N. (1986) Caribbean Wild Plants and Their Uses, Macmillan Caribbean

Table 1 The major viny weeds of agricultural crops of the Eastern Caribbean with botanical and vernacular names

FAMILY	SPECIES	VERNACULAR NAMES		
ACANTHACEAE	Thunbergia alata	black-eyed Susan	fleur jaune savane	
	Thunbergia fragrans	wild white Thunbergia	white nightshade	
APOCYNACEAE	Echites umbelata	deadly nightshade		
	Prestonia quinquangularis	?		
	Urechites lutea	nightsage	nightshade	yellow nightshade
ASTERACEAE	Mikinia micrantha	guaco	herbe a vache	liane serpent
		locafaire	wappe	
CONVOLVULACEAE	Cuscuta americana	cordon du violon	herbe z'amitie	love vine
	Cuscuta indecora	dodder	liane sans fin	sans pied
	Cuscuta umbellata	dodder vine	liane cordon	vermicelle
		vermicelli		
	Ipomoea nil	liseron blanc	liseron bleu	monkey vine
	Ipomoea pres-caprae	batate del mer	goat's foot ipomoea	seaside yam
	ssp. brasiliensis	beach morning glory	patate bord de mer	
	Ipomoea tiliaceae	caapi	manger lapin	patate sauvage
		caapi doux	morning glory	patate marron
		liane douce	patate batard	wild potato
		wild slip		
	Ipomoea triloba	petite patate marron		
	Merremia aegyptia	liane poilue		
	Merremia dissecta	know you	liane a noyau	mene-vini
	Merremia quinquifolia	rock rosemary		
	Merremia umbellata	hog vine	liane a malingres	liane douce jaune
		liane berreau		
	Quamoclit hederifolia	ivy leaf morning glory	liseron hallier	wild slip
		liseron rouge	scarlet ipomoea	
	Quamoclit pinnata	cheveux de Venus	goutte de sang	herbe a eternuer
	Turbina corymbosa	christmas pops	christmas wreath	
CURCURBITACEAE	Coccinea grandis	?		
	Cucumis anguria	small wild cucumber	ti concombre	west indian gherkin
		wild cucumber		
	Melothria guadalupensis	concombre diable	concombre poison	small wild cucumber
		ti concombre hallier		
	Momordica charantia	cerasee	miraculous vine	pomme merveille
		mexicaine	paroka	pomme z'Indiens
		pomme coolie		
EUPHORBIACEAE	Tragia volubilis	creeping cowitch	liane z'ortie	stinging nettle
		liane brulante	ortie brulante	twining cowitch
		vine nettle		
FABACEAE	Abrus precatorius	crab's eye vine	graines reglisse	liane reglisse
		graines d'eglise	gwenn legliz	red bead vine
		jumbie beads	reglisse	wild liquorice
	Calopogonium mucunoides	pois blue	pois bleu savane	pois pelu
	Centrosema pubescens	pois batard	pois sauvage	pois-pois marron
		pois razier	pois hallier	
	Centrosema virginianum	bluebell	pois marron savane	ti pois
		pois sauvage	pois-pois vrai	wild blue vine
		wild pea		
	Clitoria ternatea	blue vine	pois marron	pois tonnelle
		lentille sauvage	pois sauvage	pois-pois
		pois savane		

Table 1 (ctd.)

FAMILY	SPECIES	VERNACULAR NAMES		
FABACEAE (ctd)				
	Macroptilium atropurpureum	siratro		
	Mucuna pruriens	cowitch	cowitch vine	pois gratter
	Phaseolus adenanthus	corde a violon	pois marron	
	Pueraria phaseoloides	kudzu		
	Rhyncosia minima	burn-mouth vine	pois sucrier	pois z'oiseaux
		pois hallier	pois razier	ti pois
	Rhyncosia phaseoloides	pois hallier	wild liquorice	
	Teramnus labialis	horse vine	pois envirant	rabbit vine
		pois colibri	pois z'oiseaux	
OLEACEAE	Jasminum fluminense	jasmin a bouquet	jasmin blanc	wild jasmin
PASSIFLORACEAE	Passiflora foetida	mariboüya	marie gougeat	pomme liane coolant
POLYGONACEAE	Antignon leptopus	Bride's tears	coralita	la belle mexicaine
		coral vine	coralilla	
SAPINDACEAE	Cardiospermum microparpum	balloon vine	heart seed	persil-batard petit
		calthrops	liane persil	wild parsley
		bastard supple jack	liane a scie	persil noir
		bread and cheese	liane mangle	sucking bottle
VITACEAE	Cissus sicyoides	liane a eau	liane douce	poison wyth
		liane a chasseurs	liane moile	scratch wyth
		liane brulante	liane-corde	

Table 2 A simple dichotomous key to the major viny weed species of the Eastern Caribbean (Note that this key does not necessarily go to species level)

1 Leaves absent or reduced to scales; stems yellowy orange, often in tangled skeins; parasitic plants: **Cuscuta sp.**
1 Leaves present:
  2 Leaves simple, lobed or dissected, but not compound:
    3 Leaves alternate:
      4 Plants climbing by means of tendrils, or sprawling but attached to other plants by tendrils:
        5 Leaves angular:
          6 Flowers white **Coccinea grandis**
          6 Flowers yellow: **Melothria guadelupensis**

        5 Leaves lobed or rounded, not angular:
          7 Leaves lobed:
            8 Flowers yellow: **Cucumis anguria**
              Momordica charantia
            8 Flowers white, filamentous: **Passiflora foetida**

          7 Leaves ovate, rounded, or cordate ovate:
            9 Inflorescence a raceme, flowers usually pink, sometimes white: **Antigonon leptopus**
            9 Inflorescence umbel-like, flowers purplish red to yellow **Cissus sicyoides**

      4 Tendrils absent, plant climbing by twining, or prostrate and trailing:
        10 Leaves lobed or dissected:
          11 Leaves lobed: **Quamoclit hederifolia**
            Ipomoea triloba
          11 Leaves palmately dissected: **Merremia dissecta**

        10 Leaves rounded, ovate or cordate:
          12 Leaf base cordate:
            13 Flowers showy, tubular and bell shaped: **Ipomoea nil**
              Ipomoea tiliacea
              Merremia umbellatum
              Turbina corymbosa
            13 Flowers small, plant with stinging hairs; **Tragia volubilis**

          12 Leaf base not cordate, leaf apex notched, leaves thick: **Ipomoea pres-caprae**

    3 Leaves opposite:
      14 Leaves ovate or oblong:
        15 Flowers green, greenish-white, or white:
          16 Flowers small, in composite heads: **Mikania spp.**
          16 Flowers not in composite heads: **Echites umbellata**
            Prestonia quinquangularis

        15 Flowers yellow: **Urechites lutea**

      14 Leaves cordate:
        17 Flowers white: **Thunbergia fragrans**
        17 Flowers yellowy orange **Thunbergia alata**

Table 2 ctd.

2 Leaves compound (pinnate, bipinnate, digitate or trifoliolate):

18 Leaves pinnate, bipinnate, or digitate:

19 Leaves pinnate or bipinnate:

20 Leaves pinnate:

21 Flowers pea like:

22 Leaflets oblong, in 10-20 pairs: **Abrus precatorius**

22 Leaflets elliptical, 5-7 prs: **Clitoria ternatea**

21 Flowers tubular, red: **Quamoclit pinnata**

20 Leaves bipinnate: **Cardiospermum microcarpum**
Merremia aegyptia

19 Leaves digitate: **Merremia quinquefolia**

18 Leaves trifoliolate:

23 Leaves opposite, flowers white, 5-9 lobed: **Jasminum fluminense**

23 Leaves alternate:

24 Leaves palmately trifoliolate, with winged petioles: **Paullinia cururu**

24 Leaves not palmately trifoliolate, flowers pea-like:

25 Leaflets narrowly ovate or elliptical:

26 Flowers blue or white:

27 Flowers blue: **Calapogonium mucunoides**
Centrosema virginianum

27 Flowers white: **Centrosema pubescens**

26 Flowers pink, red, or mauve:

28 Flowers pink or red: **Macroptilium atropurpureum**
Teramnus pubescens

28 Flowers mauve, but may fade or change colour on drying: **Phaseolus adenanthus**

25 Leaflets broadly ovate, triangular, or rhombic:

29 Flowers generally purple or mauve: **Mucuna pruriens**
Pueraria phaseoloides

29 Flowers yellow, or brownish yellow: **Rhyncosia minima**
Rhyncosia phaseoloides

FORAGES

Factors influencing the ammonia treatment of rice straw

C.K. Sankat

Faculty of Engineering, University of West Indies, St. Augustine, Trinidad

B. Lauckner

CARDI, University Campus, St. Augustine, Trinidad

Small samples of ground rice straw (initial moisture content 7%) were treated at ambient temperatures with aqueous NH_3 at 2, 4, 6 and 8 % levels (on a dry matter basis). The final moisture content was 21%. Samples at each level of ammoniation were held for 7, 14, 21 and 28 days. The IVDMD of the samples, predicted from the pepsin-cellulose method, indicated a strong trend towards higher digestibility with increasing levels of NH_3 application, although the difference between 6% and 8% NH_3 was small. Treatment at ambient temperatures was completed in 7 days. In a second set of experiments, samples of straw were treated with 6% NH_3, such that the final moisture contents were 13% and 25%. These samples were stored at 30, 60 and 90^{o}C, and for 6, 18, 72 and 168 hrs. IVDMD analyses indicated that increasing treatment time, temperature and moisture content of the straw, all had positive effects on the IVDMD.

Keywords: Rice straw; Ammonia treatment; Digestibility

Introduction

Rice straw, the principal cereal crop residue in the Caribbean, has considerable potential for increased usage in livestock production systems. This is particularly so for small island states where forage production may be limited by the availability of suitable land and water resources.

In its natural form, rice straw as a feed source is characterised by low levels of digestibility and protein content, as well as poor palatability. Through appropriate physical and/or chemical processing methods, the nutritive value of rice straw can be considerably improved. Physical methods of processing include straw chopping, grinding and steam treatment. Chemical methods, reviewed by Jackson (1978), include treatment with NaOH, NH_3 or urea.

NH_3 treatment of rice straw has considerable potential advantage over other chemical treatment processes, since it adds to the N content of the straw. However, both the rate and extent of the reaction between NH_3 and straw in terms of improvement in digestibility, are less than with NaOH. NH_3 treatment of straw may be accomplished through one of two methods.

- the polythene covered stack or box method
- the oven (FMA) method

In the first method, bales of straw are covered with a plastic sheet which is sealed to the ground by sand, and anhydrous NH_3 injected into the stack. The ammoniated stack is allowed to stand for weeks, under ambient farm conditions, before the plastic is removed, excess NH_3 is liberated to the atmosphere and the straw fed to cattle. This process may be undertaken by placing the bales in a permanent structure such as a plywood box. In the oven (FMA) method, bales of straw are ammonia treated in a sealed, metal container for 24 hours at 90°C. The factors which affect the treatment of straw with NH_3 to improve the digestibility were noted by Sundstol et al (1978) as being ammonia level, treatment time and temperature, moisture content and initial quality and type of material. They noted little improvement in digestibility with increases in the NH_3 application level above 3-4 percent of dry matter. For ambient temperatures above 30°C, NH_3 treatments were less than 1 week. Waiss et al (1972) working specifically with rice straw, concluded that the optimum process conditions for ammoniation were 5 percent NH_3 for about 30 days at ambient temperature (22°C). Borhami and Sundstol (1982) reviewed the conditions necessary to obtain maximum digestibility of low quality roughages with NH_3 treatment, noting that the factors which influence the treatment process are cumulative.

This paper examines the NH_3 treatment process under ambient, tropical conditions. The effects of time, temperature and NH_3 level on the improvements in *in-vitro* dry matter digestibilities (IVDMD) of rice straw were studied. Attention was also given to the effect on the process of the reduction in moisture content of the straw which takes place after the harvest of the grain.

Materials and methods

Baled rice straw (Starbonnet) was air dried to 7 percent moisture content (wet basis), chopped to 25 mm in length by a forage chopper and ground in a hammer mill using a 3 mm screen. Ground straw samples, each of 64.5 g initial weight (60.0 g dry matter) were treated with aqueous ammonia (s.g 0.88, 33% NH_3).

In the first set of experiments, straw samples held in glass jars were treated with measured quantities of aqueous ammonia and additional water, such that 0, 2, 4, 6 and 8 percent NH_3 were applied (dry matter basis). Agitation assured effective mixing. The final moisture content of all treated samples was 18 percent. The samples were stored at 30°C in an incubator, and jars at each NH_3 level were opened after 1, 2, 3 and 4 weeks. On opening, the samples were thinly spread for 2 hours to eliminate excess NH_3. All samples were then dried at 60°C for 72 hours, prior to storage and subsequent analyses.

In the second series of experiments, samples (60 g, dry matter) of oven dried, ground rice straw were treated with aqueous ammonia to obtain a 6 percent NH_3 application (dry matter basis) and final moisture contents either 11 or 23 percent. Treated samples were stored at 30, 60 or 90°C in either an incubator or in forced convection ovens. Samples were removed after 6, 18, 72 and 168 hrs. They were aerated and dried as previously described, prior to storage and analyses.

A pepsin-cellulose solubility (ES) method, described by Goto and Minson (1977) which utilises the cellulolytic enzyme Onozuka SS was used as the basis for predicting the IVDMD of all the rice straw samples. Two procedural modifications were made to this technique. At the end of the pepsin incubation period, the supernatant was removed by filtration only, while at the end of the cellulose incubation period, the residue was removed by washing from the incubation tubes into a filtering crucible of known initial weight. The crucible containing the residue was then oven dried.

Results and Discussion

Predicting the *in-vitro* dry matter digestibilities (IVDMD): The IVDMD as determined by the rumen liquor method of Tilley and Terry (1963), is widely used to predict forage digestibility. The IVDMD of eight crop residue samples were determined by the Forage Laboratory, University of Guelph, and these results were correlated with the enzyme-solubility (ES) method used in this study. These results are shown in Table 1. The following quadratic model ($r^2 = 0.99$) was used to characterize the relationship between IVDMD and ES.

$$\mathrm{IVDMD} = -6.025 + 1.770\mathrm{ES} - 0.00894\mathrm{ES}^2 \quad . \; . \; . \; . \quad (1)$$

A close relationship was shown between IVDMD and ES, over a wide range of dry matter digestibilities (Figure 1). It was therefore used to convert all the ES determinations to IVDMD data.

Level of NH_3 application and ambient processing time: The IVDMD of rice straw, ammoniated at ambient temperature (30^{0}C) at four levels of NH_3 application are shown in Table 2. The data represent the means of two observations.

The measured moisture content of the aqueous NH_3 treated rice straw averaged 21 percent. The IVDMD of untreated rice straw (control) averaged 41.2 percent. Using this IVDMD control value at zero time, asymptotic models of the form

$$y = a + be^{-kt} \quad . \; . \; . \; . \; . \; . \; . \; . \; . \quad (2)$$

were fitted to the data, for the four levels of NH_3 application.

In this relationship; y = observed IVDMD; t is the treatment time in days; a, b and k are parameters representing the shape of the curve, where in particular, a is the estimated asymptotic value. The parameters fitted for the four levels were as follows.

NH_3 application level	a	b	k
2 %	51.3	-10.1	2.40
4 %	54.8	-13.7	0.27
6 %	58.0	-16.7	0.42
8 %	59.3	-18.1	0.38

These models are shown in Figure 2.

Analysis of variance of the data showed no significant effect due to time, indicating that the ammoniation process under ambient, tropical temperature was complete within 7 days of NH_3 application. This is illustrated in Figure 2, and is in general agreement with previous work on temperate straws (Sundstol et al 1978).

The effect of level of NH_3 application on the IVDMD of rice straw was highly significant ($p < 0.001$). Table 2 shows increasing IVDMD with higher NH_3 levels up to the highest application rate. These results differ somewhat from conclusions previously reported (Sundstol et al, 1978) with NH_3 application levels of higher than 4 percent, though in a later report, Sundstol et al (1979) noted some beneficial effects to increasing NH_3 level from 4.0 to 5.5 and 7.0 percent. The positive response obtained here at increased NH_3 application rates may be due to the initial lower quality of the rice straw and possibly to its higher moisture content.

The positive response of rice straw to NH_3 treatment is consistent with work previously reported by Kiangi and Kategile (1981). They found a maximum increase of up to 14 percent in IVDMD of straw treated with 5 percent NH_3 and noted that dramatic increases were obtained when straw was treated with up to 2.5 percent NH_3, while small but significant increases were obtained beyond this treatment level.

Table 1 Determinations of Dry Matter Digestibilities of crop residues by two methods: Pepsin-Cellulose Solubility (ES) and two-stage rumen liquor (IVDMD)

Sample	ES, (%)	IVDMD, (%)
Untreated rice hulls	5.2	3.2
3% NaOH-treated rice hulls	11.0	9.5
Untreated bagasse	14.5	19.3
3% NaOH-treated bagasse	25.5	35.8
5% NaOH-treated bagasse	35.3	48.0
7% NaOH-treated bagasse	52.7	59.8
Untreated cane tops	28.8	34.2
7% NaOH-treated cane tops	72.2	75.8

Table 2 The effect of level of NH_3 application on IVDMD (%) of rice straw

Time, (days)	Level of NH_3 Application, (% DM)				Means
	2	4	6	8	
7	51.6	51.4	58.5	58.3	55.0
14	48.8	55.7	54.4	56.9	54.0
21	53.7	54.5	57.9	61.9	57.0
28	51.2	54.0	60.5	58.8	56.1
Means[a)]	51.3	53.9	57.9	59.0	

a) SE = $\pm$ 0.85

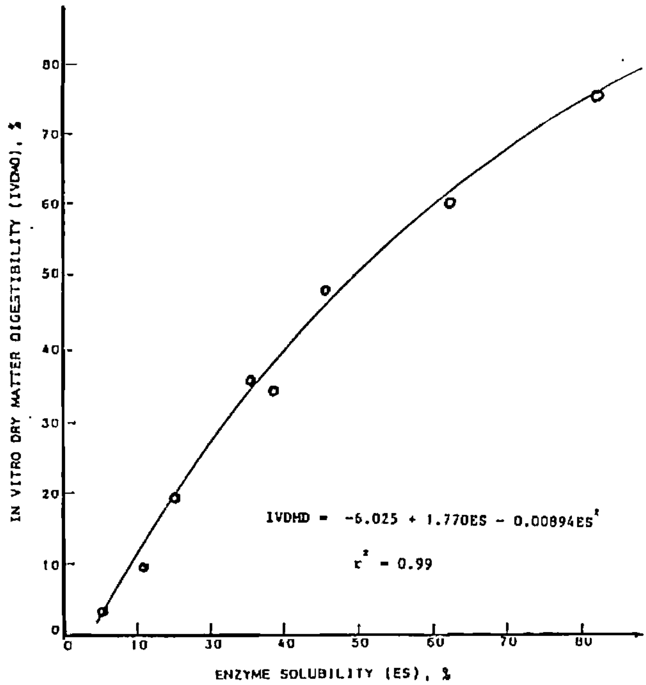

Figure 1 The relationship between *in vitro* dry matter digestibility (INDMD) and enzyme solubliity (ES)

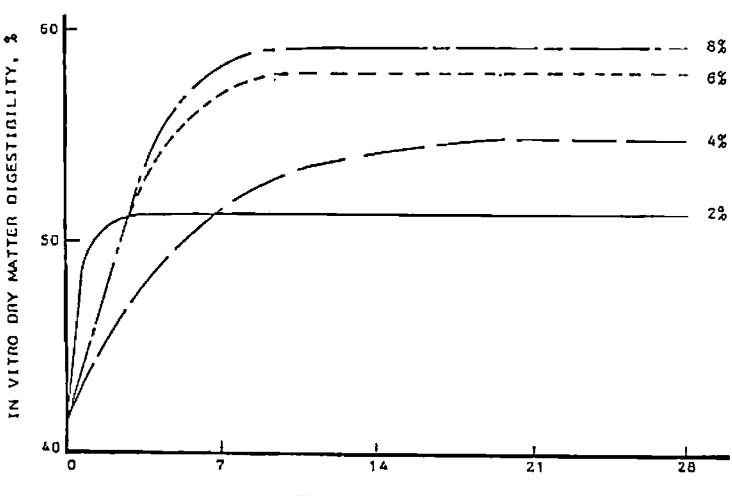

Figure 2 Regression curves for the IVDMD of NH_3 treated rice straw as a function of time at different NH_3 application levels

Process time/temperature/moisture content relationships

The IVDMDs of 6 percent NH_3 treated rice straw (at 13 and 25 percent moisture content as measured) are shown in Table 3, where the treatment temperatures were 30 (ambient), 60 and 90^{0} C. Each value given in the body of the table is the mean of two observations.

Analysis of variance revealed that all the main effects and interactions were significant ($p < 0.001$ for all main effects; $p < 0.05$ for all interactions). IVDMD tended to increase with increasing treatment time, with the maximum rates of improvement occurring within the first 6 hr. of ammoniation.

Table 3 The effect of process time, temperature and moisture content on IVDMD of rice straw treated with 6% NH_3

Process Time (Hr)	IVDMD (%)					
	Moisture Content 13%			Moisture Content 25%		
	Temperature			Temperature		
	30^{0}C	60^{0}C	90^{0}C	30^{0}C	60^{0}C	90^{0}C
6	49.3	56.0	53.1	51.2	59.0	58.7
18	51.9	54.3	55.5	50.7	56.1	57.8
72	55.9	60.6	56.7	56.9	56.6	63.2
168	56.7	58.5	60.2	58.9	61.7	64.2

Overall Means Temperature (SE +_ 0.30) 30^{0}C: 53.9, 60^{0}C: 57.9, 90^{0}C: 58.7
Time (SE + 0.35) 6 hr: 54.6, 18 hr: 54.4, 72 hr: 58.3 168 hr: 60.0
Moisture content (SE + 0.25) 13%: 55.7 25%: 57.9

Increasing the temperature generally resulted in higher IVDMD, with the values obtained at 60 and 90^{0}C being markedly higher than those obtained at 30^{0}C. As the process temperature increased, the reactions appeared to level off earlier. At 30^{0}C (ambient temperature), a treatment time of 1 week appears necessary, confirming the results reported earlier. At 60 and 90^{0}C, a treatment time of at least 3 days appears necessary to achieve the full benefits of ammoniation.

Increasing the moisture content of the rice straw from 13 to 25 percent generally raised the levels of IVDMD, with this being most apparent when the straw was processed at higher than ambient temperatures.

Conclusions

The treatment of rice straw with NH_3 is an effective method of improving the digestibility. Using the polythene stack method of treatment under ambient conditions (30^{o}C), an NH_3 application rate of 6 percent NH_3 (on a straw dry matter basis) appears suitable with the duration of treatment being seven days. The reduction in moisture content of rice straw after the harvesting of the grain will have little effect on the IVDMD of the straw, after ammoniation at ambient temperatures.

Treatment of rice straw with NH_3 at higher temperatures will increase both the rate and extent of the reaction in terms of IVDMD improvements, reducing treatment times from 7 to 3 days. Using the oven (FMA) process, a 24 hour treatment appears inadequate to produce maximum benefits. With high temperature ammoniation, straw at a high moisture content gives greater increases in IVDMD.

While this study did not investigate the effect of NH_3 treatment on the crude protein (CP) content of rice straw, results obtained indicate that at 6 percent NH_3 application level, the CP content of the straw increased from 4.5 to 9.8 percent after 1 week at ambient temperatures. Such results are consistent with those reported previously.

Acknowledgments

The authors wish to thank Mr. K. Sankar and Mr. H. Batson for technical assistance and the Organisation of American States (OAS) for financial support.

References

Borhami, B.E.A. and Sundstol, F. (1982) Studies on ammonia treated straw, I. The effects of type and level of ammonia, moisture content and treatment time on the digestibility in vitro and enzyme soluble organic matter of oat straw, *Anim. Feed Sci. Technol.* 7 45-51

Goto, I. and Minson, D.J. (1977) Prediction of the dry matter digestibility of tropical grasses using a pepsin-cellulose assay, *Anim. Feed Sci. Technol.* 2 247-253

Jackson, M.G. (1978) Treating straw for animal feed, *FAO Animal and Health Paper No 10*

Kiangi, E.M.I. and Kategile, J.A. (1981) Different sources of ammonia for improving the nutritive value of low quality roughages, *Anim. Feed Sci. Technol.* 6 377-386

Sundstol, F.; Coxworth, E. and Mowat, D.N. (1978) Improving the nutritive value of straw and other low quality roughages by treatment with ammonia, *Wld. Anim. Rev.* (FAO) 26 13-21

Sundstol, F.; Said, A.N. and Arnason, J. (1979) Factors influencing the effect of chemical treatment on the nutritive value of straw, *Acta Agric. Scand.* 29 179-190

Tilley, J.M.A. and Terry, R.A. (1963) A two-stage technique for the in vitro digestion of forage crops, *J. Br. Grassl. Soc.* 18 104-11

Waiss, A.C.; Guggolz, J.; Kohler, G.O.; Walker, H.G. and Garrett, W.N. (1972) Improving digestibility of straws for ruminant feed by aqueous ammonia, *J. Anim. Sci.* 35 109-111

Ruminant feeding from agricultural products and agro-industrial by-products at the Sugarcane Feeds Centre

F.A. Neckles

Sugarcane Feeds Centre, Pokhor Road, Longdenville, Trinidad

The Sugarcane Feeds Centre in Trinidad has shown that, particularly where animal effluent is recycled, whole sugarcane can be used in intensive ruminant production. It is fed, either freshly chopped, or ensiled, at varying levels to animals of different ages and physiological states. It can overcome the seasonal fodder shortage experienced throughout the region. Leucaena is a good protein source to use with sugarcane. Five years ago, the supplements used to nutritionally balance sugarcane diets were imported. These have been almost entirely replaced by local crop residues and by-products, reducing feed costs and increasing local economic linkages without affecting animal performance. New processing plants provide wastes from passion fruit, sorrel, cassava and breadfruit, for use as animal feeds. This benefit from crop diversification is often over-looked. As local production and processing for human consumption increases, so also will the availability of by-products for animal production. (Editor's summary).

Keywords: Animal feeds; Ruminants; Sugarcane; By products; Crop Residues; Leucaena; Diversification

Introduction

The English speaking Caribbean Community is heavily dependent on importation to feed both its human and animal populations. Despite the efforts of many countries of the region to increase food production, the food import bill is close to US $1 billion. Exports from agriculture are only half of this level (Demas, 1987).

The Sugarcane Feeds Centre, a research and development institution, was established in 1976 as a project of the Canadian International Development Agency (CIDA), to demonstrate the technical feasibility and economic viability of the use of sugarcane as a feed for cattle. After five years of operation, it was handed over to the Government of the Republic of Trinidad and Tobago in October 1981. Since that time, the Centre has increased its animal population on a zero grazing system from 500 to over 800. It maintains a calf unit that purchases and rears about 400 animals per year, has a small dairy with 45 head and a small sheep and goat unit of 120-150 head. Male cattle are grown to produce beef and females for replacements, to be sold to the dairy industry. In 1986 over 500 animals and 8000 kg of milk were produced.

The objectives of the Centre for the period 1985 to 1987 are as follows:

(a) To develop sugarcane feeding technology and to facilitate transfer of such technology in Trinidad and Tobago.
(b) To continue to work on protein, energy and other supplementation.

(c) To develop and formulate diets by incorporating local and/or farm grown ingredients to the fullest extent feasible.

(d) To develop feeding and management systems applicable to the Caribbean Region.

(e) To maximise revenue within the framework of the broad objectives.

These objectives confirm a feeding strategy started in 1982 after the Centre had been handed over to local direction and management. The use of whole sugarcane as an animal feed is one aspect of sugarcane diversification. The Centre's programme is a demonstration that further diversification of agriculture is vital to the development of local animal production. Progress can be made in solving the food importation problem if agricultural production and processing are developed and integrated with other activities in the national economy.

The infrastructure at the centre

The Centre is located on 61 hectares of mostly acid ultisol, the Piarco Fine Sandy Loam series. The soil is considered as class IV non-agricultural, and its features include, pH 3.5, - 4.5, lack of structure, low organic matter and nutrient status, high bulk density, small drainable pore space and low water holding capacity (Ahmad and Gumbs, 1978). It becomes puddled in the wet season and rapidly dries out in the dry season. Rainfall is approximately 1800 mm, with a marked dry season between January and May. Pre-implementation studies for establishing the centre revealed a public water supply deficit in the area, so before buildings were completed or lands cultivated, a dam was constructed on an existing ephemeral stream. The lake formed, initially about 3.6 hectares, was fed by rain, run-off and a water bearing gravel layer. This secured water for animal consumption and for pen hygiene (about 50,000 litres per day) and allowed development of large scale irrigation.

The irrigation system consists of a 150 mm PVC underground main with strategically placed risers and hydrants. A traveling sprinkler is used on the sugarcane traces, which are about 70 metres apart. The system is connected into primary and secondary manure ponds. The latter is needed for storage of dilute manure in the wet season. An advancing cavity pump and a diesel powered irrigation pump are used for irrigation purposes in the dry season.

Between 1977 and 1979, about 10,000 metres of sub-surface drainage tubing was installed with laterals at spacings of 10.6, 18.3 and 22.9 metres, depending on the permeability of the location. Planting takes place on ridges one metre apart, to effect surface drainage.

Sub-surface drainage lowers the water table about 30 cm in 24 hours after heavy rainfall, compared with 5 cm in undrained areas. Millable cane stalk was increased by 52 percent by drainage (Cambridge, 1980). Gumbs (1981) reported improvement in the soils after four years of cultivation and application of liquid manure and Livan (1984) reported yield increases through liquid manure application. With limited use of fertilizer (about half the recommended rates), average yields in the order of 60 - 80 tonnes per hectare (stalk and tops) are achieved, and up to five or six ratoons have been obtained.

Sugarcane cultivation is well known so will not be discussed here. The sugarcane variety first used was B41227 and in 1984 a small area of B64134 was planted. Sugarcane as a feed for ruminants is low in protein. To achieve more than maintenance, the chopped sugarcane must be supplemented with protein and starch to form a balanced diet. *Leucaena leucocephala* CF 95 has been grown at the Centre since 1978 for use as a protein source. Average annual total fresh matter yields on two hectares have been estimated at 8 tonnes per hectare from 1984 to 1986. These yields are less than half those projected by Garcia (1987) from work with small plot, short-term trials. The use of rigid cutting regimes at 6 or 8 week intervals is expected to improve both the total yield and the quality of the forage, as judged by animal performance.

Leucaena establishment on acid soils is not well known and experiences with a system of cultivation are outlined. After 24 - 48 hours soaking, seed was formerly planted in styrofoam cups or in peat pellets, with transplanting onto ridges in the field at 6 - 8 weeks. This has been discarded, in favour of direct seeding (after seed soaking) in continuous rows on ridges. Planting is done by hand. Use of pen manure is beneficial and the young seedlings must be sprayed weekly to control mole crickets and leaf eating ants. Direct seeding avoids the set back of transplanting and initial establishment is more rapid.

Weed control is essential, though the Leucaena tends to survive under weed cover. Glyphosate, used at one quarter the recommended rate and with a spray shield, was found suitable, although the legume leaves are very sensitive to the herbicide. Gramoxone can also be used, with hand weeding where necessary.

Hand harvesting with a cutlass starts after about six months of growth. The stumps are generally cut at a height of about 15 cm, but cutting at one metre allows for more efficient weed control.

Animal feeding results

For sugarcane feeding, the inverse relationship between percent sugarcane in the diet DM and animal performance has been described in the Centre's reports. The relationship is in keeping with the established forage (or fibre) to concentrate relationship. Ruminant diets need to be properly balanced for protein, energy, minerals, vitamins and fibre. The Centre has developed feeding strategies based on the physiological ability and condition of the animal, its liveweight, nutrient needs and potential for growth. This aims at optimising, rather than maximising the use of sugarcane in the diet. A young growing animal is fed 10 - 15 percent sugarcane, which increases as the animal matures up to about 50 percent, depending on the other diet ingredients and their nutrient content including the fibre levels.

Leucaena has been in use at the Centre since 1980 and is proving to be of increasing benefit to animal production. The dehydrated forage is used in rations at levels varying from 6 to 20 percent. Fed to lactating cattle, Leucaena has been found capable of replacing from 50 to 100 percent of soyabean meal in the diet, with no deleterious effect on milk yield (J.A. Brown, pers. comm.). Milk yields averaged 10.5 kg per day over 300 days when Leucaena was fed at 12 to 18 percent of the total dietary dry matter. Feeding levels at the centre's dairy are currently about 6 percent, being dependent on the quantity of dehydrated Leucaena forage available.

In calf feeding, after weaning at 35 days, dehydrated, 12 week regrowth of Leucaena produced average daily weight gains of about 0.45 kg. When six week regrowth was used, average daily gains increased by 50 percent. Preliminary results with calves fed from arrival at the centre (7 days of age average) to weaning (at 35 days of age) indicate that early growth rates can be at least doubled with Leucaena feeding.

Garcia (1987), in a growth study using Holstein bulls of 150 to 200 kg liveweight, reported growth rates of over 1.0 kg per day when dehydrated Leucaena forage was included in the diet at about 20 percent of DM. Work at the centre with weaned crossbred male sheep consistently shows growth rates of 0.18 to 0.25 kg per day at this same level of inclusion of dehydrated Leucaena forage (C.H.O. Lallo, pers. comm.).

Much of this can be related to stage of regrowth of the Leucaena. While total crude protein yield increases with a longer interval between cuts, the crude protein percentage falls and the forage becomes more fibrous. The Centre plans to extend cultivation of this crop and the Leucaena cultivars of the OAS Caribbean collection will be evaluated in an attempt to identify higher yielding types for the acid soils at the Centre.

Other crops

Until 1981, dependence was on imported maize, and soyabean and rapeseed meals in the formulation of balanced sugarcane based diets. Since that time, the more common traditional by-products of agro-processing e.g. rice endbits, rice bran, brewers grain (wet and dried), wheat middlings and dried citrus pulp have been used in feed formulations. Poultry rendered meal (combining feathers and entrails from poultry processing) was successfully evaluated as a substitute for soyabean meal as a protein source in all diets except for young calves. Diets and comparative costs are shown in Tables 1 and 2.

The latest phase of the Centre's work is on the use of crop by-products as local agriculture receives new impetus. Thus sweet potatoes and cassava tubers unfit for human use have become available in some quantity. Additionally, cassava skins and rejected tubers have been extensively utilized at 20 - 25 percent of the dietary DM as an energy source for growing animals, while the processing of cassava, breadfruit and similar crops is developing.

Two companies produce a passion fruit cordial and the waste material is collected and used as feed. Waste from sorrel processing is also available in season. Most crops give 30 to 60 percent as by-products, either through inefficient processing or by the nature of the fruit or product itself. Ruminant production systems can be based on this, and the more food locally produced and processed for human consumption, the greater will be the availability of wastes or by-products for animal feeding. Another crop residue of increasing availability is maize stover.

R.A.I. Brathwaite (pers. comm.) stated that, increasingly, farmers are achieving planting densities of up to 45,000 plants per hectare with this crop. Maize in Trinidad and Tobago is hand picked for the fresh market. Ears that are of inadequate size or maturity are left on the green stalk and later ploughed in. The Centre has used its harvesting capability to collect and ensile this product with molasses. The idea is catching on as more crop farmers are offering the product to the Centre. Silage making is not common in Trinidad and Tobago despite the severity of the dry season.

Table 1 Diet formulations on a dry matter basis (%DM) with local and imported ingredients fed to small ruminants (Cost in TT cents/kg DM)

Diet Ingredients	Local Ingredient			Imported (Corn/Soya Based)	
	Lactation/ Creep Feed	Gestation	Growing	Growing	Growing
PRM[1)]	8	7	17	0	0
Rice End Bits	10	0	15	0	0
Molasses	17	10	16	15	0
Leucaena	20	10	0	0	0
Rice Bran	43	13	17	0	0
Citrus Pulp	0	40	17	0	0
Sugarcane	0	18	17	35	35
SBM[2)]	0	0	0	24	0
Corn	0	0	0	24	5
Minerals + Vitamins	2	2	1	2	0
Commercial Concentrate[3)]	0	0	0	0	60
Total	100	100	100	100	100
Cost (TT cents/kg DM[4)])	29	41	42	58	70

1) PRM = poultry rendering meal (2) SBM = Soyabean meal (3) eg. dairy ration or calf starter: 4) In 1987. US$ 1.00 = TT$ 3.60

Table 2 Formulation and Costs of Diets for Lactating Dairy Cows (%DM)

Ingredient	Feed type	
	By-Product	Commercial Feed
Sugarcane	23	20
Molasses	17	20
Wheat Middlings	25	0
Coconut Meal	22	0
Maize/Soyabean /Minerals	13	0
Commercial Feed	0	60
Total	100	100
Cost (TT cents/kg DM[1)])	35	56

1) In 1987 US$ 1.00 = TT$ 3.60

Currently the Centre is test growing maize and forage sorghum in conjunction with the Department of Crop Science, UWI, St. Augustine. Attempting to grow the former has been an instructive experience on the acid soil at the Centre. Eventually it is hoped to produce three crops per year with harvesting before ear maturity as a measure against praedial larceny, and the entire plant will be ensiled.

Conclusions

The Sugarcane Feeds Centre is part of a diversification effort that is necessary in the Caribbean. By it's work, it demonstrates the benefits of crop-animal integration on a farm scale. The use of poor soils becomes possible when resources are properly harnessed for the purpose. Integration of crop-animal agriculture on a wider national scale is appropriate, especially for ruminant production. It is suggested that specialists interested in agricultural development should keep in mind the need to explore the possibilities and potentials that exist. In many territories that depend heavily on imported feeds, adapted crops such as sugarcane and Leucaena could be used instead. Many locally available crop residues and by-products are not fully utilized at present, but have potential for feeding. If this is done, the region could rapidly increase its degree of self-sufficiency. Integrated efforts would see a start to better utilization of such resources.

References

Ahmad, N. and Gumbs, F.A. (1978) The Soils of the Sugarcane Feeds Centre, Longdenville. *Unpublished Report, Dept. Soil Sci. Uni. of West Indies*, St. Augustine, Trinidad

Cambridge, P. (1980) An evaluation of the first production- scale subsurface drainage system in Trinidad and Tobago. *M.Sc. Thesis, Dept. Agric. Eng., Mac Donald College, Mc Gill Uni.* Montreal, Canada

Demas, W.G. (1987) Agricultural Diversification in the Caribbean Community: Some Issues. *Statement by the President, Caribbean Development Bank, Seventeenth Annual Meeting, Board of Governors*, Grenada, May 1987

Garcia, G.W. (1987) Production of Leucaena (*Leucaena leucocephala*) and Cassava (*Manihot esculenta*) forages and their nitrogen utilization by growing dairy cattle fed sugarcane based diets. *Ph.D. Thesis, Submitted to Dept. Livestock Sci. Uni. of West Indies*, St. Augustine, Trinidad

Gumbs, F.A. (1981) A further study of the soils of the Sugarcane Feeds Center, Longdenville. *Unpublished Report, Dept. Soil Sci. Uni. of West Indies*. St. Augustine, Trinidad

Livan, M.A. (1984) Ameliorating the soil physical properties of Piarco Fine Sandy Loam and the effect on sugarcane growth and yield. *M.Sc. Thesis, Dept. Soil Sci. Uni. of West Indies.*, St. Augustine, Trinidad

Practical considerations when rogueing *Acacia tortuosa* and *A. macracantha* in pastures

G. Houston Holder

Cooperative Extension Service, RR 02, P. O. Box 10,000, Kingshill, St. Croix, USVI 00850

Acacia tortuosa and *A. macracantha* are the most noxious woody plants in U.S. Virgin Islands pastures, infesting 90% of the fields and decreasing utilizable pasture area by up to 26%. These *Acacia* species are well adapted to the semi-arid climate and the calcareous soils of the Virgin Islands. Cattle grazing also creates conditions suitable for *Acacia* development by enhancing seed dispersal and reducing the competitive ability of preferred forages. Populations of the *Acacia* species can be suppressed by the natural environment, by pasture and grazing management, and by rogueing. Mechanical and chemical methods have been evaluated in St Croix. Preliminary studies suggest that extensive *Acacia* rogueing using hand tools is not practical or economical. Rogueing by bulldozer is not economical and ad-versely affects the physical condition and botanical composition of pastures. Basal herbicide applications are more effective and more economical than foliar applications. When basally applied, hexazinon and tebuthiuron are equally effective and more economical than picloram at labeled rates.

Keywords: Acacia spp; Herbicides; Hexazinon; Tebuthiuron; Trychlopyr

Introduction

Acacia tortuosa and *A. macracantha* are the most noxious woody plants in the U.S. Virgin Islands pastures, infesting 90 percent of fields and decreasing utilizable pasture area by up to 26 percent (Michaud and Michaud, 1987). They also affect the entry of light machinery into infested areas. Areas invaded by these *Acacia* species quickly become colonized by other persistent, woody plants. To ensure productive pastures, these species must be controlled.

Acacia tortuosa and *A. macracantha* are successful in the Virgin Islands because they can tolerate the semi-arid climate, irregular rainfall and calcareous clay soils that are typical of the islands. Both species are successful pasture weeds because they are not eaten by cattle, except for seed pods and the youngest shoots. This is due, in part, to their long, sharp spines which lignify with age. These *Acacia* species withstand mechanical shredding and can colonize overgrazed or degraded pastures. Mechanical rogueing methods and selective ruminant foraging enhance *Acacia* seed dispersal while reducing the competitive ability of desirable forages.

Both *A. tortuosa* and *A. macracantha* are copious seed producers (Little et al. 1974). The seeds have a very hard seed coat and can survive long periods in the soil. Viable seeds can also pass intact through the digestive system of ruminants (P.J. Michaud, pers. comm.)

The objectives of this study were to characterize local *Acacia* destruction methods and to research alternatives. Mechanical and chemical *Acacia* control has been studied before in St Croix under different economic conditions, testing control efficacy of different herbicides (Oakes, 1958; Oakes, 1970). Results of studies conducted in St Croix since 1983 are reported here. These results support and augment earlier findings.

Control of *Acacia*

Forage producers suppress *Acacia* populations by changing pasture utilization from grazing to hay production, managing grazing frequency and destroying residual plants. The environment also exerts some control pressure on *Acacia* species, e.g., by pest attack, plant competition, drought and flooding.

Traditional *Acacia* Control

Local pasture managers destroy *Acacia* plants individually. Individual plant destruction, or rogueing, is not practiced until the plant has matured to the seeding stage, since before this stage is reached, the young plants cannot reproduce themselves and so increase the population; some will die of natural causes and small, young plants do not represent a major problem in pastures.

In the Virgin Islands, there are two common *Acacia* rogueing methods: 1) Grubbing, or severing and un-earthing *Acacia* plants from below the first set of lateral roots; and 2) Applying diesel oil to the basal buds.

Mechanical grubbing is carried out using hand tools and heavy machinery. The process is simplified when the plant has one central stem and when the soil is dry rather than wet, because dry soil physically supports the plant better than would damp soil when the plant is being severed.

Hand rogueing is effective for small areas but impractical for larger fields because of high costs and a shortage of willing labour. Hand tools most commonly used for *Acacia* rogueing are the pick and mattock. Tractors and bulldozers are used for mechanical rogueing, the latter being the preferred machine. The government subsidizes agricultural rental of a bulldozer, the subsidized hourly rate being US$ 30.00 including operator and fuel. A bulldozer can remove from three to seven *Acacia* plants per minute, depending on soil texture and moisture, plant density and operator skill and persistence. This results in costs generally exceeding US$ 0.14 per plant.

One disadvantage of using bulldozers for rogueing is that it adversely affects the physical condition of pasture land. Areas where plants have been removed are less level, and therefore interfere with the passage of machinery, particularly hay cutting, raking and baling equipment. Another disadvantage is that vegetation is destroyed on up to 1.5 square metres and soil is disturbed to a depth of 0.3 m when plants of 3.8 cm basal diameter are cleared by use of a blade 2.7 m long. To decrease the amount of damaged area, some producers add a steel gouge, 0.1 m wide, extending down 0.15 m from the lower edge of one end of the blade. Effective manipulation of this extension requires greater operator skill than the use of the blade alone.

Bulldozer rogueing also adversely affects the species composition of pastures. Turning soil and uprooting plants moves dormant seed to the soil surface, while the destruction of the vegetative cover provides a place for invader plants to colonize. Common noxious colonizers include species of *Asclepias*, *Crotalaria* and *Jatropha*. *Acacia* can also reinvade the area.

Local pasture managers also rogue *Acacia* plants by applying diesel oil to the basal buds of individual plants. This method is labour intensive and is not extensively used.

Chemical control of *Acacia*

The practice of applying chemical herbicides to kill *Acacia* plants had not been adopted by local pasture managers prior to the initiation of these trials in 1983. Studies evaluated herbicide applicators, herbicide application methods, control efficacy and the economics of control methods.

Herbicide applicators and application: Two herbicide applicators were used to apply herbicides to *Acacia* plant bases: a custom granular applicator and a custom liquid (Spotgun) applicator. Herbicide application rate varied over 20 percent with the granular applicator because of the size and distribution of herbicide pellets. Herbicide application did not vary appreciably with the liquid applicator. A backpack pump sprayer was used to apply herbicides to *Acacia* foliage.

Herbicides were applied to *Acacia* plants by two methods: basal and foliar. Basal herbicide application to plants of 2.5 to 3.8 cm base diameter was three to nine times faster than foliar application.

Herbicidal *Acacia* control efficacy: *Acacia* control efficacy evaluations were made using hexazinon (*Velpar* 2L), picloram (*Tordon* 10K and 22K), tebuthiuron (*Spike* 40P and 80WP), and triclopyr (*Garlon* 4). Application rates and methods are listed in Tables 1 and 2. Treated plants were from 1 to 2 m tall, with basal diameters in the range of 2.5 to 3.8 cm. Only plant deaths were recorded as successful control, the final evaluations being made up to one year after treatment.

Results for each herbicide are a compilation of the results of at least two different tests of over 40 targeted plants each. Not all herbicides or herbicide rates were tested at the same time, nor at the same location. Results of all tests were included to demonstrate the possible variability when applying herbicides to *Acacia* plants under local conditions.

Both picloram and triclopyr break down when exposed to ultraviolet light, making them less effective foliar herbicides (WSSA, 1983). In addition, although herbicides were applied when weather conditions were conducive to rapid plant growth, these conditions did not always persist, causing targeted plants to be less receptive to herbicide uptake than they would have been had weather conditions remained stable.

Herbicides applied at the base of *Acacia* plants are more persistent than those applied to the foliage. Hexazinon and tebuthiuron are inherently more persistent in the environment than picloram and triclopyr (WSSA, 1983). Herbicides applied at the base of *Acacia* plants persist until good rains provide conditions conducive to their uptake.

Preliminary evaluations of chemical rogueing efficacy suggest that basal applications of hexazinon, pelleted picloram and tebuthiuron are more effective than are foliar applications of picloram and triclopyr (Tables 1 and 2). These data also suggest that basal applications of hexazinon and tebuthiuron are equally effective, and more economical than basal application of picloram (Table 2). Pelleted picloram is no longer available, and liquid picloram is not labeled for basal application.

Table 1 Herbicides applied to the foliage and under the canopy of *Acacia* plants

Herbicide plus surfactant	Formulation	Application Rate Product (ml/l) [1]	Application Rate AI/plant avg. (g)	Control (%)
picloram	22K, liquid	5.6	0.22	73
	22K, liquid	7.5	0.33	45
triclopyr	4, liquid	1.9	0.15	33
	4, liquid	3.8	0.30	42
	4, liquid	7.5	0.60	61

1) ml of product per litre of solution.

Table 2 Herbicides applied at the base of *Acacia* plants

Herbicide	Formulation	Application Rate Product	Application Rate AI/Plant (g)	Cost[1] US$	Control (%)
hexazinon	2L, liquid	2.0 ml	0.48	0.029	100
(*Velpar*)	2L, liquid	4.0 ml	0.96	0.057	100
picloram	10K. pellet	3.5 g	0.35	0.025	0
(*Tordon*)	10K, pellet	4.7 g	0.47	0.039	95
	10K, pellet	7.1 g	0.71	0.050	95
tebuthi-uron	40P, pellet	1.1 g	0.44	0.025	97
(*Spike*)	80W, slurry	2.0 ml	0.69	0.032	100
	80W, slurry	4.0 ml	1.38	0.065	95
	40P, pellet	3.6 g	1.44	0.083	99

1) Cost of herbicides (in US$)

Velpar	2L,	$54.00 per 3,785 ml
Tordon	10K	3.20 per 454 g
Spike	40P	10.50 per 454 g
Spike	80W	17.00 per 454 g (432 g of product plus water to make 1 litre of slurry)

Conclusions

U.S. Virgin Islands pasture managers need an economical, efficient *Acacia* rogueing method that can be utilized at any time of the year. Results of this study indicate that basal applications of the chemical herbicides hexazinon or tebuthiuron satisfy this need.

Acknowledgements

St Croix ranchers Cedric C. Nelthropp, Henry V. Nelthropp, Charles O. Schuster and Oliver Skov demonstrated traditional rogueing methods. The manuscript was reviewed by Walter I. Knausenberger, Michael W. Michuad and P. Joy Michaud. Errol Chichester, Kenneth Davis and Marti Terry-Purdy provided technical assistance while Rudolph O'Reilly helped with presentation graphics. Herbicides were provided by Dow, E.I. DuPont de Nemours and Elanco.

Disclaimer: Reference to commercial products or trade names is made with the understanding that no discrimination is intended and no endorsement is implied.

References

Little, E.L.; Woodbury, R.O. and Wadsworth, F.H. (1974) Trees of Puerto Rico and the Virgin Islands, Second Volume, *U.S. Department of Agriculture Handbook No: 449*. Washington D.C

Michaud, M.W. and Michaud, P.J. (1987) Naturally occurring legumes in the pastures of St Croix, *Virgin Islands Perspectives - Agricultural Research Notes* 2(1):7-11

Oakes, A.J. (1958) Suggested guide for brush control in pastures, *U.S. Department of Agriculture, Agricultural Research Service*, Virgin Islands Agricultural Program

Oakes, A.J. (1970) Herbicidal control of *Acacia*, *Turrialba* 20(2):213-216

Weed Science Society of America (WSSA) Herbicide Handbook Committee, (1983) Herbicide Handbook, Fifth Edition, *Weed Science Society of America*, Champaign, Illinois

Pasture seed as a crop for small farmers

R.T. Paterson and P. Philip

CARDI, P. O. Box 766, St. John's, Antigua

The advisability of promoting forage seed production as a crop for small farmers was examined in the Caribbean context. If used in rotation with crops, a minimum 3-year pasture break is capable of reducing disease and weed problems, improving soil structure and chemical fertility, and the foliage left after seed harvesting provides a valuable source of either animal feed or mulch for sale or use in other farm enterprises. The sale of seed would provide a useful cash income. Problems include the loss of flexibility imposed by a perennial crop, the weed potential of pasture species, competition for available labour and the present lack of an established local market for the seed. Government policies to stimulate the use of pastures would increase the demand for seed, while a potential export market already exists in South America. It is concluded that if central cleaning and quality control facilities are established by a regional organization such as CARDI, pasture seed production could be an attractive alternative for careful farmers.

Keywords: Grasses; Forage legumes; Seed production; Small farmers

Introduction

The production of seed of tropical pasture species is a capital-intensive, specialist operation in Australia (e.g. Humphreys, 1975) and parts of Brazil, but other countries have chosen less costly ways to provide farmers with the seed required for pasture development. Ferguson (1979) describes several levels of intensity of operations in South America, but notes that most seed is produced as an opportunist by-product of commercial grazing enterprises. In contrast, Hare (1985) refers to a successful project in Thailand, where in 1981, 200 tonnes of pasture seed was produced by village farmers using manual harvesting and cleaning methods. Where the availability and cost of labour permits, collection by hand produces higher yields and better quality seed than mechanical harvesting.

In the Caribbean, a range of pasture seed has been produced in Antigua and Trinidad by CARDI as a specialist enterprise, using a combination of mechanical and manual operations, while volunteer Guinea Grass (*Panicum maximum*) is collected manually for either home use or local sale in Jamaica. No systematic attempt has been made to promote pasture seed as a crop for small farmers. This paper attempts to examine the technical feasibility of such an exercise.

The market

The level of present demand for pasture seed in the Eastern Caribbean was discussed by Paterson (1987). It was concluded that current production levels only satisfy about half of the requirement for the drier, calcareous soils in the region, although present demand is distorted by the fact that CARDI provides seed free-of-charge to Government and Development agencies throughout the CARICOM area.

Almost certainly, the demand would fall if current world market prices were charged for the seed. Indications are, however, that commercial livestock farmers in Barbados, where about half of the production from Antigua is presently used, are sufficiently convinced of the value of improved pastures to begin to pay for the seed that they require.

Attempts to assess the demand for seed suitable for acid, infertile soils in the Caribbean have met with little success. While there is undoubtedly an enormous potential for pasture improvement in countries such as Jamaica, Guyana and Trinidad, the lack of clear species recommendations inhibits the establishment of large scale regional seed production projects. The purchase of seed on the world market is not an attractive proposition, given the present currency values and shortages of foreign exchange in these countries. The answer to these problems could lie in the production of a range of species by small-scale farmers for sale on the local market.

Climatic and edaphic requirements

A detailed description of the climatic and edaphic requirements for tropical seed production is given by Humphreys (1975), while a more recent summary is provided by Hare (1985).

Best yields of most species are obtained within the range of 10 to 23^{0} of latitude. Below 10^{0}, day length variation from season to season during the year is insufficient to induce prolific flowering in plants which are sensitive to daylength. Most commercial pasture species require short days for flowering while others require long days. Very few are day neutral. Above 23^{0} of latitude, the risk of cold weather, or even frosts at the time of flowering is too great in most countries, although in small islands the danger is lessened by the maritime influence.

An annual rainfall of between 800 and 2,000 mm is generally considered to be adequate for most species. Below about 800 mm, the wet season is unreliable, while above 2,000 mm, the lack of a well-defined dry season favours plant diseases and creates problems during harvesting.

Tropical pastures can be grown on a range of soils, but best seed yields are obtained on good agricultural soils. Very acid, saline or waterlogged areas are generally unsuitable, while shallow soils reduce seed yields, since they limit root growth.

With the exception of Guyana, which lies too close to the equator to produce high yields of most pasture species, the CARICOM countries in general provide a combination of physical characteristics which render them suitable for the production of seed of tropical pastures. Pasture seed could constitute a potentially lucrative alternative crop for those farmers who are prepared to develop the skills necessary for efficient production.

Pastures in the small farm system

There are numerous small farm systems to be found in the Caribbean region. A full discussion of the existing variation is beyond the scope of this paper; suffice to say that on most small farms in the drier areas, a combination of vegetables and annual field crops are produced. In higher rainfall areas, permanent tree crops (coconuts, fruits) or semi permanent crops such as bananas tend to assume greater importance. Many small farmers also keep livestock. Cattle are frequently tethered along road sides or on common land, while sheep and goats are often allowed to roam free during the day, being confined at night to reduce animal losses. Pasture seed production within such a system offers several potential benefits, but could also compete with existing activities. The main advantages and disadvantages are discussed below:

Advantages

Most of the tropical pastures recommended for commercial use in the region are perennial, producing good seed yields for a minimum of three years. In a commercial environment, first year yields are usually sufficient to show a profit after paying all establishment costs. Maintenance costs in the second and subsequent years are low, and profits are then considerably higher.

A three year pasture break is usually sufficient to control soil-borne diseases or persistent weeds in a problem area. Grass weeds can be smothered by the use of a legume, while broad - leaved weeds can be economically controlled in a grass stand by the use of selective herbicides.

Three years under pasture is usually sufficient to produce noticeable improvements in both soil fertility and structure, particularly if the species chosen is a legume. As well as being able to fix atmospheric nitrogen, the deep root systems of most legumes are capable of recycling plant nutrients from the deeper horizons of the soil profile. The undisturbed root mass will increase the organic matter content of the soil and improve the structure for subsequent crops.

While the harvesting of pasture seed on a small scale is carried out by hand, it is not heavy work. In many parts of the world, women and children are given the task of collecting and cleaning the seed.

The pasture foliage which is left behind after the harvesting or cleaning operations represents a valuable resource. It can be used as a mulching material in the cropping enterprise. The excellent results obtained in many tropical countries by the use of fertilizer/mulch from legumes such as *Leucaena leucocephala* are well known. Herbaceous pasture legumes are equally suitable for this purpose. While grasses have a lower nitrogen content than legumes, and consequently are less effective as fertilizer material, they decompose more slowly when placed on the soil, and therefore have a longer lasting effect on water conservation. The relative merits of grasses and legumes as mulching material will depend upon the fertility and soil moisture relations prevailing in a particular field. Mulching with guineagrass is an established practice in Jamaica and the technique has improved crop yields in Antigua (L. Daisley, pers. comm.)

The foliage can also be used as animal feed. If the home farm has no livestock, leguminous leaf and pod material can be dried and bagged for storage, while grass can be cut and made into hay. These commodities can be sold to livestock owners, particularly during the worst part of the dry season.

Several of the advantages outlined above are difficult to quantify, but it is clear that the cash payment received from the sale of seed is only a part of the economic return to be derived from pasture seed production. The reduction in soil borne diseases and the improvement in soil fertility, together with the ready availability of mulching material should lead to increased yields from the cropping enterprise, although these benefits will not become fully apparent until the area of land used for the pastures is ploughed up and returned to a cropping phase. Improvements in the animal enterprise would arise in the first year, although these will be small if attempts are made to feed too many animals with the available material. Above all, pasture seed production provides an opportunity to solve particularly difficult disease or weed problems while still generating a cash income from the affected plot.

Disadvantages

The production of pasture seed is a relatively inflexible operation, since an area should be kept under the crop for at least three years to derive the maximum benefit from the enterprise. It therefore reduces the ability of the farmer to rapidly respond to changing market opportunities.

Most pasture species have to be harvested quickly once the crop is mature, since the seed falls or the pods shatter within a few days of seed maturity. Judgement must be exercised to choose the correct time of harvesting, since a week either way from the optimum date can make a large difference to the yield of clean seed. Best yields are obtained from repeated harvesting, but this increases the labour requirement.

Careless choice of pasture species can lead to severe competition for labour between the seed crop and the other farming enterprises.

An area of green pasture during the dry season will be particularly attractive to livestock. Fences must be maintained in good condition, since the unplanned entry of livestock may ruin not only the seed crop but also other crops in adjacent areas.

There is no formal market established for pasture seed in the Caribbean region, although demand is starting to grow as farmers become aware of the benefit to be derived from the use of improved pastures. The major disadvantage is obviously the lack of a ready market within the region. There presently exists a large demand in the northern part of South America for seed of species suitable for use on acid soils. If the efficient Caribbean producer could compete in the international market, he would enjoy the advantage of being much closer to the consumer than the traditional suppliers in Australia and South-East Asia.

Species considerations

There are some aspects of pasture plants that must be taken into account by the farmer who is considering seed production.

Grasses: In general, perennial grasses are potential weeds on a cropping farm. Pasture grasses are frequently stoloniferous, and can therefore spread both by seed and by creeping along the surface of the ground. The sward can be hard to kill out at the end of the pasture phase, unless a mouldboard plough is available to completely invert the sod, or unless use is made of expensive herbicides such as glyphosate. Seed is produced during the wet season when the labour requirement for crop production is at its peak. To counteract these disadvantages, grazing (or cut grass) is available throughout the dry season. Most pasture grasses will produce at least two crops per year if they are cut back or heavily grazed after the first harvest. If harvesting is carried out at the optimum time, Guinea (*Panicum maximum*) or Signal grasses (*Brachiaria spp.*) can yield up to about 100 kg/ha of commercial seed at each harvest, although the production will depend upon soil fertility and moisture availability. After taking the seed, the forage available for grazing, mulching etc. is usually in excess of 8 tons of dry matter per hectare per year.

Legumes: Legumes are easier to eliminate than grasses. Cutting at, or close to ground level with a cutlass will kill most mature plants, while the seedlings which emerge later are susceptible to cheaper herbicides such as gramoxone or 2, 4-D, particularly in the early stages. Seed is usually produced only once during the dry season (April - May in Antigua), so inability to harvest at that time can lead to the loss of the whole crop. Grazing, cut forage and mulch are usually only available after the harvest of the seed, although a light topping or grazing is sometimes possible in December or January to reduce the bulk of foliage, well before the time of flower initiation. With frequent hand harvesting, most species are capable of producing in excess of 400 kg/ha of clean seed, particularly if the scrambling species are allowed to climb on a fence. This not only improves yield, but also makes collection a less tiring operation. The forage available after seed harvest is usually some 5 t/ha per year, but its high nitrogen content makes it suitable, either as a protein-rich animal feed or as a fertilizer.

Some seed sown pasture grasses and legumes recommended for the Caribbean region are shown in Table 1. The recommendations are taken from several sources (e.g. Keoghan, 1980; Cumberbatch, 1986) modified in the light of observations. They are intended to give an indication of the species for which there is a current demand, or for which one is expected to develop in the near future. They are the species which should be considered for potential small-scale seed production.

Table 1 Seed sown pasture grasses and legumes for the Caribbean Region

Soil Group	Grasses	Legumes
Neutral to Alkaline (pH 6.5 and above)	*Cenchrus ciliaris* *Chrysopogon sp.* *Panicum coloratum* *Panicum maximum*	*Macroptilium atropurpureum* *Neonotonia wightii* *Stylosanthes hamata* *Teramnus labialis*
Moderately acid (pH.5.0 to 6.5)	*Brachiaria decumbens* *Brachiaria humidicola* *Panicum maximum*	*Centrosema pubescens* *Desmodium spp.* *Macroptilium atropurpureum* *Pueraria phaseoloides* *Stylosanthes guianensis* *Stylosanthes hamata*
Highly acid (pH below 5.0)	*Andropogon gayanus* *Brachiaria decumbens* *Brachiaria humidicola* *Panicum maximum*	*Centrosema spp.* *Desmodium spp.* *Pueraria phaseoloides* *Stylosanthes capitata* *Stylosanthes guianensis* *Zornia spp.*

Policy considerations

Any government policy decisions designed to increase the use of improved pastures in the region will affect the local demand for pasture seed. Clearly, an investment in perennial pastures is a long-term decision. The livestock farmer will only be prepared to improve his pastures if he is confident about his land tenure and the future of the market. The price structure for local animal products must provide for a reasonable profit and the producer must be protected from the dumping practices of extra-regional countries. Any subsidies for the ruminant livestock industry should be aimed at increasing the use of high-quality, legume-based pasture while decreasing the reliance on imported fertilizers and animal feeds. Policies such as these could lead to a rapid increase in the regional demand for pasture seed.

Most of the legumes listed in Table 1 produce pods which each contain several seeds. The pods shatter when dry, and it is easy to hand separate the seed from the inert material. Other legume species (e.g. *Desmodium spp., Stylosanthes spp.*) and most grasses are more difficult to clean to acceptable international standards without the use of sophisticated machinery, which is too expensive for an individual farmer. It may not be necessary to clean seed to these levels for sale on a local market, since the price and the sowing rate can be adjusted to compensate for the inert material in the seed lot, but for export, cleaning assumes greater importance, since freight charges can constitute a considerable proportion of the final cost to the consumer. Seed for export must also be accompanied by a recent certificate of purity and germination, so that the purchaser can estimate the true value of the seed lot. For these reasons, seed destined for the export market should be produced under contract to a central organization which would be responsible for cleaning, testing, packaging and distribution. In view of its regional representation, it is thought that CARDI is in an ideal situation to fill this role.

Conclusions

The production of pasture seed offers a potential source of both cash income and soil improvement benefits to those small farmers who are prepared to master the technically simple, but logistically demanding processes involved. Grasses and legumes each have their own advantages within the small farm system, but the latter group of species are probably more compatible with annual field crop production, since the peak labour demand occurs in the dry season. CARDI has plans to encourage small farmers to produce seed under contract, although these plans will not come to fruition until a commercial market for seed of improved pastures is established in the region.

References

Cumberbatch, R.N. (1986) Pasture production in Guyana. *Proc. seminar, Potential for pasture production in acid tropical soils*, June 1986, CARDI, St. Augustine, Trinidad

Ferguson, J.E. (1979) Systems of pasture seed production in Latin America, in: P.A.Sanchez and L.E. Tergas (Eds) *Pasture Production in Acid Soils of the Tropics*, CIAT, Cali, Colombia

Hare, M.D. (1985) Tropical Pasture Seed Production for Village Farmers in South East Asia, *Dept. Scientific and Industrial Research*, Palmerston North, New Zealand

Humphreys, L.R. (1975) Tropical Pasture Seed Production, *FAO*, Rome, (First Edition)

Keoghan, J.M. (1980) Adaptable and productive forage legumes and grasses for more intensive small ruminant livestock systems in the Caribbean, *Trop. Anim. Prod.* 5:8 - 14

Paterson, R.T. (1987) Pasture seed production in Antigua, *Proc. 22nd Caribbean Food Crops Society meeting*, St. Lucia, August 1986, 327-323

Improved pastures for meat and milk production

(Script of a slide presentation)

N.R. Gibson and G.A. Proverbs

CARDI, P.O. Box 64, Cave Hill Campus, St. Michael, Barbados

Introduction

Animal production in the Caribbean, inclusive of sheep, goats and dairy cattle, has for too long depended on concentrate feeds. Most of the region's farmers consider forages solely as a source of roughage for their livestock, whereas Australian and New Zealand farmers have long relied on forages to provide most of the nutrients for meat and milk production. This concept is not new to the region, however. Jamaican farmers have relied for many years on their grass pastures for economical meat and milk production. The challenge we face now is to encourage farmers to make greater and better use of the available improved grasses and legumes. In this way, animal productivity can be improved (Proverbs, 1986). Native grasses, overgrazing, poor weed control and lack of proper management, characterise most local pastures, resulting in reduced milk and meat output per animal and per hectare. In any animal production enterprise, the need to establish high quality improved pastures cannot be over-emphasised.

Fertilizer

After the land is prepared, the pasture is planted either from seed, or from vegetative material and is subsequently managed so as to stimulate maximum growth of highly palatable material. A pure grass or grass/legume pasture must be treated as a crop, hence fertilizer application becomes necessary to maintain high yields. Since nitrogen is generally the most limiting of the essential plant nutrients, five 55 kg bags of sulphate of ammonia are applied per hectare. A well established grass/legume pasture would require about half this amount. One 55 kg bag of muriate of potash is applied twice a year per hectare, at the beginning of the rainy season and again towards the end. On some dairy farms, manure is collected in slurry tanks and spread onto the fields. Manure can also be used in large biogas digesters to produce energy and the residual material used as a fertilizer. The material is safe and non-toxic even when applied in the dry season.

Improved species

In the wet season, native grasses will provide sufficient nutrients to meet maintenance requirements. However, during the dry season, the native grasses are the first to stop growing and to die back. Even the quality of the best of the introduced improved grasses falls to levels which can no longer support maximum animal production unless irrigation is available (Paterson et al, 1986). Several improved species of grasses have been introduced to the region. These include Transvala, Bambatsi, Dwarf elephant, Green panic, Klein, African star, and Coastcross 1. The last two have been extensively used in pasture establishment in Barbados. If the crude protein content of the total diet falls below 7 percent, the animals on pasture will begin to lose weight. At this time, pasture protein supplementation is needed to prevent a drop in production or weight loss. Protein can be supplied from commercial concentrates, or from agricultural by-products such as cotton seed. However, the most economical way of supplying this protein is from forage legumes (Paterson et al, 1986).

Legumes

Legumes can be incorporated into the pasture system in several ways. They can be sown in with the grasses to form associated pastures, for year-round grazing. Ideally suited for this purpose are the twining legumes Siratro, Glycine and Teramnus. The legume used should make up 25-30 percent of the total forage component. After the grass has been planted and has just begun to establish itself, then the legume seeds are planted. This method has brought the best results under our conditions. Legumes can also be saved for use only in the dry season either as pure stands (protein banks) or associated with highly productive grasses (protein energy banks). The shrub legume *Leucaena leucocephala* is ideally suited for protein and protein - energy banks. Leucaena will yield anywhere between 2-20 tonnes per hectare dry matter per year depending upon climatic conditions. Leucaena can be sown directly into the soil using freshly harvested seed or propagated in nurseries and transplanted at about 20-30 cm high. Stored Leucaena seed has to be scarified for the seed to germinate. The seeds are immersed in water at 80^{o}C for 3 minutes and then planted. Germination occurs in 3-7 days and after 8-10 weeks, the seedlings are ready for transplanting. CARDI Cunningham Leucaena is the variety recommended for protein and protein-energy banks (Proverbs 1985). The plant is shrubby and is ideally suited for grazing animals. It must however, be pruned periodically so that it does not grow out of reach of the animals. The giant types are ideal for erosion control on steep slopes and for live fence posts. They are planted along the periphery of the field and in 3 years the fence can be attached. With proper pruning they will provide shade and a fodder reserve for dry season feeding. There are several giant types, K67, K28 and K8. K8 is the variety most widely recommended for Barbados. Forage of both K8 and Cunningham Leucaena can be cut and stored as silage for dry season feeding.

Dry season feeding

Molasses is used as an inexpensive energy source during the dry season. Molasses and legume protein encourage the animals to consume greater quantities of the poorer quality grasses during the dry season, thereby promoting weight gains and maintaining milk production. At Springhead Farm, St James, Barbados, 22 Jamaica Red calves were kept for 86 days on 10 acres of Coast cross 1. They were removed in the height of the dry season and allowed to graze a fresh Coastcross 1 pasture. After 30 days they were weighed and weight gains were of the order of 0.7 kg per day. The practice of using molasses goes a long way in alleviating seasonal variation in production. Once the rains come, the pastures grow vigorously and there is plenty of forage available, to the extent that the animals cannot utilize all of it. This is the time to conserve the excess, either as silage or hay for dry season feeding. Again the practice of conserving in times of plenty for feeding in time of scarcity helps to eliminate seasonal variation in production.

Forage conservation

Silage: Silage making is a difficult process for the small scale, non mechanised farmer. To make good quality silage requires equipment and storage facilities. The forage to be ensiled is harvested, and chopped into pieces 2.5 -5 cm long and then compacted using a tractor. During the compaction process, molasses is sprayed on at a rate of 46 kg per tonne of wilted forage material. This enhances the ensiling process. Sorghum or sorghum hybrids such as sordan, are ideal forages for ensiling. They will provide five or more cuts per year and can also be fed as green chop both in the dry and wet season. During the height of the dry season, when the soil cracks, most of the improved drought tolerant grasses lose their productivity an in many instances are reduced to standing hay. On the other hand, sordan remains green and will continue growing, thereby producing a higher quality forage.

Hay: Hay making is another method of forage conservation. With native grasses, a good quality hay can only be obtained when the pastures are very young. This is also the time of highest rainfall when it is difficult to dry the cut material. Most of the improved grasses, on the other hand, have much finer stems and will dry easier during the rainy season. They also maintain their quality for a longer period. With improved grasses, there is reduced time between cutting and baling as opposed to native grasses. You can get many more cuts per year with an improved pasture than you can with a native pasture. The best hay is made from swards of grass and legume. The legume content will ensure a higher protein forage. However the twining tropical legumes now in use do not cut as well as alfalfa, but work is being done at tropical research centres to find ways of getting around this problem. Hay is generally made using tractor-drawn cutters and balers. The grass is cut and left to dry, after which it is windrowed and baled. Traditional methods leave the bales strewn on the ground. They then have to be collected and stored. A hay baler with a chute allows the bales to be placed directly into a trailer, which effectively saves time and labour.

Conclusion

High quality hay and silage are the products of well managed improved pastures, which are able to sustain consistently high levels of animal output. The road to improved pastures can be paved with introduced forage species, or alternatively by oversowing native pastures with legumes. This is one method of increasing the productivity of native pastures. At every stage, quality assessment is necessary. Forage samples are taken from pastures periodically for nutrient analysis, and also from silage and hay. If animal production is to be economically viable it must be considered as a business. Only in this way can we hope to develop the potential that exists in the Caribbean for various animal production enterprises.

References

Paterson, R.T.; Philip, P. and Maynard, P. (1986) A Guide to Improved Pastures for the Drier Areas of the Eastern Caribbean, *CARDI*, St. John's, Antigua

Proverbs, G.A. (1985) Leucaena, A Versatile Plant, *CARDI*, St. Michael, Barbados

Proverbs, G.A. (1986) Forages for ruminants in the Caribbean - the Barbados experience, *Prepared for presentation at FAO Round Table, Animal Health and Improvement of Productivity in the Caribbean*, Kingston, Jamaica September 1986

An overview of forage trials conducted by CARDI in Dominica

G. Robin

CARDI, P.O. Box 346, Botanical Gardens, Roseau, Dominica

B. Clarke

CARDI, P.O. Box 971, Castries, St. Lucia

Since 1983, CARDI has been evaluating a "Livestock Management System" for small farms in Dominica, aimed at alleviating some of the major constraints associated with livestock production. This work is supported by on-station and on-farm trials with improved forages. An evaluation of ten grass and grass/legume mixtures for "cut and carry" systems, showed that dry matter yields of 20.4t/ha and 18.1t/ha came from grass mixes of *Pennisetum purpureum* plus *Brachiaria decumbens* and grass-legume mixes of *P. purpureum, Cyndodon plectostachysus, Centrosema pubescens* and *Stylosanthes hamata* respectively. The cutting interval was ten weeks. In a study of all year round production of *P. purpureum*, dry matter yields of about 25t/ha were obtained at two locations. In a trial evaluating four forage legumes, *S. hamata* and *Desmodium intortum* were the most persistent.

Keywords: Forage grasses; Forage legumes; Cutting materials; Sowing methods; Dominica

Introduction

The island of Dominica has a total land area of 977 sq. km. The topography is highly mountainous, with peaks rising to 1400 m above sea level. Annual temperatures average approximately 27^{o}C near sea level, dropping to 21^{o}C at higher elevations. Average annual rainfall varies from 1250 mm on the western side to 7500 mm in the central forest. The rainy season extends from May to December and the dry season from January to April. It is estimated that approximately 60 percent of the land area is unsuitable for agriculture due to the extremely mountainous terrain and heavy rainfall (Barker 1981).

The livestock production system on small farms is similar throughout the Windward and Leeward Islands. Cattle, sheep and goats are either tethered along roadsides, on fallow lands, on cleared lands with improved pastures, or on other peoples holdings, or they are allowed to roam free. Some farmers feed cut banana pseudostems or other crop residues, a limited amount of cut (improved) fodder and occasionally some dietary supplements, such as coconut meal (Robin and Clarke 1985).

Baseline surveys (Henderson and Gomes 1979; Archibald et al 1981; CARDI, 1983) indicated a need to increase local production of milk and meat. However, current livestock husbandry practices have several disadvantages, as follows:

- The nutritive value and productivity of native vegetation is low.

- The high cost of manufactured concentrates results in farmers purchasing feed supplements only irregularly and feeding limited amounts to their livestock.

- Tethering of animals on steep slopes often results in injuries and strangulation.

- The daily movement of animals to and from grazing areas is labour intensive.

- Pen manure is not easily collected for use in crop production on the farm.

This paper reviews the work done in evaluating various grasses, legumes and grass-legume combinations for productivity, nutritive value, seasonality, optimal management and persistence. The better pasture combinations will be sown on livestock farms in an attempt to overcome some of the problems listed above.

Materials and methods

Experiment 1

Ten combinations of grasses and legumes, as shown in Table 1, were evaluated over a period of 12 months in a split-plot experiment where species combinations formed the main treatments and cutting intervals (4, 6, 7, 8, 10 and 12 weeks) the sub-treatments. The main plots were 5 m x 4 m including discard areas, and the net sub-plots were 1 m x 1 m. The experiment consisted of three replications of all treatment combinations.

Land preparation involved clearing and ploughing. Species were selected for adaptability, palatability, nutritive value, high productivity, compatibility, establishment potential, persistence and availability of planting material. Where appropriate, tall grasses and tall legumes were arranged in alternate rows. Inter and intra-row distances were 1m. Short grasses were planted in rows 0.5 m apart, with intra-row distances of 10 cm. The shorter legumes were spaced midway between the tall grasses and legumes. After planting, a basal dressing of triple superphosphate (50 kg/ha) and sulphate of ammonia (20 kg/ha) were applied.

Sorghum bicolor cv Grazer was sown by seed (treated with fungicide) at a depth of 2 to 3 cm. All other grasses were planted as vegetative material. All legume seed was scarified except local pigeon pea and treated with fungicide prior to planting. Sowing took place at a depth of 2 to 3 cm, placing from 3 to 10 seeds in each planting hole.

At each harvesting date, data were collected on yields of fresh and dry forage, observations were made on persistence and samples were analysed for protein, energy, fibre and minerals.

Experiment 2

Four legume species (*Desmodium intortum*, *M. atropurpureum*, *N. wightii* and *S. hamata*) were shown as sub-treatments in a split-plot experiment to compare surface broadcasting of seed with shallow sowing. Three replicates were sown on each of three farms. At each site, the available area was different. Gross sub-plot sizes of 3.0, 4.8 and 15.0 square metres were sown, but evaluations were made using a quadrat of 1.0 sq. m.

Table 1 The grasses and grass-legume mixes evaluated in Experiment 1, Stock Farm Roseau

Treatment	Mix of Species	Description of Plant types[1)]
1	*Pennisetum purpureum* + *Macroptilium atropurpureum*	TG/VL
2	*P. purpureum* + *Brachiaria decumbens* + *M. atropurpureum*	TG/MG/VL
3	*Sorghum bicolor cv.* Grazer M AXY 392 + *B. decumbens* + *Neonotonia wightii*	TG/MG/VL
4	*P. purpureum* + *Cynodon plectostachyus* + *Centrosema pubescens* + *Stylosanthes hamata*	TG/MG/VL/BL
5	*Saccharum officinarum* + *Panicum maximum* + *Digitaria decumbens* + *Clitoria ternatea*	TG/MG/SG
6	*P. purpureum* (Control A)	TG
7	*P. purpureum* + *B. decumbens* (Control B)	TG/MG
8	*P. purpureum* + *C. plectostachyus* + *Cajanus cajan* + *Pueraria phaseoloides*	TG/MG/TL/VL
9	*S. bicolor* + *P. maximum* + *C. cajan* + *C. pubescens*	TG/MG/TL/VL
10	*P. maximum* + *D. decumbens* + *Teramnus labialis*	MG/SG/VL

1) TL = tall grass; MG = medium grass; SG = short grass
VL = vining legume; BL = bushy legume; TL = tall legume

After the experimental areas were cleared and forked, lime was applied at 3.5 t/ha. Sowing of the three sites took place on 23 July, 28 August and 12 September 1985 respectively. In the planting treatment, the seed was sown at a depth of 1.5 to 4 cm in rows 30 cm apart with 15 cm between planting holes.

Basal management included three weedings during initial crop growth, and application of NPK (16:8:24) at 250 kg/ha, three to four weeks after planting. For sown seed, this was banded around each hole, while for broadcast seed the fertilizer was evenly spread over the whole area.

Plots were harvested after seed and pod maturity, between 14 and 17 January and again between 15 and 25 September 1986, on two farms. The third farm had to be abandoned due to poor germination even after replanting. The forage legumes were cut from 3 to 5 cm above the ground with a cutlass. After the quadrat had been harvested, the remainder of the plot was cut to ensure uniform regrowth.

Data were collected on legume emergence, weed infestation and fresh and dry yields of both forage and weed components. After cutting, the legume regrowth and persistence were evaluated.

Experiment 3

Farmers at two sites (Morne Prosper, altitude 500 m, annual rainfall 5,000 mm and La Plaine, altitude 166 m, rainfall 2,500 mm) weighed the quantity of Elephant grass cut each day to feed their animals and measured the area harvested. On average, the areas were cut five time during the year. The yields measured were therefore of regrowth of from 2 to 3 months of age. Sub samples were periodically collected to estimate the dry matter content of the cut forage.

Results and discussion

Experiment 1

Total forage dry matter yields, collected over from 48 to 50 weeks after planting, are are shown in Table 2.

Table 2 Yields of forage dry matter (t/ha) from ten forage mixtures with six cutting intervals

	Cutting intervals (weeks)						
Mixtures	4	6	7	8	10	12	Mean 1)
1	13.1	10.5	18.5	13.0	21.8	23.9	16.8 abc
2	18.0	17.0	18.2	15.9	24.4	27.2	20.1 a
3	10.0	10.0	9.5	10.0	13.3	12.1	10.8 d
4	17.2	14.3	18.1	17.5	29.9	19.7	19.4 ab
5	11.8	8.7	8.7	7.6	12.9	14.0	10.6 d
6	11.1	12.8	15.5	8.9	18.6	15.6	13.8 cd
7	19.0	20.4	18.6	13.4	31.7	27.5	21.7 a
8	15.2	11.1	12.7	13.1	16.7	17.7	14.4 bcd
9	13.5	7.7	12.7	10.6	14.0	11.3	11.6 d
10	9.1	8.7	11.0	7.4	12.6	8.2	9.5 d
Mean 2)	13.8 bc	12.1 bc	14.4 b	11.7 c	19.6 a	17.7 a	

Means in either column (1) or row (2), followed by the same letter do not differ significantly ($p<0.05$)

S.E. of difference between cutting interval means (1) = 1.07
S.E. of difference between mixture means (2) = 2.28
S.E. of difference between interaction means = 3.37

The interaction of mixtures by cutting interval did not reach statistical significance. Highest yields were obtained from the combinations which included both Elephant and Signal grasses (treatments 2 and 7), while the lowest yields came from the treatments in which Elephant grass was replaced by either forage sorghum (treatments 3 and 9), sugar cane and /or Guinea grass (treatments 5 and 10) or where the elephant grass was sown alone (treatment 6). The longer cutting intervals (10 and 12 weeks) produced higher yields than the shorter ones.

Without data on the botanical composition, it is not possible to fully interpret these results. The 12 week interval may have led to suppression of the legumes and to woody growth of the grasses, giving low protein and digestibility levels. The 8 week cutting cycle, while probably giving forage of reasonable quality, produced the lowest yields in half of the pasture combinations. This result is not easy to explain, since generally, shorter intervals produce lower yields of high quality fodder.

Experiment 2

The data relating to seedling emergence and ratings of both weed and legume performance were subjected to square root transformations, while logarithmic transformations were applied to yield data before analysis. Table 3 shows the effect of establishment method (sown versus broadcast), averaged over the four legume species, while Table 4 shows the performance of the individual legumes, averaged over the two establishment methods. No data are presented for the second harvest at Farm 1 (Giraudel), since several of the sub-plots were subjected to an unplanned grazing.

The results obtained at the two sites were quite different. At Farm 1, with relatively low legume populations, the sown plots had significantly greater weed populations and poorer legume performance than the broadcast treatments. At Farm 2 (La Plaine), where the legume population was much higher, this trend was reversed. Weeds were of great importance at both sites, however, and at the second harvest at Farm 2, the legumes contributed an overall average of only 52 percent of available dry matter.

At Farm 1, *Desmodium, Neonotonia and Macroptilium* appeared to compete best with the weeds up to the time of the first harvest, when they gave significantly higher yields than the *Stylosanthes*. After this time, *Stylosanthes* and *Desmodium* appeared to regrow better than the others, while the vigour of the *Macroptilium* was greatly reduced. At Farm 2, the *Macroptilium* was the poorest species right from the start. *Neonotonia* was almost as good as the other two up to the time of the first harvest, but subsequently faded. On the relatively acid soils of Dominica, *Desmodium* and *Stylosanthes* were the most promising of the species used.

Experiment 3

Fresh forage yields from 2 to 3 months regrowth of Elephant grass at two contrasting sites are shown in Table 5, together with rainfall data for the same period. While grass yields were, in general, higher during the wetter months, there was little direct correlation between total monthly rainfall and forage production during the same period. This is hardly surprising in view of the high levels of rainfall experienced in these parts of Dominica. At the wetter site (Morne Prosper) yields of fresh forage cut each month ranged from 33 to 123 t/ha, with an average of 77 t/ha cut per month. An area of 0.23 ha produced a total of 28.6 t (124.3 t/ha) over a period of a complete year from July 1984. At the drier site (La Plaine), amounts cut each month ranged from 29 to 100 t/ha, for an average of 57 t/ha cut each month. A total of 25.1 t of fresh forage was cut from 0.18 ha (139.4 t/ha) in a year from October, 1984. The dry matter content of the forage ranged from 16 to 25 percent. These results indicate that elephant grass can make a substantial contribution to animal production on a year round basis under Dominican conditions.

Conclusions

The results of the first experiment provided guide lines for future on-station and on-farm research. Elephant grass was pre-dominant in all the treatments which gave high yields and made up 75-80 percent of

Table 3 The effect of sowing or broadcasting on the performance of four pasture legumes in Dominica

Parameter	Drilled		Broadcast	
	Farm 1	Farm 2	Farm 1	Farm 2
Emergence (plants/sq m)	38.0	124.3	26.3	196.3
First Harvest				
Weed rating (0-10)	4.8	3.2	4.3	2.6
Legume vigour (0-10)	2.1		2.6	
Legume, fresh wt (kg/ha)	1,700	3,310	3,580	5,350
Legume, DM (kg/ha)	380	1,440	920	1,210
Regrowth (0-10)	3.5	4.8	4.8	4.3
Vigour after 6 months (0-10)	2.8		5.8	
Second Harvest				
Legume, fresh wt (kg/ha)		7,700		5,000
Legume DM (kg/ha)		1,520		1,640
Weeds fresh wt (kg/ha)		3,760		6,530
Weeds DM (kg/ha)		1,030		1,900

Note: Farm 1 Drilled data are means of three legumes (without *Neonotonia*).
Farm 2 Broadcast data are means of three legumes (without *Macroptilium*).
Other data refer to means over four legumes.

Table 4 The performance of four pasture legumes in Dominica

Parameter	Desmodium		Neonotonia		Stylosanthes		Macroptilium	
	Farm 1	Farm 2	Farm 1	Farm 2	Farm 1	Farm 2	Farm 1	Farm 2
Emergence (plants/sq m)	20.0	196.0	39.2	132.3	23.0	179.5	33.5	91.3
First Harvest								
Legume, fresh wt (kg/ha)	2,040	5,810	2,000	1,370	1,500	7,000	5,170	960
Legume, DM (kg/ha)	580	1,560	660	730	380	1,950	760	860
Legume vigour (0-10)	6.5	7.0	5.0	6.0	5.5	6.5	6.5	2.0
Regrowth (0-10)	3.5	6.0	5.0	5.0	4.5	6.5	6.5	1.0
Vigour after 6 months (0-10)	4.5	6.5	8.0	4.8	7.5	4.8	1.0	4.0
Weed rating (0-10)	5.8	2.3	6.0	4.2	4.0	2.5	3.5	5.7
Second Harvest								
Legume, fresh wt (kg/ha)		8,390		2,940		9,720		3,720
Legume DM (kg/ha)		1,830		860		2,370		900
Weeds, fresh wt (kg/ha)		3,900		5,990		5,240		4,400
Weeds DM (kg/ha)		1,100		1,700		1,430		1,470

Note: Farm 1 Neonotonia data apply only to broadcast plots
Farm 2 Macroptilium data apply only to drilled plots
All other data are means of broadcast and drilled plots

the sub-samples taken for analyses. The persistent forage legumes in the grass/legume mixes, Siratro (*M. atropurpureum*) and stylo (*S. hamata*) contributed 15-20% of the sub-samples. This low percentage was due to continuous competition from the more vigorous grasses.

Experiments 2 and 3 evaluated four forage legumes and Elephant grass in pure stands. These trials were an attempt to move away from grass/legume mixes, which had not been amongst the highest producers in the earlier work.

To date elephant grass has been grown in pure stand on ten model farms and is the grass of choice for the cut and carry (zerograzing) Livestock Model Systems.

Stylo and *Desmodium* show most promise and have been established on three livestock farms. Further evaluations of the forage legumes are needed before full scale extension is implemented.

Table 5 Recorded rainfall and fresh forage yields from Elephant grass (2 to 3 months regrowth) harvested at two sites

Month	Morne Prosper		La Plaine	
	Rainfall (mm)	Forage (t/ha)	Rainfall (mm)	Forage (t/ha)
July (1984)	588.5	45		
August	321.8	33		
September	445.3	78		
October	308.1	88	325.4	50
November	835.9	111	718.3	100
December	310.6	41	206.0	85
January (1985)	253.8	70	115.8	74
February	220.5	96	67.8	29
March	257.6	90	110.5	35
April	194.0	123	342.9	62
May	176.3	78	86.0	39
June	130.0	71	38.0	60
July			159.5	30
August			316.5	28
September			315.0	92
Annual total	4,042.4		2,801.7	

Acknowledgements

Valuable contributions by farmers, the Ministry of Agriculture, the Project Manager and the Subject Matter Specialist (CARDI) are gratefully acknowledged. Special thanks are due to Mr. H. Adams who initiated the work and to the USAID FSR/D project for funding.

References

Archibald, K.; Singh, R. and Osuji, P. (1981) Animal production systems in the Eastern Caribbean. *Consultant Report No 7 Winrock Winrock International*. CARDI, St. Augustine, Trinidad

Barker, C.H. (1981) Dominica - An agricultural profile. *CARDI/USAID SFMCS Research Project*

CARDI (1983) Survey of twenty small farmers in Dominica. *CARDI/ USAID Small Farm Systems Project*. Unpublished

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. *Dept. Agric. Extension, Uni. West Indies*, St. Augustine, Trinidad

Robin, G. and Clarke, B. (1985) Evaluation of a Livestock Management System for small farms in Dominica. *Colloquium*, May 1985, Martinique

Yield and yield prediction of guinea grass pastures

M.W. Michaud and P.J. Michaud

University of the Virgin Islands, P.O. Box 10,000 Kingshill, St. Croix, U.S.V.I., 00850

Native pastures are the most important source of feed for the livestock industry in St. Croix, U.S.V.I. One of the major constituents of these pastures is guinea grass (*Panicum maximum*), found in well managed, properly stocked situations. To determine the dry matter production of this species, plots were established in existing swards located in different rainfall zones. The plots were cut periodically for a full year. Yields at each site varied according to rainfall: from 7,543 kg/ha in the driest location to 14,445 kg/ha in the wettest area. Before the plots were cut, the height of the grass was measured. Regression analysis was performed, and a strong relationship between height and dry matter yield was demonstrated. This failed to adequately predict hay yields due to uneven cutting heights and inefficient raking with large equipment. Care must be taken when using regression techniques to predict dry matter production.

Keywords: Guinea grass; Panicum maximum; Yields; Yield prediction

Introduction

Natural guinea grass (*Panicum maximum*) pastures in St Croix are green chopped, grazed or made into hay, and are one of the most important feed sources for livestock production in the island. Prohibitively high costs preclude routine application of fertilizers, and the pastures are generally managed under natural fertility conditions.

Despite the importance of this grass, however, relatively little is known about its growth and production. Applying no fertilizer, Oakes (1966) found that the five year average of guinea grass yields increased from approximately 11 tons per ha with a 2 month harvest interval to 14.5 tons per ha with a 6 month interval. The trial, though, was conducted at only one site, and since rainfall varies greatly in St Croix, results are difficult to extrapolate to other parts of the island. Knowledge of the production of guinea grass would be helpful in establishing stocking rates and useful in determining yields from green chopping and hay making operations. Farmers could then determine the number of animals they can safely support without damaging their swards. Pasture management would be facilitated, and long-term planning could be implemented.

While the knowledge of guinea grass yields are valuable, a method of determining the amount of standing forage prior to utilization would be useful, also. Harvesting for hay or green chop could then be performed when a desired yield level is achieved. In addition, stocking rates could be adjusted to match the amount of forage in a pasture.

A number of simple techniques for determining standing forage are available. Perhaps the simplest, especially for the farmer, is to measure the height above ground level of the sward. This height can then be related to dry matter yields through a prediction equation calculated by means of regression analysis.

A trial was conducted to measure the production of guinea grass pastures located at different sites in St Croix. Concomitantly, the relationship between height and dry matter yields was determined, and the feasibility of using height as a predictor for hay yields was studied.

Materials and methods

The study utilized long-established guinea grass swards located at four sites of varying rainfall. After an initial staging cut made in February, 1986, three harvest frequencies (6, 12 and 24 weeks) were imposed on the guinea grass. These three treatments were replicated twice at each site.

Individual plots measured 3.0 x 12.2 m. A strip 1.0 x 10.0 m in the centre of each was cut with a self-propelled sickle bar mower to a stubble height of 7.6 cm. The plant material was collected and weighed fresh, and a sub-sample taken for dry matter determination. Data were collected over 48 weeks, at the end of which the 6, 12 and 24 week harvest frequencies had been cut a total of 8, 4 and 2 times, respectively.

After the cutting in each plot, the height of the grass on both sides of the harvest strip was measured with a metre stick. The mean height of the highest leaves in the immediate vicinity of the stick was recorded. A total of ten measurements was made, five on each side of the strip. The ten height measurements taken in each plot were averaged together, and the relationship between height and dry matter yields in all plots across all sites determined by means of regression analysis.

Sward heights were measured at four sites in a guinea grass pasture prior to cutting for hay. The heights from each site were averaged and used to calculate hay yields by means of the prediction equations that resulted from regression analysis. After the grass was cut and baled, the bales were weighed, sub-samples taken for dry matter determination, and actual yields compared to predicted ones.

Results

Rainfall strongly affected the amount of dry matter produced by guinea grass swards. When averaged over the three cutting intervals, yields at the two lowest rainfall sites were approxi-mately 7,500 and 9,000 kg/ha, respectively (Figure 1), for the 48 week duration of the trial. Yields at the sites receiving the highest rainfall were 12,000 and 14,000 kg/ha, respectively.

In general, the longer the interval between cuts, the greater was the production of dry matter (Figure 1) In two instances (900-1020 mm and 1140 - 1260 mm rainfall sites), yields almost doubled as the cutting interval increased from 6 to 24 weeks. The only exception to this trend occurred at the 1020 - 1140 mm rainfall site, where cutting every 24 weeks resulted in less dry matter than did cutting every 12 weeks. Regression analysis performed on the data combined from the 6 and 12 week cutting intervals showed a strong linear relationship between height and yields ($p \leq 0.01$, Figure 2). There was also a strong linear relationship ($p \leq 0.01$) between height and yield for the combined data of the 6, 12 and 24 week cuts. The prediction equations resulting from the two analyses, however, were slightly different, resulting in different predictions of dry matter yields, especially at higher sward heights (Table 1).

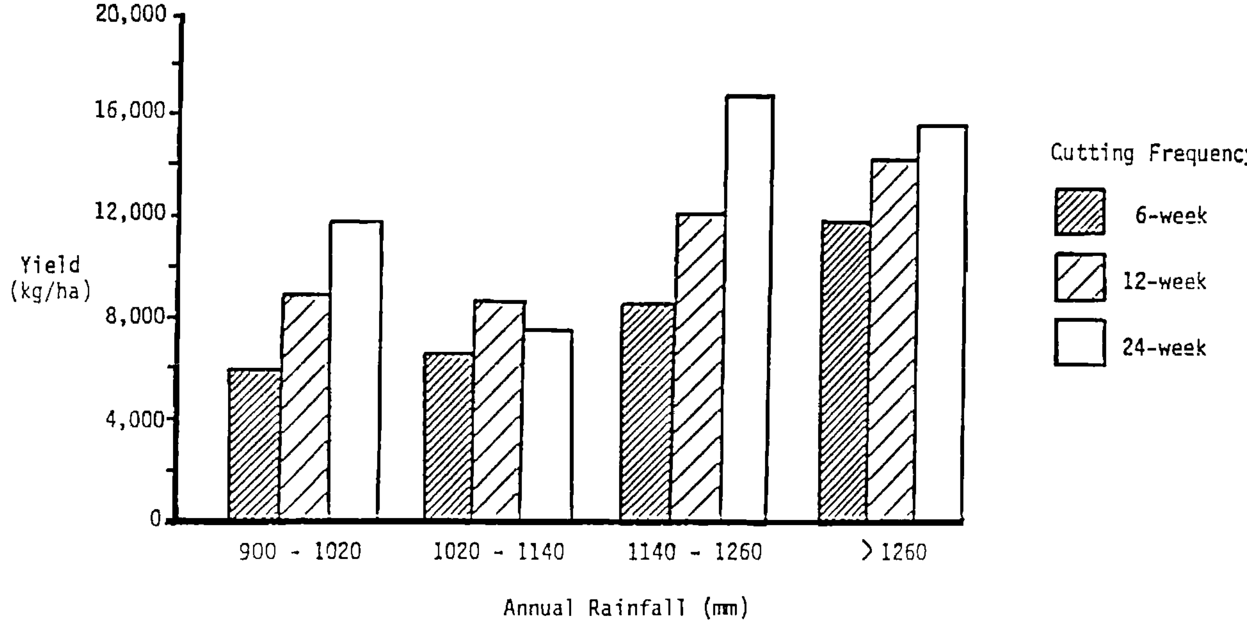

Fig. 1. The effect of annual rainfall and cutting frequencies on the dry matter production of guinea grass swards, St. Croix.

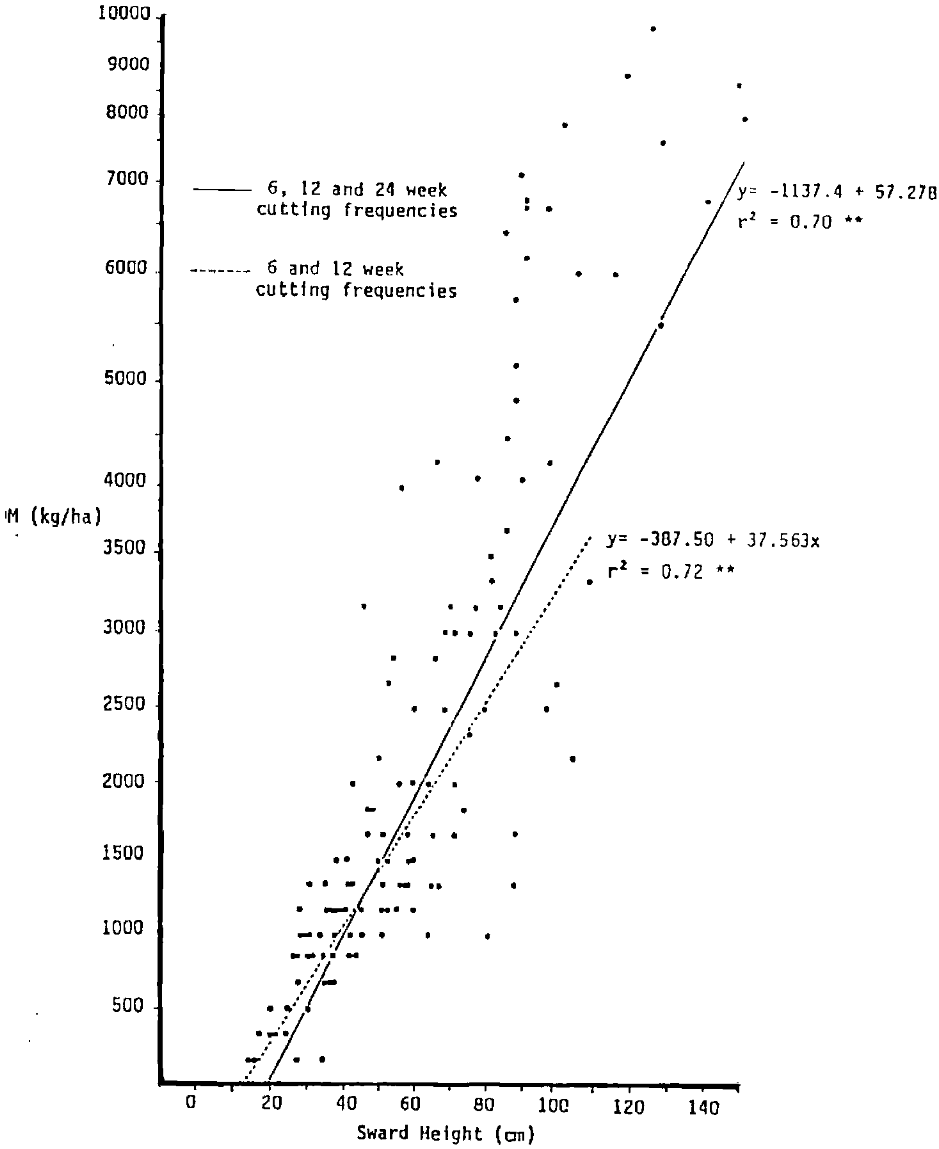

Fig. 2. Relationship between height and yield in guinea grass pastures

Table 1 Comparison of two regression formula for predicting dry matter yields from heights of guinea grass swards

Sward Height (cm)	Regression formula[1)] Formula 1 (6 & 12 week)	Formula 2 (6, 12 & 24 week)
	Predicted Yield -------- kg/ha	--------
25	550	290
50	1490	1730
75	2430	3160
100	3370	4590

1) Formula 1 has $y = 387.5+37.5x$; Formula 2 has $y = -1137.44 + 57.27x$ where y = DM yield (kg/ha) and x = sward height (cm)

Table 2 Comparison of yields predicted from sward height with actual yields from a grass pasture cut for hay

Site within pasture	Sward Height (cm)	Predicted Yield (kg/ha)	Measured Yield (kg/ha)
1	71	2265	960
2	67	2140	540
3	74	2410	710
4	79	2590	1170

Average sward heights within each of the four sites located in the guinea grass pasture cut for hay are shown in Table 2. Since the regrowth in this particular pasture was less than 12 weeks old, the formula generated from the analysis of the combined 6 and 12 week data was used to predict dry matter yields. Comparisons between actual and predicted yields showed that the prediction was poor and over-estimated the amount of hay that was actually baled. At least two factors may be responsible for this.

Yield data used in regression analyses were taken from plots cut at 7.6 cm height and carefully raked to collect all herbage. In the pasture cut for hay, however, cutting height varied from 10 - 15cm and some grass remained because of inefficient raking. In addition, the hay was cut so that the tractor tires packed the sward before the cutter passed over it, leaving strips of un-harvested grass.

There may be an inherent difficulty in the use of these regression formulae. During the course of the study, for example, actual yields at sward heights of 65 cm ranged from 1,700 kg per ha to 4,340 kg per ha, while predicted yields - using the regression formula for the 6 and 12 week data - were 2,054 kg per ha. Differences such as these could account for the discrepancies between the predicted and actual yields of the guinea grass pasture, and necessitate care in the use of formulae generated from regression analysis.

Reference

Oakes, A.J. (1966) Effect of nitrogen fertilization and harvest frequency on yield and composition of *Panicum maximum* Jacq. in tropics. *Agron. J.* 58 75-77

Effect of legume growth form on compatibility of grass-legume pasture mixtures

W.D. Pitman

University of Florida, Agricultural Research Center, Ona, Florida 33865, USA

Survival of 67 climatically adapted tropical legume accessions, representing a range of species and growth forms, was evaluated in bahiagrass pastures at Ona, Florida. Only *Vigna parkeri cv.* Shaw persisted for more than four years under continuous grazing at a moderate stocking rate. Three species, *Desmodium barbatum, Desmodium heterocarpon cv.* Florida, and *Alysicarpus vaginalis*, survived three years of grazing. These four persistent species survived as prostrate, perennial plants similar in growth form to the grazed grass canopy. Several up-right and climbing accessions survived under limited grazing, and some re-established themselves after continuous grazing was terminated. Growth form appears to be the major determinant of grazing tolerance of climatically and edaphically adapted legumes in peninsular Florida. Identification of compatible growth forms of grasses and legumes and determination of specific management techniques to enhance compatibility of less-suitable plant combinations could improve the generally poor results from introducing tropical legumes into grass pastures.

Keywords: Bahiagrass-legume pastures; Grazing tolerance; Growth forms

Introduction

Tropical legume germplasm represents a diverse and extensive gene pool for development of high quality, nitrogen-fixing pasture plants. This potential has been recognized and evaluated widely with only a very limited development of successful pasture cultivars. Although only a portion of this tropical legume germplasm is held in germplasm collections, even these available collections represent tremendous quantities of plant material. Various methods are currently used to select representative species and/or accessions from similar locations or geographic regions to reduce the volume of accessions for initial screening. However, even when climatically adapted germplasm has been identified and evaluated in spaced plantings, individual rows, and field plots, development of commercially successful pasture cultivars has not generally followed.

A more critical appraisal of materials to be evaluated and modification of the classical approaches to forage plant germplasm evaluation appear to be in order at many tropical locations where resources for plant evaluation are limited and some urgency in pasture development exists. In 1978, Tothill pointed out that growth form is important in the combination and management of pasture plants. He emphasized the need for a sufficient number of growing points to remain intact following grazing for growth and production to continue. Also noted as advantageous for forage plants were such growth forms as prostrate tendencies, sward formation, and stolon and/or rhizome production.

Tolerance of heavy grazing has been reported for tropical legumes such as *Lotononis bainesii* (Bryan and Evans, 1973) and *Vigna parkeri* (Jones, 1984). Tolerance of grazing by these palatable legumes is associated with their low growth form. Persistence and even sward dominance under high stocking rates have been obtained with unpalatable legumes such as *Calopogonium mucunoides* (Lascano, 1987). However, this legume persistence under heavy stocking is the result of lack of grazing rather than tolerance of grazing. Legumes which persist due to lack of acceptability to grazing livestock will provide little benefit to animal protein needs and may be of limited value in pasture situations.

Evaluation of grazing tolerance at Ona, Florida

Over thirty species of climatically-adapted tropical legumes have been evaluated for persistence under grazing as replicated single-row plants in bahiagrass (*Paspalum notatum*) pastures on a spodosol site at Ona, Florida from 1981 to 1986. Major plant adaptive traits required for survival in this environment include tolerance of periodic summer waterlogging, mild winter frost, spring dry periods, and mildly-acid soils. Genera represented include *Aeschynomene*, *Arachis*, *Alysicarpus*, *Centrosema*, *Desmanthus*, *Desmodium*, *Galactia*, *Lotononis*, *Macroptilium*, *Neonotonia*, *Stylosanthes*, *Teramnus*, *Vigna* and *Zornia*. Growth forms ranged from the upright growing *Aeschynomene* and *Stylosanthes* species to the twining growth of *Centrosema*, *Macroptilium atropurpureum*, and *Vigna luteola*.

Light stocking rates and/or rotational grazing resulted in the persistence of a number of accessions including *Macroptilium atropurpureum* and *Vigna adenantha*. However, continuous grazing at moderate stocking rates resulted in persistence of only the prostrate-growing *Vigna parkeri* after four years of grazing. Removal of cattle after one or two growing seasons resulted in gradual re-establishment of the twining legumes *M. atropurpureum*, *Centrosema virginianum*, *Vigna adenantha* and *V. luteola*. Since these evaluations were single-row plantings, the suggestion of Tothill (1978) that a threshold level or critical population size may be necessary for an adapted genotype to establish and persist should be acknowledged.

While appropriate pasture management could result in effective use of some of the upright and/or viny legumes, the prevailing pasture management in peninsular Florida of heavy stocking rates and continuous grazing on bahiagrass pastures appears to be compatible primarily with legumes having growth forms similar to bahiagrass. Although other low-growing species did not persist as well as *Vigna parkeri* in this evaluation, a perennial *Alysicarpus vaginalis* accession, a perennial seed-propagated *Arachis* accession, *Desmodium barbatum*, *Desmodium heterocarpon*, and *Zornia latifolia* also persisted through at least two years of grazing in peninsular Florida bahiagrass pastures at this or other sites. The accessions of *Arachis* and *Zornia* are apparently adapted primarily to the better drained sites.

One-half hectare pastures of the three *Vigna* species, *V. adenantha*, *V. luteola* and *V. parkeri*, have been planted, allowed to become well established, and then grazed continuously during the summer period each year. *V. luteola*, which has a twining-climbing growth habit, failed to persist through the first grazing period. *V. adenantha*, which is a climbing legume that roots at the nodes more effectively than *V. luteola* or Siratro (*Macroptilium atropurpureum*), decreased during the grazing period. However, grazing was terminated approximately two months before frost each year, and *V. adenantha* regrowth dominated the pastures by the time the frosts occurred. *V. parkeri* gradually spread under continuous grazing and has confirmed the conclusion from the single-row plantings that this legume is tolerant of this grazing management in bahiagrass pastures.

Discussion

While the experiences from a single location hardly justify universal recommendations, the extensive tropical legume evaluation programme in Australia provides at least a degree of concurrence. As stated by Jones and Jones (1978), the extensively planted tropical legume cultivar, Siratro, does not generally persist under heavy defoliation because of its twining, indeterminate growth habit, small number of growing points near ground level, and slow regrowth of the existing growing points. Cook and Jones (1987) noted a greater emphasis on grazing persistence in recent years as a result of the failure of the twining pasture legumes, even with their greater potential dry matter yields, to persist under 'constant or regular' grazing. Shaw Creeping Vigna (*Vigna parkeri*) is the first cultivar developed from this effort.

The relationship of legume growth form to sward stability and persistence under grazing obviously differs tremendously for different situations. With the unpalatable legumes generally adapted to the drier tropics, legume dominance can be the major constraint to grass-legume pastures, where frequent or continuous grazing may favour the less-competitive legumes grown with grasses of greater palatability (Lascano, 1987). Thus, the need for compatible growth forms and acceptable relative palatabilities. Suitable management procedures must be defined for the various pasture situations. Once these conditions are defined, identification of legume germplasm with the desired growth form and palatability should take precedence over such traditional forage plant evaluations as yield and forage digestibility determinations. Thus, preliminary evaluations of the response of tropical legume germplasm to grazing should be included early in the evaluation programme. In fact, dry matter yield under clipping regimes may often be of little value since there will probably not be a large number of persistent legumes to select between for high yield.

Of the legumes available and adapted to various areas of the Caribbean, potential for sustained contributions to livestock grazing appears to be greatest under current management for species such as *Teramnus labialis*. Paterson et al. (1986) noted that this legume is best suited to neutral or alkaline sites and is not as productive as some other species; thus, they recommend that it be planted at a light seeding rate as part of a legume mixture. This strategy should be considered more widely as grazing tolerant species are identified. When circumstances permit, management for the more productive legumes could be beneficial at least initially, and long-term pasture improvement could be realized from the persistent legume component. Emphasis should be placed on identification and commercial development of such persistent legumes, with less investment in labour intensive plot evaluations of legume yield under conditions not representative of the most-likely future grazing situation.

References

Bryan, W.W. and Evans, T.R. (1973) Effects of soils, fertilizers and stocking rates on pastures and beef production on the Wallum of South-eastern Queensland. 1. Botanical composition and chemical effects on plants and soils. *Aust. J. Exp. Agric. Anim. Husb.* **13** 516

Cook, B.G. and Jones, R.M. (1987) Persistent new legumes for intensive grazing. I. Shaw creeping vigna, *Queensland Agric. J.* (March - April)

Jones, R.J. and Jones, R.M. (1978) The ecology of Siratro-based pastures, in (Ed. J.R. Wilson), *Plant relations in pastures* CSIRO, East Melbourne, Australia, pp. 353-367

Jones, R.M. (1984) White clover (*Trifolium repens*) in subtropical south-east Queensland, III. Increasing clover and animal production by use of lime and flexible stocking rates, *Trop. Grassld.* **18** 186-194

Lascano, C.E. (1987) Canopy structure and composition in legume selectivity, In *Forage-livestock research needs for the Caribbean Basin* (Eds.) J.E. Moore, K.H. Quesenberry, K.H. and M.W.Michaud, University of Florida, Gainesville, Florida, USA, pp. 71-80

Paterson, R.T., Philip, P. and Maynard, P. (1986) *A guide to improved pastures for the drier areas of the Eastern Caribbean*, Caribbean Agricultural Research and Development Institute, St. John's, Antigua

Tothill, J.C. (1978) Comparative aspects of the ecology of pastures in *Plant relations in pastures*, (Ed. J.R. Wilson) CSIRO, East Melbourne, Australia, pp. 385-402

Some aspects of crop/livestock production in the Eastern Caribbean - A review

H.C. Patterson

CARDI, P.O. Box 70, Kingstown, St. Vincent

Pasture and livestock development activities carried out under the CARDI FSR/D programme were reviewed. Studies in Barbados have shown that 25, 40 and 100% of the imported maize in broiler starter, finisher and pig starter rations respectively can be replaced by locally produced cassava. Peanut and sweet potato residues were identified as potential livestock feeds in south-eastern St. Vincent. Pasture and forage bank establishment have taken place in Dominica, Montserrat, Nevis, St. Lucia and St. Vincent. In integrated production systems studies in Dominica, the cut and carry system has reduced the labour requirement of animal production. With some country - specific modifications, it could be extended to other, wetter parts of the region. Improved livestock management systems in Dominica have increased both animal production and vegetable yields, while producing cooking gas through the efficient use of animal manure. Improved rams have been introduced into St. Lucia and St. Vincent, while deworming of sheep at 6 to 8 week intervals has kept internal parasites at manageable levels. Suggestions are made as to the direction of future work.

Keywords: Animal production systems; Local feed production; Improved management

Introduction

Throughout the Caribbean area and especially in the Eastern Caribbean, a large proportion of all farm animals species are kept by small, often landless farmers. Animal rearing by these farmers is often complementary to crop production, to supplement farm income. In most instances the animals are an integral component of the farm system. They are however, often regarded as a 'mobile saving account' rather than a serious commercial activity. There are basically three types of crop/livestock farmers that engage the attention of the USAID-funded Farming Systems Research and Development (FSR/D) teams of CARDI.

(a) part-time subsistence farmers
(b) small and medium sized commercial farmers - usually full-time
(c) large commercial enterprises

In the case of animal production, because a high proportion of the animals are controlled by very small farmers, it is extremely difficult to plan or forecast production on a national or regional level. Nevertheless, animal production contributes significantly to food security in the region. Because of the huge importation (over 1.5 billion EC dollars) of extra-regional livestock products, there is a definite need to revise national and regional livestock development programmes aimed at self-sufficiency.

The major topics being addressed by FSR/D teams in the Eastern Caribbean are shown in Table 1.

Table 1 Areas of Crop/Livestock work being addressed by FSR/D teams in the Eastern Caribbean Countries

Type of Study	Country[1) BDS	SVT	DCA	SLY	MNT	NEV
Feed Resources	yes	yes	no	no	no	no
Forage Production and Development	yes	yes	yes	yes	yes	yes
Integrated Production Systems	no	yes	no	no	no	no

1) Country codes: BDS = Barbados, SVT = St. Vincent, DCA = Dominica, SLU = St. Lucia, MNT = Montserrat, NEV = Nevis.

Feed resources in the region

Feed cost remains the single biggest expense in livestock production. Feed efficiency is therefore of the highest importance.

Cassava as a livestock feed - Barbados

In Barbados, work is ongoing to screen cassava varieties and to develop a feed with a high proportion of cassava. The philosophy is that locally grown and processed cassava can be used to replace some of the imported corn corn used in concentrate feeds. Feeding trials have been carried out using cassava to replace 25 and 40 percent of the corn in broiler starter and finisher rations respectively and 100 percent of the corn in the pig starter ration.

There were no significant differences in average daily gain and feed efficiency for broilers and piglets on the rations containing cassava, when compared to the commercial rations.

Crop residue availability - A survey in St. Vincent

In St. Vincent a survey was done to identify local feed resources used by livestock farmers in one agricultural district (4 East). Peanuts were sown on 69 percent, and sweet potatoes on a further 23 percent of the area surveyed. The remainder of the land was sown to 10 other crops, including 0.3 percent to Pangola grass *Digitaria decumbens*). Clearly, the tops of peanuts and sweet potatoes constitute the bulk of the crop residues that could be used for feeding livestock.

Forage production and development

Forages probably constitute the most economical and efficient way to feed ruminant animals. The livestock industry in most CARICOM states, however, is based on imported feeds and native vegetation, with only limited use of improved grasses and forage legumes.

Several CARDI teams have ongoing development programmes to improve local forage 'banks' by introducing productive and adapted grass and forage legume species. Table 2 summarises the work done in forage development by FSR/D teams in the Eastern Caribbean.

Table 2 Summary of FSR/D forage production activity by country

Forage Production Activity	Country[1)]				
	DCA	SVT	NEV	MNT	SLU
Establishment of Forage Banks	yes	no	yes	yes	yes
Pasture Development/ Improvement	yes	yes	no	yes	yes
Forage Conservation	yes	no	no	yes	yes

1) Country codes: DCA= Dominica, SVT = St. Vincent, NEV = Nevis, MNT = Montserrat, SLU = St. Lucia.

There is forage activity in other countries in the Eastern Caribbean, but under different projects, which do not fall within the scope of this review. Tables 3 and 4 indicate the important species of grasses and legumes used in forage and protein energy banks in the region.

Pasture management is a form of husbandry largely neglected by livestock farmers throughout the region. The belief is that because grass grows easily in the tropics, there is no need to give the same level of care and attention to forage crops that are required by other crops. However, to obtain the maximum results it is necessary to select the correct grass/legume species, then manage them as an economic crop.

Integrated production systems

Under this heading will be discussed the livestock management system (LMS) in Dominica, the Dominica Roseau Valley Project, the deworming intervals and use of anthelmintics in St. Lucia and introduction of improved sires (rams) in St. Vincent and St. Lucia.

Livestock management systems

The livestock management system (LMS) in Dominica is a four - component model which incorporates cut/carry forage plots, an extensive grazing area, the extensive grazing and cut/carry herds.

Recently, on some of the farms associated with the LMS, biogas units have been introduced to efficiently dispose of farm waste, while yielding tangible benefits in cooking gas, slurry and manure.

The original rationale of the cut/carry system was to alleviate the forage supply problem and reduce the drudgery and time loss associated with tending animals long distances away from home or work.

Table 3 Indigenous and introduced grass species used in Forage Banks and pastures in the Eastern Caribbean

Common Name	Species Name
Pangola grass	*Digitaria decumbens*
Elephant grass	*Pennisetum purpureum*
Guinea grass	*Panicum maximum*
Bambatsi	*Panicum coloratum*
Setaria	*Setaria anceps*
Chrysopogon	*Chrysopogon sp*
Giant African Stargrass	*Cynodon spp.*
Bermuda grass	*Cynodon spp.*

Table 4 Indigenous and introduced forage legume species used in protein energy banks and pastures in the Eastern Caribbean

Common Name	Species Name
Stylo	*Stylosanthes hamata*
Glycine	*Neonotonia wightii*
Siratro	*Macroptilium atropurpureum*
Leucaena	*Leucaena leucocephala*
Rabbit Vine	*Teramnus labialis*
Calopo	*Calopogonium sp.*
	Rhynchosia sp.
Desmodium	*Desmodium intortum*

Cut and carry forage plots: Several improved grass and forage legume species were introduced. Of the legumes, *Desmodium* and *Stylosanthes* were the most persistent in mixed stands, gave a higher dry matter yield and competed most effectively against weeds. Elephant grass, which is well suited to the cut/carry system was found to be very productive under the conditions of high rainfall in Dominica. Yields as high as 25 - 31 t/ha/yr of dry matter have been realized.

The extensive grazing area: Animals are moved from the intensive rearing area in the cut/carry system to the extensive grazing area in the hills. This movement occurs usually when the cows are pregnant but not lactating. They are moved back into the system before calving or when they are again producing milk. It is difficult to estimate forage production in the extensive grazing areas, as there are varying species with variable levels of productivity.

The extensive grazing herd: This component is represented by the animals grazing in the native pastures in the hills. Not much care is given to the animals in the system at this stage, except for occasional watering and movement from one location to another.

The cut and carry herd: The only difference between the extensive grazing and the cut/carry herd is possibly one of physiological status. The cut/carry herd is usually lactating and supporting calves, while the extensive herd is usually dry and pregnant, or in very early lactation.

Over the past three and a half years the LMS has been studied by many persons, both within and outside of CARDI, and there are now the basic guidelines to develop a framework to analyze what is going on in this four component system and the interactions between sub-systems. There is the suggestion that a 5 - component system should be studied, since vegetable production has been found to be closely inter-related with the LMS. There are gaps in the information currently available, but a start has been made.

Computer templates have been developed for entering the data. All the templates include spaces to enter monthly inputs.

Roseau Valley Dairy Project

Some of the developments of the LMS in Dominica, such as livestock pens, the unique watering system of drums welded together and cut/carry forage plots, have already been transferred to dairy farmers within that country. The Roseau Valley Dairy project therefore is an extension of the LMS.

The main achievements of the project which ran from December 1984 to January 1986 were:

(1) Improved calving intervals due to better heat detection and earlier rebreeding (better reproductive efficiency). Open days were reduced from 335 to 141 days.

(2) Increased lactation length from a range of 150 - 175 up to an average of 238 days per animal.

(3) Increased milk production (range of 525 - 613 litres up to 952 litres per cow per lactation).

(4) Overall upgrading through training of the dairy farmers on the project.

Introduction of Improved Sires

A survey done among small ruminant livestock producers in the South East of St. Vincent identified the shortage of good quality sires as a major constraint. As a result, two rams, secured at no cost from the Ministry of Agriculture in Barbados, were provided to farmers in St. Vincent. The rams are already in service and doing well.

In a similar exercise to upgrade sheep in the La Pointe/Delcer/ Industry areas of Choiseul, St. Lucia, ten Blackbelly rams were imported from Barbados and distributed.

Internal Parasite Study

Wherever sheep are raised, internal parasites (worms) will be found. Worms are probably the biggest health hazard in the region.

A Programme to test four deworming intervals (6, 8, 10 & 12 weeks), and three anthelmintics (Levamisole, Synanthic and Panacur) was started in St. Lucia in January 1985 with four groups of farmers. The farms spanned two agro-ecological zones representing the dry north and the wetter central areas.

Pretreatment fecal counts revealed a high incidence of *Strongyles*,*Strongyloides* and *Monezia*. There were difficulties with this programme, mainly due to a high turnover rate of farmers, farmer indifference in one area, sale of experimental animals without notice and death of many project animals during the recent drought. These factors make the results incomplete or somewhat unreliable. Nevertheless, the general observations were that fecal counts were kept at manageable levels under the 6 and 8 week deworming intervals, but not at the longer intervals.

Suggestions for future direction

There is urgent need to intensify efforts on the development of animal feeds incorporating as high a proportion of locally produced ingredients as possible. Emphasis needs to be placed on the following areas:

(1) Forage production and conservation.

(2) Greater use of indigenous products and by-products for feeding.

(3) Selective breeding to provide good breeding stock for future generations.

(4) Outreach/extension programmes to promote aspects of livestock development.

(5) The provision of adequate incentives to production.

(6) The implementation of policies, particularly with regard to importation, to stimulate local animal production.

Pasture improvement in Tobago

Pamela Collins

CARDI, Botanic Station, Scarborough, Tobago.

Pangola is the main species which has been used in the small proportion (approximately 10%) of pasture land which has been improved in Tobago. Recent attempts to introduce other grass species and to encourage the use of grass-legume mixtures have been encouraging. The species used and the methods employed are described. The potential for further pasture improvement is discussed.

Keywords: Pasture improvement; Grass legume mixtures; Tobago

Introduction

Tobago is a small (116 sq.m.) rural island with many of the 40,000 population working in non-intensive agriculture. The southwestern part of the island is flat, dry (annual rainfall 1200 mm) and formed over coral. The more hilly northwest is wetter (up to 3800 mm per year) and the soils are mainly of volcanic origin.

Soil types should not limit pasture production. Of 38 soil types described by the Land Capability Survey (Brown et al 1965) only four were considered not suitable for pasture, because of erosion of the parent material. Throughout Tobago, soils are near neutral. Those used so far for pasture improvement have varied between pH 5.5 (Studley Park) and pH 7.9 (Lowlands). Soil nutrients are generally adequate, with the occasional exception of potassium. High salinity levels in coastal areas do not appear to limit pasture production. Any limitations to land use for pasture work tend to be physical, relating to slope, shallowness of soil and management of clay soils.

Much of the northern area is under primary or secondary forest. Cultivated areas tend to be confined to the alluvial valleys and the lower altitudes of the south.

In the whole island, there are about 3,500 ha under pastures, savannahs and coconuts undersown with pasture. The naturally occurring useful grasses in these areas are mainly savannah grass, (*Axonopus compressus*) with some guinea grass (*Panicum maximum*). *Echinochloa polystachya* occurs in some wet areas.

Naturally occurring legumes include *Desmodium* species, Kudzu (*Pueraria phaseoloides*) and *Calopogonium mucunoides*. There are stands of unimproved Leucaena (*Leucaena leucocephala*) in the south and *Gliricidia sepium* has been widely used as fence posts. Of these, only Gliricidia has been exploited as a forage source. A total of 333 ha (about 9.4 percent of available grazing land) was improved under a Government Development Programme in the 1950's, mainly using pangola (*Digitaria decumbens*). Elephant grass (*Pennisetum purpureum*) for cut and carry, and para grass (*Brachiaria mutica*) for wetter areas, were also introduced under this programme. For the past thirty years any pasture improvement had relied on these species.

The CARDI/EDF pasture improvement programme

In 1984, CARDI began a pasture improvement programme in Tobago, in co-operation with the Division of Agriculture, Tobago House of Assembly, as part of an EDF-funded regional project. The overall need for such a programme was obvious, since only a small proportion of pasture had been improved. The following features of livestock production in Tobago were taken into account in the planning and implementation of the programme.

(1) The inadequacies of Pangola in the Tobago context. This grass becomes dormant and produces little forage during the long dry season. There was a feeling that 'all the eggs were in one basket' with pangola. This was potentially dangerous, even though rust is the only disease problem so far observed. Nevertheless, Pangola was the only good quality grass available.

(2) The severity of the dry season, especially in the south, is a limitation to animal production. With one notable exception, scarce irrigation facilities are not used on pasture.

(3) Hillside farming limits the possibilities for adequate cultivation but in these areas, livestock, especially small ruminants, are more economically attractive and less harmful to the environment than annual or short-term perennial crops.

(4) Nutritional limitations; It was thought to be essential to introduce, and properly manage a legume component, to improve the nutritional status of animals in the dry season.

(5) Large farmers concentrating mainly on cattle, have different requirements from small farmers who usually keep small ruminant livestock.

In the light of these considerations, the work concentrated on species selection, appropriate methods of establishment and information generation and technology transfer. In 1984, work began on one Government Station and two private farms using limited professional time. Since May, 1986, there has been full time field assistance and the programme is now working with three Government Stations, twelve farmers and two schools. Many additional farmers have expressed interest in cooperating with the project in the future.

Species selection

Tobago is fortunate in that it has an environment very similar to that of Antigua where an enormous amount of preliminary work on selection of species has been done (Keoghan, 1980). Using the Antigua recommendations as a basis, the species and varieties shown in Table 1 were introduced. All were sown in small-scale nursery or demonstration plots, while some, as shown in Table 2, were established on a field scale for commercial animal production.

Of the grasses, African Star, Coast Cross (*Cynodon spp*) and *Chrysopogon* have so far made the greatest contribution to the programme, although in nursery plots, the Guinea grass (*Panicum maximum*) and the dwarf Elephant grass (*Pennisetum purpureum*) look very promising. Amongst the legumes, Siratro and Cunningham Leucaena have shown outstanding productivity and persistence. *Canavalia* exhibits a remarkable ability to germinate even under dry conditions, but appears to be more commercially acceptable on acid soils in Trinidad rather than on more neutral areas in Tobago.

Table 1 Pasture species introduced and established in Tobago

Grasses	Legumes	Grass-legume combinations
Panicum coloratum cv Bambatsi	*Stylosanthes hamata* cv Verano	Pangola/Siratro, Tinaroo, Roja
Chrysopogon sp. CPI 52213	*Macroptilium atropurpureum* cv Siratro	Elephant with Cunningham
Panicum maximum cv Likoni, local (Guinea)	*Neonotonia wightii* cvv Tinaroo, Cooper	Elephant with Siratro
Brachiaria decumbens cv Basilisk	*Teramnus labialis* cv Roja	Guinea with Tinaroo
Cynodon spp African Star; Coast Cross 1 and Tifton 68 Bermuda grasses	*Clitoria ternatea* *Canavalia ensiformis* (both white and brown seeded lines)	*Chrysopogon* with Tinaroo volunteer with Verano volunteer with Roja
Pennisetum purpureum N71 (dwarf elephant)	*Desmanthus virgatus*	Volunteer with Siratro, Tinaroo, Roja
Brachiaria radicans	*Leucaena leucocephala* cv Cunningham	Volunteer with Cunningham

Methods of establishment

The varying topography of Tobago, the differing demands of contrasting animal production systems and the need to make maximum use of limited seed supplies have led to the use of a number of establishment techniques. Commercial scale plantings are detailed in Table 2. On a smaller scale, sufficient planting material has been supplied to ten farmers during the course of the present project year (since October 1986) to establish small nursery areas. These will be used to plant larger areas in the future. Nursery/demonstration plots have been established at two Secondary Schools and two Government Agricultural Stations. These stations serve a double purpose. While being used for teaching purposes, they also generate information on the behavior of the species at varying sites on the island, adding to the body of knowledge relating to species adaptation in the region.

On occasions, assistance is required with pasture establishment in wetter, seasonally flooded areas. Tanner (*Brachiaria radicans*) and Antelope grass (*Echinochloa polystachya*) have been planted as vegetative material at two such sites. While these areas are of minor importance in Tobago as a whole, they cannot be ignored, since on some holdings, they represent an appreciable proportion of the area devoted to livestock production.

Information generation and technology transfer

All plots and commercial sowings are continually evaluated for productivity, persistence, vigour of regrowth and attacks by pests and diseases. The plots have been frequently used for field days. Target groups for specific sessions have included farmers, extension officers and the employees of the Government Stations. The location of the largest grass and legume demonstration area at the Kendal Farm School ensures that all graduates from that institute are well informed about improved pasture species.

Table 2 CARDI-EDF commercial scale pasture improvement in Tobago

Method of Establishment	Location	Area (ha)	Species used
1. Replanting entire pasture	Blenheim	3.3	*Stylosanthes hamata*
	Kendal	0.9	African Star/Coast Cross 1
2. Planting strips in established paddocks	Golden Grove	3.0	Siratro/Tinaroo/ Roja/in pangola
	Blenheim	1.0	
3. Planting strips in neglected pastures (flat land)	Lowlands	4.0	Siratro/Tinaroo/ Roja/and *Chrysopogon*
4. Contour planting (sloping land)	Blenheim	2.5	*Chrysopogon*
	Blenheim	1.3	Leucaena for browsing
5. Broadcast seed after minimum tillage	Lowlands	0.9	Roja in pangola
	Goldsborough	1.0	Guinea Grass in volunteer pasture
6. Cut and carry systems	Hope	2.0	Elephant grass/ Leucaena
	Mason Hall	0.2	Elephant grass/ Leucaena
	Concordia	0.2	Likoni/Leucaena
	Friendsfield	0.4	Likoni/Tinaroo
	Mason Hall	0.4	*Chrysopogon*/ Tinaroo
	Blenheim	0.4	Siratro/Elephant grass
	Kendal	0.4	Siratro/Roja/ Tinaroo/Elephant grass
	Goldsborough	0.2	Siratro/Elephant grass

Conclusions

Most progress has been made in species selection and farmer education. In terms of area, the impact so far has been relatively small. A total of about 25 ha of pastures have been improved by the introduction of selected species. There is, however, a firm basis for more rapid expansion in the future. Experience has shown that with the grasses recommended by the project, a nursery plot of 40 square metres can provide sufficient material within 12 months to plant out 0.5 ha of pasture, provided that close supervision ensures efficient management. Even if this high multiplication rate cannot be maintained over larger nursery areas, the resources are available to allow a considerable increase in the use of improved pastures over the next few growing seasons.

Farmer receptiveness to the principles of improved pasture management has been increased, due to the demonstrations and field days arranged as part of the project activities. In this regard, the severe 1987 dry season in Tobago has had a positive influence. The recommended, drought resistant grasses maintained productivity, while traditional forage sources failed to support the animals. Many farmers are now aware of the choices available to them. There remains a need for more education on the management of the legume component.

Constraints have been identified which will help to define the problems to be addressed in future work. These include the following:

(1) **Evaluation:** Improved pasture species have been introduced and are being adopted by the farming community. Further attention should be paid to the nutrient value of the pastures as influenced by the time of year. Grazing experiments would define the potential productivity of the pastures and appropriate grazing management techniques to produce optimum levels of animal production without affecting persistence.

(2) **Weed Control:** Both grasses such as Tapia grass (*Sporobolus jacquemonti*) and broad-leaved weeds such as Barrack weed and *Acacia spp* are major problems in pastures. The cost of chemicals has recently increased by 50 percent and labour costs are high. Mechanical brush cutters are not always available. Techniques such as strip planting are advantageous in this respect, since improvements can be made to a large field by sowing a relatively small proportion of the area.

(3) **Outreach:** This aspect of the programme must be maintained and accelerated. This can be achieved now that adequate nursery areas are available. To some extent, expansion of sown pastures has been limited by farmer preference for vegetatively propagated grasses. In some cases where seed has been used, germination (or establishment) has been poor. Vegetative material, though slower and more laborious, is safer in terms of farmer credibility.

(4) **Dry Season:** The dry season and lack of irrigation facilities are major constraints beyond technical control. The 1987 dry season was exceptionally long and severe. Even with improved pasture species, the seasonal lack of rain will lower pasture productivity for several months of the year.

These problems are being addressed. Improved species are available in the field. More detailed evaluations of their impact on production will follow.

References

Brown, C.B.; Hansell, J.R.F.; Hill, I.D.; Stark, J. and Smith, G.W. (1965), Land Capability Survey of Trinidad and Tobago, *Caribbean Printers*, Trinidad

Keoghan, J.M. (1980) Adaptable and productive forage legumes and grasses for more intensive small ruminant livestock systems in the Caribbean, *Trop. Anim. Prod.* 5 8-14

Perennial Peanut: Summary of animal feeding studies

E.C. French, G.M. Prine and L.J. Krouse

Dept. of Agronomy, University of Florida, Gainesville, Florida, 32611, U.S.A.

The perennial peanut was introduced into Florida from Brazil in 1936, but high yielding cultivars were not released until 1978 (Florigraze) and 1986 (Arbrook). Recent evaluation of the legume with different classes of livestock is reviewed. Unweaned calves, creep fed on perennial peanut pasture gained more, while their mothers lost less weight than when calves stayed with their mothers on bahia grass. Yearling beef cattle grazing the peanut produced twice the ADG per hectare measured from bahia grass alone, while dairy cows fed peanut hay gave similar milk yields, with a higher fat content than when alfalfa hay or corn silage were used. Peanut haylage was also useful for dairy cows. With pigs, peanut forage could replace up to 60% of the soya bean - corn concentrate, while with growing rabbits, it produced results similar to alfalfa. It can be used as a xanthophyll pigment source for chickens, and so has potential for use in extraction industries. It could soon be the most important forage crop in Florida since it is well suited to local climatic and edaphic conditions. (Editor's summary).

Keywords: Perennial peanuts; Animal forage; Peanut hay

Introduction

Perennial peanut (*Arachis glabrata*) is a high quality, perennial forage legume, adapted to well-drained soil, and humid warm climates (Prine et al, 1981). Numerous plantings throughout the state of Florida and the Caribbean have demonstrated that it is ideally suited to these growing conditions. It is unique to Florida because there is no other warm season legume with the desirable forage characteristics, persistence and broad spectrum of uses, including hay and other dehydrated products, pasture, creep grazing, silage, ornamental, conservation cover and living mulch.

Perennial peanut offers several advantages. Being drought tolerant and winter hardy in Florida, this long-lived perennial plant does not require replanting once established. Because there is no annual replanting cost, no nitrogen fertilizer, insecticide or fungicide costs, overall production expenses are kept to a minimum. It can be grown as a monocrop or in mixture with perennial grass. The practice of overseeding small grains into perennial peanut sod, beginning in November or December, has been quite successful, providing additional forage or grain production, while inhibiting emergence and growth of weeds.

Important to the development process of perennial peanut, was the release of high yielding cultivars. In 1978, the first was released in Florida under the name of Florigraze (Prine et al 1981). In 1986 Arbrook became the second named cultivar (Prine et al 1986). Florigraze was particularly important in furthering development of perennial peanut in Florida.

The developmental process, from which perennial peanut and its encompassing technology have evolved, was relatively slow due to lack of a concerted research/extension effort. Work with the crop has been ongoing since its introduction from Brazil into Florida in 1936, but most acreage expansion has occurred since 1982. Interest in perennial peanut has intensified in recent years and is presently being researched within a varied number of disciplines. This paper will discuss the important research carried out with animals.

Beef cattle

Creep grazing

Research was conducted using perennial peanut as a calf supplement in a creep grazing management scheme. Lactating Brahman cows were maintained on bahiagrass (*Paspalum notatum*) pasture. Treatment calves had free access to their mothers in addition to perennial peanut pasture, while control calves remained with their mothers on bahiagrass. The study concluded that cow weight loss was less and calf average daily gain (ADG) was greater when calves were creep fed on perennial peanut (Ocumpaugh, 1979). The results are shown in Table 1.

Beef grazing

In 1985, a trial compared the growth of yearling cattle (initial weight 340 kg) on either Pensacola bahiagrass or perennial peanut (Sollenberger and Jones, unpublished data). Grazing started on 15 May on the grass and 17 July on the legume, ending in both cases on 18 September. The stocking rate was lower on the peanut, but ADG, both per head and per unit area, were much higher. Results are shown in Table 2.

Dairy cows

Hay

Romero et al (1985) studied the effects of hay of alfalfa (*Medicago sativa cv* Florida 77) or perennial peanut, or corn silage mixed with concentrate at two levels (30 and 70 percent) on milk yields and butterfat content. The results are summarized in Table 3. In terms of yield, the peanut was similar to the corn silage, but it produced the highest levels of butterfat.

Haylage

Recent research conducted by Staples et al (1987), consisted of four experimental diets of corn silage, rhizoma peanut haylage and corn-soyabean meal fed *ad libitum* to lactating cows in differing ratios. Maximum milk yield (30.0 kg per day) was attained with a 30:20:50 ratio diet, while greater butterfat yield resulted from 35% perennial peanut haylage in the diet (Table 4).

Table 1 Performance of purebred Brahman cows and calves on Pensacola bahiagrass pasture with perennial peanut creep grazing, 13 June to 5 September, 1985

Pastures	Weight changes cow (kg)	Weight changes calf (kg)	ADG of calf (kg)
Bahia with calf creep-fed on perennial peanut	- 4.1	69.2	0.78
Cows on bahia	- 24.1	54.1	0.62

Table 2 Performance of yearling cattle on Pensacola bahiagrass (May to September) and perennial peanut (July to September)

Pasture	Stocking rate (animals/ha)	Gain (kg/ha)	Average Daily Gain (per head)	Average Daily Gain (per ha)
Perennial peanut	2.7	144	0.89	2.30
Pensacola bahia	5.0	144	0.24	1.14

Table 3 Effects of forage source, concentrate level (%) and protein content (CP%) of the diet on milk yields (kg) and butterfat content (%)

	Forage Source					
	Alfalfa hay		Peanut hay		Corn silage	
Crude protein (%)	16	20	14	18	14	18
Concentrate at 30%						
Yield (kg)	14.9	16.9	15.3	15.6	16.5	17.1
Butterfat (%)	3.28	3.26	2.99	3.84	3.64	3.28
Concentrate at 70%						
Yield (kg)	16.7	19.1	18.3	17.9	18.5	18.4
Butterfat (%)	3.21	3.47	3.47	3.77	3.15	3.73

Table 4 Lactation performance for cows fed four ratios of corn silage, rhizoma peanut haylage and corn/soyabean meal

Feed Ratio	Dry Matter Intake		Milk		Average Daily Gain
	(kg/day)	(% of BW)	Yield (kg/day)	Fat (%)	(kg/day)
50: 0:50	23.4	4.13	30.4	3.47	0.75
30:20:50	23.9	4.25	30.9	3.43	0.47
15:35:50	22.6	4.05	29.8	3.49	0.29
0:50:50	20.9	3.78	28.8	3.51	0.28

Table 5 Reproductive performance of sows fed perennial peanut during gestation

Percent perennial peanut in diet (%)	Number pigs farrowed	Number pigs born alive	Number pigs weaned
0	8.83	8.50	6.67
40	11.00	10.33	6.50
60	10.60	10.40	5.60
80	11.50	11.17	6.67

Means in columns did not differ significantly ($p < 0.05$).

Table 6 Performance of sows fed gestation diets containing perennial peanut

Dependent variable	Percent perennial peanut in diet			
	0	40	60	80
Number of sows	6	6	5	6
Sow initial weight (kg)	131.7b	146.6ab	166.9a	132.1b
Sow prepartum weight (kg)	165.1bc	186.6ab	208.9a	151.4c
Sow weight gain (kg)	33.4a	40.2a	42.0a	19.4a
Sow postpartum weight (kg)	155.0bc	169.4b	196.2a	140.2c
Litter birth weight (kg)	11.5a	15.3a	13.7a	11.1a
Placenta weight (kg)	2.1a	1.9a	1.7a	1.9a
Sow weaning weight (kg)	149.4bc	167.2ab	185.1a	134.8c

Means within a row followed by same letter are not significantly different. ($p < 0.05$, Duncan's New Range Test.)

Swine

Recent work using perennial peanut in gestating sow rations in place of soyabean-corn concentrate has produced very positive results (Lopez et al 1986). Diets containing perennial peanut at 0, 40, 60 and 80% of the ration were fed to sows during three gestation periods. Sows fed an 80% diet of perennial peanut farrowed more pigs than the other treatments and yielded an equivalent number of live weaned pigs compared to the 100% corn/soyabean ration (Table 5), but differences were not statistically significant ($p = 0.05$).

Although not statistically significant, body weight gain during gestation was greatest for sows fed 60% perennial peanut (42.0 kg) and least for those fed 80% (19.4 kg) (Table 6).

Rabbits

Research data from Oregon State University has established that perennial peanut is a superior feed source for rabbits (Gomez et al 1983). In one feeding trial, perennial peanut meal was compared to alfalfa and kudzu meal (*Pueraria phaseoloides*). No difference was observed in ADG, but feed conversion by rabbits fed perennial peanut was significantly better (Table 7).

Table 7 Performance of rabbits fed three legume forages (after Gomez et al. 1983)

Feed	Protein (%)	Total gain (g)	Average Daily Gain (g)	Feed intake per day (g)	Feed conversion (feed/gain)
Alfalfa	16.0	1111	39.7	127	3.2
Perennial peanut	16.5	1111	39.7	102	2.6
Kudzu	11.5	884	31.6	111	3.5

Poultry

Perennial peanut meal was compared with yellow corn and alfalfa meal as a xanthophyll pigment source for egg yolk colouring (Janky et al 1986). Lower wavelength properties of perennial peanut resulted in lower percent excitation purity and higher percent luminosity at both 5.5 mg/kg and 11.0 mg/kg feed ratio (Table 8).

These data indicate that perennial peanut contains adequate levels of pigments for use as a commercial feed additive. Extracted protein plus pigments opens a new potential industrial use for the legume, yielding a high value product for poultry.

Conclusions

Much has been achieved in a relatively short time toward developing perennial peanut as a new forage. Efforts are now under way that should expand understanding and use of this species. Present findings confirm the tremendous potential that it has throughout the animal industry. If the involvement of private sector, extension and research continues its present increasing trend, perennial peanut will soon be the most important forage crop in Florida and potentially in other areas of the Caribbean.

Table 8 Calculated colour values (IDL reflectance colorimeter) for egg yolks from hens fed yellow corn, dehydrated alfalfa meal, or dehydrated perennial peanut leaf meal at two dietary xanthophyll levels

Xanthophyll level and source	Dominant wave length (nm)	Excitation purity (%)	Luminosity (%)
5.5 mg/kg diet			
Yellow corn	575.5b	77.63a	35.26a
Alfalfa	575.2ab	81.67b	35.17a
Perennial peanut	574.8a	77.41a	35.99a
11.0 mg/kg diet			
Yellow corn	577.4b	91.10b	29.34a
Alfalfa	576.6ab	90.63b	31.83ab
Perennial peanut	576.1a	88.49a	33.27b

Means within a column at the same xanthophyll level, and followed by the same letter are not significantly different ($p < 0.05$).

References

Gomez de Varela, A., Harris, D.J., Cheeke, P.R. and Patton, N.M. (1983 Evaluation of perennial peanuts (*Arachis glabrata*), kudzu (*Pueraria phaseoloides*) as feed stuffs for rabbits. *J. of Applied Rabbit Research* **6** 97-98

Janky, D.M., Damron, B.L., Francis, C., Fletcher, D.L. and Prine, G.M. (1986) Evaluation of Florigraze rhizoma peanut leaf meal (*Arachis glabrata*) as a pigment source for laying hens, *Poultry Sci*. **65** 2253-2257

Lopez, F.D., White, C.E. and French, E.C. (1986) Reproductive performance of sows fed ground perennial peanut hay during gestation, *Animal Science Res. Report SW-1986-3*, 7 p

Ocumpaugh, W.R. (1979) Creep grazing for calves, *Proc. 28th Annual Beef Cattle Shortcourse. Anim. Sci. Dept., Univ. of Fla.*, Gainesville, Florida, pp. 159-165

Prine, G.M., Dunavin, L.S., Moore, J.E. and Roush, R.D. (1981) "Florigraze" rhizoma peanut, a perennial forage legume, *Univ. of Fla. Agric. Exp. Stn. Circ. S-275*, 22 p

Prine, G.M., Dunavin, L.S., Glennon, R.J. and Roush, R.D. (1986) "Arbrook" rhizoma peanut, a perennial forage legume, *Univ. of Fla. Agric. Exp. Stn. Circ. S-332*, 16 pp

Romero, F., Van Horn, H.H., Prine, G.M. and French, E.C. (1987) Effect of cutting interval upon yield, composition and digestibility of "Florida 77" alfalfa and "Florigraze" rhizoma peanut, *J. Anim. Sci*. **65** 787-796

Staples, C.R., Emanuele, S.M. and Prine G.M. (1987) Feeding value of Florigraze rhizoma peanut haylage for lactating dairy cows. Quoted in *American Society of Animal Science*, Abstract

An overview of a CARDI livestock development project in Dominica

W.P. Rolle, B.A. Clarke

CARDI, Botanical Gardens, P.O. Box 346, Roseau, Dominica

G.A. Proverbs

CARDI, Cave Hill Campus, P.O. Box 64, St. Michael, Barbados

During 1985-86 CARDI introduced their "cut and carry" system to eight small farms in the Roseau Valley, Dominica. The purpose was to improve dairy production and train farmers and extension officers in better cattle management. After one year, all farmers had established elephant grass of which they were feeding lactating cattle up to 55 kg fresh weight daily. This was supplemented daily with a high phosphorus mineral and coconut meal plus legumes and crop wastes when available. Other improved practices included housing, artificial insemination, testing for mastitis, synchronized breeding, record keeping, correct milking practices and systematic use of acaricides and anthelmintics. These practices resulted in increases in lactation length from 170-175 days to 238 days and lactation yields from 525-613 litres to 952 litres. A 194 day decrease in calving interval was also recorded.

Keywords: Livestock production systems; Milk production; Dominica

Introduction

The government of the Commonwealth of Dominica has given high priority to increasing local milk and beef production as one of their agricultural diversification strategies. This emphasis has been due to the inability of local production to satisfy demand, resulting in an increase in the cost of imported meat and dairy products from EC$ 6.0 million in 1978 to EC$ 10.5 million in 1984.

Local milk and beef production were valued at EC$ 40,000 and EC$ 680,000 respectively in 1978 (Archibald et al, 1981). These low levels have been attributed to a number of constraints including poor genetic stock, lack of improved forages, poor herd management, praedial larceny and losses due to stray dogs and strangulation (Henderson and Gomes, 1979; Harricharan et al 1980; Morley, 1983; Archibald et al 1981). In order to alleviate some of these constraints the Caribbean Agricultural Research and Development Institute (CARDI) introduced and tested an improved livestock management system for small farmers in Dominica. This work began in 1983 under the aegis of the CARDI/USAID Farming Systems Research and Development Project.

The livestock management system was based on a cut and carry (zero grazing) feeding system and integrated management of herd, forage, housing, water collection and distribution. Robin and Clarke (1985) showed that as a result of the improved system, milk production increased, collection and distribution of pen manure was easier, labour use decreased and losses of animals through larceny, wild dogs or strangulations were reduced. Based on these successes the improved technology was transferred to dairy farmers of the Roseau Valley through a project financed by the Canadian International Development Agency (CIDA). The objectives of the project were:

- to train the farmers in better cattle management practices.
- to increase milk production per lactation from 400 to 500 litres.
- to increase the lactation period from 150-175 days to 200-210 days.
- to improve the genetic make-up of the native cattle with the introduction of improved bulls.
- to increase herd size of the selected farmers.
- to train staff of the Ministry of Agriculture in small dairying practices.
- to improve the general health of the cattle through regular deworming and spraying to control internal and external parasites.

This paper summarizes these activities and compares the farmers before and after the improved system was implemented.

Methodology

Eight farmers in the Roseau Valley were selected to take part in the project, following a review of farm profile data of 60 farmers. The farms were located at Trafalgar, Morne Prosper, Biack and Fond Cani which are 3 - 10 km from Roseau, the capital. The areas were 120 m to 450 m above sea level, with mean minimum and maximum temperatures of $21^{o}C$ and $32^{o}C$ respectively. Other characteristics of the areas are slopes of 20 to 60 degrees with moderate to high erosion and mean annual rainfall of 2,000 mm to 4,000 mm. The soils were alluvials and oxisols with good drainage and water-holding characteristics.

The first activity of the project was the initial characterization of the dairy operations of each farm with respect to milking methods, herd management, labour input, levels of production, breeding and selection, feeding and watering practices and income and expenses. Collection of such data continued throughout the project, and provided a basis upon which it could be evaluated.

Project personnel visited each farm weekly and advised on, and assisted in the implementation of improved dairy management practices. The veterinary unit of the Ministry of Agriculture provided assistance with animal health matters. Two field days and a workshop were organized in which project farmers, extension officers, and other farmers in the Roseau Valley participated.

Pure stands of elephant grass (*Pennisetum purpureum*) were established on all eight farms. Stem cuttings were planted at a spacing of 0.3m by 0.3m. NPK fertilizer (16:8:24) was applied at 200 kg/ha one month after planting and top dressings of NPK 20-0-20, urea and triple super-phosphate were subsequently applied.

Demonstration plots of the forage legumes Stylo (*Stylosanthes hamata*), Glycine (*Neonotonia wightii*), Siratro (*Macroptilium atropurpureum*) Leucaena (*Leucaena leucocephala*) and Desmodium (*Desmodium intortum*) were established on one of the farms.

Feeding, watering and water storage, resting, exercise, milking and general storage facilities for three cows and two calves were established on each of the four farms. Housing units of free stall, or tie stall design were constructed of roundwood, and the exercise areas were fenced with live Gliricidia (*Gliricidia sepium*) posts. The farmers actively participated in the design and construction of the housing units and the Ministry of Agriculture assisted financially.

Three pure bred yearling bulls, one Holstein, and two Jamaica Red Polls were imported from Barbados, and located at the Ministry of Agriculture central stock farm for acclimatization. Interim breeding services were provided by a local Jersey bull and by artificial insemination using imported semen.

In addition to the training and service components, the project provided a variety of inputs including coconut meal, high phosphorous mineral supplements, anthelmintics, fertilizer, herbicide, breeding calendars, milk scales, neck chains and tags.

Farm status prior to project

Reproduction and breeding

At the start of the project, individual herd sizes ranged from four to eleven, with an overall total of 43 animals. The average length of the open period was 335 days, resulting in an extended calving interval and contributing to a shortage of potential herd replacements. Data on herd composition (Table 1) showed that only one herd had a 2 - 3 year old heifer, and four herds had heifers aged between 12 and 24 months. The average age at first calving was 39 months and the majority of the cows were over 68 months old but had borne three calves or less.

Table 1 Herd composition by age and sex on 7 project farms at January 1986

Farm No.	1		2		3		4		5		6		7	
Sex	M	F	M	F	M	F	M	F	M	F	M	F	M	F
Birth to 12 months	2	0	4	0	0	1	0	1	2	1	3	2	1	1
12-24 mths	0	1	0	2	1	0	0	0	2	0	2	2	0	2
24-36 mths	0	0	0	0	0	1	0	0	0	0	0	0	1	0
> 36 mths	0	3	0	4	0	2	0	2	0	3	0	6	0	3
Total	6		10		5		3		8		15		8	

The low breeding efficiency may be attributed in part to a belief expressed by the farmers that cows had to 'rest' for at least 100 days after calving, and also to a reliance on secondary heat signs, the absence of pregnancy testing and the occasional lack of available sires.

All the above factors, together with the high cost and scarcity of heifers on the open market, led to a shortage of replacement females. This scarcity made it impossible to do any selection based on milk yield, while the use of scrub or creole bulls reduced the possibility of improving the genetic stock.

Calves were born and consumed colostrum without any assistance. The farmers did not place iodine on the navel, dehorn, remove extra teats, or castrate bull calves. Generally, calves and their dams were kept together continuously for seven to nine days before milking commenced. Most farmers allowed calves to suckle both during and after milking and the udders were not stripped.

Milking practices and lactation

Little attention was paid to sanitation. The udders were washed with cold rain water, which appeared to distress the cows and may have affected the let down reflex. Teat dipping was not practiced. Mastitis was identified, but the farmers were not familiar with its diagnosis and its incidence was not quantified. The average length of lactation was 150-175 days and milk production ranged from 525 to 615 litres per cow per lactation.

Marketing

Five farmers sold more than 50 percent of the milk produced, 8 to 18 percent was used in the home, and the remainder was consumed by the calves. The milk was sold in 750 ml 'whiskey' bottles at a price of EC$ 1.67 to EC$ 2.00 per litre. The primary constraints to marketing were the identification of regular customers, and the distribution of milk.

Nutrition

The majority of farmers grazed their animals for limited periods, approximately four hours per day, three days per week, and the animals were usually tethered on natural pastures or along the roadside. Zero grazing was occasionally practiced in the dry season. Variable quantities of coconut meal, mineral mix and trace mineral salt were fed to the animals. Only one farmer supplied mineral mix to lactating cows.

The farmers provided water free-choice or periodically. Only one farmer with a stored supply consistently watered lactating cattle free-choice. For periodic watering, the animals were supplied once or twice per day depending on the weather, and were usually taken to water.

Main project achievements

The major achievements are summarized in Table 2. During the one year project period, the total number of animals increased to 55, with an individual herd size of three to fifteen animals. The calving interval was reduced by decreasing open days and lactation length and average milk production were both increased.

Project farmers were introduced to improved milking practices, and were taught the diagnosis of mastitis. Locally manufactured strip cups were provided in order to facilitate mastitis testing. The farmers were assisted in developing a strategy for marketing their milk, and the Roseau Valley Dairy Association was formed. The calving interval was reduced, and the genetic merit improved, by the use of a Jersey bull provided by the Ministry of Agriculture, and an artificial insemination programme based on imported Holstein and Jersey semen.

The nutritional status of the animals was improved by the establishment of a cut-and-carry system utilizing the introduced forages. The system allowed an increased intake of better quality forage (up to 55 kg per day), while reducing labour input by decreasing the number of cattle grazed and tethered. Four of the farmers cut and fed Elephant grass periodically to all their cattle but used it primarily as a dry season forage bank. Two fed *ad lib* to lactating cows and calves and one farmer fed Elephant grass *ad lib* to all his cows.

Table 2 Summary of major project achievements

	Pre-Project	Post-Intervention
Total number of cattle on 7 farms	43	55
Average number of days open	335	141
Average calving interval (days)	502	421[1)]
Services	100% Creole	58% Creole 26% improved 16% A.I.
Days dry	340	87
Average length of lactation (days)	150 - 175	238
Planted pasture (ha)	0	1.82
Milk production per cow per lactation (litres)	525 - 613	952

1) Projected, based on breeding dates

During the project the farmers began feeding from 0.9 to 2.8 kg of coconut meal plus 85 g of the introduced high phosphorus mineral supplement per day to lactating cattle. Also six of the farmers fed coconut meal and trace mineral salt to their calves. Consequently, the Ministry of Agriculture has made the high phosphorus mineral supplement available to all interested farmers.

The free-stall and tie-stall units introduced, incorporated a storage tank made up of four recycled 248 litre oil drums welded together end to end, which collected water from the roof. As a result, more farmers provided water free-choice and thus increased the frequency of watering. In addition, these units facilitated better animal security, easier collection of manure, improved sanitation and faster acceptance and implementation of other components of the introduced technology.

Economic Analysis

A comparative economic analysis of the milk production system before and after adoption is presented in Table 3. Before adopting the improved system, returns were EC$ 912 per year, material units were zero and labour costs were EC$ 2,691. Thus returns were negative (-$1,779). After adoption of the technology, the farmers milked up to four cows and the amount of milk produced per cow increased Total returns increased to EC$ 4,863 per year while total costs were EC$ 2,838, providing net returns of EC$ 2,025 or EC$ 506 per cow per year. Table 4 shows establishment costs for the improved system.

Table 3 Annual costs and returns (EC$) for milk production before and after adoption of the Improved Livestock Management System

Budget Element	Before Adoption	After Adoption
Milk Revenue[1)]	912	4,863
Operating Costs (Materials)		
Concentrate	-	408
Vet. medicine	-	-
Salt Lick	-	20
Fertilizer	-	148
Repair and Maintenance	-	12
Total material costs	-	580
Labour[2)]		
Cutting forage and feeding	-	797
Tethering, grazing and watering	2,578	-
Milking	113	638
Cleaning pens	-	239
Repairs and maintenance	-	40
Total labour costs	2,691	1,714
Total operating costs	2,691	2,302
Capital cost per year	-	536
Total costs	2,691	2,838
Net returns	(1,779)	2,025
Total cost per animal per year	2,691	710
Net returns per animal per year	(1,779)	506

1) Returns from milk at $1.67 per litre.
2) All labour costed at $2.50 per hour.

Table 4 Costs (EC$) of establishment of pen, watering system and forage plot

Item	Costs	
Building 1)		
Materials	1,029	
Labour 2)	618	
Total building costs		1,647
Watering system		
Materials	110	
Labour	82	
Total watering system costs		192
Forage Plot		
Materials	114	
Labour	726	
Total Forage Plot costs		840
Total Capital costs		2,679
Capital cost per animal per year 3)		134
Material cost per animal per year		63
Labour cost per animal per year		71

1) Building includes exercise area. 2) Labour costed at $2.50/hour.
3) Assuming a life of five years.

Conclusions

A number of constraints continue to limit production on the project farms. These include the following:

(1) absence of marketing channels and infrastructural facilities to get milk from the farm to the consumer.

(2) lack of available animal replacements at reasonable prices.

(3) inadequate technical support from the extension services.

(4) reliance on natural pastures of low productivity and nutritional value for feeding calves over six months of age and growing and dry animals.

(5) farmer reluctance to adopt all components of the 'Livestock Management System'.

(6) limited availability of land.

(7) limited credit facilities and the need for collateral of the kinds requested.

(8) inability to obtain dairy farm supplies.

Despite these limitations, the objectives of the project were satisfied, and its success is evidenced by the request of the Government of Dominica to establish a similar scheme in the Soufriere area.

Acknowledgments

The project was funded by CIDA from Mission Administered Funds. The institutional framework was provided by the Ministry of Agriculture, Industry, Trade and Tourism, representatives of which served on the project management committee. The full cooperation of the participating farmers is gratefully recorded.

References

Archibald, K., Singh, R. and Osuji, P.O. (1981) Animal production systems in the Eastern Caribbean. *Winrock International Consultancy Report No 7*, CARDI, St. Augustine, Trinidad

Harricharan, H., Fontanelle, S., Harris E. and Adams H. (1983) A proposal for the development of a small-farmer's dairy production system in Dominica, Unpublished

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*, Dept. Agric. Ext. Uni. West Indies, St. Augustine, Trinidad

Morley, R.S. (1980) Animal Health in Dominica, Unpublished

Robin, G. and Clarke, B. (1985) Evaluation of a livestock management system for small farms in Dominica, *Coloquium, Caribbean farming systems and alternatives for development* May, 1985, Martinique

Forage legumes in the Western Llanos of Venezuela

A.E. Munoz and S. Farinas

Universidad Ezequiel Zamora, Guarane, Portuguesa, Venezuela

In the Western Llanos of Venezuela, attempts to identify productive and persistent grass - legume associations have not, so far, been wholly successful. In view of the difficulties involved in the management under grazing of legumes in association, a programme of research was developed to evaluate the potential of a range of 10 legume species for hay making. When cut at the pre-, or early bloom stage, the leaf to stem ratio ranged from 0.69 to 2.23, while after drying, the range was from 0.39 to 1.63. The CP content of the leaf (16.4 to 33.1%) and stem (7.0 to 14.8%) resulted in whole plant contents from 12.9 to 26.1%. Best species for hay making were *Desmodium ovalifolium, Centrosema pubescens, Alysicarpus vaginalis* and *Macroptilium atropurpureum*, although brittleness of the dry stems makes *D. ovalifolium* risky. Annual species regrew if cut in the pre-bloom stage, provided that moisture and nutrient supply were both adequate.

Keywords: Forage legumes; Legume hay; Leaf-stem ratios

Introduction

In Venezuela, with few exceptions, well fertilized grasses harvested after 30 to 35 days of regrowth have from 10 to 14 percent crude protein (CP) and about 60 percent digestibility. However, as has been reported for tropical grasses from other areas (Minson and Milford 1965; Hutton 1974; Silva and Da Silva 1976), these parameters decrease rapidly, mainly due to an increase in fibre content and a decrease in the digestibility of both the fibre and the CP. Protein deficiency is critical and poses a problem in animal production, especially for fast growing and intermediate to highly productive dairy animals. Many Venezuelan farmers have to feed protein concentrates on a daily basis, with a consequent increase in production costs, especially since the Government has reduced the subsidy on feed concentrates.

Venezuela is rich in native forage legumes, the nutritive value of which, in general, changes little with age. More intensive and systematic use of legumes in animal production can eliminate, or at least minimize the use of concentrates, and consequently decrease production costs. Numerous reports from tropical Australia, Colombia, Brazil and Venezuela show that legumes, either alone or mixed with grasses, can produce acceptable weight gains and milk yields (Hutton 1974; Stobbs and Thompson 1975; Silva and Da Silva 1976; Mendez 1977; Chacon and Betancourt 1986; Tergas and Lascano 1986).

In Venezuela, attempts have been made to identify productive, long term grass-legume mixtures. With few exceptions, results have not been satisfactory and in most cases this work has remained at the experimental level. Grass-legume mixtures require a high degree of managerial skill. Lack of development of the extension services may explain, in part, why farmers are reluctant to incorporate legumes into their forage systems.

In an attempt to minimise grazing management problems, the present work concentrated on the use of legumes as dry forage. One difficulty with legume hay is that many species tend to lose leaves during the drying process. Leaf to stem ratio is one of the most important factors in the determination of hay quality (Sullivan 1975). Mowat et al (1965) considered that this ratio could be used as a selection criterion to improve the quality of hay of alfalfa (*Medicago sativa*) and similar legumes.

In Portuguesa state, a programme of research was developed to determine, for a range of legumes, the proportion of leaf to stem, the retention of leaf material after drying, the nutritive value of each fraction and the consumption of hay when fed as part of a balanced animal ration.

Materials and methods

The study was started at several farms in May 1985 during the rainy season. The following legumes were planted; *Indigofera hirsuta*, *Alysicarpus vaginalis*, *Macroptilium lathyroides*, *Macroptilium atropurpureum*, *Calopogonium mucunoides*, *Teramnus uncinatum*, *Centrosema pubescens*, *Stylosanthes hamata*, *Desmodium ovalifolium* and *Canavalia ensiformis*. They were seeded at 10 or 15 kg/ha, so that high plant density and rapid cover would minimize weed problems. High density would also produce taller plants with thinner stems, especially in species such as *I.hirsuta*, *A. vaginalis*, *M. lathyroides*, *D. ovalifolium* and *C. ensiformis*. Seeds were broadcast, disced in to a depth of from 2 to 4 cm and fertilized with 92 kg P_2O_5 per ha as triple super-phosphate and 50 kg K/ha as potassium sulphate. The experimental plot for each species was 0.25 ha. All legumes were evaluated at the pre-bloom stage. This varied from 50 days (*M. lathyroides*), to 150 - 180 days (*C. mucunoides*, *C. pubescens* and *T. uncinatum*).

Results and discussion

Preliminary results are shown in Table 1. With the exception of *S. hamata*, the leaves of all the legume species evaluated contributed at least 49 percent to the total dry matter yield at the time of harvest (pre-bloom or early flowering). These figures are high compared with data presented by Villaquiran and Lascano (1986) who reported leaf yields at 10 percent flowering of 43.4, 34.6 and 17.5 percent respectively for *Centrosema macrocarpum*, *Stylosanthes guianensis* var. pauciflora and *S. macrocephala* respectively. Belcazar and Schultze - Kraft (1986), in seven ecotypes of *Centrosema brasilianum*, reported leaf proportions ranging from 41.0 to 49.5 percent. From the point of view of the ratio of leaf to stem, *Macroptilium spp*, *D. ovalifolium* and *C. pubescens* appear to be better than other *Centrosema* spp. *Stylosanthes* spp, *C. mucunoides* or *I. hirsuta*.

At the time of harvest of the present study, the leaves of *S. hamata* and *D. ovalifolium* were relatively low in CP content (18.7 and 16.4% respectively), while the other species ranged from 20.0 to 33.1 percent. Similar data have been reported in the literature (Belcazar and Schultze-Kraft 1986; Chacon and Betancourt 1986; Villaquiran and Lascano 1986) for a range of tropical forage legumes. The leaves of *C. pubescens*, *A. vaginalis* and *T. uncinatum* are of much higher feeding quality than other legumes such as *Stylosanthes spp* and *D. ovalifolium*.

The CP content of the stems varied between wide limits, with lower results obtained with *D. ovalifolium*, *I. hirsuta* and *S. hamata* Similar results were reported by Chacon and Betancourt (1986), who found 9.0 and 14.9 percent CP in the stems of *S. guianensis* and *C. pubescens* respectively.

Table 1 Ratio of leaf to stem (L:S) and crude protein contents (%) of common legumes in the Western Llanos of Venezuela

Species	At cutting (pre- and early bloom)				Hay
	Ratio L:S	Crude Protein % Leaf	Stem	Whole	Ratio L:S
I. hirsuta	1.00	26.1	9.4	17.8	0.92
A. vaginalis	1.44	32.6	11.0	23.7	1.04
M. lathyroides	1.50	27.7	14.3	22.3	0.49
M. atropurpureum	2.23	22.2	11.6	18.9	1.04
C. mucunoides	0.96	24.5	11.6	17.9	0.79
T. uncinatum	1.22	30.6	14.5	23.4	0.92
C. pubescens	1.63	33.1	14.8	26.1	1.17
S. hamata	0.69	18.7	9.5	13.3	0.54
D. ovalifolium	1.70	16.4	7.2	12.9	1.63
C. ensiformis	1.56	20.0	7.0	14.9	0.39

When the CP content of the whole plant was considered, this study showed that the best legumes were *C. pubescens*, *A. vaginalis*, *T. uncinatum* and *M. lathyroides*. Under a grazing situation where the animal would be free to select a higher proportion of leaf in the diet, *I. hirsuta*, *M. atropurpureum* and *D. ovalifolium* could also be classed as legumes of good quality.

Macroptilium spp. and *C. ensiformis* lost a high proportion of leaf material during the drying process. The best legumes for hay making would be those that retain their leaf. These would be *D. ovalifolium*, *C. pubescens*, *A. vaginalis* and *M. atropurpureum*. *T. uncinatum* and *mucunoides* have thin, twining stems and acceptable leaf retention during hay making. They could be better for this purpose than legumes with thicker woody stems such as *I. hirsuta* and *A. vaginalis*. Although both the proportion of leaf in the cut material and the leaf retention during the drying process are high in *D. ovalifolium*, the dry stems are very brittle and this could lead to unacceptable losses during baling of the dry material.

This study showed that *M. lathyroides*, *S. hamata* and *C. ensiformis* are poor species from which to make hay. The thick stems of *M. lathyroides* dry out slowly, even though they are hollow, and leaf losses are high during the extended drying period. A conditioner may accelerate the drying of the stems and such a machine should be evaluated with this species. Both the proportion of leaf and the CP content are low in *S. hamata* and reports in the literature (Chacon and Betancourt 1986; Villaquiran and Lascano 1986) suggest that other species of *Stylosanthes* have the same problem. *C. ensiformis* has a thick, woody stem. Poor leaf retention during the drying process creates a serious limitation to the use of this species for the production of hay of good quality.

Preliminary results show that the annual species *M. lathyroides*, *I. hirsuta*, *A. vaginalis* and *C. mucunoides* will recover after the first cut to produce one, or even two regrowths before the end of the growing season. In the present study, the first cut of the four species yielded 2.1, 2.4, 4.2 and 2.9 t/ha of dry matter respectively. In general, yields of from 0.5 to 1.0 t/ha were obtained from each regrowth provided that the first cut was taken at the pre-bloom stage and that adequate moisture and nutrients were available.

The present work has demonstrated that legume hay of high quality can be made under tropical conditions. This can be used to complement grass pastures or to provide the protein component of a balanced ration. In the latter case, the amount of fibre in the legume would have to be considered during the formulation of the ration. Fibre content varies between wide limits. Leaf material of *A. vaginalis* contained 27 percent fibre, *M. lathyroides* had intermediate levels (17 percent) while *I. hirsuta*, at 10 percent, can be considered as being low in fibre. This feature could influence the choice of legume sown for a particular purpose. Other factors that need to be taken into account in the use of legumes could include the presence of antimetabolites and the amino acid profile of the selected species. These could be of importance when the legume is to constitute a high proportion of the total ration.

References

Belcazar, J. and Schultze-Kraft, R. (1986) *Centrosema brasilianum* (L) Benth. Descripcion de la especie y evaluacion agronomica de siete ecotipos, *Pasturas tropicales*, 8 (3) 14-19

Chacon, E. and Betancourt, R. (1986) El aporte de nutrientes por las leguminosas para la produccion animal, Alcance, Facultad de Agronomia, U.C.V. Maracay, Venezuela, 35 117-142

Da Silva, J.F.C. and Da Silva, D.S. (1976) Nutritive value of tropical forage in Brazil, in *International Symposium on feed composition, animal nutrient requirement and computerization in diets*, Utah University, pp. 177-186

Hutton, E.M. (1974) Tropical pastures in beef production, *Wld. Anim. Rev. (FAO)* 12 1-7

Mendez, L.E. (1977) Produccion de ganado de leche en Colombia en base a pastos y forrajes, in *Alimentacion de rumiantes con forrajes*, Millan, E., Cardozo, A. and Camacho, R. (Eds), *Memorias seminario Asociacion Colombiana de Produccion Animal*, Bogota, Colombia, pp. 153-160

Minson, D.J. and Milford, R. (1965) The relation between the crude protein content and digestible crude protein of tropical pasture plants. *J. Brit. Grassl. Soc.*, 20 117

Mowat D.N.; Fulkerson, R.S.; Tossell, W.E. and Winch, E.J.E. (1965) The *in vitro* dry matter digestibility of several species and varieties and their plant parts with advancing of maturity, 9th Int. Grassl. Cong., Sao Paulo, Brazil, p. 90

Stobbs, T.H. and Thompson, P.A.C. (1975) Milk production from tropical pastures, *Wld. Anim. Rev.* (FAO) 13 27-31

Sullivan, J.T. (1975) Chemical composition of forage with reference to the needs of the grazing animal, A review of recent research feedings, United States Department of Agriculture, U.S.A., 24 107-113

Tergas, L.E. and Lascano, C. (1986) Contribucion de las leguminosas a la productividad animal como bancos de proteinas en sabanas tropicales de America, *Alcance*, Facultad de Agronomia, U.C.V. Maracay, Venezuela, 35 143-165

Villaquiran, M. and Lascano, C. (1986) Caracterizacion nutritiva de cuatro leguminosas forrajeras tropicales, *Pasturas Tropicales*,8 (2) 2-6

Selected grasses and legumes for feeding ruminants in the tropics

B. Ahmed and E. Mohammed

CARDI, University Campus, St. Augustine, Trinidad

The importance of grasses and legumes as sources of feed for ruminants in the tropics is discussed. Grasses such as Signal grass, Coast Cross 1, Star grass, Bambatsi, Guinea grass, *Chrysopogon*, and the legumes *Desmanthus virgatus*, *Desmodium distortum*, *Macroptilium atropurpureum*, Stylosanthes hamata and *Centrosema macrocarpum* have proved promising in the Caribbean and their potential is discussed.

Keywords: Tropical forages; Grasses; Legumes

Introduction

Ruminants play an important role in supplying meat and milk in the tropics. The success of this depends largely on providing the ruminants with cheap and easily available feed. This may be achieved by utilizing locally grown forages which are high-yielding, of high quality and low in production costs.

Importance of grasses and legumes for ruminants

Among the chief factors which limit animal production are the quantity of green forage on offer and the quantity of legume available over time (Mannetje and Eberson, 1980). Hitherto, in the Caribbean, feed stuffs providing high nutrient quality were imported at high cost from outside the region. In temperate areas, there are traditional forages which provide high feeding quality. In the tropics, associations of improved grasses and legumes were little used until recent years. The quality of forage on offer was generally low and little protein was available to grazing animals, unless supplied as expensive imported concentrates.

Over the past two decades, however, there has been increasing interest in selected tropical pasture species. Reports have shown considerable weight gains per animal from different tropical grass-legume mixtures (Table 1). The newly identified tropical species, and their associations, have demonstrated that tropical pastures can yield levels of dry matter and protein normally associated with temperate pastures (Table 2). With the selected species, it is now possible to aim for levels of animal production comparable to those achieved in more temperate areas of the world.

Some selected grasses and legumes for ruminants

From experience in CARDI, some of the grasses and legumes that have been proven suitable for soils ranging from acid to alkaline and for both wet and drier parts of the Caribbean are described in Tables 3 and 4. Seed and planting material of these species are available from CARDI.

Table 1 Effect of tropical grass-legume associations on liveweight gain (LWG) of ruminants

Species	Mean LWG kg/head/day	References
Green panic	0.290	Paterson and Horrell (1981)
Green panic + Glycine	0.430	
Leucaena	0.760	
Elephant grass	0.580	Teeluck et al (1982)
Leucaena + Elephant grass	0.670	
A. guyanus	0.507	
H. altissima	0.551	Tergas et al (1982)
A. guyanus + Kudzu + Centro	0.715	
A. guyanus + Centro	0.730	

Table 2 Dry matter yield and crude protein content of selected grasses and legumes adapted to the Caribbean (Devers and Keoghan, 1978)

Species	Variety	Dry Matter yield kg/ha	Crude Protein %
L. leucocephala	Cunningham	1955	23.4
D. distortum	CIAT 335	1575	16.4
M. atropurpureum	Siratro	375	14.7
S. hamata	Local	1000	17.9
	Verano	660	20.1
B. decumbens	Basilisk	1470	5.8
C. dactylon	Coast Cross 1	1880	7.2
C. plectostachyus	Star	2770	8.8
P. coloratum	Bambatsi	3720	9.8
P. maximum	Likoni	4260	6.3

Table 3 Some selected legumes for ruminant production in the Caribbean

Legume	Description
Centrosema macrocarpum	Extremely vigorous and productive viny type with a high resistance to diseases. Adapted to acid, infertile soil, drought tolerant.
Desmanthus virgatus	Very productive and persistent shrubby type, suitable for both wet and dry areas. Adapted to soils ranging from moderately acid to alkaline.
Desmodium distortum	Adaptable to acid, infertile soils, good browse legume, drought resistant.
Macroptilium atropurpureum	Excellent viny type, high yielding, suitable for wet and dry areas, widely adapted to soils ranging from moderately acid to alkaline.
Stylosanthes hamata	Drought resistant erect, short-lived perennial which produces large quantities of seed. Well accepted by small ruminants and tolerant of heavy stocking rates. There are many different varieties. "Verano" is well adapted to acid soils, while local varieties do well on alkaline areas.
Leucaena leucocephala	High-yielding, small tree, drought resistant, growing on soils ranging from mildly acidic to highly alkaline.

References

Devers, C.L. and Keoghan, J.M. (1978) Some aspects of quality in contrasting forage legume and grass accessions growing under Antiguan conditions, *Proc. 2nd Regional Directors of Livestock Research Conference*, Barbados

Mannetje, L't. and Eberson, J.P. (1980) Relations between sward characteristics and animal production. *Trop. Grasslds.* 14 273-279

Paterson, R.T. and Horrell, C.R. (1981) Forage legumes in Santa Cruz, Bolivia, *Trop. Anim. Prod.* 6 44-53

Teeluck, J.P., Hulman, B. and Preston, T.R. (1982) Leucaena forage and Elephant grass as roughage and protein sources in a molasses/ urea based diet for fattening Zebu cattle. *Trop. Anim. Prod.* 7 241-245

Tergas, L.E., Ramirez, A., Urrea, G.A., Gusman, S. and Castilla, C. (1982) Potential animal production and management of pastures on on an ultisol soil in Colombia. *Trop. Anim. Prod.* 7 1-8

Table 4 Some selected grasses for ruminant production in the Caribbean

Grass	Description
Brachiaria decumbens	Versatile, drought resistant, high-yielding, acid-adapted, seed producing. Forms a thick sward which resists weed invasion, but is not very compatible with legumes.
Cynodon dactylon cv Coast Cross 1	High-quality, good yield, drought resistant, adapted to mildly acid to alkaline soils. Grows well with legumes. Vegetatively propagated.
Cynodon plectostachyus	High quality, drought resistant, high-yielding, excellent regrowth, adapted to mildly acid to alkaline soils. Vegetatively propagated.
Panicum coloratum cv Bambatsi	Drought resistant, high-yielding, prefers neutral soils and will tolerate heavy, cracking clays. Produces seed.
Panicum maximum	Excellent feed for dry season,there are several varieties which, between them are adapted to a range of soils from highly acid to alkaline. Produces seed.
Chrysopogon spp.	Drought resistant, high yielding, grows well on mildly acid to alkaline soils, produces seed.

Leucaena leucocephala as a feed for livestock in Barbados

R.C. Quintyne, D.O. Chase and R.C.A. Millington

Animal Nutrition Unit, Ministry of Agriculture, Food and Fisheries, Barbados

Leucaena is found in all parts of Barbados, where it has been traditionally harvested for feeding to all classes of livestock. Improved varieties, originally imported from Australia, have been used both in mixed pastures with productive grasses, and as protein banks for grazing or cutting at controlled times of the year. It can produce a high quality leaf meal when dried either in the sun or in a solar drier. Silage of high nutritive value can be produced either manually on a small scale or mechanically on a larger scale, but mechanization results in the harvesting of large quantities of woody material which can substantially reduce the protein content of the conserved forage. Leucaena silage is low in energy, but no toxicity symptoms have been seen in Barbados in either cattle or sheep. Used with a suitable energy source, it is capable of producing good levels of animal productivity. It is a valuable forage resource under Caribbean conditions. (Editor's summary)

Keywords: Leucaena; Leaf meal; Silage; Toxicity

Introduction

Leucaena leucocephala grows profusely in Barbados. Whether it is a native to the island or was introduced is not known. It is widely distributed, growing on all soil types and in all rainfall zones (630 to 2,000 mm annual precipitation).

Leucaena has been traditionally harvested by farmers and fed to all classes of livestock, both ruminant and non-ruminant. It is said by peasant farmers "to stop the pigs from getting fat." It is also readily eaten by rabbits and chickens. There are reports of Leucaena being fed to horses being prepared for shows. The initial loss of hair resulting from feeding the horse is followed by the regrowth of a beautiful coat.

Although Leucaena has been used for many years as a feed for livestock, it was only in 1976 (Quintyne, 1976) that any serious effort was made to begin studies with a view to using it in feeding systems or as a high protein feed ingredient. The aim of this paper is to review work done on and progress made in the development of Leucaena as a source of livestock feed in Barbados. This work has however been limited, being largely observation studies carried out at the Animal Nutrition Unit.

Forage production and utilization

In Barbados, Leucaena is usually harvested by hand, twigs and shoots being broken off and offered to animals. In Barbados, Leucaena is not eaten by humans as in some other countries.

In 1976 some seed of cv. Peru was received from Australia, while seed of cv. Cunningham followed in 1979, from the same source. The first attempts at cultivation were carried out in 1980 when Leucaena was sown into a newly planted field of elephant grass (*Pennisetum purpureum*). This field was grazed by a herd of dairy cows on a 6 - 8 week cycle. Later, pure stands of Leucaena were established, both at the research station and on farms.

The methods used in establishing pure stands were direct seeding, both by hand, by dibbling the seed in, and by a Stanhay seed planter, and by transplanting seedlings germinated in plastic pots. In the case of direct seeding, seeds were sown continuously in rows 1 m apart. Where seed had been germinated in pots, seedlings were planted on a 1 m grid.

On farms, pure stands of Leucaena are used as protein banks. Animals, whether they are cattle or sheep, are allowed access to the Leucaena for limited periods while grazing. In this way they are able to increase their protein intake. Leucaena is very acceptable to the grazing animal. Because of this, care has to be taken in managing the protein bank to ensure that animals are not allowed into the area before the plants have fully recovered. Although it is a very hardy plant, Leucaena can be killed by over grazing.

Leucaena may also be used in cut-and-carry systems. Stems are cut back and these, along with grass and other materials, are fed to animals. In this way, Leucaena may be included in the diet of other classes of livestock.

Leucaena leaf has also been dried and used as a leaf meal or has been chopped, mixed with molasses and ensiled.

Leaf Meal

Tremendous interest has been generated internationally in Leucaena leaf meal as a substitute for alfalfa meal (Brewbaker and Hutton, 1979). Leucaena leaf meal has been incorporated into rations for poultry as a source of protein and carotene and has been shown to be of value as a source of vitamin K (Brewbaker, 1976). Leaf meal has also been used as a protein source in fish rations (Ghatmekar et al 1982).

In Barbados, Leucaena stems have been cut and placed in the sun to dry. This process may take up to two days, depending on the volume of material. The leaves are then shaken or stripped off the stems, collected and stored in bags. An improvement on this method involved the use of a simple solar drier. This is a shed with a concrete floor 7 m x 3 m and covered with a clear rigid plastic material that allows the sun's rays to enter, and enclosed on the north and east to prevent rain from being blown in. There is, however, provision made on these two sides to allow wind circulation. Leucaena stems are cut and placed in this drying shed for 2 - 3 days, when the dried leaf is collected and stored in bags.

The dried leaf material collected is made up of leaflets and petioles. The material quite frequently also contains young pods and seeds. The chemical composition of the Leucaena leaf is shown in Table 1. As would be expected, the Crude Protein (CP) content and NVI of the leaflets were higher than that of either the leaf or the petiole. The CP of the petiole was remarkably high, while the NVI compared favorably with that of a grass, such as pangola, (*Digitaria decumbens*) of fair quality. The CP content of leaf meal obtained was similar to that reported elsewhere (e.g. Brewbaker, 1976).

Table 1 Chemical composition of Leucaena leaf

Source		Crude Protein	ADF	NDF	Ash	NVI[1)]
Leaflet	Barbados	33.4	19.0	32.0	12.4	89.3
Petiole	Barbados	20.8	44.1	62.7	10.3	46.8
Leaf	Barbados	31.8	21.6	36.8	10.9	80.7
Leaf	Antigua	26.2	21.1	33.4	13.0	75.9
Leaf	Antigua	27.4	18.5	31.0	13.6	84.3

1) NVI (Nutritive Value Index) = Digestible Energy Intake potential.

Silage

During the wet season, Leucaena grows profusely. During the dry season however, although there is continued growth, it is greatly reduced. In an effort to maximise the use of the wet season production, attempts were made to ensile Leucaena.

In preliminary studies, Leucaena stems were harvested, leaves and and soft stems were passed through a forage chopper for removal of the woody fraction. This chopped material was ensiled, with or without molasses in small plastic containers of about 30 kg capacity. The chopped leaf was compacted to remove as much air as possible. Before putting the covers on, a sheet of plastic was spread over the top in an attempt to produce an air-tight seal. The containers were opened six weeks later. The Leucaena leaf, both with and without molasses, ensiled very well. The resulting silage had good appearance and smell. There was no indication of putrefaction, nor any odour of ammonia, even where there was no added molasses. When offered to Blackbelly Sheep, both types of silage were readily consumed.

Small scale silage in drums: In a system that can be used by small farmers, silage was made in 208 litre steel drums. Leucaena stems were harvested by hand, the leaves and soft stems collected and chopped using a forage chopper. Before filling drums, the chopped material was mixed with molasses. As the drums were filled, the material was compacted by someone "running on the spot" in the drum. After the cover was placed on the drums a weight, either a sand bag or a large stone, was placed on it. The silage produced was of a high quality, with little sign of spoilage.

Silage Production in a trench silo: A trench was dug by means of a back-hoe and the removed soil was piled around it to give a trench approximately 8m x 4m x 1.5m. A field of cv. Cunningham was harvested using a New Holland Forage Harvester. The crop was approximately 1m tall. This was cut back almost to ground level and the chopped material blown into a forage wagon. The chopped material was placed in the trench silo, and molasses, at the approximate rate of 10 percent by weight was applied to the surface as each layer of chopped forage was spread. The whole mass was rolled by a tractor to ensure adequate compaction. When filling of the trench was completed, the silo was covered with a polythene sheet upon which soil was piled.

The use of the forage harvester proved to be quite effective, but the harvested material contained up to 41.6 percent wood (dry matter basis). This had an adverse effect on the feeding value of the silage.

This method of harvesting also had an adverse effect on the vigour of the Leucaena plants. After two cuts at eight week intervals, it was found that recovery was slow, resulting in a massive invasion of weeds in the harvested area. It was not possible to harvest again for 14 - 16 weeks, at which time the plants had grown to a height of approximately 1m.

Nutritive evaluations

Many studies have been reported which confirmed the high feeding value of leucaena (Oakes 1986). In an effort to better characterise Leucaena grown under Barbados conditions, a series of feeding studies was carried out at the Animal Nutrition Unit. These are described below.

Mimosine Toxicity

In spite of reports of animals fed high levels of Leucaena, suffering mimosine toxicity, no such condition has ever been seen in Barbados. A study was therefore designed to determine any possible toxic effect on Blackbelly lambs of feeding cv. Cunningham for an extended period.

Three groups of four weanling rams were offered one of three rations based on Leucaena. The rations were fresh (frozen) Leucaena, dried Leucaena and a complete feed containing a high level of Leucaena. Each group had free access to a mineral mix.

The composition of the complete feed and of the mineral mix is shown in Table 2 and growth performance data are shown in Table 3. .

Table 2 Composition of complete feed and mineral mix (percent dry matter basis)

	Feed	Mineral Mix
Leucaena	42.49	8.5
Molasses	20.00	
Maize	8.00	
Wheat Mill run Feed	25.00	
Soya Bean Meal	3.00	
Mineral Mix	1.00	88.0
Zinc Sulphate	0.05	3.0

The results indicate that Barbados Blackbelly Sheep full fed Leucaena not only survive, but they also put on weight, even though the weight gain is low. A ration of Leucaena alone is obviously deficient in energy and this deficiency had an adverse effect on growth.

Table 3 Growth characteristics of young Blackbelly rams on Leucaena rations

	Complete Feed	Fresh Leucaena	Dried Leucaena
No. of Days	112	112	112
Av. Daily Gain (g)	113.5	22.7	68.1
Av. Daily DM Intake (g)	953.4	499.9	726.4
Feed / Gain	8.3	22.1	10.2

There was no indication that Leucaena had any visible toxic effect on the animals. A study of internal organs after animals were slaughtered showed no lesions. An examination of thyroid glands revealed that only in one animal was there any enlargement of the thyroid, and in that case one gland was slightly larger than the other. It could therefore be concluded that prolonged feeding of high levels of Leuçaena has no toxic effect on Blackbelly Sheep in Barbados.

Intake and digestibility of Leucaena silage

Leucaena harvested by means of a forage harvester and ensiled in a trench silo was fed to six mature Black-belly rams in metabolic cages. A preliminary period of fourteen days was followed by a seven day collection period during which there was total daily collection of faeces. Samples of feed offered and rejected were taken every day. Voluntary intake was 68.8 g of DM per kg of metabolic weight. At a dry matter digestibility of 64.4 percent, the intake of digestible DM on a metabolic weight basis was 44.4 g/kg.

There are few reports on the digestibility of Leucaena. The value noted above compares with published values of 50 - 71 percent for fresh Leucaena (Singh and Mudgal, 1976; Joshi and Upadhyay 1976). Similarly, voluntary intake compares with values of 58 to 85g reported elsewhere (Jones et al 1978).

Leucaena silage in steer fattening

Six weanling Holstein steers were introduced to a ration based on Leucaena silage and cassava silage. The Leucaena was included in the ration at a high level to permit an assessment of its contribution to energy, as well as its ability to supply a major part of the protein requirement. Ration 1 was fed to animals between 75 and 205 kg, Ration 2 between 205 and 260 kg and Ration 3 above this weight. The composition of the rations is shown in Table 4, while animal performance is shown in Table 5.

The average daily gain obtained was less than expected. This was partly attributed to the high percentage of indigestible woody material in the Leucaena silage, which had the effect of diluting the nutrients, resulting in a crude protein content of only 12.5% (Chase and Millington, 1986).

Table 4 Composition of Leucaena/Cassava silage rations (kg/animal/day)

	Ration		
Ingredient	1	2	3
Leucaena Silage	5.89	7.30	7.66
Cassava Silage	1.95	2.60	4.29
Molasses	1.13	1.41	1.65
Beef Concentrate 36%	0.38	0.43	0.47
Total kg	9.35	11.74	14.07

Table 5 Performance of 6 Holstein steers fed Leucaena silage for 196 days

Parameter	Performance Data
Mean initial wt. (kg)	111.2
Mean final wt. (kg)	223.0
Mean total gain (kg)	111.8
Mean daily gain (kg/day)	0.571
Mean daily intake (kg/day)	8.149

Leucaena silage in lamb growth

Leucaena cassava silage rations were compared with pangola hay lamb feed on weanling Blackbelly ram and ewe lambs. The experiment was replicated four times so that four pens of six rams each and four pens of six ewes each were allocated to each ration. The composition of the rations used is shown in Table 6, while animal performance is shown in Table 7.

Rations 1 and 2 were fed to the end of period 2 when they were replaced by Rations 3 and 4. The broiler starter in Ration 3 was included to compensate for the coccidiostat contained in the 18% lamb feed in rations 2 and 4.

As was expected, the ADG of the rams was higher than that of ewes and the performance of the animals on the hay and concentrate was better than that of the leucaena/cassava ration. The leucaena/cassava ration was designed to provide the major portion of protein requirement from the Leucaena. The protein content of the silage was only 12.5 percent, considerably lower than the figure used in formulation of the ration, due to a high proportion of wood in the offered feed.

Table 6 Composition of rations on dry matter basis (%)

Ingredient	Ration 1	2	3	4
Leucaena	48.55	-	21.72	-
Cassava	15.19	-	23.91	-
Molasses	22.42	9.28	20.90	8.12
Dairy Mineral Mix	13.84	-	12.04	-
Hay	-	21.91	-	20.46
18% Lamb Feed	-	68.81	-	71.42
Beef Concentrate - 36%	-	-	16.91	-
Broiler Starter + 100g Colban	-	-	4.52	-

Table 7 Growth of Blackbelly lambs on Leucaena silage

	Ration: Leucaena/Cassava		Hay/Concentrate	
	Ram	Ewe	Ram	Ewe
Mean Daily Gain (g)	127.1	104.4	236.1	186.1
Mean D.M. Intake (g)	1225.8	1044.2	1044.2	1089.5
Mean Feed/Gain	9.62	10.10	4.46	5.92

Conclusions

The potential for making silage out of surplus wet season Leucaena is very great, but methods of harvesting require more attention. Harvesting at an earlier stage and cutting at a higher level above ground should reduce the amount of wood collected by the forage harvester. The development of a new machine, or the modification of an existing one is a challenge that is not beyond the agricultural engineers. The dietary problem of low protein content in silage because of a high proportion of wood could be overcome by including Leucaena at higher levels or by supplementing with a non-protein nitrogen source. This requires further study.

Leucaena has considerable potential as a source of high protein leaf meal. This characteristic can be exploited more fully. Economical systems for harvesting and drying to produce a good quality, high protein feed ingredient will, however, have to be developed.

Because of the value of the crop in pasture systems, every effort should be made to encourage farmers to include direct grazed Leucaena in their forage production plans. Leucaena grows profusely in Barbados, and is readily eaten by animals. Results from research indicate that most livestock in Barbados suffer no adverse effect from consuming high levels of Leucaena. The high protein and mineral content of the leaves of the plant make it a valuable feed. Based on all of the information generated from research being done in Barbados and in other sister territories, it may be concluded that this crop has great future in livestock production in the whole of the Caribbean region.

Acknowledgments

The authors are grateful for financial support from the Organization of American States through the Regional Leucaena Project.

References

Brewbaker, J.L. (1976) Establishment and management of Leucaena for livestock production. *Produccion de Forrajes, Mem de Seminario Internacional de Ganderia Tropical, Banco de Mexico* Acapulco, Mexico

Brewbaker, J.L. and Hutton, E.M. (1979) Leucaena, versatile tropical tree legume, in *New Agricultural Crops* Ritchie, G.A. (Ed.) Western Press, Boulder, USA

Chase, D.O. and Millington, R.C.A. (1986) Annual Report *Animal Nutrition Unit, Ministry of Agriculture Food and Fisheries,* Barbados

Ghatmekar, S.D, Auti, D.G. and Kamat, V.S. (1982) Feeding Leucaena to Mozambique Tilapia, in *Leucaena Research in the Asian-Pacific Region.* Proc. Workshop held in Singapore

Jones, R.T, Blant, C.G, and Nurnberg B.I. (1978) Toxicity of *Leucaena leucocephala*: the effect of iodine and mineral supplement on penned steers fed a sole diet of Leucaena, *Aust. Vet. J.*, **54** 387-392

Joshi, D.C. and Upadhyay (1976) An evergreen protein-rich tree fodder and the possibility of using it in the diet of animals, I Sheep, *Indian Vet. J.* **53** 606-608

Oakes, A.J. (1986) Leucaena leucocephala - description, culture and utilization, *Advancing Frontiers of Plant Sci.* (India) **20** 1-114

Quintyne R.C. (1976) Annual Report, Animal Nutrition Unit. Ministry of Agriculture, Food and Fisheries, Barbados

Singh H.K. and Mudgal, V.D. (1976) Chemical composition and nutritive value of *Leucaena glauca* (White popimac), *Indian J. Diary Sci*, 20 191-195

Establishment of forage banks in Nevis

O. Williams

CARDI, P.O.Box 442, Charlestown, Nevis

(Poster Presentation Summary)

Livestock form an important part of the farming system in Nevis. Small farmers own up to 8 or 10 cattle, or up to 100 sheep and goats which are left to roam in scrub or rough pasture. The main livestock rearing areas tend to be in the drier south and east coastal zones where severe droughts of 3 to 4 months duration occur almost every year. Overgrazing by small stock has contributed to severe soil erosion in these areas.

CARDI in Nevis is working with farmers to encourage them to plant forage banks as a reserve for the dry season, and to conserve forage as silage. Leucaena and Guinea grass are used in the drier areas (about 1000 mm rainfall), while Elephant grass of both tall and dwarf types is being assessed along with Guinea grass in the areas with more rainfall (about 1250 mm). Siratro is seeded into both mixtures.

Establishment has been most successful using vegetative material of the grasses and direct seeding of soaked Leucaena seed. Siratro seed is broadcast by hand. Leucaena is grown in rows at 1m x 2m spacing, the grasses are planted in the space between the rows. Planting Guinea grass is the most labour intensive operation.

The impact of the forage bank on the livestock production system is being assessed by regular monitoring. Data is collected on labour input and costs of establishment, forage production from both grasses and legumes, the cutting interval for both species, and also growth rates of selected animals within the system. These are compared with growth rates of animals in the unimproved situation.

The results so far are encouraging. The mean cutting interval for Guinea grass has been 61 days, while for Leucaena, the first cut was at 7.5 months. The dry weight yield for Guinea grass has increased from 6380 kg per ha in January, to 9177 kg per ha in May. The first cut of Leucaena, which was mainly for pruning, produced 1579 kg per ha. Farmer acceptance has been high, and neighbouring farmers are now expressing interest in establishing their own forage banks.

(back cover)

ACKNOWLEDGEMENTS

The Organising Committee would like to acknowledge the help of the many individuals and organizations who contributed to the hosting of these joint meetings. Among those assisting were:

The Government of Antigua and Barbuda
Antigua Commercial Bank
Barclays Bank PLC
B.W.I.A. International
Hadeed Motors
Kenneth A. Gomez and Sons Ltd.
LIAT
Mill Reef Fund
Royal Bank of Canada
British American Insurance Co. Ltd.
Antigua Printing & Publishing Ltd.
Cable and Wireless (West Indies) Ltd.
Caribbean Forwarders Co. Ltd.
Courts (Antigua & Barbuda) Ltd.
L.I.C.S. Limited
Masses House
The Bank of Nova Scotia
West Indies Oil Co. Ltd.
Brysons
Antigua & Barbuda Development Bank
GETCO
Antigua Distillery Ltd
American Airlines
Pam's Limited
Francis Nunes Construction Co. Ltd.
Antigua Masonry Products Ltd.
Original Printery
Island Provisions Ltd.
Francis Trading Agencies
Benjies
Books and Bouquets
Lee Wind Paints (1980) Ltd.
Antigua Farm and Garden Supply
Stony Hill Nusery
Buccaneer Cove
Emily's Cafe - Flora)
Morning Star Nursery
Barrymore Hotel
IICA
CARDI
EDF
OICD