CTA - Seminar Proceedings

Integrated Pest Management
New Strategies for the Caribbean Farmer

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Centre Technique de Coopération Agricole et Rurale ACP-UE
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CTA

Integrated Pest Management – New Strategies for the Caribbean Farmer

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Editor: Don Walmsley

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CONTENTS

OPENING SESSION

Chairman: Horacio Stagno, *IICA, Dominican Republic*

MESSAGE FROM CARDI

Dr Samsundar Parasram
Director, Research and Programmes

Mr Chairman; Señor Victor Hugo Hernández, Secretary of State, Ministry of Agriculture of the Dominican Republic; Mr Alan Jackson, Technical Advisor of the Technical Centre for Agricultural and Rural Cooperation (CTA); Señora Altagracia de Castillo, Executive Director of the Fundación de Desarrollo Agropecuario, Inc. (FDA); Mr Osmar Benitez of the Junta Agroempresarial Dominicana, (JAD); Dr Gilberto Páez, Head of the Instituto Interamericano de Cooperación para la Agricultura (IICA) in the Dominican Republic; Distinguished Representatives of Diplomatic Missions and International Funding Agencies; Officials and Technical Specialists; Farmers; Members of the Press; Ladies and Gentlemen:

On behalf of the Executive Director of CARDI, Dr St Clair Forde, and on my own behalf, it gives me great pleasure to welcome you to this seminar. The Executive Director of CARDI also has asked me to extend to you sincerest wishes for a successful seminar.

CARDI is an acronym for the Caribbean Agricultural Research and Development Institute with its headquarters on the University Campus, St Augustine in Trinidad. CARDI was founded in 1975 and succeeded the Regional Research Centre (RRC), itself founded in 1955.

CARDI is set up as an autonomous institute to assist its member governments in their agricultural research and development needs as identified in national plans and policies. The motto of the Institute is *'Excellence is self-sustaining'* and its mission is *'to contribute to agricultural development through the generation and dissemination of appropriate technology that benefits the Caribbean people'*.

The objectives of the Institute as provided in the Agreement Establishing CARDI are:

- to provide for the research and development needs of the agriculture of the region as identified in national plans and policies

- to provide an appropriate research and development service to the agricultural sector of member states

- to provide and extend the application of new technologies in production, processing, storage and distribution of agricultural products of member states

- to pursue, for specified periods, long-term research in pertinent areas

- to provide for the coordination and integration of the research and development efforts of member states where this is possible and desirable

- to undertake teaching functions, normally at the post-graduate level, limited to the development of the relevant research by any member state

- to seek to achieve the optimum decentralization of facilities.

CARDI's Governing Body is the Standing Committee of the Ministers responsible for Agriculture in the Caribbean Community (SCMA). The Board of Directors comprises representatives from the 12 member countries, the Universities of Guyana(UG) and The West Indies (UWI), the Caribbean Food Corporation (CFC), the Caribbean Development Bank (CDB), the CARICOM Secretariat and the Inter-American Institute for Cooperation on Agriculture (IICA).

The chief executive is the Executive Director who is assisted by two deputies. At present, CARDI has units in all member countries and they are engaged in research and development activities both of regional and national significance.

This seminar is jointly organized by CARDI and CTA . CTA has provided most of the financial assistance. In addition, several organizations within the Dominican Republic have played significant roles in making this event a reality. These are all represented here today. My colleague, Mr Alan Jackson, will tell you more of CTA in his address.

It is my belief that this seminar is both timely and relevant. It is timely because we have with us some major pests and diseases which threaten the agricultural sector such as the geminivirus spread by whiteflies, the citrus tristeza virus spread by aphids, *Thrips palmi* and the citrus fiddler beetle. Traditional control measures – chemical, biological, use of tolerant varieties etc. – are not working, partly because of the lack of integrating these various measures into a holistic package .

This leads me to why this seminar is relevant. It is relevant in two main ways:

- We need to examine the various components of an IPM strategy and identify information gaps, develop strategies to fill these gaps and recommend complete IPM packages

- We must ensure that the packages are suitable to the Caribbean region and the Caribbean farmer, who must be educated in the importance of using the package and in the various technical aspects of the package.

In his keynote address later this morning, Dr John Perfect will deal in detail with the various components of the IPM strategy. Present also at this seminar are officials of the International Integrated Pest Management Working Group (IPMWG), and the Secretary will provide you with additional information during the course of the week.

In developing the agenda for this seminar, the steering committee had great difficulty in deciding what to leave out. We were forced, however, by time and funds to focus in on whiteflies, thrips and tristeza as the major thrusts.

We are fortunate in having with us prominent international, regional and national scientists, who will present papers and be part of various working groups, as well as representatives of funding agencies and research and development interests. All of these augur well for this seminar. We look forward to a fruitful and enjoyable week and we will come up, I am sure, with major recommendations and follow-up plans.

I thank you.

MESSAGE FROM CTA

Mr Alan C Jackson
Technical Adviser

Excellencies; Honourable Minister; Distinguished Guests; Ladies and Gentlemen:

It is my very pleasant privilege this morning to extend a most sincere welcome to all of you to this timely and important seminar which has been sponsored by the organization I represent, CTA. I will say a little more about CTA in a few moments. I welcome you to this meeting on my own behalf, and on behalf of Mr Assoumou Mba, CTA's Director, who regrets that other commitments have prevented him from joining us here in Santo Domingo.

The task before us this week is to assess research on modern, integrated approaches to the management of the most serious pests of the crops of the small-scale Caribbean farmer, and to consider some of the alternative strategies that farmers may be able to adopt in the future. It is a pleasure to be addressing this task in cooperation with CARDI, IICA and the national organizations here in the Dominican Republic – the Junta Agroempresarial Dominicana, the Fundación de Desarrollo Agropecuario and the Secretaría de Estado de Agricultura, and to acknowledge their willing and enthusiastic assistance in the preparation of this seminar.

The Dominican Republic is one of the newest members of the African, Caribbean and Pacific Group of States (the ACP Group) having only recently become one of the signatories to the ACP-EEC Lomé Convention. In holding this, its first meeting in the Dominican Republic, CTA is taking the opportunity to show how the country is already participating fully in its programme of activities. We hope that one of the achievements of our meeting will be to make a positive contribution to the task of developing closer working relationships between agricultural scientists from the English-speaking and the Spanish-speaking countries of the Caribbean.

Although some of you will have known CTA for almost 10 years, others of you, particularly those from the Dominican Republic, may not know us at all. Because we offer a wide range of agricultural information services, and as all of you are entitled to benefit from these services, I would like to take a couple of minutes to explain to you who we are and what it is that we do when we are not sponsoring meetings of this kind. I ask those of you who know us well to bear with me.

All CTA's activities focus on the mandate given to us by the Lomé Convention: to improve access to technical information for agricultural development in the ACP states. All our pursuits are carried out in the context of the Lomé Convention, which is a cooperation agreement between the 12 Member States of the European Economic Community, or the European Union as it became at the beginning of this month, and the 70 African, Caribbean and Pacific States (the ACP Group) who are co-signatories to the Convention. CTA is an institute of the Convention and is entirely funded by the Commission of the European Communities. The Centre's headquarters at Ede, near the Agricultural University of Wageningen in the Netherlands, were officially inaugurated in 1985. Our working languages are English and French; we also publish a little in Portuguese.

CTA provides a range of services customized to the needs of individuals and institutions in ACP countries. I will briefly explain what these are.

Firstly, we convene technical meetings, or seminars, of which this week's meeting is an example. We support the attendance of ACP nationals at other people's conferences and have commenced a small programme of

study visits. Our CTA publications and co-publications services are very substantial. Those of you who already know CTA probably know us through reading our publication *Spore*, which appears in English and French every 2 months. A Portuguese edition is published four times a year. We publish the Proceedings of our seminars and we commission and publish various studies, bibliographies and directories. Through our co-publications service we purchase books for distribution to ACP countries at preferential rates; we jointly fund the production costs, which may include paying for translations, of joint publications. We support periodicals and network newsletters, sometimes by paying subscriptions. We also pay the not-inconsiderable costs of distributing these publications to ACP countries.

One of the backbones of CTA's work has been the establishment of a Question-and-Answer Service. In addition to responding to specific technical enquiries, this service distributes CTA publications on request and delivers primary documents. We provide support services to rural broadcasters and offer our own short training courses for documentalists and those involved in scientific communication. All these services are available free-of-charge to institutions and individuals in the ACP countries.

In addition to all this we have specific projects in the fields of information and documentation. The first is a project to provide effective CD-ROM workstations, the second is a scheme to donate agricultural reference books and the third is the selective dissemination of information and the provision of requested documents to designated research institutes.

In order to provide these services CTA maintains an Administrative Division and a Technical Division, which includes a Documentation Unit. There are at present some 32 staff at CTA's headquarters in the Netherlands. Most of our work, however, is contracted out to specialized organizations. We maintain Regional Branch Offices in the Caribbean and the Pacific and are developing National Focal Points in ACP countries. We also have a small Branch Office in Brussels. A computerized mailing-list, which also serves as a database, is maintained at headquarters.

I have taken time to outline the services CTA offers because it is likely that they can be of use to all of you in your work. Throughout the week I will be available to meet anyone who needs more information.

I would like now to say a little more about CTA's technical meetings, of which this is one. These meetings are relatively small seminars which generally focus not so much on science itself but on the application of science to development issues. Each year, as a service to ACP countries, we sponsor about six meetings similar to the one we are attending this week: these meetings are attended by experts from ACP countries, the European Union and elsewhere. The Proceedings are always published and the conclusions are given wide publicity through *Spore* and other media, such as the press and national and international radio services.

Mr Chairman, I now propose to return to the subject of this week's meeting and to begin by explaining how we chose the topic for this seminar. Exactly 1 year ago I paid a visit to the Caribbean to begin planning this meeting. Together with Dr Parasram of CARDI, I visited the Dominican Republic. We consulted major international organizations as well as national organizations in the country. The subject chosen had to be one that was important to the host country, but it also had to be of general interest throughout the region.

The control and management of crop pests was the topic in which there was the most widespread interest: every organization we consulted had proposals in this area. CTA has, of course, been addressing issues relating to pest control since its earliest days, but a meeting in England, held in November 1991 and organized by the UK's Natural Resources Institute, represents, perhaps, the major focus of our activities in this area to date. Some of you attended that meeting.

Every CTA seminar develops a character of its own, and every participant will draw his or her own conclusions as to which were the major issues. In my personal account of the meeting in England I concluded that farmers' needs must be the focus of all efforts to protect their crops from pest damage. When policy-makers try to

identify farmers' needs they must consult the farmers themselves, so that their indigenous knowledge of how to grow crops and protect them from pests is fully taken into account. Farmers and scientists need to work together far more often, and over longer periods of time; but scientists should not expect farmers to become too closely involved with their research. In addition, much more effort is needed to ensure that all relevant scientific, social and economic disciplines are jointly utilized in the development of new crop protection techniques.

Ladies and gentlemen, we have tried to build this seminar on the foundation of our earlier work. We have noted how the daily livelihood of the Caribbean farmer is threatened by pests and the diseases they carry, and have decided to examine the problems of pest management from the farmer's perspective rather than that of the scientist. We shall review relevant research and development on whiteflies and aphids and their role as the vectors of major plant diseases. We shall also examine the damage caused by thrips and other pests. We shall then try to postulate alternative strategies which small to medium-scale Caribbean farmers may be able to adopt in the future, bearing in mind the realities of their agro-socio-economic conditions. We shall then draft recommendations to all those involved in trying to improve the present situation. I hope we will not be frightened to make innovative and unorthodox proposals but that we shall be guided by Mark Twain's observation that 'a crank is a man with a new idea – until it catches on'.

I understand that during this week we are not going to partake exclusively of what people sometimes refer to disparagingly as 'the usual diet of scientific papers'. A meeting such as this serves to bring people together: it is important that we make plenty of time to allow free discussion and interchange of ideas and information, to hear the views of people from many different countries and to strengthen the personal contacts which so often form the basis of future collaboration. I hope that you will make many new friends, that you will all enjoy your week here in Santo Domingo, and I thank you all, ladies and gentlemen, for your attention.

FORMAL OPENING

Señor Victor Hugo Hernández
Secretary of State for Agriculture, Dominican Republic

A summary of the address by the Honourable Secretary of State for Agriculture

Distinguished Representatives of the Caribbean Agricultural Research and Development Institute (CARDI) and the Technical Centre for Agricultural and Rural Cooperation (CTA); Directors of the Agricultural Development Foundation (FDA), the Dominican Agro-entrepreneurial Board (JAD) and the Inter-American Institute for Cooperation on Agriculture (IICA); Distinguished Panelists and International Delegate;, Officials and Technical Specialists; Ladies and Gentlemen:

On behalf of the Government and the President of the Dominican Republic, Dr Joaquín Balaguer, and on my own behalf, I welcome you to the Dominican Republic and to this seminar.

This seminar takes place at a very opportune time when the governments of the Caribbean region need to put in place action programmes to manage the pests which attack our crops. I hope that our meeting here will allow the exchange of experiences and information on integrated pest management (IPM) that will benefit not only the Dominican Republic, but the entire region.

The subject which occupies us and which will be debated extensively in this seminar, is a burning issue in all international fora, signifying that these problems are linked throughout the region to the history of intensive monoculture agriculture, and particularly, with the imbalance of the agro-ecosystems caused by the excessive use of agro-chemicals.

I wish also that the delegates and officials present here from the Caribbean countries will develop recommendations which will enable us to obtain some feedback on this most vital topic. We foresee health problems to be of major importance to the present tariff barriers which today contribute to the obligatory discussion of the trading blocs of countries which make up the different integrate systems of the world.

I strongly believe in man's ability to find solutions. Therefore, our confidence is great, and we entertain the hope that together we are going to make our region a better place to live, sharing the responsibility of increasing horizontal technical cooperation through the exchange of information, approaches and experiences and with the implementation of the conclusions and recommendations that may arise from this seminar.

It is important in today's world that our products be of a very high quality and standard in order to compete on the open market. To this end, they must be free of pests, diseases and pesticide residues.

The whitefly has been the cause of severe losses in several parts of the Dominican Republic, especially so in the Azua and San Juan valleys. Pests and pesticide-related problems have been the cause of an enormous decrease in crops and pose a severe threat to the agricultural sector. Today, we hope to find a solution to this problem. The Government of the Dominican Republic is very committed to IPM and has taken legal action by passing aLaw No. 493 which prohibits the growing of alternative host plants of the whitefly in the Azua Valley and San Juan in Maguana.

A great deal of work on various aspects of IPM is going on in the country and there is need for increasing the level of cooperation between the private and public sectors.

Because of the importance and the far-reaching implications of this problem, the highest authorities of the Dominican Republic, including President Joaquín Balaguer, have unanimously expressed their concern for the serious problems resulting from the abuse of pesticides in the country and, being aware of the dangers associated with this fact, have given top priority to the implementation of every measure designed to face this situation.

Bearing this in mind, we sincerely believe that the topics on the agenda of this meeting – which our country serves as host to delegates from 16 neighbouring countries – are most appropriate, important and of immense interest to all the peoples of the Caribbean region.

To date, there has not been any record in the United States or elsewhere of the eradication of the whitefly. I sincerely hope that together we can find alternative strategies to better control these pests which plague our crops. In so doing, the agricultural community would benefit from this through the dissemination of information to the region.

Once again, I welcome you and wish you every success in the task that lies ahead of you.

I now take great pleasure in declaring this meeting open.

Thank you.

IPM: A COMPREHENSIVE STRATEGY FOR THE CARIBBEAN FARMER

T J Perfect
Head, Pest Management Division
Natural Resources Institute, UK

Since the early 1960s a number of factors have combined to promote and encourage a growing interest from crop protection professionals in integrated pest management (IPM). It is important to identify what IPM is and what it is not. Therefore the early part of this paper sets out to briefly trace the development of pest control practices and shifts in thinking that have underlain the different approaches prevalent over the last 30 years. Some examples are drawn from the Caribbean region, but it is often instructive to look further afield; lessons can be learnt from experiences in other parts of the world. The paper then examines component practices that make up an IPM approach and moves on to consider their application in the Caribbean region for the benefit of farmers, particularly with regard to the pests that form the principal target of this seminar.

From pest control to pest management

Characteristics of production systems

Traditional systems of agricultural production, many of which survive in the less developed countries of Africa, Asia and South/Central America, are characterized by their emphasis on robust but low-yielding domesticated varieties of plants found in the wild. Such plants were the forerunners of today's extraordinarily productive crop cultivars, developed as a result of centuries of farmer selection followed by intensive breeding and latterly the application of sophisticated biotechnologies which are unlikely to realize their full potential until into the next century.

Increase in productivity has not been without its cost and few modern high-yielding varieties would survive and produce a respectable crop under the circumstances in which their ancestors thrived. Whenever a particular characteristic in biological systems favours survival it comes to dominate over those that do not confer such an advantage; though this is a fairly safe (indeed essential) operating principle in the field, once human criteria are applied as the selective factor other characteristics of value under circumstances different to those under which the selection took place are lost. For this reason crop plants that predominate today tend to have a very restricted genetic base; this can have important implications for pest management.

Quantitative as well as qualitative charact-eristics of production systems have also changed. Traditional systems normally contain a considerable variety of crop plants. Plants vary greatly in their ability to deal with a range of climatic and biotic constraints; farmers are risk averse and in traditional systems seek to optimize the likelihood of securing a reasonable return from their invested labour by cultivating a range of plants representing a range of different tolerances to the most likely stresses. Taking a chance on the most productive/profitable crop might sometimes be a better bet, but usually will not be unless some control can be exerted on the conditions under which it will grow. Changing agricultural practice has of course been designed with precisely this in mind. Irrigation is a classic example and has contributed more than any other single factor to the huge areas of land under, for example, rice monoculture and to the greatly increased proportion of the year for which tropical crops are cultivated. Thus, not only has variability within the individual plants been reduced but also the diversity of the cropping environment in which they are grown; both of these factors contribute to increased yield potential and reduce risk.

As the productive potential of systems increases, so too does the benefit to be derived from higher levels of inputs; the agricultural revolution of the 1960s associated with new varieties of rice, wheat and maize and improved cultural practices brought with it a massive increase in the use of fertilizers to maximize outputs. The process of agricultural intensification had been in train for many years before this time and it was well recognized that human producers had active and effective competitors for the returns from their efforts in the form of an enormous range of animal and plant pests. The synthesis and manufacture of organic pesticides in the late 1940s provided what seemed to be a powerful and effective solution to these difficulties and ushered in the era of what I shall call pest control, the approach that is dominated by the notion that a successful campaign is one that kills all the pests in a field and the hoped for outcome is eradication. By the 1960s it was already clear that this expectation could not be sustained but little practical action had been taken to seek alternatives. New active ingredients and ever higher doses continued to be effective, as indeed they still are under some circumstances.

Around this time a school of thought emerged that sought to apply ecological theory to the control of pests, applying the ideas of population dynamics and introducing the concept of management of pests at acceptable levels through optimizing the role of natural regulatory mechanisms. The basis of the approach, which became known as integrated pest control or integrated pest management (IPM) was that reliance on chemical pesticides as the sole means of containing pests did not represent a sustainable option. The phenomena of resistance and resurgence had already been identified and it was clear that an over-reliance on pesticides frequently led to changes in the crop flora and fauna that upset intrinsic regulatory mechanisms to the extent that secondary pests developed or with the reducing efficacy (or inappropriate use) of pesticides the target pest itself actually increased in abundance.

An example from Asia

Where all of the above factors combine the results can be very dramatic indeed. An example drawn from Asian rice production illustrates many of the characteristics of this phenomenon. It also provides one of the relatively few examples of successful IPM implementation on a large scale for a major food crop. In the 1960s breeders at the International Rice Research Institute (IRRI) overcame one of the main constraints to increasing rice yields in tropical Asia by crossing long-strawed high-yielding varieties with dwarf rices from Asia. The shorter, sturdier new varieties were able to physically support larger amounts of grain and responded well to more intensive management and in particular high levels of fertilizer application. Thus began the green revolution in tropical Asia with IR8, the miracle rice. Sadly the new variety, which was rapidly adopted and grown over huge areas, was susceptible to the rice brown plant hopper, previously reported only as a pest of temperate rice.

Insecticides, which are effective in temperate rice-producing countries such as Japan and Korea, did not provide an answer for both biological and economic reasons. Firstly, the brown planthopper is endemic to tropical regions and not a seasonal visitor as in the sub-tropical parts of its range. There are therefore potentially many more generations in a year and this accelerates the rate at which resistance to insecticides can be developed. Observations suggest that measurable increases can be detected in the three generations that normally occur within a single tropical rice crop. Secondly the wingless reproductive morph of the insect occurs at the base of the rice plant; the higher crop densities and changed architecture of the new rices made it difficult to spray effectively and insecticides were more likely to destroy the more active foliage-inhabiting parasites and predators. These factors contributed to a dramatic increase in brown planthopper populations with very high associated levels of crop loss – often complete destruction over large areas.

Intensive research at IRRI led to the production of resistant varieties that provided a respite. However, the inherent genetic variability of the pest coupled

with its propensity to migrate selected populations able to survive and flourish on these varieties and the result was cycles of outbreaks that have continued until the present. The problem was exacerbated by a continuing need to apply insecticides for the control of other early season pests and the resultant impact on brown planthopper natural enemies that enabled low populations to increase to epidemic proportions. Ten years of research provided a sufficient understanding of the system to confidently predict that discontinuing the use of insecticides was the single most important factor in reducing the impact of what was accepted as the single most important pest of rice. This formed the basis for a massive regional IPM programme for south-east Asia with a particular focus on raising farmer awareness of the role of natural enemies in pest regulation. The programme has been impressive in its impact and has demonstrated that rice yields can be maintained through approaches that conserve and promote natural enemy action. Discontinuing insecticide use has had major health, environmental and economic benefits. The ecology and management of brown planthopper, including practical approaches to implementation is comprehensively reviewed in a recent publication (Denno and Perfect 1993).

IPM defined

The definition of IPM is a contentious subject. The concept originated from work at the University of California (Berkeley) in which pest control was based on monitoring populations of both pest and parasite to provide the basis for decision-making (integrated pest control). It has grown in scope and taken on a number of new twists since its origin in the 1960s. It is not profitable to enter into the basis for the sometimes heated debates that have taken place in recent years and I will not compare and contrast the many definitions. Most people would agree that the essence of the approach is to use whatever technology or combination of technologies is appropriate and available with due regard for social, economic and environ-mental factors. Some view IPM as an alternative to chemical control with pesticides, but this is not a practicable position to adopt. All would agree that it seeks to minimize their use in a way that is consistent with achieving an acceptable level of control.

An important feature of IPM is that it is not seen as a prescriptive approach but as a 'basket of technologies' from which the practitioner is expected to select according to a judgement of what is considered appropriate for the particular problem and production context. Some reference has been made above to the component technologies. They are further characterized below.

Chemical control

I mention this first not because it is the most important of the component technologies, but because it can be the most powerful, is certainly the most controversial and is likely to suffer the most from misuse that will eventually lead to a loss of effectiveness. Already too many chemicals have been consigned to history because they have been excessively and inappropriately used with little consideration for sustaining their effectiveness; this has led to widespread insecticide resistance (Georghiou and Mellon 1983). The rate at which new insecticides are becoming available has declined dramatically, partly because of escalating development and registration costs; introductions of new insecticides have fallen from approximately 25 between 1965 and 1969 to 10 between 1980 and 1985 (Voss and Geissbuhler 1990) and the range of circumstances under which existing active ingredients can now be used is steadily decreasing as more environ-mental disbenefits are identified. Despite this, pesticide use in LDCs is expected to continue to grow. LDCs accounted for 20% of world agrochemical use in 1990 ($19,600 million) and the proportion is expected to rise to 38% by the year 2000.

The essential features of appropriate chemical control are the correct choice of active ingredient, appropriate formulation and applic-ation techniques, intervention on the basis of a knowledge of the biology of the pest and therefore the stage at which it is susceptible, quantitative data on pest incidence and the significance of particular pest populations for yield loss; and an understanding of the potential hazards of the compound to the user,

consumer and environment. This is a daunting list and it is very frequently the case that much of the necessary information is not available or is at best imperfectly known or understood.

A key doctrine of IPM has been the pursuit of the concept of economic threshold levels (ETLs) as a basis for pesticide application (Frisbie et al. 1989). The introduction of the definition by Poston et al. (1983) of action threshold level as 'the population density at which control action will result in little likelihood of the pest population exceeding the ETL' where the ETL is 'the break-even point at which the value of loss in yield quantity or quality is equal to the cost of a control method that successfully eliminates pest damage and yield loss'. Herein lies the substance of a further series of misconceptions, confusions and heated arguments. ETLs or ATLs vary so much with local conditions (biological, economic, cultural, temporal, spatial) that it is dangerous and misleading to nominate numbers. Further, they have been derided as impractical to determine and impossible to apply; this, of course, is partly a function of the level of sophistication of the production system in which they are operated. However there is no doubt that the core concept – that investment of resources, whether human or financial, must be based on a consideration of the likely impact and benefits – is robust and lies at the heart of IPM. It is the attempt to provide rigid decision criteria that is flawed and even resource-poor farmers without formal education can be expected to operate the approach on the basis of experience and local knowledge.

Such is the power of chemical pesticides that they can be effectively used, at least initially, even where much of the knowledge required to use them efficiently is unavailable. We are all familiar with overdosing, unnecessary prophyl-actic use, badly timed application and poor application practices without due regard for the safety of operator or consumer. All of these features have contributed to the current poor image of pesticides, yet they work and can be seen to work; farmers are therefore reluctant to abandon them in favour of less obviously effective approaches. A less frequently apprec-iated side-effect of the obviously effective nature of pesticide use is that less effort than might have been desirable has in the past been put into developing more economically and environmentally sound ways of using them. This is perhaps not surprising given that much of the research on pesticides has been closely associated with the commercial sector. It is certainly the case that agrochemical companies are beginning to realize that their investment is threatened by the clear disbenefits of injudicious pesticide use; this can be expected to lead to more private sector research into ways of using pesticides in ways that minimize their adverse effects and promote their sustained use and efficacy. Several companies now recognize that IPM provides an appropriate context for the use of their products (Whitaker 1993).

Chemical control is no longer restricted to the use of the traditional classes of organic pesticides and there is an increasing interest in using chemicals that have very specific physiological or behavioural effects on the target pest that minimize their impact on other organisms. This approach was first adopted for herbicides with the advent of the synthetic plant growth regulators affecting particular classes of, for example, broad-leaved weeds but not the cereal host plant. It has more recently proved very effective for insects and insect growth regulators (IGRs) that mimic hormones, particularly the moulting hormone, have now been used successfully against a wide range of insect pests. Other classes of chemicals that are increasingly recognized as having an important role to play are the naturally occurring toxins found in micro-organisms such as *Bacillus thuringiensis* and in many wild and cultivated plants, such as azadirachtin from the neem tree. In essence protective chemicals evolved by one class of plants are being deployed for the protection of another. In their parent plants they contribute to the next category of IPM technology.

Varietal resistance

Varietal resistance is the name given to the phenomenon whereby some plant genotypes are able to withstand or resist pest attack and thus sustain higher levels of yield in the absence of any direct means of pest

control. Neither the concept nor the practice are of course new but the approach has become very much more sophisticated over the last two decades. A very considerable impetus to plant breeding dedicated to the production of high-yielding varieties of tropical food crops was provided by the founding of the commodity-based institutes of the Consultative Group on International Agricultural Research (CGIAR) in the 1960s. The rice example is quoted above and a similar contribution has been made for other cereals, wheat in particular, by the International Maize and Wheat Improvement Centre (CIMMYT). The failure of the approach based on selection for yield alone has increasingly led to breeding programmes in which traits conferring resistance (or tolerance) to pest attack are selected for in addition to those that enhance yield. Pest complexes are seldom so dominated by a single species that incorporating resistance to only one organism is adequate and the trend has been to develop varieties with multiple resistance. A major problem has been that in deploying a resistant variety a constraint is being placed on the dynamic equilibrium (in time and space) between the plant and pest populations. With their shorter life-cycles and higher mobility pests are inherently better able to adjust to the changed characteristics of their host plant; the result is that 'black box' approaches to resistance have seldom been sustainable and a continuous breeding effort is required to keep ahead of the game. Research efforts are now taking more account of the ways in which varietal resistance can best be deployed in the field to minimize the rate at which resistance is lost. An important factor in the success of this approach is an improved understanding of the underlying mechanisms that confer resistance.

Varietal resistance is a very attractive approach to pest management; because it is a 'seed-borne' technology it can be adopted easily by farmers without necessarily any associated inputs and can be used, albeit less than optimally, without much modification of existing cultural practices. The difficulties lie in managing it effectively such that enhanced yields can be sustained and the underlying technology to do so is both complex and outside the direct control of the farmer.

Biological control

Biological control is widely recognized as the most desirable, and potentially the most sustainable, approach to pest management; it attempts to put in place biological regulatory mechanisms that mimic those to be found in nature but shift the balance of population equilibrium levels such that pest numbers are contained at levels that do not cause economic losses. There is generally no attempt at eradication, though this may be the outcome under some circumstances. Initial successes were associated with the control of exotic insect pests that had extended their range into new regions, often acquiring major pest status in the process. The introduction of parasites and predators from their region of origin resulted in dramatically effective control (e.g. sugar cane etc.). Such approaches are now generally referred to as 'classical' biological control and continue to provide an important means of stabilizing severe outbreaks of accidentally introduced pests. A recent example is control of the cassava mealybug (Neuenschwander and Herren 1988) and projects are under way on pine aphids and water hyacinth in Africa.

Classical biological control has considerable advantages where it can be effectively deployed because it is an external solution that is delivered to the farmer and does not rely on continuing inputs or actions for its success; however it can require much research and complex and sophisticated technology to deliver this solution. A second approach to biological control has been the continuing introduction of parasites, predators or pathogens (commonly called microbial control) to supplement or enhance the impact of endemic populations. This has been used successfully, particularly in glasshouse environments, but it requires a high degree of management and considerable infrastructure to generate and deliver a supply of biocontrol agents. It is best suited for intensively managed systems.

Increasingly biological control is being seen in a rather broader context as an approach that involves natural enemy husbandry.

Here steps are taken, usually through habitat or crop management practices, to conserve endemic populations of natural enemies and maximize their role in pest regulation. It becomes difficult to distinguish this from IPM, since this concept is at the heart of the IPM approach; it also leads us into the next category of measures that can be considered as IPM technologies.

Cultural control

This is a rather loosely defined assemblage of practices. In essence, modifications to the crop production system are used to minimize the opportunity for or impact of pest damage. Timing of planting and synchrony or asynchrony of cropping can be adjusted for this purpose. In many ways traditional practices of bush fallowing and shifting cultivation provide a classic and straightforward example. As well as the well-known effects on soil fertility and physical characteristics, the sequence of different crops followed by a period of fallowing prevents the build-up of damaging pest populations. Weeds are of particular importance and in many cases the growing difficulty of controlling weeds is the primary factor leading to the advent of fallow in these systems.

Other examples are found in the use of crop mixtures which serve to reduce populations of specialist pests compared with monocultures by providing more varied habitat structures and lower densities of the component host plants. A special example of crop mixtures is provided by the use of trap crops intended to divert pests away from the primary crop under production.

Many of these approaches are sound in principle but difficult to apply in situations where intensification of production is a key requirement in the agro-ecosystem; most lead to a lower yield in the component crops and more labour-intensive approaches to their management.

Quarantine and sanitation

Quarantine can hardly be considered an IPM technology but it is of such importance in containing and restricting pest problems, particular in island systems such as the Caribbean, that it cannot go without mention. Many spectacular examples of pest epidemics are associated with the extension of the geographic range of a pest into areas where regulatory mechanisms are lacking. There is a clear link with classical biological control; often the most appropriate and effective solution in such situations. Two of the major pest problems being discussed at this meeting, *B. tabaci* and citrus tristeza virus (CTV) are closely associated with quarantine issues. Both will be discussed in detail later in the present paper.

IPM in practice

It is clear that IPM is a very appealing prospect and there can be very few agricultural scientists who would disagree with the concept or question the rationale. Why is it not therefore being widely adopted instead of the more common unitary approaches? The answers to this question are complex and are compounded of the technical, the economic, the social, political and cultural. An international task force was established to try and identify the constraints to IPM adoption and has produced a useful and interesting synopsis of its conclusions (NRI 1991). The consultants report that underlies this synopsis also contains much valuable information and will shortly be available in published form.

A common feature of successful IPM programmes is that they have all arisen as a result of a pesticide-induced crisis. Pesticides have always provided a pest control solution preferred by the user because they can be used in a prescriptive way, the approach and underlying rationale are clear, the techniques (if not some of the individual technologies) are simple and easily understood and the results are obvious. Where the biological or environmental costs of pesticide application have begun to outweigh the benefits and alternative production systems are an option these are likely to be adopted. Where the crop is central to the local economy and alternative control techniques must be identified then IPM has begun to have an impact. Because of the association with high-input agriculture most examples are for plantation crops such

as cotton and fruit trees and management of the system has therefore rarely been in the hands of small farmers. Centralized management in a more or less well-regulated system has facilitated IPM imple-mentation.

Rice provides the first example of IPM being implemented on a large scale by small farmers. Research clearly demonstrated that the brown planthopper problem in tropical rice was a function of pesticide mismanagement. It also provided the startling insight that simply to stop pesticide application altogether would almost completely solve the problem. An imaginative programme in south-east Asia capitalized on this knowledge (the FAO IPC Inter-Country Programme for Rice) and demonstrated that it was possible to change farmer attitudes to pesticides, to teach them to recognize and husband natural enemies. The effect has been, and continues to be, dramatic with 50,000 farmers trained in the first year of the programme in Indonesia and practising IPM, pesticide use was reduced dramatically and yields sustained (Matteson et al. 1993). Secondary problems of course arise; stemborers in the case of rice. However, in the face of such obvious success with the most important pest farmers are prepared to take a more open approach to new problems – particularly when they are aware that any pesticide mismanagement is likely to lead to a recurrence of the original crisis situation.

Another important feature demonstrated by the rice example is the critical nature of the policy environment. For plantation crops the management environment is imposed by the commercial grower and to a degree this can operate independently of government agricultural policy for the public sector. It has traditionally been a feature of government attempts to boost the production of the agricultural sector to provide subsidized access to agrochemicals. For LDCs this has often been manifested in free provision of insecticides through aid programmes; not a situation conducive to controlled and judicious use. Governments have been slow to change their thinking and need hard facts to be persuaded to do so; elegant theories are not sufficient. The IPM Task Force gave rise to an international IPM Working Group which has concerned itself with attempting to change the attitudes of agricultural policy makers in LDCs through a series of regional workshops that have targeted key policy makers and agricultural scientists through an approach to the joint identification of constraints and solutions. The Proceedings of these workshops, so far held in Africa and Asia, make interesting reading.

Can IPM be as productive as intensive crop production systems with high pesticide inputs? Given the absence of secondary problems in the latter system, the answer to that question is likely to be no. However, there is abundant evidence to suggest that it does not represent a sustainable solution to pest control problems. Over time yields decline and production can in extreme cases be discontinued altogether. IPM, with a judicious mix of appropriate component technologies (including pesticide use) adjusted according to shifts in pest pressures, can provide lower but sustainable yields often with an improved return on investment and over a longer time-frame secure greater cumulative production and optimize the potential of the system. The principal difficulty is that achieving this goal demands a high level of commitment, involvement and knowledge from the user. The user must adopt the technology and make it his or her own. The challenge is to demonstrate that farmers have the necessary attributes to achieve this and to strengthen their own confidence in their ability to do so.

IPM in the Caribbean

What is the potential for IPM implementation in the Caribbean and to what extent do crop protection practices reflect an IPM approach? The Caribbean situation is strongly influenced by its complex biogeography and history; the key factors are fundamentally linked to the fact that the region consists of a mosaic of island production systems at the confluence of the north and south American continents. Geography has contributed not only to the production systems and their management, but also to the distinctly different influences of European colonial settlers from Spain, France, UK, and the Netherlands; and more recently from the FSU. The Caribbean has a distinguished history,

with sugar cane breeding begun in Barbados in 1881 and the Imperial Department of Agriculture founded on the same island in 1898. This was later to become the Imperial College of Tropical Agriculture (ICTA) and began publishing the journal *Tropical Agriculture* in 1924. In 1960 the ICTA merged with the University of the West Indies having given rise to a generation of tropical agriculturalists who staffed many of the research stations in Africa and Asia. Much of the research conducted was commodity-based and with a major emphasis on cash crop production; banana, coffee, cocoa, cotton and sugar cane were the most important.

It would be presumptuous of me to address the audience at this seminar on the characteristics of Caribbean agriculture and how they have arisen. I will restrict myself to a rather general treatment of the key features. Diversity between, and to a lesser extent within, islands is pronounced and production systems range from high-input intensively managed plantation systems to traditional low-input multiple cropping. Even in the latter tree crops as a source of cash income form an important part of most farming systems, many of which could reasonably be described as agroforestry the way the term is currently used. The emphasis has in the past been on export of cash crops, mainly sugar and fruit, to markets in Europe and North America, though maize and rice production are important in Belize and Guyana. As market circumstances have changed crop diversification programmes have been launched to target speciality products and place an increasing importance on crops such as vegetables and roots and tubers. Crop protection practices vary greatly depending on the scale of the production system and the value of the crop and range from high levels of prophylactic pesticide application to none at all.

A key pest control problem in the Caribbean and the potential role of IPM

The main aim of the present seminar is to bring into focus current thinking on one of the key pest problems currently faced by Caribbean farmers. I have selected whitefly because of its importance to small farmers and current approaches to control will be dealt with in detail in the technical session that follows. My purpose here is to provide a wider context for those presentations and suggest ways in which an IPM approach may have something to offer.

Bemisia tabaci; the world's most important insect pest?

The choice of rice brown planthopper as an example of a problem induced by changing agricultural systems was not entirely fortuitous in the context of this seminar. Many of the biological characteristics of this insect closely parallel those of the whitefly; both are phloem feeding homopterans capable of causing severe direct damage, both produce honeydew which encourages fungal growth, both transmit (mainly) virus diseases and both are windborne migrants that can rapidly give rise to very high population levels in crops they colonize. Not unexpectedly given these similarities, the parallel extends further in that pesticides are also implicated for whitefly as the key factor in promoting their rise to major pest status through the interaction of resistance and resurgence (Byrne et al. 1990). What probably tips the balance decisively in favour of whitefly as a worse pest than brown planthopper, despite the enormous importance of rice in tropical Asia, is the breadth of its host plant range and the variety of diseases it transmits. A further characteristic that has been of fundamental importance is that several of the crops infested by whitefly are commonly propagated or transported vegetatively rather than as seeds; human activity has almost certainly made a more important contribution to expanding their geographic range than windborne migration.

B. tabaci infests a wide variety of cultivated crops and their relatives in the families Cucurbitaceae, Leguminosae, Malvaceae, Con-vulvulaceae and Solanaceae. The most important of these crops are probably cotton, cassava and vegetables and the most important diseases transmitted are African cassava mosaic, bean golden mosaic and cotton leaf curl; in all some 506 plant species in 74 families have been reported as host plants (Cock

1986). The majority of the long list of diseases associated with whiteflies are caused by geminiviruses (Bock 1982) but the pathogens associated with many disorders remain to be isolated and characterized. In the Caribbean Basin geminiviruses predominate and include Abutilon mosaic, bean golden mosaic, Euphorbia mosaic, Jacquemontia mosaic, Jatropha mosaic, Macroptilium mosaic, Rhynchosia yellow mosaic, Sida mosaic, tobacco leaf curl and tomato yellow mosaic (Brown and Bird 1992). Since the 1970s whitefly and the diseases it transmits have become an increasingly common feature of fibre and vegetable crops in the Caribbean and now cause epidemics resulting in annual losses costing millions of dollars. The trend has been to a wider host range for both insect and virus and a general failure of chemical control methods. Recent reports from various countries document whitefly infestations in cassava, pumpkin, lettuce, tomato and pepper.

B. tabaci is believed to have originated in Asia and been distributed throughout Africa, Europe and the Americas by human transport of infested plant material. It has the classic characteristics of an exploitative pest with a short life-cycle (3-6 weeks) and the capacity to pass through 11–15 generations in a year. Females produce 100–300 eggs which are laid at the growing point; nymphal stages remain attached to the host plant and dispersal only occurs at the adult stage. Taxonomy is complex and the pupal case is used for morphological identification. This has hindered studies of whitefly population dynamics, in particular studies of dispersal and migration, because of uncertainties in adult identification. Molecular techniques show promise in resolving these difficulties. Mark and recapture studies have demonstrated flight to a distance of 7 km but most displacement is thought to occur locally within the crop (Cohen 1990).

Very large populations of whitefly can build up in individual plantings, resulting in direct damage that appears to derive from nutrient removal rather than phloem damage and the secondary effects of sooty mould formation on the honeydew secreted. However, even low populations can give rise to damaging virus epidemics. Geminivirus transmission is circulative and persistent once acquisition has occurred (2–3 days optimally) and the capacity to transmit virus, with decreasing efficiency, persists for 5–20 days (Duffus 1987).

The difficulties of understanding and interpreting the epidemiology of whitefly-transmitted diseases are compounded by the problems of virus identification. Ultrastructural differences are not virus-specific and whitefly-transmitted geminiviruses cannot be dist-inguished on this basis at present. Rapidly improving molecular techniques may resolve this problem and DNA-probes have been successfully used for both virus detection and virus identification (Harrison 1985). Geminiviruses have a bipartite genome, with the two DNA components housed in separate particles within the virus. The DNA-1 component appears to vary more with geographic region and the DNA-2 component can generate species specific probes. The means therefore exists to explore the relationships and possible evolution of geminiviruses. This approach has been pursued by Harrison for cassava mosaic viruses.

Although the range of host plants for *B. tabaci* is extremely wide the phenomenon of host plant adaptation has been reported for some time. Constant rearing on a particular host plant appears to lead to first preference and then dependence on a restricted range or single species of host plant, for example between *Sida*-adapted and *Jatropha*-adapted whiteflies in Puerto Rico (Bird and Marmarosch 1978). In South America populations of *B. tabaci* were unable to reproduce effectively on cassava (Costa 1978). These observations led to the introduction of a biotype concept, a further factor that confused understanding of the epidemiology of whitefly-transmitted viruses. Recent work in Uganda has strongly suggested host plant adaptation of *B. tabaci* to cassava with very little crossover between populations on adjacent host plants (Legg, unpublished), supporting observations in the rather different environment of Côte d'Ivoire (Burban et al. 1992). If confirmed this will have substantial implications for cultural approaches to disease management.

B. tabaci has been recognized as an important crop pest in Africa and Asia for many years; what has really brought it to prominence is the devastating impact of two factors; firstly, the fact that it is steadily displacing the glasshouse whitefly, *Trialeurodes vaporarium*, as a pest of protected crops and secondly through the impact of the 'B-strain' or 'silverleaf' whitefly in southern USA and Central America. The biology of *B. tabaci* causes it to generate much higher populations under glasshouse conditions than *T. vaporarium* and it is much more difficult to control. The established biocontrol methodology using *Encarsia formosa* did not transfer effectively to *B. tabaci* and complex rotations of insecticides had to be used in conjunction with stringent sanitation procedures.

What is now known as the silverleaf whitefly was first reported in 1989 as causing squash silverleaf disorder and white streaking disorder of brassicas in Arizona (Costa and Brown 1991). Similar symptoms were reported on *Cucurbita* spp. in Florida and in Puerto Rica. The studies by Costa and Brown clearly showed the presence of two biotypes in field populations in Arizona that could be distinguished on the basis of host plant preferences and vigour. The more vigorous biotype, responsible for silverleaf disorder, resembled *B. tabaci* from greenhouse poinsettia and also differed from field-collected populations on pumpkin and cotton in esterase banding pattern, characterized as 'B-type' (as in the poinsettia population); this discovery led to its description as biotype-B or the B-strain. Huge upsurges have occurred in southern USA (including California, Texas, Louisiana, Georgia and Arizona) and north-west Mexico since 1990 and losses due to whitefly were estimated at more than $500 million in 1991 alone. More recent studies have suggested that biotype-B is in fact a distinct species from biotype-A (with A-type esterase banding) because of behavioural mating barriers between the two, hence its current designation as the silverleaf whitefly.

From the above resumé it is easy to see that we are dealing with a situation that is very complex indeed. Crudely speaking, a series of human interventions designed to promote food production through agricultural intensification (including glasshouse culture) and limit losses due to whitefly in the increasingly valuable and productive crops (attractive to consumers and pests alike!) have generated a situation that is currently out of control. It would be speculative to suggest that the silverleaf whitefly 'superbug' is a direct result of this series of actions, but not ridiculous. What can IPM offer?

Chemical control has proved generally unsuccessful because of the difficulties of placing insecticides on the lower leaf surface, the waxy covering of the sessile nymphal stages, the development of resistance and the reduction of predators and parasites. Thus in Sudan the aerial application of pyrethroids against the cotton bollworm, *Helicoverpa armigera*, controlled the bollworm but also killed insect predators and parasites and left the whitefly, located on the undersurface of the leaves where the spray did not reach them, mainly unharmed. This was one of the reasons why the previously unimportant whitefly became the major pest of cotton in that country (Ahmed et al. 1987) and in fact Abdelrahman and Munir (1989) demonstrated that on unsprayed plots the whitefly could be effectively controlled by natural enemies. A second side-effect of pesticides on whitefly populations has been shown by a number of studies which have demonstrated that the application of chemicals to resistant whiteflies results in an increase in fertility that speeds up the rate of population increase (Dittrichet al. 1990). The virtual elimination of insecticide use has been effective in Asian rice against brown planthopper, given resistance to other key pests, but most economically important whitefly host crops lack this degree of genetic protection.

There is no doubt that effective pesticide management must be a target, involving minimal use, biological sound intervention points and insecticide resistance monitoring. However, in situations of high levels of whitefly infestation and the threat of virus transmission by adults, the use of a fast-acting chemical insecticide such as a pyrethroid is probably the most appropriate strategy. Two important points must be considered. First, the need for

accurate application to ensure that the insecticide reaches the target – which, as stated earlier, is normally the undersurface of the leaves. Several developments in spray technology can aid this, ranging from simple upwardly directed nozzles that can be attached to knapsack sprayers, to air-blast attachments to tractor-mounted booms which move and twist the plant and its leaves so that a high percentage of the drops impinge on the undersurface of the leaves, and electrostatic charging of the spray cloud which has the effect of making some of the drops curve round and impact on the under surface of the leaves. The actual choice of sprayer will depend on the crop. The use of systemic insecticides also helps to overcome the problem of application, although choice is limited. The use of oil-based insecticide formulations may also enhance control as the oil will aid penetration of the insecticide through the wax covering the insect and the insect cuticle. For example, Sharaf and Allawi (1981) reported significant increases in the yield of tomato when insecticides and mineral oil were combined, virus incidence being reduced.

The extremely wide host range of *B. tabaci*, coupled with the observed phenomenon of host adaptation and the tendency for most of the host plants to be grown in multiple cropping systems, suggests that the species is sufficiently genetically plastic to present great difficulties in keeping pace with the production of resistant varieties. There has been some success in this regard with cassava following the pioneering work of Bock and subsequent efforts of national breeding programmes and the International Institute of Tropical Agriculture (IITA) in Africa. The characteristics conferring resistance are, however, poorly understood and strategies for the sustainable deployment of such varieties depend on a knowledge of the mechanisms operating in different cultivars.

Given that the impact of insecticide use on natural enemies has been implicated in the generation of the problem, can an approach based on biological control provide the solution? There is evidence of high levels of parasitism in unsprayed whitefly populations but I am not aware of many situations in which it has been demonstrated that such populations can be regulated effectively by natural enemy action. Although *B. tabaci* is technically an exotic in much of its current geographic range, including the Caribbean, it seems unlikely that given its method of introduction it would not have been accompanied by its key parasitoids. New biocontrol agents may be identifiable in its area of origin, but even so, classical biocontrol approaches have been most effective where other components of the system can themselves be controlled to optimize the chance of success. In particular, no (or low) pesticide use is necessary as was the case for cassava mealybug in Africa. Enhancing indigenous natural enemy action by suspending insecticide use presents similar problems, assuming as it does that there is no requirement for their use in control of other pests.

Cultural practices that involve shifting cropping calendars, host-free periods, sanitation, effective weed management and altering crop components in badly affected systems have promise but most are likely to militate against the high level of productivity that can be achieved in the absence of whitefly. Perhaps the most important is sanitation and its legal extension as quarantine; however, in the case of whitefly on vegetable crops or cotton this is much less likely to be effective than, for example, in African cassava. All of these practices demand a much improved under-standing of whitefly dynamics and dispersal.

Perhaps the best prospect lies with the use of novel chemical control agents such as the insect growth regulators and of microbial pesticides which are now being applied to situations such as locust control where insecticides previously provided the only workable control option. Which of these are known to be effective? Firstly, there is the use of mineral or paraffinic oils, which have been shown to provide satisfactory control at low to moderate populations (Singh et al. 1979). The oils work by penetrating the wax layer of the insect (nymphs and adults) and suffocating it. There is also the use of 'safe' insecticides. These include the modern insect growth regulators (IGRs), which are relatively harmless to natural enemies. IGRs disrupt moulting of the insect, leading to death.

Some are highly toxic to the egg and nymph stages of the whitefly. As the adult does not moult these insecticides are not effective against adults. Buprofezin is an example of this class of compound; it has a relatively long persistence (up to 1 month) and a translaminar and vapour action (de Cock et al. 1990) – both of which may mitigate to some extent the effects of generally less than ideal spray placement and timing that is normally encountered in the field. Field tests in Israel against citrus and tobacco whiteflies have demonstrated its effectiveness (Ishaaya 1990; Peleg 1990) and it has also been shown to be work well against the greenhouse whitefly.

Microbial agents may provide the most satisfactory technology. Of these the fungi hold the most promise, as unlike viruses, bacteria and protozoa, they do not have to be ingested by the insect, but penetrate directly through the cuticle. Fungi, mainly of the genus *Verticillium*, have been used to control greenhouse whitefly under glass (Ravensberg et al. 1990) and at least three commercially produced formulations are available in western Europe and the USA (Lisansky 1990). The glasshouse presents a highly suitable environment for the use of these agents as humidity can be kept high – fungal growth normally requires 90% RH. The requirement for high humidities has meant field-use of fungi has not been very successful and has rarely been attempted. However, recent developments may alter this picture. First the selection of more effective strains may be possible, or the use of a totally different genus of fungi. Fungi from the genus *Aschersonia* are specific to whiteflies and were recommended for control of citrus whiteflies in Florida as long ago as 1908 (Rolfs and Fawcett 1908). Developments in formulation technology may also solve the humidity problem. The International Institute of Biological Control (IIBC) in UK have demonstrated that with oil-based formulations of fungi, infection can be achieved at a RH as low as 30% (Abrahams et al., in press). Use of fungi is particularly attractive as not only are they safe to non-target organisms (including man) but also they can be produced relatively cheaply and easily with local technology.

An IPM strategy for control might include: monitoring of populations — methods include the use of yellow sticky traps, to which whitefly are attracted (Ekbom and Rumei 1990); use of oils at low populations levels (of course an oil should be chosen that has no phytotoxic effect); at moderate population levels the use of fungi or IGRs; at high population levels the use of conventional chemical insecticides. Such a strategy is designed to enhance the effect of natural enemies. These could also be enhanced by artificial introductions. The release of natural enemies has been successfully employed in the enclosed area of glasshouses with the introduction of the parasitic wasp *Encarsia formosa* to control the greenhouse whitefly. In field crops the situation is more difficult as the pest and parasite populations are not enclosed and thus less easy to determine and maintain. Also *Encarsia* does not parasitize the tobacco whitefly so successfully, although other parasites from the genus *Eretmocerus* could be considered. Onillon (1990) lists some 12 cases of successful biocontrol with parasites of whitefly in field crops, however, none of those listed involved tobacco whitefly. At present the introduction of parasites could probably only be considered as a 'topping up' measure, although the search for more successful parasites should also be conducted.

What is certain is that a solution to the whitefly problem is pressing and it is likely that for it to be sustainable will require consideration of different mixes of the available technologies according to the particular production system and other elements of the faunal complex. Such an approach requires a commitment from the user and a supportive policy environment that encourages independent thought, analysis, decision-taking and action.

Citrus tristeza virus

The citrus tristeza virus (CTV) was introduced with its vector *Toxoptera citricidus* from South Africa into South American countries on the Atlantic coast in the early part of this century, resulting in the devastation of the citrus industry in much of Argentina, Brazil and Uruguay over the period 1930–1960. Further outbreaks occurred in the early 1980s in Venezuela resulting from introductions from Colombia and Brazil. Trees on sour orange

rootstock were susceptible to the disease and more than six million were destroyed. By the end of the decade the vector had been detected in Costa Rica and surveys have shown it to be spreading steadily northwards, reaching Nicaragua by the middle of 1993.

CTV has already been widely distributed in southern USA, Central and South America and the Caribbean through movement of budding, grafting and planting material. Sweet orange stocks are either tolerant or resistant and the disease does not cause significant losses. However, fruit on sour orange stocks is severely affected and these remain common in the Caribbean. Spread is currently low because of the low transmission efficiency of the endemic vector species and there is a preponderance of the mild strain of the virus. Recent surveys in Belize funded by the Caribbean Development Bank (CDB) have shown, for example, that 5% of trees carry mild isolates of CTV and 0.1% have severe strains (Müller, unpublished).

This situation will change dramatically if no action is taken before the inevitable arrival of *Toxoptera citricidus*. In this case, where windborne movement occurs, quarantine cannot be effective. Since transmission of the virus is non-persistent (lost within 24 h), effective quarantine action could probably have circumvented the problem. Attempts to control the aphid are also unlikely to be effective and the most practical solution lies in sanitation. This will involve identification of infected trees by immunological tests using ELISA, and their destruction before *T. citricida* alters the dynamics of the virus epidemiology, leading to a much higher incidence of severe strains and resultant losses in production. This is a situation that is difficult to contend with where small-scale production is widespread and requires an integrated approach through education and farmer support. The impact of changing markets will have similar implications, but this is the subject of other presentations at this meeting.

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TECHNICAL SESSION I

Chairmen: Samsundar Parasram, *CARDI, Trinidad & Tobago*
Porfirio Alvarez, *JAD, Dominican Republic*

Rapporteur: Don Walmsley, *CARDI, Trinidad & Tobago*

THE STATUS OF CURRENT STRATEGIES IN BARBADOS FOR CONTROL OF WHITEFLIES, *THRIPS PALMI* AND RELATED DISEASES.

J E Jones
Ministry of Agriculture, Barbados

Bemisia tabaci (Grennadius) gained pest status in Barbados in 1987, when it ravaged fields of West Indian Sea Island cotton on the south-eastern side of the island, infesting a wide range of agricultural and non-agricultural plants. *Thrips palmi* (Karny) was discovered in 1990 – although it might have been here unnoticed for some time – and has since become a major pest on a number of agricultural crops. The thrips-whitefly complex poses a very formidable challenge to the agricultural diversification of Barbados, and severely limits vegetable production.

Early investigations done by the Entomology Unit on whiteflies and *Thrips palmi* addressed the following areas:

Pest biology/ecology

- life cycle studies of *Bemisia tabaci* on tomato, sweet potato, cotton, cabbage and eggplant.
- fecundity and longevity of adults.
- vertical distribution on host plant (cotton, cabbage and eggplant).
- movement and feeding habits on leaves.
- host range (see Appendix) – agricultural and non-agricultural crops; population abundance on these crops.
- flight and resettlement patterns on selected crops.
- adult response to different colours.

Chemical control

- laboratory bioassays with selected insecticides.
- field trials with selected insecticides on affected crops.
- Field investigations with insect growth regulators.

Biocontrol

- Investigation of the natural enemy complex; three *Encarsia* species were identified; *Orius* and *Phytoseiulus* species were found associated.

Recent and ongoing work

Biocontrol of *Bemisia tabaci*.

The status of the host parasitoid interaction on selected crops and non-agricultural plants was investigated by survey. Parasitoid activity was obvious on a wide range of host plants, though at low levels. Table 1 shows the level of parasitism that occurred naturally on selected crops and weeds. No attempt was made to separate the effects of each parasitoid.

In general, the pest populations on these selected plants were quite high, and the role of weed species as reservoirs for high populations of *Bemisia* as well as parasitoids must be recognized in any control strategy.

In a greenhouse experiment, the plant species selected in Table 1 were infested with whiteflies and placed randomly in the shed. Packets of *Encarsia formosa* obtained from Buntin's Biocontrol Institute in the United Kingdom were released in the shed. Parasitism was checked after 1 week (Sample 1), and again after 2 weeks (Sample 2). Five plants per species were taken in each sample.

Table 1. Percentage parasitism of *B. tabaci* on selected crops and weeds.

Host plant	% parasitism
Agricultural plants	
Cotton	0.0–5.0
Cabbage	2.3–12.4
Cauliflower	3.5–9.0
Tomato	2.5–8.5
Eggplant	0–11.5
Non-agricultural plants	
Milkweed	4.0–21.0
Ballbush	8.0–15.0
Prickly rose	4.5–20.0
Cassia	2.0–9.3
Seed-under-leaf	8.0–17.6

The results of the interaction on each plant type are given in Table 2.

The levels of parasitism observed were substantial, albeit under high parasitoid densities, and may indicate a potential, which could be exploited in an IPM strategy. The sustainability of parasitoid action against the background of heavy usage of chemicals on most transient or short-term crops is perhaps assured by the different alternate non-crop hosts which lend some degree of permanence and serve as refuges.

Chemical control

Investigations are continuing to find efficacious insecticides and insect growth regulators for use against *B. tabaci* and *Thrips palmi*. Early investigations showed systemic insecticides such as Anthio® 33, Perfekthion® and Orthene®, the contact insecticide Padan®, and some pyrethroids were effective as long as treatments were properly applied and timely. Tables 3 and 4 show the results of recent laboratory bioassays (using standard FAO methods) on thrips and whiteflies.

Table 2. Percentage parasitism of *Bemisia tabaci* by *Encarsia formosa* on different agricultural and non-agricultural host plants in a greenhouse.

Plant	popln.	Sample 1.	Sample 2.
Agricultural plants			
Tobacco	High	33.7	45.5
Eggplant	High	38.0	41.4
Cabbage	High	30.0	51.6
Cotton	Medium	13.6	10.5
Non-agricultural plants			
Wild marijuana	Low	4.0	4.5
Milkweed	High	50.8	43.0
Ballbush	High	30.4	36.0
Prickly rose	High	60.0	57.6
Cassia	High	15.5	14.0
Seed-under-leaf	High	57.0	53.5

Insecticide efficacy was very variable. At the lower concentration, Hostathion® gave the best results. At the higher concentration, both Hostathion® and Monitor® gave the best results.

The insect growth regulators, buprofezin (Applaud®), flufenoxuron (Cascade®) and chlorfluazuron (Jupiter®) were field tested

Table 3. Effects of three insecticides on *B. tabaci* in a laboratory bioassay.

Concn. (%)	Treatment	No. of Bemisia	No. alive	No. dead	% mortality
0.5	Hostathion®	36	0	36	100
		105	0	105	100
		104	0	104	100
		166	0	166	100
	Control	135	119	16	11.8
0.5	Lorsban®	91	0	91	100
		26	0	26	100
		166	0	166	100
		33	0	33	100
	Control	60	40	20	30
0.5	Anthio® 33	25	0	25	100
		248	0	248	100
		16	1	15	93.7
		38	6	32	84.2
	Control	61	60	1	1.6

for efficacy against both whiteflies and *Thrips palmi*.

Buprofezin caused high mortality of larval stages of *B. tabaci*, and there was some indication of delayed effects on the adult fecundity. Jupiter® and to a lesser extent Cascade®, showed some activity against *Thrips palmi*, while Cascade® showed no obvious activity against *B. tabaci*.

Integrated control experiments

Two trials were conducted for preliminary comparative evaluation of several methods. These were randomized block experiments in fields of water-melon. The treatments were as follows:

- Chlorfluazuron (Jupiter®) – foliar application.
- Diazinon® granules – soil treatment.
- Blue strips (17 cm x 10 cm) coated with vaseline and pinned onto sticks.
- Mulch – sugar cane bagasse spread on the plot at about 10 cm thick.

Jupiter® proved very effective against *Thrips palmi*. The effects of Diazinon® in the soil needs further evaluation as preliminary results were not convincing. The plot treated with mulch gave encouraging results. The mean number of thrips per plant remained at about two, but the plants in this plot appeared much stronger and vigorous.

The blue strips were attractive to thrips, but could not be considered an effective treatment.

Further trials with the above treatments and slight modifications are in progress.

Mechanical control

Yellow sticky traps, supplied by Agrisense in the United Kingdom, were used in vegetable plots for evaluation as monitoring devices for *B. tabaci*

Table 4. The effects of selected insecticides on *Thrips palmi* in four laboratory studies.

Concn. (%)	Treatment	No. of thrips	No. dead	No. alive	% mortality
0.5	Anthio® 33	56	18	8	32.1
	Lorsban®	76	18	58	23.6
	Orthene®	79	27	52	34.1
	Monitor®	45	18	27	40.0
	Hostathion®	59	53	6	89.8
	Neem	89	20	69	22.4
	Control	24	5	19	21.0
0.5	Anthio® 33	170	50	20	29.4
	Lorsban®	129	36	93	27.9
	Monitor®	138	55	83	39.8
	Hostathion®	198	122	76	61.6
	Diabeta®	113	24	89	21.2
	Control	46	8	38	7.4
1.0	Anthio® 33	72	42	30	58.3
	Lorsban®	90	59	31	65.5
	Hostathion®	81	69	12	85.
	Diabeta®	89	57	32	65.0
	Control	31	18	13	59.7
1.0	Anthio® 33	267	84	183	31.4
	Lorsban®	313	104	209	33.2
	Monitor®	272	259	13	95.2
	Hostathion®	277	256	21	92.4
	Diabeta®	244	128	116	52.4
	Control	61	16	45	25.7

populations as well as determining flight and resettlement patterns within the crop. Figures 1 and 2 show the results of these investigations.

Flight distances from the point of disturbance were very short and localized within the plot. Vertical distances above the plant canopy was less than 80 cm; 83% settled between 5 and 20 cm above the canopy on traps after being disturbed from the plant.

This resettlement pattern and short flight suggest that adult *B. tabaci* can be vulnerable to a good contact insecticide or other efficacious chemical sprayed properly on the crop.

The use of yellow sticky traps as a monitoring device seemed ineffective at low populations within the plots, but as the populations increased, the correlation between the numbers caught and the population was much more positive. The very large numbers found on the sticky traps may suggest a possibility for mass trapping with strategically placed strips within the plot.

Aspects of *Bemisia* and thrips research to be pursued

- Further evaluation of promising parasitoids and predators in the laboratory and in the field

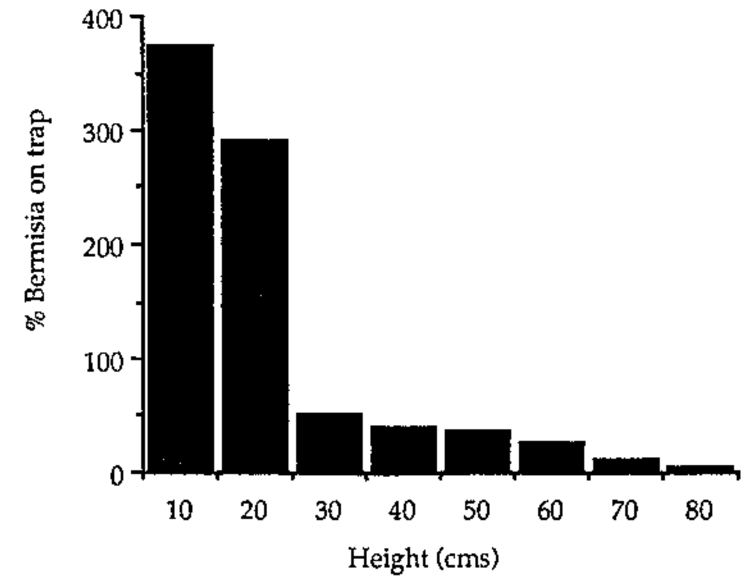

Figure 1. Flight and resettlement pattern of adults on yellow traps

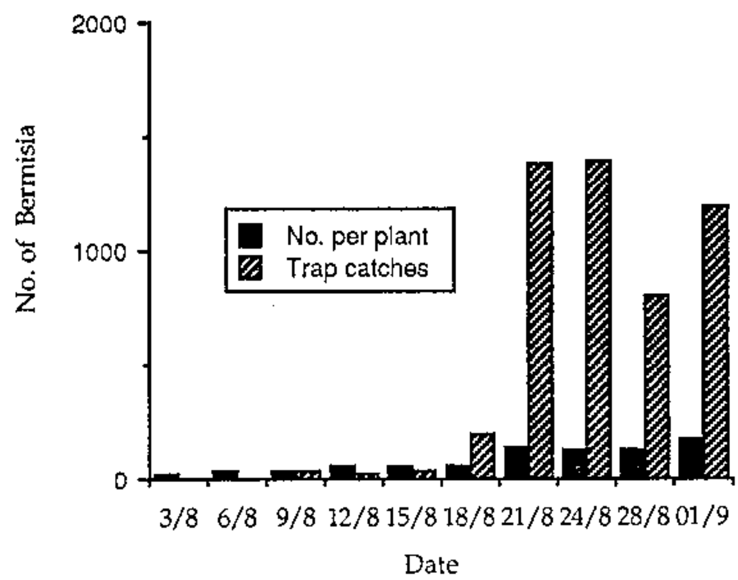

Figure 2. Trap catches of B. tabaci in an untreated cabbage plot

- investigate the role of the predatory mites (*Orius* spp.) found associated with the pest complex
    - density dependent responses and attack rate
    - aggregative mechanisms
    - effects of insect growth regulators on survival and reproduction of important natural enemies.
- Developing rearing techniques and capacity for the natural enemies with a high probability of success in an IPM approach.
- Designing mechanical equipment for effectiveness as a control measure, utilizing the behavioural aspects of the pest.
- Further investigation on the use of mulches.
- Possible introduction of exotic parasitoids /predators of promise.

Conclusions

It is clear that any successful approach to managing the pest complex and related plant diseases is to be found in the identification and careful manipulation of key mortality and distraction factors.

The dominance of conventional insecticide use by farmers is now tempered by the use of IGRs and more careful selection of chemicals. Their understanding of the pest biology and behaviour on the plant has also led to modifications of application techniques for more effective placement of chemicals.

The urgency for finding a good IPM package remains, and rigorous search for, testing, validation and transfer of appropriate strategies must be pursued.

Appendix Non-crop hosts of *B. tabaci*

Common name	Scientific name
Milkweed spurges	*Euphorbia heterophylla*
Rice grass	*Ischaemus muticum*
Morning glory	*Convolvulus arvensis*
Black Jack Spanish needle	*Bidens pilosa*
Scratchy wist, Skipping vine	?
Gallant soldier, Hairy galinsoga	*Galinsogna parviflora*
Wild cucurbit	?
Pond grass, Water grass	*Commelia elegans*
Pig weed, Calalou	*Amaranthus dubius*
White top	?
Broom weed	*Cide acuta*
Lion's ear, Governor's ball	*Leonitis nepetaefolia*
Velvet leaf	*Oxalis latifolia*
Shame bush, Sensitive plant	*Mimosa* sp.
Sow thistle, Consumption weed	*Emile sonchifolie*
Pussley	*Portulaca oleracea*
Clammy cherry, berry	?
Rabbit vine	*Teramnus labialis*
?	*Priva lappulacea*
Black sage	?
Caltrop	*Kallstroemia maxima*
?	*Ipomoea* sp.
?	*Thunbergia alata*
Milkweed	*Euphorbia hirta*

THRIPS PALMI IN THE EASTERN CARIBBEAN WITH SPECIAL REFERENCE TO TRINIDAD

M T Jones
Ministry of Agriculture and International Institute of Biological Control, Trinidad & Tobago

The Asian pest *Thrips palmi* was first recorded in the Caribbean in 1985 and infests a wide range of vegetable crops and dendrobium orchids. Its establishment on solanaceous and cucurbitaceous crops has contributed to trade reductions of over 90% in both Guadeloupe and Trinidad. In addition, local markets are dominated by smaller, deformed and scarred fruit which is unsafe for human consumption and very highly priced. Excessive use of pesticide 'cocktails' has not resulted in significant control and recommended cultural practices have not been implemented by most farmers. A range of indigenous natural enemies including predatory mites, anthocorid bugs and fungi, have been recorded and research is aimed at mass production of these for field application. It is hoped that a regional effort would be directed to those projects so that solutions may soon be available to the farming community.

Thrips palmi is now well established in the Eastern Caribbean from Puerto Rico in the north to the Guyanas in the south (Table 1). In 1985 when the pest was first recorded in the region, losses were extremely dramatic and control measures seemed totally inadequate (Franqui et al. 1991; Etienne and Van Waetermeulen 1991; Jones 1990). Now, 8 years later, there appears to be some hope for the farming community. The initial panic which resulted in excessive chemical application has given way to a more tempered approach to control as farmers experience the disadvantages associated with such action. Phytotoxic reactions, increased production costs, contaminated and rejected produce, low levels of control, pest resurgences and resistance problems have made it imperative that farmers seek alternatives to pesticide inputs. The economic situation in many Caribbean states as well as product standards now being demanded by the international markets dictate that Caribbean farmers produce in systems which are both more cost-effective and safer for human health. This is the challenge which our agriculturists must now accept if our farming systems are to sustain us.

Status and distribution

Host range

Thrips palmi infests a number of cultivated crops and weeds but losses to crops of the Solanaceae and Cucurbitaceae families and to a lesser extent, dendrobium orchids, are of greatest concern. In Trinidad the insect is now well-established on all cultivated varieties of peppers, beans, amaranthus, okra, sesame, and dendrobium orchids. Soon after introduction, wind facilitated the rapid distribution of insects. In high density areas, thrips were passively transported on to any plant within the infested area, including grasses and broad-leaved weeds, tomato and brassicas. All plant parts including harvested fruit are affected and infestation may occur at any developmental stage from seedling to post harvest.

Seasonal occurrence

Though initially considered a dry season pest, populations persist on cucurbits throughout the wet season in Trinidad. This is perhaps because the under-side of leaves is more heavily infested than the upper-side, unlike the situation in solanaceous crops. Short spells of dry weather in October 1993 resulted in heavy infestations on peppers, eggplant and water-melon.

Table 1 Distribution of *Thrips palmi* in the Eastern Caribbean.

Country	First Record	Reference
Antigua	*Cucumber at Sandersons June 1989	Jones (1990)
Barbados	Uncertain but prior to 1990	E Alleyne, pers. comm.,1990
Curacao	No information	
Dominica	Muskmelon at Grand Savanne October 1991	FAO (1991)
Grenada	Unconfirmed reports	
Guadeloupe	Eggplant, 1985	Guyout (1988)
Martinique	Eggplant and cucumber, 1985	Desnoyes et al. (1986)
Puerto Rico	Tomato at Ponce, 1987	Pantoja et al. (1988)
St Kitts	*Cucumber at CARDI	Jones (1990)
Nevis	Station, June 1989	
St Lucia	No information	
St Vincent	No information	
Suriname	Before 1990	Grauwde, pers. comm., 1990
Trinidad	Eggplant at Cunupia December 1988	Jones (1990)
US Virgin Islands	No information	

*Insects collected by C Schotman June 1989.

Economic impact

Assessment of the true impact of this pest on yield has been very difficult because: most host plants are simultaneously subjected to damage by *Bemisia*; much loss due to phytotoxicity is associated with thrip-infested crops (especially eggplant); and many farmers merely abandon infested crops. Data on losses are not available for most islands but initially Puerto Rico, Guadeloupe and Trinidad recorded losses as high as 60, 50 and 80% on eggplant (Jones 1990).

In Trinidad, trade in winter vegetables is steadily increasing in importance as a foreign exchange earner. Unfortunately field infest-ations of *T. palmi* are most severe during the period of greatest demand, i.e. January–June. In Guadeloupe, export production of eggplant declined by 90% from 1985 to 1987, and currently almost no eggplant is being cultivated (Bayart 1992). With the advent of *T. palmi* Guadeloupe has clearly lost its eggplant trade with France. In Trinidad eggplant represents less than 1% of total vegetable exports but the commodity is extremely important on the local market. Since *T. palmi* introduction, scarred and deformed fruits are being marketed at greatly increased prices (from TT$1.57/kg in 1989 to 3.92/kg in 1992). In addition there has been tremendous increase in pesticide application on this crop (Jones 1990), making it unsafe for consumption. By 1991, total export quantities of sweet and hot pepper, eggplant and water-melon had declined by over 95% from 1988 (Figure 1), *T. palmi* and *B. tabaci* being largely responsible.

In 1989 and 1990 water-melon represented roughly 20% of total fresh fruit exports from Trinidad falling to a mere 5% in 1991. Shortages on the local market are now apparent, with the crop retailing in 1992 at a 16% increase over the 1990 cost. Early records of *T. palmi* (1989 and 1990) did not reveal serious infestations in the south and east of Trinidad where most water-melon is cultivated. East coast farmers were badly affected late in the dry season of 1991 and in 1992 heavy infestations persisted through the wet season. In 1993 the deep

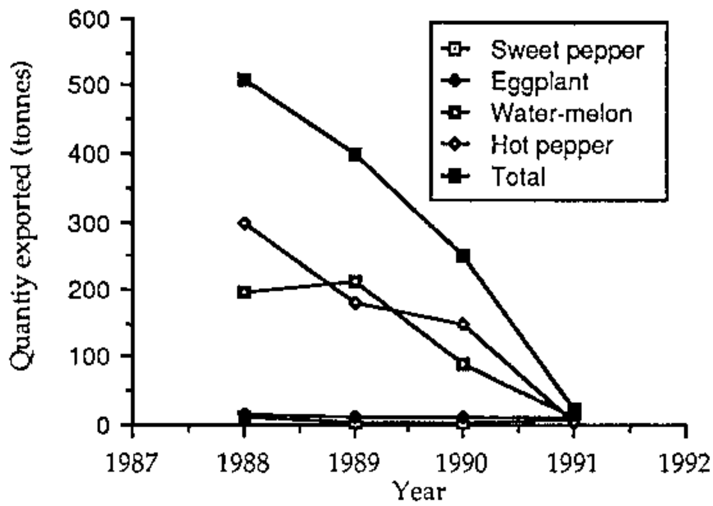

Figure 1. Export of selected vegetables from Trinidad & Tobago

south of the island experienced its first *T. palmi* infestations and farmers of Poodai lagoon suffered a yield reduction of over 70% (from 39,310 to 11,230 kg/ha). In May of 1993 densities of over 1,000 adult thrips per leaf were recorded on 5-week-old melon plants in Erin where vines had been treated twice weekly with a 'cocktail' consisting of six insecticides.

Hot pepper is a very important cash crop to Trinidad on both local and foreign markets. It accounted for 50% of total vegetable exports in 1990 and in addition there is a significant trade in pepper sauce. However, for the period 1990 to 1993, fresh pepper has been the most rejected commodity in both the United Kingdom and the United States of America. In 1990 *T. palmi* accounted for 68% of total interceptions at John F Kennedy airport, 76% of these interceptions being for hot peppers (Quarantine records, Central Experiment Station, Ministry of Agriculture, Trinidad & Tobago). Unconfirmed reports also suggest that both fresh and processed pepper have been rejected because of unacceptable pesticide residue.

Quarantine problems

In November 1991 the Pest Management Unit of Grenada refused import permits for plant material from Trinidad & Tobago due to concerns for *T. palmi* introduction. Although *T. palmi* is now present in Florida (FAO 1991) there is still a great deal of apprehension associated with produce entering Miami from Trinidad and other Caribbean countries. Ports in Europe and at the higher latitudes of North America have been more facilitating but that is likely to change since the Netherlands have reported the very high cost of irradication of *T. palmi* which became established in greenhouses there.

More recently bitter melon and dendrobium orchids have also been intercepted. Clearly the arrival of *T. palmi* to the region creates serious implications for inter and intra-regional trade. Though its significance on particular crops may vary among islands, the overall picture is one of higher production costs, lower yields, poorer quality produce for local and foreign consumers, and loss of foreign exchange.

Field and post-harvest management

Chemical control

T. palmi exhibits low cholinesterase activity (Kazano and Nishino 1986), and therefore organophosphates and carbamates are not very effective in reducing population levels. Carbaryl, the insect growth regulators(IGRs) chlorfluazuron and flufenoxuron (Nagai 1990), as well as fenthion (Nagai et al. 1988) are highly toxic to the predator *Orious*. In many cases the pest is located in protected areas under the calyces of flowers or within the fruit crevices where some insecticides may not penetrate. This further limits insecticide choice. Since cucumbers are generally harvested twice weekly there are considerations with respect to residues. On eggplant there is concern for phytotoxicity.

It has been demonstrated that insecticide application is most effective at low densities (Kawai 1987) but densities increase drastically at high temperatures reaching a maximum at 30^{o}C. Since high temperature is the norm in this region densities may reach over 1,000 insects/leaf on both melon and eggplant (Tables 2and 3), beyond the range at which chemicals may be maximally effective. Management of the pesticide component of any integrated programme for control of *T. palmi* is thus rather complex. Evidence suggests that chemical application alone is inadequate for controlling this pest. It has been recommended that chemical application be integrated with cultural control (Kawai 1990).

Cultural control

T. palmi is known to infest an extremely wide range of cultivated crops (Walker 1992) and this greatly limits using crop rotation for its control. Soil management to disrupt the life cycle by mulching with polyethylene film (Makino 1984) or rice straw (Litsinger and Ruhendi 1984), have been recommended but these are perceived as unaffordable by many farmers. Sticky traps (Kawai 1982; Nonka and Nagai 1984; Nishino and Ono 1984) have reduced thrip populations but as is the case with

Table 2. *Thrips palmi* densities on eggplant leaves in Trinidad

Date	Location	Treatment	Range of insects\leaf	Average density/leaf	Density/cm^2
31.3.93	Aranguez	unsprayed	237–1,566	917.0	7.000
2.4.93	Aranguez	'cocktail' applicn.	1–15	8.0	0.062
06.90	Aranguez	'cocktail' applicn.	0–25	23.4	0.190
02.90	Aranguez	'cocktail' applicn.	23–479	148.0	0.925
09.89	Aranguez	'cocktail' applicn.	0-6	1.3	0.002
06.89	Aranguez	'cocktail' applicn.	212–270	243.2	0.405
04.93	Macoya	unsprayed	2–26	12.0	0.970
04.93	Macoya	'cocktail' applicn.	2–45	16.0	0.153

Table 3. *Thrips palmi* densities on cucurbit leaves in Trinidad

Date	Location	Treatment	Range of insects\leaf	Average density/leaf	Density/cm^2
05.93	Erin	'cocktail' applicn.	155–1,135	700.5	8.260
02.90	Aranguez	'cocktail' applicn.	0–3	1.2	0.064
06.90	Aranguez	'cocktail' applicn.	1–81	35.4	0.45
10.89	Las Lomas	'cocktail' applicn.	0.7	1.4	0.007
02.89	Centeno	unsprayed	283–518	379.7	1.242

pesticide application, trapping is most effective at the lowest population densities. Within the Caribbean these traps may serve more as monitoring than control devices. Overhead irrigation does reduce population levels but this reduction is not significant on cucurbits where populations are greater on under-sides of leaves. Farmers therefore question the feasibility of this method of control and very few utilize it.

Post-harvest treatment

In Guadeloupe, immersion of infested fruit in water at 45 °C for 7 minutes has been recomm-ended as a post-harvest treatment (Etienne and Van Waetermenlen 1991). Farmers in Trinidad are reluctant to adopt this method of treatment. Cold storage treatment has not been considered since the insect has been observed to survive at temperatures of –3 to –7 °C in Japan (Nagai and Tsunki 1990). Clearly there are limitations to use of cultural practices and one must therefore attempt to increase the impact of biological control in management of *T. palmi*.

Biological control

Research into use of predators

A number of natural enemies of *T. palmi* have been recorded in Trinidad (Table 4). The predatory thrip *Franklinothrips vespiformis* and the anthocorids *Orius insidiosus* and *Lasiochilus pallidulus* have also been recorded in the French West Indies (Etienne et al. 1990). In Trinidad, preliminary investigations into mass-rearing systems for anthocorids, ascids and phytoseiids have focused on selection of appropriate diets. Current experiments are aimed at determining optimal requirements of temperature and humidity for predatory mites.

Under laboratory conditions, the anthocorids collected have developed on *Bemisia tabaci*, *T. palmi*, and *Tetranychus urticae*. Lepidopterous eggs are to be next evaluated. Ascids and phytoseiids have developed on *B. tabaci*, *T. palmi*, *T. urticae*, *Tetranychus tumidus*, and the astigmatids *Suidasia pontifica*, *Tyrophagus putrescentiae* and *Caloglyphus* spp. Mass production of astigmatids as the rearing medium for predatory mites has proved to be the most economical. All three Astigmatid species are easily cultured on leaf tissue, filter paper discs saturated with honey/water solution or on growing plants. In addition *T. putrescentiae* and *Cologlyphus* sp. are very prolific on a variety of powdered media including yeast, bran, cornmeal and various combinations of these with rice hull. Powdered media are more manageable than leaf and filter paper cultures and the high mite yields are encouraging but penetrability to the predatory mites has to be addressed.

T. palmi cannot be managed in isolation. On cucurbits and solanaceous crops it shares a pest complex which includes the broad mite *Polyphagotarsonemus latus*, the spider mites *T. urticae*, and *T. tumidus*, the aphids *Mysus persicae* and *Aphis gossypii*, *Spodoptera*, *Heliothis*, and *Diaphania* spp. Predators collected in this study are not specific to *T. palmi* and would develop on most species within the complex. The coccinelid *Coleomagella maculata* (Table 4) is a well-known aphid predator, while anthochorids have been known to prey on whiteflies, lepodopterans and aphids. Predators developed for control of *T. palmi* therefore have a good chance of persisting on the relevant crops once they have been introduced. In the absence of pest species, phytoseiid and ascid populations may be maintained by introduction of scavenging astigmatids which are harmless to plant tissue and easy to culture.

Use of micropesticides

In 1993, farmers in Trinidad were reporting heavy *T. palmi* infestations on both solanaceous and cucurbitaceous crops as late as November. This persistence through the generally humid period increases the extent to which fungal pathogens may be utilized in control of the pest. In addition, pathogens recorded in Trinidad (Table 4) also infect other components of the pest complex in which *T. palmi* must be managed. *Verticillium* and *Paecilomyces* attack all young stages and adults of *B. tabaci* (Peterkin 1992) and *Hirsutella* attacks both *T. urticae* and *P. latus* (Gerson, personal communication).

Table 4. Natural enemies of *Thrips palmi* recorded in Trinidad.

Natural enemy	Location	Reference
ANTHOCORIDAE		
Unidentified	Aranguez	Jones (1990)
Orius sp.	Arima, Cunupia, Pasea	Jones (1993)
Orius insidiosus	Macoya, St Augustine	Jones (1993)
Lasiochilus pallidulus	Centeno	Jones (1993)
NABIDAE		
Nabis sordidus	St.Augustine	Jones (1993)
ASCIDAE		
Proctolaelaps pygmaeus	Centeno	Jones (1993)
Asca n:sp.	Maracas	Jones (1993)
PHYTOSEIIDAE		
Clavidromus n:sp.	Mt Lambert	Jones (1993)
Amblyseius largoensis	Arima	Jones (1993)
Amblyseious n : sp.	Centeno	Jones (1993)
AEOLOTHRIPIDAE		
Franklinothrips vespiformis	Trincity	Jones (1993)
COCCINELLIDAE		
Coleomegella macculata		Cooper (1991)
FUNGI		
Hirsutella sp.	Macoya	Hall (1992)
Verticillium lecanii	St Augustine	Perterkin (1992)
Paecilomyces fumoso-roseus	St Augustine	Perterkin (1992)
Beauveria bassiana	St Augustine	Perterkin (1992)

Beauveria bassiana, Metarhizum anisopliae and *Paccilomyces* sp. have been recorded in Puerto Rico (Gonzales et al. 1992). Possibilities for use of fungal pathogens in integrated management of *T. palmi* in the region are encouraging.

Conclusions

T. palmi has within a relatively short period, attained a wide geographic and host distribution in the Caribbean. Infestations are year-round though more severe during the dry season. The pest has impacted negatively on both local and international markets and its management is exceptionally difficult. It is not well controlled by most available insecticides and recommended cultural practices are not easily implementable by Caribbean farmers.

In developing a management strategy for *T. palmi* it is necessary to:

- Increase biocontrol
- Carefully select pesticides and appropriate application technology
- Evaluate cultural methods.

Economic injury levels for specific crops and varieties must also be established before

integration into a package which is farmer-friendly. It appears that no one country has the capacity to support the volume of research which needs to be done and a regional effort must operate. This has been recognized previously at :

- The FAO workshop on Integrated Pest Management of Vegetables in the Caribbean, Grenada, 1988.
- The VIth IICA Meeting of Regional Plant Protection Directors, St Lucia, 1990.
- The CARDI Biological Control Workshop, Jamaica, 1990.
- The FAO workshop on Integrated Pest Management of Vegetable and Root Crops, Dominica, 1991.
- The VIIth IICA meeting of Directors of Plant Protection in the Caribbean, Dominica, 1992.

It is imperative that funding for work in this critical area be quickly accessed so that previous initiatives may evolve into rapid generation of data for use in an integrated package which may soon be adopted by Caribbean farmers.

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ASSESSING THE RELATIVE IMPORTANCE OF CROP PESTS AT THE NATIONAL LEVEL

M Iles and C Conroy
Natural Resources Institute, Chatham Maritime, UK

Objectives

The objectives of this paper are to examine the situation in respect of pest importance in terms of national research priorities; the case for an approach which permits the relative importance of different pests to be assessed, the options for making such an assessment and the implications for choice in the Caribbean. The application of an appropriate option is described.

Introduction

The economic importance of a pest is determined by the market value of crop loss that it causes, the costs of controlling it and the downstream effects it may have on the rest of the economy in terms of the value added that is foregone. The downstream effects are difficult to calculate and are often overlooked. Losses in production feed through into the rest of the economy – into the export and import markets, and employment in processing and marketing industries – and may affect food security at the household and national levels. Although this aspect of loss will vary by crop, determining the losses in potential value-added is very difficult and therefore costly. For this reason, most loss assessments are confined to the value of the crop affected as a proxy for total damage. Nonetheless, the losses to such crops often enters the equation when decisions are being taken on whether to control.

Direct control costs – management, labour, materials and capital costs – would normally be taken into account by the farmer or manager responsible for the crop when deciding whether or not to control the pest. Although the prime consideration will be whether or not the control costs will be exceeded by crop loss prevention, numerous other factors are also likely to be taken into account at this time. These include the indirect costs of obtaining control materials, the prospects for an adequate level of control, and whether the farmer can afford to meet the costs of control. Similarly in the case of research, what are the prospects for developing successful technologies – is this research being undertaken elsewhere?

The most important crops of the Caribbean are as follows:

Export crops
Sugar cane, banana, citrus, coffee. (Other export crops include cocoa and cotton, but these are less important for the region as a whole.)

Cereals, grain and legumes
Rice, maize

Root crops
Yam, sweet potato, cassava

Other vegetables and fruit crops
Cabbage, carrot, tomato, pineapple.

There are substantial differences between countries, and between groups of countries, in the relative importance of different crops. For example, banana has been the main agricultural export commodity for several of the Caribbean LDCs, particularly those of the Windward Islands group (i.e. Dominica, St Lucia and St Vincent and the Grenadines); but nutmeg and mace are the most important for Grenada. Sugar has been the most important agricultural commodity export for the Caribbean MDCs – Barbados, Guyana, Jamaica and Trinidad & Tobago.

In terms of pest importance in the Caribbean, insect pests dominate in the reference literature – for a recent assessment see Cruz and Segarra (1992). Although numbers are not to hand, this is thought to be influenced by the numbers of

entomologists involved in crop protection and allied activities in the region *vis-à-vis* specialists dealing with other pests. It is supported by the evidence of attendance's at workshops (the current one is a case in point) and the presentation of papers which stress insect damage. The evidence from other regions of the world where the inter-relationships between pests in cropping systems have been studied would suggest there is much more of a balance between the different pest groupings, in terms of economic importance.

Loss assessments in the region emphasize pest damage on cash crops. The pest/crop relationships most frequently quoted are citrus tristeza virus on citrus, whitefly-vectored viruses on tomato and vegetables, *Thrips palmi* on vegetables and *Plutella xylostella* on brassicas.

Pests which damage staple crops are generally under represented in research literature. These crops are of major economic importance to smallholders throughout the region. It is possible that pest damage on this group of crops is underestimated. Yams are the major staple for this group of farmers in many countries. Even overall, root staples (yam, cassava and sweet potato) rank fourth in importance after sugar, banana and citrus (Budhram and Rock 1992).

Anthracnose is the most important protection problem on yam in the Organization of Eastern Caribbean States (OECS) countries of Antigua, Grenada, St Vincent and St Lucia. In all of these islands the level of anthracnose has been increasing significantly since the late 1970s (Sweetmore 1990) and its effect is worsening (Sweetmore, personal communication). Since the late 1970s or early 1980s anthracnose has caused serious damage to the yam crop in St Kitts & Nevis, Guadeloupe and Puerto Rico (Sweetmore 1990). In Barbados yam can no longer be grown satisfactorily without fungicides (Green and Simons 1993).

Crop loss assessment methodology

The prime objective of crop loss assessment is to determine priorities for research in order to devote scarce resources to areas in which the returns or benefits are likely to be maximized. Prevailing prioritization is frequently ad hoc and is influenced by the propensities of research staff disciplines. This paper presents the case for a more rigorous interdisciplinary approach to loss assessment and for the involvement of farmers in the process to determine priorities.

Carrying out detailed crop measurement to assess losses is extremely expensive. Even so it is only likely to provide information relevant to a limited area and for the season in which it was undertaken. Alternative assessment method-ologies are therefore used to obtain proxies of probable levels of loss.

Problems in applying the methodology can arise, for a number of reasons.

- The data on the scale of crop loss are often patchy and unreliable (e.g. armyworm in Africa), and the quality of production data is sometimes low and some crops may have to be excluded from the exercise.

- Data on the production of subsistence crops may be lacking or unreliable. Further information may be needed, particularly if they make an important contribution to food security.

- There are seasonal factors which cause fluctuations to the losses inflicted by different pests.

A major problem is adequately bringing together the numerous disciplines involved in pest control technology (from entomology to weed science), together with the inability to see problems in the farmers' context (which is effectively interdisciplinary), have been the most important single factors contributing to inappropriate research. The attractiveness of the science and the rewards for producing good quality science have obscured the importance of ultimate adoption by the end-user

It is essential to compare the effects of different pests with one another, in terms of their economic importance. This confirms their relative importance and is in a sense the context in which the farmer has to

assess them.

Conventional loss studies have attempted to identify the percentage losses incurred to pest groups; weeds, diseases, insects, etc., by continent. The work of Cramer (1967) is frequently cited in this context. There have been very few studies which have attempted to make an assessment of the relative importance of the pests which are integrally involved in a system.

The most significant work on this subject was undertaken by Geddes of the Natural Resources Institute (NRI) and funded by ODA. A series of studies were carried out between 1990 and 1992 for the major regions of the world; sub-Saharan Africa, south Asia and Indonesia (as a proxy for south-east Asia). A parallel study for Latin America and the Caribbean will be completed once additional funding becomes available.

In each case, national and international scientists were asked to rank pests within the major agro-ecological zones of the region, according to their economic importance. The ranking estimates were then synthesized into ranking lists for each zone across all pests. Aggregate weighting scores were then calculated to determine the relative importance of pests within the region as a whole. Study tables were then presented back to the scientists concerned in the initial assessment, as a group, for ratification and amendment.

The studies revealed a number of interesting cases in which the resources allocated for research on a particular pest had been underestimated. The example seen for most agro-ecosystems were weeds as a group. In some cases, damage had been over-estimated. For example, groundnut rosette, which affects this crop in Africa and other regions, was researched for many years and probably out of proportion to its economic importance.

National assessments of the economic importance of different pests should be interdisciplinary and involve the researchers themselves. Otherwise, researchers may not accept the conclusions of the assessment: they may not understand how they were arrived at and question their validity; or they may resent having recommendations for re-prioritizing research imposed upon them by outsiders.

Results of crop loss assessment exercises

The main contribution that this approach makes is that it brings together scientists dealing with different loss-causing pests and requires them to assess the importance of the pest complex as a whole rather than as separate sub-groups.

The results may also correspond to researchers' previous subjective estimates of the relative importance of different crops. The exercise is nevertheless worthwhile because it provides a more thorough and systematic basis for the research programme.

Exercises of this kind may, however, sometimes throw up some unexpected results. For example, if a medium level pest affects a wide range of crops the total damage that it causes may lead to it being re-classified as a high priority pest overall. This happened, for example, with *Diabrotica balteata*, the banded cucumber beetle in the Belize study (Eden-Green et al. 1992).

On the other hand, a pest that causes severe crop loss once every few years may be perceived as a high priority problem by researchers, but may be given lower priority by an economic assessment (and by farmers).

The main emphasis of research and extension frequently reflects those areas in which researchers have disciplinary skills. Thus, if there are gaps in disciplinary expertise this can result in the importance of corresponding pests being underestimated. For example, Belize did not have staff working on post-harvest pests, and the importance of these pests had been underestimated. The economic assessment concluded that they were the eighth most important kind of pest in the country (Eden-Green et al. 1992).

It is necessary to bear in mind the comparative advantage of existing resources. Disciplinary balance is likely to

influence the importance lists, but in some cases some shift in balance may be suggested.

Farmers' rankings of pest problems

Farmers perceptions are of paramount importance since they are expected to implement the pest control technologies, and they are only likely to do so if they rank the pest concerned as a priority. Yet a literature review failed to identify any references to work in which farmers had been asked for their views on the most important pest problems facing them. Research programmes throughout the world seldom take account of farmers' views when priorities are being determined.

Farmers' rankings of pest problems could, of course, correspond to researchers' rankings, but experience from other parts of the world suggests that there are likely to be divergences. The only way to find out their rankings is to ask them. The following two examples are where farmers' rankings might be different from those of researchers:

- Seed-related pests. Smallholders often measure profitability and productivity in terms of return on their seed, which to them may be the most important input in annual crop production. Thus, direct pests on seedlings and weeds are often considered serious problems, even if impact on yields is limited.

- Weeds. The amount of research that has been done on weeds in the Caribbean has been limited. From this it follows that weed management has also been under-researched and it may be significant that none of the presentations at this workshop are concerned specifically with weeds. A list of the major weeds affecting different commodities is given in Reid and Pollard (1989).

Farmers perceptions of pest problems may be inaccurate in some respects. There are some pests, such as nematodes, which they do not see. It may be necessary, therefore, to educate them on the importance of such pests. Smallholders are also unlikely to be aware of problems in neighbouring countries which may be imminent and have implications for research priorities.

Recommendations

The primary recommendation is the development of a broad-based (involving choice between all pests) crop protection strategy. The macro- and micro-level exercises described above can provide the mechanism for effecting such a strategy. Countries wishing to make progress must ensure that they deal with pest problems in the farmer's cropping or farming system context.

A sound strategy would have three principal components:

- Identification of key pests at the national level through consultations between the various disciplines involved in research and extension.

- The process of determining priorities to include dialogue with farmers, including smallholders. The plans which evolve to provide evidence of this input.

- Research to be limited to key pests requiring farmer appropriate technologies. Full advantage to be taken of research output available from outside the country in these areas.

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INTEGRATED CONTROL OF BEMISIA – A REALISTIC APPROACH?

J C van Lenteren
Wageningen Agricultural University, The Netherlands

During the mid 1980s, the Caribbean was invaded with a new strain of the sweet potato whitefly (*Bemisia tabaci*) which is devastating key food crops. Since the invasion of this whitefly, growers are spraying 3-4 times a week and still have to destroy crops prematurely. Chemical control of whitefly is expensive and difficult because of widely developed insecticide resistance. Further, it is dangerous for humans, leads to environmental pollution and reduces biodiversity. Integrated pest management (IPM) is a durable, environmentally and economically justifiable system in which damage caused by pests, diseases and weeds is prevented through the use of natural factors which limit the population growth of these organisms, if needed supplemented with appropriate control measures. Why the development of IPM is needed, how implementation may be realized, and which barriers prevent the practical use of IPM, is discussed. An example of active farmer participation in IPM is described and the *Bemisia* problem in the Caribbean is addressed.

What is IPM?

Integrated pest management (IPM) has been defined in many ways. The Food and Agricultural Organization (FAO) of the United Nations agreed on the following description: 'a pest population management system that utilizes all suitable techniques in a compatible manner to reduce pest populations and maintains them at levels below those causing economic injury' (Smith & Reynolds 1966). The word pest includes animal pests, diseases and weeds. Quite a number of IPM researchers find this definition too meagre because it can easily be misused to defend slightly adapted conservative pest control programmes which are almost completely built on conventional chemical control. They opt for a definition which contains philosophical and ecological elements besides the more technical aspects. An example of such a definition is the one developed by P Gruys (personal communication, 1976): A durable, environmentally and economically justifiable system in which damage caused by pests, diseases and weeds is prevented through the use of natural factors which limit the population growth of these organisms, if needed supplemented with appropriate control measures.

IPM has received widespread acclaim since the 1950s as the only rational approach to providing long-term solutions to pest problems (Wearing 1988), but the rate of adoption of IPM by farmers have been slow to date. As a main bottleneck limiting progress with IPM worldwide, Wearing (1988) identified problems with the transfer of IPM technology.

IPM is not a technology of the last 50 years. A number of methods to prevent or reduce pests has been in use since the evolution of agriculture (see elements listed in Table 1). The new aspects are (i) that the IPM technology was developed in reaction to non-critical and superfluous application of chemical control, and (ii) the introduction of the concept of economic injury level. A first wave of IPM research took place between 1950 and 1970. Presently we experience a second wave of research interest, which is now supported much more widely: policy makers, extension specialists and farmers have realized after a period of euphoria that there are limits to chemical pest control and that durable and safe production of food is possible only if alternatives for pesticides become available.

Why do we need IPM?

To combat pests, diseases and weeds some 800 different chemical ingredients are used in an array of formulations. Insecticides form the most hazardous category of the pesticides because, unlike fungicides and herbicides, they are aimed at killing animal life. The majority of insecticides can be characterized as having a broad-spectrum activity, with well-known risks for producers, appliers, consumers and the environment. Several of the fungicides and herbicides have the same drawbacks. These risks are of general concern. However, the main problem for the chemical industry, at present, is the development of resistance against pesticides. The exponential increase of resistance leads to a dramatic rise in human disease problems (e.g. malaria, due to insect-vector resistance) and a decrease in the yields of crops. Furthermore, the development of new pesticides has become increasingly difficult. As many more potential chemicals need to be screened, the overall production costs are rocketing and more research is necessary before new pesticides are legislated. The rate at which insects are developing resistance to new and complex pesticides is, however, not decreasing. Chemical pest control has resulted in more than 500 insect species becoming resistant to one or more pesticides. All attempts to eradicate pest insects have failed. Harmful insects have survived all chemical tactics we have invented in order to destroy them.

The above factors, combined, will lead to ever increasing costs for chemical control. As a result, a dramatic decrease in the number of newly marketed insecticides appearing each year has already been experienced over the last two decades; 20 new active ingredients were registered yearly in the 1960s, which is in strong contrast to the less than one being registered per year at present. In relation to the problems just mentioned, it is my opinion that the role of agricultural entomologists in pest control will have to change. Since the Second World War many entomologists have been dealing merely with the technical problems of developing, testing and applying insecticides. Much of the information available on the biology of the pest organisms concerned remained unused. Development of ideas on how pests originate and how this may be prevented did not seem necessary when cheap and powerful chemical pesticides were available. Actions which are aimed at the control of individual species, will result in new problems if studies are not done within a holistic ecosystem approach. Inconspicuous, but essential changes in the functioning of ecosystems are often only perceived over many years.

Many alternative methods to chemical control are already available (Table 1), and we now see an increasing interest for these methods which is no longer restricted to scientists but also applies to policy-makers at ministries of agriculture and environment and to farmers.

What is the basis for successful implementation of IPM?

Successful IPM programmes have a number of characteristics in common, such as:

- Their use was promoted only after an IPM programme had been developed covering all aspects of pest and disease control for a crop
- An intensive support of the IPM programme by the advisory/extension service was necessary during the first years
- The total costs of crop protection in the IPM programme were not higher than in the chemical control programme
- Non-chemical control agents (like natural enemies, resistant plant material) had to be as easily available, as reliable, as constant in quality and as well guided as chemical agents.

Table 1. Methods to prevent or reduce development of pests (after van Lenteren 1991)

Prevention:
- prevent introduction of new pests (inspection and quarantine)
- start with clean seed and plant material (thermal disinfection)
- start with pest free soil (steam sterilization and solarization)
- prevent introduction from neighbouring crops

Reduction:
- apply cultural control (crop rotation)
- use plants which are (partly) resistant to pests
- apply one of the following control methods:
  - mechanical control (mechanical destruction of pest organisms)
  - physical control (heating)
  - control with attractants, repellents and antifeedants
  - control with pheromones
  - control with hormones
  - genetic control
  - biological control (natural enemies and antagonists)
  - (selective) chemical control

Control based on sampling and spray thresholds: **guided or supervised control**

Control based on the integration of methods which cause the least disruption of ecosystems: **integrated control**

IPM has not been put into practice to any great extent until recently, with the exception of IPM in rice and cotton, fruit orchards and protected crops. Some of the techniques developed for IPM such as development of damage thresholds, pest monitoring techniques (e.g. with pheromones), selective pesticides etc., however, have been incorporated into present day pest control programmes (the so-called 'supervised' or 'guided' control programmes which are based on the principle that spraying is only done when pest organisms are present and if it results in economic savings) and have resulted in a more rational use of pesticides.

How has implementation been realized?

It is rather easy to develop a set of guidelines for implementation of IPM behind a desk. Each practical situation dictates, however, a number of special aspects for consideration. Even in a small country like the Netherlands we have experienced that implementation of IPM in some crops (e.g. vegetables in greenhouses) is much easier than in others (e.g. fruit orchards), not only because of differences in cultural methods or pest problems, but also because of the different attitudes of growers. I will, therefore, not try to present specific guidelines for implementation, but rather list points to be considered on the basis of my own experience.

Technically, implementation of IPM is no different from that of other control methods. At the introduction of the first IPM programme for a new crop, special attention should be paid to extension. The degree of knowledge makes acceptance of the more complicated IPM programmes difficult for the farmer. IPM methods are rather new and demand a different attitude based on the principle of introducing a natural enemy or pesticide only when the pest insect is present and expected to lead to economic loss. A misconception is that such a practice is adopted readily if it is superior to current ones. Only when the IPM method is **perceived** to be better than conventional methods will it be adopted by growers. The phase of introducing IPM into

practice is often neglected. Experience has shown that the amount of application of IPM is strongly related to the activity and attitude of extension personnel. In quite a number of countries it is only the scientists who are interested in development of IPM, and often they forget to check whether others are interested as well. Thus, a lot of IPM work remains 'ivory tower' research. When growers, extension workers and researchers agree that use of IPM is more reliable and economically as attractive as chemical control, IPM can be implemented in a similar way as other control methods and becomes a normal management affair.

An example of the crucial role that farmers and extension workers play in getting IPM used is the UN-FAO Inter-country Programme for Integrated Pest Control in Rice in South and South-East Asia, as a result of which hundreds-and-thousands of farmers have been trained and now use IPM. An example of the success of IPM in a highly technological production system is the pest and disease control in Dutch greenhouses where a cooperative effort of all engaged in crop protection has led in the past 25 years to introduction of virus and fungus-resistant plant material, and 14 natural enemies against 18 pests on the majority of the vegetable crops. The growers have learned to rely on biological control and now ask for new natural enemies before we can provide them with the necessary information.

What are the constraints to practical use of IPM?

During the past three decades many countries have invested public money for the development of non-chemical control methods. In this section I will try to identify the reasons why so few of these methods have been extensively used.

Funding of research in IPM.

The results obtained in non-chemical pest control are, of course, in the first instance dependent on the amount of research and development work. Funding of this work is limited, especially if one realizes the complications of this type of research. Although this explains part of the story, it is my conviction that implementation is most hindered by other constraints, which I will discuss below.

Farmers' attitudes.

Until very recently, only a few farmers (organizations) asked for, or stimulated, development of non-chemical control methods. The adoption of insecticides was rapid because they allowed the farmer to decide when and where they should be used. Decision criteria were clear, the method was easily understood, it was effective (at least in the short term), reduced labour costs, and was a practice farmers could control and decide upon independently of their neighbours, institutions or agencies. Initially it was a straightforward technology. In contrast, integrated control is more complicated because of the requirement for the monitoring of various pests, the integration of different control methods and situation-specific prescriptions. The latter systems require a degree of knowledge and sophistication much greater than pesticide technology demands. But being unable to control a pest with chemicals was a strong reason for farmers to change their ideas on IPM. As soon as farmers realized that chemical control is no longer sufficient for complete control, their interest in an integrated approach was generated. We should not reproach the farmer for not being interested in IPM, because governments legislate the use of chemicals and often state that when chemicals are used as advised they do not contaminate food or the environment and do not harm plants, animals or humans. The attitude of rice and cotton farmers has already drastically changed, and many of them are applying IPM. In Europe, fruit growers and producers of greenhouse vegetables have experienced the positive aspects of integrated control and, therefore, at present they generally prefer to use IPM methods (van Lenteren et al. 1992).

The viewpoint of the chemical industries.

In general, we can state that any complication in a simple, straight chemical pest control programme is viewed as a negative development by the large industries. Alternatives like biological and genetic control not only complicate

chemical control programmes, but they seem to be unattractive commercially as well because of a combination of factors (van Lenteren 1986):

- the impossibility of patenting natural enemies
- complicated mass production
- short shelf-life
- specificity (too small a market)
- different and more complicated guidance for growers.

Chemical industries will not start the production of other than broad-spectrum pesticides on their own initiative, unless the use of those pesticides is prohibited or when pest organisms substantially develop resistance – but time is on our side! We cannot blame the chemical industry for this attitude because their goal is to make a profit. The industry provides pesticides which are allowed for use by a government's legislation and registration policy.

Role of the governments.

Therefore, it is the governmental bodies who should be the leaders here and who are in fact the only ones able to change the pest control picture through measures that make some kinds of chemical control less attractive or impossible (by measures concerning registration, taxation, side-effect labelling etc.), and by stimulating other control methods (by funding research, but above all by teaching on all levels in order to change the attitude towards nature, and improvement of the extension service). It is a rather bizarre situation that public money is used for the development of alternatives for chemical control when, at the same time, their application is often not encouraged by governmental bodies, due to the overall presence of (too) cheap broad-spectrum pesticides.

IPM for the farmer by the farmer?

The above information on IPM is of limited practical importance for the farmer and extension worker, who are faced with the demands of producing a certain quantity of food against a reasonable income. Their attitude to pest control is often a mixture of calendar spraying or see-and-panic-spraying. Forty years of marketing that pushed hazardous pesticides as 'preventive medicine' created a public perception that 'the only good bug is a dead bug'. This attitude is now slowly changing as a result of concern about health and environmental risks, as well as the experience in a number of crops that uncritical use of pesticides leads to more pest problems than no spraying.

Pest problems in the tropics were often tackled by intensifying the use of pesticides. However, pesticides endanger human health, pollute the environment and represent a serious drain on scarce foreign exchange. Pesticides are also an important cause of decreased biodiversity. Apart from these concerns, the widespread and injudicious use of chemicals often led to worsening of the pest problems over time, caused by the development of pesticide resistance on the part of the pest population and by destruction of natural enemies which normally keep pest populations in check. These 'man-made' pest outbreaks have become increasingly common during the past five decades.

With IPM for the tropics, a food production system is designed with methods that strongly reduce cash expenditure and external inputs, and at the same time aims at:

- sustaining a rich natural enemy fauna in agro-ecosystems
- developing and applying habitat management practices to make conditions less favourable for the colonization, reproduction and survival of pests and to enhance the efficacy of natural enemies.

Research in this framework must accommodate the needs of the farmer and, therefore, close contact with the prospective users and beneficiaries of research results is essential. With limited funds available for solving the whitefly problem, a new research methodology is necessary. I propose a research strategy

which appeared very successful in the development of large-scale IPM in Asia during the past decade where farmers take part in 'IPM Farmers Field Schools' and later form 'Farmers Field Research Laboratories' (Kenmore, personal communication, 1993).

Can 'Farmers Field Schools' help in implementing IPM?

An IPM Farmers Field School is a new methodology and entails a close continuing collaboration between researchers, extension agents and farmers. It aims at replacing the calendar sprays by count-then-spray techniques. It is based on a positive use of the skills of farmers and fieldworkers, contains elements of in-field training and hands-on field experience. IPM empowers farmers directly: farmers who learn IPM walk fields, diagnose symptoms, judge pest/natural enemy ratios, analyze their agro-ecosystems, and decide what to do without waiting passively for information from higher-up institutions.

In this approach farmers are considered to have a lot of experience in IPM. Training methods invite discovery, comparison, and analysis. Methods lend themselves to group involvement and non-hierarchical relationships among learners and trainers. The methods become tools for continued inquiry and improvement of programmes by farmers. Farmers are spontaneously training other farmers without government or financial support. Analysis and action revolves around three basic principles:

- grow a healthy crop
- conserve beneficial organisms like predators and parasites
- observe fields regularly to determine management actions necessary to produce a profitable crop.

The programme builds on farmers, farmer organizations, and skilled government field staff. Farmers Field Schools are 'schools without walls' where farmers and extension workers meet during at least one growing season from planting to harvest. Each field school has a 'learning field' containing a farmer-run comparative study of IPM for the main crops. Each week farmers practice agro-ecosystem analysis which includes the effects of crop rotation, crop sequencing, plant health, water management, weather, weed development, disease surveillance, and observation and collection of insect pests and beneficial organisms. Farmers interpret through direct experience, make field management decisions, and develop a vision of balanced ecological processes. Trainers train by allowing the farmers to be experts, facilitating them to bring forth and examine their own experience.

Trainers and farmers:

- produce their own learning materials from insect collections, insect zoos, field trial plots, posters and work books
- create and use analytical tools from the weekly agro-ecosystem analyses chart and live samples to produce the strengths/ weaknesses/opportunities/threats frame-work used to analyze local plans
- solve problems and make decisions: IPM specialist trainees learn to manage their own programmes and farmers learn to set-up and run complex learning activities.

The personnel of the extension service for such IPM projects are not the providers of information in the usual way. They are required to have grown their own crops for several seasons, performing all tasks including planting, weeding, fertilizing, irrigating, managing pests and harvesting the crop. Learning what it takes to run a farm builds a respect for farmers and a tremendous sense of self-confidence as the advisor becomes a skilled farmer, with better observation, agronomic and field analysis skills. The trainers in these projects distinguish themselves from the conventional situation by their commitment to long hours, hard work, willingness to go beyond the conventional limits of status and to work directly with local farmers.

Specific field studies (the effect of over-fertilization on boosting pests, the effect of pesticides on beneficial organisms, the effect of plant eating insects on the

eventual yield, etc.) implemented in the fields and shared discovery activities illustrate basic IPM principles. Group discussions/evaluations emphasize horizontal communication and group cooperation.

Research and extension (like research and action) have too long be separated at the far ends of a continuum. Too often, results from research are marketed to farmers as passive consumers through extension agents. Further research is normally on isolated topics, such as host plant resistance, fertilization, irrigation, pest control, etc. Research should be geared towards sustainable ecological processes, like natural biological control and habitat management, instead of remaining reductionistic. Only when farmers experience and understand that a new approach is useful will it be implemented. IPM implementors (researchers and extension workers) should therefore take part in participatory discovery-based processes for training, because active empowerment of farmers sustains IPM socially, environmentally and economically.

If research is not accountable to farmers, and does not address their immediate problems, it will not benefit them. Research also often remains physically separated from farmers and their fields. Within IPM an attempt should be made to put research back into touch with farm reality by involving fieldworkers and farmers directly.

Within the IPM programme everyone takes responsibility for their own learning, masters a process enabling them to teach others, makes plans and sees them through, and works to develop new methods and approaches. This process of 'self-actualization' is a strong driving force within IPM programmes. In that respect, IPM is sustainable agriculture in more than just calories of biochemical energy being recycled, it is also sustainable agriculture in the sense of human development, understanding, commun-ication and emancipation.

Should IPM in the tropics be based on conservation of natural enemies?

The cornerstone of successful integrated insect pest management is conservation of the naturally occurring populations of pathogens, predators and parasitoids. These living organisms, or natural enemies, constitute an important resource for crop protection because they kill pests and, in the process, reproduce and in that way perpetuate the control which they exert. Integrated pest management seeks, first and foremost, to conserve these natural enemies in the crop environment and not to disrupt these populations by the use of chemical pesticides. This conservation strategy of biological control constitutes a sustainable and environmentally safe component of modern pest management, and one which is seen increasingly as a desirable alternative to chemical pesticides. Work done by, for example, the FAO programmes in South-East Asia and Sudan supports the conclusion that tropical ecosystems have rich and complex communities of arthropods. Of the thousands of different species of plant eating insects only very few develop to pest status. The other potentially damaging species are kept at low numbers by the tens of thousands of natural enemies which occur in the crops and the vegetation surrounding crops.

I would like to use an analogy developed by Kenmore (personal communication, 1993) to illustrate the above. The community structure of a crop ecosystem could be considered as the 'immune system' for the agro-ecosystem. If it is weak (lacking sufficient abundance and diversity of natural enemies during the season), the system is at risk to crop losses from insect invaders. In the 'immune system' analogy, an over-reliance on pesticides is like an over-reliance on antibiotics: they seriously hinder the proper development of the immune system (natural enemy immunity), and they rapidly select for disease agents (pests) that can overcome both the antibiotic (pesticide) and the underdeveloped immune system (natural enemy community).

Studies have identified the importance of vegetation around crops to the maintenance

of natural enemies (van Emden 1990). Natural vegetation may provide shelter, alternative prey between crops, or other food sources such as pollen. If a substantial proportion of the natural enemy 'reservoir' persists in natural habitats near crops, or depends on these natural habitats for an essential element at a critical time (e.g. an alternative host when the target insect is not present), the preservation of these habitats is crucial to natural control. It is important to prevent situations in the surrounding vegetation that may boost pest development (e.g. the occurrence of plants that are very attractive to the pest and create difficulties for the natural enemies).

The abundance and diversity of natural enemies, and thus their effectiveness, can vary greatly between different crop ecosystems. The abundance and diversity of natural enemies is a function of the area and extent of non-crop vegetation. When crops are islands in a sea of natural habitats, the natural enemy reservoir will be large. But as natural habitats become smaller and smaller islands in a sea of crop-land, the number of species which those islands can support will decrease and natural enemies may become, at least locally, extinct (Waage 1991). Also the management practices of the vegetation surrounding the crop, carried out by the farmer, will affect the incidence of pests and natural enemies (see also Altieri and Letourneau 1982). Such practices include:

- cutting of the natural vegetation which could force pests and/or beneficials to move to the crops

- fire management: burning of adjacent vegetation could improve or decrease the suitability of the habitat for certain weed, pest or natural enemy species

- planting or maintaining plant species, trees or shrubs around fields: plant composition and/or windbreaks are variables which can determine effects on pest and beneficial insects

- the use of fallow-crops which could also play a role in the survival and carry-over of pests and natural enemies to the next cropping season.

Destroying or minimizing non-crop habitats may result in a severe disturbance of the natural enemy-pest balance in crop ecosystems, and therefore cause pest problems. The diverse plant and animal community in non-crop habitats may have great, but as yet unrecognized, economic importance as they sustain free and effective natural pest control.

However, at the same time these non-crop habitats may actually increase insect pest, disease and weed problems in the crop agro-ecosystem. Generalist pest species may survive on alternate host plants and food sources in the boundary habitats. Weed species and vertebrate pests may also propagate in these non-crop habitats. Hence, we cannot make a general assumption that all vegetation surrounding crop fields would be beneficial to the farmer.

Considering the potential importance of vegetation surrounding crop fields, the management and manipulation of these habitats may offer great opportunities to increase natural control in crop fields. Certain practices of farmers or farmer-communities could favour this role of non-crop habitats. Other practices, like wide-scale herbicide use, may be detrimental.

Before considering biodiversity management as a tool for integrated pest management, more should be known about the floral and faunal diversity outside the crop and its positive or negative effects on insect, disease and weed abundance in the crop. There has been an almost total neglect of environmental management or habitat management as a potential component in the utilization of natural enemies for pest control (Coppel 1986). An example illustrates this neglect: in a collection of 14,150 papers on rice in the Entomology Division library of the International Rice Research Institute (IRRI)), only 20 papers contain information of studies which were carried out outside the rice crop. The use of non-crop vegetation in a practical farmer setting involves an understanding of the relationships between farmers, plants, pests and natural enemies. The goal is to maintain or enhance natural control mechanisms through managing biodiversity.

The studies on the ecological role of non-crop vegetation for specific crop pests and beneficials, as well as the movement of these biota at the crop/non-crop interface, should be principally problem-driven. These studies should start after identification of the major pest and weed problems at the research sites. As the research is problem-driven (farmers experience specific insect pest, disease, snail, vertebrate or weed problems), studies will be focused on the role of the natural vegetation in the creation and the solution of the problem. Specific studies are possible on the enhancement of certain natural enemies (e.g. the creation of spider 'hotels' made of straw in the natural boundaries of crop fields in China). Alternate food sources (plants, hosts, prey) as well as shelter and breeding sites for natural enemies in the non-crop habitats can be identified. The research methodology may include habitat manipulation to test specific hypotheses on the ecological role of the non-crop habitats.
The previous three sections are based on information provided by the FAO and Indonesia programmes on rice IPM (Anon. 1991a,b,c,; Kenmore 1991).

Whiteflies in the Caribbean: a new problem?

Since the mid 1980s, the Caribbean has been invaded with a new strain of the sweet potato whitefly, *Bemisia tabaci*, which is devastating key food crops. Whitefly densities on Cucurbitaceae and Solanaceae are extremely high. Up to 2,000 whiteflies per leaf can be found on cucumber, and more than 3,000 per leaf on eggplant, as I personally experienced during a visit to Curaçao in 1992. Since the invasion of this whitefly growers are spraying 3–4 times a week, whereas previously they sprayed once every 2 weeks. Nowadays growers have to destroy crops prematurely, and quite often even before harvesting is possible. Although the whitefly has always been present in the Caribbean, it never led to serious pest problems. Chemical control of whitefly is expensive and difficult because of widely developed insecticide resistance. Furthermore, it is dangerous to humans and leads to environmental pollution.

Bemisia whiteflies are minute, usually inconspicuous, insects and can be extremely injurious. They are efficient vectors of plant viruses. They feed voraciously on the plant sap, and when present in sufficient numbers, cause leaf drop and prohibit the maturing of fruits. *Bemisia tabaci* has been recorded from most subtropical and tropical countries of the world. However, until a few years ago, many of these were only taxonomic records, with no substantial economic damage reported. During the last 15 years it has become a severe pest; first in Old World countries, and then in the New World. *Bemisia tabaci* is now an important pest of the tropical world and in greenhouses, attacking over 500 plant species including numerous weeds and vegetables, agronomic and ornamental crops. It has reached this status by spreading into new geographic areas, attacking previously uninfested plant species, becoming acclimatized to new environments, developing biotypes that react differently to host plants, transmitting more plant diseases, and becoming resistant to insecticides (Schuster et al. 1992).

Management of this whitefly in the Caribbean will not be an easy affair, and is unlikely to be solved simply by the introduction of natural enemies. Therefore, an IPM approach is proposed for control of whitefly, including elements of biological control. In the Caribbean growers often produce different crops, all sensitive to whitefly, next to each other. Crops ready for harvesting occur just besides newly planted material. Many species of weeds that are excellent host plants for whiteflies occur in or surround the holdings. Such situations guarantee continuing development and survival of the pest. Quite elementary and simple hygiene measures combined with cultural control would lead to lower whitefly pressure and a decrease of infestation.

Concurrent with the implementation of hygiene measures and cultural control, development of a biological control programme could start. Quite a number of natural enemy species attacking *Bemisia* have been found in the Caribbean (Schuster et al. 1992, and below). Based on their presence, a programme should be initiated to exploit and stimulate natural biological

control. Biological control can in many cases be combined very effectively with partly resistant host plant material. If essential natural enemies are not found on a certain island, or if the natural enemies which are present are insufficient in controlling *Bemisia*, introductions of other natural enemies could be made through, for example the International Institute of Biological Control (IIBC) to build up a more potent natural enemy complex. But for such natural enemies to ever be effective, the frequency and concentration of chemical sprays will have to be drastically reduced. Also, those pesticides should be chosen that do not eradicate natural enemies, which means replacement of pyrethroids with other agents.

As explained above, active farmer participation will be essential for success. Strengthening of research and extension personnel is needed for a variety of reasons – for example, to assist on the farm with implementation of cultural practices, to select crops and cultivars less sensitive to whitefly, to test the effect of different screens to prevent whitefly infection, and to inform farmers on weed control and proper pesticide use.

For entomologists/extensionists and farmers engaged in IPM projects, the following practical approach could help in solving the whitefly problem:

- Verify whether biological control has a chance of implementation (attitude of growers, policy-makers; possibilities for importation and augmentation of natural enemies etc.)

- Make an inventory of pest, disease and weed problems for particular crops

- Check whether the supposed status (importance) of the pests is estimated correctly, exaggerated or underestimated; estimate economic threshold densities

- Find out (through literature search and correspondence) which of the pests can be controlled by existing non-chemical control methods (the whole spectrum from cultural methods, natural biological control via host-plant resistance and mechanical control to manipulative biological control; for a survey of methods see Table 1).

- Find out which pests can be controlled only with regular applications of broad-spectrum pesticides. If these are key pests, their control will interfere with the use of biological and integrated control. First a solution for these pests has to be found before introduction of natural enemies is realistic. Selective application of pesticides should be developed, or selective pesticides should be used. If, however, no short-term chemical solution for such key pests can be found, these pests will be the targets for biological control research.

- If, for all the pests and diseases, biological control methods, other non-chemical or selective chemical control methods are available, an IPM programme can be designed and tested at Farmers Field Schools. An extension programme will have to be implemented and a reliable delivery of control agents should be developed.

What is known about natural enemies of whiteflies?

Whiteflies have a wide array of natural enemies, some of which have brought about several of the best-known success stories in biological pest control. Extensive literature on the natural enemies is available, including up-to-date publications (e.g. Gerling 1990; Schuster et al. 1992). Below is a summary of the knowledge on natural enemies, including some information from the Caribbean:

Parasites:

About 100 species of whitefly parasites have been identified. Still more species are expected to be found. Most of the parasites are very host-specific. It has been extensively demonstrated in inoculative and seasonal inoculative biological control that introductions with individuals of one parasite species are sufficient for economically feasible whitefly control (Gerling 1990). About 25 species of hymenopterous parasites have been

recorded attacking *Bemisia*. The parasites originate from Asia, the Mediterranean, Africa, southern California, the Caribbean and Brazil. Most come from arid regions; only those from Brazil and Pakistan originate from moist, tropical conditions (Schuster et al. 1992). Schuster and colleagues collected whitefly material and showed that some 15 species of *Bemisia* parasites occurred in the Caribbean. Three species were widely distributed and reached rates of parasitism between 11 and 97%.

Predators:

Ten species of insect predators and one species of spider were observed to feed on *Bemisia* during the Caribbean collection trips. Undoubtedly hundreds of other, generalist predators attack *Bemisia*, as was found in, for example, Sudan (Munir, personal communication, 1992).

Pathogens:

In addition to parasites and predators, pathogens may also attack whiteflies. So far, the pathogens reported from the Aleyrodidae have only been fungi, since only they are able to infect these plant-sucking insects through penetration of the cuticle. Two categories of fungi attacking whitefly are interesting for whitefly control in the more humid tropics: *Aschersonia* spp. that are specific to whiteflies, and 'broad spectrum fungi' belonging to the genus *Verticillium* (Fransen 1990).

Can *Bemisia* be controlled with IPM?

IPM is the only long-term solution for crop protection. Agriculture has created a number of environmental problems during the second half of this century. The negative side effects of chemical pest control is one of these problems. It is now generally accepted that alternatives have to be found for several of these pesticides in order to guarantee safe food production. The combination of a number of tactics within IPM programmes, with the aim to reduce or eliminate negative side-effects caused by pest control, is the most realistic option for solving this problem. In order to obtain successes in this field, scientists should leave their ivory towers and start to develop empirical integrated control programmes.

The *Bemisia* problem in the Caribbean cannot be solved through chemical control; it is too expensive and unacceptable for health and environmental reasons. Initially, biological control alone might also not lead to satisfactory control. A wider approach which takes into account all crop management procedures – including biological control – could result in reduction to acceptable levels of this whitefly species.

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RESULTADOS DE LA ENCUESTA SOBRE CONTROL DE PLAGAS Y ENFERMEDADES EN LAS ZONAS HORTICOLAS DE AZUA, LA VEGA Y REGION NOROESTE REPUBLICA DOMINICANA

A Abud, P Alvarez, A Villar, V Escarramán y E Gómez

Report of a survey on pests and diseases in the horticultural zones of Azua, La Vega and the North-East region of the Dominican Republic.

The survey was conducted by JAD under contract to CTA/CARDI towards preparing information to be used at this IPM workshop. The survey focused on vegetables, citrus and, to a lesser extent, avocado. The pests and associated diseases studied included whiteflies and geminivirus, thrips, aphids and the fiddler beetle of citrus. The survey also was required to indicate losses due to the above as well as control measures in place and their relative efficiencies. The report gives details of the methodology, questionnaire used and analyses the information leading to the conclusions and recommendations. Fifty-one farmers were interviewed. The major conclusions were:

- The majority of farmers interviewed were medium to small – 98% with irrigation and 56% owning their farms.
- The major crops in September, October and November were tomato, melon, Chinese vegetables, and cucumber; red beans from November to February; garlic from October to December; and eggplant from September to December.
- In tomato, eggplant, garlic and Chinese vegetables, the major damage or loss was sustained up to flowering, but in the Chinese vegetables damage continued up to the harvest.
- The major damage symptoms were leaf yellowing, leaf curling and black spots in tomato. Leaf curling was not severe in eggplant but necrosis and bronzing due to thrips were visible.
- The economic percentage loss was due to whitefly and geminivirus in tomato and also in eggplant. Thrips also resulted in loss. There was a 100% loss in tomato (1991/92) and 80% in eggplant in 1991.
- The most widely used chemical was mancozeb followed by endosulfan, methamidofos and profenophos. These were used to control fungal diseases (mancozeb), whiteflies (endosulfan and methamidofos) and thrips (profenophos).
- Generally, chemicals were used in excess of the recommended dosages.
- In more than 61% of the cases, spraying was done every 7–14 days.
- Fifty-one per cent of the cost of production of tomato was due to pest and disease control, and for eggplant, it was 45%.
- In 85% of the cases, the pesticides were applied with a manual knapsack sprayer which was most inadequate.
- The majority of farmers producing tomato, garlic, water-melon and melon rotate the chemicals. This does not occur in eggplant and Chinese vegetables.
- Except for Chinese vegetables and tomato, pest levels are not monitored, probably due to lack of training in pest recognition.
- Precise information on the interval between the last spray and harvest was extremely difficult to get.
- Apart from the chemical control, there was some interest in and the use of cultural and biological control methods.

Presentacion

El presente trabajo se ha realizado con el auspicio de CARDI/CTA como contribución al Seminario sobre Manejo de Plagas Nuevas Estrategias para el Agricultor del Caribe por parte del Programa de Manejo Integrado de Plagas en la República Dominicana del cual participan la Secretaría de Estado de Agricultura (SEA), la Fundación de Desarrollo Agropecuario (FDA) y la Junta Agroempresarial Dominicana (JAD). Su realización se concretó con el equipo técnico del MIP, administrado por la JAD y contó con el financiamiento del Programa del Caribbean Agricultural Research and Development Institute (CARDI) y el Centre Technique de Coopération Agricole et Rurale (CTA). La Oficina del Instituto Interamericano de Cooperación para la Agricultura (IICA) en la República Dominicana, FDA y el Departamento de Investigaciones Agropecuarias (DIA) prestaron su apoyo técnico en las varias etapas del trabajo.

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Osmar C Beneitez
Vicepresidente Ejecutivo, JAD

Antecedentes

La República Dominicana ha tenido en los últimos años cambios en la estructura de producción de hortalizas y frutales, debido en buena medida a cambios importantes que han ocurrido en el equilibrio biológico, lo que ha tornado más severa la incidencia de plagas y enfermedades.

Entre los casos más notables de estas plagas para los cultivos horticolas, figuran la mosca blanca, *Bemisia tabaci* Genn. (Homóptera: Aleyrodidae), y *Thrips palmi* Karny (Thysanóptera: Thripidae); en el caso de los frutales, por ejemplo en los cítricos, *Toxóptera citricidus* Kirkaldi (Homóptera: Aphididae) y *Diaprepes abbreviatus* (Coleóptera: curculionidae), o en caso del aguacate la denominada Chinche encaje, *Pseudacysta perseae* Heid. (Hemiptera: Tingidae).

Entré los sitios donde más cambios han experimentado los sistemas de producción de hortalizas y donde han sido mayores las pérdidas por plagas Y enfermedades, a veces por daños directos de las plagas, pero también por sus funciones de vector de enfermedades virales, figuran el Valle de Azua, el Valle de La Vega y la Regin Noroeste.

Las estimaciones sobre las pérdidas anuales ocasionadas por el ataque de las principales plagas, al inicio de la década de los 1990s por combinación de una nueva raza de mosca blanca (*B. tabaci*) conjuntamente con enfermedades a geminivirus transmitidas por éstas, fueron estimadas entre RD$250 y RD$500 millones, siendo en realidad muy dificil de cuantificar aunque se reconoce que las pérdidas son altas. En ellas, se computan no solamente los costos reales en efectivo, sino también, los costos potenciales, o costos de oportunidad. A estas pérdidas se deben agregar las que son dificiles de cuantificar pero igualmente importantes: las pérdidas de mercados exteriores como ha ocurrido con el melón y los ajíes picantes de exportación que han desaparecido como cultivos en el Valle de Azua, o los tomates para las industrias locales cuyos costos se incrementaron tanto, que se han dejado de sembrar.

Entre los cambios más notables que ha vivido el agropecuario dominicano en las últimas dos décadas figuran primera etapa, la expansión de las agroindustrias y las firmas productoras-exportadoras de productos tradicionales (tomates) y no tradicionales (melones, berenjenas, ajíes, etc) cuya principal característica fue que el negocio de la firma estaba separado del negocio de los agricultores. En una segunda etapa, más moderna y especialmente en lo que hace la producción de cítricos, han surgidos complejos integrados verticalmente de plantaciones y agroindustrias.

Las vinculaciones de las agroindustrias de procesamiento (enlatados, jugos, exportación de frutas frescas, etc.) con el sistema de producción que desarrollaron, sea de productores individuales integrado verticalmente en los hechos, o realmente, en los nuevos complejos agroindustriales, han facilitado desde el punto de vista económico y por un tiempo, la realización de negocios que resultaron atractivos comercialmente. Pero esta especialización generó un problema paralelo: la proliferación de las plagas y enfermedades transmitidas por ellas que ya no se podrían controlar individualmente por los agricultores, sino en forma colectiva e integrada, debido a la rotura del equilibrio biológico del antiguo sistema agroecológico.

Objetivos de la encuesta

Objetivos generales

Determinar a nivel de productores hortícolas los daños y pérdidas ocasionados por las principales plagas, así como reconocer algunas de las variables que pueden a ayudar a definir mejores estrategias de manejo integrado para disminuir el problema de plagas y enfermedades.

Objetivos esopecificos

- Determinar la incidencia de plagas y enfermedades en la producción hortícolas y las pérdidas ocasionadas, así como estudiar la responsabilidad en el proceso de toma de decisiones sobre formas de control.

- Determinar la naturaleza y efectividad de las medidas de control implementadas hasta el presente en cada uno de los casos bajo estudio, sean ellas de carácter individual o colectivo (acción de productores agrupados y acción del Estado).

- Obtener información sobre esquemas de control utilizados por los agricultores en los principales cultivos de hortalizas.

Materiales y metodos

La selección de las muestras de la encuesta se hizo al azar, según listado de productores establecidos en la región Noroeste y los valles de Azua y La Vega, donde se aplicó el Formulario de Encuesta diseñado para recolectar la información. El número de productores de la muestra fue de 51, con 17 por cada zona. El muestreo empleado fue el mótodo a dos etapas considerando solo una variable importante (proporción estimada de pérdidas de rendimiento potencial o rendimiento esperado) medida en porcentajes, atendiendo al mismo tiempo el complejo cultivo-plagao bien cultivo-plaga-vector, con el cual se ajustó el tamaño de la muestra en cada sitio de la encuesta hasta un número de muestras determinado por las restricciones económicas del estudio (Anexo 1).

Se constituyeron grupos de trabajo en cada zona para la aplicación de los Formularios de la Encuesta a los casos de productores entrevistados. Estos grupos de trabajos fueron formados por el personal técnico del Programa Manejo Integrado de Plagas, MIP, (SEA-JAD-FDA), y coordinados a nivel nacional por los Ings. Agróns. Porfirio Alvarez y Abraham Abud, y a nivel de sitios de la encuesta, por los encargados regionales del MIP. La localización geográfica de la encuesta se presenta en la Figura 1.

El Formulario de Encuesta fue diseñado teniendo en cuenta las recomendaciones del CARDI/CTA y del IICA con el fin de establecer algunos elementos de comparación con agricultores de otros países del Caribe y hacerlos compatibles.

Caracteristicas generales de las fincas encuestadas

Del total de 51 fincas hortícolas encuestadas, 48 eran exclusivamente agricolas con una superficie promedio de 61 tareas (3.8 hectáreas) y tres eran mixtas (agricultura, ganaderia y otros rubros). En zona plana (valle) se ubicaron 49 fincas y 2 en laderas suaves, 50 de ellas tienen riego. El 56 porciento del total son propietarios, con una superficie promedio de 119 tareas (7.5 hectáreas) en este grupo.

El tamaño promedio de todas las fincas es de 82.3 tareas (5.2 hectáreas), el predio de mayor de 1,020 tareas y el menor de 15. Para la zona de Azua la media del tamaño de la finca es la más alta (118.6 tareas), seguida de la zona Noroeste (96.4 tareas) y La Vega (32 tareas). En total resultaron encuestadas 19 fincas que producen tomate, con superficie promedio de 112.4 tareas (155.7 tareas de promedio en Azua); 15 que producen berenjena, con superficie promedio de 21.7 tareas (27.2 tareas en Azua); 14 que producen ajíes, superficie promedio de 100.3 tareas (103.8 de promedio para la zona Noroeste); seis que producen sandia y/o melón; y 12 que producen vegetales chinos, que es un grupo de productos varios como vainitas, bangaaa, muzú, etc. cuyo tamaño promedio es de 26.8 tareas (con 33 tareas de promedio en la zona Noroeste) (Cuadro 1).

En general, las fincas encuestadas son fincas familiares de tamaño mediano, con muy pocos valores extremos, atendidas por sus propios dueños y ubicadas en zonas donde hay agroindustrias envasadoras próximas. Muchas de estas fincas operan sobre la base de acuerdos con tales industrias, existiendo poca movilidad de la producción para venta entre zonas, principalmente por la falta de conexiones directas (caminos y transporte a precio competitivo).

Cuadro 1. Cantidad y tamaño de fincas y superficie con cultivo de hortilizas en las zonas de la encuesta en Azua, La Vega y Zona Noroeste, República Domincana.1993

Item	Todas las fincas	Tomate	Berenjena	Ají	Sandia y melón	Vegetales chinos
Cantidad de fincas en la muesta (Nro.)*	51	19	15	14	6	12
Tamaño de las fincas (Tareas)**						
Predio mayor	1,020	1,020	70	800	16	140
Predio menor	15	15	4	12	5	4
Superficie promedio	82.3	112.4	21.7	100.3	8.7	26.8
Superficie promedio por zona (Tareas)						
Zona de Azua	11 8.6	155.7	27.2	62.5	6	–
Zona de La Vega	32	–	16.8	140	–	24.8
Zona Noroeste	96.4	38.3	22.2	103.8	10	33

Fuente: Encuesta MIP realizada por JAD, con apoyo del CAR DI/CTA. 1993

* Incluyen doble o triple cultivo de hortalizas.
** 1 hedárea = 15.9 tareas

Resultados obtenidos en la encuesta

Permanencia de los cultivos en fincas

El Cuadro 2A relaciona los principales cultivos de las zonas bajo estudio; se observa la frecuencia de las fincas con cultivos presentes en función de los meses de un año calendario; estos datos corresponden a los años 1992/1993. El Cuadro 2B expresa el porcentaje de las permanencia de los cultivos en finca, por mes calendario; en el Anexo 2, se incluyen las Gráficas a, b, c, d, f y g que representan la presencia de los principales cultivos de las zonas de Azua, La Vega y Región Noroeste, con relación a los meses de un año calendario.

Como se puede observar en ellos, los cultivos del tomata, melón, vegetales chinos y pepino predominan en los meses septiembre–octubre y noviembre; el cultivo de la habichuela noviembre, hasta febrero; el ají de octubre a diciembre y berenjena de septiembre hasta diciembre.

Esta permanencia, está relacionada con los requerimientos de mejor época del cultivo, pero también con la programación de siembras con fines de exportación, como son los casos de melón y vegetales chinos, o industrialización en los otros casos. Como se puede observar la presencia casi permanente de cultivos atacados por plagas, hace dificil romper la cadena biológico en un esquema MIP.

Daños ocasionados por plaqas en los cultivos y regiones

La fuente de consulta principal de acuerdo con los entrevistados en el caso del tomate (74%) y en el del ají (57%) son los técnicos; para los demás cultivos es el propio productor el que lleva a cabo este reconocimiento, aunque para el caso del ají hay igual porcentaje en relación con el

técnico consultado (57%) (Ver Cuadro 3 y Cuadro Anexo 26)

En relación con la fenologia del cultivo, tanto en el tomate, berenjena, ajíes y vegetales chinos el mayor porcentaje de daños con relación a las plagas y enfermedades se detectaron en las fases de desarrollo y floración; pero para el ají se extiende hasta la cosecha. En el caso de sandia y melón los daños predominaron en la fase de crecimiento (Cuadro 4 y Cuadro Anexo 26). Los datos corresponden a estimaciones de los productores en el año 1992 y están dados sobre el cultivo principal y la plaga más importante que lo atacara.

De acuerdo a los tipos de daños observados en todos los cultivos, el amarillamiento, el encrespamiento de las hojas y la aparición de hojas negras debido a la 'fumagina' fueron predominantes. El encrespamiento de las hojas en la berenjena no constituye un daño significativo porque en el mismo no se verifican enfermedades virales; sin embargo, la necrosis de las hojas o bronceada del follaje, se debe al ataque del *T. palmi* y la fumagina, no apareció mencionada en el cultivo de ají y es baja en los vegetales chinos; en cambio predominó en los demis cultivos debido a la presencia de *Bemisia tabaci*, fundamentalmente (Ver Cuadro 5 y Cuadro Anexo 26).

Cuadro 2A. Cronograma de permanencia de cultivos en el suelo de la finca. Frecuencia de fincas con presencia del cultivo, por mes calendario

Productos	Jul	Ago	Set	Oct	Nov	Dic	Ene	Feb	Mar	Abr	May	Jun
Tomate indust.	1	1	14	14	15	10	4	3	2	1	2	1
Melón	1	1	3	3	3	2					1	1
Habichuela				1	3	3	2	2				
Vegetales chinos	6	8	10	11	9	6	5	5	3	1	2	2
Ají	4	5	7	11	10	8	5	4	1	1	2	4
Pepino	1	1	3	3	3	2	2	2	2	2	2	2
Berenjena	4	10	15	15	15	15	9	8	9	7	3	3

Cuadro 2B. Porcentaje de presencia del cultivo en fincas de la muestra, por mes calendario.

Productos	Jul	Ago	Set	Oct	Nov	Dic	Ene	Feb	Mar	Abr	May	Jun
Tomate indust.	5	5	74	74	79	53	21	16	11	5	11	5
Melón	33	33	100	100	100	67					33	33
Habichuela				33	100	100	67	67				
Vegetales chinos	50	67	83	92	75	50	42	42	25	8	17	17
Ají	29	36	50	79	71	57	36	29	7	7	14	29
Pepino	20	20	60	60	60	40	40	40	40	40	40	40
Berenjena	27	67	100	100	100	100	60	53	60	47	20	20

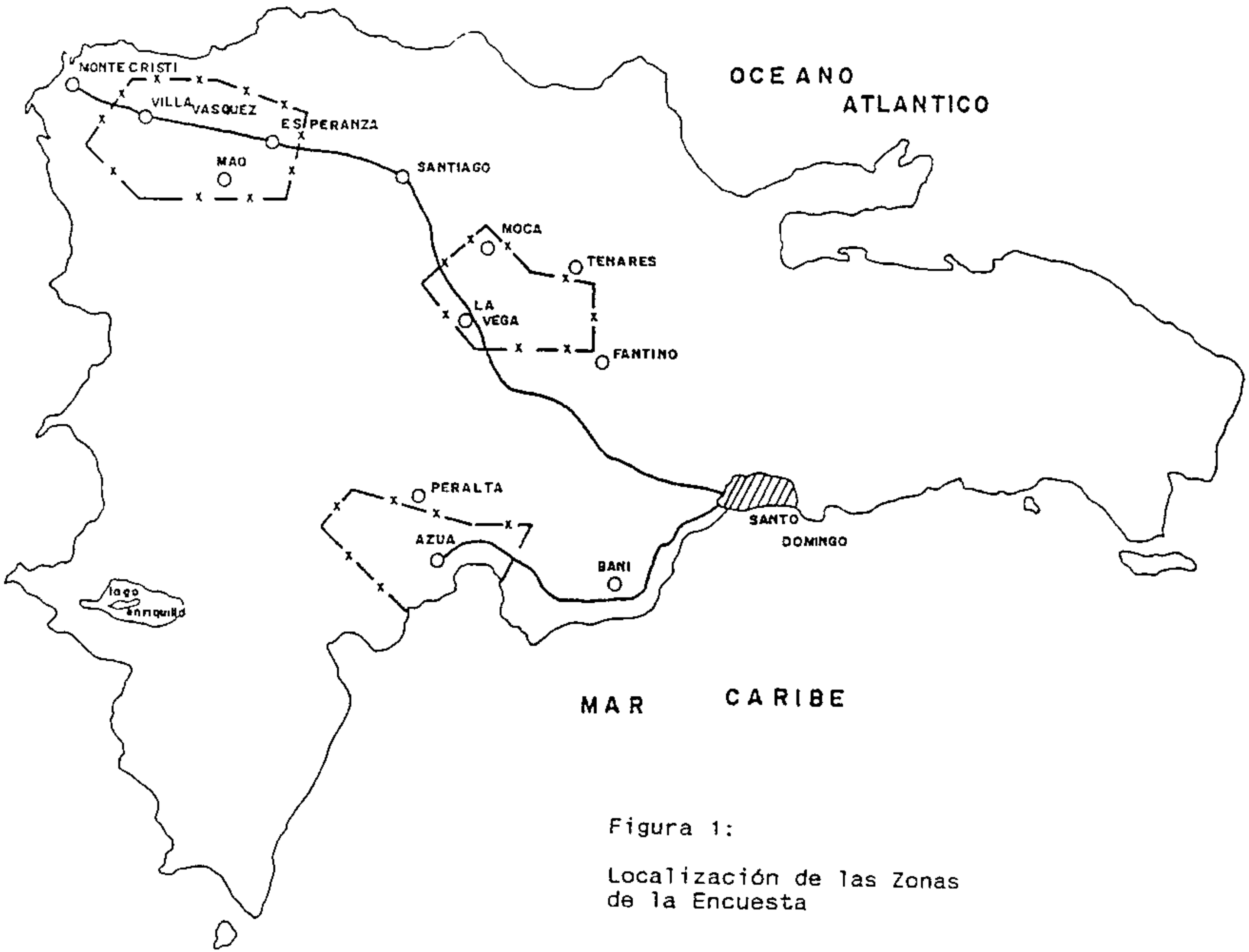

Figura 1:

Localización de las Zonas de la Encuesta

Cuadro 3 Reconocimiiento de daños (%) ocasionados por plagas y enfermedades en los cultivos. 1992/1993

Reconocimiento	Tomate	Berenjena	Ajíes	Sandia/melon	Veg. chinos
Tecnico	74	47	57	17	50
Vecino	11	0	0	17	0
Agricultur	63	60	57	67	67

Cuadro 4. Danos ocasionados (%) por plagas y enfermedades en las diferentes fases de los cultivos. 1992/1993

Reconocimiento	Tomate	Berenjena	Ajíes	Sandia/melon	Veg. chinos
Germinacion	5	0	7	33	8
Plantulas	32		21	33	2
Crecimiento	74	73	79	50	58
Floracion	79	67	79	33	67
Cosecha	21	33	36	0	42
Postcosecha	0	0	7	0	0

Cuadro 5. Sintomas ocasionados (%) por plagas y enfermedades en los diferentes cultivos. 1992/1993.

Reconocimiento	Tomate	Berenjena	Ajíes	Sandia/melon	Veg. chinos
Amarillamiento	53	33	29	17	50
Necrósis foliar	5	20	0	0	25
Caida de hojas	5	0	0	0	8
Enerespamiento	84	13	86	67	50
Hojas negras	69	67	0	50	8
Achaparramiento	16	0	7	0	0
Muerte de plantas	0	0	0	0	8

Con relación a los daños producidos en los frutos, predominaron el achicamiento o disminución del tamaño, en particular para el caso del tomate, lo que además afectó la calidad para uso industrial (Cuadro Anexo 26).

Evolución del problema fitosanitario en hortalizas

Para conocer con mayor precisión el problema de plagas en el pais se incluye la siguiente informacieon:

Caso mosca blanca (Bemisia tabaci Genn)
La mosca blanca, *Bemisia tabaci*, se reportó incialmente en el año 1975 atacando el cultivo del frijol en la región de San Juan de la Maguana, en particular como vector del virus del mosaico dorado del frijol; en 1988 apareció en la zona de Azua el *B. tabaci* raza tipo 'B' en los cultivos de melón, tomate, berenjena, pepino, frijol, y otros, ocasionando daños directos de importancia económica por su habito de extraer la savia de las hojas, asi como un daao indirecto por el desarrollo de la fumagina (*Capnodium* sp.) sobre sus secreciones azucaradas. Otro

daño indirecto observado a partir del 1991 lo constituyó la aparición de un geminisvirus principalmente en el cultivo del tomate industrial; este ocasionó pérdidas estimadas en RD$150 millones para este cultivo en la zona de Azua y es capaz de transmitir más de 19 enfermedades de virus diferentes.

En la zona noroeste del pais se detectó la mosca blanca como plaga a partir del 1990, ocasionando daños directos al año siguiente, en particular en el cultivo de algodón; el geminisvirus en tomate industrial se reportó en dicha zona el mismo año.

En la actualidad para las plantaciones de tomate ubicadas en la zona de Azua, existe una baja población de mosca blanca y una alta incidencia de virosis transmitida por este vector, a tal grado que en algunos casos la incidencia es del 100%. En San José de Ocoa una zona montañosa al nordeste de Azua, la presencia de la mosca blanca se remonta a finales de la década del 1980, pero es a partir del 1991 y hasta el presente que apareció el geminisvirus en el tomate de mesa, que ocasiona pérdidas económicas altas. En 1993 el problema se ha agrava por que se generalizó en toda la zona y a diferentes cultivos hortícolas.

Otros cultivos atacados por *B. tabaci* son: berenjena, ajíes, tabaco, molondrón, pepino, auyama, melón y sandia. Entre las malezas hospederos están: *Euphorbia heterophyla, Poinsettia* spp., *Parthenium hysterophorus*. Para la Región Noroeste con poblaciones de mosca blanca mas elevadas, la incidencia de virosis es bastante significativa.

Caso Thrips palmi Karny

Esta plaga originaria del sureste de Asia, hizo su aparició en el Caribe en 1985 en las Islas de Guadalupe y Martinica (Guyot 1985 ; Denoyes et al. 1985) y luego, en 1988 se detectó en La Cabuya, Provincia de La Vega en la República Dominicana. Pero es a partir de 1989 cuando se constituyó en una seria plaga en los cultivos de berenjena, pepino y vegetales chinos (vainitas, cundeamor, berenjena china, bangaña, etc.) llegando a ocasionar perdidas económicas tales que varios de estos vegetales se dejaron de cultivar, sobre todo en la zona de La Vega. En ese mismo año ya era una plaga de mucha importancia en las regiones Noroeste y Sur del país.

Las pérdidas estimadas en berenjena oscilaron entre 70–90% para los años 1989–1990 y entre 50–70% en otros cultivos hortícolas como son el pepino, vainita china y otros (P Alvarez, comunicación personal). En los vegetales chinos, además de los daños directos ocasionados en estos cultivos, su presencia a nivel de los frutos de exportación impedian su comercialización en los mercados tradicionales, produciéndose una disminución drástica de las exportaciones de estos cultivos. Otros cultivos afectados por el *T. palmi* son: molondrón, cebolla, cebollin, mani, frijol, ajíes, repollo, coliflor, meleon, espinaca, cowpea, pepino, auyama, lechuga, papa, etc.

Estimación de pérdidas ocasionadas por cultivos y plaqas principales

La estimación de pérdidas y otras variables para el periodo 1988–1993 se hizo en detalle para tomate, berenjena y ají, destacándose este análisis de los demas por su baja frecuencia. El caso de los vegetales chinos no se analizó porque lo compone un grupo diverso y con poca frecuencia para cada producto.

Tomate industrial

A parir de 1988, el porcentaje de agricultores que destinó su tierra a la siembra del cultivo de tomate descendió paulatinamente, alcanzando su máxima expresión en 1991, cuando apenas el 53% de los agricultores sembraron tomate; esto en comparación con 1988 da una reducción del 27%; la disminución en el porcentaje de agricultores que sembraron tomate es mayor en 1991, porque se sumaron los efectos directos causados por la mosca blanca, y las enfermedades causadas por virus que ésta transmitió (Cuadro Anexo 4)

A partir de 1992, se observa un incremento en el porcentaje de agricultores que sembraron tomate en relación a 1991, debido a que, conocida la causa del problema por el Programa MIP, conjuntamente con los productores de tomate se comenzó a implementar estratégias para controlar la mosca blanca y la virosis. Las pérdidas medias en el cultivo del tomate fueron 38% desde 1988–1990, pero luego se incrementaron al 58% en 1991 y al 67% en 1992. Las pérdidas en los rendimientos se fueron incrementando hasta llegar a un

100% para los años 1991 y 1992 (Cuadro Anexo 4). En el cuadro se presentan otras informaciones obtenidas en la Encuesta.

Berenjena
Las pérdidas ocasionadas en los años considerados 1989–1992 se debieron a la mosca blanca, *B. tabaci* y al *Thrips palmi;* estas plagas desalentaron a los agricultores que dejaron de sembrar en un porcentaje de 44% creciente desde 1988. Los aaos con mayores pérdidas fueron 1988 y 1991, superando el 50%, pero el máximo porcentaje de perdida correspondió a 1991 con 80% (Cuadro Anexo 5). El cuadro contiene información adicional obtenido de la Encuesta.

Ajíes
El ácaro blanco (*Polyphagotarsonemus latus)* constituyó la principal plaga en el ají, aunque siempre asociado de *B. tabaci* y *T. palmi.* En este cultivo el mayor porcentaje de pérdidas estimadas ocurrió en el año de 1990 con un 75% (Cuadro Anexo 6). En el cuadro se incluye otra información importante, aunque la proporción de productores de ají fue aproximadamente el 10% de la muestra.

Medidas de control utilizados

Control quimico: productos utilizados
La frecuencia de uso de los plaguicidas en el total de las muestras (51 casos) tuvieron los mayores porcentajes para el mancozeb (16% de frecuencia de uso) para todas las zonas, seguido del endosulfan (9%), methamidofos y profenofos ambos con 7%. (Cuadro Anexo 7). Se utilizaron 49 productos o mezclas de principios activos; de esta última hay cuatro mezclas de dos fungicidas y tres mezclas de dos insecticidas.

La frecuencia del uso de insecticidas por zona encuestada, indican al endosulfan y al methomyl en Azua (12% y 8%, respectivamente); en La Vega, deltametrina (10%), cipermetrina (6%) y monocrotofos (6%), seguido del acaricida, dicofol (6%); en la región Noroeste el metamidofos (12%) y el endosulfan (10%). En la Figura 2 se presentan los productos citados por los agricultores, cuya frecuencia es superior al 5%.

Con relación al uso de los fungicidas en cada zona, el producto más utilizado en Azua fue mancozeb (16%); en la La Vega, propineb (10%) seguido de mancozeb y benalaxil + mancozeb (8% en cada caso); y en la Región Noroeste el fungicida más utilizado fue mancozeb (22%).

La frecuencia de uso plaguicidas por zonas y por cultivos se presentan en las Figuras 2, 3, 4, 5 y 6 para las diferentes regiones. Los plaguicidas más utilizados en Azua (Figura 4) en tomate fueron el insecticida endosulfan (12%), y como fungicida el mancozeb (14%); en la berenjena, el endosulfan y el monocrotofos (12% en cada caso) y el mancozeb (28%); para los demás cultivos como ajíes y sandia ver Cuadro Anexo 8. Para la Región Noroeste los plaguicidas más utilizados por cultivo son mancozeb (7%) y el profenofos (5%) en los ajíes y el mancozeb (5%) en el tomate. (ver Cuadro Anexo 9).

Para la región de La Vega los productos con mayor frecuencia de uso por cultivo son la cipermetrina (11%) en los vegetales chinos, el mancozeb (5%) en la berenjena y en la auyama (2%) (Cuadro Anexo 10).

Dosis y frecuencia de las aplicacionesde plaquicidas
En sentido general, de los productos utilizados el 22% se emplea con dosis deficiente, el 28% con dosis normal y el 50% con dosis excesiva. El profenofos (21%) es el de mayor frecuencia de dosis normal; el metalaxil + mancozeb (15%) el de mayor frecuencia de dosis deficiente y el mancozeb (16%) el de mayor frecuencia de dosis excesiva (Cuadro Anexo 11).

En la Figura 6 se indica el porcentaje de frecuencia de dosis normal: el profenofos (12%), mancozeb y endosulfan (20%); con dosis excesivas: mancozeb (165), metamidofos (13%), deltametrina (11%) y monocrotofos (9%); con dosis por debajo de lo normal o dosis deficiente está el metalaxil + mancozeb (15%), methomyl (13%) y mancozeb (11%).

Frecuencia de intervalo de aplicaciones de plaguicidas en las zonas bajo estudio
En el Cuadro Anexo 12 la mayor frecuencia intervalo de aplicación de los plaguicidas, en los diferentes productos utilizados en la zona bajo estudio es de 7 a 14 días (61%), seguido del intervalo de uso de 14 a 19 días (13%). Cabe destacar, que un 18% de las

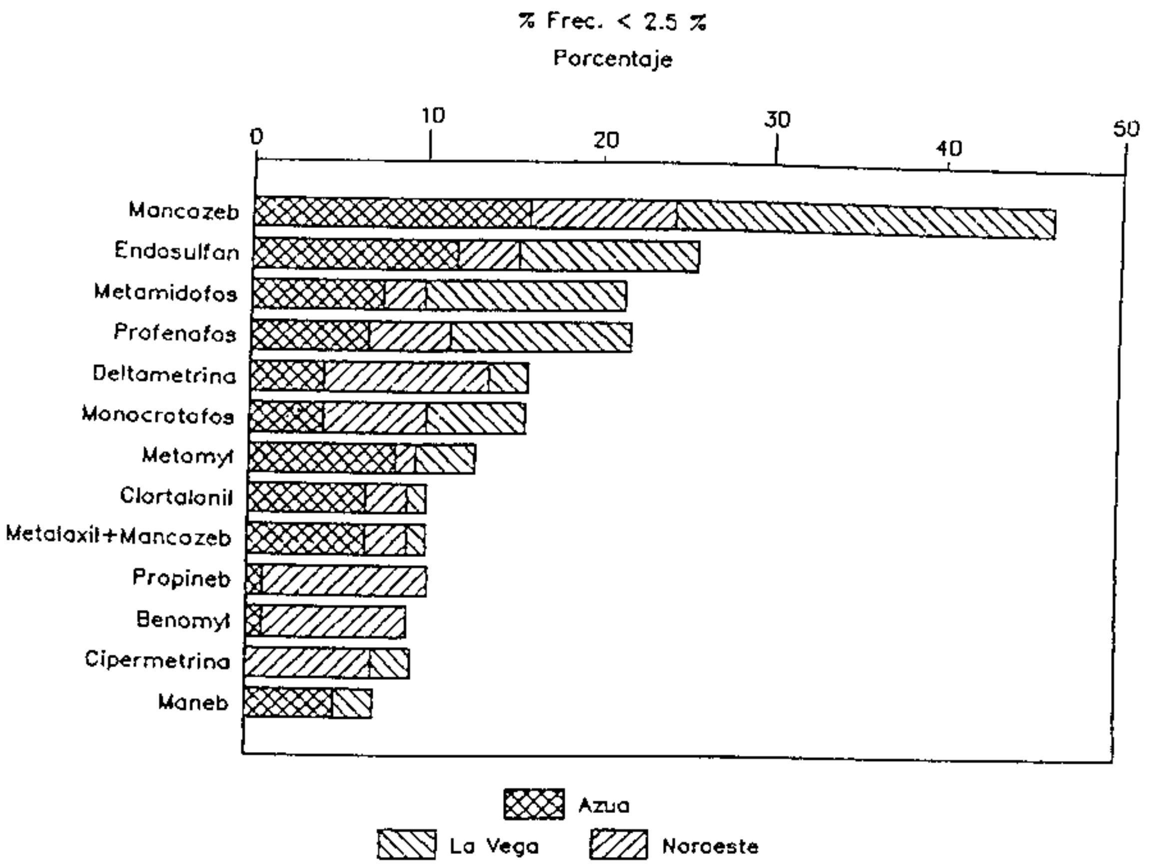

Fig. 2. Plaguicidas de mayor uso en los cultivos en las zonas bajo estudio, expresado en porciento. 1993.

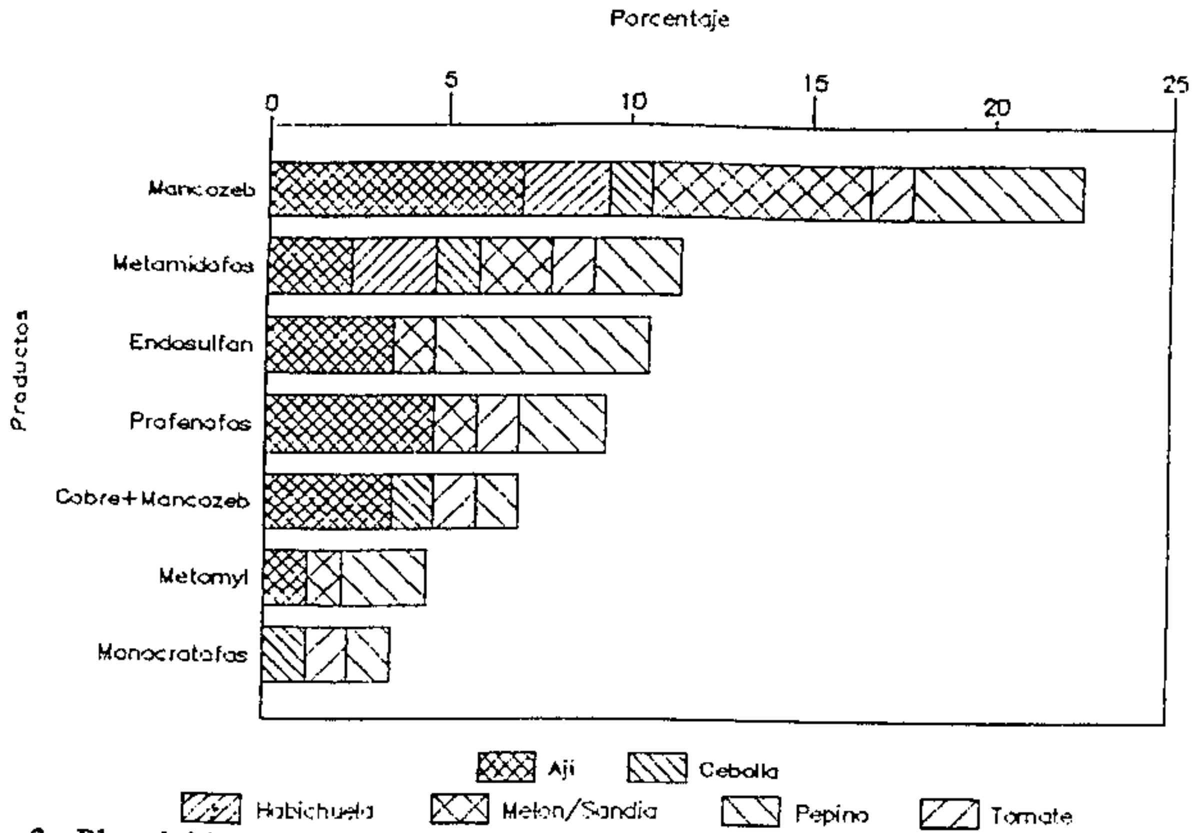

Fig. 3. Plaguicidas más utilizados, en porciento, en los diferentes cultivos en la región Noroeste. 1993.

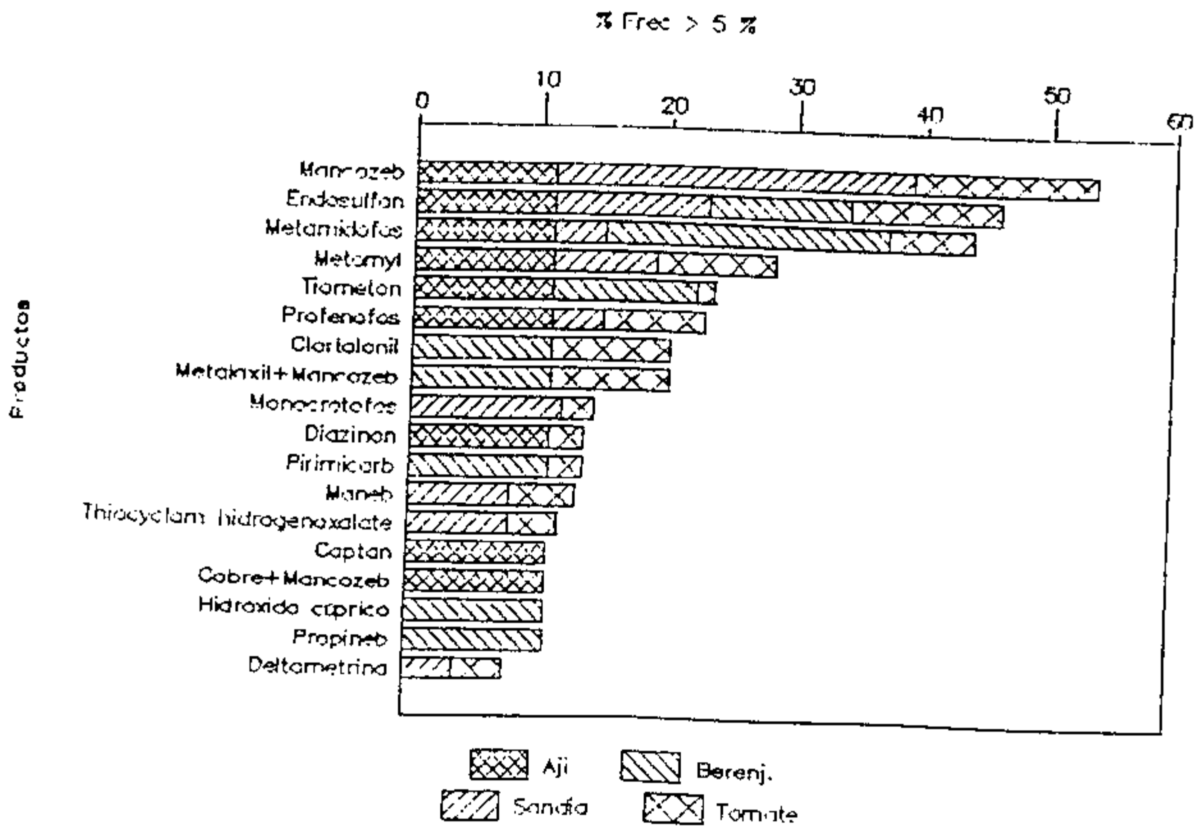

Fig. 4. Plaguicidas más utilizados, en porciento, en los diferentes cultivos en la zona de Azua. 1993.

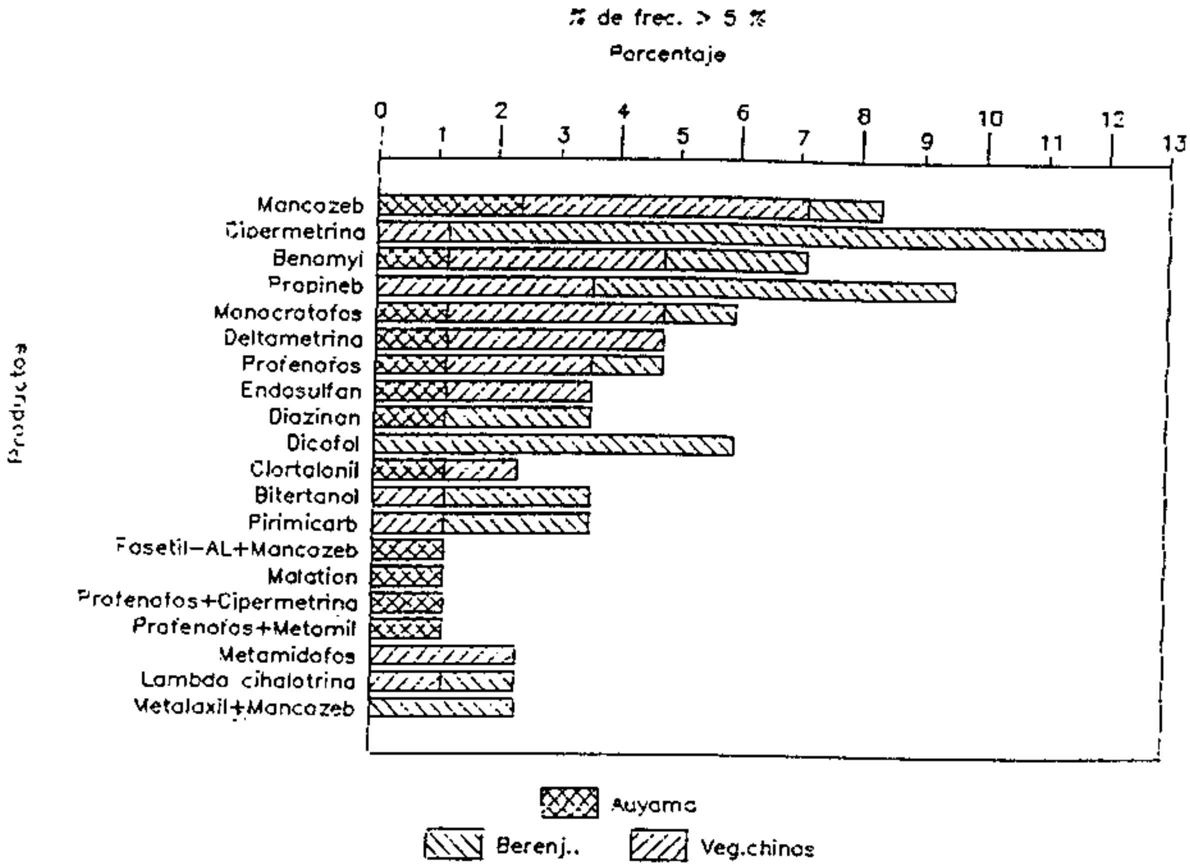

Fig. 5. Plaguicidas más utilizados, en porciento, en los diferentes cultivos en la zona de La Vega. 1993.

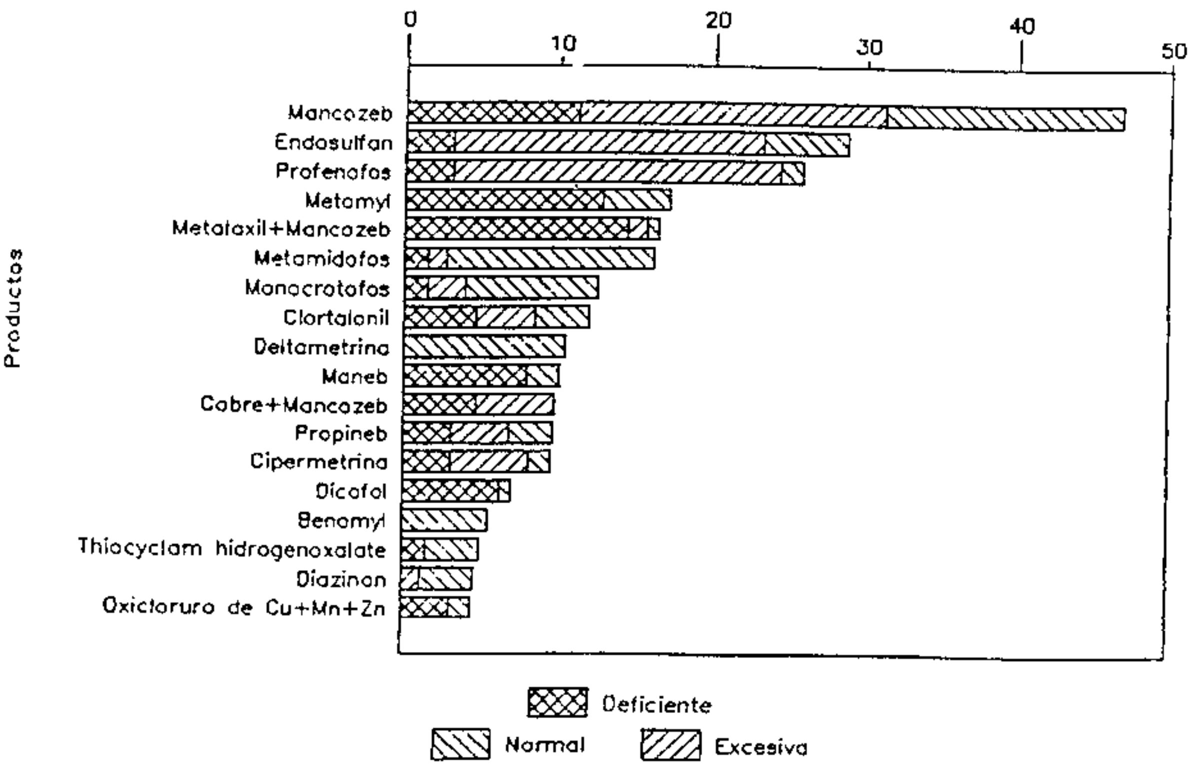

Fig. 6. Porcentaje de frecuencia de las dosis deficientes, normales y excesivas de los principales plaguicidas usados en las diferentes zonas bajo estudio. 1993.

personas encuestadas no contesteron sobre el particular y un 5% aplicaban plaguicidas con una frecuencia de 6 días o menos (ver Figura 7)

La frecuencia de intervalo de aplicación de los plaguicidas relacionadas con los cultivos demuestra que el intervalo donde se realiza la mayor aplicación corresponde al rango de 7 a 14 días con un máximo 90% en melón. En berenjena y vegetales chinos aparecen los mayores números de casos sin especificar, correspondiendo a estos un 48% y 32%, respectivament (ver Cuadros Anexos 13 al 22)

Otros aspectos del control de plagas y enfermedades

Situación económica
Según los costos totales de producción por tarea que aparecen en el Cuadro Anexo 23, vegetales chinos y berenjenas son los más elevados; pero en berenjena y tomate son los porcentajes más elevados en control de plagas. En tomate y berenjena los costos de aplicaciones y plaguicidas disminuyeron en términos reales si se consideran precios deflacionados. Esto posiblemente se debe a una disminución en el número de aplicaciones durante el ciclo de estos cultivo, pues se ha comenzado a tomar en cuenta el monitoreo de las plagas como base para la aplicación de plaguicidas, gracias a los esfuerzos del Programa MIP en alguna medida.

Otras caracterieisticas en el control de plagas

Equipos usados
Con relación a equipos de aplicación más frecuentemente utilizados, la bomba de mochila manual fue la mas frecuentemente citada en todos los cultivos, seguida de la bomba estacionaria motorizada, en particular en el cultivo de tomate. La bomba manual hidráulica es considerada como la menos adecuada y efectiva cuando se utilizan productos tales como los fungicidas e insecticidas, pues este equipo produce un tamaño de gotas y una cobertura de la parte atada, inadecuadas para el control de las enfermedades y de las plagas que afectan los cultivos (ver Cuadro Anexo 24).

Rotación de plaouicidas
En los cultivos de tomate, ajíes, sandia y melón la mayoria de los productores realizan rotación de plaguicidas; en cambio, para el cultivo de berenjena y vegetales chinos sucede lo contrario. (ver Cuadro Anexo 24).

Recomendaciones sobre el uso de plaquicidas
En el cultivo del tomate la opinión de los técnicos es la más tomada en cuenta con un 74%, para los demás cultivos existe un porcentaje variable (de 40 a 50%) entre el mismo productor o el técnico. (ver Cuadro Anexo 24).

Monitoreo de plagas
En todos los cultivos, la mayoria de los productores no realizan las aplicaciones de plaguicidas haciendo monitoreo previo (70% a 100%). En el tomate y los vegetales chinos esta práctica es más común (ver Cuadro Anexo 24).

Periodo de carencia o de seguridad
En cuanto al conocimiento relacionado con intervalo de seguridad entre la última aplicación y la cosecha, en los casos de tomate, vegetales chinos, sandia y melón, la mayoria contestó que no toma en cuenta este criterio; lo contrario sucedió para los cultivos de ajíes y berenjena (ver Cuadro Anexo 24).

Plaguicidas prohibidos en los cultivos
La mayoria de los productores encuestados contestó que desconocia de la prohibición de plaguicidas en relacón a los cultivos señalados y solamente los productores de vegetales chinos, en un 60%, tenían conocimientos sobre el particular, debido a que estos vegetales son principalmente para la exportación hacia los Estados unidos, país muy exigente en cuanto a la presencia de residuos queimicos en frutas y vegetales (Cuadro Anexo 24).

Otros métodos de control de plagas

Sobre el conocimiento de métodos de control, el control cultural, seguido del control legal en el cultivo de la berenjena y de vegetales chinos, fueron los más frecuentes. El control biológico ha sido tomado en cuenta en los cultivos de berenjena y vegetales chinos en los años 1991–1992, como se muestra en la Figura 8 (ver Cuadro Anexo 25).

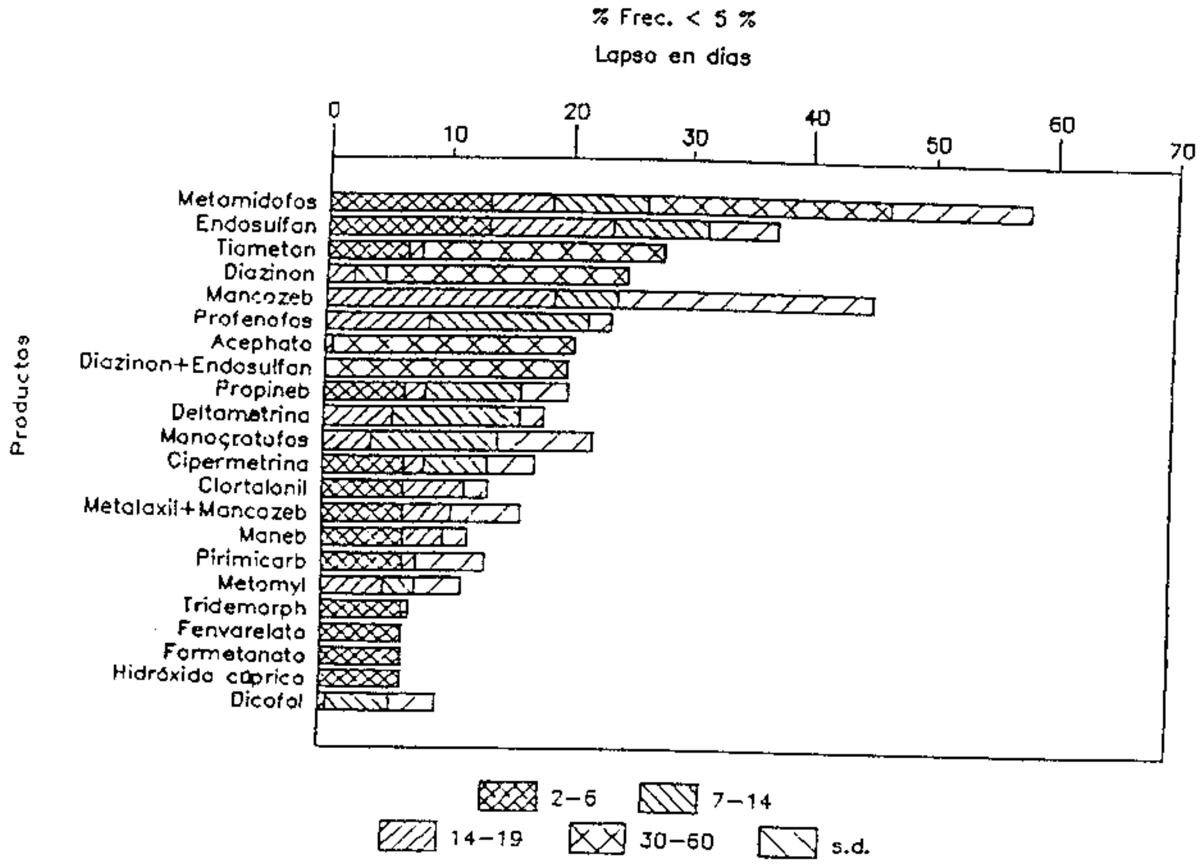

Fig. 7. Intervalos de las aplicaciones, en porcentaje, de los diferentes plaguicidas usados en las zonas bajo estudio. 1993.

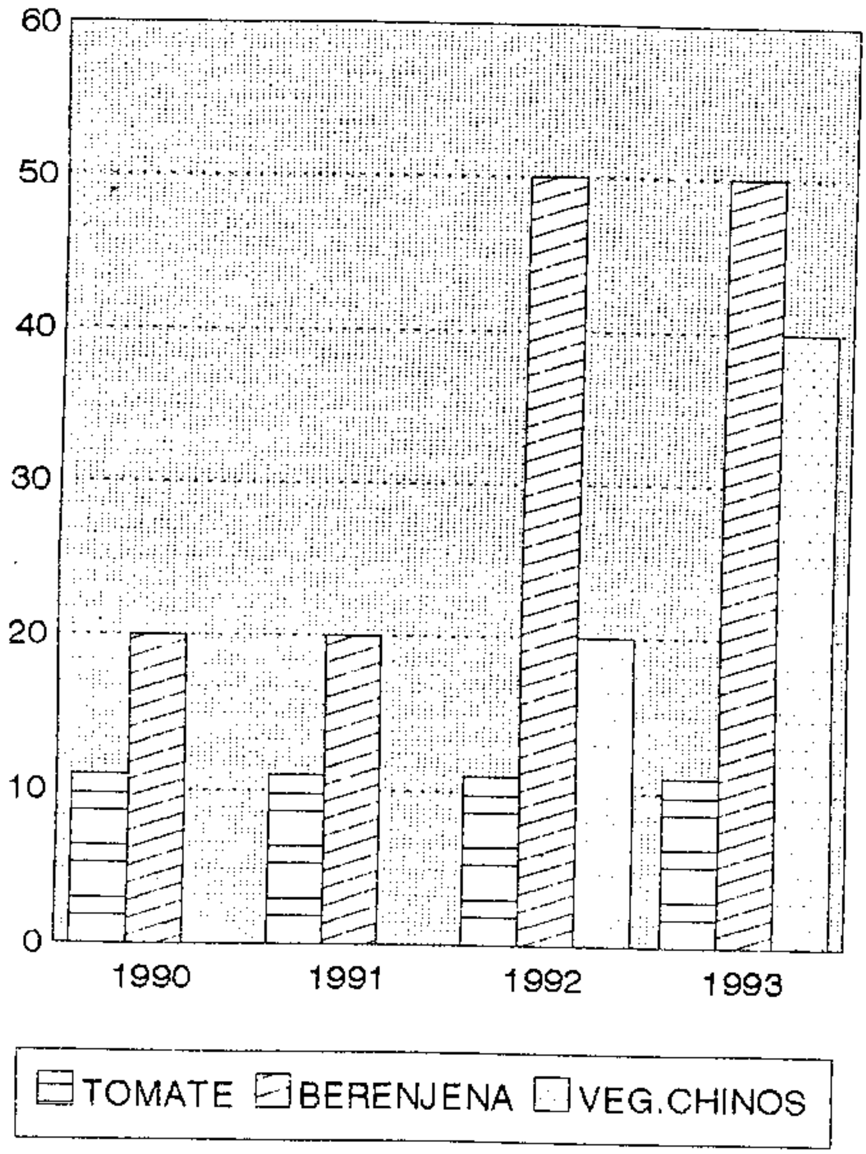

Fig. 8. Control biologico empleado en los cultivos

Limitaciones del estudio y necesidad de investigaciones futuras

La Encuesta se llevó a cabo en un período en el cual no todos los productores tienen en desarrollo todos los cultivos mencionados como el principal. Esto requirió referirse al último ciclo de producción. Debido a que la mayor parte de ellos no llevan libros de registros se confió en su memoria o en documentos parciales, lo que indujo a algunos errores.

La mayoria de los productores encuestados eran pequeños parceleros, con escaso conocimientos de las plagas y enfermedades presentes en sus cultivos, así como, en lo relacionado con las medidas de control más adecuadas a utilizar. Por ejemplo ninguno de los encuestados fue capaz de reconocer y diferenciar los daños producidos por el *T. palmi* y evaluar esta plaga desde el punto de vista economico; en estos casos, el técnico encuestador, experto del MIP, hizo lo posible para obtener información correcta sin influir en la repuesta.

Las necesidades de investigaciones están relacionadas con la evolución de los problemas de plagas y enfermedades y deben dirigirse en varias etapas a corto, mediano y largo plazo.

Entre las investigaciones a desarrollar dentro de un programa de MIP en República Dominicana están:

- Estudio de biologia de plagas principales
- Estudio de fluctuaciones poblacionales de plagas y sus enemigos naturales
- Conocimiento de los principales enemigos naturales (parásitos, depredadores y enfermedades) en relación a su biologia y hábitos
- Determinación de umbrales económicos de ataques de plagas de mucha importancia económica
- Estudios de enfermedades a virus y su relación con los vectores y las plantas hospederos
- Validacieon de variedades e hibridos en relación a enfermedades virales y otras
- Introducción y aplicación de control microbiológico a base de hongos, bacterias, y otros
- Introducción y evaluación de algunos enemigos naturales (parásitos y depredadores) de plagas tales como *B. tabaci* y *T. palmi*
- Estudios de eficacia y forma de aplicación de plaguicidas de acuerdo a la plaga a controlar
- Determinación del sistema de monitoreo de las plagas y enfermedades en cada cultivo, con tal de reducir el número de aplicaciones
- Continuar los estudios sobre métodos de control cultural, mecánico y etoleogico en diferentes cultivos y plagas
- Realización de encuestas similares a la presente cada dos años.

Conclusiones

- La mayor parte (más del 80%) de los productores entrevistados son medianos y pequeños, casi todos tienen riego (98%), y el 56% son propietarios de sus tierras y son prodominantemente agricultores (9%).
- En cuanto a la permanencia de los cultivos en los campos, el tomate, el melón, lo vegetales chinos y el pepino predominan en los meses de septiembre, octubre y noviembre; la habichuela de noviembre a febrero; el ají de octubre a diciembre r la berenjena de septiembre hasta diciembre.
- Con relación a los daños en los cultivos, se observa que en el tomate, berenjena, ajíes y vegetales chinos el mayor porcentaje de daños ocasionados por plagas y enfermedades se presenta en la fase de desarrollo (crecimiento) y floración, aunque en el caso de los vegetales chinos los daños se extienden hasta la cosecha.

- El tipo de daños estimados por los sintomas varió, siendo predominantes el amarillamiento, el encrespamiento de las hojas, y las hojas negras, debido a la fumagina principalmente en el cultivo del tomate. El encrespamiento de las hojas no fue significativo en la berenjena, aunque si tuvo importancia la necrosis o bronceado debido a la presencia del *Thrips palmi*. La fumagina no fue mencionada por los agricultores en el ají, siendo baja en los vegetales chinos; en cambio predominó en los demás cultivos y debido a la presencia de la mosca blanca. En relación al tipo de daños en frutos predominó el achicamiento, particularmente en el cultivo de tomate.

- En porcentajes de pérdidas económicas el cultivo más afectado fue el tomate debido a efectos negativos de la mosca blanca y la virosis; en berenjena, además de mosca blanca, otro factor que contribuyó al detrimento. producción fue el *Thrips palmi*. Las mayores pérdidas se registraron en los años 1991–1992 en el cultivo de tomate, con un 100%, y en 1991 para el cultivo de la berenjena con un 80%.

- El plaguicida con mayor frecuencia de utilización en el total de la muestra resultó ser el mancozeb, seguido de endosulfan, methamidofos y profenofos. El uso de estos productos está relacionado con el combate de enfermedades fungosas (mancozeb), la mosca blanca (endosulfan y methamidofos) y el *Thrips palmi* (profenofos).

- En relación con la dosis de los plaguicidas, predominaron las dosis excesivas (50% de las frecuencias de respuestas), siguiendo las dosis normales (28~%) y las deficiente (22%).

- En cuanto a la frecuencia de aplicacion de los plaguicidas, la mayoria de los casos (61%) ocurre en el intervalo de 7 a 14 días, seguido del intervalo de 14 a 19 días, con 13% de los casos, para el total de la muestra.

- En los costos de producción de los cultivos, la parte dedicada al combate de la plagas y enfermedades mostró su porcentaje más elevado en los cultivos de tomate (51%) y berenjena (45%) con una tendencia a disminuir a través de los años 1988–1992.

- La bomba de mochila manual fue la más utilizada (más del 85%) en todos los cultivos, en particular en el cultivo del tomate (89%). Este sistema de aplicación es el menos adecuado para el combate de plagas y enfermsdades en los cultivos.

- La mayoria de los productores de tomate, ajíes, sandia y melón realizan rotación de los plaguicidas que utilizan, lo cual no sucede en berenjena y vegetales chinos.

- En el cultivo de tomate, los técnicos son quienes recomiendan con mayor frecuencia para el total de las muestras sobre el uso de plaguicidas, mientras que en los demás cultivos la decisión se reparte en porce~rajes iguales entre los técnicos y el productor.

- La mayoria de los productores no practica el monitoreo de plagas, siendo los productores de vegetales chinos y tomates lo que más utilizan este sistema con un 30 y 26%, respectivamente, presumiblemente porque no han tenido acceso a este método de reconocimiento de plaga.

- La mayoria de los productores de tomate, vegetales chinos, sandía y melón no toman en cuenta el período de carencia o intervalo de seguridad entre la aplicación de los plaguicidas y la cosecha, esto se explica porque casi todos estos cultivos son para exportación y van destinados a mercados muy exigentes y los produccores responden a la presión de las exigencias de los exportadores.

- En cuanto al conocimiento de plaguicidas prohibidos, sólo en el caso de los productores de vegetales chinos, en su mayoria, afirmaron conocerlos, esto se explica debido a que este cultivo es un renglon de exportacieon hacia mercados muy exigentes. Para los demás productores, este conocimiento no supera el 40% de los entrevistados.

- En relación con las medidas de control de plagas, aparte del control químico, el más conocido resulto ser el control cultural, principalmente en tomate, berenjenas y vegetales chinos. La aceptación del método de control biológico es creciente entre los entrevistados, principalmente en el caso de los vegetales chinos y berenjenas.

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ANEXOS

Muestreo de la encuesta sobre MIP

Definición de la población y la unidad muestral

La poblacion estudiada son fincas que producen hortalizas como cultivos principales, distribuidas en tres áreas geográficas de producción de hortalizas y frutales consideradas en el estudio, Valle de Azua, Valle de La Vega y Región Noroeste; el cultivo principal y la plaga principal de dichos cultivos.

Selección de muestras

La muestras de fincas, o sea, la finca como unidad muestral fue seleccionada al azar basada en la localización de las fincas sobre la base de su posición en los caminos principales de cada área de la Encuesta como se ilustra en los mapas anexos 1, 2 y 3. El proceso de selección fue el siguiente:

- Se delimiteo el perimetro del área geográfica de la encuesta en cada una de las tres zonas y se identificaron los caminos principales

- Se tomo en un mapa a escala la carretera principal y las secundarias y se marcaron todos los posibles sitios de muestras (sitio-kilómetro) procediendo de la siguiente forma:

  - Se eligieron al azar los tramos de camino desde la base de operaciones (del Encuestador) al perimetro de la zona; sobre ello se indicó el kilómetro, iniciando el conteo desde la base de operaciones, respetando el orden sorteado de los tramos; los kilómetros se contaron del uno en adelante hasta abarcar el total de distancias de los caminos de cada una de las áreas, ordenadas con números romanos.

- Sobre la base de la numeración correlativa de dichos sitios-kilómetro se eligió al azar la muestra y su retén (o sustituto) de la muestra

- Se organizaron las visitas a las fincas seleccionadas, aplicando un criterio económico (costo-distancia) a la programación de las visitas, haciendo el itinerario a manera de cubrir ordenadamente todas las un~dades que quedaban al norte, al este, al sur y al oeste de la base de operaciones pues el orden de visita no altera el orden de selección al azar de las fincas

- Para llegar al sitio de la muestra se utilizó el cuenta kilómetro del vehiculo, desde la base de operaciones; llegado al sitio se entrevistó al productor o responsable de la finca a la derecha del camino

- En caso de que esta finca no correspondiera a la Unidad Muestral o que el propietario no estuviera dispuesto a conceder la entrevista o hubiera sido posible hacerla; se tomó como sustituto a la finca más próxima y accesible, procediéndose en el mismo momento a realizar la encuesta

- Si en este segundo caso tampoco se pudiere realizar la encuesta, se siguió hasta el próximo kilómetro muestra elegido repitiendo el procedimiento.

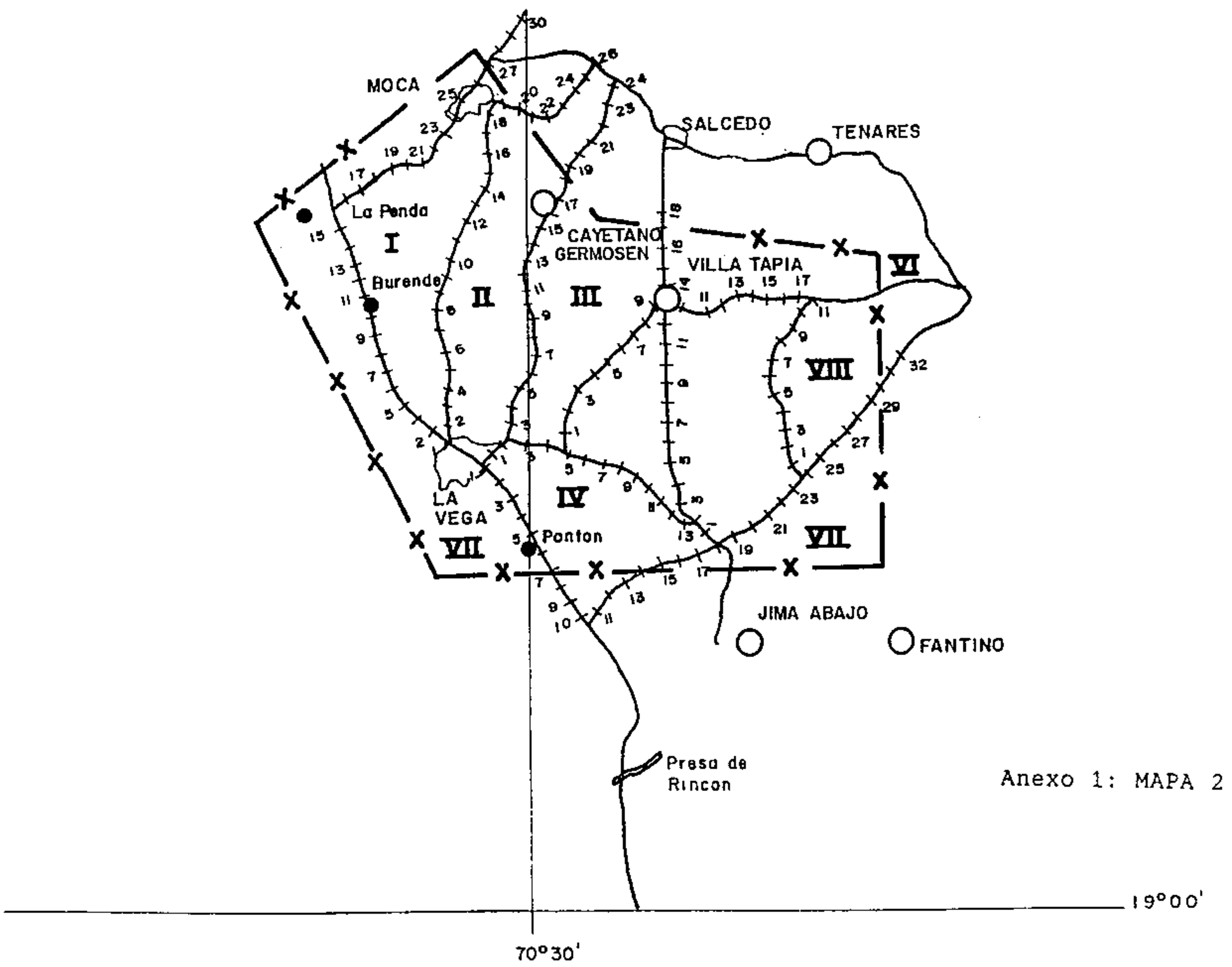
- El muestreo se hizo en dos etapas, en una primera se hicieron 30 encuestas distribuidas en las tres zonas; a partir de los datos generados, y la varianza estimada en la primera etapa se calculó el tamaño definitivo de la muestra para precisión prefijada, de la forma que se indica en el punto siguiente:

Tamaño de la muestra

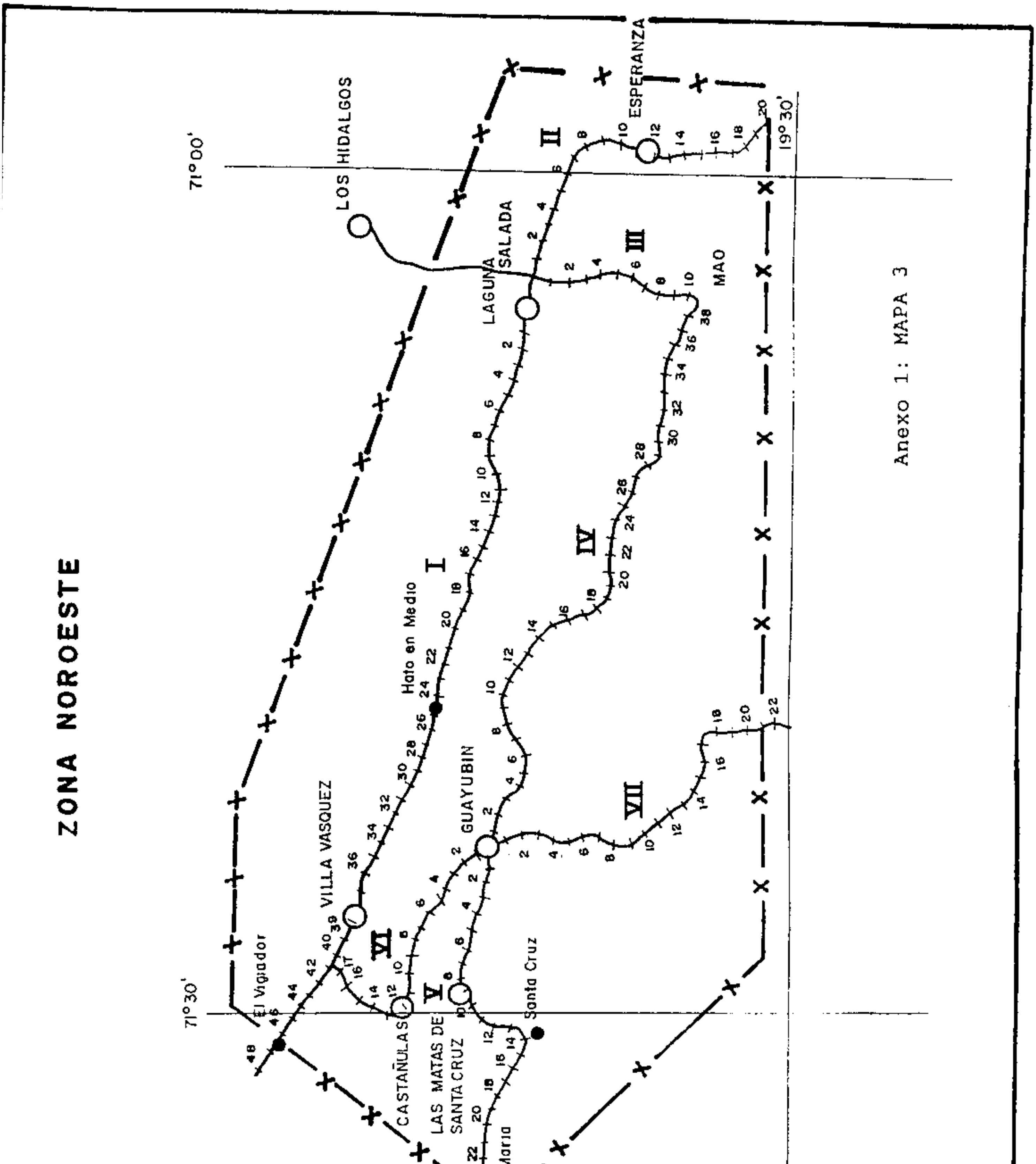
La precisión pre-asignada para estimar el tamaño de la muestra estimó entre el 5 y el 10% de la variable clave considerada y cuya varianza se estimó en la primera etapa que fue el porcentaje promedio de los tres últimos años de pérdidas potencial de producción en el cultivo principal en la finca, debido a la plaga más importante, aún cuando ella haya actuado solamente como vector.

La muestra fue elegida aceptando una probabilidad de error $p = 0.10$ y con un neumero inicial ($n_1 = 10$ elementos muestrales) ampliados luego en siete elementos dando un total de 51 muestras en total con 17 por zona.

ZONA DE LA VEGA



Anexo 1: MAPA 2



Anexo 1: MAPA 3

Cuadro Anexo 1. Daños observacios en los cultivos de tomate, berenjena, ajíes, sandia - melón y vainitas en el Valle de Azua, en La Vega y en la region Noroeste, República Dominicana, 1993

Item	Tomate		Berenjena		Ají y ají picante		Sandia y melón		Vainitas		Vegetales chinos	
	Casos	%	Casos	%	Casos	%	Casos	%	Casos	%	Casos	%
Numero de casos	19		15		14		6		7		12	
Porcentaje respecto del total de encuestados		37.30		29.40		27.40		11.80		13.80		23.50
Numero de cultivos bajo riego	18	95.00	15	100.00	14	100.00	6	100.00	7	100.00	12	100.00
Numero de cultivos en secano, o sin riego	1	5.00	0	0.00	0	0.00	0	0.00	0	0	0	0
Numero de casos por region de encuesta:												
Zona del Valle de Azua	12	63.16	5	33.33	2	14.29	2	33.33	-	-	-	-
Zona de la Vega	-	-	6	40.00	1	7.14	-	-	6	85.71	9	75.00
Zona Noroeste	7	36.84	4	26.67	11	78.57	4	66.67	1	14.29	3	25.00
Quien reconoco el daño ocaasionado por esta plaga?												
Consulto a tecnicos	14	73.68	7	46.67	8	57.14	1	16.67	3	42.86	6	50.00
Consulto a vecinos	2	10.53	0	0.00	0	0.00	1	16.67	0	0.00	0	0.00
Yo mismo	12	63.16	9	60.00	8	57.14	4	66.67	6	85.71	8	66.67
De acuerdo con la fase del cultivo, el daño principal se presenta en el momento o estado de:												
Germinación o nascencia	1	5.26	0	0.00	1	7.14	2	33.33	1	14.29	1	8.33
Plantula	6	31.58	3	20.00	3	21.43	2	33.33	0	0.00	3	25.00
Desarrollo o crecimiento	14	73.68	11	73.33	11	78.57	3	50.00	3	42.86	7	58.33
Floracion o maduración	15	78.95	10	66.67	11	78.57	2	33.33	6	85.71	8	66.67
Cosecha	4	21.05	5	33.33	5	35.71	0	0.00	4	57.14	5	41.67
Poscosecha	0	0.00	0	0.00	1	7.14	0	0.00	0	0.00	0	0.00
Cual es el tipo de daño observado en el aspecto general de las plantas?												
Amarillamiento	10	52.63	5	33.33	4	28.57	1	16.67	3	42.86	6	50.00
Necrosis hojas	1	5.26	3	20.00	0	0.00	0	0.00	2	28.57	3	25.00
Caida hojas	1	5.26	0	0.00	0	0.00	0	0.00	1	14.29	1	8.33
Encrespamiento de las hojas	16	84.21	2	13.33	12	85.71	4	66.67	4	57.14	6	50.00
Hojas negras	13	68.42	10	66.67	0	0.00	3	50.00	1	14.29	1	8.33
Achaparramiento	3	15.79	0	0.00	1	7.14	0	0.00	0	0.00	0	0.00
Muerto de plantas	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	1	8.33
Cual es el tipo de daño observado en la calidad del fruto?												
En el aspecto del fruto	3	15.79	7	46.67	5	35.71	1	16.67	4	57.14	7	58.33
En el achicamiento del fruto	17	89.47	11		12	85.71	5	83.33	4	57.14	7	58.33
En perforaciones en el fruto	1	5.26	1		0	0.00	0	0.00	0	0.00	1	8.33

Cuadro Anexo 2. Cronograma de permanencia de cultivos en la finca. Frecuencia de fincas con presencia del cultivo, por mes calendario.

Productos	Jul	Ago	Set	Oct	Nov	Dic	Ene	Feb	Mar	Abr	May	Jun
Tomate indust.	1	1	14	14	15	10	4	3	2	1	2	1
Melón	1	1	3	3	3	2	-	-	-	-	1	1
Habichuela	-	-	-	1	3	3	2	2	-	-	-	-
Vegetales chinos	6	8	10	11	9	6	5	5	3	1	2	2
Ají	4	5	7	11	10	8	5	4	1	1	2	4
Pepino	1	1	3	3	3	2	2	2	2	2	2	2
Berenjena	4	10	15	15	15	15	9	8	9	7	3	3

Cuadro Anexo 3. Porcentaje de presencia del cultivo en fincas de la muestra, por mes calendario

Productos	Jul	Ago	Set	Oct	Nov	Dic	Ene	Feb	Mar	Abr	May	Jun
Tomate indust.	5	5	74	74	79	53	21	16	11	5	11	5
Meleon	33	33	100	100	100	67	-	-	-	-	33	33
Habichuela	-	-	-	33	100	100	67	67	-	-	-	-
Vegetales chinos	50	67	83	92	75	50	42	42	25	8	17	17
Ají	29	36	50	79	71	57	36	29	7	7	14	29
Pepino	20	20	60	60	60	40	40	40	40	40	40	40
Berenjena	27	67	100	100	100	100	60	53	60	47	20	20

Cuadro Anexo 4. Elementos que describen perdidas en totes para los años 1988 a 1993 en los casos encuestados cuya plaga principal es la Mosca Blanca, *B. tabaci*

Estadisticas	Año 1993	Año 1992	Año 1991	Año 1990	Año 1989	Año 1988
Numero de casos sobre la muestra	15 de 51	15 de 51	15 de 51	15 de 51	15 de 51	15 de 51
Numero de casos con plaga principal	---	9	8	9	11	12
Numero de casos con perdidas	---	7	3	5	5	8
% agricultores que sembraron este año	60	60	53	67	73	80
% agricultores que no sembraron este año	40	40	47	33	27	20
Mediana de las perdidas registradas	---	66.5	58	37.5	37.3	37.5
% Perdida promedio por finca	---	54 ± 35	26.9 ± 42.5	34.2 ± 23.9	32.8 ± 14.3	34.9 ± 12.3
Promedio rendimientos qq/ta	---	17.4 ± 15.2	24.3 ± 15.2	31.8 ± 10.5	40.0 ± 17.3	38.6 ± 17.3
Promedio rendimientos en kg/ha	---	0	17562 ± 10985	22982 ± 7588	28981 ± 12503	27897 ± 12503
Minimo % de perdida	---	33	16	5	16.6	16.7
Maximo % de perdida	---	100	100	70	58	58.3
Medias ponderadas sobre siembra del año						
% Perdida en superficie del conjunto	---	13.6	3.2	11.6	4.1	28.6
% Perdida en volumen del conjunto	---	5.3	0.3	8.7	2.8	26.5

Cuadro Anexo 5. Elementos que describen perdidas en berenjena para los años 1988 a 1993 en los casos encuestados cuya plaga principales fueron *B. tabaci* y *T. palmi*

Estadisticas	Año 1993	Año 1992	Año 1991	Año 1990	Año 1989	Año 1988
Numero de casos sobre la muestra	9 de 51	9 de 51	9 de 51	9 de 51	9 de 51	9 de 51
Numero de casos con plaga principal	---	5	5	3	4	4
Numero de casos con perdidas	---	1	2	1	1	2
% agricultores que sembraron este año	22	66	66	33	45	45
% agricultores que no sembraron este año	78	44	44	77	55	55
Mediana de las perdidas registradas	---	20	52.5	33	40	55.5
% Perdida promedio por finca	---	20	55	33	40	55
Promedio rendimientos qq/ta	---	13.8 + 6.9	25.1	39.2 + 28.9	26.9 + 20.5	28.0 + 12.2
Promedio rendimientos en kg/ha	---	14237 + 8745	18140	28330 + 20886	19441 + 1486	20236 + 8817
Minimo % de perdida	---	20	25	33	40	52
Maximo % de perdida	---	20	80	33	40	58
Medias ponderadas sobre siembra del año						
% Perdida en superficie del conjunto	---	6.7	25	17.8	20.8	25.4
% Perdida en volumen del conjunto	---	5.1	11.9	10.6	18.9	14.2

Cuadro Anexo 6. Elementos que describen perdidas en ajies para los años 1988 a 1993 en los casos encuestados cuya plaga principal es el acaro blanco *(Polyphagotarsornemus latus)*

Estadisticas	Año 1993	Año 1992	Año 1991	Año 1990	Año 1989	Año 1988
Numero de casos sobre la muestra	5 de 51	5 de 51	5 de 51	5 de 51	5 de 51	5 de 51
Numero de casos con plaga principal	---	5	1	1	0	1
Numero de casos con perdidas	---	4	0	1	0	1
% agricultores que sembraron este año	60	100	20	20	---	20
% agricultores que no sembraron este año	40	0	80	80	100	80
Mediana de las perdidas registradas	---	32.5	---	75	---	10
% Perdida promedio por finca	---	21.3	0	75	---	10
Promedio rendimientos qq/ta	---	12.5 + 7.1	---	---	---	---
Promedio rendimientos en kg/ha	---	9034 + 5131	---	---	---	---
Minimo % de perdida	---	5	0	75	---	10
Maximo % de perdida	---	50	0	75	---	10
Medias ponderadas sobre siembra del año						
% Perdida en superficie del conjunto	---	15.7	---	---	---	---
% Perdida en volumen del conjunto	---	18.2	---	---	---	---

Cuadro Anexo 7. Frecuencias de uso de principios activos, por zona, y porcentaje por producto

Principio activo	Frecuencia de uso por zona			Total por prod.	Porcentajes de frecuencia de uso por zona y producto			Total por prod.
	Azua	La Vega	NE		Azua	La Vega	Noroeste	
Abamectina		1		1	0.00	1.19	0.00	0.34
Acephato			2	2	0.00	0.00	2.30	0.69
Alfacipermetrina			2	2	0.00	0.00	2.30	0.69
Bacilus thuringiensis			1	1	0.00	0.00	1.15	0.34
Bitertanol		3		3	0.00	3.57	0.00	1.03
Benalaxil + mancozeb			1	1	0.00	0.00	1.15	0.34
Benomyl	1	7		8	0.84	8.33	0.00	2.76
Bifentrin		1		1	0.00	1.19	0.00	0.34
Captan	1			1	0.84	0.00	0.00	0.34
Carbendazim		1		1	0.00	1.19	0.00	0.34
Carbofuran		1		1	0.00	1.19	0.00	0.34
Cipermetrina		6	2	8	0.00	7.14	2.30	2.76
Clortalonil	8	2	1	11	6.72	2.38	1.15	3.79
Cobre + manzozeb	1		6	7	0.84	0.00	6.90	2.41
Deltametrina	5	8	2	15	4.20	9.52	2.30	5.17
Diazinon	2	3	1	6	1.68	3.57	1.15	2.07
Diazinon + endosulfan	1			1	0.84	0.00	0.00	0.34
Dicofol		5		5	0.00	5.95	0.00	1.72
Dicrotofos		1		1	0.00	1.19	0.00	0.34
Endosulfan	14	3	9	26	11.76	3.57	10.34	8.97
Etoprophos		1		1	0.00	1.19	0.00	0.34
Fenpropatrin			2	2	0.00	0.00	2.30	0.69
Fenvarelato			1	1	0.00	0.00	1.15	0.34
Formetanato			1	1	0.00	0.00	1.15	0.34
Fosetil-AL + mancozeb		1	1	2	0.00	1.19	1.15	0.69
Hectacloro		1		1	0.00	1.19	0.00	0.34
Hexaconazole		1		1	0.00	1.19	0.00	0.34
Hidróxido cúprico	1			1	0.84	0.00	0.00	0.34
Iprodiona	2			2	1.68	0.00	0.00	0.69
Lambda cihalotrina	1	2	1	4	0.84	2.38	1.15	1.38
Malation		1		1	0.00	1.19	0.00	0.34
Mancozeb	19	7	19	45	15.97	8.33	21.84	15.52
Maneb	6		2	8	5.04	0.00	2.30	2.76
Metalaxil + mancozeb	8	2	1	11	6.72	2.38	1.15	3.79
Metamidofos	9	2	10	21	7.56	2.38	11.49	7.24
Metomyl	10	1	3	14	8.40	1.19	3.45	4.83
Monocrotofos	5	5	5	15	4.20	5.95	5.75	5.17
Oxicioruro Cu+Mn+Zn	2	1	1	4	1.68	1.19	1.15	1.38
Parathion	1			1	0.84	0.00	0.00	0.34
Pirimicarb	3	3		6	2.52	3.57	0.00	2.07
Profenofos	8	4	9	21	6.72	4.76	10.34	7.24
Profenofos+cipermetr.		1		1	0.00	1.19	0.00	0.34
Profenofos + metomil	1			1	0.84	0.00	0.00	0.34
Propineb	1	8		9	0.84	9.52	0.00	3.10
Thiocyclam hidrogenox.	5	1		6	4.20	1.19	0.00	2.07
Tiodicarb	1			1	0.84	0.00	0.00	0.34
Tiometon	3		1	4	2.52	0.00	1.15	1.38
Triclorfon			1	1	0.00	0.00	1.15	0.34
Tridemorph			2	2	0.00	0.00	2.30	0.69
Total de frec. de uso	119	84	87	290				
% sobre el total	41	29	30	100	100	100	100	100

Cuadro Anexo 8. Frecuencias de uso de productos y porcentaje por cultivos en la zona de Azua

	Frecuencia de uso de productos por cultivos				Porcentajes de frecuencia de productos, por cultivos			
Principio activo	Ají	Berenjena	Sandia	Tomate	Ají	Berenjena	Sandia	Tomate
Mancozeb	1	7		11	11	28	0	14
Endosulfan	1	3	1	9	11	12	11	12
Metamidofos	1	1	2	5	11	4	22	7
Metomyl	1	2		7	11	8	0	9
Tiometon	1		1	1	11	0	11	1
Profenofos	1	1		6	11	4	0	8
Clortalonil			1	7	0	0	11	9
Metalaxil + mancozeb			1	7	0	0	11	9
Monocrotofos		3		2	0	12	0	3
Diazinon	1			2	11	0	0	3
Pirimicarb			1	2	0	0	11	3
Maneb		2		4	0	8	0	5
Thiocyclam hidrogenoxalate		2		3	0	8	0	4
Captan	1				11	0	0	0
Cobre + mancozeb	1				11	0	0	0
Hidróxido cúprico			1		0	0	11	0
Propineb			1		0	0	11	0
Deltametrina		1		3	0	4	0	4
Benomyl		1			0	4	0	0
Lambda cihalotrina		1			0	4	0	0
Parathion		1			0	4	0	0
Iprodiona				2	0	0	0	3
Oxicloruro de Cu+Mn+Zn				2	0	0	0	3
Diazinon + endosulfan				1	0	0	0	1
Profenofos + metomil				1	0	0	0	1
Tiodicarb				1	0	0	0	1
Total de frecuencia de uso	9	25	9	76				
Porcentaje sobre total	8	21	8	64	100	100	100	100

Cuadro Anexo 9. Frecuencia de uso de productos y porcentaje, por cultivo en la zona Noroeste

Principio activo	Frecuencia de uso de productos								Porcentaje de frecuencias de uso de productos							
	Ají	Cebolla	Habich	Melon	Pepino	Sandia	Tomato	Veg. chinos	Ají	Cebolla	Habich	Melon	Pepino	Sandia	Tomato	Veg. chinos
Acephato		2							0	2	0	0	0	0	0	0
Alfacipermetrina			1						0	0	1	0	0	0	0	0
Bacilus thuringiensis				1					0	0	0	1	0	0	0	0
Bitertanol				1					0	0	0	1	0	0	0	0
Benalaxil + mancozeb	1								0	0	0	1	0	0	0	0
Cipermetrina	1							1	1	0	0	0	0	0	0	1
Clortalonil		1							0	1	0	0	0	0	0	0
Cobre + mancozeb	3		1		1		1		4	0	1	0	1	0	1	0
Deltametrina				1			1		0	0	0	1	0	0	1	0
Diazinon		1							0	1	0	0	0	0	0	0
Dicrotofos									0	0	0	0	0	0	0	0
Endosulfan	3			1			5		4	0	0	1	0	0	6	0
Etoprophos									0	0	0	0	0	0	0	0
Fenpropatrin	1				1				1	0	0	0	1	0	0	0
Fenvarelato								1	0	0	0	0	0	0	0	1
Formetanato								1	0	0	0	0	0	0	0	1
Fosetil-Al+mancozeb	1								1	0	0	0	0	0	0	0
Lambda cihalotrina		1							0	1	0	0	0	0	0	0
Malation									0	0	0	0	0	0	0	0
Mancozeb	6	2	1	3	1	2	4		7	2	1	4	1	2	5	0
Maneb							2		0	0	0	0	0	0	2	0
Metalaxil + mancozeb				1					0	0	0	1	0	0	0	0
Metamidofos	2	2	1	1	1	1	2		2	2	1	1	1	1	2	0
Metomyl	1					1	2		1	0	0	0	0	1	2	0
Monocrotofos			1		1		1		0	0	1	0	1	0	1	0
Oxicloruro de Cu+Mn+Zn							1		0	0	0	0	0	0	1	0
Profenofos	4			1	1		2		5	0	0	1	1	0	2	0
Tiometon		1							0	1	0	0	0	0	0	0
Triclorfon		1							0	1	0	0	0	0	0	0
Tridemorph		1						1	0	1	0	0	0	0	0	1
Total de frecuencia de uso	23	12	5	10	6	4	21	4								
Porcentaje sobre el total	27	14	6	12	7	5	25	5	27	14	6	12	7	5	25	5

Cuadro Anexo 10. Frecuencia de uso de productos y porcentaje, por cultivos, en la zona de La Vega

	Frecuencia de uso de productos, por cultivo			Porcentaje de frecuencias de productos, por cultivo		
Principio activo	Auyama	Berenjena	Vegetales chinos	Auyama	Berenjena	Vegetales chinos
Mancozeb	2	4	1	2	5	1
Cipermetrina		1	9	0	1	11
Benomyl	1	3	2	1	4	2
Propineb		3	5	0	4	6
Monocrotofos	1	3	1	1	4	1
Deltametrina	1	3		1	4	0
Profenofos	1	2	1	1	2	1
Endosulfan	1	2		1	2	0
Diazinon	1		2	1	0	2
Dicofol			5	0	0	6
Clortalonil	1	1		1	1	0
Bitertanol		1	2	0	1	2
Pirimicarb		1	2	0	1	2
Fosetil-Al +mancozeb	1			1	0	0
Malation	1			1	0	0
Profenofos+cipermetrina	1			1	0	0
Profenofos+metomil	1			1	0	0
Metamidofos		2		0	2	0
Lambda cihalotrina		1	1	0	1	1
Metalaxil+mancozeb			2	0	0	2
Abamectina		1		0	1	0
Bifentrin		1		0	1	0
Hexaconazole		1		0	1	0
Metoyl		1		0	1	0
Thiocyclam hidrogenoxalate		1		0	1	0
Carbendazin			1	0	0	1
Carbofuran			1	0	0	1
Dicrotofos			1	0	0	1
Etoprophos			1	0	0	1
Hectacloro			1	0	0	1
Oxicloruro de Cu+Mn+Zn			1	0	0	1
Total de frecuencia de uso	13	32	39			
Porcentaje sobre total	15	38	46	15	38	46

Cuadro Anexo 11. Dosis normal, deficiente o excesiva por principio activo de los plaguicidas expresados en frecuencia y porciento en relación a las dosis recomendadas

Principio activo	Dosis utilizadas			Porcentaje de frecuencias utilizado		
	Deficiente o no usa	Normal	Excesiva	Deficiente o no usa	Normal	Excesiva
Abamectina			1	0.00	0.00	0.70
Acephato		1	1	0.00	1.25	0.70
Alfacipermetrina			2	0.00	0.00	1.41
Bacillus thuringiensis	1			1.61	0.00	0.00
Bitertanol	2	1		3.23	1.25	0.00
Benalaxil + mancozeb		1		0.00	1.25	0.00
Benomyl			8	0.00	0.00	5.63
Bifentrin			1	0.00	0.00	0.70
Captan	1			1.61	0.00	0.00
Carbendazin				0.00	0.00	0.00
Carbofuran	1			1.61	0.00	0.00
Cipermetrina	2	4	2	3.23	5.00	1.41
Clortalonil	3	3	5	4.84	3.75	3.52
Cobre + mancozeb	3	4		4.84	5.00	0.00
Deltametrina			15	0.00	0.00	10.56
Diazinon		1	5	0.00	1.25	3.52
Diazinon + endosulfan				0.00	0.00	0.00
Dicofol	4		1	6.45	0.00	0.70
Dicrotofos	1	1		1.61	1.25	0.00
Endosulfan	2	16	8	3.23	20.00	5.63
Etoprophos				0.00	0.00	0.00
Fenpropatrin			2	0.00	0.00	1.41
Fenvarelato		1		0.00	1.25	0.00
Formetanato	1			1.61	0.00	0.00
Fosetil-Al + mancozeb	1	1		1.61	1.25	0..00
Hectacloro				0.00	0.00	0.00
Hexaconazole				0.00	0.00	0.00
Hidróxido cúprico	1			1.61	0.00	0.00
Iprodiona			2	0.00	0.00	1.41
Lambda cihalotrina		1	3	0.00	1.25	2.11
Malation		1		0.00	1.25	0.00
Mancozeb	7	16	22	11.29	20.00	15.49
Maneb	5		3	8.06	0.00	2.11
Metalaxil + mancozeb	9	1	1	14.52	1.25	0.70
Metamidofos	1	1	19	1.61	1.25	13.38
Metomyl	8		6	12.90	0.00	4.23
Monocrotofos	1	2	12	1.61	2.50	8.45
Oxicloruro de Cu+Mn+Zn	2		2	3.23	0.00	1.41
Parathion	1			1.61	0.00	0.00
Primicarb			6	0.00	0.00	4.23
Profenofos	2	17	2	3.23	21.25	1.41
Profenofos+cipermetrina				0.00	0.00	0.00
Profenofos+metomil				0.00	0.00	0.00
Propineb	2	3	4	3.23	3.75	2.82
Thiocyclam hidrogenox.	1		5	1.61	0.00	3.52
Tiodicarb		1		0.00	1.25	0.00
Tiometon		1	3	0.00	1.25	2.11
Triclorfon		1		0.00	1.25	0.00
Tridemorph		1	1	0.00	1.25	0.70
Total de frecuencias	62	80	142			
Porcentaje sobre total	22	28	50	100	100	100

Cuadro Anexo 12. Frecuencias de aplicación de productos, en estratos por intervalo de tiempo y porcentaje

Principio activo	Frecuencia de aplicacion de los productos Cada 2-6 d	Cada 7-14 d	Cada 14-19 d	Cada 30-60d	Sin datos	Unica aplic.	Porcentajes de frecuencia de aplicacion Cada 2-6 d	Cada 17-14 d	Cada 14-19 d	Cada 30-60 d	Sin datos	Unica aplic.
Abamectina			1				0	0	3	0	0	0
Acephato		1		1			0	1	0	20	0	0
Alfacipermetrina		1	1				0	1	3	0	0	0
Bacilus thuri.		1					0	1	0	0	0	0
Bitertanol		2	1				0	1	3	0	0	0
Benalaxil/man		1					0	1	0	0	0	0
Benomyll		3	1		3		0	2	3	0	6	0
Bifentrin		1					0	1	0	0	0	0
Captan		1					0	1	0	0	0	0
Carbendazin		1					0	1	0	0	0	0
Carbofuran					1		0	0	0	0	2	0
Cipermetrina	1	3	2		2		7	2	5	0	4	0
Clortalonil	1	9			1		7	5	0	0	2	0
Cobre/mancoz		7					0	4	0	0	0	0
Deltametrina		10	4		1		0	6	11	0	2	0
Diazinon		4	1	1			0	2	3	20	0	0
Diazinon/endo				1			0	0	0	20	0	0
Dicofol		1	2		2		0	1	5	0	4	0
Dicrotofos		1					0	1	0	0	0	0
Endosulfan	2	18	3		3		13	10	8	0	6	0
Etoprophos					1		0	0	0	0	2	0
Fenpropatrin		1	1				0	1	3	0	0	0
Fenvarelato	1						7	0	0	0	0	0
Formetanato	1						7	0	0	0	0	0
Fosetil - Al+ man.		1	1				0	1	3	0	0	0
Hectacloro						1	0	0	0	0	0	33
Hexaconazole							0	0	0	0	0	0
Hidróxicúprico	1						7	0	0	0	0	0
Iprodiona		2					0	1	0	0	0	0
Lambda cihalotr		3	1				0	2	3	0	0	0
Malation			1				0	0	3	0	0	0
Mancozeb		33	2		11		0	19	5	0	21	0
Maneb	1	6			1		7	3	0	0	2	0
Metalaxil/man	1	7			3		7	4	0	0	6	0
Metamidofos	2	9	3	1	6		13	5	8	20	12	0
Metomyl		9	1		2	2	0	5	3	0	4	67
Monocrotofos		7	4		4		0	4	11	0	8	0
Oxicloruro de Cu+Mn+Zn		3			1		0	2	0	0	2	0
Parathion					1		0	0	0	0	2	0
Pirimicarb	1	2			3		7	1	0	0	6	0
Profenofos		15	5		1		0	9	13	0	2	0
Prof.+ ciperm.		1					0	1	0	0	0	0
Prof. + metomil		1					0	1	0	0	0	0
Propineb	1	3	3		2		7	2	8	0	4	0
Thiocyc. H -oxal.		3			3		0	2	0	0	6	0
Tiodicarb		1					0	1	0	0	0	0
Tiometon	1	2		1			7	1	0	20	0	0
Triclorfon		1					0	1	0	0	0	0
Tridemorph	1	1					7	1	0	0	0	0
Total frec. uso	15	176	38	5	52	3						
%sobre total	5	61	13	2	18	1	100	100	100	100	100	100

Cuadro Anexo 13. Frecuencia de aplicación de plaguicidas – cultivo de ajíes

Principio activo	7–14 días	14–21 días	% por producto
Benalaxil + mancozeb	3	0	3
Captan	3	0	3
Cipermetrina	0	3	3
Cobre + mancozeb	0	12	12
Deltametrina	3	0	3
Endosulfan	12	0	12
Fenpropatrin	3	0	3
Fosetil-ALl+ mancozeb	0	3	3
Mancozeb	21	0	21
Metamidofos	6	3	9
Metomyl	3	0	3
Monocrotofos	6	0	6
Profenofos	15	3	18
Tiometon	3	0	3
Total	76	24	100

Cuadro Anexo 14. Frecuencia de aplicación de plaguicidas – cultivo de auyama

Principio activo	7–4 días	14–21 días	% por producto
Abono foliar	0	8	8
Benomyl	8	0	8
Clortalonil	8	0	8
Deltametrina	8	0	8
Diazinon	0	8	8
Endosulfan	0	8	8
Fosetil-Al + mancozeb	8	0	8
Malation	0	8	8
Mancozeb	15	0	15
Monocrotofos	8	0	8
Profenofos	0	8	8
Profenofos + cipermetrina	8	0	8
Total	62	38	100

Cuadro Anexo 15. Frecuencia de aplicación de plaguicidas – cultivo de berenjena

Principio activo	Sin especificar	7–14 días	14–21 días	% por producto
Abamectina	0	2	2	3
Abono foliar	5	0	0	5
Bitertanol	0	0	2	2
Benomyl	3	3	0	7
Bifentrin	0	2	0	2
Cipermetrina	0	0	2	2
Clortalonil	0	2	0	2
Deltametrina	2	2	3	7
Endosulfan	5	3	0	8
Hexaconazole	0	2	0	2
Lambda cihalotrina	0	2	2	3
Mancozeb	11	5	2	18
Maneb	0	3	0	3
Metamidofos	5	0	0	5
Monocrotofos	5	2	3	10
Parathion	2	0	0	2
Pirimicarb	0	2	0	2
Profenofos	0	3	2	5
Propineb	2	0	3	5
Thiocyclam hidrogenoxalate	5	0	0	5
Total	48	33	20	100

Cuadro Anexo 16. Frecuencia de aplicación de plaguicidas – cultivo de cebolla

Principio activo	7–14 días	8–13 días	>30 días	% por producto
Acephato	8	0	8	17
Clortalonil	0	8	0	8
Diazinon	0	0	8	8
Lambda cihalotrina	8	0	0	8
Mancozeb	8	8	0	17
Metamidofos	8	0	8	17
Tiometon	0	0	8	8
Triclorfon	8	0	0	8
Tridemorph	8	0	0	8
Total	50	17	33	100

Cuadro Anexo 17. Frecuencia de aplicación de plaguicidas – cultivo de habichulas

Principio activo	7–14 días	14–21 días	% por producto
Alfacipermetrina	0	17	17
Abono foliar	17	0	17
Mancozeb	17	0	17
Monocrotofos	17	0	17
Cobre + mancozeb	17	0	17
Metamidofos	17	0	17
Total	83	17	100

Cuadro Anexo 18. Frecuencia de aplicación de plaguicidas – cultivo de melón

Principio activo	7–14 días	14–21 días	% por producto
Alfacipermetrina	10	0	10
Bacillus thuringiensis	10	0	10
Deltametrina	10	0	10
Endosulfan	10	0	10
Mancozeb	30	0	30
Metalaxil + mancozeb	10	0	10
Metamidofos	10	0	10
Profenofos	0	10	10
Total	90	10	100

Cuadro Anexo 19. Frecuencia de aplicación de plaguicidas – cultivo de pepino

Principio activo	Sin especificar	7–14 días	14–21 días	% por producto
Cobre + mancozeb	0	17	0	17
Fenpropatrin	0	0	17	17
Mancozeb	0	17	0	17
Metamidofos	0	17	0	17
Monocrotofos	17	0	0	17
Profenofos	0	17	0	17
Total	17	67	17	100

Cuadro Anexo 20. Frecuencia de aplicación de plaguicidas – cultivo de sandia

Principio activo	Una sola vez	2–7 días	14–21 días	% por producto
Clortalonil	0	8	0	8
Endosulfan	0	8	0	8
Hidróxido cúprico	0	8	0	8
Mancozeb	0	15	0	15
Metalaxil + mancozeb	0	8	0	8
Metamidofos	0	15	8	23
Metomyl	8	0	0	8
Pirimicarb	0	8	0	8
Propineb	0	8	0	8
Tiometon	0	8	0	8
Total	8	85	8	100

Cuadro Anexo 21. Frecuencia de aplicación de plaguicidas – cultivo de tomate

Principio activo	Una sola vez	Sin especific.	2–7 d	7–14 d	14–21 d	40–60 d	% por producto
Abono foliar	0	0	0	1	0	0	1
Clortalonil	0	1	0	6	0	0	7
Cobre + Mancozeb	0	0	0	1	0	0	1
Deltametrina	0	0	0	4	0	0	4
Diazinon	0	0	0	2	0	0	2
Diazinon + endosulfa	0	0	0	0	0	1	1
Endosulfan	0	0	1	11	2	0	14
Insecticida origen vegetal	0	1	0	0	0	0	1
Iprodiona	0	0	0	2	0	0	2
Mancozeb	0	4	0	10	1	0	15
Maneb	0	1	1	4	0	0	6
Metalaxil + mancoz.	0	2	0	5	0	0	7
Metamidofos	0	3	0	3	1	0	7
Metomyl	1	0	0	7	1	0	8
Monocrotofos	0	0	0	2	1	0	3
Oxicloruro de Cu+Mn+Zn	0	0	0	3	0	0	3
Pirimicarb	0	1	0	1	0	0	2
Profenofos	0	1	0	6	1	0	8
Profenofos + metomil	0	0	0	1	0	0	1
Thiocyclam hidrogenoxalate	0	0	0	3	0	0	3
Tiodicarb	0	0	0	1	0	0	1
Tiometon	0	0	0	1	0	0	1
Total	1	14	2	76	7	1	100

Cuadro Anexo 22. Frecuencia de aplicación de plaguicidas – cultivo de vegetales Chinos

Principio activo	Una sola vez	Sin especific.	2 a 7 d	7 a 14 d	14 a 21 d	% por producto
Abono foliar	0	8	0	0	4	12
Bitertanol	0	0	0	4	2	6
Benomyl	0	2	0	0	0	2
Carbendazin	0	0	0	2	0	2
Carbofuren	0	2	0	0	0	2
Cipermetrina	0	4	2	6	0	12
Deltametrina	0	0	0	4	4	8
Diazinon	0	0	0	4	0	4
Dicofol	0	4	0	2	4	10
Dicrotofos	0	0	0	2	0	2
Etoprophos	0	2	0	0	0	2
Fenvarelato	0	0	2	0	0	2
Formetanato	0	0	2	0	0	2
Hectacloro	2	0	0	0	0	2
Lambda cihalotrina	0	0	0	2	0	2
Mancozeb	0	0	0	2	0	2
Metalaxil + mancozeb	0	2	0	2	0	4
Monocrotofos	0	0	0	0	2	2
Oxicloruro deCu+Mn+Zn	0	2	0	0	0	2
Pirimicarb	0	4	0	0	0	4
Profenofos	0	0	0	2	0	2
Propineb	0	2	0	6	2	10
Tridemorph	0	0	2	0	0	2
Total	2	33	8	39	18	100

Cuadro Anexo 23. Gastos totales de pruccion por tarea, gastos en control de plagas y porcentaje de costo de control, por cultivos. Totales para las tres zonas de encuesta: Azua, La Vega y Noroeste

	Tomate	Berenjena	Aji	Sandia y melon	Vegetales chinos
Gasto total de produccion por tarea,en RD$ del año					
1993 (RD$/ta)	900	1617 ± 177	662 ± 163	-	2,120 ± 852
1992 (RD$/ta)	794 ± 173	2,750 ± 2,250	753 ± 160	838 + 65	3,000
1991 (RD$/ta)	873 ± 138	1,683 ± 1,638	652 ± 23	800	3,300
1990 (RD$/ta)	839 ± 282	1,875 ± 1,125	500	700	-
Gasto total de aplicacion y productos de control, en RD$ del año					
1993 (RD$/ta)	405	567 ± 75	240 ± 65	-	729 ± 268
1992 (RD$/ta)	373 ± 232	2,113 ± 1,888	268 ± 69	279 ± 48	900
1991 (RD$/ta)	338 ± 81	1,148 ± 1,309	209 ± 41	240	990
1990 (RD$/ta)	451 ± 255	1,550 ± 850	200	210	-
Porcentaje de costo de control sobre costo total					
1993	0.45	0.35 ± 0.03	0.36 ± 0.10	-	0.36 ± 0.12
1992	0.45 ± 0.20	0.63 ± 0.18	0.34 ± 0.06	0.32 ± 0.08	0.30
1991	0.38 ± 0.05	0.53 ± 0.16	0.33 ± 0.08	0.30	0.30
1990	0.51 ± 0.13	0.53 ± 0.13	0.40	0.30	-

Cuadro Anexo 24. Utilizacion de equipos en aplicacion de plaguicidas, rotacion de plaguicidas, fuente de la recomendacion, conteo de plagas, lapse de espacio entre aplicaciones y conocimiento de los insecticidas prohibidos, en la zona de la encuesta, Azua, La Vega y Noroeste

	Tomate	Berenjena	Aji	Sandia y melon	Vegetales chinos
Que equipos utiliza en la aplicacion de plaguicidas?					
Bomba de espalda motorizada (%)	16	10	-	25	20
Bomba de mochila, manual (%)	90	100	100	100	100
Bomba motorizada estacionaria (%)	32	-	-	25	-
Bomba neumatica axial de tractor (%)	11	-	-	-	-
Otro (especifique) (%)	1	-	17	-	-
Hace usted rotación de los productos plaguicidas que aplica?					
No (%)	21	60	-	25	60
Si (%)	74	30	83	75	40
No contesta (%)	5	10	17	-	-
Quién le recomienda el uso de los insecticidas?					
Usted mismo (%)	32	40	50	50	40
Un tecnico (%)	74	40	50	50	40
El vecino (%)	5	20	-	-	20
La casa comercial vendedora (%)	5	20	17	0	20
Me entero por otros medios (%)	-	-	-	-	10
Utiliza conteo de plagas antes de decidir la aplicacion?					
No (%)	74	80	100	100	70
Si (%)	26	20	-	-	30
Tiene en cuenta el tiempo que debe aguardar desde la ultima aplicacion de insecticida hasta el momento en que realiza la cosecha?					
No (%)	68	20	33	75	60
Si (%)	32	80	67	25	40
Conoce usted cuales son los insecticidas prohibidos en el cultivo principal?					
No (%)	84	60	67	75	30
Si (%)	16	40	33	25	60
Conozco mas o menos	-	-	-	-	10

Cuadro Anexo 25. Frecuencias de uso de métodos de control cultural, biológico, mecánico or físico, 'lega' y mediante el uso de atrayentes en el cultivo de hortalizas. República Dominicana, 1993

Conoco usted otros metodos de control de la plaga principal en el cultivo principal y alguna vez los ha aplicado, en los últimos años?

	Tomate	Berenjena	Aji	Sandia y melon	Vegetales chinos
Control cultural					
1993 (%)	53	90	50	25	100
1992 (%)	84	80	83	100	70
1991 (%)	68	60	17	25	20
1990 (%)	68	60	17	25	20
Control biológico					
1993 (%)	11	50	-	-	40
1992 (%)	11	50	-	-	20
1991 (%)	11	20	-	-	-
1990 (%)	11	20	-	-	-
Control mecanico o físico					
1993 (%)	16	10	17	25	-
1992 (%)	32	10	17	25	-
1991 (%)	32	10	17	25	-
1990 (%)	32	10	17	25	-
Control legal*					
1993 (%)	5	90	-	-	60
1992 (%)	11	80	-	-	40
1991 (%)	11	80	-	-	40
1990 (%)	11	80	-	-	40
Usando atrayentes					
1993 (%)	5	-	-	-	-
1992 (%)	5	-	-	-	-
1991 (%)	5	-	-	-	-
1990 (%)	5	-	-	-	-

* Control legal es el cumplimiento de las Resoluciones de Veda de Siembra de cultivos, generadas por la SEA.

TRAINING-DRIVEN RESEARCH: THE FOURTH MODEL FOR DEVELOPING IPM STRATEGIES

C S Barfield and M Swisher
University of Florida, USA

(This paper was prepared for the seminar but could not be presented – ed.)

During the 1992 USA presidential campaign, now President Bill Clinton stated that the USA Government had been '...organized to fight the Cold War'. Significant re-organization would be necessary to fight different kinds of wars, including those of domestic economy and environment. Much the same can be said about integrated pest management (IPM). Since the early 1940s, agricultural policy and Research & Development (R&D) in industrialized countries have been structured to capitalize on the 'Green Revolution', which itself is a product of the driving need to satisfy consumer demands for cheap, abundant food. From the 1950s to the 1980s, we have moved from pesticide, irrigation, machinery and fertilizer specialists to biological control, cultural control and genetic engineering specialists. We have prized and rewarded ever-narrower specializations, but find that in the 1990s a new structure may well be demanded to resolve ecological problems while not reducing food production capability. The institutional models we have invented to develop and deliver IPM are fundamental.

How well do the major models of agricultural research and extension serve the needs of IPM? How well do these models preserve indigenous knowledge? If we are indeed losing such knowledge, what kind of knowledge is replacing it? Just how well has IPM fared in the major global models of research-extension? We turn attention now to those models and their assumptions, successes and failures, as a basis for analyzing the institutional context in which IPM operates.

A comparison of global models

Model of research/extension

There appear to be four institutional models of the relationship among research, extension and training. International developers and/or research scientists appear to cling to their favourite model with tenacity. Three of these models are global, and one may well soon be. They are: (i) the USA Land Grant System, (ii) World Bank's Training and Visitation, (iii) Farming Systems Research & Extension, and (iv) Training-Driven Research. Adherents to the first three tend to claim that one particular model is more effective than others and tend to view each model as universally applicable. Before looking at the Training-Driven Research model, we discuss the three global models.

Land grant

The land grant system was based on the concept of combining teaching, research and extension in a single institution. The general concept has been adopted by many institutions world-wide. International research centres usually do not have specific extension responsibilities and many do not offer formal academic degrees. Almost all do, however, provide a variety of short-term training for agricultural scientists, including extension agents. Most work very closely with national extension systems. This represents the essence of the land grant model, despite the structural modifications. Several authors (Claar et al. 1984; Butler 1983) explicitly discuss the applicability of the USA model for developing nations. In the USA, the three functions do reside in a single institution – land grant colleges in each of the fifty states.

The critical aspect of the land grant system is the linkage between research and extension. Extension agents theoretically serve as both forward and backward links in the technology delivery system. They provide new technology to farmers and they inform researchers of the problems that require solving at the farm level.

Although not all agree, most would argue that this linkage can only function when research and extension are housed in a single institution and identify priorities in an unbiased fashion. In many developing nations, this is not the case and many adherents of the land grant model argue that institutional constraints to the linkage process are the main stumbling block in the technology delivery system in nations where research and extension are separated.

Realizing its agricultural roots and potential for self-sufficiency, even global dominance, the Federal Government of the USA institutionalized agricultural research in the 186's with two successive Federal Acts – the Morrill Land Grant Act and the Hatch Act. Thirty years later, the same process would be used to add historically black colleges and universities (HBCUs) to the Land Grant System. In both cases, initial faculty were experiential practitioners of agriculture, and their research agenda was driven by on-farm priorities.

One must grasp the strengths and weaknesses of the land grant system for it is not without flaws. Increasingly, what drives the research agenda are vogue extra-mural grants programmes rather than farmer priorities. There is evidence (e.g. Meyer 1993; Gattas and Eger 1993) that land grant institutions are poorly structured to serve a changing clientele and a host of holistic issues. Land Grant Universities no longer represent the producer research agenda they did in 1870. This is not surprising given the change in mandate – from helping farmers to helping consumers. The fact that most employees in these institutions sincerely believe that they were hired to help farmers does not change certain realities. Funds for helping farmers are limited and universities are driven to compete for extra-mural sources of financing. As a result, most institutions are composed of faculty often hired in response to vogue funding programmes and the necessity to be competitive for extra-mural grants.

At the technical level of individual faculty, USA land grant institutions are superb. The rewards system for faculty in these institutions has been closely tied to grants and publications rather than to solution of problems; thus, there are literal mosaics of highly talented faculty, each with his or her narrow specialty. Such a structure is the antithesis of IPM. This is why most institutionalized IPM efforts consist of faculty committees. The net effect is that land grant institutions have been very good at refinement of individual IPM tactics and very weak at implementation of ecological strategies aimed at complexes of pests.

Training and visit (T & V)

This hierarchial system was first introduced by the World Bank in the 1970s in India, Turkey, Burma, Nepal, Sri Lanka and Thailand and is utilized in over 40 countries. The basic assumptions underlying the T&V model are: (i) that much more technology already exists than is adopted by farmers and (ii) that inefficiencies in the extension delivery system account for much of the lack of adoption (Benor et al. 1984; Baxter and Pickering 1988). The model therefore places by far the greatest emphasis on training and outreach. The research component of the model is generally restricted to site-specific testing of existing technologies. In some parts of the world, however, as it has become apparent that effective technologies for specific problems do not exist, the T&V model has tended to increase the emphasis on the research component of the technology delivery model (Mehta 1983).

Benor and Baxter (1984) describe the system fully. The basic concept is a hierarchical system. In its simplest form, one subject matter specialist trains a limited number of regional extension agents, who provide training to local extension agents, and so on, until the bottom tier of the system where village farmers form the base of the information delivery system. The model stresses timeliness and the agricultural production process is 'tracked' by the training process; e.g. training in improved seed-bed preparation will be delivered immediately prior to the time when land preparation occurs. Frequent, regular reporting and accountability are key elements in improving the efficiency of outreach.

The T & V system was in place in Indonesia prior to implementation of the current Indonesian National IPM Programme. Dilts (1991) enumerates the many problems T & V had in delivering effective IPM programmes and cites others who have referred to T & V as indicators for 'Tragic and Vain' or 'Train and Vanish'. Among the problems highlighted were (i) methods geared to top facilitators, (ii) force-fit schedules, (iii) programmes with no clear goals, (iv) lack of well-trained facilitators, (v) no link to broader issues and (vi) no sanctions on attendance at training sessions. For these and other reasons, T & V had a poor track record in Indonesia and has been/is being replaced with training-driven research as the national model.

This model may have worked well in India (although some question even that), but evidence is mounting that, most often, T&V results in a sort of institutionalized message delivery service. Once trained, both farmers and their support network are left to fend for themselves, and follow-up training is rare. This is a fragile model that depends heavily on high-level training, efficient networks, mutually compatible objectives and, most of all, frequent adjustments in both technical knowledge and response to problems.

Farming systems

The farming systems approach to technology delivery grew out of development projects in Latin America. Over the last 20 years, this approach has been promoted by several international development agencies, perhaps most conspicuously by the United States Agency for International Development (USAID) during the 1980s. Many international research institutions, such as the International Institute for Tropical Agriculture (IITA), the International Centre for the Improvement of Maize and Wheat (CIMMYT) and the International Potato Centre (CIP) have stressed the use of this model in their work.

The farming systems approach does differ widely from the T&V system in the sense that it primarily emphasizes research. The underlying assumption is that most existing technology is not adapted to the specific conditions present in a given region. Farmers are therefore unable to adopt improved technologies. The major emphasis is on site-specific, or adaptive research (see Shaner et al. 1982 and Simmonds 1985, for a comprehensive discussion of the farming systems approach). While some 'new' technology is developed, most farming systems research in fact revolves around local tests of existing technologies.

Although adherents of the model often argue that there are major differences between the farming systems and the land grant approach, many people find it difficult to discern any basic differences between the two. For example, both the land grant and the farming systems model depend on linkages between research and extension and prove difficult to utilize where the two are not housed in the same institution. Many adherents of the land grant system would claim that the farming systems emphasis on such features as on-farm, site-specific testing and multi-disciplinary research teams are in fact inherent to the land grant model as well. One major difference has emerged in practice. The fact is that most farming systems projects emphasize research much more than extension; examples of farming systems projects where mass dissemination of new technology is a key element are difficult to identify.

A basic tenet in the emergence of farming systems was that a significant segment of global farmers had been by-passed by the Green Revolution. Either their land holdings were too poor to grow high-yielding crops and/or their economies too poor to afford necessary inputs. To date, however, most on-farm tests have involved variety trials and/or fertilizer trials – two of the very specifics that the clientele served by farming systems were not supposed to be able to afford. This seems puzzling.

Fundamental use of regression analysis as a predictive tool for various on-farm environments leaves many quantitative ecologists highly skeptical of the rigour of farming systems methods. There are serious questions, mostly by those outside farming systems, of the use of modified stability analysis, now being heavily promoted by

long-time farming systems scientists. Despite the immense pressure from a host of pests, there are apparently few if any cases of on-farm analysis targeting improved pest management with anything other than pesticide use. Partly, this is true because most farming systems types are social scientists rather than ecologists.

The three models and IPM

Which of these three models is best prepared to develop and deliver IPM strategies in poor, tropical countries? How successful have they been in doing so? How might the models be altered to better deliver IPM strategies?

Scale is an important consideration in IPM, particularly IPM of the second School-of-Thought. Pests are mobile. A strategic approach to pest management therefore, by its very nature, implies a larger-than-field and usually a larger-than-farm approach (see Bottrell 1979). The tendency to focus on field level approaches appears to be due partly to the research paradigm utilized by IPM researchers, which stresses a rapid approach to reducing pest numbers. Capitalism-focused agricultural enterprises, where economic decisions are made by individuals rather than societies, are also pertinent in this sense. The agricultural science research tradition focuses on subjecting a limited number of variables to manipulation within an experimental setting where, to the degree possible, variability is controlled. Results are measured in terms of the relative effectiveness of one treatment versus others included in the field setting.

This approach differs strongly from that of other sciences where manipulation is stressed less and observation more. In the biological sciences, for example, scientific research which is based on observation of organisms' responses to environmental variability is common and results of such studies are considered valid. These studies, of course, provide insights into the behaviour of organisms. Although the results of such studies can ultimately be used to influence their behaviour, the immediate 'utility' of such studies is lower than that of the agricultural science approach where the emphasis is placed on finding ways to reduce unwanted numbers of organisms in the short term.

Not surprising, the approach of the agricultural sciences tends to excel in developing specific tactics to reduce pest numbers over the short term. These may include use of chemicals, biological control methods, or cultural practices. Also not surprising, this approach tends have little effectiveness in explaining the longer term behaviour of organisms or in predicting how variables extraneous to the experimental design will affect their behavior. Hence, by its nature, the applicability of results of agricultural experimentation tend to be limited to the field. They also tend to stress the suppression of specific pests for specific crops (or animals) over a relatively short period of time, often a single growing season.

All three models (T&V, land grant, and farming systems) have relied on the same research paradigm. Thus, it is not surprising that one finds relatively little difference in approach to IPM among the three. More or less, farmers are relegated to a 'passive recipient's' role. Various recipes for pest control are delivered by a host of media. A strategic approach to IPM not only requires a larger-than-field approach, but a multi-disciplinary approach. Pests interact with each other and with the environment as an ensemble of organisms. Weed populations will clearly affect nematode and insect populations, for example, which will in turn affect the weed population. The need to view pest management from a holistic perspective has been clearly identified, and is implied in the term 'integrated' pest management. Nonetheless, a multi-disciplinary approach to pest management has proven difficult to achieve in practice.

This difficulty in achieving the 'I' in IPM is related at least in part to the development of highly specialized disciplines within the agricultural sciences. Agriculture is faced with a dilemma: as we learn more, a higher degree of specialization is needed on the part of individual researchers. At the same time, however, there is an even greater need to integrate the knowledge that these specialists produce which is, by its very nature, highly specific.

To date, our success has been limited. The approach that has been utilized has been primarily that of the multi-disciplinary team. Even in the case of the farming systems approach, which is theoretically based on the concept of multi-disciplinary field teams, true integration is lacking. While we can form multi-disciplinary teams, we appear to be lacking the training or perhaps individuals who are specifically trained in the ability to synthesize highly specialized information. Synthesis, as opposed to mere summation, cannot be achieved simply by adding component pieces of knowledge together. It requires analyzing that knowledge, understanding the potential interactions between different components in the system, and being able to predict how those components will react, based on the specific knowledge provided by component specialists.

The 'sophistication' of researchers, extensionists, and farmers has increased significantly over the past 40 years. IPM has led the way in this increasing sophistication in many cases. In fact, the very aspects of IPM we have criticized, as currently practiced, exist in large part because of the level of complication IPM has achieved. In the early years of the industrial revolution in agriculture, and still today in many parts of the world, researchers, extensionists, and farmers all stressed yield as the primary measure of success. Industrial inputs to agriculture were relatively inexpensive, and research and farmers focused on applying **biologically optimum** rates of inputs. In these pre-IPM days, one did not question whether there was an 'acceptable' level of infestation of pests. One concentrated on eliminating to the degree possible all pests from a crop or animal.

This simplistic approach led to serious problems, which showed up first and most seriously in pest management. Continual, high levels of application of pesticides produced resistance in target organisms. We quickly found ourselves on an unending treadmill of chemical–resistance–new chemical. IPM first grew out of this understanding that a biologically optimum rate of application could vary, could in fact be less, than the rate required to essentially eliminated an organism from the agroecosystem.

Movement away from continual, high levels of use of industrial pesticides was reinforced in the mid 1970s when the price of petroleum-based inputs rose precipitously. Farmers and researchers began to think in terms of economically optimum rates of application of pesticides. These rates were often much lower than even the re-defined biologically optimum rates. Again, IPM was quick to incorporate this new reality, developing the concept of economic thresholds which remain a mainstay in the application of integrated pest management.

Today, we are faced with yet another challenge. Agriculture's impact on the environ-ment is of growing concern. Again, the use of pesticides has come to the forefront. As early as the 1960s, off-site impacts of pesticide applic-ation, particularly of DDT, began to appear, causing growing concern. Today, IPM is more concerned than ever with the question of unwanted impacts from pest management, but, to date, increased emphasis on the environmental consequences of pest management has resulted in little change in strategy. We have continued to focus on short-term management. Although reduced reliance on chemicals has been stressed, with some arguing that chemical control should be viewed as a 'last resort' measure, we have relinquished our reliance on the quick fix of chemicals reluctantly. Indeed, major efforts have gone into making chemicals 'safer' by decreasing needed active ingredients, reducing their mobility, and reducing their persistence in the environment.

The challenge that faces us is to incorporate yet another new concept in IPM: the concept of environmentally optimum pest management. This will require consideration not only of the efficacy and economic viability of a particular pest management tactic, but also the environmental impact of the tactic. While some argue that environmental protection is prohibitively expensive, assumes exaggerated importance, or is not an issue of importance at all, the growing public concern over these issues demands that we re-think our approach to pest management

and to move beyond the use of tactics to the development of strategy.

Which model performs best?

Despite the apparent differences in the three models of technology development and delivery described above, real differences in their ability to develop and delivery strategies for pest management are minimal. All, on the other hand, have proven adept at using the menu of pest management tactics that has been developed over the last several decades. This does not reflect upon the practitioners of one or the other system, nor does it argue that these approaches to technology development and delivery are inherently weak. Rather, it argues that the larger research and technology delivery system within which we all work has imposed upon us (or, rather, we have imposed upon ourselves) a series of constraints which make it difficult to approach pest management, and indeed agricultural development, from an integrated, strategic perspective.

Training-driven research: a viable alternative?

In many ways, this approach overcomes historical problems with the other three global models. The need to develop 'new' technologies is not demanded unless absolutely necessary. At least the land grant model continues to adhere to a 'research at all cost' paradigm, even if much of that research is redundant and inapplicable. Such is to be expected in systems that place high value on grants and publications.

Training-driven research promises to do one additional thing the other three models do not even mention: prioritize and orchestrate discipline expertise. Land grant cooperative ventures tend to form collaborations as a part of competition for funding. If, once funded, the real field situation demands a virologist (rather than the fungal specialist on the team), there are often problems. The core of this problem is the ever-narrowing expertise of land grant faculty. Under training-driven research, a broad range of narrow expertise is ideal; however, it must wait in the wings until called upon for research by those performing the training and identifying the problems needful of research or demonstration. Further, once called upon, it must perform quickly and must have as its ultimate objective feedback into the training process. Such a paradigm is totally different than now practiced by land grant faculty. There can be no discussion of abilities to simultaneously meet the needs of training and of credentials for refereed journal articles. With land grant faculty, the latter will always win. This, by the way, was the same dilemma land grant faculty faced during the 1980s when modelling and simulation were in their heyday. Necessary experiments for parameter estimation in models tended to take a back seat to journal editors' demands for publication. Far beyond the other three models, training-driven research offers a totally new and refreshing approach that is relevant, is field-based, is farmer-driven and that orchestrates a broad array of technical experts.

Training-driven research in Indonesia

Conventional wisdom in 1992, from the veterans of the pest wars, would say that practice of IPM in the tropics is not likely to be successful without use of synthetic organic pesticides and that a well-developed research infrastructure is demanded. These two ingredients are fundamental in the philosophy of the aforementioned IPM School. The 'trick', they say, is to use pesticides judiciously and safely (some feel the slogan 'Use Pesticides Safely' is an oxymoron), to search for alternatives, and to maintain a large, broad-based research effort aimed at seeking improved tactics. Develop an economic threshold, sample and spray 'only when necessary' is a typical early recommend-ation (see Bottrell 1979). Keep this going while you search for alternatives. History shows us that the alternatives come most often as slightly renovated tactics, not completely new strategies.

In 1970, Indonesia had only 10% of its rice area in modern varieties, and the brown planthopper was not considered to be a pest (Kenmore 1991). By the early 1970s, several multinational chemical companies were

given government contracts to treat tens of thousands of hectares of rice by air, as part of a national programme for rice self-sufficiency. By the late 1970s, Indonesia was subsidizing the frequent, prophylactic, often indiscriminate use of synthetic organic pesticides to the tune of about $162 million (1991 dollars, accounting for inflation). The supposed target of this bombardment was the brown planthopper which, by the late 1970s, was a resistant, secondary pest.

President Suharto, under economic strain from the large pesticide subsidies that were not resolving the problem and with evidence from a regional project that convinced him that pesticides were causing his problems in rice, signed a Presidential Decree in November 1986 declaring IPM to be national policy in Indonesia and eliminating governmental pesticide subsidies. No doubt, fear and anxiety spread like wildfire, especially from the subsidized multinational vendors of chemicals. Even some in Indonesia's Ministry of Agriculture predicted total destruction.

A grant from USAID for US$17 million was allocated for IPM implementation, and a contract was signed on 12 May 1989. With a portion of these funds, the Government of Indonesia contracted the United Nation's Food and Agriculture Organization (FAO) to provide technical support for the development of a national IPM programme. Since there had been almost 20 years of total neglect to any practice save pesticide application, the predominant question was: 'Just who is going to deliver this new national IPM programme?' Appropriately, the national project would begin with a massive training campaign.

Training had three basic objectives:

- to provide experiential training (in the paddy) crucial to rice production, including IPM
- to provide interpersonal and analytical skills training
- to backstop those trained.

Critically, oversight of the national programme was vested with the National Planning Board rather than the Ministry of Agriculture which is often the case. This one move proved crucial to success, as interdisciplinary and inter-agency cooperation could be managed without many of the provincial wars so often fought in such efforts.

In 3 years, the programme reached over 100,000 farmers with at least 50 hours of intensive, season-long field training. This is by far more than any other programme in the world. Within 18 months of project initiation, five separate training models (several of which were spontaneously derived by Indonesians themselves) were in existence, including farmers training other farmers in organized field schools paid for by farmers' organizations. By 1991, pesticide use in some locales had dropped by >90% and by more than 70% across the nation. Despite doomsday predictions, national rice yields increased by an average 10% and profits by even a larger percentage.

From a simple demonstration (see Barfield et al. 1991), an area-wide programme that removed in excess of 7 million rice stem borer eggs from nursery rice evolved. Such community-wide action prevented an area-wide pesticide application promoted by the Ministry of Agriculture. Now, a major community-run biological control effort exists by capturing and re-releasing natural enemies emerging from collected egg masses. Economic benefits are rivalled only by human health and environmental benefits derived from IPM training.

A concept has emerged from the Indonesian National IPM Project – a concept termed 'Training-driven research'. A fundamental premise is that, if no research is needed, do not conduct research. Likely, such a statement would be considered heresy in any US Land Grant Institution. The premise is to begin IPM with training, not research. The research agenda becomes set only when an attempt to train farmers how to be good husbanders of their rice crops identifies pieces of missing information – information not known or not extractable from the literature, traditional knowledge or minds of the users. The end-product of any research is not necessarily a refereed journal; rather, it is feedback into the next training session. Training is experiential (in

the paddy), not of the classroom/lecture variety. Training materials, both language and culture relevant, are abundant but do not drive the training programme. Evidence is that this approach works, and what more can be said to merit attention?

As part of the compromise needed to get the Government of Indonesia to sanction this programme, the principal agricultural univer-sity insisted that all participants in field school training attend the university for a minimum of one semester after field training. A principal problem the FAO project staff had to confront was keeping university faculty from 'undoing' all the experiential field training. Many university staff were educated in the USA or other locales adhering to the reductionist, industrialized agriculture model and its seeming concomitant partners, grants and publications. Experiences in the universities left many Indonesian IPM practitioners confused, as classroom lectures did not jive with the realities they had witnessed in the rice paddy. This experience further illustrates one of the major negative consequences of the compartment-alization of agricultural institutions whose primary motivations are grants and publications. From many accounts (e.g. Stone 1992), the Indonesian National IPM Programme has been identified as the model for future IPM.

There have been various indicators of the success of the training-driven research in Indonesia. Indiscriminate application of pesticides has dropped dramatically (Table 1). Training has been the primary factor responsible for an average 57% drop in use of all pesticides across all provinces (Table 2) and an average 63% drop in use of insecticides particularly (Table 3). Use of banned insecticides, those particularly harmful to applicators, the environment and to natural enemies was reduced significantly due to training (Table 4). As expected, significant decreases in the cost of rice production have accompanied these changes (Table 5). Of particular note in Tables 1 and 5 are the significantly reduced estimates of standard deviation, indicating more consistent farmer behavior after training. With these remarkable changes in farmer use of pesticides (a fundamental requisite before IPM becomes possible), rice yields have increased by an average 10% across all provinces (see Barfield et al 1991).

Data in Tables 1-5 were taken directly from a project review document (Barfield et al. 1991), based on data provided by the FAO project staff in Indonesia. These are not original data from the authors of this paper. More recent data are not available at this writing, but would undoubtedly demonstrate even more impressive results as training and implementation of training-driven research have continued since the 1991 project review.

Let's get a little perspective on the cruciality of deriving an appropriate model for the relationship between research and extension. With what we have now globally, here is some 'food for thought':

- Some 3,000 species of plants have been grown for food throughout history. Now, only about 20 highly 'engineered' species make up the vast majority of commercial agriculture (Vietmeyer 1988; Rhodes 1991).

- Agricultural R&D institutions (like Land Grant Universities) in 1993 are compartmentalized into small, degree-granting units called departments and thus are ill-equipped to tackle problems holistically.

- On-farm problems do not drive the research agenda – extra-mural grants programmes do, and they are indeed fickle. At any given moment, universities are comprised of a mosaic of funded, dynamic faculty and the moribund bodies of ex-funded projects that have matured, but are no longer competitive for grants – not because of how well they can perform R&D, rather, because of what R&D they wish to perform.

- 'Pest disciplines' (entomology, plant pathology, weed science, nematology, acarology) and the 'input disciplines' (e.g. agronomy, agricultural engin-eering) exist as autonomous units. Internal budget struggles have resulted in faculty in different departments competing with each other.

Table 1. Average number of applications per field (all pesticides) before and after IPM training; includes insecticides, rodenticides, fungicides and herbicides.*

	Before	Std. Dev. before	After	Std. Dev. after	F Stat	Signific.
North Sumatra	5.17	2.52	1.72	1.59	7.84	0.0001
West Java	2.39	1.52	1.04	1.25	48.56	0.0001
Central Java	2.23	1.60	1.37	1.50	19.30	0.0001
East Java	2.31	2.13	1.17	1.38	19.84	0.0001
South Sulawesi	2.33	1.31	0.48	0.76	12.70	0.0001
All provinces	2.58	1.94	1.13	1.36	58.51	0.0001

*These are not original data from authors, but were taken verbatim from Barfield et al (1991) based on information provided by FAO project staff in Indonesia during 1991 project review. Original report Table 6 (Annex 8).

Table 2. Average number of applications per farmer (all pesticides) before and after IPM training; includes insecticides, rodenticides, fungicides and herbicides.

	Before		After		Percent change
	Mean	N	Mean	N	
North Sumatra	6.39	195	2.09	193	67
West Java	3.17	580	1.37	576	57
Central Java	3.10	483	1.93	476	38
East Java	3.02	394	1.51	384	50
South Sulawesi	2.99	318	0.58	315	81
All provinces	3.41	1,970	1.48	1,944	57

*These are not original data from authors, but were taken verbatim from Barfield et al (1991) based on information provided by FAO project staff in Indonesia during 1991 project review. Original report Table 7 (Annex 8).

Table 3 Average number of applications per farmer (insecticides only) before and after IPM training.*

	Before		After		Percent change
	Mean	N	Mean	N	
North Sumatra	4.82	195	1.01	193	79
West Java	2.87	580	1.15	576	60
Central Java	2.30	483	1.24	476	46
East Java	2.70	394	1.25	384	54
South Sulawesi	2.73	318	0.42	315	85
All provinces	2.87	1970	1.06	1944	63

*These were not original data from authors, but were taken verbatim from Barfield et al (1991) based on information provided by FAO project staff in Indonesia during 1991 project review. Original report Table 9 (Annex 8).

Table 4. Banned insecticide applications by type after training.*

	All provinces	North Sumatra	West Java	Cent. Java	East Java	South Sulawesi
Organophosphates	1,552	389	333	313	295	222
Organochlorines	406	64	92	84	97	69
Pyrethroids	13	5	2	2	4	0
Carbamates	129	30	19	16	3	61
Other	61	17	14	12	13	5
		After training				
Organophosphates	341	70	51	102	109	9
Organochlorines	41	6	5	11	17	2
Pyrethroids	18	1	0	4	13	0
Carbamates	21	3	2	2	3	11
Other	41	1	17	14	8	1

*These were not original data from authors, but were taken verbatim from Barfield et al (1991) based on information provided by FAO project staff in Indonesia during 1991 project review. Original report Table 14 (Annex 8)

Table 5. Cost to farmer (1990 Rupiah) before and after IPM training.*

	Before			After			
	Mean	Std. Dev.	Median	Mean	Std. Dev.	Median	% change
North Sumatra	27,212	37,866	18,500	8,525	11,259	5,700	68.7
West Java	31,373	58,586	10,500	19,394	65,484	2,460	38.2
Central Java	12,417	18,189	7,000	7,501	13,473	2,950	39.6
East Java	12,765	21,178	6,950	5,647	11,182	2,225	55.8
South Sulawesi	22,523	29,337	12,000	3,660	9,573	0	83.8
All provinces	21,180	38,582	9,500	10,138	37,524	2,300	52.1

* These were not original data from authors, but were taken verbatim from Barfield et al. (1991) based on information provided by FAO project staff in Indonesia during 1991 project review. Original report Table 21 (Annex 8).

- What has resulted is gross over-specialization in IPM and a reporting protocol (publications) more akin to industrial processing than to holistic problem solution.

- IPM R&D institutions have not been very good at developing IPM strategies. The reason is quite simple: their structure and rewards system preclude it. Got a virus problem – call the Plant Pathology Department. Got an insect pest – call the Entomology Department. Who do you call when you desire an economically and environmentally rational and sustainable IPM strategy for complexes of attacking pests – the normal situation?

- IPM is a misnomer. The idea is marvellous, well-stated, ecologically balanced, and rational. In practice, there is virtually nothing integrated about 'integrated' pest management. Given this, should IPM really be exported under the guise of a 'sustainable strategy'?

- IPMers have demonstrated remarkable creativity in the development of IPM tactics and associated research. Problems being discussed in this chapter are not ones of lack of imagination and creativity; rather, of focus. Structure has led to such a milieu of tactics, independent recommend-ations and recipe-orientated approaches that some (e.g. Goodell 1984) question the intentions of those who promote IPM in this fashion.

- Perusal of refereed agricultural research journal articles will reveal a predominance of Randomized Complete Block exper-iments, followed by regression analysis and/or a multiple range test. This 'assembly line science' is tailor-made for refinement of tactics, not development of strategies. There are few (if, indeed, any) analytical tools available for analysis of items like simultaneous impact of pest complexes which act in concert in nature, or compatibility of control tactics.

- Economists seem lost if a definite price cannot be placed on every component in the equation. Given a dollar value, economics models can run. An ability to place such a value on volatile, but crucial, components like loss of biodiversity, loss of endemic knowledge, and narrowed germplasm base generally has led to the exclusion

of these costs from economic evaluation models.

Global constraints

The driving force behind USA research and development in IPM since the 1970s has been profit. With the OPEC oil embargo of the 1970s, farmers literally could not afford 'calendar spraying' of pesticides, nor overuse of fertilizers. Concerns over environmental contamination by input-oriented agriculturists were not the major concerns of the majority of producers and those who advised them (Federal and State). It is enlightening to 'look back' and ponder how we got where we are today.

The majority of today's aged seers of IPM were the radicals of agricultural research during the height of the pesticide era. They were often lone voices against the misuse of synthetic pesticides. Thus, it was to their sheer delight that many of the inputs to industrial agriculture got overly expensive in the 1970s. The door opened wide to use of economic injury levels (EILs) and economic thresholds (ETs) and, up to today, these two criteria are used exclusively for timing pesticide application. Why has no one explored using these criteria for some other tactical intervention? Today's young IPMers were not around during the height of the pesticide era. They do not bear the scars of battles fought with the pesticide conglomerates. To them, that era is historical perspective. On the other hand, they work on IPM in an atmosphere of shrinking economies, budget cuts, and an institutional-ization of the 'publish or perish' criterion for tenure.

The real constraints to further progress in IPM are much more visible in what we can not do than in what we have done. In terms of more options (tactics), progress has been made since the 1940s and 50s. We seem to be at a plateau today, however. Focus has turned to what we shall term 'pet tactics'. Rather than fertilizer, pesticide, or irrigation specialists (who still exist), we have biocontrol specialists, cultural tactic specialists, plant breeders, genetic engineers, etc. Our R&D institutions have demanded ever-narrowing specialists. Of course, overspecialization is wonderful for building international reputations, garnering grants and publishing papers. It is the antithesis of practicing IPM. We have become so compartmentalized and 'special' that we use different vocabularies, have totally different colleagues, publish only in specialized locales and form committees to try to do something in concert. Our institutional structures, rewards systems and educational curricula, in many ways, preclude the development of holistic IPM strategies.

International donor organizations are astute to the dilemma posed between what is needed to develop sustainable IPM strategies and the above anomalies. Thus, they draft RFPs that demand interdisciplinarity. We argue that what most often results is a collection of individual efforts, not a concerted effort. Given arguments presented earlier in this text, nothing else really should be expected In short, we export both the relevant and the irrelevant parts of our agricultural and IPM R&D system.

In the 1990s, general society is concerned about the environment. Much akin to the shift from blanket pesticide applications to the use of EIL/ET values, we have opportunity for progress. Progress in IPM, however, will not come from simply having a richer arsenal of tactical weapons. We must pay attention to the ecological concert necessary to develop global sustainable strategies.

The following appear critical to further progress in IPM on a global scale, and we must be attentive to selection of institutional models capable of addressing such issues: (no priority indicated)

- A focus on IPM strategies, rather than tactics
- Development of integrative tools aimed at assessing compatibility of control tactics and the net effects of communities of pests and natural enemies acting in ecological concert
- As per Levins (1986), research aimed at re-structuring agricultural systems to avoid pests
- Re-structuring of the idea of EIL/ET values so they become continuous,

dynamic functions of pertinent parameters usable for making decisions on a wide array of interventions

- Re-structuring of R&D institutions to emphasize and reward concerted, rather than unilateral, efforts

- Re-structuring of educational 'majors' and curricula to emphasize experiential, rather than theoretical, learning

- Deliberate comparison, across a broad range of criteria, of industrial agriculture to other types

- Close scrutiny of training-driven research as a new paradigm

- A new agricultural policy that emphasizes maintenance of farm families rather than only cheap food

Some testable hypotheses

For detailed discussion on these hypotheses, see Barfield and Swisher (1993). They are presented here in abbreviated fashion so as not to replicate totally previous publications. Readers should ponder creative experimental designs to test each.

Hypothesis 1
There is no evidence that the industrial model of production is successful on anything more than a short-term basis, under highly specific socio-economic conditions.

Hypothesis 2
There is no system of food production that is sustainable under conditions of continuous population growth and/or continuously increasing consumption per habitant of the planet.

Hypothesis 3
Other systems of agriculture, such as ecologically-based agriculture, could produce just as much food, just as reliably, and at an equal or lower cost than industrial agriculture.

Hypothesis 4
Industrial agriculture is an expensive, not cheap, way to produce food.

Hypothesis 5
The Land Grant System, in conjunction with the representatives of industrial agricultural production, have created a set of consumer expectations and concerns which can not be fulfilled simultaneously.

Hypothesis 6
The reductionist, scientific approach to agriculture, combined with the concentration on a single model of production, has led to a net decrease in the world bank of knowledge about agricultural production.

Hypothesis 7
The current configuration of expertise in research institutions leads to a focus on tactics for maintaining the industrial agricultural production system, not strategies for moving toward a more ecologically sound production system.

As collections of IPM and production tacticians, Land Grant agricultural scientists perform admirably. Reductionism is an ideal approach for defining, testing and refining tactical approaches to the problems of agricultural production. There is one glaring problem, however. As the demand for environmental sanctity grows and the call for ecologically-based, sustainable production/protection strategies gets louder, we tacticians are lost as to what to do. Simply, our training has been insufficient. We view the world through the microscope, and the need is to use the telescope. The problems are structured in such a way, that the departmental configuration of R&D institutions (e.g. Land Grant Universities) can not address them concertedly. Committees spring eternal. Extra-mural grants programmes try to force interdisciplinarity by demands listed in RFPs, the result of which is often laundry lists of 'cooperating' faculty. Often, when the grant ends, so does the 'collaboration'. This is pure and simple the proverbial case of 'the square peg trying to fit in the round hole'. Our institutions are not structured to tackle holistic ecological problems. We do not have the technical knowledge, analytical tools nor institutional incentives to do so. Since the late 1950s, systems modelling has been around as an analytical and integrative tool that offered promise to help resolve this dilemma. It has worked in the space industry, but not in agriculture,

and the reasons are larger than physical versus biological systems. In the 1970s, departments competed to get their bevy of resident modellers because grants programmes were funding modelling approaches to agriculture. Like other topics, that's not vogue anymore. Those scientists are now tenured, full professors who are, by and large, frustrated that the 'systems approach' got out-gunned by departmental territories, needs to senior-author everything for tenure purposes, and waning interest from extra-mural sources. Our structure has proven to be deleterious to the new, holistic agenda of the 1990s. This is not to say the problem cannot be overcome; however, such is not likely unless we stop and re-think who sets research agendas, what gets rewarded, and why.

Hypothesis 8
We in agriculture must play an increased role in setting domestic and international agricultural policy, rather than simply responding to a policy aimed primarily at providing consumers with cheap, abundant food, not at solving farmers' problems.

Hypothesis 9
IPM is a misnomer. There is virtually nothing 'integrated' about the way it is researched or extended (practiced).

Hypothesis 10
Training-driven research offers the highest potential for correcting the issues hypothesized in 1–9 above.

Simply, training-driven research offers high potential for putting agriculture in perspective. It focuses on the clientele directly. It demands complete utilization of existing knowledge (both technical and indigenous). It does research only if research is needed. Its primary end-product is a more capable producer, not a refereed journal article. It relegates tacticians to their proper role – as researchers of narrow spectrum subjects, but only if needed. This is, indeed, a role they are highly qualified to fill. This approach does have two problems, however. First, there are the egos of the plethora of tactical researchers who feel their individual lifelong careers represent agriculture's ultimate 'magic bullet' solution and who likely will resist training-driven research with passion. Second, there is the problem of where to locate the superb trainers required to bring off this system. The Indonesian programme has them, so it's certainly not impossible.

Barfield and Swisher (1993) offer 10 suggestions for overcoming constraints to IPM outlined in this paper and for testing the hypotheses presented above. These are presented below in abbreviated form, without the full explanation so as to avoid duplication of previous publications, and permit readers to focus mentally on creative ways to accomplish stated goals.

A few suggestions

Suggestion 1
Re-think the role of experiential learning in agriculture and IPM. Currently, it is entirely possible for a PhD agriculturist, even one specializing in IPM, to graduate without ever setting foot in production agriculture. IPM begs for such experiential learning requisites as mandatory steps in formal education.

Suggestion 2:
In side-by-side, replicated experiments, evaluate the utility of the US Land Grant, T & V, FSR/E, and Training-Driven Research models for their utility to develop, deliver and train in agriculture, including IPM.

Suggestion 3
Re-think the job descriptions and rewards system for agriculturists.

Suggestion 4
In side-by-side, replicated experiments, compare industrial to other types of agriculture over 10-year blocks of time, and do not punish researchers for not producing larger numbers of smaller, less significant journal articles in the process.

Suggestion 5
Lobby for establishment of grants programmes whose primary objectives are not pest or commodity-driven, but rather integration-driven.

Suggestion 6
Establish monitoring, manipulating and dissemination systems to much more

precisely chronicle and share the economic impact of a wide range of pest complexes.

Suggestion 7
Infuse agricultural classrooms with a much broader array of literature than is required under the industrial agriculture, science-based approach.

Suggestion 8
Re-think the issue of 'students as technicians' or 'students as future scientists'. Most faculty will argue that the first is necessary to produce the second. We disagree and argue that the first is nothing more than an artifact of how we are structured and rewarded.

Suggestion 9
Consider invoking fundamental changes in future IPM practitioners, from perspectives of attitude and capability.

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DISCUSSION: SESSION I

J Perfect (NRI, UK):
Is there any merit or advantage in distinguishing between control measures for whitefly and thrips? Is not the overlap so considerable that they should be considered together?

M Jones (MoA and IIBC, Trinidad & Tobago):
I agree; it is not worth it, especially as regards control measures. Applaud® and Hostathion® both give good levels of control on both pests. Also the predators identified are effective for both of them. It is important to identify the whole pest complex; *T palmi* cannot be managed in isolation from the other components of the pest/disease complex; we must look at all the interactions before deciding on a management strategy.

S Parasram (CARDI, Trinidad & Tobago):
Which is more important – *Bemisia per se* or the associated viruses? Even if the thrips and whitefly are controlled at a satisfactory level for crop production, viruses can still be transmitted. What level of control of the thrips is needed to overcome this?

P Stansly (University of Florida, USA):
Both are pests in Florida but *T. palmi* is not as serious as the sweet potato whitefly, especially on tomato. However, *T palmi* does attack other vegetable crops such as beans, peppers, and cucurbits. One strategy would be to plant tomato early followed by whitefly-insensitive crops. The sensitivity of a crop to a particular pest is an important tool in devising control measures.

R Hall (NIHERST, Trinidad & Tobago):
Since the threshold for the pest is so low – one to five whiteflies per plant – is it worthwhile for small-scale farmers in small areas trying to use pesticides at all?

Quite a lot is known about the effect of pesticides on other thrips and their predators. This knowledge could be applied to *T. palmi* management in the Caribbean.

S Parasram:
Is there any chemical to eradicate whitefly? It would seem not; we must look for alternative strategies. We should be able to give farmers some affordable recipe to give control for a few years at least until other solutions are found.

G Rajnauth (MoA, Trinidad & Tobago):
In Trinidad, tomato farmers are testing an insect growth regulator for an agricultural input supplier. Reasonable control of whitefly has been achieved but nearly all the plants showed symptoms of geminivirus infection.

We need to look at other aspects of the geminiviruses. The pathogen is probably indigenous to the Caribbean and we do not know its pathogenicity. New varieties should not be put under high pest pressure until more is known about this pathogenicity.

J Jones (MoA, Barbados):
In small ecosystems it may not be economical for farmers to control the pests on tomato because of virus infection but nevertheless if they do not spray against the pests it may affect neighbours' crops.

Participant (Dominican Republic):
When high populations of whitefly were recorded in the south region of the Dominican Republic, the government introduced a policy of host eradication which at first resulted in lower populations. However, the insect kept moving from cultivated crops to weeds and it is now more difficult to control.

S Parasram:
No single measure will give the required solution. We need to devise a fully integrated programme and implement it at the same time. The nature of the programme will hopefully be provided by the experts at this meeting.

Participant (Dominican Republic):
In the survey conducted on losses and damage to vegetables in the Dominican it would seem that the symptoms were described , not the diseases themselves. Also how were percentage losses established?

A Abud (JAD, Dominican Republic):
The survey so far has covered small and medium-sized producers; it will be expanded to cover large producers who

have been collecting data for some time now. We used symptoms to see if farmers could recognize the different types of damage. What they recognized most easily were symptoms such as yellowing and leaf curling.

H Stagno (IICA, Dominican Republic):
Given the large number of farms , crops and pests we need set up priorities – primary, secondary and tertiary crops: tomato, eggplant, 'Chinese' vegetables. Seventy per cent of the farmers are growing a single crop.

The survey data are available to anyone interested.

P Alvarez (JAD, Dominican Republic):
The commercial production of tomato in the Dominican Republic is done with agri-business financing. Farmers lack the basic knowledge of how to manage pesticides since this is done in collaboration with agri-business interests.

Participant (Dominican Republic):
What happens in the Dominican Republic could be relevant in other Caribbean countries. Commercial chemical companies develop their own extension service to market their products and can sometimes misinform farmers. farmers listen to them more readily than officials from the ministry. Insecticides affect predators as well as the targeted pest but agrochemical companies do not emphasize this.

J van Lenteren (Wageningen Agricultural University, The Netherlands):
IPM in greenhouses may be easier because here we are dealing with isolated units. In the 1970s Dutch farmers were scared to take risks – when they first saw a pest they sprayed immediately. However, after a few years of training they were prepared to take risks. Schools for farmers were set up where they became familiar with the names of pests and beneficial insects. Farmers formed themselves into associations so as to become independent of the chemical industry. They were able to delay spays and eventually stop their use.

E Gomez (ISA, Dominican Republic):
With respect to the survey on crop damage and losses in the Dominican Republic, I am one of the people working with farmers in the field. We needed to be close to reality and wanted farmers to answer freely what they were doing, i.e. what actually takes place in the field. For example, some farmers could not remember what they sprayed 3 months ago – we had to look at old bills and receipts etc. to find the names of the pesticides they used.

Participant (ISA, Dominican Republic):
With regard to *T palmi* in on beans in Trinidad & Tobago, what are the loss rates and what are the control measures implemented?

M Jones:
There are no density data available for beans – we concentrated on the more affected cucurbits and eggplant. In general we recommend: overhead irrigation, Nomolt® and Applaud®. Foliar fertilizer should be kept to a minimum since the thrips population builds up with an increased N level in the leaves – soil fertilizers are recommended instead. Farmers are persuaded not to use chemicals detrimental to the natural predator, *Orius* sp. In biocontrol we are now at the point of being able to provide predators to farmers as is done in Holland.

P Stansly:
I would like to point out that we all depend on the chemical industry fro agricultural development. We have joint interests which should be recognized – we need to cooperate in the best interests of the farming community

R Barrow (MoA, Trinidad & Tobago):
I was impressed with the detailed and informative report presented by Dr Abud. The results are the same as those that pertain in Trinidad & Tobago. How is it that the farmers are using pesticides that are banned? Farmers tend to listen to commercial people rather than technical officers from the ministry. Are any pesticide residue measurements done on crops in the Dominican Republic in view of the large vegetable export market?

Dr van Lenteren, When you spoke of the planthopper on rice you mentioned that a good many pesticides had been banned. Was this with the consent of the farmers or

by government order? How did you determine resistance?

A Abud:
Legal controls do exist in the Dominican Republic – laws and regulations date back to the 1950s. Present regulations relate to 'primary crops'. In certain regions these determine what crops can be farmed and when and also when land is to be left crop-free. This applies to whitefly host plants.

Laboratories in the Dominican Republic can perform crop pesticide residue analyses but the presence of the pest alone is enough for the produce to be rejected. The IPM programme sends samples to USA for analysis. Pesticide residues are a big problem. In 1984–1988 *T. palmi* became a serious pest in 'Chinese' vegetables but farmers did not report it. They began to use heavier doses of chemicals and more frequent applications. When high residues were detected they changed to pyrethroids which were considered a little safer. During this period they also eradicated many natural enemies *T. palmi* populations jumped and other pesticides were tried and the cycle repeated. However, the situation has now been brought under control.

J van Lenteren:
An open relationships needed with the chemical companies. Indonesia is a very large collection of islands and it was found that if on particular islands spraying was discontinued yields did not go down. This was sufficient demonstration that under these conditions spraying of pesticides was unnecessary. Safe alternatives which are not more expensive are always welcomed by governments. Only three or four insecticides are currently in use.

C Serra (ISA, Dominican Republic):
In the Dominican Republic, a pre-inspection programme has been set up for some crops including pineapple, melons and avocado.

In the past we have suggested for tomato that the number of pesticide applications should be reduced and that alternative pest management techniques such as intercropping with sorghum should be practised. However with the coming of geminiviruses, we had to quickly change this strategy and advise technicians to apply heavy doses of chemicals to prevent the spread of geminiviruses. This of course causes confusion among the technicians. In the real world we can achieve more if we go about things gradually rather make drastic changes. The chemical companies are now more understanding and do try to implement IPM techniques.

TECHNICAL SESSION II

Chairmen: Raphael Pérez Duverge, *FDA, Dominican Republic*
Alan Jackson, *CTA, The Netherlands*

Rapporteur: Denyse Johnston, *CARDI, Trinidad & Tobago*

PROSPECTS FOR NON-CHEMICAL CONTROL OF *BEMISIA TABACI*

D Gerling
Tel Aviv University, Israel

The whitefly *Bemisia tabaci* causes damage by direct sucking, honeydew and sooty mould contamination, and virus transmission. The latter aspect has been especially severe in the Dominican Republic during the last 3 years. In order for control methods to be effective, they must be integrated. Moreover, any one particular method of control will necessarily effect the choice of others. The chemicals employed are often 'hard' persistent insecticides. However, insect growth regulators, oils and detergents are also available, and these materials are more compatible with biological control measures and with the environment. Biological controls are carried out by predatory parasitoids or fungi, which may occur naturally or be introduced and manipulated by the grower. Biological control activity can be enhanced by the judicious use of refuge plants and weeds that may serve as locations for shelter and development of natural enemies. Agrotechnical methods for pest control are numerous. Those most employed against *B. tabaci* include the use of partially resistant plants, mulches, and various sanitational techniques including host-free periods. The latter two methods are especially important when trying to avoid virus transmission. Additional methods for disease control include the utilization of trap crops on which the pest prefers to settle and which do not serve as hosts for viruses.

The whitefly *Bemisia tabaci* (Gennadius) has been known in many parts of the world for over 30 years. However, since 1985 it started to spread in Florida and the Caribbean Basin. Severe damage and crop losses followed these whitefly outbreaks, including the killing of plants through direct feeding, crop and produce contamination (through honeydew production and sooty mould development) and, most severely, viral infection of tomatoes. The latter, when occurring at an early stage of the plant's development, precludes crop production.

Taxonomic, biological and enzymatic studies have shown that the whiteflies that are presently causing these problems can be distinguished from those previously known to occur in California. Therefore, the pest is considered to constitute a new strain, biotype, or even a new species, named the silverleaf whitefly or *B. argentifoliae*, due to its capability of causing silvering of squash leaves through a physiological (rather than virological) process.

Control methods should not stand alone, as each affects the others (Figure 1). Therefore, one must look for an integrated approach in which the methods and techniques that are used in each case can be integrated into the general pest management scheme. They should also be the least expensive in terms of environmental cost, resistance build-up and direct financial expenditure.

The list of methods available for pest control (ranging from chemical through biological to agrotechnical control) is very large and varied. In each case, their use requires a knowledge of their control potential and of the pertinent characteristics of the pest's biology aimed at by the intended control method.

In the following section, various ideas for control techniques against *B. tabaci* will be discussed in relation to the pest's biology and the other methods of control, thereby demonstrating the interdependence of pest management methods.

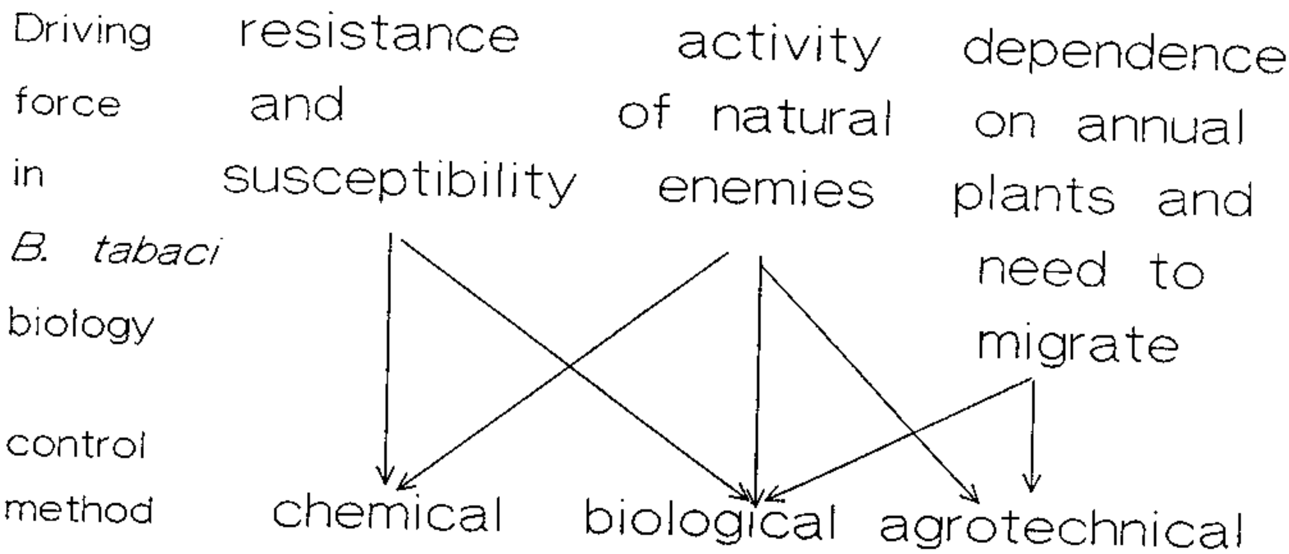

Figure 1. **Factors associated with *B. tabaci* control under typical outdoor conditions: An overview.**

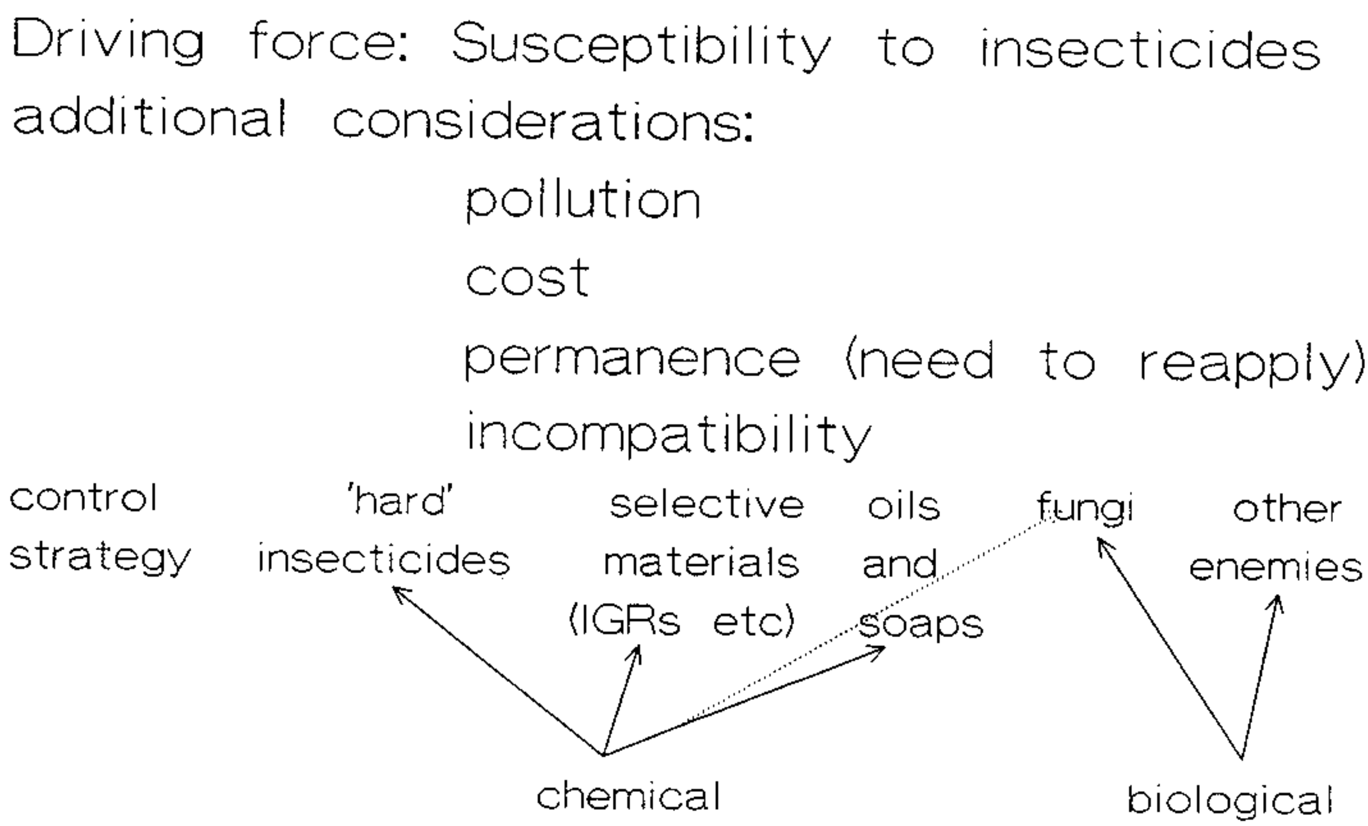

Figure 2. **Chemical control of *B. tabaci***

Chemical control (Figure 2)

Chemicals are used for pest control because they are capable of killing the injurious insects. Their value, however, is limited to this characteristic alone, and once the pest has become resistant, their usefulness declines accordingly. Moreover, such materials are often undesirable due to their side-effects.

The reduction or elimination of chemical control is one of the underlying premises of integrated pest management (IPM). However, concomitantly with the development of IPM strategies, new chemical are being developed that are more selective and that can be integrated into an overall pest management scheme.

The materials indicated as 'hard' insecticides include biocides that have a persistence of several days at least, such as many of the often used organophosphates, organochlorides, carbamates and pyrethroides. Alternatives to these insecticides for whitefly control exist in the form of insect growth regulators, such as buprofezin or pyroproxyfen that also have a residual effect but are more selective in their biocidical activity and can be used in conjunction with parasitoids. Their utility is limited by adverse effects on several species of predators and by the build-up of resistance. Another group that has recently become available, includes the oils, soaps and detergents. These materials are usually broad spectrum insecticides but non-persistent and biodegradable. Thus their effect on non-target insects, including beneficials, can be reduced through the correct timing and manipulation of application methods.

Biological control (Figure 3)

Biological control capitalizes on the fact that numerous carnivorous insects (parasitoids and predators), and fungi feed on whiteflies and are therefore considered to be natural enemies and, from our point of view, manipulatable beneficial organisms. These beneficials may occur naturally, or may be introduced by man; they may be active permanently or may be introduced periodically. Fungal preparations may be sprayed directly upon the plants, whereas parasitoids or predators may be released periodically, when needed. This necessitates the existence of appropriate rearing facilities that can produce the required organism at an economically viable cost.

Biological control can and should also employ direct and indirect methods intended to conserve natural enemies and direct their activity towards more efficient pest management. These methods, many of which are agrotechnical in nature, include the selective exploitation of weeds, some of which may harbour a large number of whiteflies but show little parasitism – and these should be discouraged or eliminated; whereas other species may show high parasitism and should be encouraged. Another practice, known as refuge plant culture, is akin to weed manipulation, using intentionally planted hosts for *B. tabaci* and its enemies. This practice has the benefit of allowing us to maintain populations of natural enemies in the field at a time when the host populations decline due to host-plant desiccation or harvesting. Attention should be paid to the population dynamics of the whiteflies and their enemies on these refuge plants in order to avoid an increase in the pest populations and thus aggravate the situation rather than improve it. It is evident that numerous other methods, some of which will be discussed in the next section, must also be examined in the light of their contribution to natural enemy activity and biological control.

Agrotechnical methods (Figure 4)

The number and variety of these methods that may be employed in the management of *B. tabaci* is only limited by the imagination and, accordingly, new ideas and techniques are continually being devised. Several main groups of such methods can currently be recognized. Some are aimed principally at whitefly control; others at disease control.

Many plant species or varieties show variability in their susceptibility to whitefly attack, and this is reflected in different levels of infestation in different

Driving force: susceptibility to natural enemies
additional considerations:

- viable alternative to other methods
- applicable to small and isolated plots
- non toxic
- compatibility
- permanence

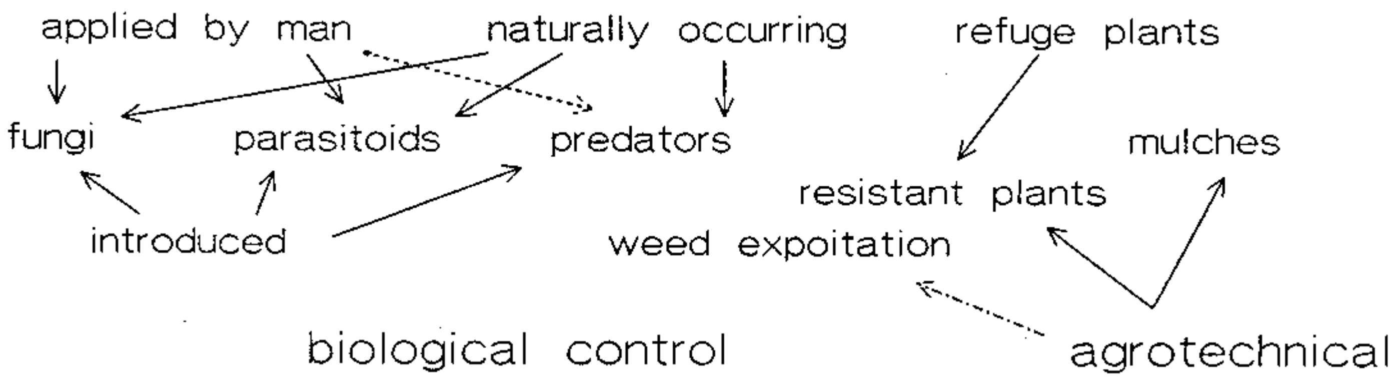

Figure 3. Biological control of *B. tabaci*

Driving force: Host dependence upon annual plants and migratory biology of *B. tabaci*

Additional considerations:

- cost effective
- usually simple and easy to apply
- compatible with most contr ol methods

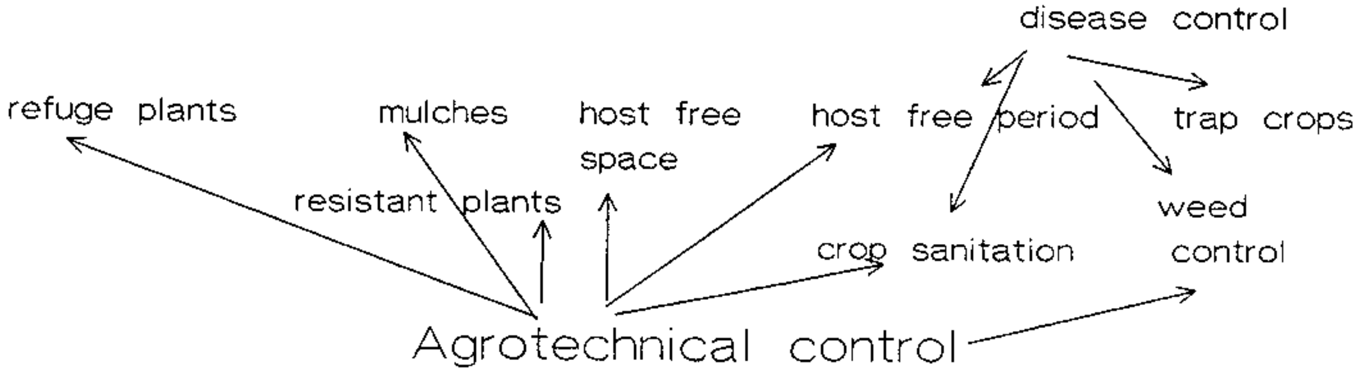

Figure 4. Agrotechnical control of *B. tabaci*

crops. The advantage of using plant varieties showing at least some resistance and, consequently, supporting lower whitefly populations, is two-fold: insecticide treatment may be avoided due to the low infestation levels; and, concomitantly, lack of insecticidal treatments facilitates the development and action of natural enemies that will further reduce the pest populations.

The use of mulches has been well established. It is also discussed by P. Stansly and K. Sponagel in this symposium. However, observations of mulch use have led to the realization that the principle involved requires elucidation: airborne whiteflies spot, and are attracted to, ground level shining or well-illuminated, light coloured surfaces. Thus, it has been shown that straw or yellow surfaces (recently similar results have been reported from Florida using white or aluminum coloured plastic), which cover the ground among the plants, attracts the whiteflies to land on it. Once this occurs, they usually remain there, trapped by the high temperature of the mulch, and die. Thus, the effectiveness of mulch use is limited to the early parts of the season, when large open spaces of mulch can still be visible among the plants. At that time, its use can bring about a 3–4 week delay in whitefly-caused virus transmission.

Other methods aimed at disease control can be divided into preventative ones (dealing with the destruction of virus sources in different habitats) and active ones – planting trap crops that are aimed at preventing virus infected *B. tabaci* from reaching the susceptible crop.

The preventative methods include crop sanitation, the removal of weeds that may harbour viral diseases, the thorough removal of all plants from the field following harvest, and the strict observation of a host-plant free period of 40 days or more.

Trap crops, like cucurbits, that whiteflies prefer to solanaceous plants, can be planted at field margins. The benefits from trapping the whiteflies there are three-fold: prevention of invasion into the tomato field; 'cleaning' the virus from the whitefly – being a non-carrier of the tomato virus, the cucurbit acts as a substrate for production of the next whitefly generation, producing virus-free individuals; providing a place for the development of natural enemies.

Conclusions

B. tabaci has become a severe pest owing to its great mobility, rate of increase, capacity to transmit diseases, and resistance to insecticides. The methods of controlling it ought to be based upon an integrated approach, whereby the need of the pest to move from one crop host to another should be exploited; novel, less toxic pesticides be used; and the activity of natural enemies be encouraged both through manipulation of host plants and direct encouragement.

EL NIM COMO INSECTICIDA EN SISTEMAS DE MANEJO INTEGRAL DE PLAGAS: POTENCIALES Y PROBLEMAS

F Taveras y A Brechelt
Instituto Politécnico Loyola, Republica Dominicana

Neem as an insecticide in IPM systems: potential and problems

Derivatives of the neem tree have been long used in Asia and, more recently, in Africa for controlling insect pests. A project in the Dominican Republic, which began in 1987, has the objective of testing and transferring IPM technologies based on neem. The project has worked directly with 150 farmers. The neem plant can produce up to 30 kg of fruit/tree. The insecticide is found in the seed cotyledons. The paper describes the methods of harvesting, depulping, drying, preparation and application of an aqueous preparation of the insecticide. For soil insects, the powdered form may be applied directly to the soil. All applications should be done in the early morning or late afternoon for best results. The results of trials on insects feeding on crucifers, solanaceous crops and cucurbits of commercial value are presented. An extract from 50 g of neem seed in 1 litre of water or a 2% formulation of neem oil gave economic control of *Plutella*, aphids, whiteflies and several tingids on the crops tested. Neem breaks down rapidly, is non-toxic to animals and humans and because it contains various insecticidal substances is unlikely to result in insect resistance. Major limitations to its use are the unavailability of adequate quantities of seed and the cost of the complete process from harvest to formulation, i.e. a question of commercialization. Also, neem being a stomach poison, it is unlikely to control internal feeders and sucking insects. The future of the product will depend on the resolution of the above.

Los derivados de nim (*Azadirachta indica* A. Juss) han sido usados tradicionalmente por agricultores en Asia y Africa contra insectos-plagas de importancia en el hogar, en medicina y en la agricultura. A diferencia de los insecticidas ordinarios basados en ingredientes activos simples, los principios de la bioactividad de nim, son un complejo de compuestos con comportamientos y efectos fisiológicos diversos sobre los insectos (Schmutterer et al. 1981; Schmutterer y Ascher 1984; Schmutterer y Ascher 1987).

La problemática actual de los insecticidas sintéticos, su uso indiscriminado, la creación de resistencias en plagas y como resultado la contaminación del medio ambiente tanto como el envenenamiento de animales, organismos benéficos y seres humanos ha creado una gran necesidad de encontrar insecticidas altamente eficientes y específicos pero, que respeten la flora y fauna así, como la salud humana. Por lo tanto ahora se está intentando elaborar sistemas de manejo integrado de plagas con el uso de insecticidas botánicos como el nim.

En 1987 se iniciaron las actividades del proyecto Fabricación de Insecticidas Naturales a partir de Plantas Tropicale, en el Instituto Politécnico Loyola (IPL) , bajo un convenio de cooperación técnica entre los gobiernos dominicano y alemán, con la asesoría de la GTZ.

El objetivo del proyecto es transferir y adaptar las tecnologías generadas a nivel supraregional y realizar las investigaciones básicas en el control de plagas de los cultivos hortícolas de pequeños productores bajo riego con el uso del nim.

El trabajo en conjunto y la constante capacitación tiene como meta que los agricultores estén capacitados para dar continuidad al mismo sin necesidad de asesorías e integrar el Nim a sistemas de manejo integrado de plagas.

Situación actual.

Actualmente el proyecto trabaja directamente con alrededor de 150 agricultores en zonas bajas y secas de la República Dominicana. Con ellos se ha elaborado un método simple y útil para aprovechar el extracto acuoso de las semillas de Nim y se ha probado la efectividad en varios cultivos y contra la mayoría de las plagas existentes en dichos cultivos. Los resultados se describen a continuación.

El método nim

Procesamiento de las semillas del árbol Nim

Cosecha
Los árboles de nim florecen y dan frutos, por primera vez, generalmente a partir de los dos primeros años de edad, de acuerdo con el desarrollo de las plantas y de las condiciones del clima del país o región en que estén sembradas.

Por lo general dan frutos una vez al año. Sin embargo en la República Dominicana existen zonas en donde las plantas permanecen con frutos todo el año. Durante la primera cosecha la producción oscila entre 2.4 kg/árbol, pero el 5o. año la producción se puede elevar a 20-30 kg/árbol. Los frutos pueden ser cosechados de las ramas, sacudirlos y/o recogerlos del suelo.

La forma más práctica para la recolección consiste en observar cuando los frutos comienzan a madurar lo que da una indicación de que los frutos que corresponden a la misma inflorescencia están llenos. Con frutas en estas condiciones y con la ayuda de un objeto cortante adherido a una vara se puede realizar la cosecha economizando mano de obra y trabajo. Solo que los frutos verdes deben ser colocados a la sombra hasta que terminen de madurar.

Despulpado
Las semillas de nim poseen una pulpa de sabor dulce. Esta capa debe ser eliminada similar o como se hace con el café, para evitar la proliferación de hongos y el consiguiente daño de las semillas en donde se encuentran las sustancias activas que actúan como insecticidas.

El despulpe puede hacerce a mano o con máquina despulpadora que no quiebren las cáscaras. Luego se procede a lavar con agua las semillas para terminar de desprender las sustancias azucaradas.

Secado y almacenamiento
Las semillas lavadas se esparcen sobre lonas, sacos, yaguas o papel periódico, sobre una base sólida o un secadero, evitando el contacto directo de las semillas con el cemento, dándole un día a pleno sol; luego las semillas se colocan debajo de sombra para que el aire termine de eliminar la humedad que queda en las semillas. Esto se hace porque se han realizado estudios en donde se determinó que el sol reduce considerablemente el contenido de sustancias activas en las semillas de nim.

Los granos secos pueden enmohecerse en el almacén. Por esta razón, deben ser guardados solo en recipientes que permitan su aireación (sacos de fibras, cestos, etc.), por el contrario los recipientes cerrados o cubetas no son adecuados. Las semillas bien secadas pueden ser almacenadas por más de dos años.

Preparación y aplicación del insecticida de las semillas del árbol nim (extracto acuoso).

Preparación del extracto acuoso.
Las sustancias insecticidas se encuentran concentradas en los cotiledones de las semillas del nim. Para elaborar el insecticida, estas deben ser trituradas con un mortero o preferiblemente con un molino ya sea manual o eléctrico. La harina debe ser lo más fina posible para lograr una mejor mezcla.

La mezcla del nim molido con el agua debe hacerse varias horas antes de la aplicación, preferiblemente de 8 a 10 horas, de tal modo que las sustancias puedan desprenderse bien, para pasar al agua y luego aplicarse.

La cantidad de semillas molidas para la mezcla va a depender de la calidad de la semilla (contenido azadirachtina) y del tipo y cantidad de plagas presente. Generalmente se recomienda de 25 a 50 g/litro de semillas molidas.

Formas de aplicar el insecticida nim a los cultivos
Para la aplicación con equipo es necesario filtrar la mezcla separando así las partículas sólidas, para que el equipo no se tape. La mezcla debe moverse para facilitar la separación de las sustancias activas. Al momento de la aplicación se introduce en el tanque de 55 galones un canasto del tamaño un poco menor que el tanque, forrado de una tela permeable. De esta manera la solución con el insecticida pasa libre de partículas al centro del tanque, de donde se puede sacar con un cubo para echarla en el equipo.

Otra forma es el uso de una tela o gasa sobre un recipiente adecuado. Se vierte la mezcla, quedando las partículas sólidas encima de la tela. La solución que pasa al recipiente contiene el insecticida ya listo para la aplicación.

Una tercera forma de colado y que ha sido creada por los agricultores, consiste en hechar el polvo de nim en una tela o saco permeable, introducirlo en el tanque y dejarlo filtrar, luego mover con las manos la tela o saco para facilitar el desprendimiento de las sustancias activas y al cabo de 8-12 horas ya la mezcla está lista para ser aplicada, evitando el trabajo del filtrado.

El extracto de nim puede aplicarse también con una brocha de paja fina o una escoba en forma manual, esto para la aplicación en áreas reducidas (huertos familiares, semilleros, etc.). En este caso no es necesario filtrar la mezcla.

Otra forma especial es el control de *Spodoptera frugiperda* (J E Smith) del maíz y plagas de semilleros, solo es necesario pulverizar Nim molido y para el caso del semillero, se aplica la forma directa en el suelo.

Es importante señalar que tanto para la aplicación con equipo o manual se deben elegir las primeras horas de la mañana o las últimas horas de la tarde en razón de que los rayos solares disminuyen la acción de las sustancias activas del Nim y además aplicar la mezcla por abajo o envés de las hojas.

Cultivos y plagas en que se usa nim.

El nim funciona para la mayoría de los cultivos vegetales en el control de insectos-plagas, principalmente contra larvas de lepidópteros, en cultivos de cucurbitaceas, solanaceas entre otras. (Ver Anexo 1)

La dosis a aplicar dependerá de la plaga, hay algunas plagas que fácilmente se controlan con concentraciones bajas, y de la procedencia de las semillas. Ya que el contenido del ingrediente activo, Azadirachtina, en las semillas muestran grandes diferencias bajo diferentes condiciones ambientales (Ver Anexo 2). Es decir, que en el caso de un contenido alto de Azadirachtina se puede usar una dosis más baja.

Experiencias con el nim en el manejo integrado de plagas

Los resultados aquí presentados son el producto de varios ensayos dirigidos contra especies fitófagas en los cultivos de repollo, coliflor, berenjena, pepino, molondrón, tomate y maíz, con un extracto acuoso a base de 50 gramos de semillas de nim finamente trituradas por litro de agua.

Repollo y coliflor

La plaga mas importante es la polilla *Plutella xylostella* que ha desarrollado resistencia en la localidad.

El áfido *Lipaphis erysimi* es de poca importancia, sin embargo, cuando aparecen altas poblaciones causan la destrucción del cultivo.

La mosca blanca *Bemisia tabaci* se ha presentado en las zonas bajas cálidas de la República Dominicana en los últimos tres años con poblaciones tan altas que han provocado la muerte prematura de las plantas.

El extracto acuoso de 60 g de semilla de nim/l de agua fue comparado con *Bacillus thuringiensis* (thurice) a una concentración de 2g/l de agua, a la cual se le agregaron 10 ml de melaza por litro de agua para el control de *Plutella xylostella* en repollo (Ver Anexo 3 y 4). Estos tratamientos también fueron evaluados para el control de

Lipaphis erymisi, obteniéndose muy buenos resultados (ver Anexo 5).

Con el objetivo de detectar a tiempo estas plagas y disminuir la concentración y el número de aplicaciones , se integró con el nim el método etológico , que consiste en postes amarillos impregnados de sustancias pegajosas y tazones amarillos con mecha o lámparas. Los atrayentes visuales también resultaron efectivos contra los áfidos y moscas blancas. Con la integración de estos métodos se redujo la concentración de 60 a 50 g de semilla de nim/l de agua y economizamos tres aplicaciones.

Pepino

Es seriamente atacado por un complejo de tres insectos plagas. El más conocido y destructor es el lepidóptero *Diaphania hyalinata* que puede defoliar totalmente el cultivo desde la aparición de las primeras hojas verdaderas, pero especialmente al momento de la floración. También *Aphis gossypii* y *Bemisia* causan problemas.

El nim a una dosis de 50 g de semilla/l de agua fue comparado con ambush 0.5 ml/l de agua y no hubo diferencia significativa entre ambos en el número de larvas y daño foliar; en cambio, en el testigo los daños fueron tan fuertes al momento de la floración que destruyeron totalmente las parcelas (Ver Anexo 6).

Con la manipulación etológica (uso de trampas amarillas) y la manipulación agronómica (represión parcial de malezas y raleo) se redujo el número de aplicaciones.

Berenjena

En las zonas secas es atacada por *Corythaica cyathicollis* y en los últimos años por *Bemisia tabaci* y áfidos (*Aphis gossypii y Myzus persicae*).

El extracto acuoso de 50 g de semilla de nim/l de agua y el aceite de nim formulado al 2% fueron comparados con butacarboxin a 1.5 ml/l de agua y un testigo. Los productos a base de nim y el butacarboxin resultaron igualmente efectivos contra *Corythaica cyathicollis*. El butacarboxin no evidenció eficacia contra los áfidos y moscas blancas comportándose como el testigo; en cambio, los extractos de nim controlaron satisfactoriamente estas plagas (Ver anexo 7).

Tomate

Desde finales de 1988, *Bemisia tabaci* ha ido desplazando a *Keiferia lycopersicella y Heliothis virescens* como plaga clave del tomate.

El único antagonista de importancia encontrado en la zona es el también fitófago Miridae *Cyrtopeltis tenuis* que causa serios problemas desde el momento de la floración por la succión de savia.

Con el extracto acuoso de 50g de semilla de nim/l de agua, y la manipulación de la población de *Cyrtopeltis tenuis*, se ha logrado reducir notablemente la población y los daños por *Bemisia tabaci*. Similar efecto se ha tenido con el uso de las feromonas sexuales contra *Keiferia lycopersicella y Heliothis virescens*. Con este sistema de manejo se ha reducido en un 50% el número de aplicaciones (Ver Anexo 8)

Como en estos ejemplos se puede integrar el Nim en cualquier sistema integrado para otros cultivos, reemplazando insecticidas químicos contra las plagas mencionadas en el Anexo 1.

Ventajas del nim

Usando nim en cultivos intensivos de hortalizas se presentan varias ventajas que son las siguientes:

- El nim no es tóxico para seres humanos, animales de sangre caliente y benéficos.
- Se descompone rápidamente y así no hay acumulación en el medio ambiente.
- Como el extracto acuoso contiene una mezcla de 25 diferentes ingredientes activos, entre ellos por lo menos 9 que afectan el crecimiento y el comportamiento de insectos, para ellos resulta difícil desarrollar rápidamente resistencias. (Jones et al 1989, Völlinger 1987).
- La cantidad inmensa de otros usos tanto del árbol como de sus productos.

Limitaciones

A pesar de todas las ventajas que tiene el nim existen también algunas limitaciones.

Dependiendo del trabajo que significa la cosecha y el procesamiento de las semillas y la cantidad necesaria hasta ahora el proyecto solamente ha trabajado con pequeños agricultores de hortalizas tomando en cuenta la dificultad de conseguir grandes cantidades de semillas bien preparadas.

Algunas plagas importantes como trips, ácaros, larvas de moscas de la fruta, chinches grandes, escamas y cochinillas no muestran ningún tipo de reacción tratándolas con nim. Por su modo de alimentación y de vivir no consumen suficiente de la sustancia activa para ser controladas. Como el nim principalmente actúa por ingestión, inhibiendo el crecimiento y la metaforfosis, y no es un veneno por contacto.

Hasta ahora la falta de árboles en producción y un sistema efectivo para la cosecha y el procesamiento es la limitación más grande.

Perspectivas y conclusión

Por el momento parece ser que la restricción más grave para el uso de los productos del nim, tanto en la República Dominicana como en otros países es el bajo número de árboles productores de frutos. Solucionar este cuello de botella será la tarea de los próximos años.

Con una cantidad suficientemente grande se podría producir extracto acuoso, aceite y torta de nim para trabajar también con agricultores de parcelas más grandes.

Tomando en cuenta que el nim no controla todas las plagas importantes es recomendable alternar el uso de nim con insecticidas o acaricidas específicos para bajar la frecuencia de aplicaciones de pesticidas químicos. De todas maneras este método es favorable para evitar cualquier riesgo de que las plagas desarrollen resistencia contra el nim porque este peligro siempre existe.

Usando el nim junto con otros componentes del manejo integrado de plagas se puede lograr un control efectivo de un gran espectro de plagas en cultivos intensivos.

Pensando más en el futuro sería importante aprovechar todas las ventajas y usos del nim, tanto en diferentes formas de insecticidas como otros productos. Jabón, pasta dental, aceite formulado y extractos alcohólicos, junto con otros son un potencial increíble, pero requieren un cierto nivel de comercialización y producción industrial. A largo plazo el uso múltiple de *Azadirachta indica A. Juss* llegará a hacer la siembra del árbol más económica y aceptable.

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Anexo 1 Plagas que se controlan con nim (extracto acuoso)

Cultivo	Plaga (nombre cientifico)	Nombre comun	Dosis a aplicar (g/l)
Berenjena (*Solanum melongena* L.)	*Bemisia tabaci*	Mosca blanca	50
	Spodoptera spp.	Gusano costancero	25
	Phthorimea operculeta	Pega hoja	25
	Corythaica cyathicoliis	Palo de chivo	50
	Scrobipalpula abroleta	Pega hoja	25
Tomate (*Lycopersicum esculentum*)	*Bemisia tabaci*	Mosca blanca	37
	Spodoptera spp.	Gusano constancero	25
	Keiferia lycopercella	Minador o calador	25
	Manduca sexta	Gusano del tabaco	25
	Helicoverpa zea	Gusano de la mazorca	25
	Heliothis virecens	Gusano del fruto	25
	Liriomyza trifolii	Minador	25
	Liriomyza sativae	Minador	25
	Trichoplusia ni	Falso medidor	25
	Pseudoplusia includens	Falso medidor	25
Aji (*Capsicum anuum*)	*Spodoptera* spp.	Gusano constancero	25
	Manduca sexta	Gusano de tabaco	25
	Bemisia tabaci	Mosca blanca	50
	Heliothis virencens	Gusano del fruto	25
	Aphis gossypii	Piojillo	50
Pepino (*Cucumis sativus*) Melon (*Cucumis melo*) Sandia (*Citrullus vulgaris*) Auyama (*Cucurbita pepo*)	*Bemisia tabaci*	Mosca blanca	50
	Diaphania hyalinata	Gusano verde	25
	Diaphania nitidalis	Gusano verde	25
	Liriomyza trifolii	Minador	25
	Liriomyza sativae	Minador	25
	Aphis gossypii	Piojillo	50
Molondron (*Abelmoschus esculentus*)	*Aphis gossypii*	Piojillo	50
	Helicoverpa zea	Gusano de la mazorca	25
	Liriomyza trifolii	Minador	25
	Bemisia tabaci	Mosca blanca	50

Cultivo	Plaga (nombre cientifico)	Nombre comun	Dosis a aplicar (g/l)
Repollo coliflor	*Lypaphis erysimi*	Piojillo	50
(*Brassica* spp.)	*Plutella xylostella*	Plutella	25
	Brevicorne brassicae	Piojillo	50
	Hellula phidilealis	Falso medidor	25
	Trichoplusia ni	Falso medidor	25
	Spodoptera frugiperda	Gusano cogollero	25
Habichuela	*Bemisia tabaci*	Mosca blanca	50
(*Phaseolus vulgaris*)	*Hedylepta indicata*	Gusano	25
Frijol	*Urbanus proteus*	Pega hoja	25
(*Vicia faba*),	*Liriomyza trifolii*	Minador	25
Caupi	*Helicoverpa zea*	Gusano de la mazorca	25
(*Vigna unguiculata*)	*Spodoptera* spp.	Gusano constancero	25
	Psara bipunctalis	Pega hoja	25
	Empoasca kraemeri	Empoasca o esperancita	25
Maiz	*Spodoptera frugiperda*	Gusano cogollero	25
(*Zea mays*)	*Helicoverpa zea*	Gusano de la mazorca	25
	Aphis maidis	Piojillo	50
Remolacha	*Spodoptera exigua*	Gusano constancero	25
(*Beta vulgaris*)			

Fuente: Investigación Proyecto.

Anexo 2 Contenido de azadirachtina en muestras de semillas originadas en Nicaragua, Haiti, La India y República Dominicana

Origen de la muestra	Contenido de azadirachtina en la materia seca (mg/g)
Nicaràgua	
Sébaco I	4.03*
Sébaco II	4.00*
Sta Isabel	3.83*
Mateare	5.49*
San Francisco	4.03*
Haiti	2.10
La India	3.50
República Dominicana	
Baní	4.90
Azua	4.20
Cumayasa	2.60
San Cristóbal	4.20
Barahona	5.40

Gruber (1991); Ermel (1992)

* Promedio de 4 años (1986–1989)

Anexo 3 Resultados de un ensayo con repollo

	Incidencia de daño en hoja 4 ta evaluación *P. xyllostella* (0–3)*	*L. erymisi***	Rendimiento lbs/parcela
Testigo	2.2b	2.3b	0
Thuricide (2 g/l) + Melaza (10 g/l)	0.5a	2.3b	0
Nim EA (60 g/l)	0.4 a	0.0a	104

Tratamiento con la misma letra no difiere al nivel del 5% de probabilidad.

Nivel de significancia P = 5%

*Daño foliar en 4 hojas externas

0 = sin daño

1 = hasta 20%

2 = 20–60%

3 = > 60%

**Daño foliar en 4 hojas externas

0 = sin daño

1 = pocas manchas cloróticas

2 = hojas cloróticas con bordes neocróticos.

3 = > 50% superficie de hojasneocróticas.

Anexo 4 Grado de infestacion por *Plutella xylostella* (0-3)*

Tratamientos	Evaluaciones días después de transplante 16 días	30 días	45 días	59 días
Testigo	0.41 b	0.74 b	0.41b	2.15b
Thuricide (2g/l) + Melaza (10 ml/l)	0.13a	0.25a	0.13a	0.51a
Nim EA (60 g/l)	0.11a	0.26a	0.11a	0.41a

Tratamiento con la misma letra no difieren al nivel del 5% de probabilidad.

*Grados de daños:

0 = cero daño
1 = 0-20%
2 = 20-60%
3 = > 60%

Anexo 5 Intensidad de daño por *Lipaphis erysimi* (0-3)*

Tratamientos	Evaluaciones días después de transplante 45 días	 59 días
Testigo	2.2b	2.32b
Thuricide (2 g/l) + Melaza (10 ml/l)	2.2b	2.26b
Nim EA (60 g/l)	0.03a	0.0a

Tratamientos con la misma letra no difieren estadísticamene al nivel del 5% de probabilidad.

Intensidad de daños:

0 = Cero daño
1 = Manchas cloróticas
2 = Clorótica y seca en los bordes
3 = Más de un 50% superficie foliar seca.

Anexo 6 Resultados de un ensayo con pepino

	Incidencia de plaga en 4 ta. evaluación			
	*D. hyalinata**		*A. gossypii***	
	L1-2/L3-5/pup	% defol.	Grado (Inf. 0–7)	Rend. (lbs/parcela)
Testigo	30.3/20.5/1.5	21.0a	3.5a	11.4
Nim EA (50 g/l)	6.5/6.8/0.3	3.8b	0.8b	44.8
Ambush® (0.5 ml/l)	6.3/2.7/0.3	1.2b	1.4b	46.5

Nivel de significancia P = 1%

Evaluación de tres sitios (50 cm x 50 cm) en la hilera central.

*No. de individuos en hojas evaluadas y daño foliar en % (estimado)

**No. de áfidos por hoja: 0 = sin áfidos; 7 = > 50 áfidos.

Anexo 7 No. de ninfas de *C. planaris** por 2.3 cm^2 en berenjena.

	Evaluaciones 3era	4 ta	5 ta
Testigo	0.6a	0.6a	2.2a
Nim EA (50 g/l)	0.0b	0.0b	0.0b
Aceite de nim (2%)	0.1b	0.0b	0.0b
Butacarboxim (1.5ml/l)	0.0b	0.0b	0.0b

Nivel de significancia P = 1%

*Evaluación de tres hojas por planta (base, centro, punta) con un marco localizado en el centro de la hoja.

Anexo 8 No. de individuos de *B. tabaci* por 1 cm^2 en tomate

	Evaluaciones 1era ninfa	2da huevo/ninfa	3ra huevo/ninfa
Combinación insectidas químicos	9.2	11.6/6.1	19.2/54.8
Aceite mineral (0.75%) + combinación insecticidas químicos	5.0	10.8/4.9	17.6/23.5
Aceite de nim (1.5%)	2.2	7.2/2.4	5.9/4.2
Nim EA (50 g/l)	3.5	9.5/3.7	7.8/9

INSECT PATHOGENS IN INTEGRATED PEST MANAGEMENT FOR THE CARIBBEAN

R A Hall
National Institute of Higher Education, Research, Science and Technology, Trinidad & Tobago

Problems with chemical control whether due to resistance of insect pests to pesticides and the enormous cost of bringing new chemicals on to the market, or to environmental considerations are beginning to dictate the pace at which the development of bio-control agents is moving. Furthermore, farmers are caught in a vicious spiral of evermore frequent cycles of pesticide application the cost of which can comprise up to 50% of the wholesale value of a crop (and even intensive applications on this scale do not always result in satisfactory control). The Government of Trinidad & Tobago has, therefore, recently invested in several research programmes to develop alternative strategies to chemical control on vegetables and other edible crops. In the capacity of the Commonwealth Secretariat (London) biological control expert, the author has a team of postgraduate students who are being trained in various important aspects of microbial control research in order that a permanent biological control capability may be established in the Caribbean.

With minimal resources, a new bio-control laboratory has been established and within 2 years has become one of the most productive and efficient in the region. The training is being accomplished through the expedient of research programmes targeted against the major pests of food crops in Trinidad & Tobago and are as follows:

- Control of whitefly by fungi.
- Control of caterpillar pests on vegetables by bacteria and fungi.
- Control of thrips by fungi.
- Control of thrips by predators.
- Control of sugar-cane froghopper by fungi.
- Control of locusts by fungi.

These projects are being financed and assisted by various organizations in Trinidad & Tobago, notably the National Institute of Higher Education, Research, Science and Technology (NIHERST), Caroni (1975) Ltd., the Ministry of Agriculture, the University of the West Indies (Trinidad & Tobago), the International Institute of Biological Control and (in London), the Commonwealth Secretariat.

Whitefly (*Bemisia tabaci*) and *Thrips palmi* are the principal targets of our studies and our focus is on the use of pathogens which we envisage will ultimately comprise an important component of a fully integrated approach (integrated pest management; IPM). Our research thrust is orientated to determine the minimum predictable standards of control that we can expect from these agents so that their use – or non-use – can be considered in the totality of the various possible measures which may be applied to control these pests.

Additionally, we do not feel that we can consider the integrated control of these pests in isolation from other major pests which inhabit the same crops or agricultural ecosystem. In Trinidad & Tobago, most vegetables are grown on smallholdings and many different crops comprise an intimate and interlacing patchwork. Therefore, perhaps one should not discuss IPM of thrips and whitefly without reference to IPM of other major pests such as lepidoptera on crucifers. Quite simply, the heavy applications of chemicals on the latter crops cannot be

divorced from IPM strategies on other crops (e.g. eggplant, cucumber, melon etc.) on which whitefly and thrips are problematical. In the context of IPM, considerable reliance will be placed on the contributions of natural enemies of whitefly and thrips which on smallholdings will be adversely affected by spray drift. Furthermore, whiteflies have recently achieved pest status on certain cruciferous crops.

Therefore, in Trinidad, we are examining the role of pathogens to control thrips and the major lepidopterous pests, such as diamond-back moth (*Plutella xylostella*) and *Hellula phidilealis* also.

This paper outlines our efforts to date to develop microbial insecticides against these pests. However, the theme of this meeting is IPM of whitefly and thrips and I will concentrate mostly on these pests. In addition, I will refer to the only successful precedent anywhere else in the world to control whitefly and thrips with pathogens in European glasshouses.

Firstly, I will say a few words about our work on pathogens of lepidopterous pests on crucifers.

Pathogens of the major pests in Trinidad & Tobago

Bacillus thuringiensis against diamond-back moth

Of the pathogens of diamond-back moth, *Bacillus thuringiensis* (Bt) is the best known. *Bacillus thuringiensis* is a complex of bacterial strains producing bi-pyramidal, cuboidal or irregular protein inclusions. Some strains are toxic for Lepidoptera, while others are so for Diptera or Coleoptera. Recently, strains have been found with nematicidal potential. Many companies in Europe and North America produce a range of *B. thuringiensis* products based both on naturally occurring and engineered strains. However, there is no mass-production in Latin America or the Caribbean.

Various formulations ranging from the traditional (e.g. Dipel®) to the new genetically engineered formulations (MVP) are used in Trinidad & Tobago. In fact, traditional formulations of Bt have been used by farmers for a number of years. Unfortunately, farmers are not aware of the bacterial nature of the product they are spraying let alone its advantages and limitations. Therefore, the product has never been used optimally. Furthermore, farmers are encouraged by distributors to spray Bt in the same tank mix with broad-spectrum chemicals. This advice unfortunately means that the greatest benefit associated with Bt, i.e. its specificity and innocuity to parasites and predators is lost; in the absence of chemicals, naturally occurring parasitoids and predators will go a long way to controlling *Plutella* populations (Mustata 1992) – though we must always be aware of the possibility that even specific agents may, by lowering pest density, indirectly negatively affect the parasitoid population, e.g. with respect to searching efficiency.

In Trinidad, we are focusing our Bt effort in the following areas:

- optimization of the use of Bt by farmers in Trinidad & Tobago
- a screening programme in Trinidad to find strains with activities superior to those of the existing commercial strains
- development of an appropriate method-ology of mass-production of Bt
- monitoring of populations for resistance to Bt.

With respect to the latter, we have undertaken surveys of various *Plutella* populations in Trinidad both those which have been heavily treated with Bt for some years and those which, as far as we can tell have never been treated with the bacterium. At worst, resistance to Bt in Trinidad is incipient. However, there is no room for complacency here as further abuse of the product will undoubtedly provoke higher levels of resistance in the populations, as is the case with other countries, e.g. Korea, Japan.

We are now conducting field trials to determine how best to employ Bt to control

both *Plutella* and *Hellula*. As well as proprietary formulations of Bt, we are also testing our 'home-grown' preparations. (Additionally, we are testing an aggressive strain of the fungus, *Paecilomyces fumosoroseus*, against diamond-back moth).

Fungi

Most of our pests in Trinidad are being targeted by fungal pathogens. This is because thrips, whitefly and froghopper feed on sterile plant juices (phloem), which, being virtually sterile, contain no micro-organisms capable of causing disease in insects. Therefore, in order to provoke disease in such an insect and kill it, a disease-causing micro-organism must invade via the cuticle or natural orifices or wounds. Invasion via the latter route would be expected to be comparatively rare and so will not be considered here. Of the various groups of micro-organisms (bacteria, viruses, protozoa and fungi) only fungi possess the ability to literally bore a hole through the insect cuticle thereby achieving infection. Thus, microbial control of pests such as thrips and whitefly means, exclusively, control by fungi.

Fungi from many taxonomic classes infect insects. However, we are concerned chiefly with the Class Deuteromycetes. This is mainly because this Class contains species which are highly infective for insects and because they are the most amenable from the point of view of ease of culture, including mass-production. The species with which we are concerned are, in addition, considered to be highly safe for plants, animals and humans and, for the most part for non-target insect pests also. Deuteromycete species reproduce asexually by spores called conidia or conidiospores.

Mention in this talk is also made of some species of the Class Zygomycetes – the Entomophthorales. Species in this Class tend not to be easily manipulable but I refer to them briefly as they are amongst the most effective of insect pathogens in nature.

Do fungal pathogens work?

With very few exceptions, all fungi have an absolute requirement for high humidity (>93%) for spore germination and growth. It does not matter whether this humidity requirement is satisfied at a microclimatic or macroclimatic level. Microclimate humidity in certain areas of certain insects may be sufficiently high (particularly in the supple connective tissue between sclerites) to permit fungal infection regardless of ambient relative humidity but there can be no doubt that optimal levels of spore germination and infection of insects occur when the ambient humidity is high, e.g. *Verticillium lecanii* (Milner and Lutton 1986). The best successes to date have been recorded where humidity was expected to be high, e.g. in greenhouses and here we may cite the example of *Verticillium lecanii*, a pathogen of aphids and whiteflies. I spent several years working on many strains of this fungus which culminated in the commercialization of two such strains – an 'aphid strain' (Vertalec®) and a 'whitefly strain' (Mycotal®) (Hall and Papierok 1982; Hall 1984). These two products are currently produced by the world's largest commercial producer of biological control agents, Koppert B.V. in Holland.

I will use the example of *Verticillium lecanii* to demonstrate that fungi can exert dramatic control in commercial conditions.

Until relatively recently, whitefly in European protected crops meant *Trialeurodes vaporariorum*. Although *Bemisia tabaci* is now present on some crops, *T. vaporariorum* is likely to remain the major pest species because the temperatures which occur in protected crops are too low to permit *B. tabaci* to predominate except in the hottest summer months.

Back in 1977, I observed particularly severe fungal epizootics caused by the fungus, *Verticillium lecanii*, devastating whitefly populations. The strain was isolated in the laboratory and following evaluation, was applied to low-density whitefly populations on cucumber and tomato. However, multiple applications of the fungus were required to prevent such populations from reaching economic proportions. To overcome this problem, we incorporated a substrate into the spore formulation which permitted sparse fungal growth and sporulation on the leaf surface. Such 'natural' sporulation not only had the effect of conferring a degree of persistence

on the fungal preparation (spores in whole sporulating structures remain viable for weeks while naked spores in a spray die within a few days), but also by creating many well-distributed 'reservoirs' of infection, controlled low density populations of whitefly scales and adults; a single spray of such a formulation sufficed to control even well-established whitefly populations for the duration of a crop.

As a result of these experimental successes, this strain of *V. lecanii* was developed as a commercial 'myco-insecticide'. Together with the British company, Tate and Lyle, systems of mass-production were developed both on solid substrate and in liquid fermentation. Then came the hard part – formulation of the spores as a dry powder with a reasonable shelf-life. This was finally achieved but only with some difficulty and in 1981 the product Mycotal® was registered for commercial use. Eleven years later the product has changed hands several times and is now produced and sold by the Dutch company, Koppert BV. There have been a few minor changes to the formulation – before the infective propagules were blastospores produced in liquid fermentation whereas conidiospores have now replaced these. The strain in the commercial formulation remains unchanged since its initial discovery in 1977.

Do fungal pathogens work outside glasshouses?

Many people pose the question 'Do fungi really work in the outdoor environment?' We might have said a few years ago 'yes', as long as we do not stray too far from the ecological niche and host range within which these pathogens are naturally very and sometimes dramatically effective. However, very recently, some developments have indicated that it might be possible to stretch the capabilities of fungi beyond their traditionally perceived limits. Instead of aqueous sprays, spores may be applied in oil-based formulations. Fungal spores have been shown to kill locusts at ambient humidities of 35% (Prior et al. 1992). However, such formulations would not help a fungal pathogen spread from an infected insect to a healthy one if the humidity were not sufficiently high for a reasonable length of time to permit reproduction of the infectious propagule, i.e. sporulation on the insect body. To overcome this constraint, repeated applications at judiciously chosen intervals would be necessary in certain situations to bring about control of such insects.

Another strategy whereby fungi may be rendered more effective focuses on accelerating the infection process so that spores may germinate during a shorter 'window' of high humidity or before they become dislodged, preened off or inactivated for whatever reason. At least two phenomena have been discovered by our group in Trinidad & Tobago which may lead to methods of accelerating the infection process. One discovery relates to the fact that spores produced in very young cultures germinate significantly faster than those from older cultures (but still in an exponential phase of growth). (These spores are probably the first-formed spores on a phialide; Hall et al., in preparation). The elucidation of the reasons for faster germination may eventually result in more efficient spore preparations and possibly genetically modified strains with greatly improved epizootic potential.

Such improvements in application technology and a greater understanding of the fundamental key processes in the infection cycle are ushering in a new and exciting era for research into pest control by fungi.

Pathogens of whiteflies

The following species have been and are being investigated as whitefly control agents and their potential for controlling *Bemisia tabaci* will be discussed.

Aschersonia aleyrodis

Verticillium lecanii

Paecilomyces fumoso-roseus

Beauveria bassiana

Aschersonia aleyrodis

This species is frequently found on whiteflies in lowland tropical zones, though we have yet to find it on *B. tabaci*

in Trinidad. However, the species is common on citrus scale in Trinidad, as is *Aschersonia turbinata*. *A. aleyrodis* has been shown to attack *B. tabaci* in Florida.

A. aleyrodis is an intriguing fungus since inasmuch as it is slow germinating it would be expected to infect insects rather more slowly than other pathogens such as the faster germinating *V. lecanii*. In reality, against the glasshouse whitefly (*Trialeurodes vaporariorum*), the speed at which sprayed *A. aleyrodis* spores infect the pest is quite surprising – faster than *V. lecanii* – even when humidity appears to be sub-optimal. *A. aleyrodis* infects only the larval stages of whitefly, adults and eggs rarely becoming infected. Consequently, in European glasshouses, it does not spread from infected to healthy insects and so must be sprayed several times to achieve control of this rapidly reproducing pest. However, evidently on citrus whitefly the fungus does spread – extremely efficiently - as evidenced by the virtual 100% natural control of this pest each season. Osborne and Landa (unpublished) have recently made observations which may explain this apparent contradiction.

A. aleyrodis is highly specific for whiteflies and does not harm natural enemies. Therefore, in glasshouses, it may be used against whitefly in conjunction with the parasitoid, *Encarsia formosa*, and is especially useful as a 'knock down' agent when whitefly populations have become too large for *E. formosa* to control. There are some outstanding problems with this fungus relating to mass-production and stabilization of spores.

In Trinidad & Tobago, we have tested in the laboratory a strain of *A. aleyrodis* which gave good results against *T. vaporariorum* in the UK (Hall, unpublished observations). However, we have not been able to achieve any infection of *B. tabaci* in Trinidad with this strain. We have recently acquired, from Dr Lance Osborne (University of Florida), a strain known to infect *B. tabaci*. If the results which I obtained in the UK on the glasshouse whitefly can be repeated on *B. tabaci*, then we shall be focusing a good deal of attention on this fungus.

Verticillium lecanii

There are many strains of *V. lecanii* attacking a wide variety of insect hosts and plant pathogens. The classification of this fungus is open to question, some workers preferring to split the complex into further species. Certainly, *V. lecanii* can be divided into large-spored and small-spored strains (Hall 1984). In nature, large-spored strains are found infecting exclusively aphids though they will also infect other pests in the laboratory including whitefly (Hall 1982). The commercial aphid-killing product Vertalec® is based on such a large-spored strain (Hall 1982; 1984). Strains from thrips, whitefly, mites and phytopathogenic fungi are always small-spored and the commercial product for whitefly and thrips (Mycotal®) is based upon a small-spored strain (Hall 1982; 1984). However, small-spored strains are sometimes found in nature on aphids also. To simplify the situation, naturally-occurring small strains perform best against whitefly and thrips while large-spored strains do best against aphids.

From the point of view of whitefly control therefore, we are interested in small-spored strains. These have a temperature optimum of about 24 °C which may limit their potential in the humid tropics where average temperatures are often higher than this. In general, constant temperatures a few degrees beyond the optimum have a dramatically negative effect on the performance of insect pathogenic fungi. While *V. lecanii* is the only fungus found infecting the glasshouse whitefly (*Trialeurodes vapor-ariorum*) in glasshouse environments in temperate regions and at high altitude in Colombian plastic houses, it is very rarely found infecting whitefly in lowland tropical areas in the Caribbean region. For this reason, I feel that *V. lecanii* has little potential against *B. tabaci* in such areas. However, in other lowland tropical zones, it is important to be aware that temperatures may not necessarily be as high.

V. lecanii infects both larval and adult stages of whitefly but not eggs. First instar stages of *B. tabaci* are much more resistant to disease than subsequent stages (Peterkin and Hall, unpublished) This fungus may be

mass-produced on solid-substrate or in liquid medium.

Paecilomyces fumoso-roseus

This species has a rather wide insect host range including whiteflies. Amongst the latter, both larval and adult stages are attacked and, to a certain extent, if humidity is very high, the eggs (Peterkin and Hall, unpublished). Other workers report that all larval stages of *B. tabaci* are attacked but we have been unable to achieve satisfactory infection of first instars by *P. fumoso-roseus* – or other fungi for that matter (Peterkin and Hall, unpublished); all other larval stages are highly susceptible. This fungus has a temperature optimum of 28 ^{o}C, considerably higher than the small-spored strains of *V. lecanii*. For this reason, I believe that from an ecological standpoint, *P. fumoso-roseus* is better adapted than *V. lecanii* to exploit the lowland tropical niche. It is not surprising therefore that *P. fumoso-roseus* is the only fungus found in Trinidad on *Bemisia* – and it is quite common. By the same token, this species has, to my knowledge, never been found in European glasshouses or high altitude plastic houses in Colombia.

Since *P. fumoso-roseus* is amenable to mass-production and displays high virulence to *Bemisia tabaci*, we are concentrating much of our research effort on this fungus.

Beauveria bassiana

The fungus, *B. bassiana* is not considered to be a natural pathogen of whiteflies. However, it is included in this list because scientists in the USA report that a strain of this fungus (isolated from the cotton boll weevil), provides very good control of *Bemisia tabaci* in greenhouse and field vegetables. In arid areas in Arizona and California, they reported that oil-based formulations of *Beauveria bassiana* conidia gave adequate control. Eggs, larvae and adult stages are reported to be infected by this strain.

Pathogens of thrips species

Many of the species which attack whitefly also infect thrips. The fungi known to attack thrips species are as follows:

Verticillium lecanii

Paecilomyces fumoso-roseus

Beauveria bassiana

Neozygites parvispora (Entomophthorales)

Entomophthora thripidum (Entomophthorales)

Metarhizium anisopliae

Hirsutella spp.

Verticillium lecanii

This species has been described above. In temperate zones, *V. lecanii* may easily be found infecting thrips species in glasshouses and, in both temperate and tropical zones, laboratory cultures. Small-spored isolates of the fungus are exclusively associated with these insects. The commercial product Mytocal® also possesses the best thrips activity of any strain of *V. lecanii* so far examined. We have established that *Thrips palmi* is susceptible to the Mycotal® strain but, for the reasons given above, it is not likely that the known strains of this fungus will be of much value in controlling *T. palmi* in lowland tropical areas in the Caribbean.

Paecilomyces spp.

Paecilomyces spp. have rarely been associated with field infections of thrips. However, there is at least one report from Puerto Rico of a *Paecilomyces* sp. infecting *Gynaikothrips ficorum*. In Trinidad, we have encountered *Paecilomyce fumoso-roseus* killing *Thrips palmi* in laboratory cultures.

Beauveria bassiana

There are several reports in the literature of this species attacking thrips species most

notably *Selenothrips rubrocinctus* on cocoa (Myers 1931). In the laboratory, *B. bassiana* is pathogenic to *Thrips palmi.*

Metarhizium anisopliae

There is but one report of this fungus attacking thrips – *T. palmi* – in a greenhouse in Puerto Rico.

Neozygites parvispora and *Entomophthora thripidum*

There are numerous reports of these fungi attacking a range of thrips species. *N. parvispora* has been reported from Japan on *T. palmi* (Saito et al. 1989). *Entomophthora thripidum* has been found on *T. tabaci* (Samson et al. 1979). These fungi provoke spectacular epizootics in thrips populations. However, neither of these fungi has been successfully cultured and so the prospects of producing sufficient infective material for wide-scale application are, at present, poor.

Hirsutella spp.

Recently, several isolations of new *Hirsutella* species from thrips species have been made. At least two have been made from Trinidad – one by C Prior from *Limothrips* sp. and a new species from *Thrips palmi* (Hall 1992). The latter has been cultured and its potential is being investigated in the laboratory by our group in Trinidad.

To summarize, there are only two reports of fungi attacking *T. palmi* in natural field conditions - *Neozygites parvispora*, and *Hirsutella* sp. *Metarhizium anisopliae* was found only once in a greenhouse in Puerto Rico. Of the fungi found consistently on thrips in general, we may cite *Beauveria bassiana, Verticillium lecanii, Hirsutella* spp. and members of the Entomophthorales.

Research strategy

Once pathogens have been found and brought into the laboratory, experiments to evaluate their effectiveness should be commenced. It is useful to examine some of the principles which should orientate this research phase as carefully conceived experimental protocols can save much time, effort and money.

Once we have a collection of pathogenic isolates of fungi, how do we decide which performs best against the target pest? The definitive way of doing this is to spray infective material in the field. However, prior to investing scarce resources in field trials, one must develop laboratory systems which provide information which is reasonably predictive. Such a laboratory system of quantifying the ability of a pathogen to infect its host is called a bioassay. A well-designed bioassay system will provide information which will enable researchers to predict which of the strains of pathogens at their disposal will perform best under field conditions. An ill-conceived system will yield practically no information at all. For example, the literature abounds with examples of bioassay systems which do no more than demonstrate how insects react to a stressor (in this case a pathogen) in already stressful conditions, e.g. continuous high humidity which, of course, favours the fungal pathogen. Some insects may react negatively to continuous high relative humidity and this is revealed by high control mortality. Furthermore, small, highly mobile insects such as thrips may drown in small condensation droplets, may escape or become trapped or hidden in crevices – all of which contribute to a high control mortality. Whatever the reason, a high control mortality prevents an accurate assessment of the infective ability of a pathogen. Very little work has been published on the bioassay of fungi against thrips. However, high control mortalities have been a feature in many of these and consequently, the significance of the results is, frankly, questionable.

Therefore, it is important to develop a bioassay system which permits almost all control insects to survive, apparently healthily, to the end of the assay period. Using previously developed systems for thrips species, we first encountered unacceptably high control mortalities in *Thrips palmi* – sometimes as high as 90%. Consequently, we developed a totally new bioassay system (Hall et al. 1993 which fulfilled the following important criteria:

- the insects must be individually contained to eliminate the risk of cross-contamination
- the insect should be able to move freely within the bioassay chamber
- the system should permit clear observation of the insects at all times
- there should be sufficient air exchange to supply the needs of the insect and leaf tissue and to prevent condensation (in which small insects such as thrips may drown) on the walls of the chamber or on the leaf discs
- the substrate (normally leaf tissue) must be maintained in a palatable form for the duration of the bioassay
- there should be minimal handling of the insect
- the control mortality must be low (below 10%)
- the cages must be escape-proof
- the system must be reasonably simple to set up so that large numbers of assays may be performed without undue difficulty.

Our new system relies on using a Plaster of Paris matrix for supporting leaf discs, the whole contained in a compartmented square Petri dish. Control mortalities of *Thrips palmi* including escapes has been reduced from a maximum of 90% using other systems to a maximum of 8% using the Plaster of Paris system. Furthermore, a much simplified version of this system is suitable for sessile insects such as *Bemisia* immatures (Hall et al. 1993).

Traditional bioassays usually involve treating test insects with spores and calculating the LC_{50} or dosage required to kill 50% of test insects after a given time.

At this stage, I would like to further define the function of a laboratory bioassay in terms of the epizootiological field characteristics of a pathogen. If a pathogen is expected to infect only those insects which are hit by a spore spray – such as dry-season multiple application of oil-based spore sprays – then the sort of infectivity assay which has been described will probably be adequate. However, a new factor enters the equation when we consider post-application spread of the pathogen from diseased insects hit by a spray to healthy insects – in other words epizootic potential. Epizootic potential becomes very important when, within rapidly reproducing pest populations in conditions which are favourable for the fungal pathogen, we expect the disease to achieve control after only one or a very few applications. How do we measure epizootic potential? Since it is difficult to define we cannot measure it. Can good epizootic potential be predicted from high infectivity as measured by bioassay? The answer is probably

Table 1. Mortalities of adult aphids (treated with spores of different strains of *V. lecanii*) and their progeny acquiring disease from the adults through contagion

Strain	Adult mortality (%)	Progeny mortality (%)	Epizootic potential
1-72	100	84	good
93-82	100	77	good
57-81	91	9	poor
79-82	100	0	poor
18-78	91	8	poor

no, usually – in the case of the fungus, *Verticillium lecanii* on aphids, while strains with good epizootic potential always exhibited high infectivity, the reverse was most certainly not true (Table 1). We cannot measure epizootic potential but we can certainly compare epizootic potentials of pathogens as the data in Table 1 adequately demonstrate.

Recently, there have been reports that bioassays at sub-optimal relative humidities may serve to select the most aggressive strains of fungi, and possibly those with good epizootic potential also. This may stem from the fact that, as I mentioned before, some insects are stressed under conditions of continuous high humidity probably because they cannot get rid of excess moisture sufficiently rapidly. At sub-optimal humidities, insects may be in much better shape and only the most pathogenic organisms may be able to provoke significant mortality. In our laboratory we are modifying the Plaster of Paris assay system along these lines to test this possibility.

To conclude this section on bioassay, there are no hard and fast rules as to what sort of assay system one should employ to screen fungal pathogens prior to testing them in the field. What is important is that researchers should have a very clear idea of what their objectives are and therefore what pathogenic charact-eristics they wish to focus upon.

Our microbial research projects in Trinidad have only been in progress for just over 2 years. However, what can we conclude so far about the potentials of the fungi at our disposal?

In working with the three major pests in Trinidad & Tobago, we have come to a rather surprising and interesting conclusion. As a species, *Paecilomyces fumoso-roseus* would appear from laboratory bioassay studies, to be the most promising fungus not just against *B. tabaci*, but also the diamond-back moth (see above) and *Thrips palmi*. Furthermore, we now have a single strain of this fungus which demonstrates strong pathogenicity against all three pests. As far as *T. palmi* is concerned, the only other pathogen which approaches the high activity of *P. fumoso-roseus* is the new species of *Hirsutella* isolated from this insect. However, like many species of *Hirsutella*, it does present problems with respect to cultural manipulation and the possibilities of econom-ically feasible mass-production. In contrast, *P. fumoso-roseus* is very amenable and easy to manipulate.

Therefore, at present, we have a rather unusual situation whereby we may ultimately be able to recommend the use of a single fungal product (based on *P. fumoso-roseus*) against three very different pests.

Field trials are now in progress in Trinidad to test our strains selected from laboratory bio-assay. Both aqueous and oil-based formulations are being tested.

Integrated control

Insect pathologists tend to consider the use of pathogens as specific agents which alone will solve a particular pest problem. Only exceptionally is this so. For example, under the most favourable conditions, commercial preparations of the fungus, *Verticillium lecanii*, will without any other inputs, virtually wipe out the target pest. However, in the open field where climatic conditions cannot be precisely controlled, such total control will not be so common. What is important is predictability of performance. This will be different during different seasons. Let us look at control of *Bemisia tabaci* and *Thrips palmi* by fungi. These pests are most serious in the dry season. Therefore, at this time, fungi are not going to be in an 'epizootic phase'. So, in this scenario, only oil- or emulsion-based spore sprays would have any impact on populations. The mortality arising from such interventions (assuming consistency of quality of sprayed product) will be predictable and either acting alone or in conjunction with other naturally-occurring or inundatively-introduced biological control agents, the economic feasibility of the use of the fungus can be evaluated.

At other times during the wet season, we may envisage a strategy whereby wide-scale applications of fungal strains with good epizootic potential may eliminate populations from an area enabling farmers

to have a 'clean start' at the beginning of the dry season. In the context of sound integrated pest management practices, this 'clean start', provided it is accomplished over a wide area, could be expected to last well into the dry season.

Compatibility of pathogens with other control measures

Preparations of the bacterium, *Bacillus thuringiensis* are compatible with most other control measures. Few chemical insecticides are known to interfere with the toxic action of the crystal in the insect mid-gut. Some insecticides and fungicides do inhibit *B. thuringiensis* spore germination but the consensus of opinion is that the spore plays only a minor role, if any, in *B. thuringiensis* toxicity.

There have been several publications over the years which deal with compatibility of insect-pathogenic fungi with insecticides and fungicides. As far as our most promising fungus, *P. fumoso-roseus* is concerned, there is little in the literature on the subject of compatibility. However, it is not unreasonable at this stage to assume that it will not differ markedly from other entomogenous Deuteromycetes in its reaction to chemicals, e.g. *Verticillium lecanii* (Hall 1981). It can certainly be said that, in general, insecticides are less harmful to fungi than fungicides. Since that publication (Hall 1981), the author has carried out much (unpublished) work which shows that so-called *in vitro* tests (e.g. growth of fungi on agar containing chemicals) do most certainly not give reliable data which can be extrapolated to the field situation. The only laboratory tests which have any value are those which involve applying pesticides at varying periods before, simultaneously and after application of the pathogenic agent to the pest, preferably on its host plant. Only by doing this can one make a judgement as to how prejudicial application of a pesticide might be to: (i) the initial infection level of a pest population and (ii) subsequent development of epizootics. Existing data for *Verticillium lecanii* (Table 2) will serve as a guide for other fungi but, *in vivo* testing along the lines suggested above should eventually be done for the most commonly-used insecticides and fungicides. (One must bear in mind that such tests are not easy and normally one can only countenance a limited programme of testing.)

Often beneficial parasitoids will be used in the same cropping systems as entomopathogenic fungi. Use of *V. lecanii* has been found to be compatible with the hymenopterous parasitoid, *Encarsia formosa*. Although the fungus will provoke a certain mortality among parasite adults at very high humidities, this does not matter since under such conditions, the fungus will control the pest population on its own. In drier conditions, where the fungus could not, by itself, always control the whitefly population, virtually no parasitoids succumbed to disease and so the system was self-regulating in this respect. A similar situation may arise with *P. fumoso-roseus*.

Conclusions

We probably already have, in our collections, the best species and strains of pathogens of *Bemisia tabaci* and *Thrips palmi*. In the past, we would have been restricted to wet season application of infectious spores of these fungi in high-volume aqueous suspensions. Oil-based spraying technologies now open up the possibility of dry-season applications also. Further advances hold the promise of increasing the natural efficiency of these pathogens. For example, our work in Trinidad & Tobago has revealed two methods of accelerating spore germination, and by implication the infection process. Given that in the field, fungal spores can only germinate during a 'window' of favourable humidity and temperature which occurs usually at night and is usually of limited duration, such discoveries could lead to a disproportionately high increase in infectivity or epizootic potential. These developments give cause for considerable optimism about the potential of insect-pathogenic fungi. It is not anticipated that fungi and other pathogens will, except under the most favourable conditions, constitute the sole means of controlling whitefly or thrips or other target pests on crops such as vegetables in the Caribbean. However, we know that they have a role to

Table 2. Chemicals* compatible or otherwise with *Verticillium lecanii*

Trade name	Common name	Diseases	Compatibility
Fungicides			
Afugan	pyrazophos	Powdery mildew, *Helminthosporium*	B
Antracol	propineb	Powdery mildew, Septoria, Sigatoka Cercospora, Alternaria Phytophthora	B
Bavistin	carbendazim	Many	A
Baycor	bitertanol	Powdery mildew Rusts, others	B/C
Bayleton	triadimefon	Many	A/B
Benlate – spray – drench	benomyl	Many	C A
Brestan	fentin acetate	Many	C
Calirus	benodanil	Rusts, *Rhizoctonia*	A
Captan (see Orthocide)			
Copper oxychloride		Many	B/C
Daconil	chlorothalonil	Many	C
Delan	dithianon	Many	B
Derosal	carbendazim	Many	A
Dithane	maneb	Many	C
Elvaron	dichlofluanid	Many	C
Euparen	tolyfluanid	Many	C
Fernasan (see Thiram)			
Fungaflor	imazalil	Many	C
Impact	flutriafol	Many	B
Karathane	dinocap	Powdery mildew	B
Kumulan	nitrothal-isopropyl plus sulphur	Powdery mildew	C
Mancozeb	maneb plus zinc	Many	C

Table 2. (continued)

Trade name	Common name	Diseases	Compatibility
Maneb (see Dithane)			
Nimrod	bupirimate	Powdery mildew, Rusty spot	B
Orthocide	captan	Many	C
Pallinal	metiram + nitrothal-isopropyl		Many C
Phaltan	folpet	Many	C
Plantvax	oxycarboxin	Rusts	A
Ridomil	metalaxyl	Phycomycetes	A
Ronilan	vinclozolin	Many	A
Rovral	iprodione	Many	B
Rubigan	fenarimol	Many	B
Saprol	triforine	Many	A
Sulphur		Many	C
Terrazole	etridiazol	Many	A
Thiram	thiram	Many	C
Topsin	thiophanate	Many	B
Tritisan	quintozene/PCNB	Many	A
Vitigran (see copper oxychloride)			

Source: data from Hall (1981) and Ledieu (1985)

A: May be used within 24 h of applying *Verticillium*.

B: May be used within 3 days of applying *Verticillium*.

C: Try not to use within 7 days of applying *Verticillium*.

* In general, insecticides and acaricides tend to be compatible with *Verticillium lecanii*.

play. We need to quantify their potential and limitations so that we can ascertain precisely what contribution they might make in the context of integrated pest management.

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MANAGEMENT OF THE WHITEFLY, *BEMISIA TABACI*, AND GEMINIVIRUSES ON TOMATO IN FLORIDA AND THE DOMINICAN REPUBLIC

P A Stansly
University of Florida, USA

The so-called 'B' strain of *Bemisia tabaci*, otherwise known as the 'silverleaf whitefly,' has been a vegetable pest in the Dominican Republic since at least 1988. The situation there in regard to *B. tabaci* has parallels in the Florida vegetable industry. The whitefly was probably introduced into both regions through the importation of infested poinsettias. In both cases the whitefly preceded geminivirus into tomato by about a year, after which the virus quickly became the direct cause of most economic loss. In both cases, summers free of the host crop were proposed as a partial solution and have provided some relief.

Here the parallels stop. Systems of production, ecological conditions, and probably the biology of the geminiviruses involved differ in Florida and in the Dominican Republic. Florida tomatoes are grown in large production units, so control practices tend to be relatively uniform on a regional scale. High fresh-market prices and commensurate production costs justify an advanced spray technology sufficiently effective, thanks in part to good spray coverage possible on staked plants, to control in-field populations of whitefly. The only virus known to be transmitted by *B. tabaci* in Florida tomatoes is tomato mottle geminivirus (TMoV). Fortunately, TMoV has an extremely limited host range which does not include other vegetable species except for some cultivars of common bean (*Phaseolus vulgaris*), tobacco and tomatillo. Thus, the maintenance of virus inoculum in most production areas depends on the presence of tomato plants and virus inoculum can be largely eliminated by a tomato-free period. As a result of all these factors, the severity of the geminivirus epidemic in tomato has greatly diminished in south-west Florida where summer fallow periods and a winter break have been most rigorously practiced.

Most tomatoes in the Dominican Republic are grown in small units for processing. However production is contracted by large processors who provide technical assistance to their growers and therefore some uniformity of practices. Production costs are relatively low and insecticidal control less effective than in Florida due to differences in spray technology and poor coverage on unstaked plants. There are at least two geminiviruses affecting tomato in the Dominican Republic, but little is known of their biology and ecology. However the host ranges of the Dominican geminiviruses could be broader than for TMoV. A summer fallow period has not have been rigorously practiced in the past, although the 1993 season may have been an exception. If so, and the severity of tomato geminivirus has still not significantly diminished, then non-crop sources of whitefly and virus may be important factors in carrying inoculum over the summer.

An understanding of the biology and ecology of both vector and virus are necessary for their successful management in any production system. Principal sources of virus and whitefly entering crops must be identified. Such sources are most often other crops, although weeds could also play a significant role early in the crop cycle. Information on sources would then be used to decrease vector and virus inoculum moving into susceptible crops, especially in the critical early stages. If biological control is to be part of the management system, then the principal natural enemies of whitefly and their sources must be identified. Sources of natural enemies may be certain weeds or crops which act as refuges or food sources for beneficial insects. The biological control programme would

then concentrate on augmenting the types and abundance of natural enemies through introductory or augmentative release and/or habitat management to expand the capacity of refuges. Once basic information on the sources of whiteflies, geminivirus and natural enemies has been acquired, it will be possible to build an effective management system adapted to the realities of local production conditions and practices.

Whitefly management in south-west Florida

Silverleaf whitefly was first reported infesting poinsettia in Florida in 1986 and moved quickly to vegetables. Irregular ripening of tomato caused heavy financial loss in 1988 and TMoV has become widespread in 1989. Losses and control costs to the $550 million tomato industry were estimated at $125 million for the 1990/91 season (Schuster et al. 1993).

Exhaustive host range studies have given the fortunate result that most crop genera outside *Lycopersicon* are not susceptible to TMoV with the exceptions noted above, and only one weed species, *Solanum viarum* (Polston et al. 1993). Post-harvest field sanitation became critically important as a means of removing sources of TMoV inoculum for the following year's crop. Growers in south-west Florida responded well to this recommendation with the desired result of reducing movement of viruliferous whiteflies into fall crops. Other production areas in Florida have not been as successful in creating crop-free periods and have suffered accordingly.

With only limited immigration of whiteflies into fall crops, growers were able to control the vector adequately with improved spraying methods. However, movement from fall to spring crops became a problem when unseasonably warm weather eliminated a winter break. Since temporal separation between fall and spring crops was not adequate, spatial separation became necessary to prevent contamination of new crops by whiteflies and virus from old crops. There are no set rules on the necessary distance between crops. The number of whiteflies migrating, the intervening vegetation and to some extent wind direction all come into play. Whiteflies will generally remain where they are as long as host-plant quality is maintained. Mass movements are usually initiated by plant senescence or plant destruction. The insects continue flight and are carried by the wind until exhaustion or the perception of a yellowish green substrate indicative of rapid plant growth induces them to stop. Discrimination decreases with increasing flight time. Once landed upon a plant, probing is initiated and feeding commences if an acceptable host has been found. Again, discrimination decreases with need and starvation may result in acceptance of a non-preferred host. An empty field between two tomato fields would do little to deter movement. A wood or orchard might at least divert flight, whereas a squash field would act as a trap crop.

Whitefly management in Florida depends on two necessary conditions, one and preferably two crop periods per year, and sufficient refuge habitat for whitefly natural enemies in summer. Refuge habitat is a given in Florida where lush vegetation abounds in summer. However, crop-free periods must be diligently maintained. Harvest of the area's staked tomato, pepper, water-melon and cucumber normally ends in late May or early June and planting commences in August. Many growers in the past left crop residues after harvest until ground preparation for the next crop. Now crop residues are disked in immediately after harvest. Fields are maintained clear of volunteers during the summer by disking and/or the planting of grass cover crops. By these means, massive immigration of whiteflies into the fall crop is avoided and control can be maintained with an efficient spray programme.

Whitefly situation in Dominican tomatoes.

About 8,000 ha are planted in the country, 6,000 in the southern production area and the rest in the north. Fields are irrigated via a canal system flowing from reservoirs on both sides of the central mountain range (cordillera). The land is farmed by small landholders under contract to six major processors satisfying a high local demand. Outdoor beds are seeded in September. The

bare root transplants are set in the ground from October through December and the crop is harvested from January through April.

The presence of *B. tabaci* and geminiviruses in the Dominican Republic was reported by Bird in the 1970s (unpublished). Of particular note was bean golden mosaic virus (BGMV) which caused considerable losses to dry bean production. However, there are no reports of *B. tabaci* attacking tomato until 1989 when considerable losses were incurred from plant debilitation, sooty mould growth and irregular ripening. Geminivirus epidemics were not associated with these infestations until 1991. Virus symptoms first occurred in the south and the pathogen was identified as a geminivirus by J Brown of the University of Arizona (unpublished). Virus incidence in Azua probably reached close to 100% that year, although the north had not yet been affected.

At the urging of tomato producers, the government made the prudent move of banning tomato, pepper, melon, eggplant and okra cultivation in the south during July and August to remove crop sources of geminivirus and whitefly for the fall planting. Unfortunately, adherence to the ban was not universal and off-season vegetable cultivation continued. In the summer of 1992 a severe epidemic of a geminivirus appeared in the north, hitherto virus-free. Seed-beds in both regions were located in close proximity to affected fields so that the prospect of severe losses from geminivirus was great and much of the tomato production area was either reduced or relocated to escape the threat. The ban on off-season production in the south was better enforced in 1993, reportedly resulting in lower whitefly populations although geminivirus levels are still unacceptably high, even in fields set with transplants grown elsewhere or under row covers. The apparent failure to control geminivirus by summer fallow periods and supposedly clean transplant production indicates that either data on the sources of virus inoculum are incomplete or else the technology being used to protect plants from known sources is inadequate.

Steps toward management of whitefly and geminivirus.

Satisfactory control of *B. tabaci* in the Dominican Republic remains elusive, in part because important information on the source of geminivirus and whitefly inoculum is insufficient. Therefore, identification of these sources must be a first priority.

I. Identify sources of geminivirus.

- Survey of crops for whitefly-transmitted viruses.
  - Development of detection techniques.
- Host range studies of principal geminivirus(s).
  - Crops
  - Weeds
- Survey of production areas during off-season to identify most important virus sources.

II. Identify principal sources of *Bemisia*.

- Survey of production areas during off-season to identify most important whitefly sources.
  - Crops
  - Weeds
- Determine the function of natural enemies in weeds and unsprayed crops during the off-season.
  - Population dynamics.
  - Role of major parasitoids and predators.

Once the principal sources of geminivirus and whitefly inoculum have been identified, management of these sources and their impact on crops becomes feasible.

III. Protect crops from geminivirus infection.

- Pre-transplant.
  - Location of seed-beds/greenhouses away from virus sources.
  - Physical barriers (screens, row covers). Monitoring systems.
- Post-transplant.
  - Removal of virus and whitefly sources.
  - Relocation of fields away from sources of virus and whiteflies.

- Vector suppression.
  - Chemical control.
    - Application technology:
      - spray equipment
      - soil-applied systemics (NTN).
      - economic thresholds.
    - Bio-rational insecticides:
      - efficacy of control.
      - effect on natural enemies.
  - Biological control.
    - Augmentation of natural enemies:
      - weed hosts.
      - refuge crops.
      - inundative releases.
      - importation of new species.

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TOLERANCIA DE ONCE CULTIVARES DE TOMATE INDUSTRIAL A GEMINIVIRUS TRANSMITIDOS POR MOSCA BLANCA, (*BEMISIA TABACI*, GENN.) EN LA REPUBLICA DOMINICANA

E Gómez, I Tavarez, F Pérez
Regional Norte-noroeste Programma MIP/Santiago, República Dominicana

Tolerance of 11 cultivars of industrial tomato (*Lycopersicum esculentum*) to geminivirus transmitted by whitefly (*Bemisia tabaci*) in the Dominican Republic

In the north and north-east of the Dominican Republic, there are some 1,150 small and medium producers cultivating some 3,150 ha of tomato, worth approximately 44 million pesos per year. The crop is subject to various levels of attack by the whitefly which transmits the geminivirus that leads to serious reduction in yields. In some countries as much as 100% infestation has been recorded, often accompanied by losses of over 60%. The paper reviews briefly the history of the whitefly in the region, and indicates that geminivirus was positively identified in the Dominican Republic in 1989. In 1984, the use of tolerant varieties for managing the problem was recommended. Here, studies to evaluate 11 industrial tomato cultivars for tolerance to the virus are described. Each cultivar was studied in two situations: (i) with protection of nylon covers and (ii) without protection. This resulted in 22 treatments with four replications. The variables studied were: incidence of virus symptoms; production of fruit (weight and number); the brix grade; the weight of five fruits. The evaluation was done every 5 days. None of the varieties was resistant to the virus. There were no virus symptoms at 15 days, but at 20 days from transplant, all but four varieties showed symptoms of virus infection and in those four, the symptoms started after 25 days. By 50 days, all the varieties were infected. The analysis of variance showed significant differences for the factors studied. Unexpectedly, there was no significant difference between the protected and non-protected conditions.

A partir del año 1990 cuando aparece en la zona tomatera del Sur, sobre todo en el Valle de Azua, República Dominicana, ciertos virus del grupo de los geminivirus, los cuales son transmitidos por mosca blanca (*Bemisia tabaci* Genn.) es cuando esta plaga toma una mayor importancia y se ve como una gran amenaza para la economía de dicha región. Esta situación trajo como consecuencia la necesidad de poner en práctica una serie de medidas de tipo legal, con la finalidad de establecer estrategias de manejo de mosca blanca (*B. tabaci*) en los cultivos hospederos de la misma en la referida zona (Alvarez et al. 1992)

Las agroempresa dedicadas a la producción y procesamiento de tomate han manifestado marcado interés en la implementación de prácticas, que tiendan a reducir los riesgos en la inversión por causa de la patogenicidad de estos virus. Esto debido a la permanente existencia del vector, así como las fuentes de hospederos alternos durante los doce meses del año, en todas las zonas productoras de tomate, en la que se incluyen las regiones norte y noroeste del país.

En visita realizada al país, en enero de 1992 por la Dra. Judith K Brown de la Universidad de Arizona, EEUU, se diagnosticó en tomate, en las zonas de Navarrete, Santiago y Cerro Gordo, Guayubín la presencia del virus del mosaico dorado del frijol (BGMV) y del virus del

mosaico dorado del tomate (TGMV), aunque con baja incidencia y en pequeños focos. En vista a esta realidad, ejecutivos de las agroindustrias de tomate de la región expresaron su peocupación a las autoridades correspondientes por la suerte que podría correr la producción de este rubro en las regionales Norte y Noroeste, donde tradicionalmente se siembran unas 50,000 tareas (3,150 hectáreas), involucrando unos 1,150 pequeños y medianos productores, de manera directa y una inversión aproximada de 44 millones de pesos por año. Inversión que favorece por concepto de empleomanía en mano obra y maquinarias a una gran parte de la población rural de la región, ligada al cultivo (Gómez 1992)

Bird et al. (1982), reportan mosaico amarillo, trasmitido por mosca blanca, en 10 especies de malezas en regiones aledañas a Santiago de los Caballeros.

En la actualidad en la región noroeste se ha detectado un virus que parece ser de los más agresivos en el cultivo de tomate. Los focos de la citada enfermedad se han encontrado desde Navarrete, Santiago, y se extienden hasta la zona tomatera de Montecristi. El desarrollo epidemiológico de la virosis es vertiginoso, pues se pudo observar plantaciones que en tan sólo 11 días tuvo un aumento en la incidencia de aproximadamente de un 40 a un 100% de infección, en una plantación en la fase de floración, edad en que resulta muy significante el factor fisiológico para la producción, es decir, plantaciones con este tipo de infección temprana no logran fructificar (Gómez, 1992)

Las alternativas para enfrentar situaciones de este tipo son complejas, lo que necesariamente debe incluir el aspecto legal, pruebas de material varietal con posibles niveles de tolerancia, identificación de hospederos alternos del vector y el virus, entre otros. Estos trabajos deben iniciarse a la mayor brevedad posible, como parte de la estrategia de investigación que desarrollará un equipo interdisciplinario.

Según, Urias y Valenzuela (1992) los geminivirus del tomate fueron reportados por primera vez en 1970 en el el Estado de Sinaloa, México, causando pérdidas de un 30% en la producción y para el 1983, se registraron incidencias de un 100% en siembras tempranas de tomate.

De las aproximadamente 1,200 especies de moscas blancas (Homoptera: Aleyrodidae) descriptas hasta la fecha en Centroamérica y el Caribe, *B. tabaci*, Genn. y *Trialeurodes vaporariorum*, West) revisten la mayor importancia como plaga directa y como vector de virus (CATIE 1992)

Inspecciones biográficas en poblaciones de *B. tabaci*, Genn. durante el 1989 indican la presencia de un nuevo biotipo 'B' en las mayores localidades agrícolas del Suroeste y Sureste de los Estados Unidos y Hawai, Norte de México, la Cuenca del Caribe, Centroam_rica y algunos países de Suramérica (Brown 1992)

La combinación del control genético clásico con la hibridación de plantas están siendo usado actualmente para desarrollar cultivares resistentes a los geminivirus (Brown y Bird 1992)

Desde 1989 hasta la fecha en la República Dominicana han sido reportadas positivas para geminivirus muestras de habichuela, ají, tabaco, tomate y varias especies de malezas y prueba de esterasa no específica demuestra la presencia del biotipo 'B' de *B. tabaci*, asociado al síntoma de la hoja plateada de la calabaza (Brown 1992)

García (1992) asocia los desórdenes fisiológicos exhibido por el tomate a micoplasma, más que a virus y presenta la posibilidad de que los mismos pueden ser también transmitidos por mosca blanca, porque adultos y ninfas se alimentan en el floema de la planta, lugar donde se alojan los micoplasma.

En resultados de estudios reportados por el CATIE (1990) se informa que en Venezuela se obtuvo un aumento en los rendimientos de un 45%, protegiendo los semilleros con malla de nilón.

King y Saunders (1984) recomiendan el uso de variedades tolerantes para el manejo de mosca blanca y virosis.

El objetivo de este trabajo es evaluar la tolerancia genética de cultivares de tomate industrial a geminivirus y potyvirus, seleccionar un cultivar que permita un mejor

manejo de las virosis transmitidas por mosca blanca y por áfidos en la producción de tomate industrial, evaluar el efecto del uso de protección de las plántulas en la etapa del semillero

Materiales y métodos

Este ensayo se desarrolló en el Período Noviembre 1992–Febrero 1993, en el noroeste de la República Dominicana en la zona de Navarrete, donde se detectó uno de los primeros focos de infección de la virosis, a principios de Octubre 1992.

Para la ejecución de éste ensayo se tomaron 11 líneas de tomate industrial de uso local y de reciente introducción, en las cuales se hicieron observaciones cada 5 días, a partir de los 15 días después del trasplante, sobre el comportamiento de las mismas en el desarrollo de la epidemia viral.

Cada línea se estudió en dos modalidades: comportamiento sin protección del semillero y semilleros protegidos con malla de nilon, antes de su germinación para evitar la inmigración de adultos de mosca blancas.

De estos dos factores resultan los siguientes tratamientos:

1 1A. Nápoli sin protección del semillero

2 1B. Nápoli con protección del semillero

3 2A. Petto 98 sin protección del semillero

4 2B. Petto 98 con protección del semillero

5 3A. Petto 97 sin protección del semillero

6 3B. Petto 97 con protección del semillero

7 4A. UC-82 sin protección del semillero

8 B. UC-82 con protección del semillero

9 5A. Nápoli III sin protección del semillero

10 5B. Nápoli III con protección del semillero

11 6A. Río grande sin protección del semillero

12 6B. Río grande con protección del semillero

13 7A. Híbrido NVH 4777 sin protección del semillero

14 7B. Híbrido NVH 4777 con protección del semillero

15 8A. Híbrido La Rossa sin protección del semillero

16 8B. Híbrido La Rossa con protección del semillero

17 9A. Híbrido N 4764 sin protección del semillero

18 9B. Híbrido N 4764 con protección del semillero

19 11A. Híbrido NVH 4784 sin protección del semillero

20 11B. Híbrido NVH 4784 con protección del semillero

21 12A. Híbrido Centurión sin protección del semillero

22 12B. Híbrido Centurión con protección del semillero

Variables a evaluadas.

Las variables a evaluadas en este experimento son:

- Incidencia de síntomas virales.
- Producción, basada en peso de los frutos y número de frutos de calidad industrial.
- Grado Brix de cada variedad
- Peso de cinco frutos

Se evaluó el total de plantas en cada parcela (30), y se estimó el porcentaje de plantas infectadas sobre el total de la unidad experimental.

Se determinó la presencia de mosca blanca en prácticamente todas las fases fenológicas del cultivo.

El tamaño de cada parcela fue de 2.4 m x 3 m (7.2 m^2)

Las evaluaciones del desarrollo de la epidemia viral, a nivel de campo, se realizó cada 5 días a partir de los 15 días de edad de la plantación. La primera evaluación se realizó el 9 de diciembre y la octava y última el 14 de enero de 1993

Diseño experimental.

Bloques completos al azar con 22 tratamientos factoriales (11 cultivares por dos formas de semillero, protegido y sin proteger) y cuatro repeticiones (bloques), igual a 88 parcelas.

Análisis estadísticos.
Análisis de varianza y separación de media por medio de la prueba de Duncan.

Resultados y discusion

Los resultados matemáticos de producción presentados en los Figuras 1 y 2 demuestran que las variedades que presentaron mayor índice de rendimiento fueron la Peto-98, Nápoli-III y la NVH-4777.

Para los fines de industrialización se debe considerar con mucho interés el grado brix de cada variedad, lo que puede ser afectado por un ataque temprano de virus. El mayor grado Brix registrado (de 3.83 a 4.80) pertencieron a los cultivares Peto-98, Peto-97, NVH-4777, y La Rossa (Figuras 3, 4, 5 y 6). Estos grados son aceptables para la industria, lo que conjugados con una producción promedio en presencia de la virosis lo haría un cultivar promisorio.

Ninguna de las variedes en estudio resultaron resistentes a los geminivirus. En la evaluación realizada a los 15 días no apareció virus en el campo experimental, pero a los 20 días después del trasplante se inició el desarrollo de la epidemia en la mayoría de las variedades en estudio, exceptuando, Peto 97, Nápoli III, NVH-4764 y NVH 4784, en las que se inició la epidemia a partir de los 25 días. Las evaluaciones se realizaron hasta los 50 días después del trasplante, cuando todas las variedades habían llegado a un 100% de infección viral (Figuras 7, 8, 9, 10 y 11). Lo que coincide con Urias y Valenzuela (1992) quienes determinaron un 100% de incidencia de geminivirus en siembras de tomate realizadas tempranas.

Lo anterior indica que no apareció variedad con resistencia, sino con algún elemento de tolerancia dado el comportamiento de la curva epidemiológica y la diferencia en los datos cuantitativos de productividad, peso de cinco frutos y grado brix.

En el análisis de varianza, presentado en el Cuadro 1, resulta con diferencia altamente significativa entre las 11 variedades para las variables rendimiento, grado brix, peso de cinco frutos y el porciento de incidencia viral. Esto indica que a pesar de haber una alta incidencia de virus a los 50 días después del trasplante (aproximadamente 100%), existen variedades que son tolerantes al ataque del virus, dado en su rendimiento y su cantidad de sólidos solubles, expresada en grado brix.

No resultó diferencia significativa entre las parcelas provenientes de plántulas protegidas y sin proteger (Protecc. en Cuadro 1), resultados que se contraponen a los obtenidos en el CATIE (1990), donde esta práctica resultó significativa. La diferencia de peso en cinco fruto, podría derivarse de aspectos genético, pero los resultados de rendiminetos y grado brix pueden estar relacionados a una respuesta varietal a la epidemiología.

En la prueba de rango múltiples de Duncan (Cuadro 2) se presenta el resultado de cada variedad a las variables en estudio. Dos aspectos relevantes deben observarse; un rendimiento aceptable, combinado con un buen grado brix. Algunas variedades tales como Peto-98, NVH-4777, Nápoli III y Centurión conjugan estos factores; La Rossa resulta con el mejor grado brix (4.59), pero está entre las dos inferiores en lo referente a rendimiento. No obstante esta variedad se debería seguir estudiando.

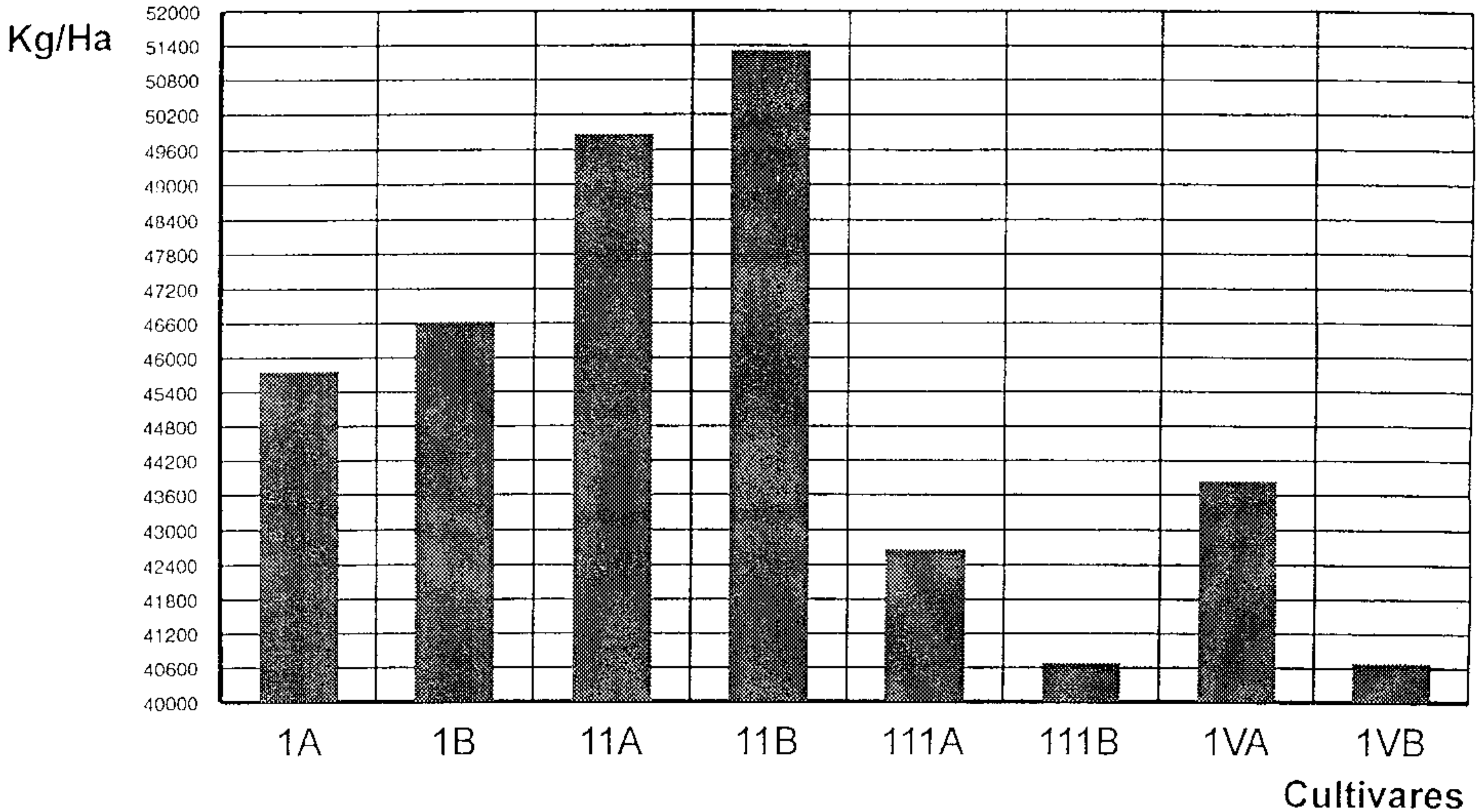

Figura 1. **Rendimientos (kg/ha) de cuatro cultivares de tomate industrial en semilleros protegidos y sin proteger.**

(I– Nápoli; II – Peto-98; III – Peto-97; IV – UC-82; A - semillero sin proteger; B – semillero protegido).

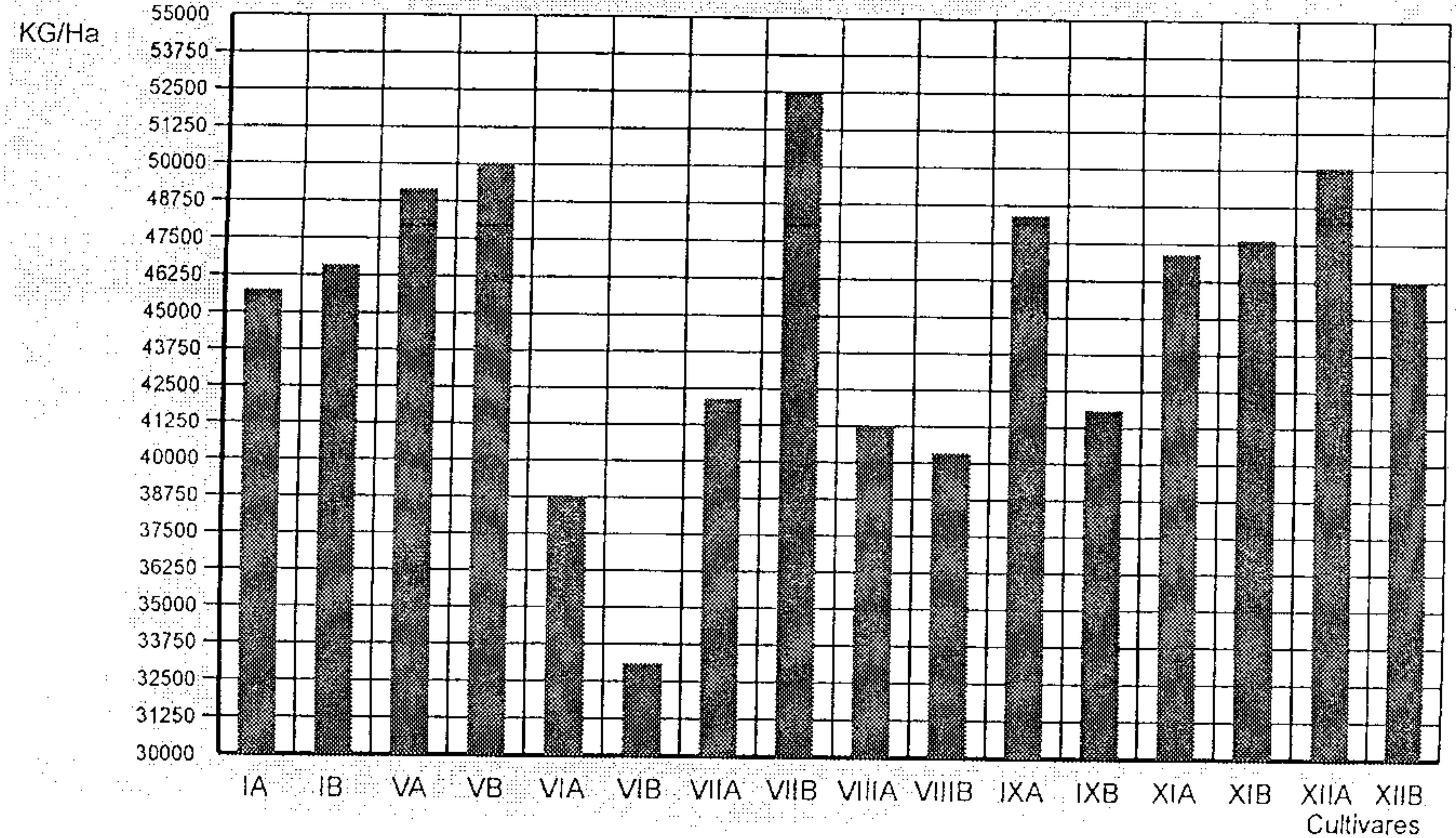

Figura 2. **Rendimientos (kg/ha) de ocho cultivares de tomate industrial en semilleros protegidos y sin proteger.**

(I – Nápoli; V – Nápoli III; VI – Rio Grande; VII NVH-4777; VIII – La Rosa; IX – N-4764; XI – NVH-4784; XII – Centurion; A - semillero sin proteger; B – semillero protegido).

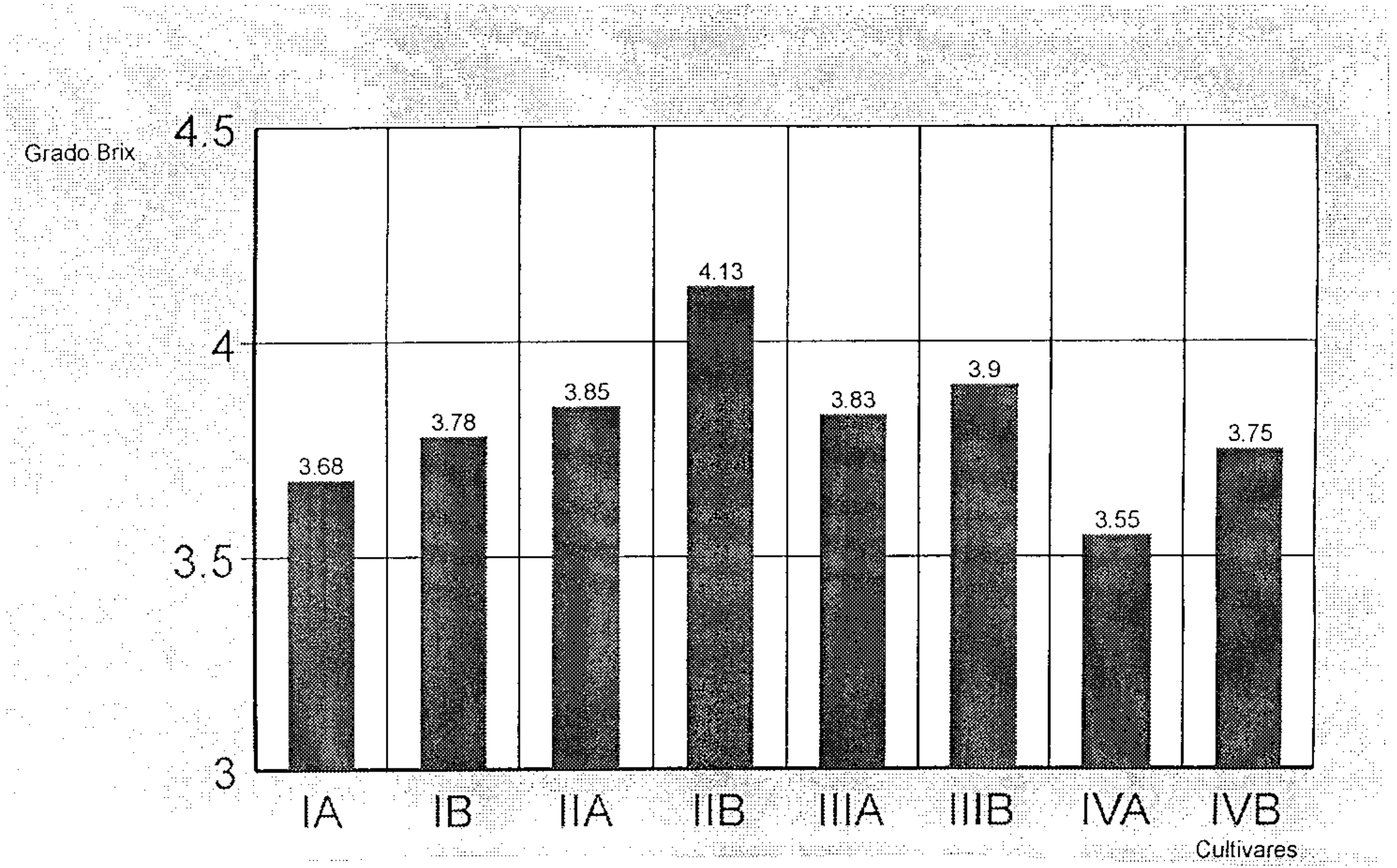

Figura 3. **Grado brix de frutos en cuatro cultivares de tomate industrial. Navarrete, 1993.**

(I- Nápoli; II – Peto-98; III – Peto-97; IV – UC-82; A - semillero sin proteger; B – semillero protegido).

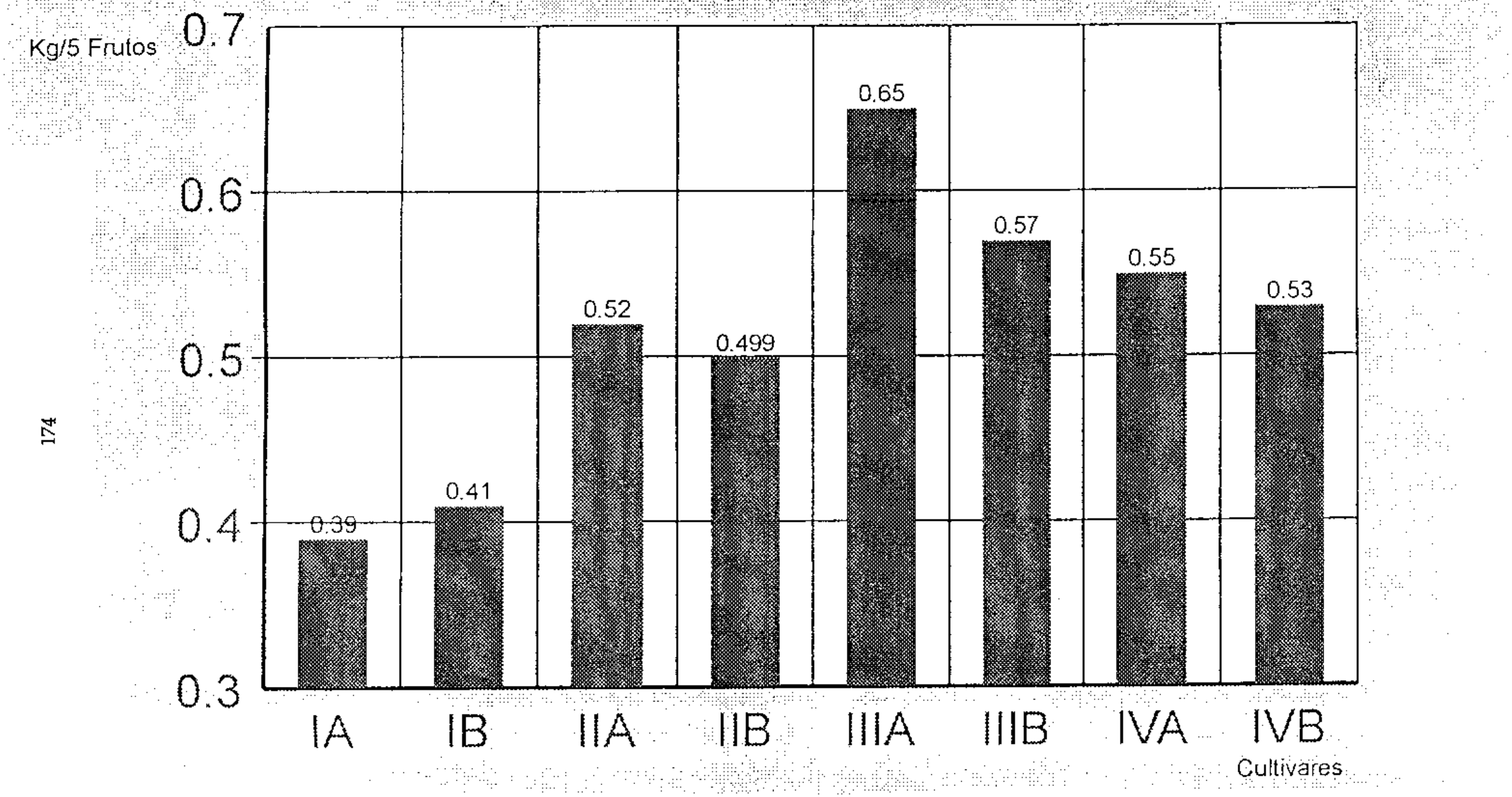

Figura 4. Peso (kg) de cinco frutos de cuatro cultivares de tomate industrial en semilleros protegidos y sin proteger.

(I– Nápoli; II – Peto-98; III – Peto-97; IV – UC-82; A - semillero sin proteger; B – semillero protegido).

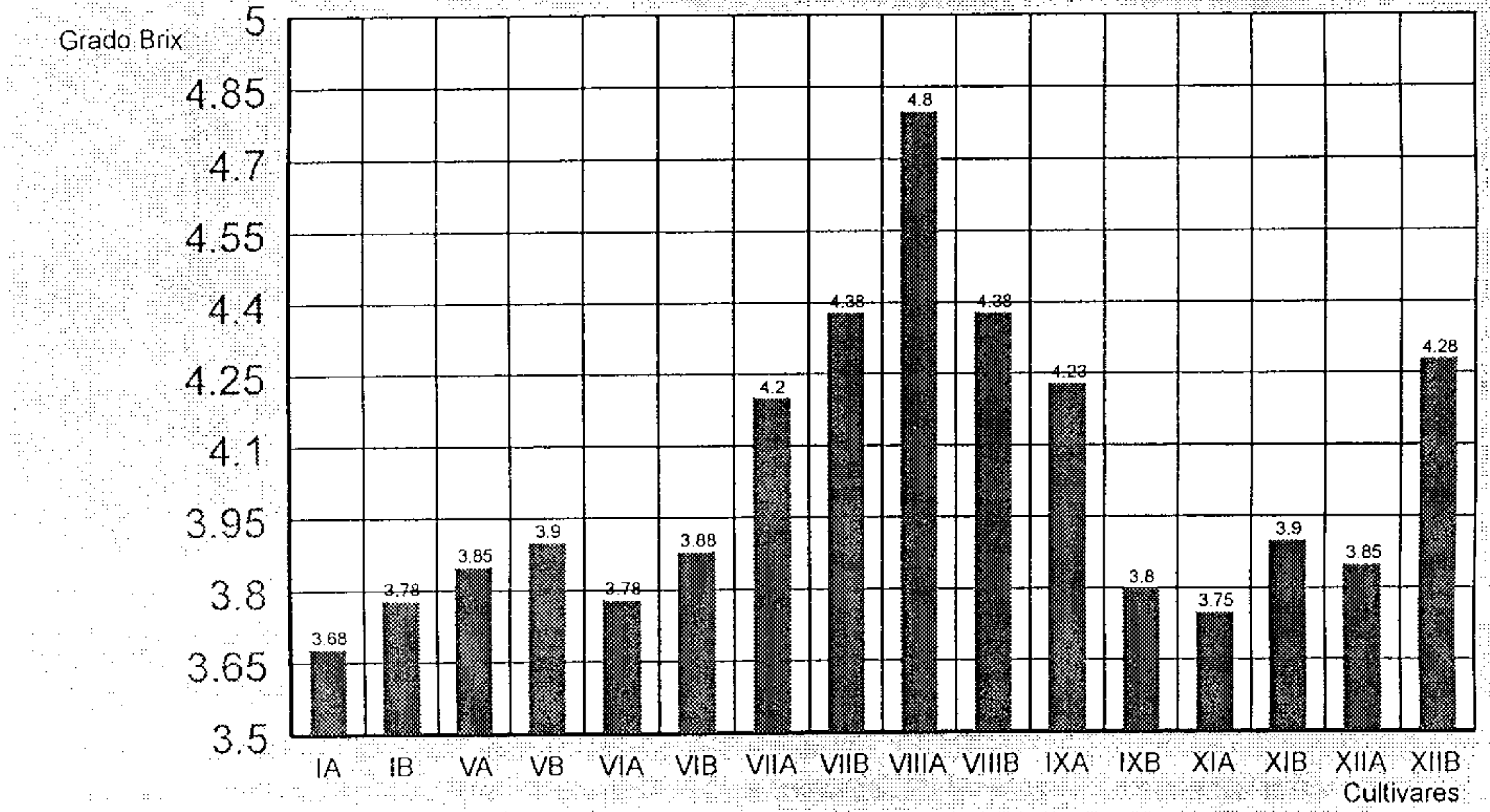

Figura 5. **Grado brix de frutos en ocho cultivares de tomate industrial. Navarrete, 1993.**

(I – Nápoli; V – Nápoli III; VI – Rio Grande; VII NVH-4777; VIII – La Rosa; IX – N-4764; XI – NVH-4784; XII – Centurion; A - semillero sin proteger; B – semillero protegido).

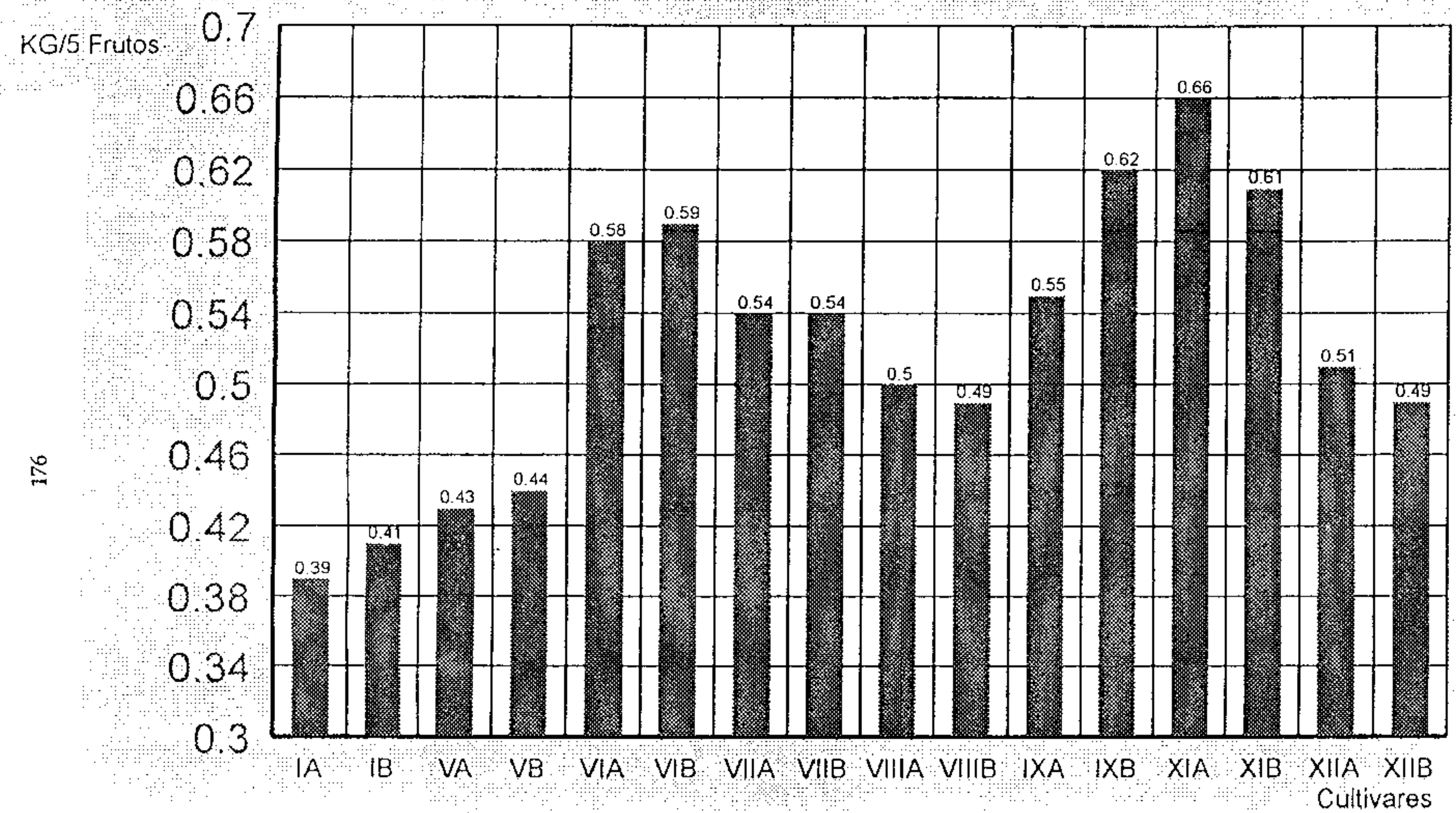

Figura 6. Peso (kg) de cinco frutos de ocho cultivares de tomate industrial.

(I – Nápoli; V – Nápoli III; VI – Rio Grande; VII NVH-4777; VIII – La Rosa; IX – N-4764; XI – NVH-4784; XII – Centurion; A - semillero sin proteger; B – semillero protegido).

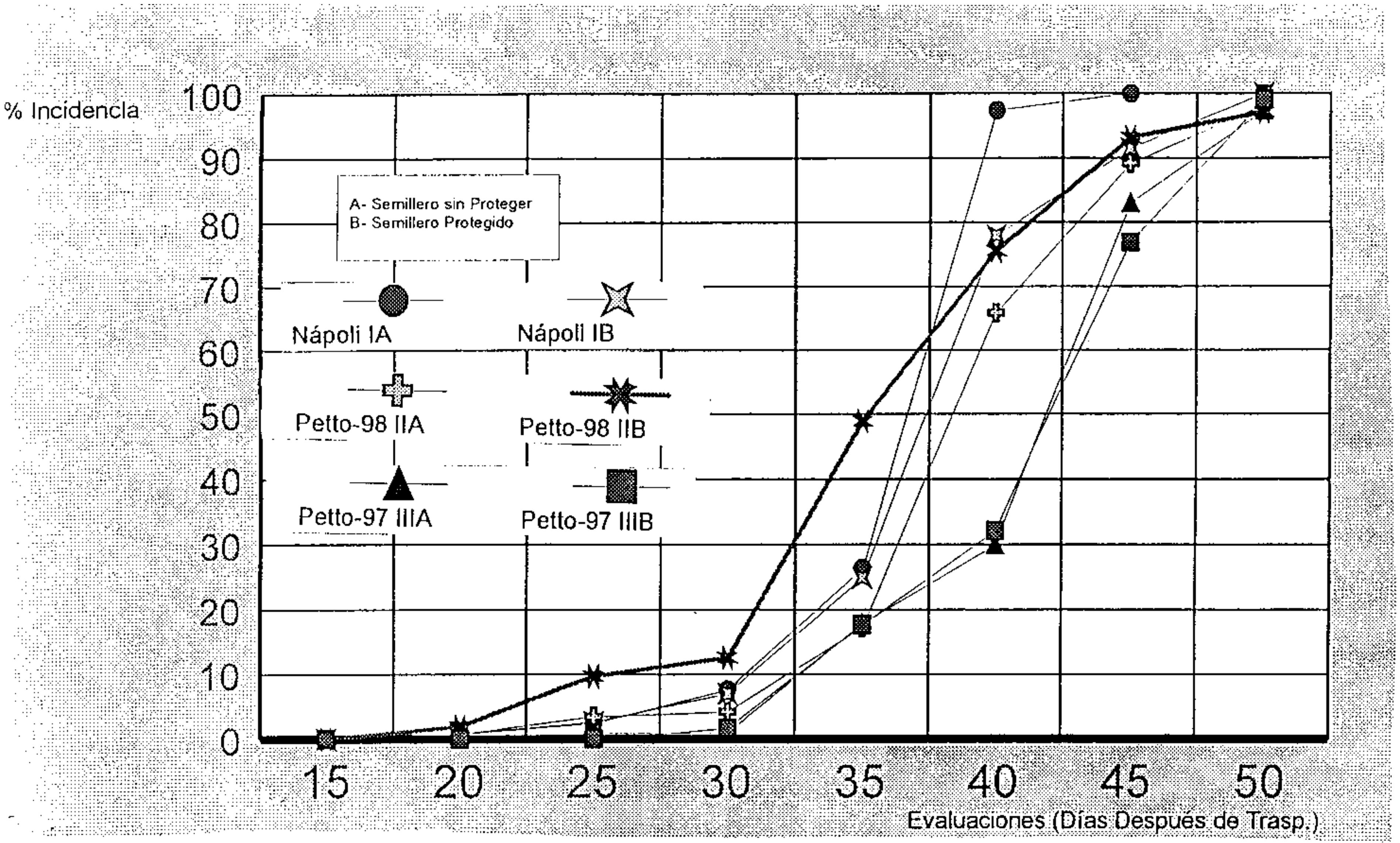

Figura 7. **Desarrollo de la epidemia viral (%) durante el ciclo vegetativo en tres cultivares de tomate industrial. Navarrete, 1993.**

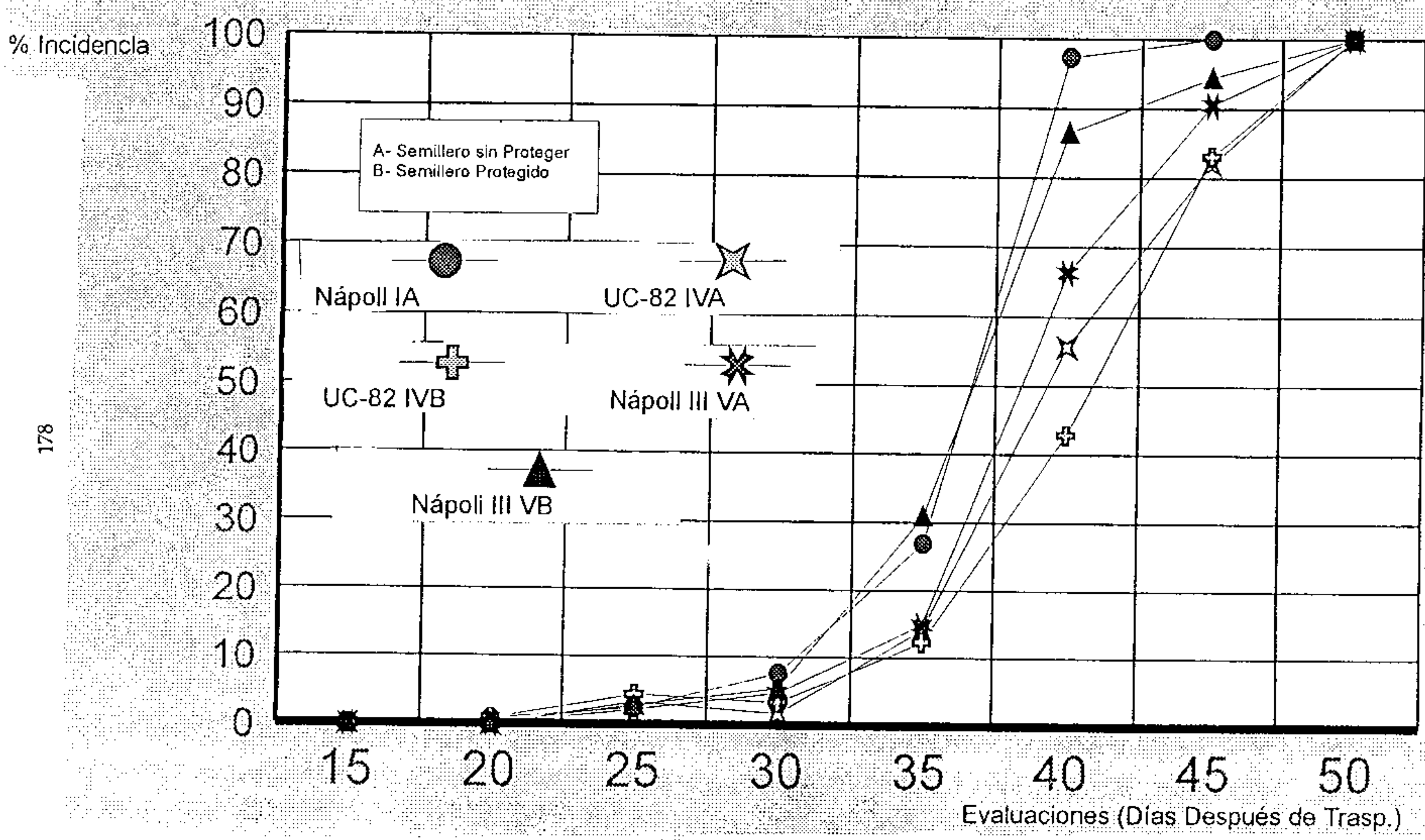

Figura 8. **Desarrollo de la epidemia viral (%) durante el ciclo vegetativo en tres cultivares de tomate industrial. Navarrete, 1993.**

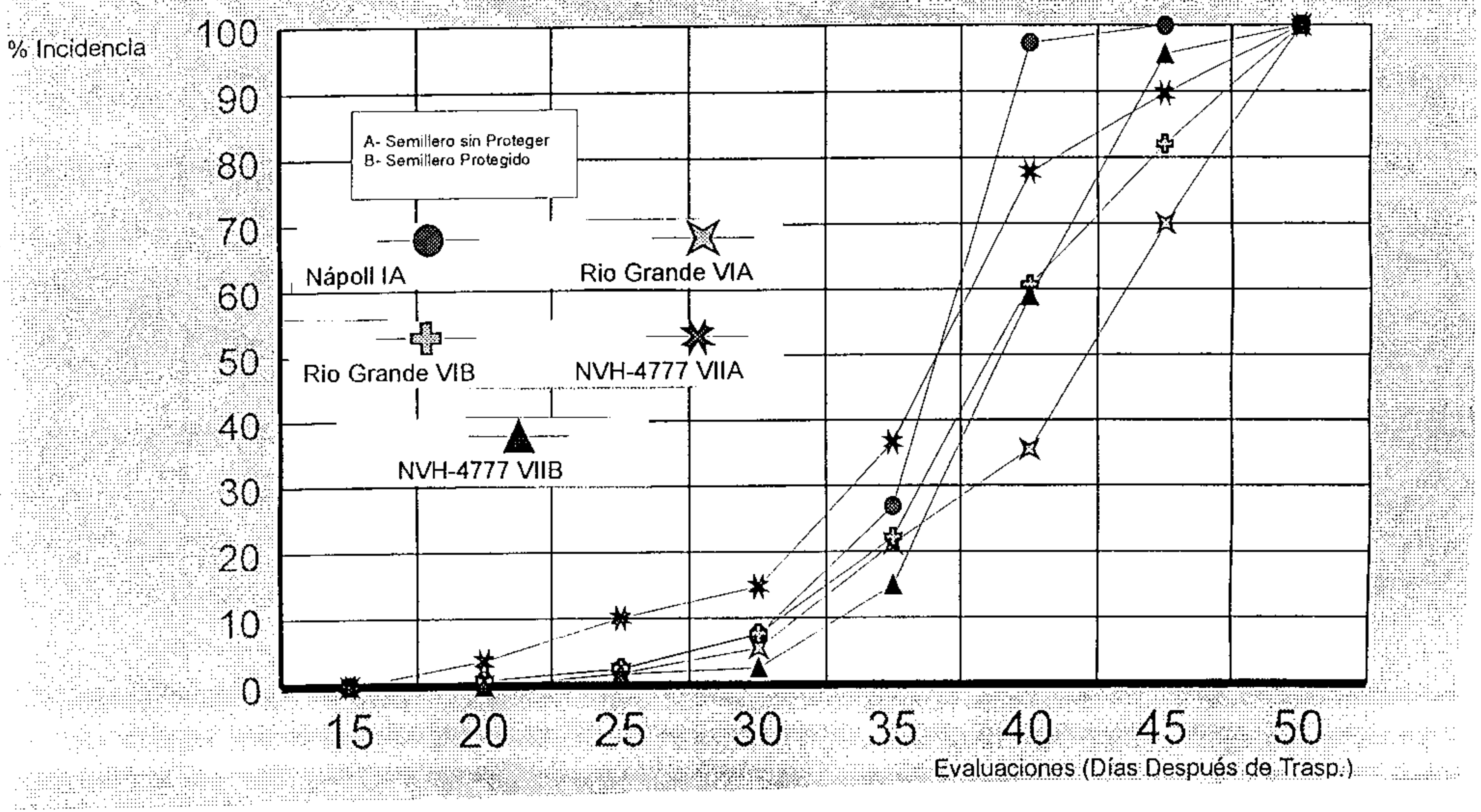

Figura 9. **Desarrollo de la epidemia viral (%) durante el ciclo vegetativo en tres cultivares de tomate industrial. Navarrete, 1993.**

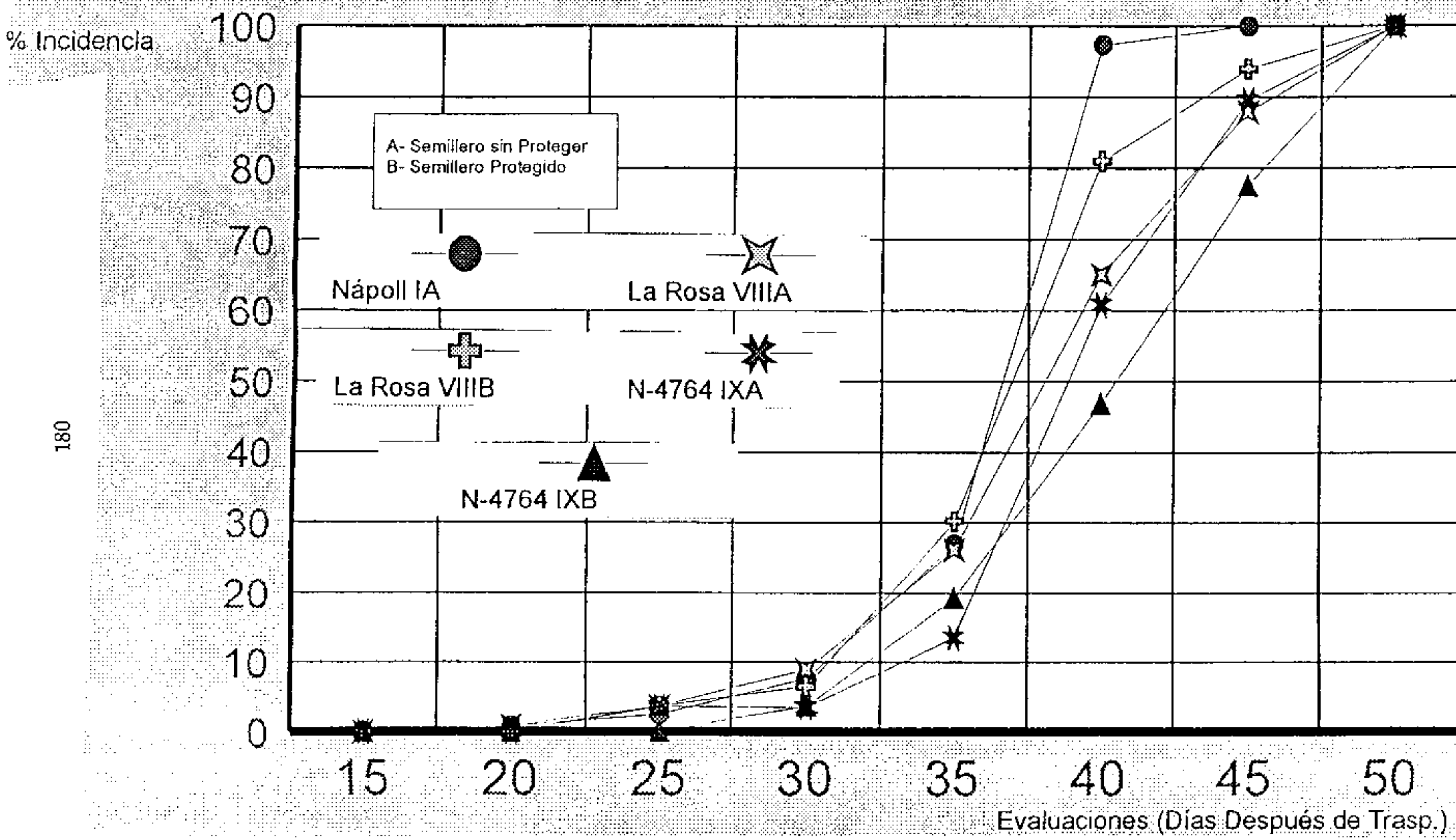

Figura 10. **Desarrollo de la epidemia viral (%) durante el ciclo vegetativo en tres cultivares de tomate industrial. Navarrete, 1993.**

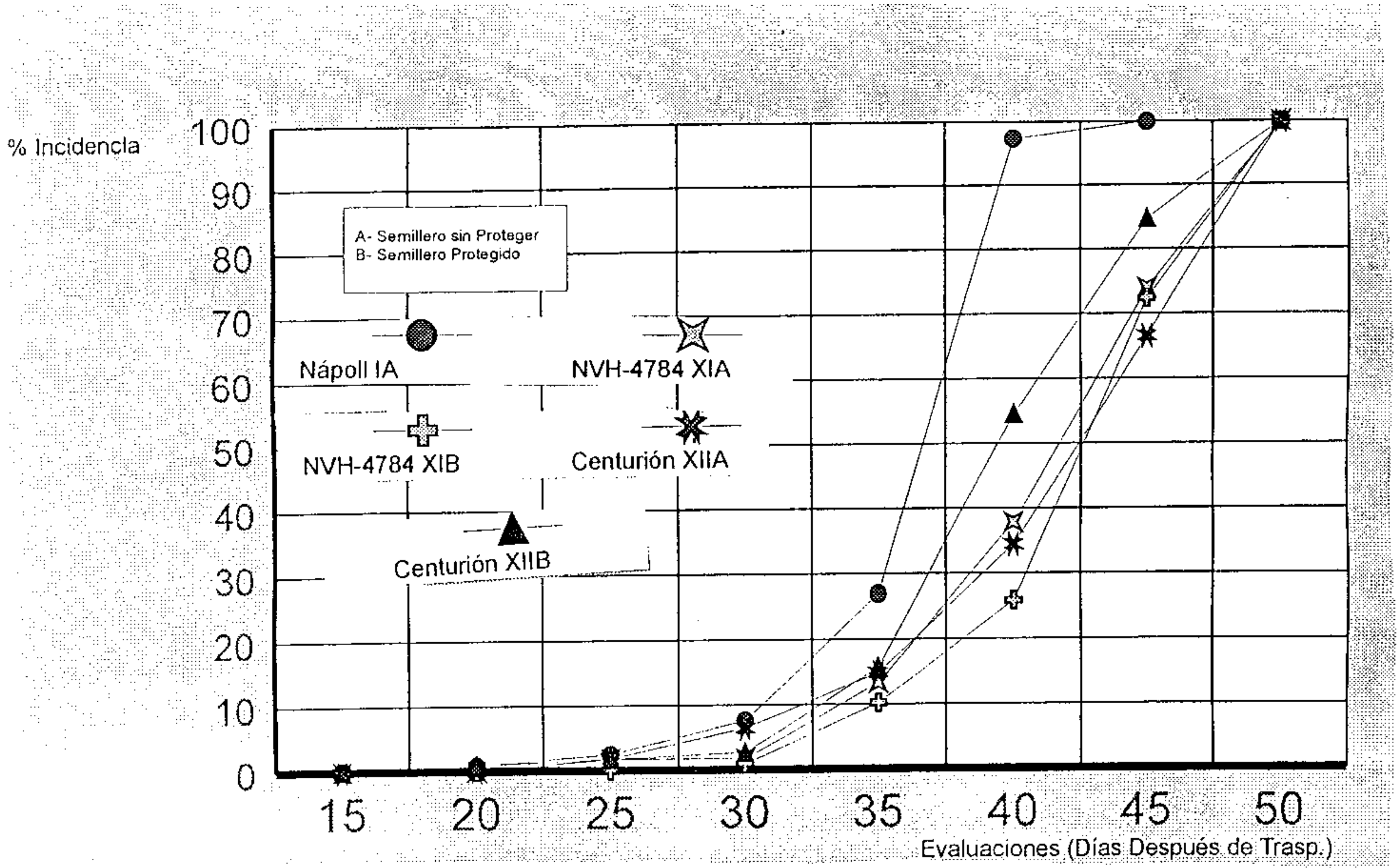

Figura 11. **Desarrollo de la epidemia viral (%) durante el ciclo vegetativo en tres cultivares de tomate industrial Navarrete, 1993.**

Cuadro 1. Análisis de varianza de las variables rendimiento (kg/ha), grado brix y pesos de cinco frutos (kg).

Fuentes virus	GL	Rendimiento Valor F	Pr>F	Grado Brix Valor F	Pr>F	Peso Valor F	Pr>F	Incidenc. Valor F	Pr>F
Bloque	3	302.82	0.7730	0.41	0.7483	1.055	0.0796	5.48	0.0010
Variedad	10	5047.00	0.0001	3.76	0.0005	7.392	0.0001	8.27	0.0001
Protecc.	1	338.87	0.4938	0.58	0.4475	0.511	0.2853	0.78	0.3780
Epoca	7							976.91	0.0001
Var*Prot	10	1355.48	0.0651	0.91	0.5294	0.496	0.3716		

C.V.:Rendimiento=10.52%; Grado Brix=9.83%; Peso=9.57; Incidenc.Virus=36.46%

Cuadro 2. Prueba de Rango Múltiple de Duncan para las medias de remdimiento (kg/ha.), peso por cinco frutos (kg) y grado brix

Variedad	kg/ha Media	Peso/5 frutos Media	Grado Brix Media	Incidencia de virus**
Peto-98	50823a*	0.51c	3.98bc	38.30a
Nápoli III	49619ab	0.43d	3.88bc	37.03a
Centurión	48191ab	0.50c	4.06bc	30.05b
NVH-4784	47420abc	0.63a	3.83c	27.43b
NVH-4777	47326abc	0.54bc	4.29a	37.78a
Nápoli	46208abcd	0.40d	3.73c	39.66a
N-4764	45156bcde	0.59ab	4.01bc	32.25b
UC-82	42272cde	0.54bc	3.65c	31.33b
Peto-97	41681de	0.61a	3.86bc	28.44 b
La Rossa	40823e	0.49c	4.59a	38.06a
Río Grande	35934f	0.58ab	3.83c	31.39b

* Las medias seguidas por la misma letre no difieren entre si al 5% de probabilidad según la prueba de comparaciones múltiples de Duncan

** Promedio de 8 evaluaciones desde los 15 hasta los 50 días después del transplante, especiadas cada 5 días

En el Anexo 1 se presenta datos cualitativos tales como llenado del fruto, coloración, contenido de agua y forma del fruto; en esto se observa que las variedades que presentaron buenos resultados cuantitativos, como se expuso anteriormente, también tienen resultados cualitativo apreciables para fines industriales, a excepción de Peto-98 que resultó poco jugoso, y de coloración interna pálida

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Anexo 1. Cronograma de evaluación de virosis en cultivares de tomate industrial. Transagrícola, Navarrete. Nov. 1992.

Evaluación	Fecha	Edad (días después del transplante)
1	9/12/92	15
2	14/12/92	20
3	19/12/92	25
4	24/12/92	30
5	29/12/92	35
6	04/01/93	40
7	09/01/93	45
8	14/01/93	50

Anexo 2. Datos cualitativos* de once cultivares de tomate industrial en estudio de tolerancia a virus transmitdos por mosca blanca

Cultivar	Llenado fruto	Coloración	Consistencia	Forma
Nápoli	Completo	Pálido	Jugoso	Pera
Petto-98	Completo	Pálido	Poco Jugo	Redondo
Petto-97	Completo	Rojo	Jugoso	Redondo
UC-82	Hueco	Pálido	Jugoso	Redondo
Nápoli III	Completo	Pálido	Jugoso	Pera
Río Grande	Completo	Pálido	Jugoso	Ovoide
NVH-4777	Completo	Rojo	Jugoso	Redondo
La Rossa	Semi-completo	Rojo	Jugoso	Ovoide
N-4764	Completo	Rojo-pálido	Jugoso	Redondo
NVH-4784	Completo	Pálido	Poco jugo	Redondo
Centurión	Semi-completo	Pálido	Jugoso	Redondo

* Observaciones realizadas en cuatro repticiones (bloques)

EFFECTS OF SELECTIVE INSECTICIDES, SYNTHETICS AND EXTRACTS FROM THE NEEM TREE (*AZADIRACHTA INDICA* A. JUSS.) ON POPULATIONS OF *BEMISIA TABACI* (GENN.) (HOMOPTERA: ALEYRODIDAE)

C A Serra
Instituto Superior de Agricultura, Dominican Republic

Results obtained in southern Dominican tomato fields (1988–90), pointed out that only a few available insecticides, mainly with a selective mode of action, kept non-viruliferous *Bemisia tabaci* (Genn.) populations under their relatively high damage levels. The best results in reducing densities of immature whitefly stages (eggs, larvae and puparia) were obtained by spraying insecticidal detergent (Safer® 2%), neem-seed oil emulsion (NOE 1%), water extracts of neem seeds (NSWE 4–5%) and neem-cake (NSKCWE 1.5%), as well as buprofezin (Applaud®), a synthetic insect growth regulator (IGR). The effects of neem products lasted at least for 2 weeks and reduced significantly the oviposition on treated undersurfaces of leaves, probably by repelling the adults. Over longer periods, the selective products only reduced densities of adults to a small extent. Besides the lack of important contact action, this was probably due to the high mobility of adults between the different test plots. Several conventional combinations of broad-spectrum insecticides caused resurgence of whiteflies, despite significant reductions of adults in the short term. Detergent, neem oil and NSWE 5% could cause yield losses due to phytotoxicity when sprayed weekly throughout the season. The use of selective product combinations was also economically sound due to a reduced number of applications and increased yields. Nevertheless, extremely low damage levels for viruliferous whiteflies limit the successful use of these products in tomato during the first half of the crop since the recent appearance and wide distribution of very destructive whitefly-transmitted geminiviruses.

The sweet potato whitefly, *Bemisia tabaci* (Genn.) (Homoptera: Aleyrodidae), has reached special importance as a key pest of crops worldwide attacking a great number of host species. High reproduction rates and several generations per year encourage its population outbreaks, as well as the build-up of resistance to numerous insecticidal compounds (Prabhaker et al. 1985). As a vector, it transmits persistent geminiviruses to numerous crops (Brown and Bird 1992). Since the end of 1988 it has caused serious damage to numerous crops in the south-western valleys of the Dominican Republic. Yield losses up to 50% were observed apart from beans - the traditional hosts of the whitefly – in formerly unpreferred hosts like tomato, melon, squash, cucumber, eggplant, okra and 'Chinese vegetables'. Up to then, *B. tabaci* did not complete its life-cycle on tomato and other 'new' hosts (Serra 1992a).

Use of the traditional monovalent insecticide combinations (e.g. organophosphates, carb-amates) increased whitefly populations to extremely high levels. Direct damage through sucking the plant sap and secretion of honeydew (colonized by 'sooty mould') led to severe defoliation and in consequence devastated tomato fields even before the widespread transmission of geminiviruses since 1990/91 (indirect damage). In addition to serious yield losses, since 1989 the quality of the fruits deteriorated due to sunburn effects and a previously unknown problem with 'uneven ripening' (Serra 1992a). In Florida, the latter and the 'silverleaf' of cucurbits were confirmed to be physiological problems linked to the saliva of sucking adults of the only recently determined so-called 'B' biotype (Hoelmer et al. 1991). According to Perring et al. (1993), this variant is a new whitefly species tentatively called 'silverleaf whitefly'

and in consequence a revision of the morphological species *B. tabaci* is proposed. The appearance of the new disorders in the Azua plain confirmed the introduction of this new variant of *B. tabaci* with a wider host range as well as higher virulence and resistance levels to insecticides from regions (Florida, California, etc.), where similar 'whitefly' problems had occurred not so long before.

Previous field studies (CIAZA-1-88/89) on the efficiency of synthetic insect growth regulators (IGRs; cyromazine and teflubenzuron), neem-seed cake water extracts (NSCWE; 1.5 and 2.5%) and neem-seed water extract (NSWE; 5%) showed a satisfactory reduction of immature stages only by the latter (Serra 1989, unpublished report). A further trial (Monte Río-1-89) underlined the effects of NSWE (5%) and neem-oil emulsion (NOE; 1–1.5%) decreasing densities of eggs, larvae and puparia. Plots sprayed with a conventionally used combination (dimethoate, monocrotophos, methamidophos alternated weekly) reached very high populations confirming the observation mentioned above. An 'improved' combination of mineral oil (JMS®; 0.75%) and commercial insecticides (including deltamethrin, endo-sulfan, malathion, oxamyl and permethrin) did not prevent high whitefly densities nearly as much as a national expert commission for the Azua plain expected (Serra 1992a).

This paper presents results of studies that were carried out to test and combine alternative methods compatible with the concepts of integrated management of tomato pests. These were mainly based on the use of selective compounds from neem seeds, IGRs, insecticidal detergents and mineral oils, and included an estimate of the side-effects on beneficial arthropods such as mirid bugs (*Engytatus* [syn. *Cyrtopeltis*] *tenuis* and *E. modestus*), spiders, predatory mites (?*Amblyseius* sp.) as well as parasitoids of the vegetable leafminer, *Liriomyza sativae*, and the tomato pinworm, *Keiferia lycopersicella* (Serra 1992a; 1993). In all of the trials described in this paper whiteflies have been by far the most important pests.

The results represent 3 years of research in processing tomato fields mostly located in the irrigated south-western Azua plain (< 700 mm rain/year), the main national production area. Complementary laboratory work was done in San Cristóbal at the Instituto Politécnico Loyola (IPL), the headquarters of the supraregional project Fabricación de Insecticidas Naturales (GTZ-IPL). Since 1987 this project has encouraged small vegetable farmers in the Dominican south-west, and other developing countries, in the use of neem insecticides and IPM for crop protection.

Materials and methods

All the three trials were run with four replications (blocks) with plot sizes of 131 m^2, 141 m^2 and 440 m^2 respectively.

Test substances

All the field trials tested home-made water extracts from crushed neem seeds including shells (NSWE; 4–5%) or from decorticated neem seed kernel cake (NSKCWE; 1.5%), neem-seed oil emulsion (NOE; with 1–1.5% of oil) and/or ethanolic extracts (NSKCAE; 4.5%). The neem seeds (originating from Haiti; 1988/89) contained between 2.2 and 2.9 mg a.i. azadirachtin/g NSK and were processed as previously described (Serra 1992a; 1992b). For comparison, a few other relatively selective insecticides available in the country, or with registration in process, were tested against *B. tabaci*. These included buprofezin (Applaud®; a synthetic IGR) and Safer® containing 49% of a potassium detergent as well as mineral oil combined with other commercial products.

Spray schemes

The plots of the 1st trial were only sprayed twice (24 May and 5 June). After previously having proved the efficiency of single selective products against at least one major pest, these were tested in combinations with neem products. The treatments and spray schemes for Trials 2 and 3 are given in Table 1. The insecticides were sprayed in the field plots using a manual knapsack

Table 1. Treatments tested in the 2nd and 3rd trials (Barceló–1 and –4)

Date (m/d)	Treatments compared to an untreated check (Barceló-1-88/89)				
	Detergent	'Conventional'	Neem oil	IPM-1	IPM-2
10/17	Safer 2%	endosulfan 0.3%	NOE 1%	NSKCWE 1.5%	NSWE 4%
10/24	Safer 2%	methamidophos 0.57%	NOE 1%	chlorfluazuron 20 ml a.i./ha	
10/31	Safer 2%	trichlorfon 0.1% + MO	NOE 1%	NSKCWE 1.5%	NSWE 4%
11/7	Safer 2%	butocarboxim 0.15%	NOE 1%	cyromazine 28 g a.i./ha	
11/14	Safer 2%	endosulfan 0.3% + MO	NOE 1%	NSKCWE 1.5%	NSWE 4%
11/21	Safer 2%	*Bt* 0.75 kg/ha + MO	NOE 1%	Bt 0.1%	
11/28	Safer 2%	malathion 0.25% + MO	NOE 1%	NSKCWE 1.5%	NSWE 4%
12/5	Safer 2%	endosulfan 0.3% + MO	NOE 1%	chlorfluazuron 20 ml a.i./ha	
12/12	Safer 2%	*Bt* 0.75 kg/ha + MO	NOE 1%	NSKCWE 1.5%	NSWE 4%
12/19	Safer 2%	*Bt* 0.75 kg/ha + MO	NOE 1%	chlorfluazuron 20 ml a.i./ha	

Date (m/d)	Treatments compared to an untreated check (Barceló–4–90)				
	'Conventional'	IPM-1	IPM-2	IPM-3	Alcoholic extract
4/10	butocarboxim 0.15%	NSWE 4%	NOE 1%	–	NSKCAE 0.45%
4/17	endosulfan 0.25%	*Bt* 0.1%	NSWE 4%	NSWE 4%	NSKCAE 0.45%
4/24	methamidophos 0.2%	NSWE 4%	–	NOE 1%	NSKCAE 0.45%
5/2	Safer® 1%	*Bt* +Safer 1%	NSWE 4%	NSWE 4%	NSKCAE 0.45%
5/8	TCHO 0.36kg a.i./ha	NSWE 4%	NOE 1%	–	NSKCAE 0.45%
5/14	butocarbox 0.42%	Safer 0.75%	NSWE 4%	NSWE 5%	NSKCAE 0.45%
5/21	Safer® 1%	NSWE 4%	buprofezin	--	NSKCAE 0.45%
5/29	endos 0.3% + MO	*Bt* 0.1%	*Bt* 0.1%	NSWE 5%	NSKCAE 0.45%
6/5	*Bt* + MO	NSWE 4%	NSWE 4%	–	NSKCAE 0.45%

Bt: *B. thuringiensis* var. *kurstaki* (Dipel® 10G) Bt: Javelin® WG 0.1%)
MO : mineral oil (JMS® 0.75%);
TCHO: thiocyclam-hydrogenoxalate (Evisect®; 95 g a.i./ha (=IGR)

sprayer Guarany® 201 (Trial 1) or engine-powered knapsack sprayer (Nuvola® L80). The spray volume varied according to the trial: 530–600, 220–510 and 195-280 l/ha respectively.

Evaluations

Leaflets (50 per plot) were sampled weekly at random from central sectors of the plants. Juvenile stages of *B. tabaci* (eggs, larvae and puparia) were counted within a central marked circle (1–1.5 cm^2) on the undersurface of the leaflets (enlargement 40x). In Trial 1, 'small' larvae (< 0.5 mm) were distinguished from 'big' ones and the number of puparia counted per leaflet. Adults were caught immediately before spraying and, in most of the weeks, the day thereafter using a method used by a national research team (Reyes and Abud, personal communication). A dark bucket (25 l) was put upside-down on plants (10–20 times per plot) at random. Attracted by the sunlight, the alarmed winged insects flew through a hole in the base of the bucket and were captured in exchangeable transparent cups coated with oil. After the univariate analysis of variance (ANOVA) or the nonparametric H-test (KRUSKAL-WALLIS) the mean numbers of whiteflies and yield data were compared by using the Tukey-test (TT) or the Nemenyi-test (NT) respectively.

Results and discussion

1st trial (Galindo–3–90; variety Napoli-VF)

In most of the previous trials, high whitefly populations led to a quick colonization of almost 100% of the tomato leaves. In the 1st trial a late and relatively low infestation permitted a closer observation of the colonization and lethal effects caused by a synthetic and natural IGRs on juvenile whitefly stages. Figure 1a shows that buprofezin did not significantly reduce the percentage of leaflets having eggs but it did reduce the percentage with larvae and puparia. NSWE-treated leaflets showed a significantly reduced percentage of eggs (minus 65–72%) and larvae (34–53%) within 1.5 cm^2 circles marked on the undersurface. Additional larval mortality through the use of the IGRs (Figure 1b) led to lower numbers of (entire) leaflets with puparia (35–50%). These results confirm a oviposition deterrent effect on neem-treated cotton leaflets complemented by ovicidal and growth-inhibitory effects on juvenile stages (Coudriet et al. 1985; Price and Schuster 1991; Serra 1992a).

Figure 1b shows an almost analogous reduction of all juvenile stages as well as of empty pupal cases, an indicator of emerged adults. NSWE 5% achieved the highest degree of effectiveness (DE=69%) followed by NSWE 4% (51%) and buprofezin (51%) with respect to the average puparia densities.

Numbers of emerged parasites, differentiated by presenting a round gap instead of a longish slot, were only observed on the last date (12 June) with a low average number of pupal cases (4.6, 3.4, 1.9 and 0.8 pupal cases per 10 leaflets respectively) and parasitism rates of 15, 5, 19 and 63% respectively.

In further studies, buprofezin and NSWE 5% significantly reduced the populations of noxious mites (*Aculops lycopersici*; Eriophyidae) while only the synthetic IGR showed a noticeably increased mortality of predatory mites (?*Amblyseius* sp.; Phytoseiidae), also natural enemies of *B. tabaci* (Serra 1992a). Further studies are necessary to confirm side-effects on these and other beneficial arthropods. The promising IGR, buprofezin, needs to be integrated with other methods to delay whiteflies in becoming tolerant as Cahill (1993) mentioned has happened in Dutch greenhouses.

2nd trial (Barceló–1–89/90; variety Supersol)

The number of puparia on the undersurface of leaflets provide easily obtainable and reliable information on population dynamics, at least of non-viruliferous whiteflies. Figure 2 shows the population dynamics of *B. tabaci* as affected by different products, and/or combinations, with reference to puparia densities per leaflet. While selective products kept populations at very low levels, an outbreak of the whitefly population occurred in conventionally treated plots after the fourth date reaching maximum levels twice as high as in untreated check plots. Detergent and neem oil achieved the best results, but they were only slightly more effective than both 'integrated variants' which consisted of alternating weekly non-whitefly specific selective products with neem water extracts. Therefore, the quite good effects of the latter (NSKCWE 1.5%: 81%; NSWE 4%: 69% DE) were due to neem seed ingredients sprayed every 2 weeks.

Table 2 shows, that all the treatments reduced the incidence of damage by fruitboring noctuids (*Helicoverpa zea* and *Heliothis virescens*) significantly, especially the NOE and the 'integrated' treatments.

Despite the extremely high whitefly populations, the 'conventional variant still increased yields. Weekly sprayed insecticidal detergent and NOE (GP -2.8 and -2.2) led to decreased yields, due to phytotoxic side-effects. Tomato plants were shown to be sensitive to neem oil, especially when frequently applied during the early developmental stages of the plant as a component of NSWE (5%) or NOE (1%). Damage from a delayed and reduced fruit setting, up to phytotoxic symptoms (necroses), occurred (Serra 1992a). To avoid negative effects these products were used at lower doses and frequencies – increasing yields significantly

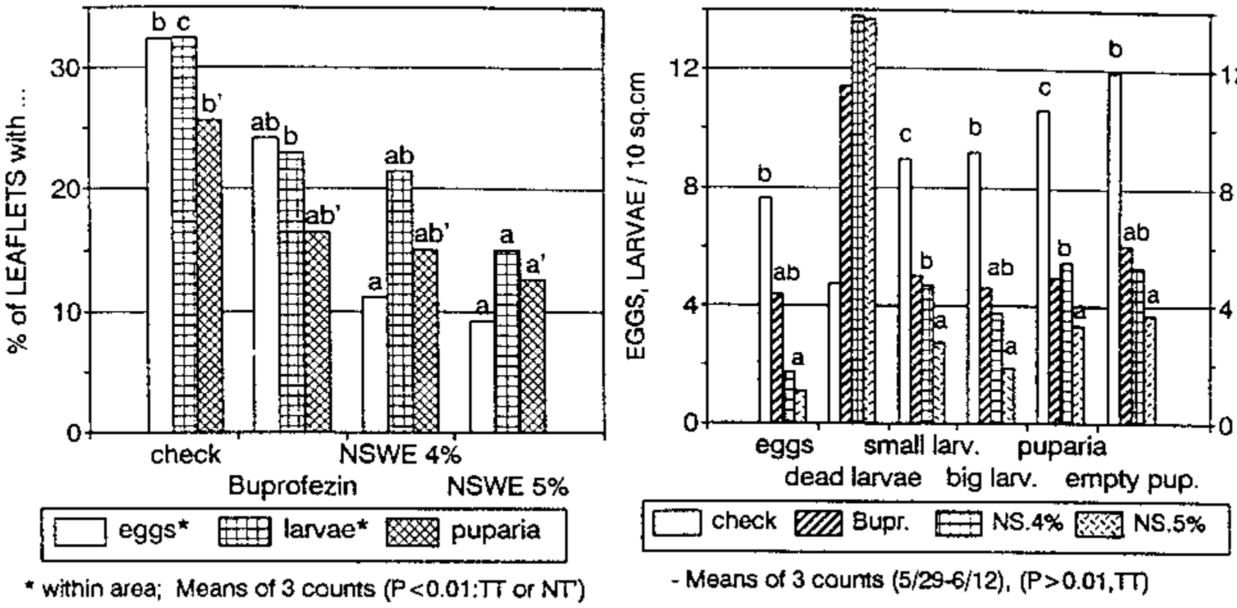

Figure 1. **Influence of IGRs on colonization of tomato leaflets and effects on juvenile stages of *B. tabaci***

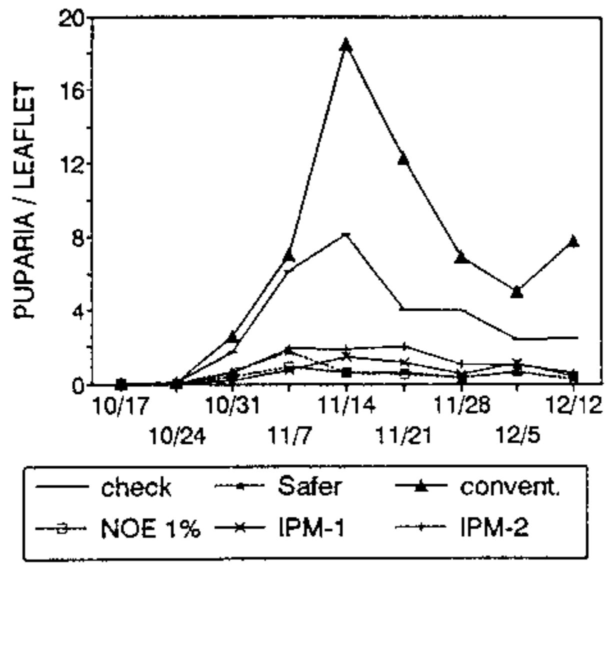

Figure 2. Effect of conventional or selective insecticides on densities of *B. tabaci* puparia

Table 2 Crop yields per hectare, field trial Barceló–1–89/90

Treatment	Fruits	Undamaged '000s/ha	Undamaged t/ha	Weight g/fruit	Damaged Total	Damaged Bored
Check	533 ab	383 ab	30.7 a	80 a	150 b	44 c
Safer® 2%	400 a	299 a	29.7 a	99 b	101 a	16 ab
Conventional	550 ab	458 bc	34.5 ab	75 a	92 a	19 b
NOE 1%	432 a	350 ab	30.3 a	86 ab	81 a	10 a
IPM-1	598 b	508 c	39.9 b	79 a	89 a	11 a
IPM-2	589 b	499 c	393 b	79 a	90 a	10 a

when NSKCWE and NSWE were alternated with available selective insecticides (IPM-1 and -2). An economic analysis of the pest management measures indicated that the additional monetary value did not justify the intensive insecticide combination employed for the 'conventional' variant (GP: -0.6) and permitted only a slight gross profitability (GP: 0.3 and 0.4) to both IPM variants (Serra 1992a).

3rd trial (Barceló–4–90; variety Barceló-101)

The results of Trial 2 confirmed high levels for the damage threshold concerning non-viruliferous whitefly populations, which do not permit calendar spraying. As a consequence, the 3rd trial was carried out to optimize integrated combinations of efficient selective products, reducing their spraying frequency and/or dosage. This trial was done outside the growing season during a risky hot and humid period. Similar to the 2nd trial, the 'conventional' combination recommended was inefficient, even when including detergent twice. The two peaks of the population dynamics represented in Figure 3 demonstrate this trend for larval densities. The other variants of IPM or the NSKCAE treatment reduced densities of larvae below the levels of the untreated check. IPM-3 with a reduced number of applications (five instead of 9), obtained similar results.

The effects of single products (Table 1) on adults are represented in the short and long-term in Figure 4. The reduction of juvenile stages on leaves by selective insecticides did not imply a similar reduction of adult whitefly densities determined by 'bucket catches'. The detergent application on 14 May (IPM-1) was shown to have some contact effects on adults but did not prevent increases of their densities in 'conventional' plots.

Several products of the 'conventional' treatment showed an efficient short-term reduction of adults. However, their densities recovered quickly as confirmed by the two peaks in Figure 4 which correspond to those of Figure 3. Partly, this trend was due to the lack of efficiency in reducing juvenile stages, but also to pest resurgence caused by eliminating natural enemies such as mirid bugs, and also minor sucking pests. Results obtained in the same trial pointed out the importance of the predator-prey interaction between *B. tabaci* and *Engytatus* spp. for biological control (Serra 1992a; 1992b).

To show the eventual suitability of any pest control method tested in Trial 3, additional economic parameters were compared to an untreated check. The underlying prices for the particular products or methods compared in this and several other trials have been described by Serra (1992a). For the comparison, data from neighbouring plots were included which consisted of rows of *Sorghum bicolor* intercropped every six rows of tomatoes and sprayed only once (12 June) with *Bt*. While the 'conventional' treatment resulted in yield losses and in consequence economic losses, plots sprayed with selective products (IPM-1 to 3; NSKCAE) increased yields significantly. After taking into account additional monetary values, costs and gross margins, the highest gross profitability was achieved by using the treatments with the lowest input for pest control, the 'mixed cropping' and IPM-3.

Table 3. Additional yields (t/ha), values, costs, gross margins (US$/ha) and gross profitability for pest control measures compared to untreated plots at different processing tomato price levels+

		Yield*	Values		Costs	Gross margins		Profitability
			a	b	a=b	a	b	1: a / b
Mixed cropping	(1)	+8.0 a	56	126	29	27	97	0.9 / 3.3
Conventional	(9)	-2.1 a	-144	-327	309	-453	-635	-1.5 /-2.1
IPM-1	(9)	+2.1 b	145	329	186	-41	142	-0.8 / 0.8
IPM-2	(8)	+3.1 b	218	494	194	24	300	0.1 / 1.5
IPM-3	(5)	+2.9 b	199	451	111	88	340	0.8 / 3.1
NSKCAE	(9)	+3.5 b	246	557	179	67	378	0.4 / 2.1

+ tomato prices: a= industry 1989/90: 69.4 US$/t ; b= market 4/90: 158 US$/t
* means denoted by the same letter do not differ significantly (P 0.01, TT)

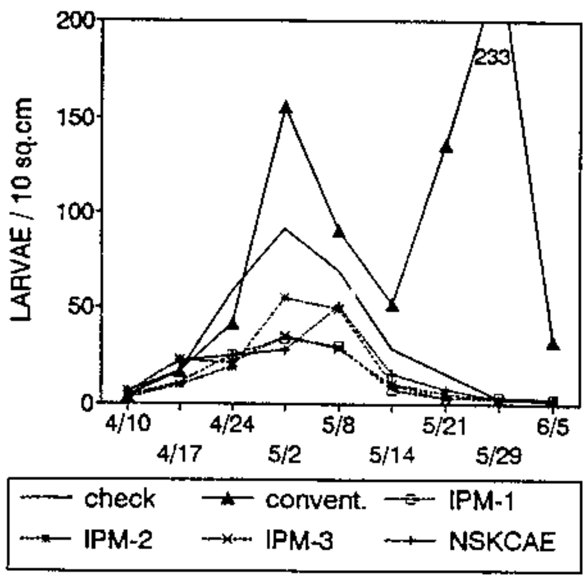

Figure 3. Effect of conventional or selective insecticides on densities of *B. tabaci* larvae

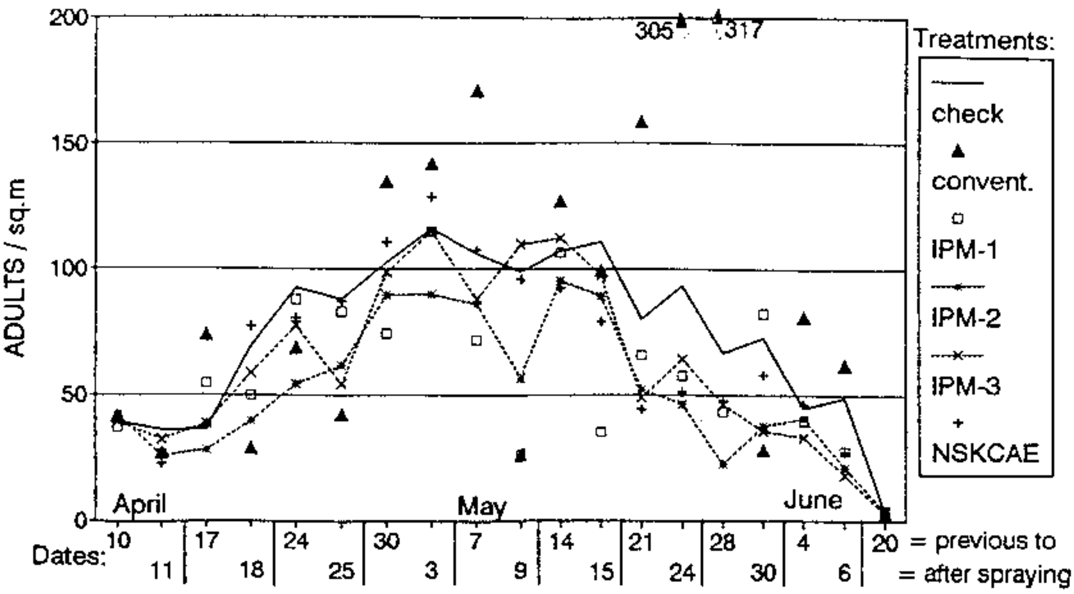

Figure 4. **Densities of adult *B. tabaci* before and after spraying selective and conventional insecticides**

Based only on the second price level (market) for tomatoes the plant protection measures were justifiable for NSKCAE, IPM-3 and the 'mixed cropping'. On the other hand, the relative low yield was due to off-season conditions and by the time the fruits were harvested the price was even higher.

Nevertheless, selective insecticides have a serious limitation as a tool for whitefly control in tomatoes and have to be integrated into a package of other necessary measures because of the recent high incidence of destructive whitefly-transmitted geminiviruses. Their presence requires a strict avoidance of early virus transmission at any price by reducing damage levels to a minimum during the first weeks of the crop even by using contact insecticides. Stansly and Schuster (1992) studied the relationship between the first appearance of geminivirus symptoms and yield losses in Florida. While an early detection in the fourth week led to yield losses of 70%, an appearance in the 11th week only resulted in a loss of 25% of the potential yield. That is why the use of selective insecticides in tomato at our present stage of knowledge can only be recommended for the second half of the crop.

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DISCUSSION: SESSION II

F Toral (Agroindustria de Barahona, Dominican Republic):
You said that neem was not giving good control of aphids and mites. We were thinking of spraying with a solution of boiled neem, do you think that this is a good idea?

F Taveras (IPL, Dominican Republic):
When we say that it does not work we mean that it is not as effective as other methods. The population does drop by 30–40% but that is not enough. The results we obtained were with crushed leaves and not with boiled leaves.

M Feliz (ANAP, Dominican Republic):
In your tests and assays on the control of insects with neem, have you done any work on the control of urban pests such as flies and cockroaches?

F Taveras:
No we haven't. Neem acts upon ingestion. It is not a contact poison and there are limitations with pests which do not feed on neem-impregnated material. For household pests it depends on how they feed. The effects will be seen in larvae.

C Serra (ISA, Dominican Republic):
What is the idea behind doing transmission studies with a non-virus vector and a virus vector?

P Stansly (University of Florida, USA):
We have two negative controls. We identify that the whitefly is not affected and there is no symptom in the suspected tomato plant. The third control is positive to see if the whitefly used to infect the suspected plant is infected.

L Zoquier (Famosa Agricola, Dominican Republic):
In the south there has been a radical change in the virus as seen from last year, even with 95% parasitism. Has any study been done to see how the virus is transmitted in instances of uncontrolled parasitism?

D Gerling (Tel Aviv University, Israel):
I don't know if the study has looked at that. In Israel, *Bemisia tabaci* can transmit the disease for half an hour. Generally the number of *B. tabaci* in the environment would be low. Without migration of large numbers, the chances of infection would be lower.

P Stansly:
The question is if there is an economic threshold for whitefly. With the virus the issue is the number of virus-bearing flies. There might be a high population of whitefly with no virus and a low population with high virus infestation. It is important to know the virus sources and attempt to break the cycle.

R Duvergé (FDA, Dominican Republic):
Dr Stansly, what short-term research activities would you recommend in an integrated management programme?

P Stansly:
The first thing is to know the range of virus hosts. When you know the virus hosts you can remove the weeds which are a bridge from one crop to another. After that use bio-control.

A Sanchez (SEA, Dominican Republic):
Dr Stansly: isn't it possible that the virus can link itself to the tomato crop and ultimately the crop would be a source of the virus?. I don't think getting rid of the host weeds for one year would make a difference.

P Stansly:
Tomato is a host plant. It could serve as a bridge between two crops. If the virus is present, it is necessary to ban the production of tomato for a period of time.

O Tineo (Cooperativa de los Bananeros, Dominican Republic:
I am concerned about some of the data in the paper presented by Emigdio Gomez. In your trials comparing protected and unprotected plots you said that the virus was greater in the unprotected plots.

E Gomez (ISA, Dominican Republic):
I said that the methodology was imperfect. The experiment stressed varietal differences.

TECHNICAL SESSION III

Chairman: Alan Jackson, *CTA, The Netherlands*

Rapporteur: Garth Rajnauth, *MoA, Trinidad & Tobago*

CURRENT PROPOSED STRATEGIES FOR CONTROLLING CITRUS TRISTEZA VIRUS IN THE CARIBBEAN: AN ANALYSIS

P Cao-Van
CIRAD-FLHOR, Martinique

The citrus industry is of varying importance for the Caribbean countries. However it is of economical interest for some of them that have worked to develop the industry for 10–20 years. Produce of good quality and quantity is now available and export markets have been developed. But a new threat is now impending for the citrus industry of the Caribbean Basin. This is the citrus tristeza disease which killed more than 50 million trees over the past 40 years world-wide. Tristeza is caused by a virus, against which pesticides are ineffective. Current proposed strategies for controlling citrus tristeza virus (CTV) will be presented and discussed below.

Historical and epidemiological background.

No *Citrus* species is indigenous to America. The first introduction of this botanical group took place in the form of seeds of oranges, lemons and citrons during the second expedition of Columbus to Hispaniola (now the Dominican Republic and Haiti) in 1493. Citrus was subsequently disseminated by seed, a propagation method that avoids the transmission of most virus and virus-like diseases of citrus, especially tristeza.

Citrus tristeza virus (CTV) and its most efficient vector *Toxoptera citricidus* Kirkaldy were introduced into Argentina in the 1930s, apparently through contaminated planting material originating from South Africa. The immediate consequence was the development of CTV epidemics in Argentina and Brazil which destroyed large plantations of oranges previously established on Sour Orange rootstock. Since the introduction of both organisms into this part of South America, they spread slowly but inexorably northward, reaching at present Central America and the Caribbean islands.

Specific aspects of citriculture in the Caribbean Basin.

As mentioned above, citriculture in the region can be traced back for five centuries before gradually expanding into a true industry.

Citrus output in the region amounts to 5.8 million tonnes for a population of 208 million inhabitants (see Appendix 1). A regional production of 6.2 million tonnes is expected by the turn of this century for a population of 250 million (these figures do not include Florida).

There are common characteristics with regard to citriculture in the region. The area is located below the 20° N parallel, i.e. under tropical mild winters or winterless climates where citrus trees often display more than one flowering season per year. Annual rainfall generally amounts to 1,500–2,500 mm and irrigation is not essential. The monsoon season is often disturbed by hurricanes and night temperatures are generally too high to induce a marked colouration of conventional mandarins and oranges. Not enough attention has been paid to rootstock trials and the present nursery practices rely excessively upon Sour Orange rootstock. In many situations, Sour Orange is indeed the only rootstock that is currently used. Specific aspects of citriculture in the Caribbean islands are presented in Appendix 2.

Tristeza in the Caribbean islands.

The tristeza status in a given territory and its ultimate commercial damage are answerable to three main biological factors: the scion rootstock combinations that are chosen by the farmer; the severity of local CTV strains, which is often related to the accidental introduction of contaminated budwood; and the aphid vector situation.

Each country or territory displays a specific pattern of CTV in relation to its citrus historical background, the exchange of budwood and the movement of aphids. Four main stages of disease intensity can be identify such as ultra mild, mild, severe and ultra severe.

A recent update of the status of CTV and *T. citricidus* was presented during the CTV workshop held in Maracay, Venezuela in September 1992. This was made possible, by the many surveys done during the last few years by different organizations. For its part, CIRAD-FLHOR worked in the French West Indies (Martinique and Guadeloupe), Trinidad & Tobago, St Vincent, Barbados, Grenada, Dominica, Antigua, St Kitts & Nevis through taxonomic identification of aphid samples or CTV detection. An extract of this status is presented in Appendix 2.

The rapid evolution of the status of both CTV and *T. citricidus* which was observed in the Caribbean between 1991 and 1993 is not really due to a new spread of tristeza or *T. citricidus*.. In fact, the present situation seems to indicate that CTV could have been introduced many years ago in some islands through the exchange of material and that a recent spread of *T. citricidus*, characterized as 'explosive' is now a real threat for tristeza propagation. New surveys, both for CTV indexing and aphid inspection, were done from December 1991 to June 1992, as a result of the sudden awareness of the risk of a new threat following information provided by CIRAD-FLHOR in Martinique and Guadeloupe. An upsurge of citrus aphids was noticed in these two islands and a close inspection showed (in November 1991) that *T. citricidus* was a recent invader of the last 15–18 months. *T. citricidus* could have been blown by the trade winds or introduced through commercial exchanges. In December 1991, *Toxoptera citricidus* and CTV were detected in Trinidad. Then, the presence of *T. citricidus* was pointed out in St Lucia and the Dominican Republic. In 1992, researchers from USDA indicated the new status of *T. citricidus* and CTV in Puerto Rico and Jamaica and helped researchers from the Dominican Republic to establish their own status. More recently (June 1993), a survey funded by the IICA Fruit Project and conducted by CIRAD-FLHOR Martinique allows researchers from the French institute to point out any new status.

What strategies are to be used for controlling tristeza ?

Some islands of the Caribbean are now expanding their citrus industry. The disorders that may occur in citrus production could be of great impact. This situation is worrying for different reasons :

- *Toxoptera citricidus*, the most efficient vector of CTV, is present in many islands and may be in all islands
- Citrus tristeza virus is present in different places in two types of severity – mild and severe isolates
- The citrus industry in the Caribbean is mainly established on Sour Orange, a rootstock highly sensitive to tristeza.

All these reasons mean that the citrus industry in the Caribbean will have to face important sanitation problems in the coming years.

Strategies for controlling CTV do exist but they require first a thorough knowledge of the regional situation, such as :

- CTV status (severity of the isolates)
- Aphid status (with special attention to *T. citricidus*)
- Natural enemies of aphids
- Rootstocks commonly used
- Other diseases known.

According to the environment and the severity of the virus strains, different strategies could be used to control the disease (see Appendix 3). Everywhere, in the presence of CTV, the first strategy would be a new rootstock policy to improve the behaviour of combinations by :

- getting tristeza resistance or tolerance
- maintaining acceptable characteristics of soil conditions and sanitation status
- not promoting other diseases, which could be masked by the tolerance of Sour Orange (special mention will be made of exocortis).

It is important to note that each rootstock has its specific characteristics which could reduce the possible choices. To avoid a greater restriction, it is necessary to use only budwoods free of transmissible diseases.

The presence of both severe strains of CTV and *T. citricidus* (as is the case of many Caribbean islands) means a higher risk of propagation of severe isolates for which the effect of tolerance from the rootstock may not be enough to protect the trees. In this case, a second strategy has to be added and cross protection could be required.

Cross protection is based on the fact that once a plant is infected by a strain of virus, it becomes protected against other strains of the same virus. For tristeza, this technique is used to protect trees against severe or ultra severe strains of CTV by pre-immunizing healthy trees by inoculating a selected mild strain which should be controlled by the rootstock tolerance. In practice, it requires a rootstock tolerant to CTV and disease-free material before inoculating. Because there is no standard mild strain of CTV for cross protection, people in charge of the citrus industry have to select their own isolate according to the following :

- No possibility of eradication of severe strains exists
- The mild virus must be mild for all cultivars and hosts
- The mild virus isolate must be stable – not prone to mutation or change in severity.

Before developing such techniques, it is necessary to know exactly which strain of CTV has to be faced; that requires reliable detection methods. Then, certified disease-free material will be required to develop strategies of control, such as rootstock policy or cross protection.

Analysis

A new rootstock policy

The first step to manage CTV will be to put tolerant or resistant rootstocks in place of Sour Orange. Unfortunately, in practice, changing a rootstock cannot be done in a short time and it entails serious problems. For the Caribbean, it means not only getting tolerance against CTV but also to keeping or to improving the characteristics allowed by Sour Orange. In this way, the characteristics of Sour Orange will still be a reference.

Sour Orange, before the spread of tristeza, has been considered as the best rootstock as much for its good performance in a large range of soils and its resistance to *Phytophthora* (root rot and collar rot) as for the productivity and quality of the fruits. In the Caribbean it is still a rootstock for which seeds are easily available.

Supplying the nurseries with seeds should not be the greatest problem, but the choice of new rootstocks has to be well studied. It needs a long period of experimentation to show their qualities, defects and particularities. The main characteristics of a good rootstock may be summarized as follows :

- Tolerant or resistant to *Phytophthora* sp.
- Tolerant to tristeza
- Good performance in heavy soils with possible short periods of waterlogging

- Compatible with the common varieties, easy to graft for propagation, and producing homogeneous trees
- Positive influence on fruits, i.e. early bearing, high and consistent productivity, acceptable size and juice content.

Unfortunately, a rootstock, combining all these qualities does not exist. Each rootstock for substituting for Sour Orange has characteristics very close to these qualities but also has some defects.

In Martinique, Sour Orange was mainly used for back-yard trees, while in orchards, *Citrus macrophylla* was selected for Tahiti lime (C. *latifolia*) combination and Carrizo Citrange for sweet citrus and grapefruits. Aware of the defects of both *Citrus macrophylla* and Sour Orange, CIRAD-FLHOR's researchers have tested nine new rootstocks since 1989: 'Goutou' Sour Orange, Carrizo citrange, Riverside and Lindcove Troyer Citrange, Sunkipon, Cleocar, Cleopatre and Fuzhu mandarins and *Citrus amblycarpa*. In the trial, the trees show good development and look healthy but 4 years of data are not enough to make conclusions. Today, and since two years ago, four rootstocks are mainly used at the CIRAD-FLHOR's nursery, which produces about 15.000 citrus trees per year: Carrizo Citrange (40%), Citrus Volkameriana (20%) and Trifoliate Orange cv. Pomeroy (20%) and cv. Flying Dragon (20%). Each of them has its good qualities and defects :

Carrizo Citrange performs well when the soil is well prepared (without compaction).

(+) resistant to *Phytophthora* sp. and tolerant to tristeza

(+) high amount of nucellars (about 100 %) that allows an excellent homogeneity

(+) growth and vigour of the young trees in the nursery may be better than with Sour Orange

(+) compatibility with a very large range of varieties

(+) good productivity and quality of fruits

(-) high susceptibility to exocortis that requires the use of only disease-free material in the nursery

(-) bad performance when subjected to waterlogging and compact soil, requiring the farmers to do very efficient soil preparation and drainage

Trifoliate Orange cv Pomeroy has much the same qualities as above but its main defect when managing such an orchard is its strong susceptibility to nutrient deficiency.

Trifoliate Orange cv Flying Dragon has the main added quality is its dwarfing effect that allows the establishment of high density orchards (700–1,200 trees per ha) under a humid tropical climate. This rootstock appears at present to be a possible and technical answer for the development of the citrus industry in Martinique.

Citrus Volkameriana is mainly used for acid citrus combination.

(+) tolerant to both tristeza and exocortis

(+) good productivity

(+/-) high vigour

(-) may be susceptible to *Phytophthora*

(-) may decrease the quality of sweet citrus fruits.

According to this short review of rootstocks used in Martinique, the most important problem when using rootstocks such as Carrizo Citrange or Trifoliate Orange is their high susceptibility to exocortis. In Martinique, a disease-free germplasm collection of 147 varieties allows CIRAD-FLHOR to use these as rootstocks. Exocortis is a viroid disease that is transmissible only by grafting contaminated budwood or by working with tools not disinfected. This disease does not show any symptoms on trees grafted on Sour Orange. So, prior to using Citrange or Trifoliate rootstocks it is

necessary to run indexing for exocortis on the mother trees with special attention to those grafted on Sour Orange. In other words, this means grafting only certified budwood. Unfortunately, most Caribbean islands do not have a certification programme for citrus material. For this reason, other rootstocks such as Cleopatra Mandarin, Citrumelo or Citrus Taiwanica should be tested. These rootstocks are both tolerant to tristeza and exocortis. Of course they also have defects.

An other point is the difficulty of transposing results from one place to another. Even if Caribbean countries all appear as sunshine countries, differences bring to mind the agronomic reality. Thus, citrus experiments are conducted on brownish heavy soils (55–60% clay) in Martinique, but most of the citrus plantations in Trinidad are in 90% clay soils. In these extreme conditions, only trials can confirm a possible choice for new rootstocks.

Working against CTV also means some practical measures for nurseries such as :

- concentration of the citrus nurseries in areas free of tristeza to make the control of plants easier

- ban on using Sour Orange as rootstock in combination with orange, mandarin, clementine and grapefruit

- efforts to popularize the use of new rootstocks tested in trials.

For the farmers, changing rootstock can be synonymous with loss of time and money. Of course, it is also the only way to protect trees. Every citrus grower knows that it needs 3-4 years, under a humid tropical climate, before the trees begin to produce. It will also take some months before a contaminated tree declines. So, it will be possible to reduce the loss by planting new trees, grafted on a tolerant rootstock, between the old rows contaminated by tristeza. Even if the growth of the young trees is not as good as it should be because of shade, once the old trees begin to decline, the young ones will be in place and ready to start. The loss of time will be shorter. This technique was used in Venezuela with success.

Cross protection

This technique has been developed especially in countries where ultra severe strains of tristeza are present or more generally where using tolerant rootstocks was not enough to protect the trees. Developing cross protection could take a long time before it becomes efficient. On account of the large range of CTV strains all over the world (228 isolates have been collected in Beltsville, USA) and the different behaviour of scion-rootstock combinations that may occur, it is necessary to find for each epidemic area the mild strain giving the most advantages. Information from Beltsville's collection should help in comparison, identification, cross protection possibilities, level of tolerance or resistance of the host plants.

There are two different options for obtaining an efficient mild strain:

- introduction of isolates

- selection of isolates from surviving trees.

The first option could be dangerous and in many countries it is strictly forbidden.

The second choice takes account of the local situation but will be a long-term study.

Whatever it may be, before running cross protection, each country has to develop its new rootstock policy and to identify the different strains.

Controlling aphid vectors

As mentioned above, *T. citricidus* is recognized to be the most efficient vector of tristeza and is present all over the Caribbean. This situation is worrying because of the fact that virus spread has been correlated with aphid population densities. Controlling *T. citricidus* should help to reduce CTV propagation.

In this way, biological control directed against *T. citricidus* is another possible avenue of control, especially through the increase of local natural enemies or the introduction and acclimatization of exotic natural enemies. First preference should be given to specific parasitoids that establish

not only on crop plants but also on alternative host plants that afford shelter to the vectors, i.e. *Lysiphlebus japonicus, L. fabarum, L. testaceipes, L. delhiensis.* Second preference should be given to general predators that are effective at low prey densities and are active at the lower temperatures in early spring. In Martinique and Trinidad, following the spread of *T. citricidus,* observations have shown an increase in the populations of *Lysiphlebus testaceipes.* First observations show the high efficiency of this parasitoid with a parasitism rate reaching 2–20 aphids per day per *L. testaceipes* while the propagation rate of *T. citricidus* is about 23 descendants per day.

An other way of controlling aphids is the use of pathogenic fungi. This method has been explored in the Dominican Republic.

Conclusions

Citrus tristeza is one of the major diseases affecting citrus production world-wide. The economic losses caused by this malady vary considerably according to the particular horticultural situation in each epidemic area.

In almost all cases, infections of nurseries and movement of infected propagative material were the main sources for distant infections and eventually contributed to the fast spread of the disease.

Among the possible control strategies, it is advisable to avoid an excessive dependence upon a particular rootstock, but rather to rely on a range of rootstocks that would ensure reasonable yields of good quality fruit for a long economic life. Tristeza tolerance can be combined with foot rot tolerance, good yield and high brix inducing rootstock. Carrizo Citrange, Swingle Citrumelo, Trifoliate Orange are interesting possibilities.

Developing a new rootstock policy, a control strategy for aphid vectors, or selecting a mild strain for cross protection involve large technical and human resources.

Finally, a coordinated research programme is necessary to further assess the severe strains of CTV that have been or will be found in the Caribbean and monitor the various epidemiological scenarios in different ecological situations for implementing relevant preventive measures.

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Appendix 1. Populations and corresponding citrus production in the various countries of the Caribbean Basin

	Population ('000s)		Citrus production ('000 tonnes)				
	1991	Projected 2000	Orange	Lime	Grapefruit	Mandarin	Total
Continental countries							
Mexico	90,208	109,724	2,200	612	100	169	3,081
Colombia	33,236	39,720	350	60	-	-	410
Venezuela	20,238	25,275	427	15	9	34	485
Guatemala	9,560	11,835	100	10	-	15	135
Honduras	5,425	7,141	49	9	36	3	97
El Salvador	5,311	6,236	90	9	-	-	99
Nicaragua	3,709	4,797	66	-	-	-	66
Costa Rica	3,116	3,960	86	-	-	-	86
Panama	2,474	2,983	34	-	-	-	34
Guyana	763	757	15	-	-	-	15
Belize	184	226	55	-	32	-	87
Total	174,224	212,654	3,472	715	177	221	4,585
Major northern islands							
Cuba	10,639	11,532	520	68	280	30	898
Dominican Rep.	7,408	8,g31	66	9	9	-	84
Haiti	6,500	7,367	30	25	10	9	74
PuertoRico	3,314	3,374	29	1	3	-	33
Jamaica	2,540	2,803	20	24	40	20	104
Total	30,401	34,007	665	127	342	59	1,193
Southern islands							
Trinidad &Tobago	1,294	1,547	7	1	4	4	16
Guadeloupe & dép.	346	372	1	2	1	-	4
Martinique	335	347	1	1	-	-	2
Barbados	300	325	-	-	-	-	-
Curacao & Bonaire	184	187	-	-	-	-	-
St Lucia	158	197	-	-	-	-	-
UK Virgin Islands	16	17	-	-	-	-	-
US Virgin Islands	111	127	-	-	-	-	-
St Vincent	106	112	-	1	-	-	1
Dominica	86	99	5	6	9	-	20
Grenada	90	91	1	1	-	-	2
Antigua & Barbuda	64	65	-	-	-	-	-
Aruba	63	65	-	-	-	-	-
St Kitts & Nevis	40	41	-	-	-	-	-
Anguilla	6	7	-	-	-	-	-
Monserrat	10	10	-	-	-	-	-
Bahamas	254	297	-	-	-	-	-
Total	3,463	3,906	15	12	14	4	45
	208,088	250,567	4,152	854	533	284	5,823

Appendix 2. Citriculture and CTV/*Toxoptera citricidus* status in various Caribbean islands

Country	Size of citrus industry	Rootstocks currently used	*T. citricdus* detection (year)	CTV mild	CTV severe
Cuba	140,000 ha	Sour Orange (90%)	+	?	?
Dominican Rep.	9,000 ha .	Sour Orange (90%)	1992	+	+
Haiti	74 ,000 t/year	Sour Orange	+		
Puerto Rico	33,000 t/year	Sour Orange	1992	+	+
Jamaica	104,000 t/year	Sour Orange	1993	+	+
Trinidad	6,000 ha	Sour Orange (95%)	1991	+	+
Dominica	2,200 ha	Sour Orange (99%)	1992	+	?
St Lucia	524 ha	Sour Orange (99%)	1992	+	?
Martinique	350 ha	Carrizo Orange Citrus macrophylla Trifoliata Orange Sour Orange (20%)	1991	-	-
Guadeloupe	270 ha	Sour Orange (50%) Citrus macrophylla Citrus Volkameriana	1991	-	-
Grenada	70 ha	Sour Orange (90%)	?	?	?

Appendix 3. Various scenarios in tristeza severity with corresponding damage and possible control strategies

	Severity of strains			
	Ultra-mild	Conventional	Severe	Ultra-severe
Type of disorder, symptoms:				
VC + SP on Mexican lime	-	+	+	+
SD on Sour Orange rootstock	-	+	+	+
Seedling Yellow	-	Occasional	(+)*	(+)*
Other symptoms	not known		SP on grapefruits	also grapefruits
Serological detection		+	+	SP on oranges & mandarins
Polyclonal antibodies		+	+	+
Specific monoclonal antibodies				+
Vectors associated	not known	all species except *T. citricidus*	mostly *T. citricidus*	mostly *T. citricidus*
Commercial losses expected	not known	Destruction of orchards grafted on Sour Orange	crop losses on grapefruit & limes**	crop losses on oranges & mandarins**
Strategies of control		new root-stock policy	cross protection by mild strains	eradication if feasible
Countries or group of countries concerned	Florida Corsica (only on Kumquat)	Mediterra-nean Basin Caribbean Basin Florida, California	South Africa South America S E Asia Australia	specific regions of Brazil, Peru Indonesia Thailand Japan

VC – vein clearing SP – stem pitting SD – stionic decline

* frequent ** irrespective of the rootstocks tolerance to SD

THE INCIDENCE OF CITRUS TRISTEZA VIRUS DISEASE IN BELIZE AND MONITORING THE ENTRY OF THE APHID VECTOR,*TOXOPTERA CITRICIDUS* .

P S Reddy and H Sabal
Belize Citrus Growers Association

(This paper was prepared for the seminar but was not presented – ed.)

Citrus tristeza virus (CTV), which is one of the most destructive diseases of citrus, is a big menace to the Belize citrus industry, because 90% of the productive citrus plantations are on CTV-susceptible Sour Orange rootstock and the aphid vector *Toxoptera citricidus* is heading towards Belize. CTV was first reported from Belize in 1985. A recent survey wherein the budwood source trees were tested, revealed the presence of CTV severe and mild strains up to 4.01 and 14.87% respectively. An aphid trapping programme started in August 1993 indicated the presence of only *Aphis spiraecola, A. gossypii* and *Toxoptera aurantii,* but not the efficient vector *T. citricidus.* Because of the imminent threat by the entry of *T. citricidus* into Belize, an eradication programme of CTV severe strains is going to be undertaken to reduce the source of severe strains inoculum for *T. citricidus* on its entry and to delay the impact of CTV on the citrus industry.

Citrus tristeza virus (CTV) disease is one of the most devastating citrus diseases worldwide. CTV is a phloem restricted clostero virus having large flexuous filamentous particles and is known to be transmitted by *Toxoptera citricidus*. CTV was introduced with its aphid vector *T. citricidus* from South Africa into South America in the 1930s and wiped out the citrus industries of Argentina, Brazil and Uruguay by killing 30 million trees on Sour Orange rootstock.

Afterwards, it spread to Peru, Bolivia and Colombia and killed all the citrus on Sour Orange. The last biggest disaster occurred in the 1980s in Venezuela after the arrival of *T. citricidus*, where some 6 million trees on Sour Orange collapsed.

CTV is known to exist in a large number of strains and these differ greatly in the severity of the symptoms which they induce on susceptible rootstock-scion combinations. Some strains are so mild that even sensitive hosts are not affected. Other strains cause decline or death of orange and grapefruit budded on Sour Orange, irrespective of age. Inverse stem pitting, black discolouration at the bud union, stem pitting on branches, reduction in size of leaves and fruits, mineral deficiency symptoms, production of insipid fruits are some of the symptoms caused by severe strains of CTV.

CTV in Belize

Belize has approximately 19,000 ha under citrus cultivation which is the second largest agricultural export earner to the country. Sweet orange varieties contribute 64% and grapefruit 36% of the total fruit yields. An estimated 90% of the productive citrus plantations are on CTV-susceptible Sour Orange rootstock. CTV symptoms were first noticed in Belize in 1985 on grapefruit budded on Sour Orange (Chubb 1985) but it probably had been introduced long before. This was later confirmed (Delbeke 1988) with the help of Enzyme Linked Immunosorbant Assay (ELISA). The CTV survey conducted in 1991/1992 had indicated the presence of CTV severe strains up to 3% (Caroline 1992). None of the aphid collections from citrus groves of Belize were identified as *T. citricidus*.

T. citricidus movement in Caribbean and Central American countries.

T. citricidus is found throughout citrus growing areas of south-east Asia, Australia, east and south Africa and South America. In the mid 1980s it was found spreading from South America to Central America having reached Panama, Costa Rica, Nicaragua and recently Honduras (unconfirmed report). It is also making its pathway through Caribbean countries and within the past 3 years it was recorded in St Lucia, Martinique, Guadaloupe, Puerto Rico, the Dominican Republic and Trinidad. Recently its presence was reported from Haiti, Cuba (Guantanamo Bay) and Jamaica.

1993 CTV survey in Belize

In Belize, the citrus industry is gravely concerned about the movement of *T. citricidus* close towards Belize. A CTV survey was designed to identify the trees infected with CTV severe strains and uproot them, which should result in a reduction of the inoculum source of severe strains available for the aphid when it arrives in Belize.

The Research Unit of Belize Citrus Growers Association (CGA) undertook the survey from January to May 1993 and tested (using ELISA) primarily the trees country-wide which might be used as budwood sources in order to prevent the spread of CTV through nursery plants. A follow-up survey is planned for the month of December 1993 to test all citrus plantations aimed at the eradication of CTV severe strains .

The budwood source trees were tested in composites, each sample consisting tissues from 10 trees. Polyclonal and MCA-13 antisera were used to detect mild and severe strains of CTV respectively.

The results shown in Table1 reveal that the percentages of citrus infected with severe and mild strains are as high as 4.01 and 14.87 respectively. As the strategic approach is not to propagate any form of CTV, growers are advised not to cut budwood from CTV-positive tree, whether it has severe or mild strains.

Table 1 Percentage incidence of CTV in budwood source trees in Belize.

District	No. of samples tested	Per cent citrus infected Severe strains	Mild strains
Stann Creek	5,516	0.01–2.59	0.31–14.87
Toledo	1,095	0.23	2.21–4.98
Cayo	2,237	0.21–2.16	0.34–10.71
Orange Walk	218	0.09	0.76
Belize	334	1.07–4.01	0.51–5.32

Monitoring the entry of *T. citricidus* into Belize.

Because *T. citricidus* has been found in neighbouring countries of Belize, an aphid trapping programme was initiated in the month of August 1993 to monitor the entry of *T. citricidus* into Belize. This will enable the formulation of integrated approach methods of aphid control to restrict its spread in the citrus groves.

Galvanized funnels with a 38 cm face diameter, painted yellow on the inner side were used for the trapping programme. A water and soap solution mixture was used as the medium to trap winged aphids. Sixteen aphid traps were installed country-wide, along the border and sea coast, at a height of 1.5 m above ground level in citrus groves. These traps have been monitored once in every 3 days for aphids. The trapped aphids were separated from other insects and collected in vials containing 95% alcohol. Later the trapped aphids were identified in the CGA laboratory.

The results presented in Table. 2 indicate that the majority of the aphids trapped were identified as *A. spiraecola* followed by *T. aurantii* and *A. gossypii*. None of the aphids were identified as *T. citricidus*.

Table 2. Particulars of aphid trappings at CGA, Belize, from August to October 1993

Date (d-m-y)	No. of aphids from 4 traps	*Toxoptera citricidus*	*Aphis spiraecola*	*Aphis gossypii*	*Toxoptera aurantii*
03-8-93	64	-	+++	++	++
06-8-93	2	-	+++	+	++
10-8-93	19	-	++	++	+++
13-8-93	11	-	++	+	+++
17-8-93	7	-	+++	-	++
20-8-93	4	-	-	-	+++
03-9-93	26	-	+++	++	-
07-9-93	31	-	-	-	+++
09-9-93	15	-	+++	-	-
14-9-93	7	-	++	-	+++
23-9-93	22	-	+++	-	+
28-9-93	6	-	++	-	+++
5-10-93	7	-	+++	+	++
12-10-93	6	-	+++	-	++
15-10-93	4	-	++	-	+++

* Identified at the CGA laboratory. +++ >50%; ++ >10%; + up to 10%

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STRATEGIES TO COMBAT THE CTV THREAT IN BELIZE

P Hunt
NRI/ODA and Ministry of Agriculture, Belize

Belize is a small Central American country of about 23,000 km^2, bordered by Mexico, Guatemala and the Caribbean Sea. Citrus is the second most important crop, after sugar, with an estimated area of 22,000 ha, approximately two-thirds in oranges and one-third in grapefruit, much of it planted in the past 10 years. The crop is nearly all processed into frozen concentrate with an annual export value of US$20–40 million. Belize's population is only 200,000, so that the per capita value of the crop ($100–200 per head) is very high, exceeding that of any other Caribbean country. The citrus industry is thus vital to Belize as a source of foreign exchange and as major employer of labour.

Unfortunately almost all of the mature plantings (over 90% of the productive acreage) are budded on to Sour Orange (SO), a rootstock very well suited to Belizean citriculture but very vulnerable to citrus tristeza virus (CTV). The highly efficient vector of CTV, the brown citrus aphid, *Toxoptera citricidus*, is rapidly spreading north-westwards through Central America and its arrival in Belize is imminent. By analogy with other countries that have experienced its invasion, e.g., Brazil, Venezuela, a catastrophic spread of quick-decline strains of CTV is expected (Roistacher et al. 1991; Aubert et al. 1992) and we anticipate the death of all citrus on SO rootstocks in less than 10 years of its arrival.

Growers have very mixed perceptions of the CTV threat. Many, particularly among those with smaller holdings, express serious doubts about the extent of the expected devastation and they are unwilling to believe that trees on SO, which have performed so well in the past, will collapse and die. The most pressing need is to educate growers to the reality of this situation and to prepare them for the change to CTV-tolerant rootstocks and, with it, the attendant risks of other virus and virus-like diseases becoming important. They will need to understand and support programmes for budwood certification and nursery registration which will totally change citrus nursery practices in Belize and without whose regulation the industry is unlikely to survive. This paper examines the technological changes which are proposed for introduction in Belize and views some of their logistical constraints.

Projected losses to CTV

The citrus industry in Belize started modestly in the 1930s using budded orange and grapefruit trees imported from Florida. There was a considerable expansion in the 1950s using selected budwood from the earlier plantings plus fresh imports. Apart from some experimental trees, virtually all commercial plantings until 1980 were budded on to SO rootstocks. Since the mid 1980s, largely in response to the CTV threat, an increasing proportion of nursery trees have been budded on to CTV-tolerant rootstocks (Cleopatra Mandarin, Carrizo Citrange, Swingle Citrumelo, Rangpur Lime, Troyer Citrange and Volkameriana, in decreasing order of popularity). Past importation of budwood was not subject to the strict quarantine now in place and it is probable that many strains of CTV are already present in Belize. Dr Reddy has given evidence of the extent of mild and severe strains of CTV in Belize. Blight, psorosis and exocortis diseases are also regularly diagnosed at the laboratory of the Citrus Growers' Association and have been confirmed in samples sent to international overseas laboratories.

Figure 1 shows a graph of the area planted to oranges and illustrates the massive new planting which has occurred in the past 10 years. Data are derived from a recent government survey (awaiting publication) of citrus growers. This graph also shows the

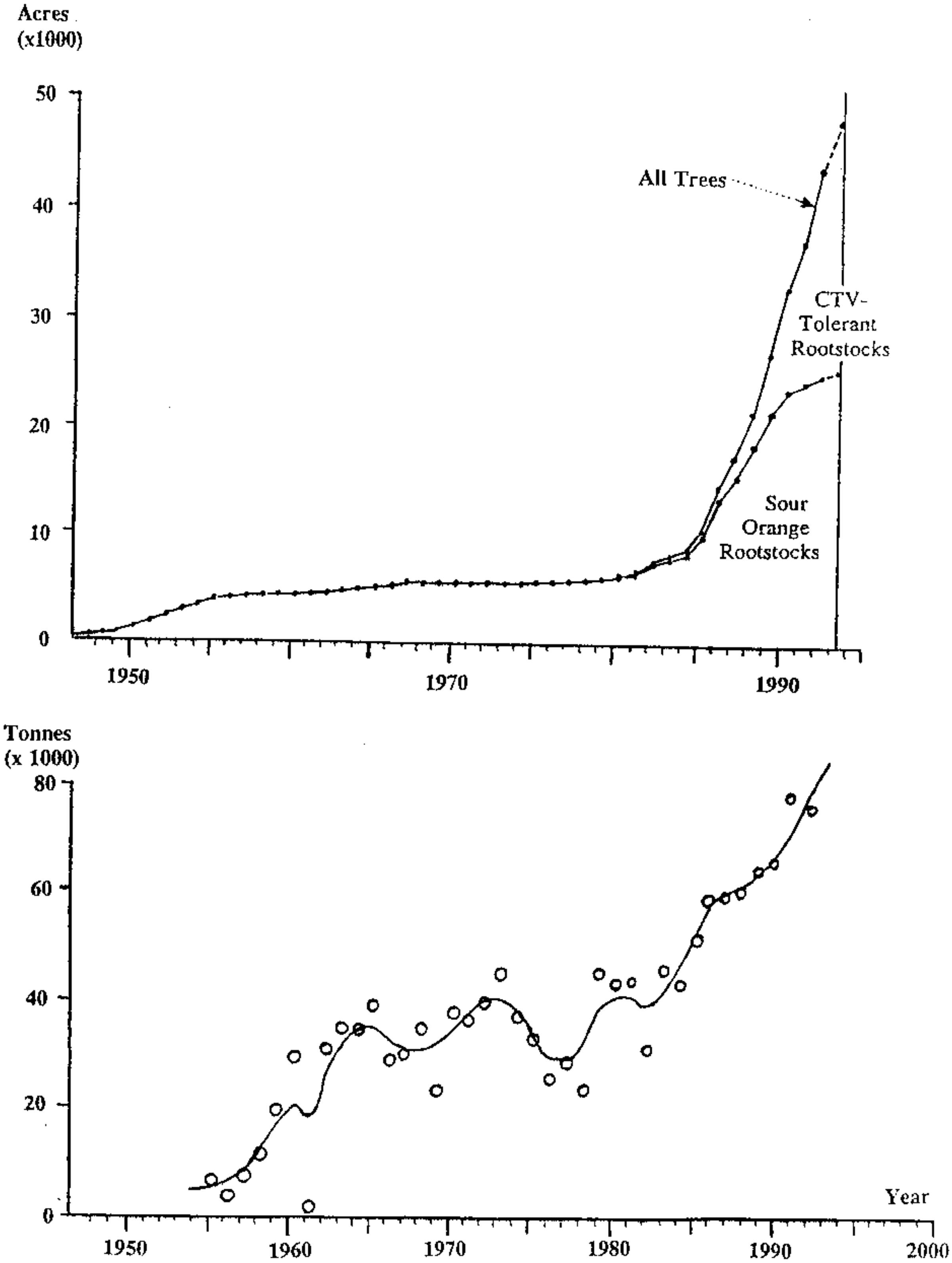

Figure 1. **Upper graph: Accumulated areas of orange trees in Belize, 1948-1993 (estimated for 1994) showing massive new plantings since 1984 and recent switch to CTV-tolerant rootstocks. Lower graph: Yields (tonnes) of oranges over same time period with plot of weighted 5-year rolling mean.**

division between SO and CTV-tolerant rootstocks. Approximately 90% of the area planted in 1992/93 was on CTV-tolerant stocks, compared to 90% on SO 10 years earlier. The production figures (based on a weighted [1 : 2 : 4 : 2 : 1] 5-year rolling mean) are also displayed on a contiguous graph; note that the yield is rising rapidly even before most of the recently-planted trees have come into bearing.

Figures 2 and 3 present yield data for the immediate past and projections for the future. These are based on past performance relative to area and take into account the age-profile and yield potential of the trees making up the area at any time. Planned new plantings after 1994 have not been allowed for. These Figures also show various yield predictions in response to loss of existing populations of trees on SO rootstocks through spread of CTV. In Figure 2, the arrival of *T. citricidus* is timed, hypothetically, to have occurred in 1992 (lowest curve), or in any of the subsequent years to 1997 (ascending series of curves); these yields are plotted for a model in which 95% of the trees on SO will have died 6 years after *T. citricidus* arrival (mortality: Year-1 = 0%; Year-2 = 4%; Year-3 = 15%; Year-4 = 43%; Year-5 = 80%; Year-6 = 95%; Year-7 = 99%; Year-8 onwards = 100%) which approximates to the experience in Venezuela (Mendt 1992). In Figure 3, *T. citricidus* is assumed to have arrived in 1993 for all curves; the various yield projections are based on different periods (of 4–9 years) for the assumed time from *T. citricidus* arrival in 1993 to 95% mortality.

From these graphs, it is very clear that any delays in the establishment of *T. citricidus* in Belize (Figure 2) or reductions in the rate of subsequent CTV spread (Figure 3) will have a significant impact on production. Despite the expected incursion of CTV, yields are still projected to rise because of the large area of young trees that is now coming into bearing. Only in the worst case scenario (aphid arrives this year and 95% of trees on SO will be dead in 4 years) does the production fall close to the present (1992/93) level.

In the Figure 2 projections, the area enclosed between each successive curve represents the increased yield which would result from a delay of 1 year in the arrival or establishment of *T. citricidus*. Evaluation of these areas suggests that future yields can be expected to rise by approximately 150,000 tonnes (spread over about a 5-year period) for each year by which the establishment of *T. citricidus* can be postponed. This is almost double the current annual production and has a value of about US$50 million to the industry ($10 million for each of the 5 years). Similarly, from the graphs in Figure 3, total yields will be approximately 95,000 tonnes higher (again spread over about a 5-year period) for each year by which the time span between aphid establishment and 95% mortality can be extended.

These projections do not diminish the disaster which faces individual growers with trees on SO rootstocks – all such trees will die – but the particular distribution in Belize of a large population of young trees on CTV-tolerant rootstocks emphasizes the value of protecting the older vulnerable trees on SO rootstocks until the trees on tolerant rootstocks have come into full bearing. Nationally, the impact of CTV would then be much less. Various possible strategies aimed at delaying aphid establishment or later CTV spread are explored below.

In this section data have been presented with respect to yields of oranges in Belize and the projected death rates of Sweet Orange trees budded on to SO rootstocks. A similar scenario is also applicable to grapefruit but, because of the reduced acreage, the projections would be about 30–40% of those given for oranges.

Possible strategies to delay losses due to CTV

Several strategies aimed directly at the aphid vector and/or at slowing down the rate of CTV spread are investigated. Each is evaluated within the Belizean context for its practicality and potential benefit.

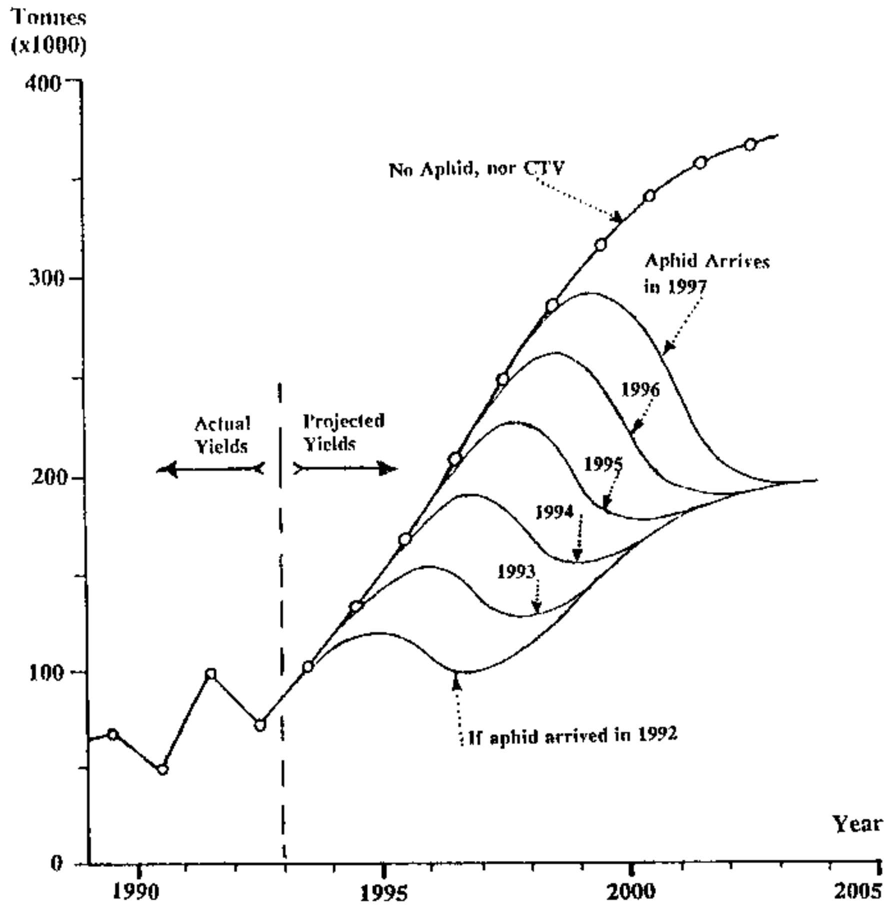

Figure 2. Recent past yields of oranges and future projected yields in relation to assumed arrival dates for *T. citricidus*.

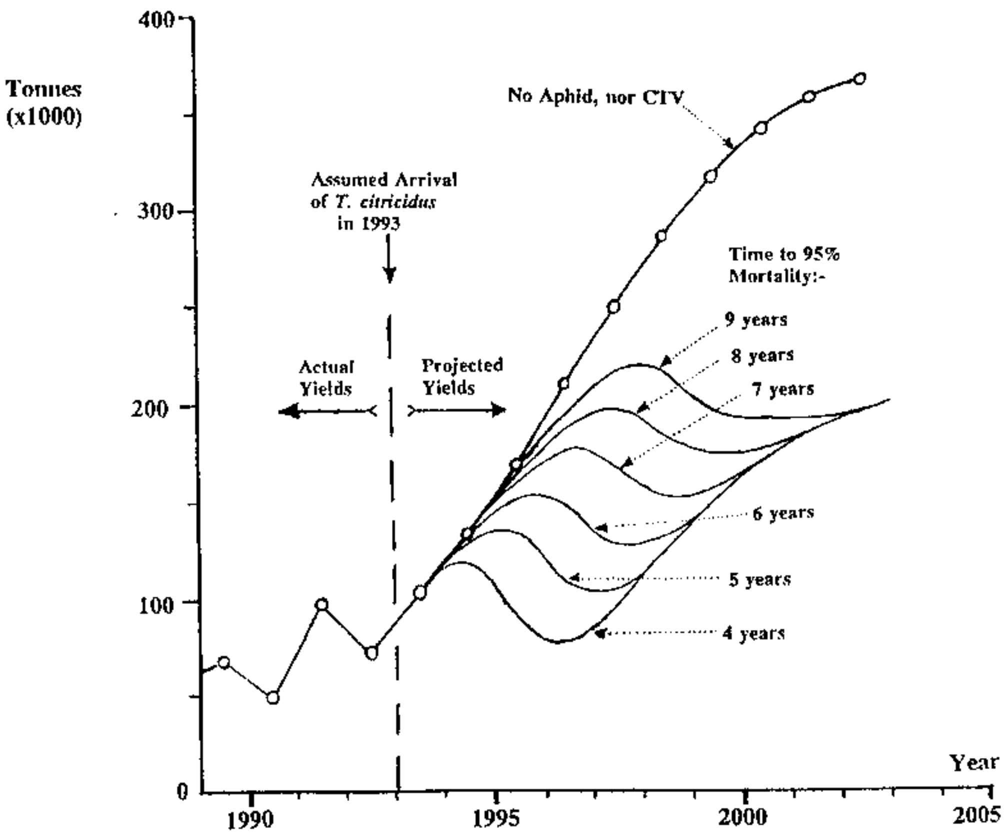

Figure 3. Future projections of orange yields in response to different models for time spans between *T. citricidus* arrival (assumed to be in 1993) and 95% mortality of trees on Sour Orange rootstocks.

Quarantine and preventing aphid establishment

T. citricidus might arrive in any of three possible ways: by natural long-distance air-borne spread in strong winds – hurricanes are suggested as a possible mechanism; by long-distance transport by man as a 'hitch-hiker' in vehicles or aeroplanes, or on planting material transported between countries; by short-distance spread from nearby sources of infection by natural migration of the insect, or by the movement of plants, e.g. nursery stock, budwood, within a local framework.

The first two methods are so subject to hazard that it is virtually impossible to predict their relative importance. Certainly, the tightening up of quarantine inspections on plant material coming from infested countries and the routine spraying of such conveyances would limit the risk of accidental introduction at small cost. Since *T. citricidus* almost never colonizes plants outside of the Citrus section of the Rutaceae, these quarantine inspections need not disrupt normal commerce in other plants. Belize is adopting more stringent quarantine procedures for goods and persons travelling from South and Central America. We are also alerting the travelling public to the dangers of uncontrolled movements of citrus and other plants.

At present, the nearest known source of the brown citrus aphid is believed to be in western Nicaragua, about 500 km from the Belize border. We hope to be informed of its movement towards us. In addition, funnel traps have been located in scattered citrus groves and are monitored weekly to determine the aphid species present. Farmers are also being told how to recognize *T. citricidus* colonies and to report any unfamiliar aphids which they see. In this way it is hoped that advanced warning of the arrival of the aphid will be given or that any primary infestations will be recognized before they have had an opportunity to become firmly entrenched and establish secondary foci. Isolated primary foci will be treated rigorously with insecticides (which ones have not yet been selected) in an attempt to eradicate the outbreak or to contain it from spreading into citrus areas at large. The financing of such an eradication/containment programme ought not to be difficult once it is appreciated that each year by which the aphid's establishment is delayed should net an additional $50 million in conserved yields over the five following years.

By reference to experience elsewhere, it is recognized that sooner or later, *T. citricidus* will become widely established and that, with present technology, attempts to control it will not succeed. Because of its CTV vectoring efficiency, aphid populations would need to be enormously reduced to have a significant impact on CTV spread. Unless a new control technology is developed (e.g. pheromone lures) we do not expect to pursue measures to control aphid populations once they have become nationally established.

Eradication of trees with severe CTV strains

It is widely held that catastrophic outbreaks of CTV among trees on SO rootstocks following the arrival of *T. citricidus* result from the spread of pre-existing strains of CTV resident in the country rather than from virus introduced along with the aphid. Thus Roistacher (1992) cites several examples where so-called 'sleeping' strains of CTV have exploded into prominence, causing rapid decline, only after *T. citricidus* establishment and suggests that such strains may have long been present but were only occasionally transmitted by the inefficient aphid vectors previously present (usually *Aphis spiraecola*, *A. gossypii* and/or *T. aurantii*). Under such circumstances, the identification and removal of trees harbouring severe CTV strains presents a powerful method for slowing down CTV spread despite the presence of *T. citricidus*.

Rapid decline strains of CTV can almost always be recognized by the field symptoms induced in scions on SO rootstocks. However, their presence may be completely hidden in trees on other (CTV-tolerant) rootstocks or in some varieties, e.g. mandarins. ELISA is a quick, efficient and relatively inexpensive method for detecting CTV in symptomless carriers or for confirming its presence in equivocally

symptomatic trees. By careful selection of mono- or poly-clonal antibodies whose response to local CTV strains has been tested, it is possible to screen large numbers of trees for the presence of mild and severe strains, at least during the cooler months of the year. On a large scale, composite samples from 10 or so trees can be run as a single test; among positive samples, the trees can later be retested individually to determine which are affected. Confirmation of the presence of severe strains can also be done by biological indexing on West Indian Lime and a proportion of ELISA-positive trees should routinely be spot-checked in this way.

It is proposed that samples from all areas of Belize will be so tested in the next 5 years, starting with those trees being used as budwood sources but also including known 'hot-spots' from previous ELISA surveys, trees displaying questionable symptoms or trees whose provenance is uncertain. The survey will later be extended to all groves. Any trees testing positive to severe strains will be destroyed once the guidelines for the eradication have been set and the terms of any possible compensation have been agreed. Present indications are that some 15–20,000 trees (<0.5%) in Belize are infected with severe strains and will need to be individually identified and destroyed. The policy of eradication will remain in effect until it is clear that the 'battle has been lost' and too many (a threshold of about 5% seems probable) trees on SO are becoming infected. It is hoped that this policy will slow down the disease spread, at least initially, and that the benefits of an extra year or two of production will be achieved. Unfortunately, there is no simple way to determine the efficacy of the policy.

One additional advantage of the removal of rapid decline strain trees is that any of the other severe CTV strains (causing stem pitting and seedling yellows, for example) will also be destroyed before they have an opportunity to be disseminated by *T. citricidus*. Such strains often come into prominence in trees on CTV-tolerant rootstocks after the rapid decline phase on SO has run its course and they are now the major CTV problems in Brazil (Muller and Costa 1992), South Africa (Lee et al. 1992) and Venezuela. Hopefully, most sources of these strains would be eradicated along with the targeted rapid decline strains.

Cross protection

Cross protection against CTV involves the deliberate introduction of mild (symptomless or nearly so) strains of CTV into trees to protect them against later infection with debilitating severe strains. This is most easily accomplished at the nursery stage by introducing budwood from sources infected by mild strains but can also be done on mature trees, at considerably more cost, by inserting infected buds (or blind buds) simultaneously into several branches. The presence of the mild strain prevents the establishment of a later (severe) strain or reduces its reproductive capacity once established and therefore stops or delays the onset of symptoms by the challenging strain. The benefits of cross protection have recently been reviewed by Roistacher (1992). The degree of cross protection depends on the characteristics both of the primary (typically mild) strain and of the challenging (typically severe) strains and is strongest where the two strains are closely related. The procedure has some danger because there is convincing evidence (Moreno et al. 1992) that 'mild' strains can regain their pathogenicity and become 'severe'.

For countries infected with severe strains which affect trees regardless of the rootstock (stem-pitting, seedling yellows and Capao Bonito strains, for example), cross protection is the only effective technique available to limit the impact of CTV. However its use to protect trees on SO against rapid decline strains remains questionable and there are many instances where the presence of mild strains prior to colonization by *T. citricidus* seems to have afforded little or no protection.

Belize is keeping its options open with respect to cross protection. Less than 10% of the existing population of mature trees contain mild strains, as determined by ELISA tests. Some isolates of these mild strains are being typed in USA and tested for their cross protection potential against a basket of severe strains. Strains showing promise for protection will be bulked up in preparation for their possible release (as buds) to protect trees on SO but this is only

likely to happen after *T. citricidus* has become established and the identity of the severe strain(s) and of the best cross protecting strain(s) have been determined. If stem pitting or other "super' severe strains become important, cross protection will almost certainly become a routine operation in the nursery.

Elimination of CTV from budwood and of Sour Orange as a rootstock

Presently, the law does not regulate citrus nursery operators and anyone may graft plants and offer them for sale. Most large growers carry out their own nursery operations and have traditionally selected budwood from the best of their own trees, usually on SO rootstocks. Only in the past 2 years has Belize been equipped to test many of their budwood sources for the presence of CTV using ELISA. A few instances of budwood sources having mild CTV have been detected and their further use, for the present at least, has been discouraged. Equally, the use of SO as a rootstock is being strongly discouraged but cannot yet be enforced.

It is planned (see below) that the entire nursery industry will soon become regulated and a budwood certification programme implemented. However, this is unlikely to have any major impact on the immediate threat from rapid decline if *T. citricidus* arrives in the next few years – existing infected trees will be the main source of CTV inoculum unless we are successful in eradicating almost all of them.

The interplanting of seedlings on CTV-tolerant rootstocks between existing trees on SO is also being recommended, particularly where the groves are less than about 10 years old. This may lead to temporary overcrowding but would permit the cutting-out of the trees on SO in a few years time, when they are expected to become CTV-affected, and their tolerant replacements are already beginning to bear.

Future changes in nursery practice

The conversion of the Belize citrus industry during the past 5 years from the predominant use of SO to CTV-tolerant rootstocks, a period during which the citrus area has approximately tripled, will provide a sound basis for recovery from the impact of the rapid decline CTV which must affect the mature acreage once *T. citricidus* becomes established. However, this change has been made with very little reference to various other citrus diseases, notably exocortis, psorosis and blight, which are known to be present in Belize. All of the CTV-tolerant rootstocks are susceptible (often highly susceptible) to one or more of these virus or virus-like diseases (and to *Phytophthora* diseases) in a way that the traditional SO is not. Almost all budwood used in the recent expansion has been taken from selected trees on SO so that the presence of these other diseases would have been masked. We are already aware of exocortis problems in some groves under 5 years old and we are therefore fearful that a substantial proportion of the newly-planted area is at serious risk. We have recently acquired apparatus for detecting blight, exocortis and psorosis and, in conjunction with biological indexing in the screenhouse, will be assessing the extent of such infections in the field.

This technology will also permit the introduction of programmes for budwood certification and the registration of citrus nursery operators, adapted from the model used in California. The requisite legislation is scheduled for enactment and implementation in 1994. The sale of nursery stock would be restricted to approved nursery operators who would be obliged to register their budwood source trees and have them frequently indexed or to use budwood approved (and provided?) by the Research Department of the Growers' Association. In this way, all new plantings should be free from any of the known virus and virus-like diseases and be free from CTV unless the deliberate introduction of cross-protecting mild strains becomes accepted policy. It is expected that the onus for the day-to-day policing of the new regulations will be the responsibility of the growers and the industry at large, backed by national laws.

In the meantime, budwood trees or their primary sources are being screened wherever possible against these diseases. In addition, selected budwood lines, chosen on the basis of their proven yield and

adaptation to the Belize environment, are being cleaned of all known diseases by shoot-tip meristem thermotherapy in USA and these, on their return, will be used to establish elite foundation stock from which budwood sources will be rapidly multiplied. It is hoped that these strategies will ensure the long-term viability of the Belize citrus industry after the threatened losses from CTV have run their course.

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CASO ESTUDIO: VIRUS DE LA TRISTEZA DE LOS CITRICOS Y SU AGENTE VECTOR EN LA REPUBLICA DOMINICANA

J C Borbón and A J Abud
Junta Agroempresarial Dominicana, Republica Dominicana

Case study: CTV and its vector in the Dominican Republic

In the Dominican Republic, severe and mild strains of citrus tristeza virus (CTV) were detected by ELISA in 15% of the 200 samples analysed in a survey conducted in 1992. These samples came from the main citrus growing regions – south and east. The southern region had the higher percentage of infected citrus fields (86%). In 1993, preliminary results from an epidemiological study indicated the prevalance of mild strains of CTV. *T. citricidus* was found to be distributed island-wide (including Haiti).

En la República Dominicana, raza severa y benigna del Virus de la Tristeza de los Cítricos (VTC) fue detectado mediante los análisis de ELISA en un 15% de un total de 200 muestras, resultado del sondeo realizado en 1992. La muestras analizadas procedieron de las principales regiones productoras del cítricos del país: Sur y Este. La región sur representó ser la más afectada con un 86% de las muestras positivas. En 1993, resultados preliminares del estudio epidemiológico del VTC y su vector, muestra la prevalencia de raza benigna del virus de la Tristeza. La distribución del *T. citricidus* es generalizada en todo el país incluyendo Haiti

Hoy, el crecimiento vertiginoso que ha experimentado la industria citrícola de la República Dominicana, se manifiesta en el paso de simple productor de cítricos (*Citrus sinensis* L.) en plantaciones silvestres a gran productor industrializador y exportador de frutas frescas y sus derivados. La producción nacional de citrícos esta destinada en un 25% y 60% para el mercado internacional y local respectivamente como frutas frescas y el restante 15% para el procesamiento de las frutas. Las industrias procesadora están ubicadas en la ciudad capital (Santo Domingo), Villa Altagracia y en la Provincia de Hato Mayor.

En la actualidad existen más de 10,000 ha de cítricos en producción con una edad promedio de 6–7 años, la mayoria de las cuales distribuidas en las regiones sur y este del país, concentradas en más de 20 proyectos comerciales. Estos proyectos están ubicados en las localidades de Hato Mayor, La Romana, Higuey, San Cristóbal, Villa Altagracia, Cotuí, Baní y Barahona. Estas regiones han demostrado ofrecer las condiciones climáticas, de suelo y de localización óptima para el desarrollo de cultivo de cítricos y el establecimiento de plantas procesadoras de jugos concentrados.

Los factores fitosanitarios que tradicionalmente han afectado la citricultura dominicana son *Diaprepes abbreviatus*, *Phyllocoptruta oleivora*, *Toxoptera citricidus*, *Aphis spiraecola*, Mancha grasienta (*Mycosphaerella citri*), Gomosis (*Phytophthora* sp.), Antracnosis (*Colletotrichum gloeosporoides*), recientemente 'Post-blossom fruit drop' (*Colletotrichum* sp.), enfermedades causadas por Bacteria, Nematodos y Virus, específicamente el Virus de la Tristeza de los Cítricos (VTC).

Antecedentes

Tradicionalmente los citricultores han utilizado la naranja agria (*Citrus aurantium* L.) como patrón o porta injerto, que en ocasiones llegó a representar más del 90% en las plantaciones. Entre las razones de su extensivo uso se señala la resistencia a enfermedades, los altos rendimientos por superficies sembrada y la calidad de los frutos. Sin embargo, los citricultores

dominicanos han ido sustituyendo este patrón susceptible al VTC por otros con buenos rendimientos y mayor tolerancia al mismo; asi encontramos que actualmente tenemos aproximadamente entre un 70-75% de variedades de naranja sobre patrones agrio.

En cuestionamiento sobre la presencia del VTC en la República Dominicana se inicia concret-amente en 1990, cuando R Lee presenta un informe técnico a la actual Junta Agroempresarial Dominicana (JAD). Recientemente, se ha reportado la presencia de *Toxoptera citricidus* Kirkaldy (Homoptera: Aphididae) en plantaciones comerciales y no comerciales de cítricos. Sin embargo, no han causado efectos negativos en la producción citrícola dominicana por corresponder, aparentemente, a una raza benigna del virus que causa la misma, e incidir en plantas injertadas sobre patrones tolerantes.

En julio-septiembre de 1992, se conduce el trabajo de sondeo con el propósito de conocer la presencia y distribución geográfica del VTC y su agente vector *T. citricidus*, mediante muestreos realizados en las zonas más importantes de producción de cítricos, así como en plantaciones a pequeña escala y plantas ubicadas en residencias. Luego ese mismo año S M.Garnsey, T R Gottwald y J C Borbón establecen un estudio epidemiológico del VTC y su vector *T. citricidus*, en las localidades de Villa Altagracia, Bayaguana y Hato Mayor.

Situacion actual

En resultados obtenidos fruto del sondeo realizado en las principales zonas productoras del pais en 1992, muestran la presencia de ambas razas del VTC. Las determinaciones fueron realizadas mediante la prueba de ELISA, y basado en la reacción positiva del proceso monoclonal MCA13 para la raza severa y 1052 para la raza benigna.

En estudio epidemiólogico más reciente establecido en las mismas zona productoras donde se realizó el sondeo de 1992, se ha detectado unicamente la raza no severa del VTC. Esta raza ha mostrado un incremento positivo en el primer año de evaluación (Figura 1). Para los análisis de estas muestras se han utilizado un mezcla de dos anticuerpos monoclonales procedentes de Taiwan, ambos de amplio espectro y en combinación puede detectar todas las razas. De igual manera se hizo uso del monoclonal MCA13 (Garnsey, Gottwald and Borbón 1992; no publicado).

No obstante los resultados positivos a raza viral severa en naranja producida sobre patrones agrio (Cuadro 1), no se han observado síntomas de declinamiento de estas plantas. Estas plantas aún permanecen en el campo y están en producción, se están observando para detectar cualquier síntoma de declinamiento. Esta situación nos permite pensar en la posibilidad de una protección cruzada natural, o en caso contrario una débil reacción del virus presente con los anticuerpos utilizados para su detección.

Para septiembre del 1992, *T. citricidus* está distribuido en las 18 provincias visitadas (Figura 2). Estas provincias representan las regiones: Sur, Sur-Oeste, Central, Nor-Central y Este del país. En la region Sur-Oeste que incluye las Provincias de Perdenales, Bahoruco e Indenpencia fue colectado el *T. citricidus*, estas localidades hacen frontera con la República de Haití. La presencia del *T. citricidus* ha sido detectada en altitud de más de 1,000 msnm, tal es el caso de las localidades Constanza, y Paraiso. La presencia del más eficiente vector del VTC, ha sido confirmada en todo el país. Recientemente se reportó en la vecina República de Haití (R Lee, comunicación personal). Conjuntamente con este áfido fueron encontrado depredores (Coleoptera:Coccinellidae), entre ellos al *Cycloneda sanguinea* asi como un Hymenoptero parásito correspondiente a la Familia Aphiididae del genero *Lysiphebus*. La presencia del *T. citricidus* he reportada tanto en plantaciones de cítricos establecidas y en producción, asi como en plantas individuales localizadas en residencias familiares. Su incidencia es variable.

Hasta el presente el VTC y *T. citricidus* no han tenido ningun impacto socio-económico en la industria citrícola de la República Dominicana. Los citricultores dominicanos, en su mayoria los grandes productores, están consciente del impato económico que esta enfermedad puede ocasionar en en sus

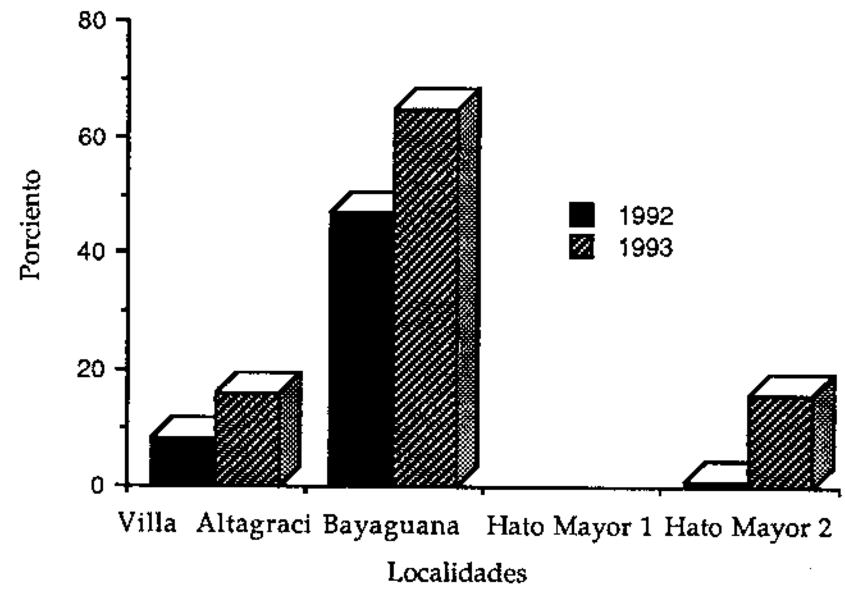

Figure 1. Distribución del VTC raza benigna en la República Dominicana

Fuente: Garnsey, Gotterald and Borbón (unpublished data)

plantaciones, de manera particular, y en la economia nacional en sentido general. Es por esto, que observamos en ellos la implementación de algunas medidas preventivas como la sustitución de patrones agrio por aquellos indicados como tolerantes al VTC.

Estrategia de manejo

- Programa de Certificación de Material Vegetativo. Entre las bondades que ofrecería el establecimiento de un programa de certificación, esta la de prevenir la introducción y distribución de enfermedades exóticas como razas severas de VTC. Además de la propagación de enfermedades causadas por patónes de suelo, como *Phytophthora* sp. y nematodos.

- Dado que en la actualidad esta enfermedad no constituye un serio problema en el país, es necesario fortalecer las medidas cuarentenarias tanto locales como de materiales procedentes de otros países. A nivel local se hace mandatorio evitar el tráfico de material propagativo de zona donde se ha detectado la enfermedad a zonas donde aún no se ha detectado o su incidencia es menor para evitar la propagación de la fuente de inóculo. Haciendo énfasis en la protección de las regiones Norte y Este.

- Evaluar constantement el material vegetativo (yemas) usado para detectar la posible presencia del VTC. Esto permitiría una erradicación a tiempo en caso que fuese positivo y se evitarií la diseminación del virus en las plantaciones.

- Cuando sea necesario sustituir plantas, independientemente la razón de la sustitución, usar plantas sobre patrones indicados como tolerante al VTC.

- Colateramente, promover la caracterización de las razas benignas detectadas en el país, con la finalidad de determinar su potencialidad en una protección cruzada natural o inducida.

Cuadro 1. Relación de la presencia de la Tristeza de los Cítricos en función de localidad, variedad, patrón edad, a septiembre del 1992 en la República Dominicana.

LOCALIDAD	VARIEDAD	PATRON	EDAD	CONDICION	CEPAS SEVERA	VIRALES MODERADA
V. Altagracia	Piña Florida	Mandarina	4 Años	Buena/Com.	MAC13	3DF1 + 3CA5
V. Altagracia	Piña Florida	Agrio	4 Años	Buena/Com.	MAC13	3DF1 + 3CA5
V. Altagracia	Piña Florida	Carrizo	4 Años	Buena/Com.	MAC13	3DF1 + 3CA5
V. Altagracia	Piña Florida	Carrizo	2 Años	Buena/Com.	MAC13	3DF1 + 3CA5
V. Altagracia	Piña Florida	Carrizo	4 Años	Buena/Com.	MAC13	3DF1 + 3CA5
V. Altagracia	Piña Florida	Carrizo	1 Año	Buena/Com.	MAC13	3DF1 + 3CA5
V. Altagracia	Piña Florida	Carrizo	2 Años	Buena/Com.	MAC13	3DF1 + 3CA5
V. Altagracia	Piña Florida	Agrio	4 Años	Buena/Com.	MAC13	3DF1 + 3CA5
V. Altagracia	Piña Florida	Carrizo	4 Años	Buena/Com.	MAC13	3DF1 + 3CA5
V. Altagracia	Piña Florida	Carrizo	3 Años	Buena/Com.		3DF1 + 3CA5
V. Altagracia	Piña Florida	Carrizo	4 Años	Buena/Com.		3DF1 + 3CA5
V. Altagracia	Valencia	Agrio	5 Años	Buena/Com.	MAC13	3DF1 + 3CA5
V. Altagracia	Valencia	Agrio	2 Años	Buena/Com.		3DF1 + 3CA5
V. Altagracia	Valencia	Agrio	6 Años	Buena/Com.	MAC13	3DF1 + 3CA5
V. Altagracia	Valencia	Agrio	5 Años	Buena/Com.	MAC13	3DF1 + 3CA5
V. Altagracia	Valencia	Agrio	4 Años	Buena/Com.	MAC13	3DF1 + 3CA5
San Cristóbal	Valencia	Agrio	1 Año	Buena/Com.		3DF1 + 3CA5
San Cristóbal	Valencia	Agrio	8 Años	Regular/Res.	MAC13	3DF1 + 3CA5
Higuey	Valencia	Agrio	8 Años	Buena/Com.		3DF1 + 3CA5
Higuey	Valencia	Agrio	3 Años	Buena/Com.	MAC13	3DF1 + 3CA5
Romana	Valencia	Agrio/Macr.	4 Años	Buena/Com.		3DF1 + 3CA5
Hato Mayor	Campbell	Agrio	3 Años	Buena/Com.	MCA13	
Azua	Valencia	Agrio	6 Año	Buena/Com.		3DF1 + 3CA5
Guerra	Valencia	Agrio ???	5 Años	Buena/Com.		3DF1 + 3CA5
Bayaguana	Valencia	Cleopatra	2 Años	Buena/Com.		3DF1 + 3CA5
Yamasa	Valencia	Agrio	?? Años	Buena/Com.		3DF1 + 3CA5
Yamasa	Valencia	Agrio	?? Años	Buena/Com.		3DF1 + 3CA5
Yamasa	Valencia	Agrio	3 Años	Buena/Com.		3DF1 + 3CA5
Dist. Nacional	Valencia	Agrio	3 Años	Buena/Res.		3DF1 + 3CA5

Com. = Comercial
Santo Domingo = Dist. Nacional
Guerra = Santo Domingo, Distrito Nacional
Bayaguana y Yamasá = Provincia Monte Plata
Villa Altagracia = Provincia San Cristóbal

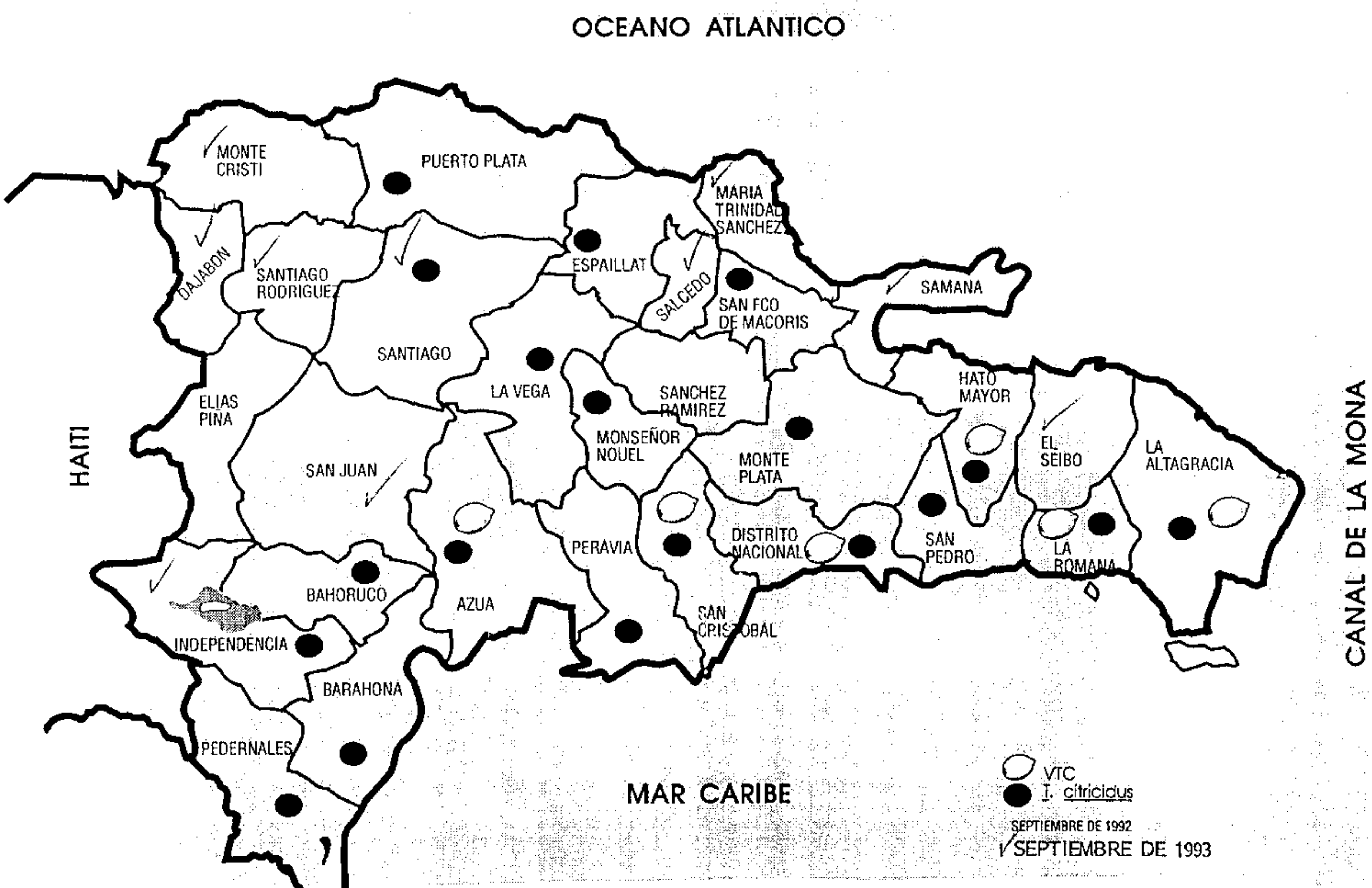

Figura 2. Relación de la presencia del virus tristeza de los cítricos (VTC) y su agente vector *Toxoptera citricidus* en la República Dominicana

- Establecer invernadero protegido con mallas, para conservar el material libre del VTC existente en el país. De manera tal, que en el eventual caso un establecimiento del VTC severo, no haya necesidad de importar material vegetativo libre del virus para su propagación en el país.

- Llevar a cabo un control racional del principal agente vector *T. citricidus* utilizando insecticidas específicos contra este áfido con tal de no afectar a sus biorreguladores; actividad ésta que debe ser incorporada a los Programas de Manejos Integrados de Plagas en cítricos.

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DISCUSSION: SESSION III

R Angeles (CESDA, Dominican Republic):
Correct diagnosis is crucial in all viral and mycoplasmal disease investigations. Lethal yellowing was diagnosed in the Dominican Republic on coconut some years ago, yet at present there is no widespread outbreak. There is need for care and caution in the diagnosis of CTV, especially in the identification of strains being severe or mild. Also, I would question whether cross protection exists in the Dominican Republic.

J Borbón (JAD, Dominican Republic):
I only made a mention of cross protection in the Dominican Republic; not a statement of confirmation. With respect to diagnosis, I agree that mistakes could be made but we have worked assiduously to confirm our findings.

P Stansly (University of Florida, USA):
The situation in Florida is not as good we had hoped. Twenty per cent of citrus is still on Sour Orange rootstocks and a loss of US$500 million is expected when *Toxoptera citrcidus* arrives in Florida as the severe strain of the virus already exists there. Is the Dominican Republic thinking of implementing a programme to certify budwood?

J Borbón:
One of the recommendations in my presentation was the establishment of a certification programme. Recent articles in the literature stress the importance of certification but no such programme exists in the Dominican Republic.

R Hall (NIHERST, Trinidad & Tobago):
With respect to the relatively low temperature optimum of *Verticillium lecanii,* I would like to stress that this only applies to the whitefly strains of the fungus and not to the aphid strains. *V. lecanii* has been found on aphids in Trinidad but there is difficulty in extrapolating from the whitefly strains to the aphid strains.

TECHNICAL SESSION IV

Chairman: Julio Borbón, *JAD, Dominican Republic*

Rapporteur: Denyse Johnston, *CARDI, Trinidad & Tobago*

STATUS OF ROOT WEEVILS ON CITRUS WITH SPECIFIC REFERENCE TO THE CARIBBEAN AND AN ANALYSIS OF THE IPM STRATEGY

D O Clarke and M M Alam
Caribbean Agricultural Research and Development Institute, Jamaica

Over 150 species of citrus root weevils have been reported occurring in the Caribbean. The problem of controlling pest species of the citrus root weevil complex has been tackled for decades. Cultural methods were virtually replaced by chemical control. The resulting problems of pest resistance and environmental contamination led to exploration of other control methods, with promising results. No unilateral approach can be expected to provide adequate control for these pests, therefore various components have to be systematically formulated into a usable and effective control strategy. To ensure implementation of any developed IPM strategy proper incentives and intensive dissemination programmes must be provided.

Citrus root weevils have been a major pest problem to citrus growers in the Caribbean and Florida for many decades. The species comprising the pest complex vary from one country to another but the nature of damage is the same. These weevils are polyphagous but show a distinct preference for *Citrus* species. Adult female weevils deposit eggs in between two leaves or in the fold of a single leaf and secure them with a vaginal adhesive. The larvae hatch, fall to the ground and burrow into the soil to the roots below. Young larvae feed on small roots and subsequent instars attack larger and larger roots until the main root system is attacked. Seedlings and young plants easily succumb to this attack while older trees may be resuscitated.

The control of these pests has been mainly chemical however adequate control has not been obtained due to the development of insect resistance to these chemicals and the rapid deterioration of the active ingredient. Also the ever-increasing concern for the deleterious effects of chemicals on the environment and mankind have intensified the need for a shift in emphasis or a more integrated approach.

Distribution of citrus root weevils (CRW) in the Caribbean

Over 150 species of CRW have been identified by various authors. These belong to seven genera from three subfamilies of Curculionidae (Watson 1971). Woodruff (1985) reported 159 species occuring in the the Caribbean: 76 *Exophthalmus*; 7 *Pachnaeus*; 19 *Diaprepes*; and 57 *Lachnopus*.

Watson (1971) reported eight species of CRW occuring in Jamaica, namely, *Exophthalmus vittatus, E. similis, E. farr, E. impressus, E. pulcher, E. viridipulpillatus, Pachnaeus citri* and *Lachnopus aurifer*. CRW were distributed island-wide with some species more widespread than others. *E. vittatus* was the most widely distributed being present in 11 parishes. Current investigations report only four species: *E. vittatus, E. similis, E. impressus* and *P. citri* (Clarke et al. 1990, unpublished report). For Cuba, Estrada (1979) identified eight species distributed thoughout the country. In the Leeward Islands, weevils of the genus *Diaprepes* have been recognized as the primary species of CRW affecting citrus but other weevil species occur. There are 23 root weevil species known to attack citrus in Martinique and Guadeloupe. The four most common species since 1973 were given by Mauleon and Marival (1986) as *Diaprepes abbreviatus, D. famelicus, D. marginatus* and *Litostylus pudens* (see Table 1).

Table 1. Distribution of some species of citrus root weevils in the Caribbean

Country	Species; Reference
Jamaica	*Pachnaeus citri*, *Lachnopus aurifer*, *Exophthalmus vittatus*, *E. similis*, *E. pulcher*, *E. viridipulpillatus*, *E. farr*; (Watson 1971)
Montserrat	*E. esuriens*; (Anon. 1914c)
Antigua & Barbuda	*E. esuriens*; (Anon. 1915a)
Dominica	*E.* sp.(nr. *esuriens*); (Anon. 1934) *D. abbreviatus*; (Briton-Jones 1928 and 1929; Rhodes 1991) *D. bolloui*; (Fennah 1942) *D. famelicus*; (Rhodes 1991) *E. famelicus*; (Ballou 1914)
St Kitts & Nevis	*E. esuriens*; (Anon 1915b)
Martinique	*D. abbeviatus*, *D. famelicus*, *Litostylus pudens*; (Mauleon and Marival 1986; Mauleon and Mademba-Sy 1988) *D. reticulatus*, *D. variegatus*, *Exophthalmus hemigrammus* *E. martinicensis*; (Mauleon and Mademba-Sy 1988) *D. hemmigrammus*; (Fennah194)
Guadeloupe	*D. abbeviatus*, *D. famelicus*, *D. marginatus* *Litostylus pudens*; (Mauleon and Marival 1986; Mauleon and Mademba-Sy 1988) *Compsus gentilis*, *C. lacteus*, *D. rufescens*, *Exophthalmus aurarius*, *E. dufaui*, *E. foveicollis*, *E. interuptus*, *E. marginicollis*, *E. marmoreus*, *E. vitraci*, *Lachnopus campechianus*, *L. curvipes*, *L. lineicollis*, *Litostylus leucocephalus* and *L. strangulatus*; (Mauleon and Mademba-Sy 1988)

Table 1. (continued) Distribution of some species of citrus root weevils in the Caribbean

Country	Species; Reference
Cuba	*Lachnopus hispidus*, *L. sparsinguttatus*, *L. splendidus*, *P. azurescens*, *Exophthalmus scalaris*;(Broche et al. 1991)
Puerto Rico	*D. abbreviatus*; (Fennah 1942)
Dominican Republic	*D. abbreviatus*; (FDA 1993)
Haiti	*D. abbreviatus*;(Fennah 1942)
St Lucia	*D. boxi*; (Fennah 1942)
St Vincent	*D. excavatus*; (Fennah 1942)
Barbados	*D. abbreviatus*; (Fennah 1942)

Status of citrus root weevils in the Caribbean

Damage to citrus by these pests in the Caribbean and Florida has been severe, costing citrus industries millions of dollars.

In Dominica, *Diaprepes* and *Exophthalmus* species were confirmed to be associated with widespread damage to lime orchards in 1928 (Briton-Jones 1928; 1929). In 1950, *Diaprepes abbreviatus* was reported to cause 50% reduction in output of citrus nurseries. *D. famelicus* is currently a serious pest of citrus plants during nursery propagation, *D. abbreviatus* also occurs but to a lesser extent (Rhodes 1991). Whitwell (1991) reported weevil infestation ranging from 3,000 to 10,000 adults/ha and 70,000 late instar larvae/ha from monthly monitoring. Losses in citrus nursery beds was put at US$30,000/ha.

D. abbreviatus is reported to be a major pest of citrus orchards and nurseries in Puerto Rico (Woodruff 1964). It also attacks other fruit trees, bananas, plantains, grasses, forest trees, starchy crops, vegetables and ornamentals. Martorell (1945) lists 41 host plant species for adult weevils. It is however primarily a problem on sugar cane and in 1977/78 was estimated to have caused $27.7 million in losses on 28,000 ha with 46% of the sugar cane infested.

Biggs-Allen (1990) estimated losses due to citrus weevils in Jamaica at approximately US$2 million. This estimate does not include losses due to reduced vitality of citrus trees. An island-wide survey, estimated a 20% loss of citrus plants under 2 years old and showed that plants 5–10 years old exhibited signs of reduced vitality when under heavy attack (A Mansingh, personal communication, 1985). van Whervin (1968) lists plants from over 25 genera which have been reported to be attacked by adult citrus root weevils.

In the French West Indies, *D. abbreviatus* was recently found infesting 500 ha of citrus in Guadeloupe and Martinique (Mauleon et al. 1989)

Control of citrus root weevils in the Caribbean

Chemical control

Chemical control has been by far the strategy the most often employed for control of root weevils in the Caribbean. Biggs-Allen (1990) lists over 30 chemical

formulations used in the Caribbean and Florida against these pests since the turn of the century. The list includes foliar sprays, used against eggs, neonate larvae and adults, and the soil drenches, granules and fumigants applied within the drip circle to the soil surface or incorporated into the soil, against larvae and emergent adults. The chemicals listed – organochlorines, except Vorlex®; organophosphates, except chlorpyrifos (Dursban® 10 G) and fenamiphos (Nemacur®); and carbamates except aldicarb – were generally reported to be moderately to very effective. Dieldrin was the most effective and popular soil insecticide used in the Caribbean.

In Jamaica, chemicals used include: carbon bisulphide, lime, Cyanogas® and bluestone, paradichlorobenzene (crude), Aldrin® E C, Chlordane® E C and dieldrin (Biggs-Allen 1990); malathion, Basudin® (diazinon), Sevin® (carbaryl), Primicid® (pirimiphos-ethyl), Mocap® (ethoprop) and Furadan® (carbofuran) (Clarke et al., 1992, unpublished report). The organochlorine pesticides listed by Biggs-Allen (1990) have been banned for varying reasons and pesticides currently in use have been perceived by farmers to be ineffective.

Some insecticides reportedly in use from other Caribbean countries include: dieldrin from Barbados (Woodruff, 1968); fensulfothion (Terracur®) and prothiophos (Tokuthion®) from Cuba (Mollineda et al. 1983); and Carbaryl Plus® from Puerto Rico (Wong et al. 1975).

It is now widely accepted that chemical control is not effective for long-term control and the problems of insect resistance, and rapid degradation of the active ingredient in the environment limit its effectiveness for short-term control. With the spiralling costs of pesticides the benefits of chemical control are increasingly being outweighed. New ways now have to be found to combat the problem (Mauleon and Mademba-Sy 1988; Biggs-Allen 1990).

Cultural control

The major cultural control practices for root weevils include baring the roots of soil thereby making them inaccessible to larvae, hand-picking of adults and egg masses from trees and destroying the collected weevils in kerosene baths. Root baring of citrus trees gave effective control of the pest in Jamaica (Anon. 1908). In Dominica, hand-picking, deep tillage and cover cropping of propagation stations between successive citrus crops were practised in the late 1920s.

Biological control

The diversity of natural enemies, both indigenous and exotic, has been documented by several authors. Biggs-Allen (1990) cites an extensive list (approximately 50 species of bacteria, fungi, nematodes, spiders, insects, reptiles, birds, and mammals) of those present in the English and Spanish-speaking West Indies and Florida, and gives a measure of the effectiveness of each species as a control agent.

The parasites have been widely researched in the Caribbean and Florida. The groups more popularly studied are the egg parasitoids and entomophagous nematodes.

Egg parasites

Hymenopteran egg parasites cited by Biggs-Allen (1990) as ocurring in the Caribbean and Florida were: *Brachyufens osborni*; *Fidiobia* sp.; *Tetrastichus haitiensis*; *T.* sp. nr. *marylandensis*, *T. ufens*; and *Ufens* sp. In addition Clarke et al. (1990) reported *A. gala*; *Eutetrastichus fennahi* and an unidentified eulophid occurring in Jamaica. The taxonomy of the English Tetrastichidae has been revised by Graham (1987); three species of *Tetrastichus* (viz. *T. gala*, *T. haitiensis*, and *T. marylandensis*) were placed in the genus *Aprostocetus*.

For the French West Indies, Etienne et al. (1990) reported five species of primary egg parasites attacking *D. abbreviatus*. – Eulophidae: *Aprostocetus gala*, *A. haitiensis* and *Aprostocetus* sp. and Trichogrammatidae: *Ceratogramma etiennei*, in Guadeloupe; and in Martinique, Eulophidae: *Eutetrastichus fennahi* A sixth species, Platygastridae: *Fidiobia citri* was observed but its host is not clear. Etienne et al. (1990) cites an additional four species present throughout the rest of the Caribbean and Florida attacking citrus root weevils – Eulophidae: *Pediobius*

irregularis, Mymaridae: *Cleruchus* sp., Trichogrammatidae: *Brachyufens osborni; Trichogramma* n. sp. The egg parasite cited as the most widely distributed is *A. haitiensis* present in seven Caribbean territories and Florida. These parasitoids have been reported to inflict appreciable mortality among root weevil species; Wolcott (1929) reported 50% parastism of *Exophthalmus quadrivittatus* eggs by *Tetrastichus haitiensis* in Haiti.

Bennett (1976 unpublished) reported 50% egg masses of *Exophthalmus* and *Pachnaeus* species, collected in Jamaica were parasitised by *T. haitiensis* and *Fidiobia citri*; More recent reports are just as encouraging for the use of these insects in control strategies against these pests. Field monitoring on two Jamaican citrus plantations showed 71 and 94% parasitism respectively of the total number of egg masses collected. Assessment of the impact of field releases of egg parasites on field parasitism rates showed higher rates of parasitism in areas where releases were carried out (Clarke et al. 1993, in press).

van Whervin (1968) cites Bennett (1965, unpublished report) as the first record of *T. marylandensis* in Jamaica. Etienne et al. (1990) do not however include this species in the list of egg parasites for the Caribbean region. There has been controversy as to whether this species is a parasite or a predator as its eggs are laid among host eggs and its larvae feed externally on more than one host egg (van Whervin 1968). Also in question is the nature of parasites of the genus *Horismenus*. These are suspected to be hyper-parasites (Fennah 1941; Schauff 1987).

Entomogenous nematodes

Entomogenous nematodes affect a wide range of soil-dwelling insect species (Poinar 1971; Georgis and Poinar 1989). In the Caribbean and Florida much work has been done to assess the potential of these nematodes to control root weevil species. In Florida, two species, *Steinernema feltiae* Filipjev (*Neoaplectana carpocapsae* Weiser) and *Heterorhabditis bacteriophora* Poinar have been found to infect citrus root weevil larvae (Beavers et al. 1982; Schroeder 1987). Commercial formulations of these nematodes are being manufactured by Biosys, Palo Alto, California. Field experiments conducted by Schroeder (1987) showed a total reduction in adult weevil emergence of 50% compared to controls.

In Puerto Rico, Roman and Figueroa (1985) reported effective control of *D. abbreviatus* by *Steinernema feltiae* (= *Neoaplectana carpocapsae*). Gonzales (1986) also reported control of this pest with *Heterorhabditis bacteriophora* and *H. heliothidis*. Local strains of nematodes are now being evaluated. Trials are also being conducted on other soil-dwelling weevils. *S. feltiae* and *S. bibionis* gave successful results with *Cosmopolites sordidus* (Figueroa 1990). *S. feltiae* and *H. heliothidis* are being tested against *Cylas formicarius* (Cruz and Segarra 1991).

In Guadeloupe, nursery trials, against *D. abbreviatus* gave a maximum of 94.5% grub mortality with *Heterorhabditis* (Mauleon et al. 1989).

In Dominica, laboratory tests with *N. carpocapsae* against *D. famelicus* gave up to 84% mortality of neonates and 78% mortality of two-week-old larvae. In the absence of host larvae infectivity of nematodes remained high – up to 10 days in soil (Rhodes 1991).

Epizootic organisms

Entomopathogenic fungi *Beauveria bassiana* and *Metarrhizium anisopliae* are much researched in biological control of root weevils. They have been found to be ideal because of their prolific nature and ease of application. In the Caribbean and Florida these have given promising results against different species of these pests.

In Cuba, a survey of citrus plantations reported the occurence of these fungi at various locations island-wide, attacking adult, pupal and larval stages (Montes and Broche 1975; Montes 1979; Perez 1985; Montejo et al. 1986; Broche et al. 1991). The species attacked by *B. bassiana* were *Pachnaeus litus*, *P. azurescens Lachnopus splendidus*, *L. sparsinguttatus*, *L. hispidus*, and *Exophthalmus scalaris*. *M. anisopliae* was only found attacking *Pachnaeus* spp. and *L. hispidus* (Broche et al. 1991). Application trials of *M. anisopliae* have resulted in up 99% mortality of neonate

larvae of *Pachnaeus litus* in soil (Montes and Montejo 1991).

Mass production techniques for culturing these fungi are being developed and advances are being made in the use of industrial by-products of the sugar cane and rice industries as rearing media (Calderon et al. 1991; FDA 1993).

Predators

Biggs-Allen (1990) also lists various species of predators of root weevils in the Caribbean and Florida, inclusive of ants, beetles, mites, reptiles, birds and mammals.

In the French West Indies namely, Guadeloupe, Les Saintes, La Desirade and Martinique Jaffe et al. (1991) list 21 species from four subfamilies of Formicidae attacking eggs, neonates and newly emerged adults of *Diaprepes abbreviatus*.

Whitcomb et al. (1982) lists nine species of ants attacking *Diaprepes abbreviatus* in Florida. Predation rate studies showed that 47% neonate larvae were removed by predators (predominantly ants) after 20 minutes. Other predators were spiders and earwig juveniles.

Integrated pest management of citrus root weevils in the Caribbean

IPM incorporates various compatible control technologies into the management system of a pest. Bottrell (1979) gives the five fundamental principles of true IPM systems as: (i) the population of the pest species will be maintained at tolerable levels, not eradicated; (ii) the entire ecosystem is the management unit, not just the pest; (iii) an interdisciplinary systems approach is essential; (iv) undesirable unpredicted effects are likely therefore the system must be monitored; (v) the use of biological control agents is maximized.

The repertoire of historical and contemporary methods for controlling citrus root weevils includes all aspects of integrated control. Historically, some forms of integrated management were (advertently or inadvertently) used which resulted in effective short-term control. In Dominica, handpicking, deep tillage and cover cropping of propagation stations between successive citrus crops and incorporating a fumigant into the soil were the control methods employed in the late 1920s and this system was credited with the reduction in the levels of infestation in subsequent years, 1931–1939 (Whitwell 1991). Other similar examples could be found in the region, as often combinations of control strategies cited in the above review have been used in individual territories. However, the heavy reliance on chemical control in most cases superceded the effects of other forms of control, especially biological control.

Goodell (1984) states that for IPM, farmers need to have more fine-tuned management practices – determination of action thresholds, regular monitoring of pest populations to predict surges and timed pesticide applications, and use of selective chemicals to protect natural enemies. When viewed in a the Third World context this may be seen by farmers as laborious and expensive. To ensure implementation of IPM strategies, exceptional incentives and intensive training are suggested. The shared responsibilities of research (to refine the IPM formula) and extension (to disseminate information) are also emphasized. Parasram and Rai (1980) implored the need for the implementation of technological transfer projects to follow development projects. This approach would facilitate easy adoption and implementation of new control strategies for insect pests. These recommendations are relevant to the implementation of effective integrated management of CRW in the region.

Biggs-Allen (1990) proposed that the integrated approach to citrus root weevil control should include investigations on trap crops and alternate hosts, biological control of eggs and adults and soil treatment (with chemicals and entomogenous nematodes). Numerous recent research projects, completed and current, involve investigations on methods of control previously neglected and some new options. In many cases the results are promising and sould be included in the IPM model (see Figure 1). Scientists have over the years paid lip service to such an inter-disciplinary approach to pest management

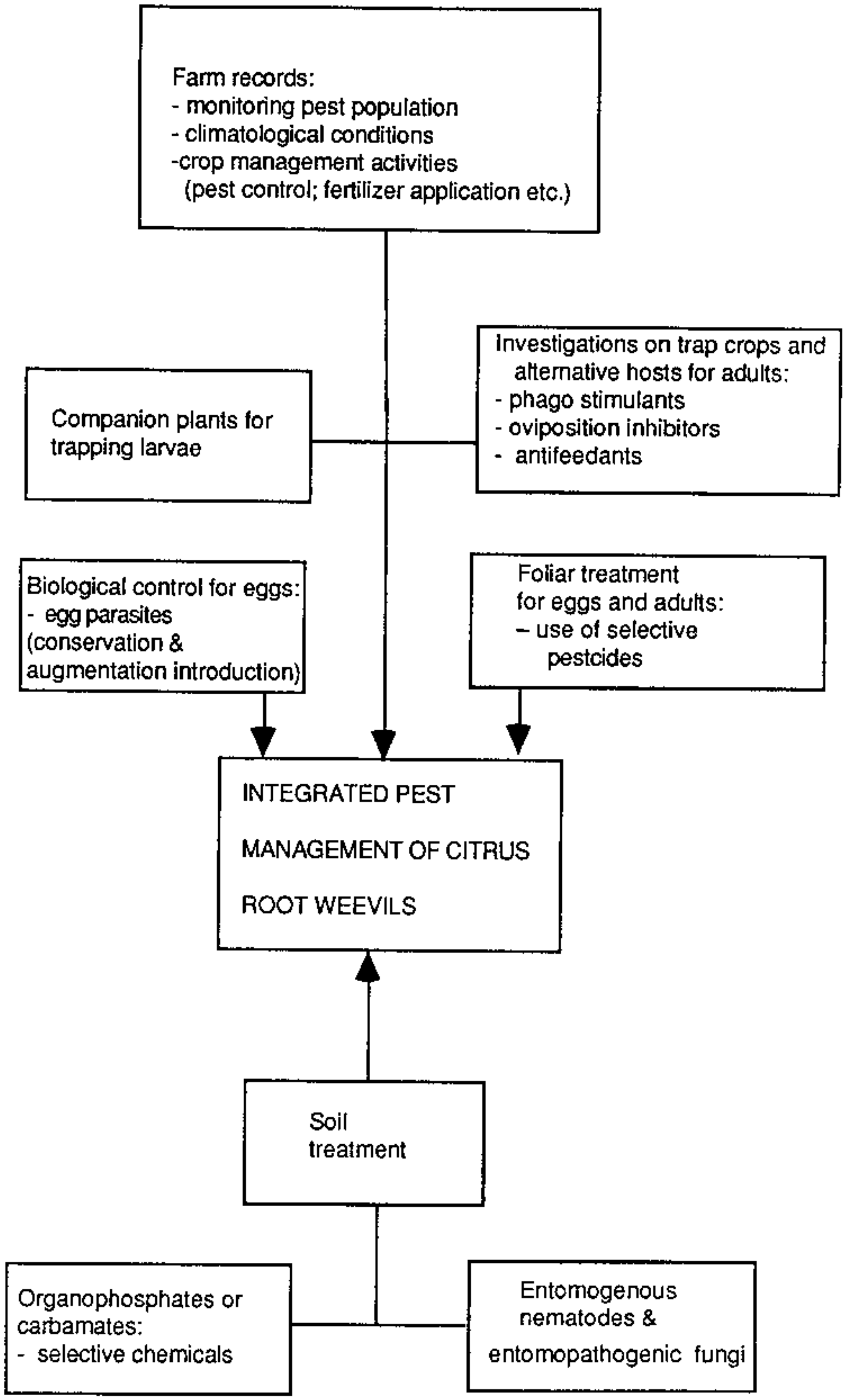

Figure 1. Recommendations for integrated pest management of citrus root weevil. (Revised and adapted from Biggs-Allen 1990.)

but have most often fallen short of implementing any process whereby this may be acheived.

A systematic approach to designing a pertinent and sustainable IPM system requires background information on the production systems on citrus farms. Citrus production systems are a complex of multiple pest and other biotic systems, management style, and maintenance systems (pest control, fertilizer application etc.). All these systems interact and should complement each other for optimal results. Farm records need to be so structured that they become a reliable database. Such data would facilitate more accurate cost benefit analyses, would elucidate constraints, and provide a basis for appropriate decisions on type and timing of action.

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REPRODUCCION MASIVA DE *TETRASTICHUS HAITIENSIS*, GAHAN (HYMENOPTERA: EULOPHIDAE) PARA EL CONTROL DE *DIAPREPES ABBREVIATUS* L.

O C Jiménez

Regional Este, Progama Manejo Integrado de Plagas, República Dominicana

A Díaz

Consorcio Citrícola del Este, República Dominicana

Mass reproduction of *Tetrastichus haitiensis* for the control of *Diaprepes abbreviatus* L.

In May 1992, populations of *T. haitiensis*, *T. gala* and *T. ferani* in citrus plantations of the Consorcio Citrícola del Este were found to be controlling the egg (embryonic) stage of *D. abbreviatus*. Methods for mass reproduction of *T. haitiensis* were developed using *D. abbreviatus* eggs as a medium for multiplication. It was found that the leaves used for the oviposition had to be treated with fungicides to control fungus, and be disinfected with 5% formalin for 3 minutes to control predatory mites. The yield from the mass production of *T. haitiensis* depended on the quantity of *D. abbreviatus* eggs obtained by manual collection and the manner in which the insect was treated at the moment of its capture. In Field 1 (15 ha) there was a low level of parasitism, and after seven consecutive releases of 3,000 adults of *T. haitiensis*, the population of *D. abbreviatus* was considerably reduced. In Field 2 (46 ha) and a constant high level of *D. abbreviatus*, the result of inverse correlation analysis between *T. haitiensis* and *D. abbreviatus* was 24.91% at the end of 10 months, following releases of 2,500 parasites every 20 days. The population level of *D. abbreviatus* was reduced with releases of *T. haitiensis* in fields with low populations of parasites. Regular releases made between May 1992 and October 1993 significantly reduced the population of *D. abbreviatus* .

En mayo de 1992 se determinó la presencia de *T. haitiensis, T. gala* y *T. fehani* en plantaciones de citricos del Consorcio Citrícola del Este, controlando el estado de huevo de *D. abbreviatuss*. Las identificaciones fueron realizadas por el Dr H Brawning, de la Universidad de Florida, EE. UU. Se desarrollaron observaciones sobre la reproducción masiva de *T. haitiensis*, utilizando huevos de *D. abbreviatuss* como medio de multiplicación. Se determinó que las hojas utilizadas para la oviposición deben tratarse con fungicidas para control de hongos y desinfectarlas con formol al 5% durante 3 minutos, para controlar los acaros predactores. Se observó que el rendimiento de la producción masiva de *T. haitiensis* depende de la cantidad de masas de huevos de *D. abbrebiatus* obtenidos mediante recolección manual y la forma en que se maneje el insecto al momento de su captura. El Campo 1, con una extensión de 238 tareas, tenía un bajo nivel de parasitismo, y después de siete liberaciones consecutivas de 3,000 individuos de *T. haitiensis*. Después de las liberaciones, la población de *D. abbreviatuss* se redujo considerablemente. En el Campo 2, con una extensión de 731 tareas y un nivel elevado y constante de *D. abbrebiatus* el resultado de los análisis de correlación entre el *T. haitiensis* y el *D. abbrebiatus* fue 24.91%, luego de reali2ar liberaciones de 2,500 parásitos cada 20 días. El nivel poblacional de *D. abbrebiatus* se reduce realizando liberaciones de *T. haitiensis* en los campos de baja poblaciones de parásitos. Se observó que liberaciones ligeras realizadas entre mayo 1992 y octubre 1993 redujeron la población de *D. abbrebiatus* en 189,991 individuos.

En la Región Este de la República Dominicana se cultivan 120,560 tareas de cítricos, propiedad de 423 productores. La provincia de Hato Mayor concentra 95,521 tareas, equivalentes a 79% del área total de la región, pertenecientes a 260 productores, equivalentes a 61% del total de productores de citricos de la región, según encuesta sobre citricos realizada por el Programa de Manejo Integrado de Plagas (MIP).

D. abbreviatus es la principal plaga de los cítricos en la República Dominicana, pues provoca pérdidas que van desde la destrucción total de una plantación, caso en San Juan de la Maguana, hasta la realización constante de resiembras para reponer plantas destruidas por esta plaga en la mayoría de las plantaciones de cítricos. La encuesta realizada por el MIP reveló que el Central Romana eliminó 190 tareas de cítricos y se apresta a quitar otras 120 tareas que han sido afectadas por *D. abbreviatus* .

El Consorcio Citrícola del Este inició el control de esta plaga con prácticas manuales de control, registrando las recolecciones a partir del año 1990. En mayo de 1992 se determinó la presencia de*T. haitiensis*, *T. gala* y *T. fehani* es este Consorcio, controlando *D. abbreviatus* en su estado de huevo. Las identificaciones fueron realizadas por el Dr H.Browning, de la Universidad de Florida, EE.UU. Dado que se producía un incremento anual de los niveles de población de *D. abbreviatus*, se procedió a evaluar el *T. haitiensis* realizándose varias liberaciones a partir de mayo de 1992, conforme se avanzaba en definir la metodología de multiplicación de *T. haitiensis*. Bearvers y Shelhime (1975) auguraban grandes perpectivas en *T. haitiensis* para los programas de control biológico. En 1993 se logró una producción libre de contaminación, precediéndose a desarrollar los estudios que se exponen en este trabajo.

Materiales y métodos

Los *D. abbreviatus*, colectados en el programa de recolección manual del Consorcio Citrícola del Este se utilizaron para la obtención de posturas en masas de huevos que serian utilizadas en la reproducción de *T. haitiensis*. Para tales fines, se introdujeron en naves para posturas de masas de huevos, construidas en madera y tela metálica, con dimensiones de 304 cm de largo, 120 cm de ancho y 180 cm de alto.

Dentro de las naves de posturas se colocaron plantas de vivero de *Citrus sinensis* L. para alimentar los insectos, y prolongar su ciclo de vida en cautiverio.

Para las posturas de masas de huevos se identificó follaje de plantas determinadas como hospederas, como son el piñon cubano *Jatropha multiflda* L., el Jobo *Spondias mombin* L. y la gina *Inga laurina* Willd, escogiéndose finalmente el follaje de jobo (*S. mombin*) para la postura definitiva.

Para evitar el crecimiento de hongos en el follaje se procedió a desinfectarlo, sumergiéndolo en solución de fungicida cuprico a razón de 2 libras/22 galones de agua.

Las ramas que se introducian a las naves de posturas, fueron utilizadas por el *D. abbreviatus* para ovipositar, uniendo dos hojas, depositando masas que iban desde 20 hasta 125 huevos cada una.

La recolección de las masas se realizaba a las 24 horas, notándose que los insectos ovipositaban durante todo el día. Una vez las masas eran colectadas se procedía a desinfectarlas con formol a 5%, durante 3 minutos, práctica ésta utilizada por el Dr Hassan para desinfectar huevos de *Sitotroga cerealella* Oliv. en la reproducción de *Trichograma* sp.).

Las masas de huevos fueron introducidas en cámaras de parasitación de 40 cm de largo, ancho y alto, respectivamente, inmediatamente después de su desinfección. En los laterales y la parte superior de las cámaras se utilizó de mica transparente, mientras que para la parte delantera, la posterior y el piso se usó madera. En el fondo de la parte interior se hicieron divisiones con tela metálicas para colocar las masas y facilitar la movilidad de los parásitos.

Los parásitos fueron introducidos en las cámaras de parasitación a razón de 100 parásitos/20 masas de huevos. Las masas de huevos se sustituían diariamente por

nuevas posturas que se cosechadas también a diario. Las posturas parasitadas eran colocadas en tubos de emergencia, que consistían de tubos cilíndricos transparentes, con facilidades para la aireación en ambos extremos y protegidos con telas de nylon para evitar el escape de parásitos. En estos tubos transcurrieron todo el ciclo, hasta la emergencia de los parásitos en su estado adulto, observándose las conclusiones a que llegaron González y Estradas (1981) en sus estudios sobre la biologia de *T. haitiensis.*

Cuando los adultos emergian se trasladaban a la nave de salida, construida de madera y dotada con una tapa en su parte superior para la introducción de los tubos, de cierres herméticos y color oscuro en todos los extremos, con lo que se facilitaba a los parásitos la búsqueda de luz. La nave tenía, además, tres orificios en uno de los frentes, en los cuales se colocaban tubos transparentes, tapados con tela osura en el extremo opuesto. Este lado de la nave era colocada de frente a la iluminación, siendo colectados los *T haitiensis* con facilidad en los tubos transparentes debido al fototropismo positivo que presentan estos insectos.

Luego de colectar todos los adultos que emergían durante el día, se procedía a introducirlos en la cámara de parasitación, o se liberaban en el campo programado para tal fin.

Los campos donde se realizaron las liberaciones fueron seleccionados con base en un estudio de parasitismo que permitió la búsqueda de masas de huevos en 30 árboles/campos, seleccionando las plantas al azar. En cada árbol se buscaron todas las masas posibles, en un período de un minuto/planta. Las masas colectadas, fueron rotuladas y evaluadas diariamente, contandose el número de masas de huevos, las larvas de *D. abbreviatus* y los parásitos emergidos. La toma de muestras se hizo cada 15 días.

Para evitar consanguinidad estrecha se procedió a mezclar los parásitos de reproducción matriz con los que emergían del estudio de parasitismo en cada campo. También, se buscaban masas parasitadas procedentes de zonas distantes.

Para evaluar la efectividad de *T. haitiensis* se tomaron tres campos con dimensiones diferentes y con niveles de parasitismo muy bajo. El Campo 1 con 238 tareas, el Campo 2 con 731 tareas, y el testigo o Campo 3 con 214 tareas.

En el Campo 1 se realizaron evaluaciones desde julio hasta noviembre de 1993. Se realizaron siete liberaciones consecutivas de 3,000 *T. haitiensis* en la última quincena de agosto.

En el Campo 2, durante el período marzo-julio se hicieron muestreos para evaluar los niveles de parásitos y plagas. Se hicieron cinco liberaciones cada 20 días de *T. haitiensis* a razón de 2,500 individuos por liberación.

Para determinar la efectividad de *T. haitiensis* sobre la plaga, se utilizó el Campo 3 como testigo. En este campo se realizaron evaluaciones cada 15 días, desde julio hasta principios de noviembre.

Para comprobar si las masas que se desprendían estaban parasitadas por el *T. haitiensis,* se tomaron 10 masas y se introdujeron en la cámara de parasitación, a temperatura promedio de 22 ^{o}C, durante 24 horas. Los adultos emergieron a los 17–18 días, observándose una gran movilidad de los parásitos. El procedimiento fue repetido sin que se observaran variaciones.

Resultados y discusion

En la búsqueda de medios para la oviposición de *D. abbreviatus* se pudo apreciar que el uso de las ramas de jobo *S. mombin,* con abundante follaje y debidamente desinfectadas, facilitaban la emergencia de una mayor cantidad de *T. haitiensis,.*

Se observó la coincidencia con las conclusiones de Gonzealez y Estradas con relación al ciclo biológico de *T. haitiensis,* que va de 12 a 13 días, a temperatura promedio de 27 ^{o}C y 80% de humedad relativa, con marcadas diferencias entre machos y hembras.

Se determinó que con liberaciones consecutivas durante 7 días de 3,000 *T.*

haitiensis, bien distribuidos en los meses de julio a noviembre, en el área de 238 tareas, se bajó drásticamente el nivel de plagas de *D. abbreviatus* a los 15 días después de las liberaciones, notándose que al principio ocurre un ligero aumento de la plaga y que posteriormente desciende nuevamente la población de *D. abbreviatus* en las demás evaluaciones.

Se determinó, además, que en los meses de marzo a julio, en un campo de 731 tareas con un nivel poblacional alto de la plaga *D. abbreviatus*, realizando liberaciones de 2,500 pareasitos cada 20 días, se obtuvieron resultados de análisis de correlación en el *T. haitiensis* y *D. abbreviatus* de un 21.91%, con una relación inversa parásitos-plaga.

En el campo testigo la población de la plaga *D. abbreviatus* se mantuvo constante y el nivel de parasitismo fue bajo.

Además, se observó que las masas de huevos de *D. abbreviatus* adheridas a una sola hoja (despegada) puede ser eficientemente parasitada por el *T. haitiensis* y obtener adultos sanos.

Pudo notarse que las hojas lisas son parasitadas con gran facilidad. Armstrong (1981) determinó una baja eficiencia en el parasitismo de *T. haitiensis* en caña de azúcar que se debe, probablemente a la dificultad que tiene el parásito de moverse en este tipo de hojas.

Se detectó una especie de ácaro blanco y un Trips negro con franja blanca entre el tórax y el abdomen, atacando pupas de *T. haitiensis*.

Se observó que el jobo, *Spondias mombin*, la gina, *Inga laurina*, y el pinñón cubano, *Jatropha multifida* son hospederos de *D. abbreviatus*, pues fueron encontrados huevos y adultos en el follaje, así como larvas en el sistema radicular.

Se registró que el crecimiento poblacional anual que se producia de *D. abbreviatus* desde 1990 hasta abril de 1993, se redujo en 189,991 individuos durante los meses de mayo a octubre de 1993 con relación al mismo período de 1992. Es importante destacar que durante el período enero-abril 1993, (cuando no se realizaron liberaciones en esa época del 1992), se produjo un incremento de 198,504 individuos de *D. abbreviatus*, con relación a igual período de 1992. Esto relaciona directamente la reducción registrada de mayo a octubre de 1993 con las ligeras liberaciones realizadas mientras se determinaba la metodología definitiva de producción masiva de *T. haitiensis*..

Sumario

T. haitiensis. es un efectivo biocontrolador de huevos de *D. abbreviatus*; su reproducción masiva puede ser efectiva si se dispone de suficiente cantidad de *D. abbreviatus*

La multiplicación de *T. haitiensis*. sugiere una buena desinfección de las hojas en las cuales deposita sus huevos el *D. abbreviatus* .

T. haitiensis. tiene un ciclo biológico de 12 a 13 días a temperatura promedio de 70 ^{o}C y humedad relativa 80%.

Con liberaciones de 3,000 parásitos diarios, durante 7 días consecutivos, previa determinación de bajo nivel de parasitismo y en un área de 238 tareas dedicadas al cultivo de citricos, al cabo de 15 días se logra bajar rápidamente el nivel de población de *D. abbreviatus* .

En campos de alto nivel de población de *D. abbreviatus* , y en un área de 731 tareas con liberaciones cada 20 días de 2,500 parásitos se producen resultados de análisis de correlación inversa entre el *T. haitiensis*. y *D. abbreviatus* de un 24.91%, al término de dos meses.

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THE STATUS OF PLANT QUARANTINE IN THE CARIBBEAN AND ITS ROLE IN INTEGRATED PEST MANAGEMENT WITH REFERENCE TO MOKO DISEASE IN GRENADA

G V Pollard

Food and Agriculture Organization of the United Nations, Trinidad & Tobago

Despite its long history in the Caribbean plant quarantine has been seriously neglected over the years. For example, more rapid air transport, containerization of cargo and present moves towards trade liberalization all require that legislation and subsidiary regulations be updated as necessary. FAO, through the International Plant Protection Convention, has a mandate to provide guidelines on plant quarantine matters. One of its more recent and urgent efforts concerns the definition of principles and guidelines for plant quarantine harmonization, including that of pest risk analysis. These are assuming increasing importance in the light of current global policies of increased trade liberalization. The primary step in any pest risk analysis. is to determine if a pest is of quarantine importance or not. Once this has been determined the pest has to be managed so as to minimize the risk to a country's agriculture. Since plant quarantine is often regarded as the first line of defence in a country's plant protection system it is therefore an integral part of any pest management strategy. It is widely accepted that an organism assumes pest status essentially because of some ecological imbalance, for example, through the introduction of exotic organisms into a new environment. Hence one may argue that an understanding of the ecological implications of pest introduction as a cause of potential pest outbreak is critical to develop any effective pest management strategy. One implication here is that such understanding is one basis for the development of efficient quarantine measures. The introduction of Moko disease in Grenada has been used to illustrate the importance of effective plant quarantine in managing a newly introduced pest species. Because of poor quarantine services in place at the time Moko disease was able to enter Grenada and become established to the point where it is now considered endemic to that country.

The fundamental basis of plant quarantine is to prevent the entry and establishment of exotic pest species into a country or new geographical area in order to safeguard local agriculture. To achieve this goal almost all countries have established laws and regulations. Such legislation is often within the framework of international conventions or inter-governmental agreements. The chief international organization providing guidelines on matters of plant quarantine is the Food and Agricultural Organization of the United Nations (FAO) through the International Plant Protection Convention (IPPC). Under the IPPC several Regional Plant Protection Organizations (RPPOs) have come into existence over the years representing various geographic groupings; for example the North American Plant Protection Organization (NAPPO) comprising Canada, USA and Mexico or the Inter-African Phytosanitary Council (IAPSC) with 48 members. In this region we have the Caribbean Plant Protection Commission (CPPC) with 18 members representing practically all the Caribbean island states as well as Suriname, Guyana, Venezuela and Colombia in South America; Costa Rica, Nicaragua and Panama in Central America; Mexico and the USA; in addition France, UK and the Netherlands represent their territories in the Caribbean.

Over the years FAO has initiated a number of activities to enhance the performance of plant quarantine activities in member countries. Two of the most important are efforts to harmonize legislation between countries and to develop agreed principles of pest risk analysis. While it may have seemed that harmonization of plant

quarantine legislation should have been relatively easy to implement, especially since FAO had published a general format or model for such legislation, even providing a model for regulations for possible use in the Caribbean (FAO 1983), this has not proved so easy to achieve. In the CPPC region, though, some countries have enacted new legislation based on these guidelines. What might be even more difficult is an agreement on principles and guidelines for pest risk analysis (PRA).

This paper is of two parts. Firstly the status of plant quarantine in the region is briefly reviewed; secondly I will consider the role of plant quarantine in integrated pest management (IPM) strategies using as a case study attempts to eradicate Moko disease of banana in Grenada.

Status of plant quarantine in the Caribbean

There has been a long history of plant quarantine activity in the Caribbean dating back over 100 years. In fact there was plant quarantine legislation with fairly comprehensive regulations in nearly every colony of the then British West Indies as early as the 1890s (Table 1). However, over the years there seemed to have been an indifference to plant quarantine development and advancement.

Pollard (1986) has described the status of plant quarantine in the English-speaking Caribbean highlighting a number of shortcomings at that time. Essentially these shortcomings relate to the existence of outdated and inadequate legislation and the lack of technical expertise. In an earlier assessment Brathwaite (1984) had also noted a general lack of personnel including untrained inspectors, as well as poor record keeping and a lack of physical facilities as important impediments to effective plant quarantine services in the sub-region. The reasons for such shortcomings are unclear.

With regard to legislation, for example, only Grenada, Dominica and St Lucia have enacted new legislation in the recent past based on FAO's guidelines (Table 2).

Table 1. Plant quarantine laws in existence in the British West Indies by the late nineteenth century.

Country	Legislation	Year
Jamaica	No. 4	1884
	No. 25	1891
Trinidad & Tobago	No. 8	1890
	No. 28	1894
Windward Islands		
Grenada	No. 14	1891
St Vincent	No. 19	1895
St Lucia	No. 5	1895
Leeward Islands		
Antigua	No. 4	1897
St Christopher & Nevis	No. 2	1897
Montserrat	No. 3	1897
Virgin Islands	No. 3	1897
Dominica	No. 3	1897

Source: Ballou (1910)

Table 2. Existing plant protection /quarantine legislation in the Caribbean. (Those countries highlighted have adopted FAO's guidelines).

Country	Legislation
Antigua & Barbuda	Plant Protection Act No. 14 of 1941
Barbados	Plant Pest and Disease (Eradication) Act No.6 of 1983
Belize	Plant Protection Act (Cap. 178) 1941 as amended in 1963
Dominica	**Plant Protection and Quarantine Act No. 10 of 1986**
French West Indies	Act No. 47-1347 of 1947
Grenada	**Plant Protection Act No. 10 of 1986**
Guyana	Plant Protection Act (1973)
Jamaica	Plant Protection Act (1925)
Montserrat	Act No. 11 of 1941
St Christopher & Nevis	Act No. 2 of 1923
St. Lucia	**Plant Protection Ord. No. 21 of 1988**
St Vincent & the Grenadines	Plant Protection Ord. No. 10 of 1941
Trinidad & Tobago	Plant Protection Ord. No. 8. of 1940

Sources: Lewis (1992); FAO (1993a)

Since the mid-1980s, however, there has been a very conscious effort by these countries to significantly improve their plant quarantine services. This has been achieved through the collaborative efforts of national governments and various regional and international agencies of which the Food and Agricultural Organization of the United Nations (FAO), the Inter-American Institute for Cooperation on Agriculture (IICA), The University of the West Indies (UWI) and the United States Department of Agriculture/Animal and Plant Health Inspection Service (USDA/APHIS) have all played major parts. More recently a FAO Technical Cooperation Programme (TCP/-RLA/2258) on harmonization of plant quarantine in CARICOM was completed. A comprehensive report has now been submitted in which is included a draft proposal for a project to improve plant quarantine services in the CARICOM region (FAO,1993b).

Plant quarantine activities

Since the essential role of any plant quarantine service is to safeguard its country's agriculture through active measures to keep out unwanted exotic pests, then it becomes imperative to be able to determine those pests which may pose such a quarantine risk. According to the IPPC a quarantine pest is defined as:'A pest of potential national economic importance to the country endangered thereby and not yet present there, or present but not yet widely distributed and being actively controlled'. While this definition has being widely

applied since its inception in the 1979 revised text of the IPPC, there have been some recent suggestions for modifications by NAPPO which however do not substantially change the substance of the definition but which attempt to clarify certain possible mis-interpretations of key terms (Phillips and Chandrashekar 1992).

Principles of plant quarantine harmonization and pest risk analysis

In order to assist in easier determination of pests of quarantine importance there have been recent attempts by the IPPC in association with RPPOs to develop workable guidelines and principles for PRA. This is part of the wider concern of harmonization of plant quarantine principles of which PRA is but one. These principles are contained in the paper 'Plant quarantine principles as related to international trade' (FAO 1991) which was developed after considerable discussions among RPPOs. One of the more important principles is that of risk analysis: '... To determine which pests are quarantine pests and the strength of measures to be taken against them, countries shall use pest risk analysis methods based on biological and economic evidence and, wherever possible, follow procedures developed within the framework of the IPPC' (FAO, 1991). More recently, guidelines for PRA have been developed by RPPOs and an FAO panel of experts (FAO 1993c). The European and Mediterranean Plant Protection Organization (EPPO) has also published guidelines on pest risk analysis for their member countries (OEPP/EPPO 1993a;1993b). Such guidelines as these, or others, as they become universally acceptable will greatly assist countries to more easily assess the risks associated with the introduction an any pest organism.

According to Smith (1989) the objectives of any pest risk analysis are: to justify placing a pest on a quarantine list; to screen for quarantine pests from a long list; and to ascertain whether an intercepted and identified pest should be regarded as a quarantine pest. These are all aimed at answering the question: is this pest a quarantine pest? These objectives, however, represent only Stage 1 of the FAO guidelines which is the initiation of the process (FAO 1993c).

In order to apply a PRA there are three major steps to be followed (FAO 1993c; Phillips and Chandrasheka, 1992); these include:

- initiation of the PRA process – the risk identification step (Is this a quarantine pest?)
- risk assessment to characterize the risk of entry and establishment – are the criteria for quarantine pest status satisfied?
- the risk management step – review risk of management options.

In resource-poor countries plant quarantine activities have usually focused on the third step in the PRA process, i.e. on management options like inspections and treatments. Decisions on what constitutes a quarantine pest and what is the risk posed should that pest be introduced into a country are often made on very skimpy information. Often a decision to ban a commodity is usually made because of the lack of hard data or alternatively a lack of defined criteria on which to make any other decision. As Smith (1989) has described: 'A risk assessment ... is in fact a screening of a large number of potentially risky pests, each of which is initially rather poorly known.' In the absence of any data, prohibition is always the safest, though not a nil-risk, option. A prohibition can in itself generate additional risks by serving to encourage illegal import to satisfy a need.

One example of this dilemma was highlighted when mango seed weevil (MSW), *Sternochetus mangiferae* (F.), was first reported in the Caribbean in 1986. There was a great deal of discussion as to whether this pest should be considered only one of quarantine significance or equally, a pest of economic importance. This confusion derived solely from the lack of relevant information in those countries which felt themselves at risk. The result was a widespread embargo on the importation of mangoes into some countries, even from those countries which had not reported the presence of this pest. As Hopper (1991) has expressed it:..'The determination of the potential of an exotic pest to cause crop losses is the preliminary

component in a pest risk assessment (PRA) process'. Hence, where that capability is deficient in any plant quarantine service decision-making will be severely restricted and be very cautionary in nature as was the case for MSW in the Caribbean.

Plant quarantine and integrated pest management

Plant quarantine is often referred to as the first line of defence in any plant protection system. Hence, this must be regarded as an intimate input to any integrated pest management (IPM) strategy. In fact, poor plant quarantine services will only exacerbate the problems confronting a management programme for a newly introduced pest species. Generally there are two broad objectives of plant quarantine. The first is to keep exotic pests out of a geographic area, be it a country or a part of a country which has remained free of the particular pest; the other is to ensure as far as possible that if an exotic pest were to enter a new area that active measures are taken to eradicate that pest. Both of these activities relate directly to any IPM programme. In the first case recognized inspection and treatment protocols attempt to keep pests out of those areas where they are not currently reported. Similarly, eradication of a newly introduced pest relies on a variety of standard chemical and non-chemical control measures utilized, at best, in some kind of integrated fashion for optimally effective results.

IPM has been variously defined since the idea was first conceptualized some 40 years ago by Stern et al. (1959). Essentially, all definitions recognize that any IPM strategy must take into account the utilization of suitable and compatible control techniques in order to keep the targeted pest population below levels where economic injury is caused. For example, though the following definition is specific for insect pest management it may serve equally well for integrated pest management, i.e. '... a pest management strategy that, in the socio-economic context of farming systems, the associated environment and the population dynamics of the pest species, utilizes all suitable techniques and methods in as compatible a manner as possible, and maintains the pest population levels below those causing economic injury' (Dent 1991).

In a sense IPM can also be regarded as ecological management of a pest species. An insect species, for example, assumes pest status because of changes in certain ecological factors affecting that species (Cherrett and Sagar 1977). Such factors may include a shift from natural ecosystems to monocultural agriculture, the introduction of new crop cultivars or species into new geographic areas, the introduction of exotic insect species into a new area, or the relationship of pest outbreaks to changing weather patterns. Other man-made interventions may also cause pest outbreaks, the chief of these being excessive use of chemical pesticides or non-resistant cultivars (Dent 1991). One may therefore argue that in order to control an insect pest an ecological approach should be implemented. Hence, an understanding of the ecological implications of pest introduction as a cause of potential pest outbreak is critical and emphasizes the importance of plant quarantine as a crucial component of any IPM strategy.

To illustrate the importance of effective plant quarantine in the management of a pest, the case of Moko disease of banana and plantain in Grenada will be used.

Moko disease in Grenada

Moko disease, caused by the bacterium *Pseudomonas solanacearum* (E F Smith) Race 2, is a devastating wilt disease affecting banana and plantain. It has been reported for the English-speaking Caribbean for over 150 years but distributed only in Guyana and Trinidad until 1978 when Grenada was reported as having this disease (Cronshaw and Edmunds 1980). Apart from these three countries, present distribution of Moko in the CPPC region includes Belize, Colombia, Costa Rica, Mexico, Nicaragua, Suriname, Venezuela (FAO/RLAC, 1989).

Bananas contribute significantly to the foreign exchange earnings of Grenada. In 1978 when Moko was first reported bananas were contributing approximately 30% of GDP in Grenada. For the period 1977–1982

Table 3. Chronological development and implementation of the eradication programme for Moko disease in Grenada, 1978–1984.

April 1978	Discovery of Moko disease
July 1978 – June 1980	Local ministry of agriculture funded programme
17 December 1979	FAO Project – TCP/GRN/8901 (M) – approved and signed on behalf of Director General, FAO
6 February 1980	Project document signed by Grenada government
16 July 1980	Commencement of project
31 July 1980	Completion of project
May – October 1981	Support of eradication programme by Grenada Banana Cooperative Society
1 November 1982	Commencement of project supported by the European Development Fund (EDF)
30 April 1984	Scheduled completion date for EDF-funded programme

Source: Pollard (1983)

there was a steady decline in exports from 14.5 million kg to just over 10 million kg. Whether this decline and the incidence of Moko disease were coincidental or whether there was a real causal relationship was not studied at the time. What should also be pointed out was the belief that Moko was present at least 2 or 3 years before it was first reported. Hence the decline which began in 1977 could have been due to the effects of the disease now being manifest.

On the discovery of Moko in Grenada various initiatives were put in place to attempt to eradicate this pest. These activities are listed in Table 3 (Pollard 1983). The cost of these programmes over the period July 1978 to June 1980 amounted to approximately EC$1.1 million or US$408,000, excluding direct inputs from the Ministry of Agriculture. The latter could not be easily ascertained at the time (Pollard 1983). While this was not insignificant funding for an early eradication programme, the intermittent nature of the various activities was a major constraint to any likely success of eradication. In addition, Ambrose (1982) discussed other important constraining factors; for example, the majority of banana farmers in Grenada at that time (67%) farmed 1.2 ha or less; 64% farmed on steep hillsides and only 8% had pure-stand banana.

According to Small (1982) experience has shown that the disease is most severe in smallholdings rather than in large plantations because of the lack of resources to conduct costly management programmes.

Management of Moko involves:

- regular surveys for diseased *Musa* plants
- eradication of diseased and buffer zone trees
- control of movement of diseased planting material

- replacement of most susceptible varieties (Small 1982).

In fact without early detection and timely destruction of diseased and buffer zone plants the success of any management programme for Moko is most unlikely, if not impossible. In considering management strategies for Moko control it is apparent that these are all activities associated with an internal quarantine programme, except for the replacement of susceptible varieties which may be regarded as a cultural control measure. However, the experience with Moko disease in Grenada has highlighted the consequences of poor plant quarantine services in the entry and spread of a major pest. Consider the following;

- Moko disease is known to be a pest of major quarantine significance.
- Trinidad has long been known as an infected area.
- There is major movement of people and produce between Grenada and Trinidad.
- Banana is extremely important to the economy of Grenada.

One would therefore have expected that quarantine personnel in Grenada would have been most vigilant in preventing entry of banana material into Grenada from Trinidad. However, even if entry could not have been prevented then, having detected the disease, no effort should have been spared to ensure eradication. This was not an impossible goal at the time since the infected area was determined to be limited to only 10 km^2 in the parish of St Patrick in the north of the island (Cronshaw and Edmunds 1980). But as Ambrose (1982) had indicated there were a number of factors which militated against a successful eradication programme and even though this author acknowledged that quarantine is an important feature in any Moko control programme, Brathwaite (1984) could still report 2 years later that plant quarantine services in Grenada were almost non-existent. The result is that today Moko disease is spread throughout the island except for the southernmost parishes of St Georges and St David (P Hunt, unpublished) and could probably be now considered endemic.

The economic impact of this disease to 1983, when there still was optimism that this disease could have been eradicated, was determined to be nearly EC$5.6 million or US$2.1 million, excluding costs resulting from activities of the Ministry of Agriculture (Pollard 1983). While there are no comprehensive data on the total economic impact of Moko disease since that earlier report losses have been substantial. At a recent seminar[1] the following data were presented (P Hunt, unpublished):

- total grants over the past 10 years have been over EC$10 million (over US$3.7 million), mostly from the European Development Fund (EDF) of the Lomé Convention
- annual field control costs since 1989 have been estimated at approximately EC$350,000 (US$130,597) and borne wholly by the Government of Grenada
- uncalculated quanta provided both by the government and the Windward Islands Banana Association (WINBAN) in support of the EEC programme, for compensation payment to farmers and for research
- support of the Grenada Banana Cooperative Society (GBCS) who provided field staff, some interim funding, administrative services for the EEC programme, cooperation of its extension staff
- in addition no account has been taken of actual financial losses suffered by individual farmers including the potential loss in foreign exchange resulting from fruit which could not be delivered.

This analysis attempts to underscore the importance of plant quarantine to the management of a newly introduced pest. In this case if there had been an effective

[1] Seminar on Control of Moko Disease, EEC/WINBAN Moko Research Project, 20 February. 1992, Grenada.

quarantine service in operation supported by an effective national monitoring service then maybe Moko disease would never have entered Grenada or, if introduced, then effective internal quarantine would have detected it sufficiently early to have implemented a successful eradication scheme. In fact, in hindsight, there should even have been an emergency action plan in place to deal with the eventuality of the introduction of Moko disease given its quarantine significance and the importance of bananas to the local economy.

Conclusions

The importance of plant quarantine and its long history in the region have been highlighted. However, apart from recent efforts on the part of national governments and various regional and international organizations, plant quarantine development for a long time has been seriously neglected in the region. despite recent efforts, only three countries in the region (Dominica, Grenada and St Lucia) have adopted new legislation based on FAO's model law. Also moves towards harmonization of plant quarantine legislation are still proceeding fairly slowly, notwithstanding the efforts of FAO. One other area of concern at the moment is the development of common mechanisms of pest risk analysis. Again there is international action within the IPPC Secretariat to develop these standardized procedures.

To highlight the importance of plant quarantine as part of any IPM strategy the attempted eradication of Moko disease in Grenada was described. What this study has suggested is that ineffective quarantine was largely responsible for subsequent establishment if not introduction of this disease. Additionally, had there been an emergency action plan in place and effective internal quarantine measures initiated immediately on first report of this dreaded disease, including strong enforcement of recommended cultural controls, then there would have been a good chance of eradicating it. However, 15 years later today Moko disease is in all likelihood endemic in Grenada.

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ECONOMICS OF PESTICIDE USE – A CASE STUDY ON BANANAS

C Pemberton and C Henderson-Brewster
The University of the West Indies, Trinidad & Tobago

This paper will discuss the economics of pesticide use in the context of the sustainability of agricultural production systems. There are two major concerns with respect to the sustainability of agricultural production practices. The first concern is the level of environmental degradation caused by the practices. Agricultural production practices will only be sustainable if any resultant degradation of natural resources is sufficiently small so that these natural resources maintain their intrinsic properties over time. Thus, for resource exploitation to be sustainable it must proceed so as to meet the developmental and environ-mental needs of the present and future generations.

The second concern is for the economic efficiency. Agricultural production practices will only be sustainable if they allow producers to obtain the economic rewards (e.g. profit) necessary to ensure their consumption activities. This condition will exist once market forces continue to dominate the organization of society and the distribution of resources.

These concerns of sustainability form the basis of this paper on the use of pesticides in banana production in St Lucia, the largest producer of bananas in the English-speaking Windward Islands. Pesticide use in banana was chosen since concerns have been raised about the possible impact of the use of pesticides on the natural fauna of the Windward Islands. Also, the need for banana producers in these islands to produce better quality fruit, may lead to an increased use of pesticides in bananas, without regard to other more sustainable approaches to pest manage-ment. It is hoped therefore that this paper would encourage research on these alternative approaches, such as integrated pest management (IPM).

The paper first deals with the level of pesticide use in banana production in St Lucia then attempts an analysis of the economic efficiency of banana production and the contribution of pesticides to costs of production. Finally the paper explores the possible net benefits of the alternative use of integrated pest management in banana production in St Lucia.

Pesticide use in banana in St Lucia

Information on pesticide use in St Lucia was obtained from the Windward Islands Banana Association (WINBAN). This information consisted of the quantity of inputs purchased and distributed by the St Lucia Banana Growers' Association (SLBGA), and the pesticide use of seven WINBAN farmers whose resource use was being monitored. Using these sources, the mean levels of use of pesticides by banana farmers in St Lucia were calculated.

The statistics relating to the SLBGA sales and distribution of pesticides to farmers for 1990 are presented in Table 1 on a per hectare basis. These means were obtained by dividing the total pesticide inputs distributed by SLBGA for 1990 by the total hectarage of bananas in St Lucia and assumes that all of these pesticides are applied only to bananas.

More detailed farm data on pesticide use were obtained from WINBAN with respect to the seven banana farms whose actual resource use was being monitored. The data pertaining to pesticide use on these farms are presented in Table 2. An examination of the data reveals that herbicide use averaged 16.20 L/ha, which was somewhat less than the national average distribution given in Table 1. However the mean use of Furadan® by these farmers at 24.5 kg/ha is much higher than the national distribution

of 13.5 kg/ha (Table 1). The monitored farmers however used less Mocap® than the national average. The average cost of pesticide use on the seven monitored farms was US$249 as seen in Table 2.

Table 1. Distribution of pesticides by the St Lucia Banana Growers Association in 1990

Type of pesticide	Total distributed/ha
Herbicide	18.28 litre
Vydate®	3.50 litre
Primicid®	2.88 litre
Mocap®	14.55 kg
Miral®	2.87 kg
Furadan®	13.49 kg
Benlate®	1.17 kg
Rat bait	0.01 kg
Total area of bananas	7,116 ha

Source: WINBAN

Table 2. Mean recorded use of chemicals by seven WINBAN farmers

Type of pesticide	Mean use /ha	Mean cost/ha (US$)
Herbicide	16.20 litre	176
Furadan®	24.50 kg	59
Mocap®	4.87 kg	12
Vydate®-L	3.53 litre	2
Total		249

Economics of pesticide use

Table 3 presents data relating to sales, cost of production per ha and Gross Margin for each of the production systems. The data are for St Lucia and were obtained from profiles of the seven WINBAN farmers previously mentioned. For these farmers, the sales/ha averaged 16.29 tonnes – a figure higher than the Windward Islands average of 13.01 tonnes/ha. Cost/ha averaged US$2,612 and revenue had a mean value of US$3,831/ha. The resulting gross margin therefore had an average value of US$1,219.

Table 3. Economics of production of one hectare of bananas in St Lucia

	Actual	Hypothetical with 77% IPM
Sales (tonnes)	16.29	16.29
Cost (US$)	2,612	2,420
Revenue (US$)	3,831	3,831
Gross margin (US$)	1,219	1,411

Source: WINBAN Farm Profiles

Total cost of production was US$2,612 of which pesticide cost of US$249 were about 9.5%.

Potential benefits of integrated pest management

Luna and House (1990) define integrated pest management as:

> 'A strategy of pest containment that seeks to maximize the effectiveness of biological and cultural factors, utilizing chemical controls only as needed and with a minimum of environmental disturbance.'

Clearly such a definition categorizes integrated pest management as a sustainable approach to dealing with the pest problems of agriculture. Since other papers in this seminar would undoubtedly go into the nature of integrated pest management, I will not attempt any layman's discussion.

Luna and House (1990) however discuss the potential benefits of integrated pest management (IPM). They state that in the United States, IPM programmes save

farmers more than $500 million annually and significantly reduce pesticide use. They further state that the investment for IPM services by USDA and farmers is of the order of $32 million which yields the annual return of $500 million just mentioned.

Luna and House (1990) further point out that IPM programmes have resulted in decreases in the use of pesticide active ingredients in the order of 77% for cotton, grain, sorghum and peanut. IPM programmes they state have also resulted in a 46% decrease '...in total acreage treated with insecticides.' They go on to state that in spite of these obvious successes, only an estimated 8% of cropland (11 million ha) is enrolled in state IPM programmes in 30 states of the US.

Figure 1 illustrates the potential benefits of IPM as suggested by the results of Luna and House (1990) and other similar studies. Here it is seen that IPM can lead to a higher efficient level of percentage pest control (E_{IPM}) than the use of pesticides. As also seen in Figure 1, pesticides would achieve a lower efficient level of percentage pest control at E_p, with higher marginal and total costs of this lower pest control.

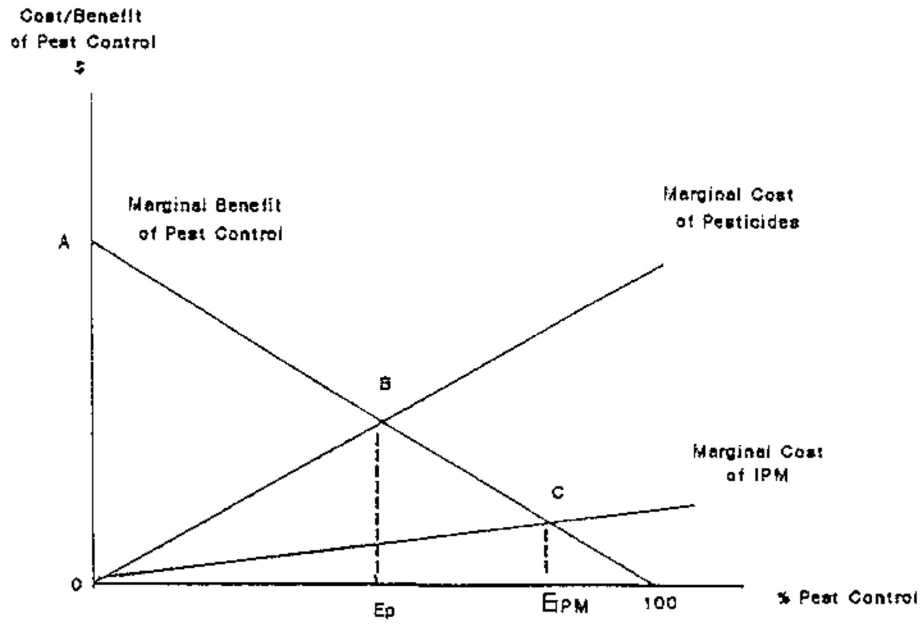

Figure 1. Economics of integrated pest managenent (IPM) – An illustration

Looking at the banana production in St Lucia and assuming that the same kind of effectiveness (77% reduction in pesticide use) can be achieved in an IPM programme for the banana industry, this can result in the mean cost of pesticides for the seven WINBAN farmers under case study to drop to US$57. This would increase their gross margin per ha from US$1,219 to US$1.411 a 16% increase in gross margin.

A rough calculation puts the amount of money paid to WINBAN by farmers for the pesticides reported in Table 1 at US$1.93 million. Farmers also paid an additional US$35,200 for spraying equipment. Focusing only on the chemical inputs, a 77% reduction of these costs would put them at $0.44 million, with a benefit of approximately $1.5 million. Given the same effectiveness as the US programme, the IPM programmes would cost farmers and WINBAN annually about $96,000.

Conclusions

Very little evidence or factual evidence could be located on the environmental impact of pesticide use in banana in St Lucia, or for that matter the rest of the Windward Islands. While generally, a lot is known about the nature of agricultural pollutants in surface and ground water – knowledge of the environmental risk from present and alternative agricultural production systems is very limited (Logan 1990). Thus even though this paper has identified the levels of chemical use in the banana industry in the Windwards (St Lucia in particular), little is known about the contribution of this chemical use to water contamination or to the health of human or wild life populations. (The situation is even worse for soil loss and soil contamination of water bodies, where even the levels of soil loss and contamination are unknown.)

This paper can only then support the position of Logan (1990) that a major research need for sustainable agriculture and water quality is 'to perform a comprehensive assessment of the environmental risk from present and alternative agricultural practices.'

It is also clear that based on the world-wide evidence available that IPM can bring potential benefits in the reduction of pesticide use in banana production in St Lucia and the Windward Islands of CARICOM. This could bring about an improvement in the profitability of banana production and increase its competitiveness especially with respect to its Latin American competitors in the European market.

There is however urgent need to begin or expand research on IPM in banana production so that these benefits can occur before it is too late to save the banana industry.

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POLICY FRAMEWORK FOR PROMOTING SUSTAINABLE DEVELOPMENT THROUGH INTEGRATED PEST MANAGEMENT IN SMALL ISLAND STATES

R H Singh
The University of the West Indies, Trinidad & Tobago

Economic development in the Caribbean region is highly dependent on the performance of agriculture and tourism – two key sectors which rely on the quality of the natural resource base. The sustainability of the development process is therefore a function of the integrity of the region's natural resource base. However, the risk of degradation beyond the critical threshold is particularly great for countries of the region. In this regard the small island states are most vulnerable given their fragile ecosystems and the inability of such systems to absorb 'degradational shocks' resulting from human activities.

There are numerous examples in the Caribbean of activities which are degrading the environment at such levels and rates as to seriously compromise the region's capacity to sustain economic growth and development into the future. These include 'slash and bur" of natural forests, encroachment and unauthorized building development in protected watersheds, degradation of coastal areas and swamplands, soil losses due to inappropriate farming activities and practices and widespread use of agrochemicals which have shown drastic increases in recent years, both in terms of the range of chemicals as well as the levels.

Although the environmental impact of agrochemicals is a major source of public concern, it has not received much attention at the national and regional policy levels. While professionals working in plant protection are indeed mindful of the environmental consequences of the high levels of agrochemical usage, typical of many Caribbean countries, this has not yet been articulated as a major national/regional issue in terms of its implications for sustainable development.

This paper examines trends in agrochemical use as well as the institutional, economic and policy issues which are contributing to the rapid environmental degradation in the Caribbean region. Trinidad & Tobago is selected as a country case study to demonstrate the extent of the problem. The paper advances an economic argument for the adoption of an integrated pest management (IPM) strategy for agriculture and proposes a policy framework to encourage farmers to shift to IPM, away from a reliance on mainly chemical plant protection systems.

The orientation towards crop technologies reliant on high agro-chemical usage

Prior to the 1950s agriculture in the Caribbean was characterized by low levels of chemical usage for plant protection. This was especially so on small farms. The trend thereafter was one of increasing reliance on pesticides. According to Alam (1988) : 'because of the development of resistant pest and weed species, chemical pesticides were used in larger quantities/concentrations at short intervals. 'Insurance' or 'calendar' applications are made at specific times of the year irrespective of whether there is any evidence of pest and disease damage.'

The 1950s and 1960s thus witnessed the widespread adoption of crop technologies which were characterized by a heavy reliance on chemicals. Both institutional and policy factors contributed to this shift. With respect to the former, research and development institutions as well as agricultural extension appeared to be

largely oriented towards the generation and diffusion of chemically oriented technologies. The structure of research programmes, the disciplinary profile of scientific staff and the budgetary allocations for research and development institutions showed a strong bias towards technologies relying heavily on agrochemical usage, particularly pesticides and herbicides. Similar biases were also reflected in agro-technologies being promoted by the extension system as evidenced by the range of tech-packs which were available through brochures. Also the agribusiness sector, both the multinational manufacturers of agrochemicals as well as domestic distributors, exerted a strong influence on technological orientation of the farmers of the region through their aggressive marketing and promotion programmes. Many farmers rely on agricultural supply shops for information and inputs, especially with respect to seeds and crop protection. For example the adoption of hybrid seeds often meant less resistance to native pests and therefore increasing reliance on pesticides.

Government policy has also been instrumental in encouraging the widescale adoption of agro-technologies which are heavily reliant on chemical use. In particular low tariff levels as well as price subsidies on agro-chemicals have encouraged excessive use of these inputs. This has effectively excluded other methods of pest and weed control. Furthermore, pesticides have been virtually used as 'crop insurance' in that applications are liberal and are intended to minimize the incidence of pests.

Additionally, the ecological degradation and the loss of natural biological crop protection organisms which have resulted from increasing chemical applications have in turn resulted over time in the growth in demand for a wider range of pesticides as well as pesticides of greater toxicity. This has meant increasing expenditure and foreign exchange outflows for agrochemical imports which, given the serious fiscal and foreign account deficit which many countries have been experiencing, are unsustainable.

Environmental degradation resulting from agrochemical use also threatens the future of the tourism industry in the region. Many countries in the Caribbean have targeted tourism as one of the major economic sectors. Clearly the future of this industry, particularly ecotourism, will depend on the quality of the environment. Accordingly, current orientation and policy towards high pesticide use is not only a threat to the sustainability of agriculture but to the entire development process.

In summary, the policy and institutional environment for the farm sector in the Caribbean Region over the past four decades have been largely responsible for the orientation of crop production systems in ways that make them unsustainable as well as compromising the sustainability of the overall development process.

Agrochemicals in Trinidad & Tobago: trends and risks

This section of paper examines the risks and trends in agrochemical use in the Caribbean region through a selected country example. Trinidad & Tobago was selected principally on account of data availability as well as information on scientific and financial resources which have been allocated to agricultural research over the years. The latter information gives an indication of the inherent capacity of the agricultural system to shift to other forms of crop protection.

Risks

Trinidad & Tobago is one of the Caribbean countries that has seen dramatic increases in pesticide use in agriculture over the years. Increasing pest resistance to chemicals as well as the consequential destruction of beneficial organisms have resulted in exponential increases in the intensity of pesticide use. Increases in the level of pesticide per application as well as in the frequency of application and the use of a wider range of chemicals have contributed to this situation. Application is on a scheduled basis irrespective of pest population. Dosages are often at levels intended to provide 'insurance' or 'preventative' control of crop damage. Accordingly there is widespread concern in

the country on the environmental damage and risks from such high levels of pesticide including:

- health risk to the producers themselves
- environmental degradation – soil, air and water pollution/contamination
- public health risks from chemical spraying/application, particularly from aerial application in the sugar industry
- health risk to the population at large from pesticide residues on agricultural produce
- the damage to the ecology, particularly the habitats for birds, fishes and wildlife, and the loss of biodiversity.

Trends in agrochemical use

Expenditure on agro-chemicals (excluding fertilizer) in Trinidad & Tobago increased dramatically over the years 1963 to 1984 as shown in Figure 1. From a value of TT$1.8 million (current prices) in 1965 expenditure grew to TT$20.6 million by 1984. Major increases were noted from the late 1970s. While a large proportion of this was due to price changes (see Figure 2), the data also reflect significant increases in quantities.

Insecticides constitute the major expenditure amongst agrochemicals, exceeding that for fertilizer (Figure 3). In 1980 77.5% of agrochemical expenditure (excluding fertilizers) was for purchases of insecticides; herbicides accounted for 17.8% of expenditure, and fungicide 4.6% (Figure 4). By comparison insecticide expenditure in 1991 was 66% of that for agrochemicals.

Expenditure on herbicide had increased from the 1980 level to 26.6% of purchases. As a share of the value of aggregate agricultural output, expenditure on pesticides has generally maintained its share over the years – 7% in 1965 and 6.3% in 1984. This has not been the case for expenditure on fertilizer which declined from 8.2% of the value of aggregate output in 1965 to 2.3% in 1984 (Figure 5).

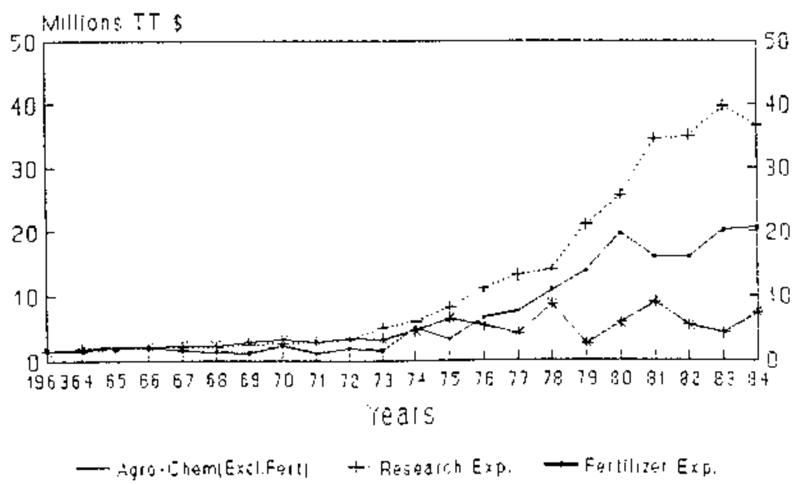


Figure 1. Total expenditure on agrochemicals, fertilizers and agricultural research: Trinidad & Tobago, 1963–84

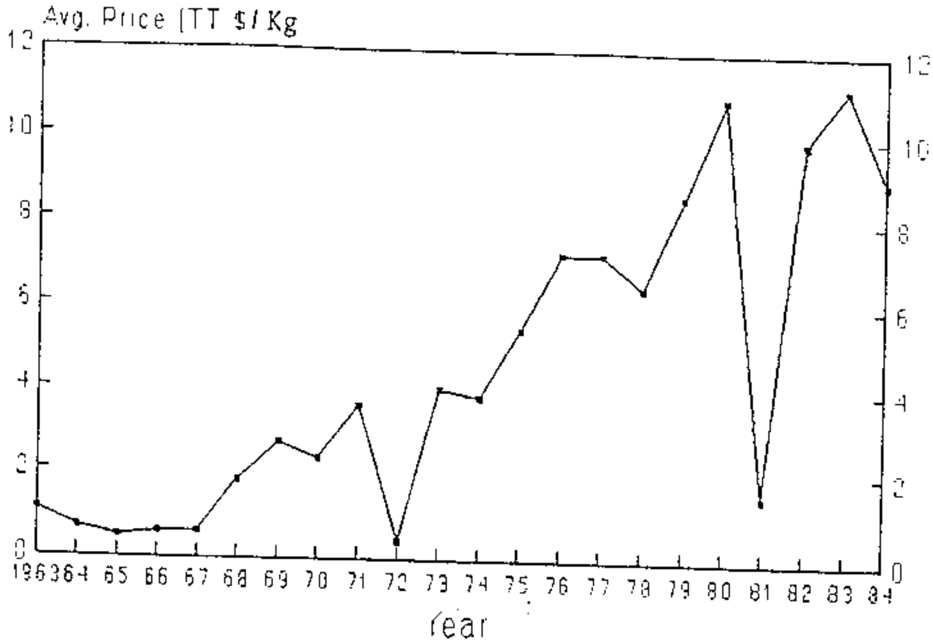


Figure 2. **Average cif price of agrochemicals: Trinidad & Tobago, 1963–84**

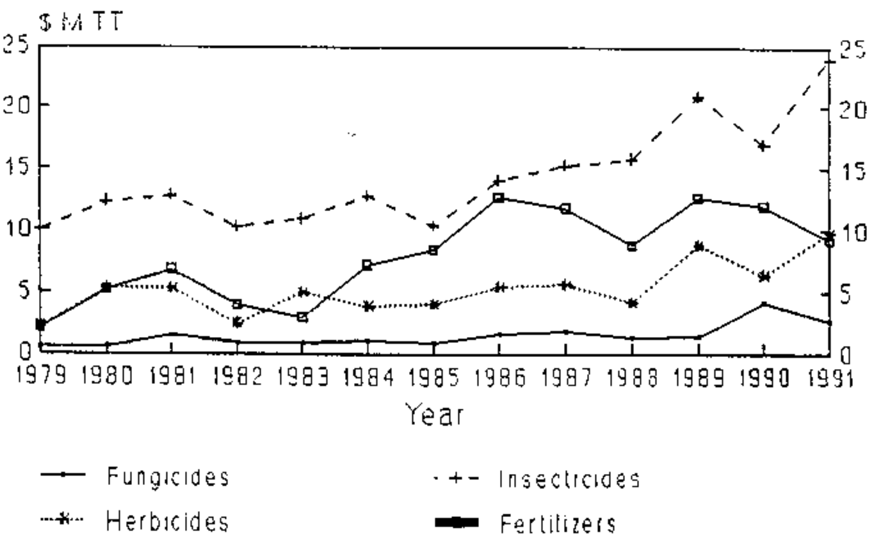


Figure 3. **Cif value of insecticides, fungicides, herbicides and fertilizers imported: Trinidad & Tobago, 1979–91**

Research and development

Trinidad & Tobago is relatively well-endowed with scientific resources for research and development in agriculture. The National Agricultural Research System (NARS) includes the Ministry of Agriculture, the University of the West Indies (Faculty of Agriculture) and the State Sugar Corporation – Caroni (1975) Ltd. The NARS is also supported by the Caribbean Agricultural Research and Development Institute (CARDI).

A survey of scientific personnel involved in agricultural research in Trinidad & Tobago in 1989 (Singh and Rankine) revealed a cadre of well-trained professionals – over 100 qualified professionals amongst the various institutions. The programme of research in crop protection however reflected a strong orientation towards chemical control. Very little emphasis on biological control or IPM was evident.

Financial resources to support research and development activities in Trinidad & Tobago have shown significant increases over the years. Relative to agricultural contribution to GDP agricultural research expenditure reached as high as 11% in 1984. This compares with a value of less than 1% for most industrialized countries.

When one considers the access to scientific personnel together with the financial resources and institutional support for research and development in Trinidad & Tobago, the orientation of agro-techniques and the approach to agricultural development in ways which are degradative and unsustainable represents a gross misallocation of resources. The scientific resource pool is ample to induce a shift to environmentally benign /environmentally friendly approaches to agricultural development. Such a re-orientation is urgently required in order to place the country on a path of sustainable development.

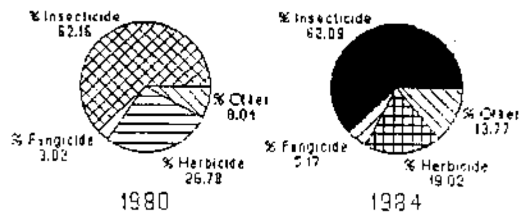


Figure 4. Relative expenditures on insecticides, herbicides and fungicides: Trinidad & Tobago, 1980 and 1984

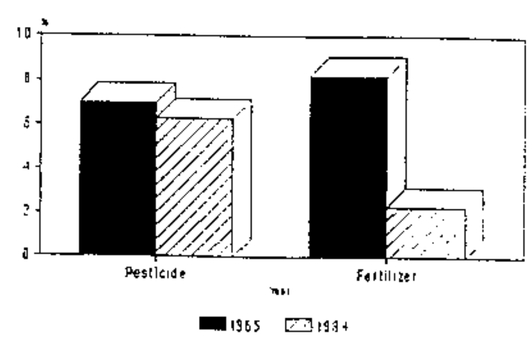


Figure 5. Expenditure on pesticides and fertilizers as a percentage of the value of agricultural output: Trinidad & Tobago, 1965 and 1984

An alternative to the pesticide problem: IPM

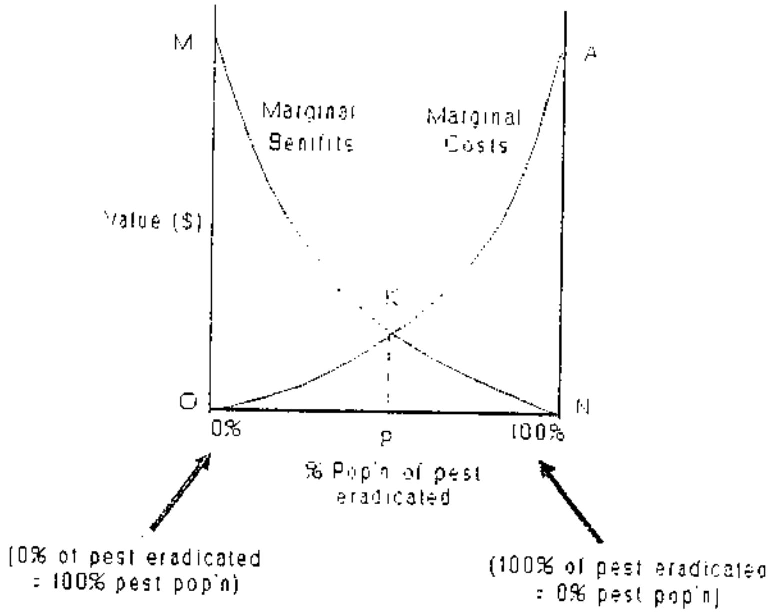
In an attempt to develop more sustainable agricultural production systems many countries have been moving to the multi-dimensional strategy of integrated pest management (IPM). Minimum agrochemical use, minimal impact on the environment and ecological resources, reduction in the health risks to consumers and farmers, the conservation of beneficial organisms and acceptance of tolerable economic levels of crop losses are key features of the IPM approach. The United Nations handbook on agro-pesticides (Oudejans 1991) defines IPM as: 'a pest management system that in the context of associated environment and population dynamics of pest species, utilizes all suitable techniques and methods in as compatible a manner as possible and maintains pest population at levels below those causing economic injury.'

An economic model which demonstrates the concepts of the IPM approach, principally in terms of the optimum pesticide use is shown in Figure 6. Of course the IPM approach considers other methods of control as well as sequencing in order to determine the minimum pesticide use. The model therefore abstracts from a more complex set of relationships which are typically inherent in IPM. The presentation in Figure 6 assumes an initial situation in which a fairly significant pest population is observed for a particular crop. For demonstration purposes such a level is referred to as a 100% pest population. The normal response of farmers in the region to this situation is to fully eradicate the pest – that is, reduce the pest population to zero per cent. The alternative approach embodied in IPM is basically to determine the level of losses which are tolerable in terms of the economic benefits and costs associated with incremental reductions in the pest population.

The key economic consideration in IPM is that the incremental (marginal) cost for the eradication of injurious organisms increases as the level of eradication increases – OA in Figure 6. The potential marginal benefits in terms of higher yields and quality of produce is greatest when control takes place in the presence of high pest populations. A small level of control at high pest population results in high levels of benefits, e.g. OM in Figure 6. However, as increasing proportions of the pest population are eradicated, the marginal benefits from reduction decline as shown in the Figure. The optimum level of control is given by OP^*, i.e. where the marginal benefit of control equals the marginal cost. At the optimum the pest population is reduced by OP per cent. The tolerable level of the pest population at the economic optimum is NP. Accordingly, the economic threshold (ET) in terms of pest population which should be tolerated is (100 – OP)% or NP% of the pest population.

The potential economic benefits accruing from the adoption of an IPM approach to pest management include:

- reduced cost of chemicals
- any reduction in labour application cost in future years
- possible increases in the value of production (price, yields)
- damage avoided from preservation of the environment
- reduced damage to human health and lower incidence of pesticide related illness
- improved return to tourism from environmental conservation
- social benefits from conservation of environmental resources – recreation, wildlife, water, ocean.



Note : Marginal Cost = Cost associated with the eradication of an incremental % of pest population

Marginal Benefit = Benefit in terms of reduced crop losses from incremental reduction in the pest population

Figure 6. An economic model for determining economic threshold (ET)

The costs associated with an IPM programme include:

- research and development costs for developing IPM information, techniques and natural control mechanisms/organisms
- field monitoring and data collection costs
- training of farmers and extension workers
- any reduction in yields.

Some of the savings arising from cost reductions associated with lower agrochemical usage could result in a re-allocation to other technological inputs such as fertilizer and irrigation, thereby improving productivity. The real benefits associated with expenditure savings from chemical usage should therefore be measured in terms of the opportunity cost.

The nature of the IPM approach is such that the surplus of benefits over costs as a result of adoption is expected to widen over time. The principal reason for anticipated increases in net benefit from IPM is the trend observed with respect to chemical control cost in the absence of IPM. As indicated earlier increasing resistance results in increasing cost of chemical control. Another factor which is likely to result in higher levels of benefits to IPM in future years is the probable improved effectiveness of IPM over time due to better knowledge on the part of both researchers and farmers as well as from increases in the population of beneficial control organisms.

Potential benefits and cost of an IPM programme for Trinidad & Tobago

Attempts at quantification of benefits from IPM have largely been restricted to savings in the cost of chemical pesticides. This obviously is the likely minimum level of benefits since all other economic benefits are not included due to the difficulty in quantification. Additionally, the real benefit of lower expenditure in chemical control is the opportunity cost in terms of improved productivity of the financial resources which are likely to be released through the adoption of an IPM programme. Wohler (1989) reports that the adoption of an IPM programme in Germany resulted in a 50% reduction in fungicide and a 25% reduction in insecticide. Brader (1989) indicates that the most successful IPM programme has been the Food and Agriculture Organization/United Nations Environment Programme (FAO/UNEP) programme for rice in south-east Asia. One reason advanced was that the programme was able to take advantage of the vast knowledge of pest problems in rice in south-east Asia which has been accumulated by the International Rice Research Institute (IRRI) and the national research programmes. Farmer training was central to the rice programme. An evaluation of the IPM programme in rice found that farmers who applied IPM were able to reduce insecticide use by 90% while maintaining increased yields (Brader 1989). The study concluded that IPM could be successful. However pre-conditions for success include:

- strong political support
- excellent understanding of the pest problems and dynamics
- full involvement and training of farmers.

Waibel (1989) in evaluating on-farm trials for IPM in the Philippines in 1980/81 found that 90% of the increases in net returns were from reduced cost of control and 10% were due to higher yields at the economic threshold.

Given the high levels of pesticide application in Trinidad & Tobago (often considered excessive) an estimate could be made of the probable lower range of benefits which may be possible from the adoption of an IPM strategy and programme. The following parameters are assumed as the basis for an estimate of probable lower range of benefits:

- Expenditure reduction in chemical control apply principally to insecticides and fungicides
- Probable cost reductions are in the range of 50% of expenditure
- Only direct cash savings are considered rather than opportunity cost.

Table 1 provides the expenditure data on insecticide and fungicide application in Trinidad & Tobago over the 12-year period 1980–1991. The total undiscounted expenditure is TT$177.1 million for insecticides and TT$18.8 million for fungicides. Assuming a 50% savings in expenditure the total benefit over the 12-year period equals TT$97.9 million in current value or TT$51.5 million at a discount rate of 10%.

Table 1 Expenditure on pesticides and fungicides for Trinidad & Tobago (million $TT)

Year	Insecticides	Fungicides
1980	12.3	0.6
1981	12.8	1.5
1982	10.2	0.9
1983	10.9	0.9
1984	12.8	1.1
1985	10.3	0.9
1986	14.0	1.6
1987	15.1	1.8
1988	15.7	1.3
1989	21.4	1.5
1990	17.3	4.2
1991	24.3	2.7
Undiscounted total	**177.1**	**18.8**

Present value of total expenditure (1980–1991) @ 10% discount rate = TT$102.9 million

Given the level of financial and scientific resources involved in agricultural research in Trinidad & Tobago – over 100 professionals and more than TT$55 million in annual expenditure – it is felt that the research and development requirements for an IPM programme could be mounted with existing resources. The assumption therefore with respect to the cost for an IPM programme is that little additional expenditure would be required. The reallocation of existing research and development resources to IPM related activities is likely to be adequate.

Under the above assumptions the net present value (NPV) of benefits of introducing an IPM programme in Trinidad & Tobago is the estimated gross benefits – TT$51.5 million over a 12-year period. As discussed above this estimate is considered to be the lower end of the range of benefits which are associated only with reduced pesticide expenditure. This sum however is quite substantial. Other environmental/ecological and health benefits as well as benefits from conservation of the natural resource base have not been considered. Additionally from an economic perspective the NPV of TT$51.5 million represents foreign exchange benefits. Given the over-valuation of the Trinidad & Tobago dollar the real economic benefits of IPM at the shadow exchange rate are therefore well in excess of the amount estimated. The benefit/cost ratio is infinitely large due to the fact that costs are likely to be nil or negligible.

Policy proposals for inducing a shift to IPM

The strong orientation of agro-technology in the Caribbean towards the use of pesticides is unlikely to respond to isolated initiatives on the part of individual scientists or institutions. Current policy and institutional factors exert an overwhelming influence in maintaining the status quo. A redirection of agriculture towards a system which relies on minimal chemical usage requires initiatives at the highest levels. A clearly stated national policy on IPM as well as fiscal incentives and institutional re-orientation are essential elements of any reform programme. The following policy instruments are proposed for countries of the region as the basis for facilitating the adoption of a comprehensive IPM programme:

- Declaration by the government of its adoption of IPM as the strategy for crop protection in sector

- Development of a comprehensive public awareness/public education programme targeted to both the general population as well as the farming community. Such a programme should focus on:

    - conservation

    - risk associated with chemicals in crops as well as generally

    - benefits from other control measures – IPM and biological control

- Establishment of specialized research and development programmes in IPM among existing institutions through:

Wohlers P W. 1989. German integrated pest management activities and their relevance for subtropical and tropical agriculture. Proc. seminar on Integrated Pest Management in Tropical and Subtropical Cropping Systems. Vol. 1. Federal Republic of Germany.

THE ECONOMICS OF PEST CONTROL ON SMALLHOLDER FARMS

M Iles and C Conroy
Natural Resources Institute, U K

Objectives

To examine the existing crop pest management situation in the region, focusing on factors which constrain farmers from wider adoption of those initiatives which have potential to improve crop protection in the region.

Background

The focus is on IPM/MIP (Integrated Pest Management/Manejo Integrado de Plagas). IPM is an approach to crop protection which seeks to maintain levels of agricultural productivity while protecting natural resources and emphasizing environmental sustainability and human development. IPM frequently reduces the use of polluting substances, maintaining pest populations at an acceptable level and encouraging natural regulating mechanisms.

IPM is an approach which seeks to increase agricultural productivity through crop protection which recognizes the farming or cropping system. Within this system there are likely to be a number of different types of pests operating. Although farmers are likely to be aware of each type of pest, or at least each group, they are also likely to see them in terms of the damage they do to their crops. Once infestation has taken place, farmers then have to decide whether or not to control the pest; is the level of damage sufficient to merit control, or are there more important problems that need tackling on the farm? If control is considered necessary, what control measures are available; i.e. what does the farmer know of alternative control methods and how relevant are they? Are they affordable, do they have the skills to use them or will further training be necessary? Is such training available? Do they imply changes in the farming system which the farmer would find acceptable?

Small island economies are characterized by problems of 'open' borders making quarantine difficult and in which a high proportion of crops are high value and grown for tourists or export markets. There may be few crop alternatives.

Smallholder agriculture in the Caribbean

The small-farming sector makes a major contribution to domestic food production in most Caribbean countries. In recent years it has been recognized that the sector may also have a role as a potential foreign exchange earner.

A general characteristic of Caribbean agriculture has been the dominance of one or two commodities in the sector's contribution to GDP, employment and foreign exchange earnings. With the possible exception of Jamaica, Caribbean countries have remained dependent on a few major traditional export commodities (sugar and banana) and have failed to develop alternative crops in a significant way (Budhram and Rock 1991).

Sugar

The sugar industry has rapidly declined since its peak in the 1960s. In most countries there has been an absolute decline in both yields and acreage planted (Budhram and Rock 1991).

Banana

The banana sector boomed in the 1980s, but has been affected by problems in recent years that have begun to affect its economic viability. These include a scarcity of farm labour in some countries, persistence of the Moko disease and declining product

Jamaica labour was a constraint in one of the two study districts (Meikle 1992). In the Dominican Republic there has been a migration of labour from the agricultural sector into the construction industry, where the wages were better. As a result, farm labour has become scarce and expensive, and is arguably the most limiting factor in farm production (Dominica Banana Marketing Board 1990, cited in Martin 1991).

The design of effective IPM systems requires a knowledge of seasonal peaks and troughs in labour requirements, but there seems to be a dearth of published literature containing information about seasonal labour calendars. There is also a lack of references to the gender division of labour and the contribution of women to smallholder agricultural production. A study of smallholder agriculture in the OECS countries found that labour is hired-in primarily at the stages of land preparation and weeding (Bourne and Weir 1980), which strongly suggests that these are times of peak labour demand.

Capital

Scarcity of capital severely restricts the productivity of many small-scale farmers. For example, a typical Windward Islands farmer has access to little more than a cutlass, fork and spade (Martin 1991). For small farmers the most important capital factor in annual crop production may be seed (Martin 1991). Banana farmers fare better than others as, through their banana associations, they are provided with credit or inputs including fertilizer, pesticides or applicators (Martin 1991).

Crop protection inputs are expensive: an average knapsack sprayer costs about US$150, a motorized knapsack sprayer about US$650, and pesticide costs range between US$10 and 25 per litre (Martin 1991). Not surprisingly, therefore, the bulk of pesticides (and inorganic fertilizers) are used on export crops. In the Windward Islands the banana industry is by far the largest user of chemical fertilizers and pesticides, and the cost of these inputs makes 'a significant contribution to the high cost of production and the low competitive status of the banana industry' (Martin 1991).

Only a small proportion of farmers who are primarily growing domestic food crops use chemicals for pest control (Bourne and Weir 1980). Many resource-poor farmers only apply these inputs when there is an outbreak of a pest or disease – but often by then it is too late (Martin 1991). Alternatively, if they are also banana farmers, they may use inputs from their bananas in their other crops, with the result that both crops receive less than optimum levels of input, and control is less than satisfactory (Martin 1991).)

General record of IPM in the Caribbean

A major group of constraints on the adoption of IPM by farmers are socio-economic. Farmers are aware of conventional pesticide control, either because the private sector has been active in promoting pesticides, or because they are made available through credit programmes. It is often easy for farmers to see how pesticides can fit their farming system. If the correct pesticide is selected, the farmer can see the dead pest which results.

There appears to be a consensus in the literature on pest control in the Caribbean that, in terms of the key indicator, adoption, there has been a lack of success in developing IPM technologies suitable for smallholders (Martin 1991; Pollard 1991; Andrews et al. 1992). Many of the basic crop protection methodologies developed (both pesticide-dominated and IPM) are incompatible with the agro-ecological or socio-economic conditions facing resource-poor farmers, or are technically difficult and economically impossible to implement effectively (Martin 1991)

The pest control systems that have been developed are generally better suited to commercial farmers specializing in export crops: an example is given below of the development of an IPM system to deal with the coffee berry borer. A lack of pest control technologies suitable for smallholders is by no means peculiar to the Caribbean. A similar situation exists, for example, in Central America, where there have been several IPM success stories in capital-intensive export crops (such as sugar cane,

coffee, and banana), but 'virtually no impact on small producers' (Andrews et al. 1992).

The following lessons have been drawn from the limited and generally unsuccessful experience of IPM in the Windward Islands (Martin 1991):

- the small size of holdings makes the effective use of non-residual chemicals difficult because neighbouring plots serve as sources of reinfestation

- natural enemy manipulations are less than optimally effective because of the movement of pesticides and pests into the plot, and because of the migration of natural enemies

- many cultural and mechanical controls suffer from the same limitations

- time invested in scouting to take the minimum number of samples can be cost-prohibitive.

Factors inhibiting the effective use of IPM in the Caribbean

Quantity and appropriateness of research

Many technologies that have been developed on research stations in the region have not taken account of the on-farm situation, nor has the development included assessment or testing by farmers.

There is considerable scope for the interdisciplinary approach, involving non-conventional as well as conventional means. This includes working through NGOs, which are active in the region in involving farmers in the development process, often assuming the research and extension functions with encouraging results. In some areas governments have virtually abrogated their responsibilities to NGOs – what is the rationale for this, since their roles are not mutually exclusive? Do extension services have similar strengths and weaknesses to those in Central America?

The dearth of social science analysis in references may be indicative of insufficient attention being paid during the research process into the farmers' situation in respect of their perception of the problem, the resource base and constraints on adoption. This would in turn affect farmer adoption and may be a factor in the low level of adoption cited for the region (Rueda et al. 1993).

There has been a lack of adequate research into pest management strategies that are suitable for smallholders (Martin 1991). For example, insufficient research has been done on the management of vegetable crop pests (Pollard 1991).

A major problem has been the 'inappropriate strategy and *modus operandi* of past and existing IPM research and extension programs' (Andrews et al. 1992). Smallholders are seldom involved in strategic planning of investigations, but unless they are involved it is unlikely that technologies useful to them will be developed (Andrews et al. 1992).

The public sector has been shrinking in the wake of liberalization policies, and as a result the emerging role of governments is confined to regulation rather than to implementation, the latter often being considerably more costly. Also important is the complexity of pests which affect crops. It is not easy for scientists who have been trained and rewarded by thinking in single discipline terms to adapt to broaden their approach to examine the pest complex.

It is important here to make a distinction between the specialized knowledge which scientists can bring to a particular problem and the context in which the resulting technology will be used. The ideal situation is therefore one in which scientists are developing technical solutions while being fully aware of the difficulties the farmer is likely to face when implementing them. While the pursuit of scientific excellence is important in order that scientists are able to develop the skills needed to solve problems, in itself this development is insufficient. The ultimate objective – the central issue – in agricultural development is whether or not farmers adopt technologies which will enable them to increase productivity. Although in the case considered this refers to crop protection which is sustainable,

these remarks could equally well apply to any other branch of agricultural research.

Research is often directed towards the needs of farmers to whom technological change is readily accessible. They are often those who have been well-educated often with the researchers themselves to whom they are frequently well-known. They are generally of above-average literacy, frequently commercial in approach and therefore less risk-averse in the sense that they are dependent on a small proportion of their production for their own subsistence (although risk does attach to the capital investment).

The individual farmer may well not conform to this stereotype. Although they are quite often unique it is possible to group farmers according to the similarity of their resource bases, constraints and social type.

It is also often assumed that farmers are of one type; the role model usually being the large-scale commercial farmer. It is difficult persuading researchers who have been single discipline-trained to think in terms of the contribution which other disciplines can bring to bear on farmers' problems and to allow that farmers differ widely from one another.

Given this, it is virtually impossible for a research or extension officer to understand a particular farmer's situation and to consider the resource base, constraints and social type and predict the technology they are likely to adopt. It is therefore necessary to develop a range of technologies from which farmers can select those which appear most appropriate for their particular system and then to test them under farm conditions.

Labour requirements

One potential problem for IPM 'is that labour-intensive cultural practices may be required on the resource-poor farmers' crops at precisely the same time as lucrative employment opportunities become available off the farm. The cash flow from such employment may be essential for the family, but the opportunity cost of resulting absences due to increased pest and weed damage may be substantial' (Martin 1991). For example, in Trinidad 65% of local vegetable farmers are part-time and do not have the time to spend on cultural and other IPM practices (Jones 1985).

Consumer attitudes and market requirements

Consumers tend to have a strong preference for products with minimal damage or blemishes, even if they are superficial. The markets for export crops in the industrialized countries demand high quality standards, and to satisfy these standards smallholders have no choice but to purchase fertilizers and pesticides (Martin 1991). The same problem arises for some crops for domestic markets – for example, local consumers are unwilling to tolerate cabbages that have been damaged by insects (Pollard 1991). Farmers are aware of this, and hence are themselves intolerant of any damage – and hence tend to opt for high levels of pesticide use on cabbages and other high value crops.

Extension

The lack of relevant research means that extension staff are not able to give smallholders useful advice on IPM.

Location

The problems faced by islands and characterized by 'open' borders makes quarantine difficult and can undermine IPM initiatives.

The Way Forward

In spite of these difficulties, the IPM approach to crop protection faces similar problems in other locations. The economic vulnerability of small islands arguably predisposes the Caribbean smallholder to the low-cost control technologies which IPM can offer.

A better understanding of the socio-economic conditions affecting smallholders is essential. This can be achieved by social and natural scientists working closely together, carrying out surveys and working with smallholders in the determination of research priorities and the implementation of adaptive research.

There are some traditional production/ protection practices that can be built on in the design and development of IPM systems. These are multiple cropping; destruction of crop residues; planting by the phase of the moon; and the use of traditional crop varieties, which are often more pest-resistant (Martin 1991).

The components of a sustainable pest control programme are aimed at raising agricultural productivity, environmental sustainability (reduced reliance on pesticides) and human resource development.

Increased levels of training of trainers and farmers.

Although it is the system practised by traditional farmers, IPM is not an easy concept to explain or comprehend. There are many differing views as to what constitutes IPM. Carefully designed training programmes are needed if farmers are to be able to understand the importance of beneficials within the ecosystem. They need to be guided by the prospect of economic damage and know that this is influenced by the numbers of pests attacking an individual plant and that it may not be necessary to spray pesticides every time a pest is detected , and that some control measures do not result in the death of pests immediately.

Clear extension messages to farmers of which choice in technologies to test or adapt for adoption is an important component.

Given the non-sustainability of adequately funded extension services, cost-effective alternative methods of widespread dissemination need to be considered. Small farmer groups which bring together farmers of similar type, offer a possible mechanism. Similarly, extension systems should be encouraged which allow farmers to learn from one another through appropriate contact.

Examples of successful IPM

In Jamaica the control of the coffee berry borer by thge Coffee Industry Development Company (CIDCO) is an example of an effective IPM programme. CIDCO engaged scientists at the University of the West Indies (UWI) and CARDI to develop an IPM strategy that would minimize pesticide use. The borer is now controlled by keeping the ground clean of fallen berries from trees, stripping off all unharvested berries from the trees, and spraying with endosulfan once or twice between May and August (Mansingh 1986).

The Dominican Republic MIP project has been set up principally to resolve the problems of whitefly-vectored virus damage on tomatoes, with a view to extending the work subsequently into other areas. It involves an institutional arrangement between the government (GoDR) and the private sector in the form of Junta Agroempresarial Dominicana Inc (JAD); set up in conjunction with the GoDR.

IPM technologies have been pursued in order to control the whitefly, including: scouting; avoiding the use of pyrethroids; use of selective and less toxic chemicals; fewer applications avoiding times of predator activity; and rotation of crops (Dupuy and Sencion, undated). This has led to the virtual elimination of whitefly on tomatoes, but not to the elimination of the virus which has the potential to cause considerable damage

It is important in situations which are common in the Caribbean and Central America, where farmers are contracted to commercial companies to grow crops, that the losses considered are not confined to those experienced by the company – the farmers make additional losses. These principally concern the opportunity cost of not having the land in productive use, but are also likely to involve the farmer's investment of his own management and labour. Also, we are dealing with small farmers who are heavily dependent on the crop and for whom, in the absence of a readily available alternative, the costs of crop failure have an extremely high social cost.

An encouraging start has been made with research, validation, diagnosis and transfer of technology. An admirable attempt is being made to develop an appropriate mechanism to bring the results

of this work into the farmer's sphere. A number of suggestions are made below as to how impact can be improved during the forthcoming second phase:

- Closer consultation with farmers to enlist their involvement in the technology development process.

- The technical approach to the problem of development of resistance to pesticides needs to be broadened to consider socio-economic factors. We need to understand why farmers do what they do – the factors which underlie and influence their pest management practices – if we are to persuade them to adopt different methods.

  The validation work needs to recognize differences between farmers' resource bases and constraints. It is unlikely that one approach can be used by all farmers. Farmers need to be able to either choose from alternatives, or, if management is limited to one control option, research must focus on how farmers can adapt it to their systems (i.e. it must have flexibility). Is that feasible from a research point of view? The question doesn't appear to have been asked. Compare this for example with plans to undertake a full-scale ecological survey to examine the range of insect life present. Although this is also important, the risk is that if we ignore the farmer's context, the emerging technologies will be inappropriate and they will be unable to adopt. Balance is advocated for allocating resources between diverse disciplinary activities in order to make the necessary progress on a broad front.

Conclusions

There is a wide range of political, legal, trade, social, economic, technical and institutional factors which influence pest control practices on smallholder farms in the Caribbean. In given situations, they vary in importance, although it is probably safe to assume that none of them can be ignored entirely.

Amongst these, crop protection specialists concerns (those within their sphere of influence) are largely limited to technical, institutional and socio-economic constraints. Technical constraints are those which receive by far the greatest attention – through research to better understand causal factors and develop methods for pest control. Institutional constraints have been an neglected area. There is considerable potential for a more rational use of scarce resources through improved linkages between national and international institutions. Attendance at this meeting bears testimony to interest in strengthening these linkages.

It is, however, in the sphere of socio-economics that perhaps the greatest potential lies for improving the pace of IPM implementation. Although work in other Caribbean countries and internationally can help provide insight, it is the local situation that is most pertinent. There are good prospects for encouraging results through the involvement of farmers in the technology development process. A better understanding of the farmers' resource base, constraints and perceptions lies within the grasp of the natural and social scientist. This can be generated through inter-disciplinary work and contribute to appropriate research and extension which guides effective crop protection.

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THE STATUS OF CURRENT STRATEGIES IN JAMAICA FOR CONTROL OF WHITEFLIES AND RELATED DISEASES

M M Alam, J Reid
Caribbean Agricultural Research and Development Institute, Jamaica

A Mansingh
The University of the West Indies, Jamaica

The sweet potato whitefly, *Bemisia tabaci* (Gennd.) is a cosmopolitan pest, attacking over 500 species of plants in 74 families throughout the world (Butler and Henneberry 1985; Cock 1986, 1993; Gerling 1990). It is considered an important pest of cotton, cucurbits, lettuce, soya bean, tomato and over 500 ornamental and garden plants (Osborne 1992). More recently, it has become of increasing importance as a pest of field crops and as one of the most serious pests of greenhouse plants (Osborne et al. 1990).

In the Caribbean,the sweet potato whitefly (SPW) has been reported from the Greater and Lesser Antilles (Fennah 1947). In Barbados, it was reported as a minor pest on sweet potato, *Ipomoea batatas*, during the 1970s (Bennett and Alam 1985) and in Grenada and Dominica as a serious pest on cole crops, eggplant and cucurbits (Alam 1978–85, unpublished reports).

While SPW has long been present in Jamaica, its importance was associated with the occurrence of golden mosaic virus on red kidney bean, *Phaseolus vulgaris*. It was considered as only a minor pest on cole and other crops. Even after outbreaks of this pest had been reported from the Dominican Republic in 1989, Jamaica remained apparently free of the problem. However, by August 1990, there were reports of marked increases in numbers and in the apparent host range of *B. tabaci*. Major losses were reported in tomato and some changes noticed in the appearance of cucurbits, especially cucumber (*Cucumis sativa*), pumpkin (*Cucurbita maxima*) and water-melon (*Citrullus vulgaris*).

The present report provides a brief review of recent developments of this problem, comments on the present status and suggests possible approaches to loss reduction.

Nature of damage

The adults and immature stages of the whitefly suck sap from the lower surface of the leaves, causing stunting and mottling. The honeydew secreted by the pest falls on the lower leaves. The sooty mould which develops on this may interfere with photosynthesis, makes the crop look unhealthy, and lowers its marketability.

The pest is also known to transmit a number of viruses, such as the geminiviruses which cause stunted, distorted growth and significant size reduction in tomatoes, necrosis of peppers and silverleaf disorder in pumpkins (Brown and Bird 1990). The uneven ripening of tomato fruit is also considered to be associated with feeding by the nymphs (Gerling 1992). While no viral symptoms have yet been reported for cabbage, the crop can suffer serious physical and cosmetic damage caused by large populations of the pest.

The exact etiology of the Gemini virus infection on tomato is not yet fully known, but useful information is already available from scientists in Florida (R Yokomi, USDA, Orlando; D Schuster, IFAS, Brandenton, through D Gerling, personal communication). Infected tomato plants are the only source of the virus. It is not transmitted through the seeds. Once an adult SPW has fed on an infected plant for a minimum of half-an-hour, it remains infectious for its 2–4-week lifespan. All SPW strains can transmit viruses, although their efficiency varies. While plants may be infected from the time of seed germination, symptom expression need not

occur until the flowering stage. Greatest damage is done when infection occurs within the first 2 months after seed germination. Plants infected after the onset of flowering are able to produce a reasonable crop although they become a source of infection for younger plants.

Systems of production

Peculiarities or constraints in the systems of production for the target crops are important considerations in any assessment of pest management needs. *P. vulgaris* is produced on individual lots of <0.2ha by small farmers who have adopted practices borne of 'traditional wisdom'. The majority cultivate this crop on hillsides where the cooler temperatures provide protection from *B. tabaci* activity. Cultivation on the lower-lying hotter areas is usually restricted to the cooler months of September to January/February.

Cultivation of solanaceous and cucurbitaceous crops follows a similar pattern. Tomatoes, sweet (bell) peppers and hot peppers (*Capsicum* spp.) are grown in pure stands on small plots of land ranging from 0.02 to 1 ha. Cucumbers and melons are grown separately or as companion crops on plots adjacent to the tomatoes. In a very few instances melon, pumpkin and tomato were observed in a mixed system. Climatic and soil types vary considerably from the dryland 'mulch' system used in south St Elizabeth to the irrigated plains of St Catherine and Clarendon.

Table 1. Changes in the production and value of selected crops in Jamaica, 1989–1992

Parameter	1989	1990	1991	1992
Total area reaped (ha)				
Pumpkin	1,161	1,949.1	2,003.8	2,193.3
Tomato	1,799	1,245.6	1,058.1	1,173.9
Cucumber	721.4	710.0	593.8	728.0
Melon	277.3	315.7	303.2	436.9
Yield (tonnes/ha)				
Pumpkin	14.5	13.2	12.8	-
Tomato	4.5	10.7	10.5	-
Cucumber	12.5	11.0	10.4	-
Melon	16.0	13.8	14.3	-
Total production (tonnes)				
Pumpkin	26,120	25,931	26,244	34,187
Tomato	16,832	14,102	10,963	14,068
Cucumber	9,042	8,148	6,520	9,137
Melon	4,439	5,405	4,697	8,103
Value (J$'000)				
Pumpkin	129,033	146,421	214,241	38,111
Tomato	382,760	143,719	179,139	34,508
Cucumber	46,838	44,990	52,959	74,713
Melon	31,206	37,378	44,999	106,903
Price (J$'000/tonne)				
Pumpkin	4.94	5.73	8.09	11.15
Tomato	22.74	11.80	17.12	24.53
Cucumber	5.18	5.56	7.96	11.00
Melon	7.03	7.17	9.41	13.19

- No data available

These crops are important to the small farmers because they attract good prices on the local market and provide them with a comparatively lucrative opportunity to enter the export trade via the Cayman Islands or niche ethnic/gourmet markets overseas. Data in Table 1 summarize changes in the area, volume and value of these crops between 1989 and 1993. Tomato is clearly the most profitable to the small farmer with returns of J$11,800 (US$390) to 24,500 (US$817) per tonne. The very significant increases in price of the commodities in 1992 compared with 1989–1991 are a combined reflection of the fall in the value of the Jamaican dollar and, even moreso, the ravages of SPW damage. Perhaps of greatest significance is the reduction in overall value of the production of nearly J$600 million in 1989 to about J$250 million in 1992.

Whereas for *P. vulgaris*, many of the tasks of production are performed by the farmers and their immediate family, the more profitable cultivation of the Solanaceae and Cucurbitaceae attract high cost inputs of labour and agrochemicals. Additional labour is hired to assist with all practices but especially those for land preparation and pesticide application.

For some farmers, seedlings of the Solanaceae are produced in one batch in a seedbed and used to grow a crop of uniform age. For others, seedling production occurs intermittently within the area being cultivated in order to facilitate a regular supply for continuous planting. Plants of different ages are thus often present in the field. Age of the crop from different holdings also varies since time of planting on any holding is influenced by other domestic demands on the farmers' time as much as on weather.

Cultivation of ornamentals for home or commercial purposes is also at risk. A major, well-known, alternate host of *B. tabaci* is the poinsettia, *E. pulcherrima*, a favourite with Jamaican homeowners. The popularity of the imported miniature plant has increased at Christmastime and its importation is implicated in the appearance of the virulent *B. tabaci* strains in Jamaica. Other ornamentals are generally grown under shadehouses and tend to be monocultures of favoured species. The zero tolerance for disfigurement of foliage plants has long caused them to be subjected to routine applications of 'prophylactic' pesticide treatments.

Recent history of *B. tabaci* activity

Increasing reports of the 'epidemic' proportions of the whitefly populations led to surveys being carried out in different parts of the island from October 1991 to February 1992. Comparatively high populations were reported on cabbage, cauliflower, eggplant, cucurbits and tomatoes. By February 1992 it was evident that, while the pest was present in all areas visited, there were sites where incidence of viral damage was not as prominent. The pattern of disease incidence suggested that the disease was spreading from west to east (Gerling 1992). The pest was causing heavy crop damage with geminivirus symptoms evident in tomatoes and silverleaf disorder in cucurbits. The latter has also been reported from Florida and is believed to cause some loss in quality and quantity of production (Gerling 1992).

The populations of *B. tabaci* were exceedingly high on cabbage, sweet and hot peppers (*Capsicum* spp.), pumpkins, 'susumba' (*Solanum torvum*), and milk weeds (*Euphorbia* spp.) in the Portland area. At the Ministry of Agriculture Experimental Station, Bodles, St Catherine the first serious outbreak was observed on cabbage in May 1992, and later it also attacked water-melon (*Citrullus vulgaris*), pumpkin (*C. maxima*), cucumber (*C. sativus*), and papaya (*C. papaya*).

After the surveys done in 1992, it has been difficult to obtain reliable, consistent, quantifiable information on the extent of the areas affected and the degree of loss experienced. However, even from crude estimates, the situation is understandably critical. In the four major parishes where production is largest, over 1,000 farmers have been affected this year, direct losses have ranged from 30 to 100% of the crop. From 50to >80% of them have indicated that they intend to replace tomato cultivation by melon, pumpkin, escallion and thyme.

As observed earlier by Gerling (1992), most farmers now understand the relationship between the whitefly and the disease which they call 'jherri curl' because of the severe distortion evident in badly affected plants. Several approaches to control have been tried. Some are based on trial and error combining farmers' observations with some knowledge of pesticide selectivity. One field in 1992 had combined early 'roguing' of infected plants with application of dimethoate and had managed to produce a satisfactory crop. However, within 2 months, a return visit revealed all old plants with the virus which had also spread to >20%of the younger plants. Another farmer moved his seedling nursery to new location, seeking to protect the seedlings from infected mature plants at the first site. Some have attempted to 'rotate' to another subplot on the same holding.

In the majority of cases,however, the response is random use of any available pesticide, almost always applied incorrectly and at intervals of too short or extended duration. Some reported that, because of SPW, they have made seven rather than three applications in one crop season. Chemicals used include fenpropathrin (Danitol®), diafenthiuron (Pegasus®), pirimi-phos methyl (Actellic®), deltamethrin (Decis)®, fenvalerate (Belmark®), Karate®, dimethoate (Perfekthion®), malathion, dicrot-ophos (Bidrin®) endosulphan and profenofos (Selecron®). Innovative farmer practice has included Jeyes® liquid disinfectant. Farmers have also remarked that they observed adults dying when they rested on tobacco leaves. There are unsubstantiated reports that the use of Dipel® or Thuricide® has been observed to enhance the control of the pest.

Table 2. Host plants attacked by sweet potato whitefly, *Bemisia tabaci*, in Jamaica

Common name	Scientific name
Amaranth	*Amaranthus viridis*
Amaranth	*Amaranthus spinosa*
Beans	*Phaseolus vulgaris*
Blackeye beans	*Vigna unguiculata*
Broad beans	*Phaseolus lunatus*
Broccoli	*Brassica oleracea* var. *italica*
Cabbage	*Brassica oleracea* var. *capitata*
Canteloupe	*Cucumis melo*
Cauliflower	*Brassica oleracea* var. *botrytis*
Cucumber	*Cucumis sativus*
Eddoe	*Colocasia esculanta*
Eggplant	*Solanum melongena*
Hot pepper	*Capsicum annuum*
Jamaican ackee	*Blighia sapida*
Mint	Prob. *Mentha* sp.
Milk weeds	*Euphorbia glomifera*
	Euphorbia heterophylla
	Euphorbia hirta
Okra	*Abelmoschus esculentus*
Papaya	*Carica papaya*
Poinsettia	*Euphorbia pulcherima*
Pumpkin	*Cucurbita maxima*
Shrimp plants	*Pakistashia* spp.
Sweet pepper	*Capsicum annuum* var. *grossum*
'Susumba'	*Solanum torvum*
Tomato	*Lycopersicon esculentum*
Water-melon	*Citrulus (=vulgaris) lanatus*

Role of alternate host plants

During these studies, the pest was found throughout the country feeding and breeding on 28 host plants (Table 2). It is possible that there may be a number of other cultivated and wild plants attacked by it, which have not yet been detected. During the presence of cultivated host plants, the activity of the pest is usually confined to these, although a small number of adults and immature stages feed on certain weeds. Some of these host plants may not be very conducive to the rapid build-up of the pest, but their presence ensures its survival during critical periods such as when the main host plants are not in the field. On such plants the pest also avoids the direct effect of chemical pesticides, which are mostly applied to the economic crop .

Role of natural enemies

A large number of natural enemies, namely five species of encyrtid parasites, seven species of coccinellids, one chrysopid, three syrphids, and three species of entomogenous fungi were recorded for the first time attacking *B. tabaci* in Jamaica. *E. hispida* was the most common parasite, whereas, the population of *E. nigricephala, E. quintancei, E. formosa* and *Eretmocerus* sp. was low (Table 3).

At times, the populations of *Paecilomyces* and prob. *Zoophthora* sp. were fairly high, whereas, *Aschersonia* was only recorded once from Portland. Two spiders, *Chrysso pulcherrima* and *Theridula gonigaster* were common on the underside of the leaves of various host plants, including cabbage. *Stethorus caribus* and *Delphastus nebulosus* were common during heavy infestations, while the other coccinellids, syrphids and chrysopid larvae were frequently found feeding on the pest. Other potential natural enemies were observed during a brief survey in Barbados in 1990/91. These were: *P. fumosoroseus, C. sanguinea, Diomus* spp., *C. lanata, C. limitata, E. hispida* and *E. nigricephala*, attacking *Bemisia* on cabbage, cauliflower and eggplant (M M Alam, 1990-91, personal observation).

In spite of different levels of parasitism during the year, their significance as biocontrol agents cannot be ignored. At times, the combined mortality caused by these natural enemies approximated 33% at Bodles and about 44% at Portland, resulting in an appreciable reduction in pest populations (Table 4). Osborne et al. (1991) stated that the 4th instar nymphs of *B. tabaci* were rapidly infected and killed by high concentrations with more than 90% mortality occurring within 72 hours. The preservation of such natural control agents is essential to keep the pest population under control. Rao et al. (1989) reported that three species of aphelinids, coccinellids, phytoseiid mites and fungi, had a direct effect on whitefly populations.

Implications for Jamaica

Several of the problems described above point to fundamental issues that need to be addressed for any successful IPM programme in Jamaica. The present crisis related to SPW must have been influenced by the inappropriate, ill-timed use of pesticides impacting continuously on the variety of host plants of *B. tabaci* – cultivated or wild.

The erratic population explosions on cabbage and lettuce could have been caused by the sudden switch by many farmers to the less selective pyrethoids capable of further disruption of the indigenous natural enemy complex. The dilemma is clearly compounded where farmers and information transfer agents conditioned to focus on pesticides are challenged by a pest that rebuts such attempts by its phenomenon of hormigliosis (Gerling 1992). The challenge is further complicated by the pest's ability to shelter in several refugia that make penetration by pesticides even more difficult.

Gerling (1992) provided valuable recommendations for the short term containment of SPW attack (Table 5). The strategy involves several basic components of IPM which should be incorporated as elements of good crop husbandry. Chief of these are proper field sanitation to reduce the source of inoculum, use of physical

exclusion and/or very selective pesticides to ensure virus-free planting material of uniform age, as well as protection of transplanted seedlings for at least 2 months.

Table 3. Natural enemies of sweet potato whitefly, *Bemisia tabaci*, recorded during 1991–93 in Jamaica

Parasites

HYMENOPTERA
Encyrtidae
Encarsia hispida De Santis
Encarsia nigricephala Dozier
Encarsia quintancei Howard
Encarsia formosa Gahan
Eretmocerus sp.

Predators

COLEOPTERA
Coccinellidae
Coleomegilla maculata (De Geer)
Cycloneda sanguinea (L.)
Delphastus nebulosus Chapin
Diomus sp.
Hippodamia convergens (Guer.)
Hyperaspis connectens (Thunbg.)
Stethorus caribus Gordon and Chapin

NEUROPTERA
Chrysopidae
Ceraeochrysa claveri Navas

DIPTERA
Syrphidae
Pseudodoros clavatus (Fab.)
Toxomerus dispar (Fab.)
Toxomerus watsoni (Fab.)

ARANEA
Theridiidae
Chrysso pulcherrima Malls-Leitao
Theridula gonygaster (Simon)

Entomogenous fungi

Aschersonia aleyrodis (Zimm.)
Paecilomyces fumosoroseus (Wize.)
Prob. *Zoophthora* sp.

There are socio-economic issues that are also to be considered. The most critical is that any successful IPM programme for SPW depends heavily on community participation. Innovative ways have to be found to overcome the wariness of many of these farmers to exposing themselves to undetermined risks and surrendering their independence to ensure cooperative effort. In addition, implementation of the changes proposed requires patience, careful planning, active collaboration of scientist, extensionist and farmer in a pilot area where strategies will incorporate non-chemical control measures that are cost-effective, practical and adaptable to the local systems of production. Such collaboration is not easy to achieve since it assumes some sacrifice of individual interests for the benefit of ensuring the successful development of a strategy that is appropriate to the farmers' needs.

A longer-term strategy is necessary in order to ensure sustained improvement in *B. tabaci* control (see Table 6). Emphasis must be placed on: providing practical information to determine the exact nature of the pest-virus complex; testing exotic and indigenous potentially effective natural enemies; and clarifying the relationships between pest/natural enemy/pesticide in different ecozones. In addition, reliable information must be collected on the scale of loss (qualitative or quantitative) incurred after pest attack. The final requirement is the establishment of a sustainable base of highly trained scientists and extension agents invigorated by the institution of regional and international linkages.

Table 4. Percentage of parasite and fungal induced mortality of *B. tabaci*, on cabbage sampled at four localities in Jamaica

Location	No. SPW observed	Percent mortality Min.	Max.	Mean	Natural enemy (% mortality caused)
Bodles, St Catherine	49,791	0.02	33.0	19.9	*Paecilomyces* (13%) *Zoophthora* (6%) Others (0.9%)
Long Bay, Portland	45,876	0.00	43.9	4.2	*Zoophthora* (1.8%), *Paecilomyces* (1.6%), Others (0.8%)
Douglas Castle, St Catherine	3,112	0.32	23.4	3.3	*E. hispida* (1.3%), *Paecilomyces* (0.8%), *Zoophthora* (0.8%), Others (0.4%)
Castle Kelly, Clarendon	6,452	0.00	2.1	1.8	*E. hispida* (1.2%), Others (0.6%)

Table 5. Summary of strategies recommended for short term reduction of *B. tabaci* damage to tomatoes in Jamaica (Gerling 1992)

	Objective	Steps to be taken
a.	Sanitation	Completely clean field Uniform tomato plant age Area as large as possible
b.	Obtaining clean planting material	
	- Screening	Seeds planted in a small completely screened enclosure. Screen mesh at least 25 by 50 holes per linear 2.5 cm On a community basis with several growers sharing the same nursery stock
	- Mulching	Use of yellow or orange straw or plastic sheet Place at ground level
	- Insecticides	Weekly application of materials effective against whitefly adults, e.g. detergents (Zohar®, LQ-215) and insect growth regulators (IGRs) – buprofezin and pyroproxyfen.
c.	Protecting field tomatoes	Ensure protection – by insecticides, mulch, screen etc. – until plants approximately 2 months old
d.	Prevent importation of other SPW strains	Strict, effective quarantine – regulations and inspection

Table 6. General recommendations for strategies to ensure long-term reduction in *B. tabaci* damage

- Determining the exact nature and host plant ranges of tomato infecting viruses
- Training of personnel
  - Recognize the components of the problems
  - Know the technology for implementing control
- Use of multi-disciplinary teams including:
  - Virology
  - Biological control
  - Integrated pest management
  - Natural enemy introduction: introduction and establishment of more species-specific, efficient enemies should be undertaken
  - fungal epizootics
- Further research
  - The dynamics of SPW. Yearly cycle of the pests – in the west (Manchester, St Elizabeth etc.), the Central hills, and the east (especially east St Thomas and Portland).
  - Insecticidal effectiveness
  - The spread, kinds, hosts, and effects of SPW-transmitted and other viruses and plant disorders should be determined
  - The possibilities for biological containment of SPW through natural enemy utilization:
    - Introduction
    - Conservation
    - Fungal application

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ESTRATEGIA PARA LA DISMINUCION DE LA INCIDENCIA DEL VIRUS GEMINI EN EL CULTIVO DE TOMATE Y CHILE TABASCO EN HONDURAS

K Sponagel
Fundación Hondureña de Investigación Agrícola, Honduras

Strategies for the reduction of incidence of the geminivirus in cultivars of tomato and tabasco pepper in Honduras

In 1990 the Fundación Hondureña de Investigación Agrícola (FHIA) initiated a programme of applied research on whiteflies and their transmission of viruses onto vegetable crops, principally tomato and tabasco pepper. The studies were carried out at the FHIA station in the Comayugua Valley, as well as on several farmers' fields in the Comayagua and Yoro Valleys, and the La Lima/Progressoregion. The objective was to develop an IPM approach that was effective and economical. *Bemisia tabaci* has been recovered from 445 plant species representing 356 families and was present in all the climatic zones in the country. In 1989, virus reduced tomato yields in Comayugua by 50%; use of an IPM programme reduced the loss to 10%. The paper describes the development and spread of the infestation. The IPM approach included the use of mechanical, cultural, biological and chemical methods. Mechanical methods included: protection of the nursery from whitefly until the plants were about 22 days old; use of plastic mulch (particularly black) – this gave a significant relative reduction in infestation of the whitefly vector (from 100 to 12.9% after 31 days). Culturally, high plant densities had significantly less virus infestation. The time of planting also had a marked effect on the beginning and level of infestation of whitefly. Out of 11 insecticides tested, fenpropathrin applied twice per week gave 80% control of whiteflies. The natural insecticide, neem, performed much better than the control. A fully integrated IPM approach is in operation resulting in a population of 0.2 whiteflies/plant and a virus infestation of less than 10% in the field.

Los Departamentos de Protección Vegetal y de Hortalizas de la Fundación Hondureña de Investigación Agricola (FHIA) han venido trabajando desde 1990 en un programa de investigación aplicada con la presencia de la mosca blanca (MB) y su actividad transmisora de virus en los campos hortícolas hondureños. La investigación se concentró en los cultivos de tomate (*Lycospersicon esculentum*) y chile tabasco (*Capsicum frutescens*). Los estudios y experimentos fueron ejecutados en la Estación Experimental de Hortalizas de la FHIA ubicada en el Valle de Comayagua (Las Liconas) y en varios proyectos de asesoramiento en plantaciones particulares en el Valle de Comayagua, Valle de Yoro y la zona La Lima/Progreso.

El objetivo de la FHIA en este programa de investigación aplicado del manejo integrado de la MB en Honduras es asegurar la implementación de los cultivos de tomate y chile tabasco en el plan de producción agropecuario nacional, los cuales presentan en la actualidad perspectivas económicas favorables, en razón de la demanda local e internacional existente.

Presencia de la mosca blanca en Honduras

La existencia de *Bemisia tabaci* representa por su actuación de trasmisor del virus gemini, el factor clave para la producción de tomate (*Lycospersicon esculentum*)) y chile (*Capsicum annuum* y *C. frutescens*) en Honduras. El daño directo del insecto por el succionamiento de la savia y la formación de fumagina sobre las excreciones de la MB generalmente es poco significativo.

La raza predominante del insecto plaga en el país es la Raza A (R Caballero, comunicación personal). Se estableció que *B. tabaci* ataca en Honduras 445 especies silvestres y cultivadas provenientes de 35 familias botánicas y se presenta en todas las zonas climáticas del país.

La gravedad del complejo MB/virus gemini se hizo evidente en el Valle de Comayagua a partir del año 1989 cuando el rendimiento de tomate de 50–65 t/ha declinó a raíz de este problema a menos de la mitad con una producción de 25–30 t/ha. Con el empleo de un concepto integrado del manejo se logra limitar el daño a una perdida cuantitativa de menos del 10% del potencial de rendimiento, – aunque con costos más altos de producción.

Desarrollo de la infestacion

Los adultos MB inician su ataque a las plantas de tomate y chile en estado temprano cuando forman las primeras hojas y en el caso de provenir de un vivero protegido inmediatamente después del transplante.

Los adultos inmigran de campos vecinales, son arrastrados por el viento y en el caso de plantaciones no libres de malezas infestan el cultivo desde adentro del campo. Por medio de la colocación de trampas cilíndricas de color amarillo se observó que la mayor parte de los adultos inmigrados son transportados pasivamente por corrientes de aire, en tanto que sólo una minoria de las moscas se mueve activamente hacia las plantaciones. La capa más frecuentada por los adultos migratorios es la zona que llega hasta 50 cm encima de la cama de siembra.

El nivel de infestación (adultos MB/planta) asciende linealmente con el tiempo por la por la llegada de nuevos adultos inmigrados (Figura 1). A partir del 30.–40. día despuós de la primera infestación por adultos el grado de infestación asciende drásticamente por la eclosión de la primera generación de adultos sedentarios (descendencia de los adultos inmigrados).

En el caso del tomate con un ciclo corto este nivel se mantiene hasta la cosecha. En plantaciones de tomate adecuadamente manejadas se observó por lo general niveles naturales de infestación de la MB que no superaban 50 adultos/planta en el período previo a la cosecha. Razón por la que no fue notable en este cultivo la presencia de fumagina en las hojas. Contrariamente en el cultivo de chile tabasco con un ciclo mucho más largo donde se desarrollan varias generaciones las poblaciones de la MB explotan y encontrar miles de adultos de MB es común. Bajo esta alta infestación del insecto plaga se presenta también en gran escala fumagina en los dos lados de las hojas.

Transmision del virus gemini

Todos los parámetros obtenidos por los experimentos indican que las poblaciones MB existentes en las zonas de estudio son altamente portadoras del virus gemini. Si los niveles de infestación en el cultivo de tomate en las primeras tres semanas después del transplante se encuentran por encima de 0.5 adultos/planta se obtiene un grado de incidencia viral de 100%. Con un nivel de 0.05–0.15 adultos/planta se obtienen grados de incidencia viral de 8-20% entre las plantas de tomate. Para lograr una incidencia del virus gemini por debajo del 8% el nivel de MB debe mantenerse bajo 0.05 adultos/planta, lo que significa que debe encontrarse sólo 1 mosca por 20 plantas de tomate.

El periodo de incubación (infección – primeros síntomas) en tomate con la variedad M-82 fue determinado por lo ensayos en promedio en 15 días (mínimo 12 días; máximo 18 días). Se observó en todos los experimentos la presencia de una resistencia por edad. Esto es, cuando la planta de tomate no muestra los síntomas de la virosis hasta el 48. día después del transplante (valor promedio – mínimo 42. día; máximo 54. día) la planta no presentará los síntomas típicos posteriormente (Figura 2). Si se descuenta de la edad de 48 días el tiempo de incubación (12–18 días) únicamente el succionamiento de la MB en las primeras 4 semanas después del transplante es importante para la trasmisión del virus. Lo

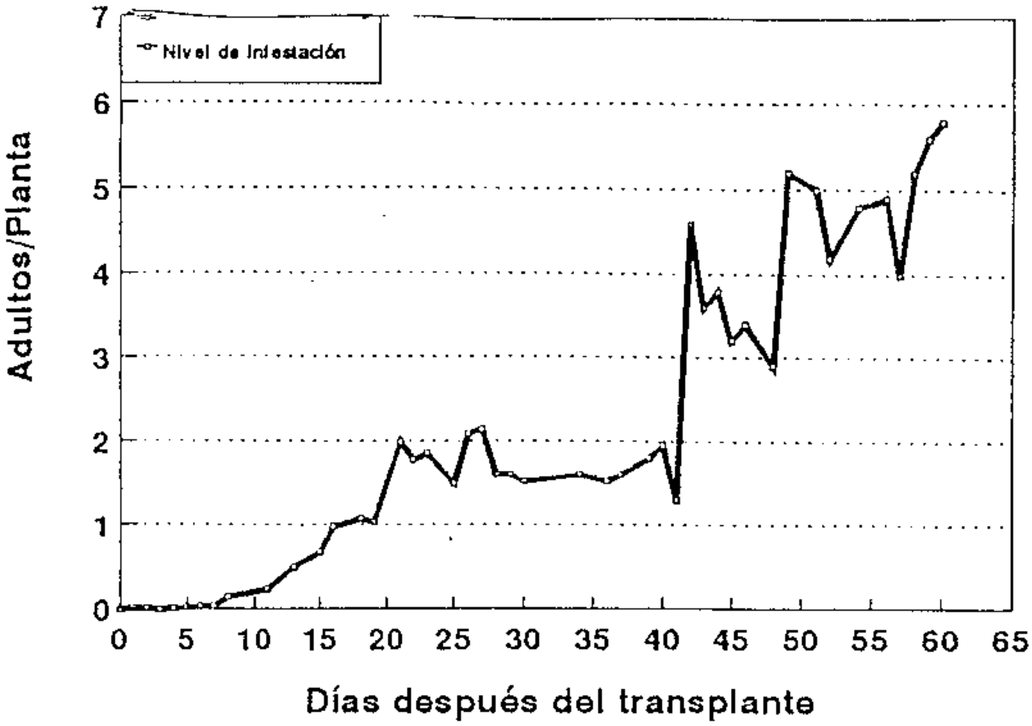

Figura 1. Desarrollo de la infestación de la MB en una plantación de tomate sin aplicación de isecticidas.

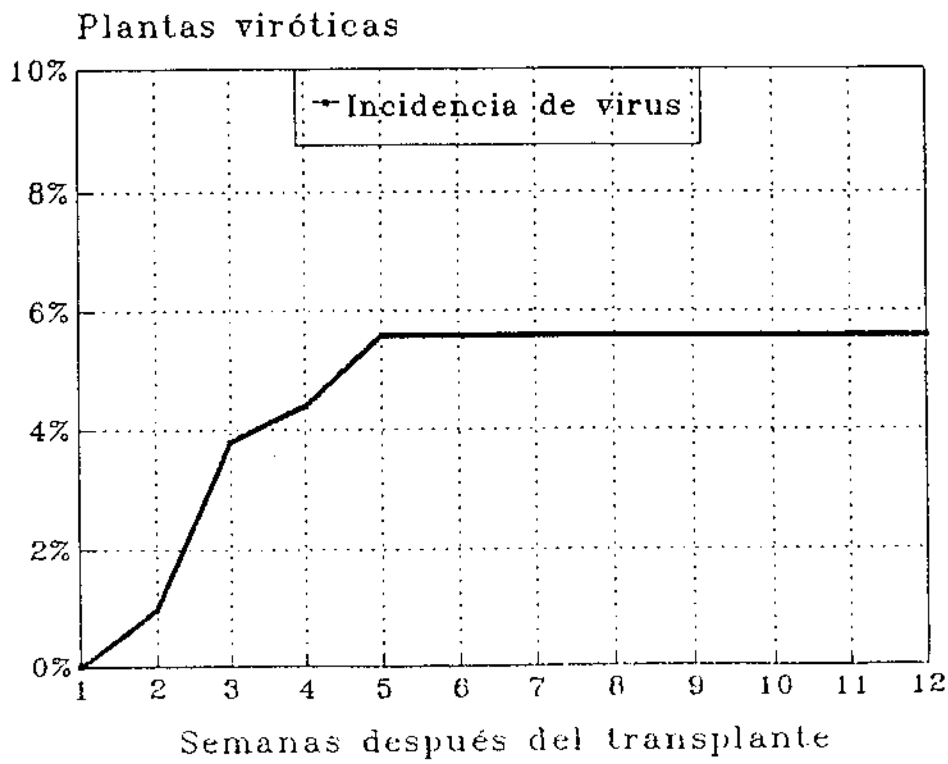

Figura 2. Desarrollo de la incidencia viral en una plantación de tomate con aplicaciones de insecticidas

que significaría que la planta de tomate es resistente al virus gemini a partir de la quinta semana después del transplante y medidas de control de la MB para prevenir la transmisión viral sólo tienen sentido en el primer mes del cultivo. Este período es determinante para el éxito del método de control utilizado – mientras más tiempo se puede extender el período después de la siembra o transplante libre de ataques de la MB, menos grave será el perjuicio causado por la enfermedad virótica. Estas observaciones como se mencionó anteriormente se realizaron con la variedad M-82.

Los datos obtenidos con chile tabasco muestran que este cultivo tolera la presencia de la MB en mayor medida. La incidencia viral es por lo general menor, encontrándose al final del ciclo un grado de incidencia de sólo 50–70% sin tomarse medidas de control contra la MB.

Medidas de control

Para la elaboración de conceptos de control de la MB accesibles tanto para horticultores pequeños como para grandes se ejecutó en el lapso de los últimos tres años experimentos de campo con medidas mecánicas, culturales, biotecnológicas y quimicas.

Medidas meciánicas

Viveros protefidos

Experiencias en las regiones de estudio demuestran que la siembra directa de tomate conduce bajo las actuales condiciones de la presencia de MB, aún con control químico, a una incidencia del virus de 100% con una reducción drástica en el rendimiento. Frecuentemente horticultores perdieron en su totalidad la cosecha a causa de la infección con la enfermedad – razón por la cual debe descartarse la siembra directa del tomate.

La tecnología que permite retrasar la infección viral en la planta consiste en desarrollar semilleros totalmente sellados con una malla adecuada para proteger las plántulas de los ataques de la MB. Las plantitas permanecen 18-22 días en el vivero protegido hasta alcanzar el tamaño apropiado para ser transplantadas al campo.

Uso de mulch plástico

El empleo de diferentes colores de mulch plástico fue uno de los focos de investigación de los departamentos de la FHIA. El método consiste en la cobertura de la cama de siembra con una lona plástica. Las ventajas agronómicas que ofrece esta técnica son los propósitos primarios de la exposición de la cobertura plástica: facilitar el control de malezas, preparación anticipada de la tierra, ahorro de agua de riego y producción de frutos limpios para el mercado. El sistema es difícilmente aplicable para el pequeño productor en razón que el uso del mulch plástico está ligado con el riego por goteo que requiere altos costos de instalación y exige mantenimiento técnico permanente.

Se observó en las plantaciones de tomate con el mulch plástico, comúnmente de color negro, grados de infestación de la MB significativamente menores en comparación con plantaciones sin la cobertura. A raíz de estas observaciones se inició ensayos con coberturas plásticas de diferentes colores.

En un ensayo de campo en una área de 2,400 m^2 (25 parcelas tratadas y 25 parcelas de separación; tamaño de una parcela 48 m^2; cinco tratamientos; cinco repeticiones) sin aplicación de insecticidas, se advirtió que en las primeras 4 semanas después del transplante se presentó en el tratamiento con mulch plástico de color negro sólo el 13% de las moscas adultas presentes en el testigo (sin plástico). Dentro de los diferentes colores probados el color más repelente resultó el blanco (Tabla 1, Figura 3). Aún cuando estos resultados sorprendentes establecidos en parcelas pequeñas no se podria lograr en plantaciones grandes, muestran claramente los efectos positivos que tendria el uso de coberturas plásticas en la prevención de la infestación de la MB.

Tabla 1. Efectos repelentes del uso de coberturas plásticas contra los adultos de la MB. Durante el tiempo de evaluación (31 días después del transplante) sin aplicación de insecticidas

Color mulch plástico	Nivel promedio MB durante 31 días (adultos/planta)	Infestación relativa (%)
Testigo (sin plástico)	9.0	100.0
Negro	1.16	12.9
Aluminio	0.68	7.6
Gris	0.38	4.2
Blanco	o0.34	3.8

En dos ensayos de campo con diferentes colores de coberturas plásticas ejecutados con aplicaciones de insecticidas se observó la superioridad de los colores blanco, gris y aluminio sobre los colores negro, marrón, café y amarillo con respecto a la repelencia a la MB.

Los efectos repelentes son visibles únicamente en las primeras 4–6 semanas después del transplante debido a que el follaje cubre completamente después de este periodo las lonas plásticas expuestas (Figura 3).

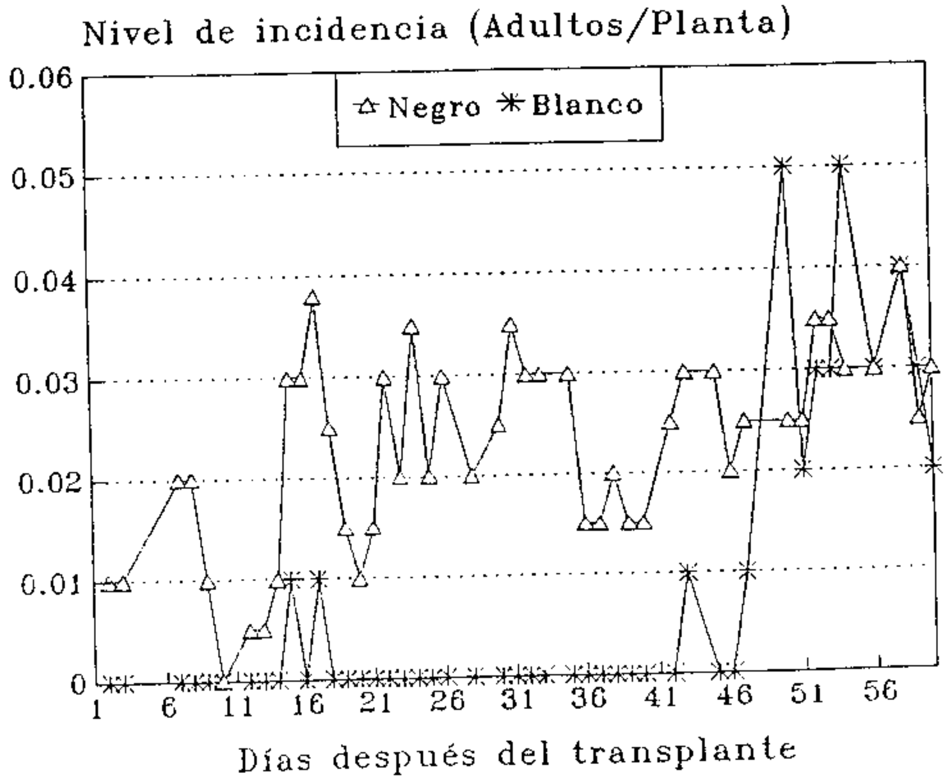

Figura 3. Nivelación de los efectos repelentes de diferentes colores de mulch plástico en el transcurso del ciclo del tomate

Las observaciones realizadas en Honduras demuestran que el uso de mulch plástico de preferencia de color blanco es una medida complementaria eficaz en la reducción de la infestación de la MB.

Empleo de trampas de color amarillo

El uso intensivo de trampas plásticas amarillas (lonas con pegante) colocadas verticalmente en las plantaciones de tomate no lograron bajar la infestación del insecto plaga.

Su utilidad en el campo se basa exclusivamente en un sistema de monitoreo para detectar posibles concentraciones de la MB. En los invernaderos protegidos podría servir adicionalmente para el control de la MB, si se encuentran adultos adentro.

Medidas culturales

Crecimiento óptimo del cultivo

La optimización de los factores fitotécnicos en el cultivo como fertilización, variedad adecuada, riego, manejo fitosanitario, etc. es de gran importancia para lograr un crecimiento rápido y vigoroso de la planta. Plantas vigorosas son en menor medida perjudicadas por la infección del virus gemini que plantas con un desarrollo deficiente.

Alta densidad de siembra

Una alta densidad de siembra tiene la ventaja fitosanitaria de permitir la eliminación de plantas tempranamente y/o gravemente infectadas por el virus gemini. Las plantas vecinales compensan durante el ciclo la remoción de dichas plantas. Este método es aconsejable para cultivos que son sembrados generalmente con una baja densidad como el caso del chile tabasco. Se determinó en un ensayo de campo que con una alta densidad de siembra también puede lograrse una reducción de la incidencia viral aún cuando no se remuevan las plantas tempranamente infectadas (Tabla 2). La causa es que la población presente de la MB se distribuye en un mayor número de plantas y la probabilidad de que una planta sea infectada es menor. Es importante señalar que existe una diferencia estadísticamente válida sólo entre la densidad de 69,400 plantas/ha y las densidades de 39,000 y 35,700 plantas/ha (ANOVA; Prueba-t; p=5%).

Tabla 2. Porcentaje de incidencia de virus en diferentes densidades de siembra en el cultivo de tomate. El conteo fue realizado al final del ciclo

Densidad (plantas/ha)	Incidencia de virus (%)	Rango estadístico
69,400	9.0	a
62,500	10.6	ab
56,800	11.8	ab
50,000	12.7	ab
41,700	12.4	ab
39,000	15.0	b
35,700	14.5	b

Siembra sincronizada en la región

Se observó en el Valle de Comayagua, zona donde se cultiva en gran escala tomates, que la incidencia natural de la MB es poco significativa en los primeros meses de la temporada del cultivo de tomate que se extiende desde septiembre hasta mayo, en tanto que en los meses finales ha alcanzado niveles altos de la MB. Este ciclo se explica en razón que la población adulta migratoria de *Bemisia tabaci* existentes en la vegetación natural y en otros cultivos se distribuye a una área más grande cuando las compañías tomateras inician su siembra en cientos de hectáreas. Por ser uno de los principales hospederos para la MB las poblaciones de la plaga suben linealmente hasta el final de la temporada. Es aconsejable por esta razón para los pequeños productores sembrar el tomate o chile al inicio de la temporada.

Medidas químicas

A pesar de la existencia de ciertas medidas eficientes en el control de la MB,

especialmente el uso de viveros protegidos y mulch plástico, la producción de tomate y chile requiere de aplicaciones de insecticidas específicos para obtener una producción satisfactoria de frutos. El objetivo de las investigaciones de la FHIA es la minimización de las aspersiones quimicas para no perturbar el equilibro natural, disminuir el contenido de residuos tóxicos en los frutos alimenticios, evitar intoxicaciones en los seres humanos y animales y obtener una rentabilidad económica favorable por la reducción de costos de aplicación de insecticidas.

Insectcicidas químicos

Se ha evaluado en las diferentes zonas de estudio la eficacia de insecticidas sintéticos mundialmente recomendados para el control de moscas blancas. Cada ensayo fue ejecutado con 6-10 tratamientos, 4-5 repeticiones y con parcelas de un tamaño de 48 m^2 con 240 plantas en el cultivo de tomate y de 90 m^2 con 150 plantas de chile tabasco (área total del ensayo entre 1,100 y 2,400 m^2). Las aplicaciones se realizaron dos veces por semana con una bomba de mochila de motor. Por medio de ciertos insecticidas se logró bajar la infestación de la MB significativamente (Tabla 3, Figura 4). La eficacia máxima alcanzada por un insecticida sintético fue de casi 80%. Resultando como el insecticida más eficiente contra la MB el fenpropathrin.

Cabe destacar que en aplicaciones continuas de un sólo insecticida las poblaciones de la NB forman rápidamente resistencia. Insecticidas que se utilizaron en el Valle de Comayagua inicialmente con éxito en los años 1989/1990, hoy en día tienen únicamente pequeños efectos en el control del insecto plaga. Una rotación de insecticidas provenientes de diferentes grupos químicos es recomendable para no perder su efectividad en un corto plazo.

Insecticidas naturales e insecticidas de baja toxioidad

En varios ensayos de campo fueron evaluados además algunos insecticidas naturales e insecticidas de baja toxicidad. En este grupo se determinó como el más eficaz el extracto acuoso de nim (Tabla 4) aún cuando este insecticida no logró el grado de reducción de la incidencia de la MB alcanzado por los mejores insecticidas sintéticos (Figura 4).

Tabla 3. Insecticidas quimicos efectivos contra *Bemisia tabaci* en tomate y chile en Honduras

Producto	Eficacia
Danitol® (fenpropathrin)	****
Avid® (avermectin)	***
Kelthane® (dicofol)	***
Polo (diafentiuron)	***
Tambo® (profenofos/cypermetrina)	**
Applaud® (buprofezin)	**
Talstar® (bifentrina)	*
Tamaron® (metamidofos)	*
Thiodan® (endosulfan)	*
Ethion® (Ethion)	*
Drawin® (butocarboxim)	*

El uso de aceite mineral presentó efectos sólo cuando se lo asperjó con un equipo de alta presión (del tipo 'boom'). Asperjado con una bomba manual o motor de mochila el producto no mostró efectos en la reducción de la incidencia del virus.

Equipos de aplicación apropiados

Se determinó que un factor importante para un control exitoso de la MB es la selección del equipo de aplicación. Los mejores resultados se obtuvieron con un aspersor de barra acoplado a un tractor que es además combinado con un sistema de ventilación que produce una cortina de aire hacia la capa vegetal (tipo 'boom'). Con este equipo ae

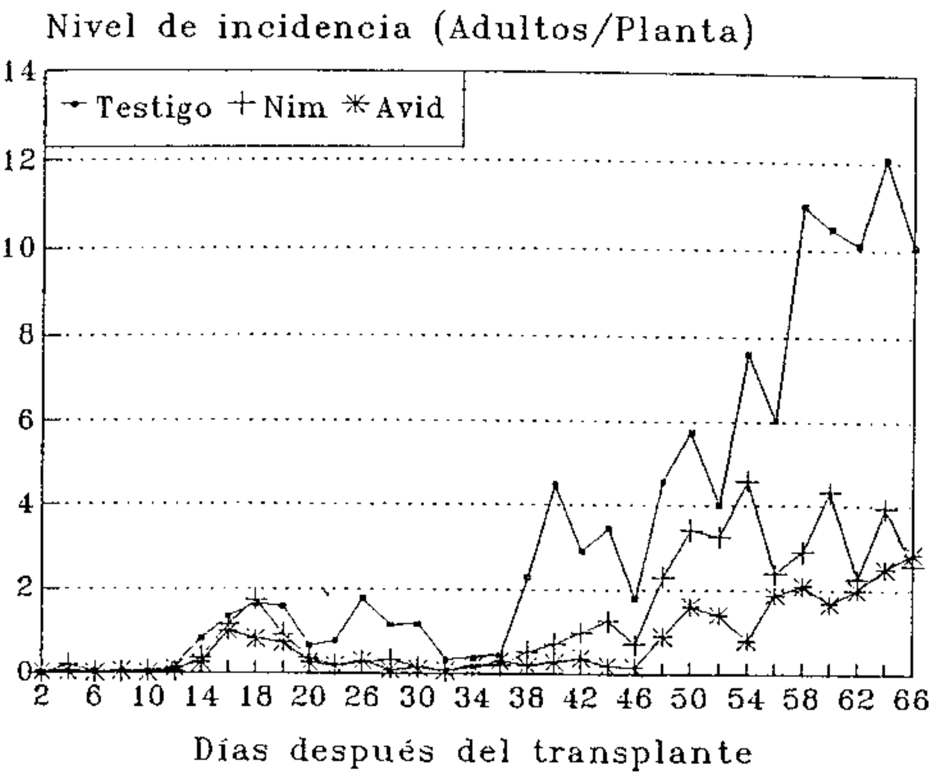

Figura 4. Desarrollo de la infestación MB en el cultivo de tomate con aplicaciones de un insecticida sintético (Avid®) y un insecticida natural. Por semana 2 aspersiones. Hasta la 8. semana después del transplante en total 16 aspersiones

logran coberturas con el caldo insecticidal de hasta 80% de las hojas en los dos lados.

Aplicaciones con bombas manuales y de motor de mochila resultaron en comparación al equipo 'boom' insatisfactorias. En todo caso con el uso de bombas de mochila se debe asperjar las plantas de los dos lados, desde arriba y desde abajo para cubrir especialmente el envós de las hojas donde se encuentran los insectos.

Aplicaciones a base de umbrales de control

Para minimizar el uso de insecticidas por razones ecológicas y económicas se recomienda ejecutar las aplicaciones en base a umbrales de control. Estos umbrales de control dependen de varios factores y son resultado de un monitoreo permanente de los niveles de infestación de la MB y de la

Tabla 4 Insecticidas naturales e insecticidas de baja toxicidad probados contra *Bemisia tabaci* en tomate y chile en Honduras

Producto	Eficacia
Extracto acuoso del nim	**
Margosan® (azadirachtin)	*
Aceite mineral (Stylet® oil)	*
Jabón insecticidal (Safer®)	0
Jabón común	0
Inhibidor de crecimiento (Enstar®)	0

incidencia viral en la plantación. En el cultivo de tomate en el Valle de Comayagua se estableció un umbral de control de 0.2 MB adultas/planta. Con este nivel se puede mantener una incidencia viral debajo del 10%.

Estrategia integrada en el manejo de la mosca blanca

En base a resultados de los estudios realizados en varias zonas, la FHIA ha elaborado el siguiente concepto para el manejo del complejo MB/virus gemini en Honduras (Tabla 5)

Tabla 5. Estrategia para la disminución de la incidencia del virus gemini en el cultivo de tomate y chile tabasco

Medida aplicada	Importancia práctica para la reducción de la incidencia viral
Medidas mecánicas	
- Viveros protegidos	*****
- Uso de mulch plástico	****
- Empleo de trampas amarillas	
Medidas culturales	
- Crecimiento óptimo del cultivo	****
- Alta densidad de siembra	**
- Siembra sincronizada en la zona	**
Medidas químicas	
- Uso de insecticidas eficaces	****
- Cobertura óptima con el caldo insecticidal	***
- Equipos de aplicación adecuados	**
- Uso de aceites	*
- Aplicaciones a base de umbrales de control	*

ESTUDIO DE CASO: LA CHINCHE ENCAJE DEL AGUACATE, *PSEUDACYSTA PERSEAE* HEIDEMANN (HEMIPTERA: TINGIDAE), EN LA REPUBLICA DOMINICANA

A Abud
Junta Agroepresarial Dominicana Inc., *República Dominicana*

E Gómez
Regional Norte-Noroeste Programa MIP/Santiago, República Dominicana

Avocado lacewing bug, *Pseudocysta perseae* Heidemann (Hemiptera: Tingidae) in the Dominican Republic

Avocado is important to the Dominican Republic as an important food for the population and in recent times has assumed increasing export importance due to markets in the USA and Puerto Rico. The Dominican Republic is also free of the Mediterranean fruit fly and other insects affecting avocados and which are of quarantine importance. The paper summarizes studies on taxonomy, general characteristics, geographic distribution, biological cycle, natural enemies, damage caused and economic importance of the bug; it also provides data on losses due to the insect, as well as on control measures used. Studies have shown that the pest is present throughout the island. The life cycle is, on average, 22 days – egg, 10 days; nymphs, 12 days. The females live for 21 days and males for 13 days. The female lays an average of 34 eggs with a hatching rate of 79%. The average loss for the years 1991–93 were 27, 42 and 16% respectively. The following natural enemies have been found: *Franklino thrips vespiformis*, *Chrysopa* sp., mites of the genus *Dictyna* as well as migratory birds.

El aguacate (*Persea americana* Mill.) es considerado como uno de los frutales con mayor distribución nacional y el cual es cultivado tanto a nivel particular como en predios de pequeños productores. Actualmente este ha pasado a ser parte de los rubros de exportación por el incremento que ha tenido en productores asociados en mayor escala de exportación.

Su fruto muy apreciado como parte de la dieta del dominicano, por su contenido de grasas, proteínas, vitaminas (específicamente B) y otros elementos nutritivos. Puede ser consumido directamente o como ensalada, como es la manera tradicional de los dominicanos, entre otras formas de prepararlo.

El aguacate dominicano goza del privilegio de ser aceptado en los mercados internacionales de mayor exigencia: Estados Unidos y Puerto Rico. Esto representa, obviamente, una ventaja competitiva con otros países del Caribe y Centroameerica, ya que nuestro cultivo no tiene ninguna restricción de exportación debido a que no se ha detectado en la República Dominicana la mosca de la fruta del Mediterraneo (*Ceratitis capitata* (Wiedemann), ni otras especies de interés cuarentenario, como son *Conotraechelus perseae*, Baber., *C. aguacate*, Barber., *Heilipus lauri* Boheman (Col. curculionidae) y *Stenoma canifer* Wals. (Lep. Stenomidae).

Hoy, el cultivo de aguacate está seriamente afectado por una alta incidencia de la

chinche encaje del aguacate *Pseudacysta perseae* Heidemann (Hemiptera: Tingidae), la cual está causando severos daños, tanto a nivel urbano como en plantaciones establecidas en nuestros campos de producción comercial.

El presente estudio tiene como objetivo dar a conocer la presencia de esta nueva plaga en nuestro país, asi como datos sobre su descripción, identificación y aspectos bioleogicos, daños e importancia económica de la misma.

Aspectos generales de las plagas

Schmutterer (1990) en un censo llevado a cabo para ese año nos indica que hay un predominio de ciertas plagas que atacan a este cultivo entre las que se destacan los Homoptera Diaspidae tales como: *Selenaspidus articulatus* (Morg.) *Aspidiotus destructor* (Sign) *Fiorina fioiniae* (Targ); Coccidae como: *Protopulvinaria pyriformis* (Ckll), *Killifia acuminata* (Singg), *K. mangiferrae* (Green) el Pseudococcidae *Nipaecoccus nipae* (mask); el Aleyrodidae, *Aleurothrixus floccocus* (Mask); asi como el Thysanoptera Thripidae: *Selenothrips rubrocinctus* (Giard).

Recientemente hemos podido identificar plagas que afectan este cultivo tales como: *Trachyderes succinctus* (Coleoptera: Cerambycidae); el saltahojas *Idona minuenda* (Ball.) (Homoptera: Cicadellidae); *Amorbia emigratella* Busch (Lepidoptera: Tortricidae); *Frankliniella cephalica* (Craw) (Thysanoptera: Thripidae) un gusano pegando las hojas nuevas del aguacate, Jocara mayúscula. Walker (Lepidoptera: Pyralidae); también un Coleoptero, Curculionidae, el denominado *Caulophilus latinasus* (Say) atacando las semillas secas de aguacate. Pero a partir de noviembre de 1990, Abud y Marcano (1990), observaron primero la presencia y luego reducciones importantes en la producción de frutas de aguacate, debido a la aparición de una pequeña chinche encaje que resultó ser la *Pseudacysta perseae* (Heidermann). Esta chinche estuvo restringida por más de 80 años en la Florida, donde era considerada una plaga secundaria, aunque en los últimos dos años ha causado daños de importancia económica en este Estado.

Desarrollo

Aspectos taxonómicos

Blathley (1926) presenta a esta plaga como nuevo género con el nombre de *Pseudacysta* y con las siguientes caracteristicas: 'Es pequeño y de forma oval, teniemdo la cabeza corta e insertada en el torax hasta los ojos; el vertex presenta dos espinas convergentes y cortas antenas delgadas en toda su longitud, el primer segmento es 1.5 más largo que el segundo; el tercero es dos veces más largos que los otros, y el cuarto es fusiforme; pronotum con una sola carina simple en la parte media, su porción posterior, triangular es aguda al final; paranoto representado solamente por un pequeño y pálido apéndice en forma de oreja, en cada ángulo lateral; elitro ovalado siendo una vez y media más largo que el abdomen, siendo más ancha por la mitad y con el márgen debilmente curvado y redondo al final; área costal ancha con tres a cuatro líneas discoidal de células hialinas a todo lo largo, área subcostal con células muy pequeñas y reticuladas'.

'Este género se llama *Acysta perseae* Heid (1908,103) como género tipo. Este difiere ampliamente del *Acysta* spp. de Champion (1898, 46),pues éste último tiene cuatro espinas en la cabeza, el pronoto tricarinado, el paranoto se extiende a todo lo largo del márgen del pronoto y el área discoidal cerrada por detrás. Braylovski y Torre citado por Mead y Peña (1991) redescriben el género *Pseudacysta* para México, el cual se reconoce por presentar el paranoto reducido y confinado al ángulo humeral y con 1–2 células pequeñas y presenta el área discoidal abierta apicalmente. *Pseudacysta perseae* es la única especie descrita en este género hasta el presente.

Nombre científico y sinonimia

Según Henry y Froeschner la nominación correcta seria: Género *Pseudacysta* Blatchley, 1926 Het. E.N. Am, p. 497 especie, tipo:

Acysta perseae Heidemann, 1908 Monotipo.

Pseudacysta perseae (Heidemann), 1908
1908 *Acysta perseae* Heidemmann, Proc. Ent. Soc. Wash. 10:103 (Fla)
1926 *Pseudacysta persea* (Sic): Blatchley, Het, E.N. Amp., p497
1946 *Pseudacysta perseae*: Hurd, la St Coll J Sci 20:259

Caracteristicas de *Pseudacysta perseae* Heidemann

Descripción: Mide 2 mm. forma oval-oblongo Cuerpo por debajo, cabeza, pronoto exceptuando el borde anterior y la punta de tercio posterior, y una barra cruzada en la tercera basal del élitro, pero alcanzando sólo ligeramente el borde del área discoidal, de color negruzco o marrón opaco; por arriba es de color blanco amarillento, las patas y las antenas son negruzco: pronoto subpentagonal, con márgen anterior obtuso y convergiendo fuertemente hacia el apex, porción posterior plana, triangular y terminada en punta aguda, el disco fino y densamente punteado y con una carina media simple y completamente baja. Elitro sobrepasado el abdomen, con sus extremos muy redondeados: área discoidal larga, estrecha y abierta por detrás. Segmento genital del macho es oblongo con una pequeña placa ('Flovea') a cada lado (Blatchey 1926)

Hospederas

Prefiere el aguacate *Persea americana*, pero también ataca al *Persea carolinensis* y *P. borbonia* el alcanfor, *Cinnamomum camphora*.

Distribución geográfica

Esta plaga fue colectada por Heidemann y Baber citado por Blatcheley (1926) en Orlando, Miami, Eustis, Baldwin y Ft. Meyers, Florida.

Coronado y Márquez (1972) lo citan en México atacando al aguacate también es citado para las islas de Bermudas y Puerto Rico. Fue colectado en esta última isla en el año 1990 (Medina-Gaud et al. 1991)

Fue determinada el 4 de noviembre en el Ensanche Ozama Santo Domingo, R.D. atacando plantas jóvenes de aguacate (Abud y Marcano 1990). A partir de esa fecha hasta septiembre del 1991 esta plaga se había encontrado en Santo Domingo D N , San Cristóbal y Baní por el Sur; desde Bonao hasta la Vega por la parte Nor-Central y en toda la región Este sobre todo en San Pedro de Macoris y la Romana. Recientemente, ha sido reportado en Santiago, Constanza, Mao, Montecristi, San José de las Matas, entre otras localidades del pais. Ya está distribuida en todo el territorio nacional.

Aspectos bionómicos

Datos preliminares sobre el ciclo biológico

En trabajos realizados por los Brs. Zapata y Bruján (1992) en el Laboratorio de Lucha Biológica de la UASD, se hicieron estudios sobre la biología de esta chinche encaje, con énfasis en la duración del ciclo desde huevecillo hasta adulto, capacidad reproductiva y longevidad de los adultos Se hicieron algunas observaciones sobre sus enemigos naturales a nivel de los campos visitados.

El *P. perseae* pasa por las fases de: huevecillo, 4 instares ninfales y adulto. El ciclo completo duró 21.89 días en promedio, de las cuales 10 días correspondieron a la fase de huevecillo y 11.89 a los cuatro instares ninfales (ver Cuadro 1).

Cuadro 1. Duración (en días) del ciclo biológico de la chinche encaje del aguacate *P. perseae*, bajo condiciones de laboratorio, Engombe, Santo Domingo, 1991.

Fase de desarrollo	Min.	Max.	Promedio
Huevo	9.00	11.00	10.00
Instares ninfas			
I	1.70	2.80	2.44
II	2.50	2.80	2.67
III	2.00	3.20	2.57
IV	3.20	4.80	4.21
			x= 21.89

Capacidad reproductiva

Las hembras depositan un promedio de 34 huevos con un máximo de 8 y un mínimo de 60 huevecillos Se observaron 463 huevos con un 78.83% de fertilidad Los huevos fueron puestos aislados o en pequeños grupos (masas) y tienen la forma de barrilitos, con un pedícelo y presentando una cobertura oscura viscosa, casi negra, que es segregada por la hembra al depositar los mismos en el envés de las hojas; su largo es de 0 6mm con 0 17 mm de ancho.

Longevidad

La longevidad de los adultos hembras con alimentos fue de 20.88 días en promedio y la de los adultos machos con alimentos fue de 12.67 días en promedio; sin alimento apenas duraron 1.19 días y 0.90 días respectivamente.

Daños e importancia económica

Tanto las ninfas como los adultos viven en estado gregario en el envés de la hoja del aguacate y al chupar la savia del follaje produce severos daños que se reconocen por el color blancuzco que toman las hojas, luego se tornan amarillentas en el área atacada (esta se observa por el haz de las hojas), más tarde se secan y caen produciendo una defoliacióan completa de las plantas. Cada mancha crótica corresponde a la presencia de chinches encajes en el enves de la hoja lo que provoca la muerte de las células del parénquina foliar, esto trae como consecuencia un retardo en el desarrollo de las hojas y una disminución en la cantidad y calidad de los frutos. *P perseae* prefiere atacar la raza de aguacate de las antillas con respecto a otras (Wol et al. 1949 citado por Mead y Peña 1991).

Cuando aparecen áreas necróticas de color marrón a nivel de las hojas, se han encontrado hongos tales como: *Colletotrichum gleosporioides* y *Oidiun* sp. asociados a estos síntomas (Schubert, citado por Mead y Peña 1991).

Características de las fincas

En el Cuadro 2 aparecen las características generales de las agroempresas encuestadas.

Cuadro 2. Datos de un estudio realizado en cuatro fincas productoras de aguacate en la Provincia Valverde, Mao, R.D. Octubre 1993

Finca	Ubicación	Area (ta)*	Riego (tipo)	Inversión (millón RD$/año)	Edad plantas (año)
Agropecuaria Báez	Amina, Mao	3,700	Gravedad	3.50	9
Cheroby Agroindustrial	Baguazuma, Mao	1,500	Aspersión	3.00	6
Carlos Madera	Amina, Mao	500	Gravedad	1.00	10
Avocado Export Business	Maizal, Mao	500	Gravedad	0.50	7

* 15.9 ta= 1 ha.

Fecha de aparición de la plaga

La plaga apareció ocasionando perjuicios en la zona de las cuatro empresas consultadas a finales del año 1991.

Pérdidas ocasionadas por daños de la plaga:

- *Agropecuaria Báez*: En el anno 1992 afectó severamente las plantaciones, la defoliación fue de manera general, la reducción en la producción fue de aproximadamente un 60%. Para el año 1993, las combinacion de buenas condiciones climáticas y la aplicación de un programa de manejo integrado de la plaga, redujeron considerablemente las pérdidas; estas se encuentran en proceso de evaluación definitiva.

- *Cheroby Agroindustrial*: En 1991 causó daños defoliando las plantas y disminuyendo la cantidad y la calidad de frutos exportables (no cuantificadas). Para el 1992 las pérdidas fueron estimadas en un 25%, mientras que para el 1993 debido a la aplicación de medidas correctas en el manejo de la plaga, las pérdidas se estiman en sólo un 3 %.

- *Carlos Madera*: Las pérdidas durante los tres años después de su aparición han sido: 1991 de un 30%, 1992 fueron estimadas en un 35%, y para el 1993 descienden a un 20%.

- *Avocado Export Business*: Para el año 1991 se estimaron las pérdidas en un 25 %, en 1992 se elevaron a un 50% y en el 1993 descienden a un estimado de 25%.

Tipo de manejo aplicado a la plaga por finca:

- *Agropecuaria Báez:* Uso de químicos tales como endosulfan, malathión y aceites agrícolas, mediante aplicaciones aérea y terrestre. Utilización del record de monitoreo ante de tomar la decisión de aplicar; se hacen localizaciones de foco de la plaga para realizar aplicaciones dirigidas. En la medida de lo posible se hace uso del concepto MIP.

- *Cheroby Agroindustrial:* Uso de ciertos umbrales de acción para decidir aplicaciones de químicos, por ejemplo, 30 adultos por árbol. Aplicación de malathión y endosulfan por vía aérea y terrestre. El uso del concepto MIP ha dado resultados existosos.

Cuadro 3. Estimación de las pérdidas ocasionadas por *P. perseae* Heid. en 4 fincas de la Prov. Valverde, Mao, R.D. 1992.

	Pérdidas en porcentaje		
Agroempresa	1991	1992	1993
Agropecuaria Báez	-	60	-
Cheroby Agroindustrial	-	25	3
Carlos Madera	30	35	20
Avocado Export Business	25	50	25
Promedio	**27**	**42**	**16**

- *Carlos Madera*: Aplicaciones de methamidofos cada 15 días, siendo este el único insecticida utilizado.

- *Avocado Export Business:* Monitoreo por medio de trampas amarillas pegantes aplicaciones de aceite agrícola, (citrinoil), de acuerdo a las poblaciones capturadas.

Costo por concepto del manejo de la plaga de la inversión total.

Estos datos basados en el porcentaje de la inversión total son presentados en el Cuadro que aparece a continuación.

Cuadro 4. Porcentaje de la inversión utilizada por concepto de manejo de *Pseudacysta perseae* en el cultivo de aguacate. Valverde, Mao. 1993

Agroempresa	Costo del manejo de plagas (%)
Agropecuaria Báez	40
Cheroby Agroindustrial	25
Carlos Madera	40
Avocado Export Business	15

Control biológico

Enemigos naturales

Se observaron larvas de *Chrysopa* sp. (Neuroptera: Chrysopidae) alimentándose de esta plaga, así como un thrips predator denominado *Fraklinothrips vespiformis* (Crawford) (Thysanoptera: Aeolothripidae) agente beneficioso, reportado para el país detectado e identificado por Abud y Reyes en mayo del 1991, primero controlando la mosca blanca, *Bemisia tabaci* Genn. en la zona de Mao Provincia Valverde y más tarde sobre esta chinche encaje en Santo Domingo, depredando ninfas y huevos. Aunque Russo en 1936, citado por Rodríguez Vélez (1974) lo había identificado para la República Dominicana, es esta la primera vez que se observa depredando a esta chinche encaje. También se han visto arácnidos pequeños con manchas claras sobre el cefalotórax alimentándose de adultos correspondientes al género *Dictyna* (familia Dictynidae); asi como un hongo imperfecto aún no determinado sobre los huevos con posibilidades de ser utilizado en el control biológico de esta plaga.

Aves denominadas 'Pinchitas' fueron observadas en Santo Domingo alimentándose de la chinche encaje por L Fernández (comunicación personal).

Conclusiones

Generalmente el *P. perseae* es considerada la plaga más importante al producir grandes mermas en la producción de frutos en el aguacate.

Los muestreos indican que esta plaga ya está presente en todo el país: Santo Domingo, San Cristóbal, Baní, La Vega, San Pedro de Macoris, La Romana, Santiago, Valverde, entre otros, causando daños económicos y de manera generalizada en las zonas de grandes plantaciones.

El ciclo biológico tiene una duración de 22 días en promedio, los huevos unos 10 días y ninfas 12 días; adultos 21 días las hembras y 13 días los machos.

Las hembras son capaces de depositar 34 huevos en promedio y con una fertilidad de 79% de los mismos.

Algunas empresas productoras de aguacate están realizando un manejo correcto de la plaga mientras que otras necesitan mejorar la estrategia de manejo, de manera que puedan minimizar los daños y continuar operando con rentabilidad.

Las pérdidas promedio fueron de 27, 42 y 16% para los años 1991, 1992 y 1993 respectivamente.

El costo de las aplicaciones de los insecticidas varios de un 15 a un 40% con una medida de 30% en las fincas consultadas.

Se han detectado los siguientes enemigos naturales: *Franklinothrips vespiformis*, *Chrysopa* sp. arácnidos del género *Dictyna* y hongos no identificados; también el ave migratoria 'Pinchita'; ninguno de estos biorreguladores ejercen un control efectivo sobre la chinche encaje.

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THE ROLE OF BIOSYSTEMATICS IN INTEGRATED PEST MANAGEMENT

C K Starr

The University of the West Indies, Trinidad & Tobago

(This paper was prepared for the seminar but was not presented – ed.)

Biosystematics – the scientific study of the diversity of life – includes a substantial service component to other branches of basic and applied biology, including integrated pest management (IPM). An effective IPM strategy must include early identification of the species involved and will often rely on comparative information from closely related species. This latter requires an understanding of phylogenetic relationships. The history of the discovery of the carambola fruit fly (*Bactrocera* sp.) and of efforts to control the cassava mealybug (*Phenacoccus manihoti*) illustrate the costs incurred from reliance on inaccurate biosystematic data. A review of biosystematic resources in the wider Caribbean region indicates a number of strengths and weaknesses. Present collections are of respectable size, but their utilization leaves much to be desired. In particular, there is a pressing need for information and resource sharing, both within the region and globally. The impending organization of an international technical cooperation network, to be known as BIONET, is intended to address this situation. It is expected that improved networking will facilitate the strengthening of individual collections, to the benefit of all users, including IPM practitioners. The Caribbean regional sub-network of BIONET is to be initiated at an adjunct workshop to the present conference.

The nature and tasks of biosystematics

Systematic biology, or biosystematics, is the scientific study of the diversity of life. It includes such deep topics as biogeography and the evolutionary background to present patterns. Among its more quotidian tasks are the description of new species, arrangement of species in a workable storage/retrieval system (classification), assignment of stable names to taxa (nomenclature), generation and maintenance of collections of specimens (curation), identification of specimens, and preparation of identification materials.

Perhaps more than any other branch of biology, biosystematics has a necessary, built-in disregard for national boundaries. And more than any other branch of biology, it is dependent upon information storage/retrieval and on the efficient transfer of information among practitioners. Accordingly, networking among collections and individual specialists is crucial to good biosystematic practice. This includes not only the sharing of data but also of the specimens from which data are drawn, and today no credible collection withholds access to its holdings from legitimate investigators. The loaning of even unique material through the mail is now becoming routine. Improved institutional networking, together with electronic data management, is increasingly seen as the key to success in the biosystematic enterprise.

Biosystematics in relation to integrated pest management

The relevance of biosystematics to integrated pest management (IPM) is readily seen when we consider the large service component of biosystematics to workers in other branches of basic and applied biology (e.g. Girling 1990). Biosystematic specialists in economically important groups routinely spend a significant fraction of their time in the service of IPM. This often close relationship has long been recognized in many countries in which major collections of

insects and some other groups are within, or associated with, the agriculture ministry.

The most widely recognized such service function is the identification of specimens. In an age when pest control was mainly a matter of applying enough pesticide to kill whatever happened to be eating the crop, accurate identification of the pest could be of minimal concern, but that age is long gone. As stated by Girling (1990), for example, 'The first step in developing a [biocontrol introduction] programme is to accurately establish the identity of the pest.'

The rapid and accurate diagnosis of difficult pests requires the attention of specialists in the groups involved. This point is explicitly made in the remark that 'Parasitoids are a diverse group of insects whose identification is very difficult. ... It is best to have the identification of a parasitoid confirmed by a museum with a good regional collection and skilled taxonomists.' (Girling 1990). However, an ordinary technician or research assistant can learn to do routine identifications, and these should certainly be taken out of the hands of specialists. Analogously, there is much that can be done to decentralize the diagnosis of economically important species. It is widely concurred (e.g. Pollard 1993) that much of the material from tropical countries now sent to major overseas museums for identification ought to be handled in the region of origin.

Among the other service functions of biosystematics are such things as the prediction of food habits of unstudied insect species from the known habits of closely related species. An understanding of the evolutionary relationships among species is critical to the success of such predictions.

Two recent case studies will serve to illustrate how the quality of biosystematic information can have a major impact on IPM efforts.

- The carambola fruit fly is a member of the *Bactrocera dorsalis* (Diptera: Tephritidae) group of at least 40 known species in Southeast Asia. It was collected in Suriname in 1985 and misidentified as the oriental fruit fly, *Dacus (Bactrocera) dorsalis* [the subgenus has since been raised to genus rank]. Members of this group attack a broad range of plants, and several are significant pests of fruit crops, but none was known to be established in this hemisphere. The possible significance of this find was thus recognized, and an intensive survey was undertaken in the Guianas. By reference to existing collections, it was then found that this particular insect had previously been collected in Suriname in 1975 and 1981. It was further found not to be *B. dorsalis* but a previously recognized, undescribed species from Southeast Asia (Huiswoud and Schotman 1990; White and Elson-Harris 1992). The carambola fruit fly is established in Suriname and has since been detected in French Guiana (Enkerlin et al. 1989). Its economic impact in Suriname includes depression of fruit exports because of quarantine restrictions.

- The case of the cassava mealybug, *Phenacoccus manihoti* (Hemiptera: Pseudococcidae), in Africa (Cock 1985; Herren and Neuenschwander 1991) is of a considerably larger scope. The insect was first noticed as an exotic pest of cassava in 1973 and was described and named in 1977. It spread very rapidly and soon became a very important pest, in some areas reducing yields below 40% of previous levels (Herren 1981). Together with another pest introduced at about the same time, the mite *Mononychellus tanajoa* (Acarina: Tetranychidae), *P. manihoti* threatened the staple crop of over 200 million people, raising the potential for famine. A search for the source population revealed a very similar mealybug in the Caribbean and northern South America, believed to be the same species. A search for natural enemies of this mealybug was successful and led to the propagation and release of some parasitoid species in Africa. These, however, failed to breed in *P. manihoti* and showed no control effect. A closer look by specialists at mealybugs of the two populations then revealed that they in fact represented distinct species. A renewed search showed *P. manihoti* in southern South America in 1981. Among the results of a search for natural enemies of this

population was *Epidinocarsis lopezi* (Hymenoptera: Encyrtidae), the propagation and release of which brought *P. manihoti* under control in Africa (Gutierrez et al. 1988).

Although the carambola fruit fly was collected in Suriname in 1975, it was more than a decade before it was correctly identified and the first steps taken toward its control. It is reasonable to suppose that this delay benefited the pest's spread and establishment. This delay had two apparent causes. First, analysis of the *Bactrocera dorsalis* group had not reached a point to allow ready distinction of its component species. It is for this reason that many published studies on members of this group cannot be matched to particular species (White and Elson-Harris 1992). Second, the biosystematic infrastructure was not of a quality to facilitate quick identification of a potentially important introduced species, even if the basic information were accessible.

On the one hand, the story of cassava mealybug in Africa has an unmistakable happy ending. With the aid of an accurate biosystematic diagnosis, biological control principles were brought to bear upon a very serious problem, averting a potentially disastrous situation. On the other hand, it is a grave cautionary tale. A lapse in attention to a fundamental biosystematic question brought about a delay of some years in solving the larger problem, with a very large loss in food production during the delay period. This is among the several cases that could be cited in which a failure to devote sufficient resources to biosystematic analysis at a very early stage significantly delayed successful biocontrol efforts.

Biosystematic service functions can only flourish if nurtured by IPM practitioners and researchers. In particular, it must become routine practice for studies in any area of IPM to include the deposition in a suitable collection of properly prepared voucher specimens for later verification of identity and further study. In this way, collections of relevant specimens are permanently strengthened. A failure to deposit voucher specimens can place the value of research at risk if later biosystematic analysis shows, for example, that what appeared to be one species is in fact several. This is seen in the fate of some studies of *Bactrocera dorsalis* group members.

Present status of biosystematics in the wider Caribbean

The wider Caribbean region is conceived here as embracing the islands of the Caribbean Sea, the Bahamas, Central America south from Yucatán, and much of northern South America (Figure 1). Recent surveys of biosystematic resources in this area include those on insect/arachnid collections (Arnett et al. 1993; Pollard 1993; Starr 1992), herbaria and plant systematists (Toledo and Sosa 1993) and biosystematics of bacteria, fungi and nematodes in the Carribean Community (CARICOM) countries (Bala et al. 1993). While these are not entirely comparable in scope and focus, they appear to present a consistent picture of Caribbean biosystematics. Among the features of this general picture are:

- A respectable number of small and medium-sized collections, but by international standards very few major collections. Figure 1 illustrates this point with respect to collections of land arthropods. Toledo and Sosa (1993) record a comparable number of herbaria in the region.

- Extreme heterogeneity in the size, mandate, institutional conditions and working methods of existing collections.

- A moderate rate of growth in the sizes of collections. Specimens in herbaria show an annually compounded increase of about 5%/year (after Toledo and Sosa 1993), with no marked discrepancy between different parts of the region.

- A striking paucity in personnel. Not only are there very few jobs in biosystematics at any level but the number of persons qualified for even basic diagnostic work is very small. Personnel in plant systematics shows an average yearly increase of only about 2% (after Toledo and Sosa 1993).

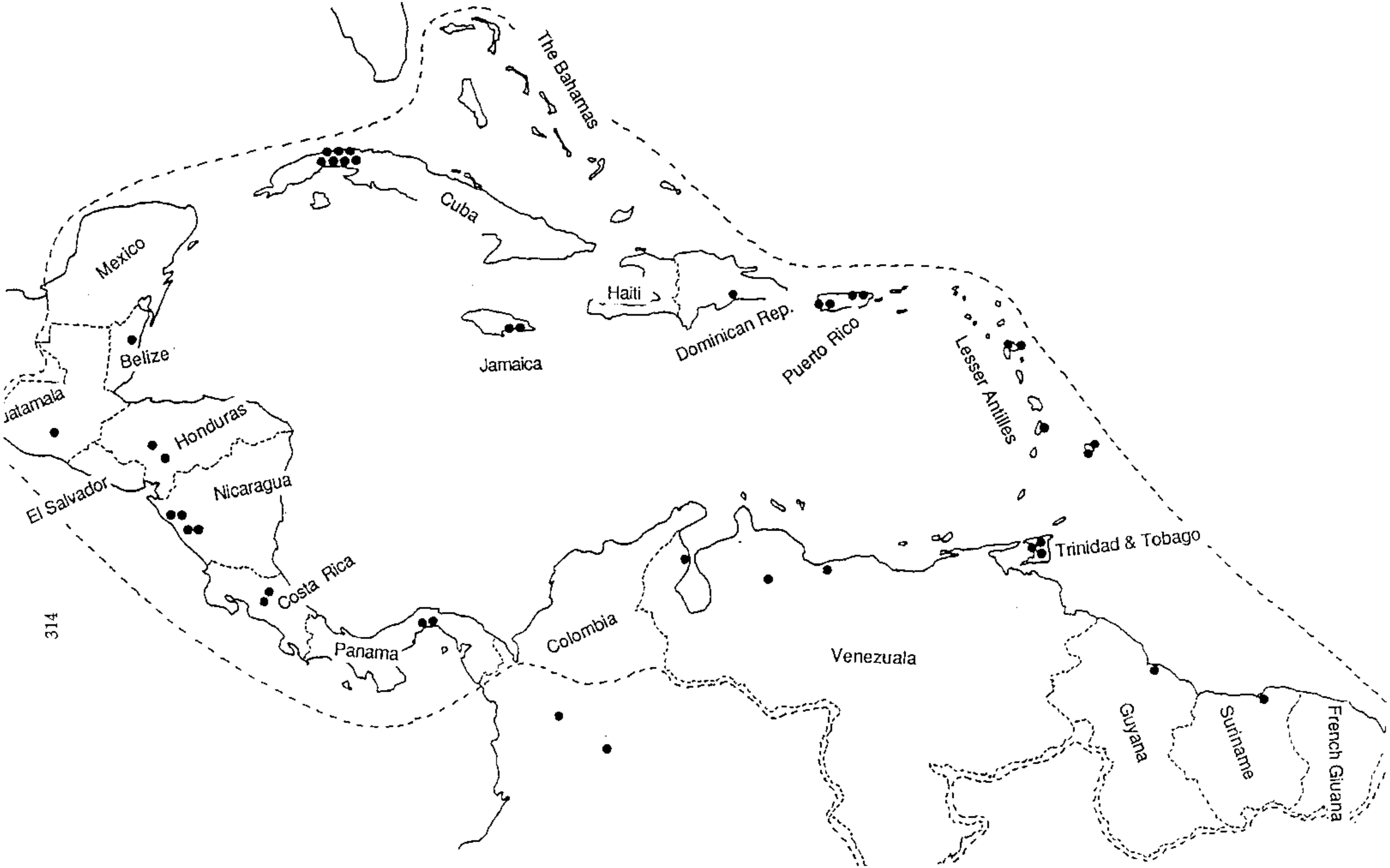

Figure 1. Insect/arachnid collections in the wider Caribbean region. (Two collections from the non-Caribbean part of Colombia are included on account of the considerable material from Caribbean Colombia). Based on Starr (1992)

Closely related to this is the continued high level of reliance on major overseas collections to furnish important identifications (Pollard 1993).

- Acceptable linkages between some collections and major collections outside of the region, but extreme underdevelopment of networking within the region. Accordingly, there is little capacity for specialists and clients to extract information at a distance. It is in this respect that one finds the greatest disparity between biosystematics in tropical and advanced-industrialized countries.

- A keen interest in overcoming such isolation as now exists.

One's overall assessment thus depends in part on whether the focus is on information storage (the size, coverage and condition of collections) or information retrieval (the transformation of specimens into new knowledge). The first focus gives a more positive picture than the second.

Within the region, no consistent correlation is evident between the relative economic stature of a country or territory and the strength of its biosystematic resources. Political and educational factors seem much more decisive, so that one finds the best collections and biosystematic activity where a literate populace has enjoyed a long period of relative civil peace. This pattern makes sense when we consider that biosystematics can be an exceptionally cost-effective branch of science. In my view, the present level of biosystematic activity in the Caribbean is well below what the region's economic resources could reasonably support.

It is not clear how closely this pattern applies to tropical countries elsewhere. However, it appears consistent with that found in Brazil, the largest country in the New World tropics (W L Overal, personal communication).

Prospects for improved integration

In the coming period, networking must be the key element of any strategy to improve the overall status of biosystematic resources in the Caribbean. That is, integration of existing collections and other biosystematic resources will unavoidably increase the effectiveness of individual units. This in turn will strengthen the hand of biosystematic practitioners seeking additional allocation of resources to the units and the whole.

The recent trend toward international technical cooperation networks provides excellent models of what can be done to integrate biosystematic units (Canhos et al. 1992; Jones 1993a, 1993b). This has led to a move to link existing collections and specialists in a world-wide network, to be known as BIONET, comprising several regional sub-networks linked by a central technical secretariat (Ainsworth and Hawksworth 1992; Jones 1993a, 1993b). It is expected that the first sub-network to begin operations will be in the Caribbean region and that it will be initiated in November 1993 at a workshop immediately following the present conference. Among the expected benefits are:

- shared access to existing specimen data

- cooperation in identification

- a planned avoidance of non-dynamic duplication of attention.

Given the present pattern of regional integration in the Caribbean, this sub-network will initially link collections of the CARICOM countries and any others prepared to join at this time. Meeting in June 1992, the Standing Committee of Ministers responsible for Agriculture (SCMA) of CARICOM endorsed the formation of the sub-network. However, these English-speaking countries make up only a small fraction of the land area, population and biodiversity of the region, so that it is understood that the sub-network must grow beyond CARICOM if it is to have any lasting impact. This view of the dynamics of regional integration in the realm of biosystematics is closely consistent with that of the West Indian Commission (1992; 1993) in the larger political-economic sphere.

Acknowledgements

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TECHNICAL SESSION V

Chairman: Ronald Barrow, *MoA, Trinidad & Tobago*

Rapporteur: Donald Walmsley, *Trinidad & Tobago*

WORKING GROUPS

NOTES FOR THE GUIDANCE OF THE WORKING GROUPS
(prepared by John Perfect)

The following Working Group structure was discussed and agreed at the plenary session on Tuesday 24 November at the conclusion of Technical Session III. The brief notes for each are intended to clarify the remit of the group, but the group can redefine its terms and scope as it finds most constructive.

GROUP 1. IPM FOR VEGETABLE CROPS

To cover issues arising from Technical Sessions I and II on *B. tabaci* and *T. palmi*. Both are principally pests of annual vegetable crops in the Caribbean; both are significant as virus vectors and both are believed to have assumed significant pest status as a result of current insecticide usage patterns. Approaches to the control of both are likely to be interdependent with each other and with other aspects of vegetable production systems, including other components of the cropping system within which they are grown.

GROUP 2: IPM FOR CITRUS

To cover issues arising from Technical Session III on CTV. Problem characterized as capable of being analysed more in terms of a set of strategic issues concerned with the interactions between distribution and abundance of the various vectors (particularly *T. citricidus*), strains of the virus, and characteristics of the predominant rootstock material.

GROUP 3: IPM FOR SMALL-SCALE FARMERS IN MIXED SYSTEMS

Groups 1 and 2 are likely to be concerned primarily with medium-large scale production systems. The need was identified to specifically address the way in which the problems would be likely to impact on small-scale (1-2 ha?) farmers given other constraints they face, and what approaches might be within their power to adopt.

GROUP 4: INSTITUTIONAL MECHANISMS TO PROMOTE IPM

If IPM approaches are to be effectively promoted and implemented this process must be supported by appropriate instutional mechanisms that ensure communication between those concerned within national systems, and within the region. The Caribbean also needs to consider linkages with the international community concerned with IPM technologies and their implementation.

A PROPOSED FRAMEWORK FOR WORKING GROUPS

The chairperson to lead the discussion, summarizing agreed conclusions (or divergence) at the end of each stage. The rapporteur to draft notes covering any principal points raised and record the summary remarks for each stage. The chairperson to present the findings of the group in a plenary session and the rapporteur to be responsible for a written statement to be submitted to the organizers before leaving the seminar.

Stage 1: Attempt to characterize the current situation in terms of the following sets of issues:

technical
policy
institutional
social/cultural
economic

Stage 2: Explore the potential for improving the current situation through an IPM approach, identifying any likely problems or constraints (1hr)

Stage 3: Define key needs to bring about the improvements identified above against the following headings:

research
technology transfer
information management and dissemination
institutional mechanisms

Stage 4: Nominate proposed actions for defined target groups and associate specific outputs

at the local level
at the national level
at the regional level
internationally

WORKING GROUP REPORTS

GROUP 1: IPM FOR VEGETABLE CROPS

Chairperson:	**Ronald Barrow**
Facilitator:	**John Perfect**
Presenter:	**Jeff Jones**

Dan Gerling	Josefa Mancebo	Juan Sanchez Pimeltel
Alfonsina Sanchez	Myrlene Chrysostome	Jose A Martinez
Ramon Alberto Mora Tavera	Felipe Rivas	Garth Rajnauth
Juan Cedana Mateo	Everest Ferguson	Ayub Khan
Carl Pemberton	Munir Alam	Rodney George
Dudley Meade	John Link	

The current situation

Technical issues

- Presence of whiteflies and thrips throughout the region
- Overwhelming farmer response to chemical control
- Ongoing screening of chemicals – selectivity and discretion; farmer adoption/education
- IGRs currently exploited and recommended to control whiteflies and thrips.
- Natural insecticides being tested, but not widely in use (e.g. neem).
- Characterization of viruses ongoing.
- No characterization of strains or species in the region.
- Some technical capability exists for identification and characterization (e.g. present work at the University of the West Indies).
- Probability of success of IPM components emerging from somewhat sporadic trials:
  - mechanical methods – colour traps, mulches
  - pheromone technology
  - biocontrol – pathogens, predators, parasites
  - role of weeds as refuges for natural enemies
- Responsiveness/practicability of IPM to smallholders and large producers

Policy issues

- Level of awareness of governments/policy-makers of:
  - the problem
  - IPM as a sustainable solution
- Implementation of policies to reflect the relative importance of IPM with respect to other R&D programmes (not generally obvious)
- The role of the pesticide control boards in driving an IPM strategy – no positive action.
- Initiatives for private and/or public sector involvement for IPM thrust – generally not in place

Institutional issues

- Human resources often available but not focused
- Absence of networking and usually narrow self-serving programmes

- Fragmentation/overlapping of effort at local as well as regional level
- Recognition of present and future role of chemical companies/ institutions
- Organizational framework for support of IPM
- Capabilities through to technology validation, transfer and follow-up

Social/cultural issues

- Increasing rates, frequency of application, additive effect of mixing
- Kill all! Kill dead! Kill now! (encouraged by input suppliers)
- 'Insurance' treatments for perfect product
- Possible changes in farm management skills to accommodate IPM
- Allegiance of some estates/producers to chemical outlets/suppliers
- Education of farmers to effect attitude and practices – ongoing in some countries
- Education of children/students concerning the dangers/advantages of bad/good practices (evident in few institutions)

Economic issues

- Financing – deficient, unsympathetic to change
- Cost of production:
    - optimum input for optimum outcome
    - economic thresholds to be developed for certain crops
- Relationship between cost effectiveness of IPM vs traditional methods – not much is done
- Implications for foreign exchange savings/earnings

Potential for improving the current situation through IPM

- Improvement of farmers' attitude and practices through education (on-farm demonstrations):
    - effect reductions in insecticide applications
    - promote the use where necessary of selective, efficacious and less deleterious chemicals
    - threshold guides for action (scouting and monitoring implicit)
    - effective application techniques consistent with pest location and behaviour
- Exploitation of alternative methods/tools which have been identified as workable such as:
    - mulches
    - mechanical devices for monitoring, mass-trapping etc.
    - use of natural products and insect growth regulators (IGRs)
    - conservation and inundative releases where possible of natural enemies, biopesticides
    - pheromones for monitoring, mass-trapping, mating disruption
    - crop sanitation and general maintenance
    - crop rotation, or cropping mix, known to reduce spread of viruses and populations of vectors
- Harnessing and coordination of technical expertise in the region; the impetus and conviction about IPM development

Constraints and likely problems

- Capabilities of individual countries
- Inadequate extension activities for effective technology transfers
- Limited financial resources for research, technology development and validation activities

Key needs for identified improvements

Research

- Biological control investigations:
  - survey of natural enemies of whiteflies and thrips
  - evaluation of natural enemies for effectiveness against target species
  - efficiency of biopesticides against different stages of the pest
- Investigate the role of:
  - mulches for specific pests
  - mechanical devices (e.g. traps)
  - pheromones and IGRs
- Cropping mix and floral diversity for natural enemy conservation and reduction in the incidence of disease transmission
- Investigate novel methods of control of *Bemisia* with egg stage as target
- Application technology, control devices
- Virus categorization and host differentiation
- Social and economic impact analyses

Technology transfer

- Clearly defined pathway for technology transfer
- Clearly defined roles/relationships of personnel in the transfer process
- Method of transfer:
  - tech-packs, factsheets
  - demonstrations, lectures/discussions
  - TV, radio programmes
  - on-farm testing/demonstration
- Compensation/incentive/financing for on-farm research

Information management and dissemination

- Research information:
  - CD ROM support
  - on-line databases
  - information gathering (from farmers' perspective), processing and storage
  - networking – small territories need to have some way of accessing information, e.g. CD ROM
- Farmer information:
  - IPM videos
  - talk shows
  - manuals
  - programme exchanges

Institutional mechanisms

- Involvement of:
  - research institutions
  - farmer organizations/commodity organizations/cooperatives
  - government research and extension agencies
  - agrochemical companies
  - embassies of friendly governments

DISCUSSION

R Barrow (MoA, Trinidad & Tobago): Resources have to be put in place for technology tranfer activities. Will CABI continue to provide an identification service free of charge? The Bionet meeting will address this problem.

Proposed actions for defined target groups

Target group	Actions	Outcome
Local		
Researchers foreign	Technology transfer activities	Reduced costs; increased exchange; reduced farmer injury
Farmers	Demonstrations of IPM to selected farmers	Decreased pesticide use; environment enhancement
Input suppliers	Sensitizing	Collaboration/cooperation
National		
Pesticide Control Board	Influence regulations in favour of IPM	IPM-driven decisions
Policy-makers	Sell concept and importance of IPM	Appropriate resource allocation
Farmer groups	Sensitizing; demonstrations	Adoption of IPM
Documentalists	Sensitizing	Facilitation of information flow
Researchers	Sensitizing	Focused investigations
Input suppliers	Sell IPM; sensitize concerning alternatives	Promotion of IPM-compatible products
Regional		
UWI, CARDI etc. CPPC, CFC	Collaboration with national effort; regional networking	Better resource management and allocation
SCMA	Government support	Regional support for IPM
International		
CTA, CABI	Information sources; review status of member governments with CABI;	Specimen indentification; information flow
IIBC	Facilitate development of biopesticides	Viable option for control
FAO et al.	Financial support	Improved funding

GROUP 2: IPM FOR CITRUS

Chairperson and Presenter:	**Rafael Pérez Duvergé**	
Facilitator:	**John Perfect**	
Rosendo Angeles	Philippe Cao-Van	Leslie Munroe
Frank Portalatin	Manuel Ant. Savinon	Bienvenido Arias
Francisco Jose Toral Cordova	Hector E Polanco	Hipolito Baez
Juan Maria Baez	Elvio Carrasco	Peter Hunt
Ramon Emilio Garcia De Leon	Evaristo Perez Solano	Odelis Jimenez
Tulio Santana	Andres E Diaz	Miguel A Santana
P S Reddy		

Issues

- We recognize that all citrus-growing countries in the region are threatened by the recent arrival of *Toxoptera citricidus*, the most efficient vector of tristeza virus (CTV). Most countries have already determined if *T. citricidus* is present. They also have investigated the status of CTV but there are technical difficulties in assuring whether the strains are severe or mild.

- In some countries other problems, e.g. root weevils like *Diaprepes* sp., may for the moment be as serious as the CTV threat.

- Few countries have evolved a coherent national policy to meet the CTV threat. Most large growers and growers' associations are well informed about the CTV threat and of the economic losses which are likely to result for trees budded on to Sour Orange rootstocks, but smallholders generally are not.

Potential for improvement

- Each country in selecting among the various CTV management strategies for those appropriate to its own circumstances must include those which control other virus and virus-like diseases. However, until these strategies can be better defined and can be tested, it will not be possible to integrate them with management strategies for all citrus pests and diseases nor with those for other crops.

- While the CTV management strategies must be chosen for compatibility with those existing for other citrus pests and diseases and for minimal ecological disturbance, we consider it is premature to attempt to define them within any broader IPM programme for citrus.

Key needs to bring about improvement

- Development of national budwood certification programmes, which include recommendation for use of CTV-tolerant rootstocks only.

- Strengthening of quarantine at national and international levels to avoid introduction of more severe CTV strains and of other virus/virus-like diseases in bud wood.

- Coordinate protocols for CTV detection in the various countries to allow consistent characterization of wild and severe strains to permit establishment of their inter-relationships, e.g. for cross protection purposes.

- Identify natural enemies of *T. citricidus*.

- Promote all of the above topics by strengthening national and regional institutions.

- Supplement national policies for CTV management which have the full cooperation of growers, processors, technicians and government agencies.

Proposed actions

- **Local and national**

  If not already present, establish local and national organizations through which contact can be maintained with all growers and through which all policy decisions can be analyzed and approved before their implementation

- **Regional and international**

  Proposals for regional and international cooperation in citrus have already been proposed (FAO and IACNET) but have not yet been accepted. While not wishing to proliferate yet more proposals, we regard it as essential that a system for regional cooperation in transfer of information, budwood and technology be established and that the status of past proposals is clarified.

  The conclusions of this group will be presented at a CTV workshop in Mexico next week at which similar matters of international cooperation and of funding will be considered.

  The offer of safe citrus germplasm transfer to the region through Martinique made by the French inter-ministerial fund for regional cooperation (FIC) under IBPGR approval is noted.

DISCUSSION

Participant:
We cannot say that because the insect vector is present that CTV is also present. We need reliable diagnostic techniques. ELISA tests alone are not sufficient. Electrophoresis and electron microscopy can be done in Europe and USA but it takes a long time. We should implement IPM strategies now, but along with parallel testing.

R Pérez (Dominican Republic):
That was one of the basic needs identified by our group. We must have consistent characterization.

P Hunt (NRI Project, Ministry of Agriculture, Belize):
I agree that it is essential that the identification of strains is done in such a manner that we can have confidence in the results. The present technologies do have problems. We need to cooperate regionally on the identification of severe or mild strains but may require more sophisticated techniques. What we need is a consistent technique. Mild strains offer the possibility of cross protection. Severe strains will manifest themselves through the symptoms.

No country where the citrus industry is based on Sour Orange rootstocks has escaped rapid decline when the vector is present.

GROUP 3: IPM FOR SMALL-SCALE FARMERS IN MIXED SYSTEMS

Chairperson and Presenter: **Mona Jones**
Facilitator: **John Perfect**

Malcolm Iles, Antonio Cuevas Moronta, Luis A Mato
Hector Tavares, Benito Toribio, José Guzman
José Veloz, Osvaldo Tineo, Bernard Nation
Colmar A Serra, José De La Cruz Herasme Carvajal

The current situation

- **Technical.**

  A variety of crops are cultivated within each production system. There are low levels of mechanization and high inputs of manual labour. Technology is often imported from more developed societies. It is inappropriate for the cultural, physical and climatic environment and thus not cost-effective for small-scale production, being more suitable for adoption by large-scale farmers. Cultural practices and the integration of animal and crop production systems have not been adequately studied. Inappropriate pesticide regimes have often been imposed on the farming community by pesticide salespeople, extension officers, consumers, exporters and importing countries. Farmers still produce in spite of these problems. Some aspects of IPM, including monitoring, use of bio-control and cultural practices, are already practised.

- **Policy**

  Policy is inconsistent; it fluctuates both with political goals and with personal goals of administrators. National policy fails to address IPM and specific small farm issues. There is insufficient support in IPM for technicians, extensionists and farmers.

- **Institutional**

  There is insufficient collaboration among research institutions, farmer organizations, extensionists and funding agencies.

- **Socio-economic and cultural.**

  There is limited investment and poor access to credit. Market arrangements benefit middlemen. Although they feed a large proportion of the population, small farmers are not seen as important. They tend to be marginalized and generally do not have access to good education. The culture of the farmer is a factor which is frequently ignored by agricultural planners and researchers.

Potential for improving the current situation and likely constraints

The potential to improve the situation through an IPM approach is definitely there. Some IPM already exists and this can be further developed. The present climate is encouraging as both farmers and consumers have begun to recognize the need for more healthy and stable production systems. Concern for harmful residues by importing countries and the high cost of pesticides further facilitate an environment in which IPM can be implemented. Organic farming and the benefits that can accrue also help to reinforce the benefits of IPM. The difficulties involved in the management of newly introduced pest species have forced farmers to consider alternatives to pesticide inputs.

In the short term, finance is an obvious constraint. In the short, medium and long term, national policy may be a constraint. Literacy in some situations may reduce the rate of implementation. Insensitivity of policy-makers, researchers, extensionists and educators may also hinder implementation of IPM. An inability of researchers to focus on small-farmer needs may be the biggest constraint.

Key needs for identified improvements.

- Research.

  Research institutions need to be more farmer orientated. Researchers need to develop a capacity for quicker diagnosis and to investigate economic thresholds which are specific to the farmers' situation. Pesticide application technology must be more relevant to the farming system. Further work is needed on natural pesticides, bio-control agents and cultural practices. Risk assessment must be conducted. Research funds must be adequate and on time if they are to generate the required technologies. Government policy and directorship must have consistent goals and be divorced from politics. Plans and budgets must be realistic.

- Technology transfer

  There should be full collaboration amongst researchers and extentionists so that the farmer receives a coherent message. On-farm research and data from farmers should be documented and used as a base on which to further develop IPM systems. Pilot area information should be more widely disseminated.

- Information management and dissemination.

  Research results should be documented in the language of the farmer. Researchers should be trained in extension methods. Project priorities must include information and technology transfer, which must be budgeted for. Demonstration plots within the farming community can be developed. There is a need to strengthen extension programmes with increased resource allocation. The mass media should be better utilized

- Institutional mechanisms.

  Greater collaboration is needed among all agricultural institutions including farmers groups. Farmer cooperatives should be encouraged.

Proposed actions for defined target groups.

- Policy-makers

  - *Local and national.*
    They must develop clear and consistent policy objectives with a view to providing a healthy and stable environment. There must be strong support for better pesticide management. Agriculture must be given high priority. Directives and project development must be based on reality and objectivity. Financial support must be adequate for the development of IPM programmes. Policy-makers must be informed by those on whom the policy will impact,

  - *Regional.*
    Harmonization and a Caribbean position on IPM are required.

  - *International.*
    The regional position should be recognized and respected

- Researchers.

  - *Local.*
    They must reinforce their professional commitment to the farmer and assess the role of traditional methods of pest control.

  - *National and regional.*
    More coordination of research activities is needed among universities, government stations and other research organizations.

  - International
    Research organizations should liaise with international institutions in order to strengthen the development and transfer of relevant technology. Mechanisms for promoting professional exchange should be encouraged.

- Extentionists

  - *Local and national.*
    They must have confidence in themselves as the key to IPM

implementation in the farming community. Their commitment to farmer service must be renewed. A higher degree of professionalism must be promoted amongst extensionists. They must demonstrate the ability to bring solutions which result in profit for the farmer and positive gains for the wider community.

- *Regional and international.* Organizations can assist in preparation and dissemination of information through factsheets, audio-visual materials, etc.

DISCUSSION

Information is available on the management of vegetable pests (whiteflies and *T. tabaci*) and citrus. Could two factsheets on IPM be made available from this seminar?

GROUP IV: INSTITUTIONAL MECHANISMS TO PROMOTE IPM

Chairperson: and Presenter **Gene Pollard**
Facilitator: **John Perfect**

Richard A Hall
Humberto Sanchez
Samsundar Parasram
Vinicio Escarraman
Mario Bonilla Mejia
Masaaki Shiraishi
Alan Jackson
Amauris Rodriguez
Diego Antonio Borbon
Ranjit Singh
Leovigildo Bello Guerrero

Essentially the Group considered what roles could the various organizations/institutions in the region play in facilitating mechanisms to promote and/or improve IPM strategies in the region. The major organizations identified were:

- The Food and Agriculture Organization of the United Nations (FAO)
- The Inter-American Institute for Cooperation on Agriculture (IICA)
- The Caribbean Agricultural Research and Development Institute (CARDI)
- CAB International (CABI)
- Centre de Coopération Internationale en Recherche Agronomique pour le Développement (CIRAD)

It was recognized that some of these organizations had a more international focus (e.g. FAO, CABI) while others had a more local focus (e.g. IICA, CARDI). The role of national organizations was also recognized.

Out of the discussions the following recommendations were made:

- Considering that one of the major constraints to IPM development and implementation in the Caribbean is the lack of timely and relevant information; and recognizing that there are important differences in the wider Caribbean in language, culture, socio-economic conditions etc.; and further, notwithstanding the important role that CTA plays in the dissemination of information, the Group recommends:
  - That a group be constituted to develop a proposal to put to CTA that it supports a specific study to determine what information is currently available, what information gaps exist and how best to facilitate collection, communication and dissemination of information on IPM in the Caribbean – possibly through the publication of a Caribbean-wide IPM newsletter.
  - That this group should comprise one representative of the Dominican Republic, CARDI, CIRAD, FAO, IICA and CABI.
  - That this proposal be prepared and submitted to CTA for consideration at their June 1994 review committee meeting.
- Considering that FAO is the major international organization responsible for plant protection and quarantine and that IICA and CARDI are the major inter-regional organizations operating in the region, it is recommended:
  - That these three organizations (i.e. FAO, IICA and CARDI) collaborate in developing an inventory of human and physical resources for IPM available in the region, including NGOs.
- Considering that some of the major pest and disease problems in the region at present have resulted from their introduction into the Caribbean (e.g. *Thrips palmi*, *Bemisia tabaci*/*Bemisia* spp., citrus tristeza virus) and recognizing the importance of plant quarantine as an

effective component of any IPM strategy; further, recognizing the important responsibility of FAO in promoting plant quarantine among its member states, and noting the recent appointment of a new Regional Plant Protection Officer it is recommended:

- That FAO once again assume its important lead role of plant quarantine implementation in the region.

• Again, considering the important role of CTA in information provision and dissemination, it is recommended:

- That CTA assist the region in the provision of all relevant information as identified and requested by the Group.

• Recognizing the existence of the international IPM Working Group (IPMWG) and the intention to launch the Latin American and Caribbean Sub-group of the IPMWG in March 1994 in Costa Rica, it is recommended:

- That the recommendations arising out of this present meeting be placed before the Latin American and Caribbean Sub-group for IPMWG in Costa Rica in March 1994 for endorsement.

- That a Caribbean Chapter of the Latin American and Caribbean Sub-Group of IPMWG be formed.

• Considering that in developing countries only government services have the resources to initiate national IPM activities, it is recommended:

- That regional governments be encouraged to adopt as national policies the development and implementation of IPM strategies.

DISCUSSION

R Barrow:

The CARICOM ministers of agriculture (SCMA) have been asked to bring up the question of collaboration at meetings of IICA and FAO in Mexico and Italy.

CONCLUSIONS AND RECOMMENDATIONS

- Policy-makers in the region should be made aware of the concept and importance of IPM to agricultural development; consistent with a healthy and stable environment.

- Noting that the International Pest Management Working Group intends to launch a Latin American and Caribbean Sub-group at its 1994 meeting in Costa Rica, steps should be taken to have the recommendations arising from this present meeting placed before the sub-group for endorsement. Also initiatives should be taken to establish a Caribbean chapter of the sub-group with its own newsletter.

  For citrus, the status of proposals for international and regional cooperation (FAO and IACNET) should be clarified. The conclsions of this meeting will be presented at a CTV workshop in Mexico at which international cooperation and funding will be considered. It is essential that a system of regional cooperation in transfer of information, budwood and technology be established. The offer of safe citrus germplasm transfer to the region through Martinique by the French Inter-ministerial Fund for Regional Cooperation with approval from the International Board for Plant Genetic Resources, was noted.

- There is an urgent need for the education/training of farmers and extension workers to bring about a change in attitude and to give them the required knowledge in the appropriate use of recognized IPM components in local farming systems. This would involve working with farmers and farmer organizations using successful models developed elsewhere and adapted to Caribbean conditions.

- A group should set up with the responsibility to produce hand-outs/factsheets on the several approaches recognized at the meeting for the control of *Bemisia*, thrips, tristeza and *Diaprepes*. These should be addressed to farmers, extension workers and researchers and be made available in the three main languages of the Caribbean – Spanish, English and French. The support of CTA, CABI etc. for this exercise should be sought.

- A study of economic losses incurred in the region due to pest damage is needed along with the establishment of economic thresholds.

- An inventory of the regional physical and human resources available for IPM should be developed along with a database on all aspects of IPM.

- Plant quarantine should be strengthened (possibly with the assistance of FAO).

- Increased control of pesticide use should be implemented through updating legislation and regulations at the national level.

- Coordination of research activities is needed among universities, government institutions and other research organizations. Networks for research and information should be established with linkages to international groups.

- Although there is need for support from the international donor group, it is very important that budgetary support is provided at the national and regional levels.

CLOSING REMARKS ON BEHALF OF CARDI

Samsundar Parasram
Director, Research and Programmes

Mr Chairman; the Honourable Secretary of State for Agriculture, Señor Victor Hugo Hernández; Representative of the Technical Centre for Agricultural and Rural Cooperation (CTA); Executive Members of the Agricultural Development Foundation (FDA), the Dominican Agro-entrepreneurial Board (JAD), and the Inter-American Institute for Cooperation on Agriculture (IICA); Distinguished Panelists and International Delegates; Officials and Technical Specialists; Ladies and Gentlemen:

It is my pleasure to address you once more at this important seminar. I would easily be reflecting the general feeling if I said that this has been a most rewarding seminar. The hospitality extended to all of us has been warm and affable. The field day was very exciting – inclusive of the police outriders. I wish also to personally thank the minister for those beautiful baskets of fruit.

This is the first seminar that CARDI has held in the Dominican Republic and I have had the fullest cooperation and collaboration with so many persons and institutions. It is simply remarkable. The girls in the secretariat worked assiduously and were always courteous and smiling, despite the long hours. I want to say thanks to one and all and that I will always cherish the memories of the last few days.

This seminar set up four working groups in the areas of:

I IPM for vegetable crops
II IPM for citrus
III IPM for small-scale farmers in mixed systems
IV Institutional mechanisms to promote IPM

Each group dealt with the following areas:

- Current situation
- Constraints to IPM
- Key needs to bring about improvements
- Proposed action for policy-makers, researchers, extensionists and farmers.

It is my pleasure to provide a brief summary of the major conclusions/recommendations of this seminar:

- It is necessary to provide information to policy-makers to sensitize them to the importance of IPM and its components and to set up mechanisms for national and regional coordination, possibly through collaborative networks.

- The meeting recognized the existence of the IPM working group and the various initiatives taken to establish regional sub-groups. A meeting is upcoming for Latin America and the Caribbean in Costa Rica in 1994.

- It is proposed that steps be taken to set up a Caribbean sub-group. CARDI also recognizes the need for education /training of farmers and extension workers to bring about a change in attitude and give them appropriate knowledge in the use of pesticides and other components. This would involve working with farmers and farmer groups using successful models adapted to the Caribbean.

- Several approaches have been reviewed for *Bemisia*, thrips, tristeza and *Diaprepes*. A group is to be set up to put these as a hand-out for farmers, extension workers and researchers with support from CTA, CABI, etc. This hand-out will be done in the three main languages of the Caribbean.

- A study of economic losses and thresholds is needed.

- An inventory of regional, physical and

human resources needs to be developed, along with a database.

- Quarantine needs to be strengthened.

- Increasing control of pesticides via updates, regulations, legislation, etc. should be presented at national levels.
- Budgetary support will be required to provide for these national and regional integrated efforts referred to above.

- Regional collaborative networks for research and information need to be developed. These should also be linked to international groups.

- We need to take cognizance of the three major languages in use in the Caribbean – English, Spanish and French – and to ensure all necessary information is available in the three languages.

After discussions with my colleagues, it has been decided that:

- there will be a publication in Spanish and English of the full conclusions and recommendations of the seminar

- abstracts of all papers will be done in English and Spanish

- There will be one publication containing all papers. The presentations in Spanish will have the text in Spanish with English abstracts.

These publications will be sent to all participants by the middle of 1994.

Once more, my sincerest thanks.

CLOSING REMARKS ON BEHALF OF CTA

Alan C Jackson
Technical Adviser

Mr Chairman, Honourable Minister, Distinguished Guests, Ladies and Gentlemen:

I would like to begin these closing remarks with a few observations of a very general nature, after which I will try to summarize my personal interpretation of our meeting.

The world in which we live is changing more rapidly than ever before: this is mainly the result of the spectacular advances that have been made in science and technology during our period of history. These advances have brought many rewards, but they have also made some aspects of life much more difficult and complex for us all. The gap between traditional agricultural practices and western high technology approaches has never been wider and the task of finding the right technologies for any given situation gets more and more difficult. Technical knowledge and social and economic considerations are changing so rapidly that the formal education we received during our training can actually be a handicap when we try to address some of the issues which arise today.

When many of us received our training it was sufficient to address pest control strategies through the scientific disciplines of entomology, biochemistry, biometry, mycology, botany, taxonomy, physiology and so on. These sciences formed the foundation of our control strategies and, of course, they still underpin all that we do. They are no less important than ever they were.

However, in more recent times the successful application of these sciences has had to respect criteria that seemed to matter little a generation ago. Nowadays we not only need good science: we need, for example, to be able to show that we are developing systems approaches which take other criteria, many of them non-technical, into account. Such criteria include the need to involve farmers in the development of new strategies; the need to remember the special considerations that apply to women in rural communities; the need to protect the environment; the need to conserve biodiversity; the need to recognize the increasing power and influence of non-governmental organizations; the need to promote sustainable methodologies; and the need to respect a host of criteria with regard to the adoption of new biotechnologies, such as legal and environmental safety aspects. It has been said that nowadays we must not only consider the technical fixes: we must become more people-centred.

In addition to these demands, the nature of the challenges that face us are changing more rapidly than before: increased human activity is bringing about fundamental changes to the pest and disease complex, and market requirements for produce never seem to remain static for long.

There are issues that all participants at this seminar must nowadays address in their daily work. The need to keep up with developments is a challenge to us all and is one of the main reasons why CTA holds meeting of the kind we have attended this week. We hope that those who have attended this meeting will be able to carry out their responsibilities more effectively in the future as a result of the new information, new approaches and new friendships which have arisen out of this seminar.

As I said at the beginning of the week, every CTA seminar that I have attended has developed a character and atmosphere of its own. We have tended to view problems from similar perspectives this week and, in consequence, we have been spared from debating issues that can become

confrontational. Shortly before the discussion group met, someone pointed out that most of the presentations had had a technical focus: social objectives had not been high on the agenda. The deliberations of our Working Groups, the success of which went far beyond our expectations, broadened our perspectives on pest management and made a real contribution to mapping out the future of integrated pest management in the Caribbean region.

During the first part of our meeting the size and importance of pest problems in the Caribbean was made very evident. Clearly thrips, whiteflies, aphids and citrus tristeza virus pose the most serious threats. They threaten, and are actually destroying, farmers' livelihoods and national incomes.

As our discussions progressed it became evident that reliance on chemical control at the farm level had become dangerously high, resulting in pesticide resistance, environmental pollution, human health hazards and, in some cases, loss of export markets and produce value due to pesticide residues. The adoption of chemical control methodologies has proved less and less effective, has failed to prevent the introduction of new pests, is expensive, requires good advisory services because of the high level of technical understanding required on the part of the farmer and is not sustainable because resistance eventually emerges.

This meeting has had no hesitation in advocating integrated pest management as a sustainable solution to pest control problems. An impressive number of IPM components that could be, and are being, adopted have been identified. They include scouting methodologies to decrease the number of pesticide applications needed to achieve adequate control; the use of natural insecticides; new spray technologies; the adoption of new cultural practices; the use of more selective pesticides; refuge habitats; cross protection techniques; the use of parasites, predators and pathogens and so on. It is an impressive tool kit on which to base new strategies.

And so to the all-important question: how can IPM be promoted in the Caribbean region? Here the meeting has made some specific recommendations: I will comment only in general terms. Firstly, a driving force for IPM is needed. Secondly, efforts to promote IPM must be more sharply focused and better coordinated. Educational campaigns are needed to change attitudes and practices. There needs to be strong governmental support for better pesticide management and the adoption of IPM strategies. Finally, quarantine procedures need strengthening.

There is a general message for the research community also: researchers must accept the need to work more closely with farmers, especially small-scale farmers, and they need to be more involved in extension and the transfer of technology.

CTA will do its utmost to assist with the information requirements that have been identified at this meeting; this will mainly be achieved through the framework of its existing services. The Proceedings of this meeting will, of course, be published as quickly as possible.

How do we evaluate the success of a CTA seminar? We have two main criteria. Firstly, it must have helped to circulate ideas and information. With such a large number of participants, and such a substantial set of technical contributions, that criterion has surely been satisfied. Secondly, the seminar must have achieved the specific objectives set by the steering committee. By reviewing research and development work on major pests such as whiteflies, thrips and aphids and the diseases they carry, by considering alternative control strategies for farmers and by drafting specific recommendations for the farming community, researchers, administrators and policy-makers I feel we have succeeded here also.

In my opening address I gave two additional objectives for this meeting. One was to show that the Dominican Republic was now fully integrated into CTA's activities: that is evident for all to see. The second was to develop closer working relationships between Spanish and English-speaking scientists in the Caribbean. I am certain that everyone in this room can say he or she now has better contacts with his or her counterparts in the

other language group as a result of this meeting.

And now it is time for me to express CTA's appreciation to all those who have contributed to the success of this week's meeting. I would like to begin by thanking our hosts here in the Dominican Republic for their hospitality and cooperation. In particular, I would like to thank the Secretaría de Estado de Agricultura for their support: and of course my special thanks go to the Minister for finding time in his busy schedule to honour us with his presence. I would like to thank all the staff of the Junta Agroempresarial Dominicana and the Fundación de Desarrollo Agropecuario who participated at the meeting as well as those who served on the Steering Committee. Similar thanks go to the staff of IICA and CARDI. On behalf of everyone present I would like to thank all those who helped to organize Wednesday's field trip, which enabled us visitors to appreciate the beautiful and spectacular scenery and vegetation in the interior of the Dominican Republic. Thanks also to our speakers, chairmen and rapporteurs. Finally, I would particularly like to thank our tireless interpreters and also the ladies of the secretariat.

Ladies and gentlemen, this will be remembered as the seminar which was nearly grounded by American Airlines. But thanks to your persistence, everybody finally got here. I would like to pay special tribute to those of you who, as a result of travel delays and frustrations, were called upon to make presentations when you were still jet-lagged or were not yet fully prepared. In conclusion, to those of you who must leave this island at the weekend, may I wish you a safe and trouble-free journey home!

Thank you all.

CLOSING ADDRESS

Señor Victor Hugo Hernández,
Secretary of State for Agriculture, Dominican Republic

Distinguished Representatives of the Caribbean Agricultural Research and Development Institute (CARDI) and the Technical Centre for Agricultural and Rural Cooperation (CTA); Directors of the Agricultural Development Foundation (FDA), the Dominican Agro-entrepreneurial Board (JAD) and the Inter-American Institute for Cooperation on Agriculture (IICA); Distinguished Panelists and International Delegates; Officials and Technical Specialists, Ladies and Gentlemen:

On behalf of the Government and the President of the Dominican Republic, Dr Joaquín Balaguer, and on my own behalf, I wish to express my profound satisfaction for the dedication and hard work demonstrated by all during the hosting of this scientific seminar, which is of great regional importance.

Likewise, I wish to thank the organizers for affording me the opportunity of attending this seminar for a second time, to share with this select audience some strategies in respect of plant and animal health aspects that are of major importance to the future of the agricultural sector, and which could lead to an expansion of our markets and the consequent development of our economies.

As we all know, the Caribbean region is not a completely homogenous entity. It represents a region of great geographical, racial, cultural and institutional diversity, with a common history whose origins lie in the colonial period. It is a region whose countries bear similar economic problems, some inherited due to severe exploitation by the different colonial powers and others, more recent, the products of the instability of the international economic order.

The magnitude of the problems that affect our economies and especially the agricultural sector, requires great efforts, actions and solutions on the part of all the world economic bodies – solutions, that by their nature cannot be found internally since these problems transcend national boundaries and are of a much larger regional nature.
Regional cooperation and integration is then a vital mechanism in light of the great challenge facing us to increase the productive capacity of the sector, as well as to provide the basis for economic development within the existing global circumstances. I strongly believe that contributions arising from this forum will provide the basis for future actions of the participating countries, whose presence here is a clear indication that common objectives would emanate, thereby leading to early action.

I think that to face the challenges before us, we must tap the great human and natural resources that we possess but which have not been fully exploited for reasons that I will not mention here.

Most of our countries today have democracies with social development in which there is great uneven distribution of wealth. Faced with this reality, we must think objectively of the possibility of achieving an integral harmonious development aimed at improving the quality of life for our fellow citizens. The road is undoubtedly narrow, tortuous and long, but not impassable. It is imperative that we develop a national psyche that will enable us to unify viable views and actions in our effort to resolve these problems.

I also believe that we need the cooperation of external sources who would appreciate our situation and would be willing to form relations with us, not for our economic wealth but for our human values, which undoubtedly are great.

The traditional misuse and lack of knowledge where pesticides are concerned in our countries agriculture, have been rapidly absorbed by the non-traditional export sector since the early 1980s.

From then on, a wide variety of chemicals were applied to the new crops in an effort to assure adequate profits based on the relatively high initial investments. This technology soon proved to be inefficient against certain pests as the insects developed resistance to a wide range of pesticides, and as the chemicals reduced the population of useful predators, thereby facilitating a proliferation of secondary pests.

The pests and pesticide-related problems have caused an enormous decrease in particular crops, both domestic and for export, and have posed a more general threat to significant sectors of our agriculture. If these problems persist, the farmers of the region stand to lose their access to international markets. In this highly competitive sector, temporary interruption of the supply to the consumers could result in the search for more dependable suppliers. Once a market is lost, it is extremely difficult to regain.

As we can see, not only technological but economic consequences result from this situation. To this end, we ought to be advocating the adoption of more effective and promising methods for the control of pests and the present problems of pesticides, as well as providing the basis for the prevention of future outbreaks.

The implementation of an informed strategy of integrated pest management is a method which has proven to be effective in various parts of the world in response to problems of this nature. The IPM strategy has been developed, promoted and sponsored world-wide as such a method.

On this note, I would like to point out to you that various studies on the problems of pests and pesticides in our country have hastened the search for such a strategy, in an attempt to achieve and maintain an adequate ecological balance and an effective control of pests. However, experience has shown that more extensive investigations should be carried out, since having applied the recommendations formulated by national and international experts, most of the problems related to pests still persist. Such is the case with whitefly and geminivirus, to which I made mention previously.

Countries throughout the region are making an effort to find feasible alternatives which would be implemented under a scheme of regional integration, since the challenges that face us and will continue to face us in the medium term, will be enormous and very complex, and we ought to be cautious but resolute.

I want to emphasize that in the Uruguay Round of GATT, it was recently recognized that unjustified quarantine restrictions could be used in the future to reduce the free circulation of trade. The contracting partners of GATT insisted that the reasons for plant quarantine measures must be evident and that the situation could be improved by means of a harmonization consisting of the establishment, identification and application of health and phytosanitary measures common to all parties concerned, and that as regards plant health, the standards, guidelines and international recommendations given under the auspices of the Secretariat of the International Convention for Phytosanitary Protection, in collaboration with the regional organizations that operate within the framework of that International Convention, ought not to be questioned. Therefore, the FAO has expressed the need to prepare norms and guidelines for plant quarantine that are accepted and recognized internationally, and whose standards should be comparable to the those of the Commisión del Codex Alimentarius.

Today, more than ever, we are convinced that in other areas of the region, concern has been given to this matter, and therefore we feel encouraged to put before you the idea of discussing the possibility of creating a regional mechanism called a Caribbean Association or Committee that would incorporate the efforts, will and resources of the public and private sectors, in order to confront and resolve these problems which are common to all, and which greatly affect the stability of the food producing sector on which the socio-

economic development of many countries depend.

At this time, I would like to take the opportunity to call upon the international financial organizations as well as the cooperating bodies and nations to make this dream come true – to contribute to the creation and upkeep of this mechanism, which to my mind is of utmost importance.

I wish also that the delegates and officials present from the Caribbean countries put forward these recommendations to the highest authorities of their respective nations in order to obtain some feedback on this most vital proposal.

Before I go, I wish to thank the organizing committee for hosting this meeting and for having afforded us this opportunity to forge close links with our neighbouring countries. On behalf of the Government of the Dominican Republic, especially our Honourable President, Señor Joaquín Balaguer, and the Ministry of Agriculture, I wish you success in your endeavours and hope you have a safe return to your respective countries.

We trust that you will take follow-up action to the recommendations that came out of this seminar which, I must emphasize, constitute a real effort towards integration among our Caribbean countries.

Thank you very much.

ANNEX I

COUNTRY PAPERS

INTEGRATED PEST MANAGEMENT FOR ANTIGUA & BARBUDA: IMPLICATIONS FOR USE AND CURRENT PRACTICES.

R George
Ministry of Agriculture, Antigua & Barbuda

Antigua & Barbuda is a small Caribbean country where the use of pesticides for pest control on agricultural crops poses a high risk to human health, wildlife and the overall disruption of the agro-ecosystem. Despite the danger of pesticide usage, farmers have become dependent on chemical control to deal with the increasing pest problems. Increasing amounts of chemicals are imported, some of which are quite dangerous, for pest control on agricultural crops. The natural enemies of the local pests are affected by the indiscriminate use of these pesticides resulting in economic levels of pest infestations. In addition, most of the pests have become highly resistant to most pesticides available to farmers in Antigua & Barbuda. Alternative control measures that were attempted on a pilot scale have been ignored by farmers. In this way chemical control predominates and at present pest control is almost equivalent to chemical control. Integrated pest management, now at the developing stage in Antigua & Barbuda should be further developed as a replacement to sole reliance on chemical control. Research and development work and added facilities are necessary for the development of dependable programmes for farmers in Antigua & Barbuda that avoid side-effects and allow for increased yields and returns.

Definition of integrated pest management (IPM)

Integrated pest management as it relates to Antigua & Barbuda is the control of insect pest populations by the utilization of all suitable techniques in a compatible manner so that damage is kept below economic levels. This procedure is interpreted as an ecological approach that minimizes adverse side-effects and also avoids economic damage. The most significant considerations of the integrated approach to pest management are the agro-ecosystem, the economic threshold and the least disruptive programme.

Background

Since the European settlers came to Antigua & Barbuda in the 17th century until the early 1970s, sugar cane was the main crop produced. With the decline and subsequent abandonment of the sugar industry in the 1970s, the agricultural sector was diversified to include large-scale production of vegetables and food crops. Over the years, this has resulted in the development of many monocropping production systems giving rise to proliferation and build-up of a vast and massive pest population which has become increasingly difficult to control by natural, cultural or biological means. Consequently, a large amount of dangerous chemicals for spraying crops against pests have been imported into Antigua & Barbuda. Farmers virtually ignore or consider impractical other control measures apart from chemical control and are constantly looking for new and effective chemicals to deal with their increasing pest problems with quick success. The reliance on chemicals as against more cultural and biological controls has grown tremendously over the years with the result that pest control in Antigua & Barbuda at present is almost equivalent to chemical control The reduced sole reliance on chemicals and development of a strong integrated approach to pest control is very important for Antigua & Barbuda – more than for most other countries in the world.

Antigua & Barbuda is relatively very small with both islands having a mere 441

km^2 of land space. Within the rather confined environment of the islands, the agricultural districts in which chemicals are widely used are quite close to residential areas. This situation poses a danger to human health and wildlife by way of drinking water. When crops are sprayed, some of the spray droplets remain in the air to be carried around by the wind. Rain falling in the vicinity could take in these chemical droplets and fall on residential roofs where it is collected as drinking water. The concentration of chemicals in drinking water can build up depending on the situation and constant exposure could result in accumulation of some of the more persistent chemicals in humans and animals.

In addition, surface water catchments could become contaminated by both rain water from contaminated air and chemical residues in watershed areas of streams and dams. Also, water for domestic use could be contaminated as the rain-water percolates through the soil on agricultural lands accumulating in the bedrocks beneath to form various wells around the islands from which water is taken to supplement other sources for national domestic needs.

Chemicals abuse by some farmers in Antigua & Barbuda has resulted in pests becoming highly resistant to most pesticides. As a result, higher doses are required with shorter spraying intervals.

In some cases, farmers faced with a pest problem which threatens their crops close to the harvesting period spray with high residual chemicals and being unable to observe the necessary withdrawal period, still harvest and supply to the market. In Antigua & Barbuda, facilities are inadequate for random sample testing of crop products for pesticide residues thus increasing the risk of exposing humans to chemicals hazardous to their health. In addition, pesticides are relatively expensive farm inputs that are imported with scarce foreign exchange, thus increased usage of these expensive chemicals is likely to increase cost of production of agricultural crops.

Alternatives are urgently needed to reduce sole dependence on chemicals for pest control with increased emphasis on biological and cultural control measures and where chemicals are used, improved and safe methods of application should be selected. In this way, development towards an integrated approach to ensure compatibility and balance in the agro-ecosystem of all the pest control measures utilized is very important.

Attempts have been made at biological control with introduction of a number of parasites and some measures of cultural control tried on demonstration plots. These have proven to be quite inadequate, due mainly to a lack of resources to cater for a relatively wide range and high infestation of insect pests resulting from the dominance of many monocropping systems used for crop production. Also, conservation and establishment of natural enemies have proven to be difficult because of the wide range of broad-spectrum pesticides used by farmers.

This paper attempts to give consideration to the implications of pest control by IPM against the current practices of farmers where chemical control dominates. The essential focus areas are:

- major pests
- control measures
- degree of success or failure of IPM attempts
- causal factors
- the potential for development of IPM in Antigua & Barbuda.

Status of IPM in Antigua & Barbuda

IPM is not highly developed and widely practiced by farmers in Antigua & Barbuda, however, work on a pilot scale was carried out in the 1980s with emphasis at developing biological control for some of the major pests. This programme was discontinued after the later 1980s due to a number of factors. There are now pockets of cultural control methods used on a pilot scale. The status of IPM is considered in

this paper with reference to major pests, current control measures, successes and failures of IPM strategy for Antigua & Barbuda.

Diamond-back moth (*Plutella xylostella*)

Diamond-back moth is specific to cole crops (cabbage, cauliflower, and broccoli) in Antigua & Barbuda and has developed resistance to most chemicals available to farmers. A new generation of chemicals, the insect growth regulators, are now utilized to give effective chemical control on cole crops.

The *Plutella* caterpillar, usually about 1 cm in length, feeds on the leaves contributing to considerable losses, especially on cabbage where the heads are affected. Wide-scale indiscriminate use of pesticides has resulted in the decline, and in some areas eradication, of the natural enemies of this pest so that the pest populations build up rapidly and feed extensively on the crop in a short period of time. Usually major economic damage to a crop of cabbage occurs at about the 5–8 week stage resulting in a high economic loss and it is at this stage that most failures are recorded, reaching as high as 100% economic damage.

In early 1980s when cabbage production was on the increase, biological control was attempted where the parasite wasp, *Apanteles plutellae* was introduced, reared for mass production and released for parasitizing *Plutella* larvae. Subsequently, random sampling was done to collect parasitized larvae of *Plutella*. There were large numbers of affected larvae collected but the overall control was ineffective biologically. Some chemicals which were used affected the *Apanteles* wasp, and this along with loss of dedicated professional staff from the Plant Protection Unit and lack of full cooperation from farmers resulted in the failure of this programme. *Apanteles* wasps are still present in some areas of the island but populations are insufficient to effect natural or biological control of *Plutella*.

Farmers have been depending on chemicals to control *Plutella* for a number of years. Various chemicals imported into Antigua & Barbuda gave good control for a period of time but thereafter became less effective as local pests developed resistance. Presently, farmers are using the insect growth regulators chlorfuazuron (Jupiter®) and teflubenxuron (Nomolt®) in combination with profenofos (Selecron®), profenofos plus cypermethrin (Tambo®), permethrin (Ambush®), *Bacillus thuringiensis* (Dipel®) and acephate (Orthene®) with good results. Farmers have been advised to use a combination of four chemicals using each not more than three times. Some farmers are now getting good control but this may not be for very long if solely chemical control continues. The insect growth regulators used in recent times have been giving good results, however, some side-effects are observed, e.g. in one case the *Plutella* larvae was controlled but a build-up of the cabbage aphid, *Brevicoryne brassicae*, occurred. Farmers have attempted to get around this problem by spraying chemical 'cocktails'. Such applications are made by applying two or more compatible chemicals mixed together in the water needed for spraying the crop area. The insect growth regulators used in small doses are quite effective against the target pests and also are more persistent on leaf surfaces in comparison to other chemicals used, thus avoiding quick reinfestation and decreasing the spraying interval required.

With respect to improved applications, farmers have been advised to use Jupiter®, Tambo® and Orthene® during the early crop growth stage. Nomolt®, Ambush® and Dipel® towards harvesting, and only Dipel® during harvesting with Nomolt® where necessary. The procedure has been accepted by most of the successful cabbage farmers. In this way the risk of dangerous chemical residues on crop products can be avoided. However, it is noted that some of the chemicals widely used for *Plutella* control, such as the synthetic pyrethroids, could also be harmful to some natural enemies, It is also possible that there will come a time when no chemicals are available for effective control of *Plutella* in Antigua & Barbuda. Consequently, sole dependence on chemicals for control of this pest should not be encouraged.

In that case, chemicals should be selected more carefully and usage adopted to allow

a programme of least disruption to the agro-ecosystem. The natural enemies of *Plutella*, the *Apanteles* wasp should be reared and released to build up populations in specific cabbage growing areas along with improvement in cultural control such as use of trap crops, inter-cropping cabbage with other crops and good field sanitation throughout.

The development of such an IPM programme requires research into dependable alternatives to chemical pesticides, and monitoring of *Plutella* larvae and forecasting in an effort to clarify the economic threshold levels, on which at present neither farmers nor consumers are well informed.

Whitefly

The whitefly (*Bemesia tabaci*) is a sucking insect affecting a range of vegetables (solanaceous, cruiciferous and cucurbits), sweet potato and some weeds in Antigua & Barbuda. Adults and larvae suck the sap from the crop leaves leaving a sticky residue which is often covered with a black mould. *Bemesia tabaci* is resistant to most insecticides used at present in Antigua & Barbuda.

Biological control of *Bemesia* has not been tried yet in Antigua & Barbuda and there is potential for development considering that pest populations build up quickly and are resistant to chemicals. Fly traps are being tried on a pilot scale at present as one aspect of cultural control. Farmers have been advised to do field scouting to assist them in managing the pest population below economic threshold. This pest has got out of control throughout Antigua & Barbuda with infestation reaching well above economic threshold levels.

The whitefly became a major pest only during the later 1980s and its presence has been significant for the past 4–5 years. The build-up of pest populations is believed to have originated from the wide-scale indiscriminate use of insecticides in all the agricultural districts which eradicated the natural enemies of the insect. Also the development of the ornamentals industry meant that alternative hosts were offered. Like for *Plutella*, there is a need for the strengthening of IPM to include this pest in a programme where chemicals are carefully selected, attempts are made to identify and introduce where necessary the natural enemies to facilitate population build-up for biological control, and cultural control such as the use of sex pheromone traps continued as is practised at present in some cases. There is need for research and development to put an effective, least disruptive programme in place.

Effective chemical control is achieved by some farmers with insecticidal soaps, Vydatel® (oxamyl), Padan® (cartap) and Tambo® (profenofos and cypernethrin) but regular spraying is necessary. Some farmers have started using sprays made from natural extracts of various parts of the neem tree and hot peppers with good effects but there is great need for more of the natural enemies to be present to effect natural and biological control.

Armyworms

Armyworms (*Spodoptera* spp.) are serious pests on sweet potato, tomato, eggplant, pepper, cauliflower, carrot, onion, lettuce and spinach. Under conditions of severe attack all the leaves of the plant maybe eaten up. The mature caterpillars also bore holes into fruits.

Presently, *Spodoptera* larvae are controlled by routine spraying with a range of chemicals. In the 1980s pilot-scale work was carried out where the parasite *Telenomus remus* was introduced mass-reared and released; *Spodoptera* larvae were collected randomly to determine the level of parasitism. The programme had become unsuccessful by the mid 1980s as the use of broad-spectrum chemicals was affecting the build-up of the parasite in sufficient numbers to obtain effective control of the pest. The potential exists for the control of the pest by IPM where biological and cultural control would play the more important part, compatible with the use of limited amounts of insecticides. *Telenomus remus* is still present in Antigua & Barbuda but only in small numbers and confined to certain areas. There is great need to reduce the use of chemicals in general. *Telenomus remus* has been shown to be an effective parasite of the pest but the population needs building up for

effective control below economic damage level. Mass-rearing of locally captured and introduced parasites should be initiated with the objective to promote biological control as a component of IPM. Adequate facilities for mass-rearing in Antigua & Barbuda are lacking at present and should be improved together with research and development for a dependable IPM programme for control of this pest.

Sweet potato weevils

Sweet potato weevils, *Cylas formicarius* and *Eusceves* spp. (Jacobs), are major pests affecting sweet potato production in Antigua & Barbuda. In this case, even low level infestations reduce quality and marketable yields, since sweet potato produces terpenoids in response to the weevils feeding that make even slightly damaged roots unfit for consumption.

Very little attempt has been made with chemical control of these weevils over the years. Usually, farmers would discard the affected tubers and market the unaffected ones. However, there have been many cases of severe infestation resulting in high economic losses. Crop rotation, selection of healthy cuttings and good sanitation have been aspects of cultural control. In more recent times, attempts have been]made at keeping the population below economic level by using sex pheromone traps to attract the male insects of these pests, thus reducing reproduction. Traps are used at present on a pilot scale at selected farms and on government commercial crop production stations where results are revealing effective control with respect to reducing economic damage.

Other pests

There are a number of pests in Antigua & Barbuda which are considered as minor pests. With wide-scale indiscriminate use of chemicals there is potential for these to become major pests, which has happened in the case of the whiteflies. Reference is made below to some of these pests indicating potential for IPM with the objective of preventing these from reaching economic levels of infestation.

Thrips palmi

Thrips palmi infestation has been identified in Antigua & Barbuda appearing as white dots along the veins of leaves of crop affected. This pest mainly affects eggplant, sweet pepper and cucurbits, and onions in some cases. Both larvae and adults are found on the undersides of the leaves and suck the content of the plant cells dry. These tiny insects are showing signs of high resistance to pesticides used in Antigua & Barbuda. However, thrips infestation is not widespread at present, especially where the natural enemy, lady-bird beetle, is present in large numbers. Thrips build-up is more prominent in areas where the populations of lady-bird beetle are affected by the use of broad-spectrum chemicals. Conservation of the natural enemies of thrips should be given adequate consideration with regard to the possibility of natural and biological control in the development of an IPM programme.

Leaf miners

Leaf-miners *Liriomyza* spp. are pests affecting tomato, cucurbits, beans and onion. Damage (mainly to leaves) is due to the activity of the larvae making mines inside the leaves of affected crops. These pests are showing signs of high resistance to the range of chemicals used in Antigua & Barbuda for pest control. There is great need to identify and conserve the natural enemies of these pests to keep the population below economic levels, and avoiding the need for spraying with chemicals where possible.

Heliothis spp.

Heliothis spp. are pests attacking the harvestable products of a number of crops in Antigua & Barbuda. Among the main crops affected are tomato, corn and pigeon pea where burrowing of larvae into fruits affects marketability. In the case of tomato, yields are reduced depending on the level of infestation, by spoilage. There are a number of pesticides used at present that control these larvae and reduce economic damage. However, sole dependence on chemicals should not be encouraged in integrated pest management. Cultural control such as using resistant varieties and identifying and conserving

natural enemies could limit the development of these pests.

Discussion

The agro-ecosystem in Antigua & Barbuda is quite small and should be adequately protected. Crop production is vital to the economy but steps should be taken to ensure that in this process the environment is not altered to the extent where human and animal existence is adversely affected. Many farmers in the country have the feeling that the only good insect is a dead insect without much regard for natural enemies and other beneficial insects. Balance in the agro-ecosystem would allow aspects of natural control and as monocropping systems increase, natural enemies should be encouraged to give biological control. Cultural control, improved chemical control and biological control should be utilized with an integrated approach.

The strengthening of IPM is of vital importance to Antigua & Barbuda and increased research and improved extension are key necessities. Adequate consideration should be given to the relatively small agro-ecosystem, sound economic threshold levels, and a programme of least environmental disruption.

Antigua & Barbuda, being a developing country is lacking in any of the needed facilities to achieve a very effective IPM programme. There is a shortage of trained extension personnel to implement IPM among farmers in general, and research data such as economic damage and efficiency of natural enemies, in general are lacking. Where there are trained extension and research staff members, facilities needed to make their work effective are not present. There is need for a government policy that acknowledges IPM as rational and a priority, thus allocating resources for improving facilities, including the functioning of a pesticide control organization.

With respect to research, crop protection practices, cultural and biological, as alternatives to pesticides are vital components. Essential work should be done on efficient methods of conserving the natural enemies, overall efficiency of biological control (including microbial insecticides), and cultural measures such as use of sex pheromone traps. Unfortunately, there are very few published data on IPM work attempted in the past in Antigua & Barbuda. Research findings should be presented through demonstrations and reports.

Where chemicals are used as a component of IPM, research work is needed to determine how, where and what rate under local conditions would maintain balance in the agro-ecosystem.

The issue of possible chemical residues on crops and contamination of domestic water sources by agricultural chemicals should be researched.

Thirdly, research should be conducted to determine sound economic thresholds for the various crops. Data should be presented that would be acceptable by farmers, agriculturalists and the consumers. Pest monitoring and forecasting, along with overall interaction of all components of the agro-ecosystem, should be adequately researched to provide important data such as reduced or increased crop yields.

After research work has been conducted, findings must reach the farmers to be meaningful. Farmers in Antigua & Barbuda are reluctant to change unless they can envisage benefits from alternative approaches. In this respect, more extension personnel should be trained in IPM and be able to transfer local research findings to farmers with confidence and positive interactions. Adoption of IPM by farmers in Antigua & Barbuda depends on its effectiveness in alleviating economic losses of crop yields. Very successful IPM implementation should be able to achieve increased yields and returns to the farmers.

Economics is the driving force as to which way the pendulum will swing with regard to IPM in Antigua & Barbuda. The pesticide salesmen are now doing brisk business and, in attempting to sustain their business interest, seek to convince farmers that only pesticides would work for pest problems, At present, the words of pesticide salesmen are heeded more than those of

extension personnel with regard to pest management.

In conclusion, alternatives to chemicals for pest control must be developed in Antigua & Barbuda and the integrated approach with several control measures should be adopted. The successful implementation of IPM among Antiguan farmers depends on adequate research and improved extension. Inputs regarded as necessary for IPM include: resource personnel, receptive farmers, data on pest life cycles, crop losses and economic thresholds.

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INTEGRATED PEST MANAGEMENT IN THE BAHAMAS

G Hammerton

The Commonwealth of the Bahamas comprises an archipelago of more than 700 islands and cays spanning an area of 215,000 km^2 of the Atlantic Ocean. It is located about 80 km to the south-east of southern Florida, between latitudes 20 and 27° N and longitudes 72 and 79° W. The land area is about 15,000 km^2. Twenty-two of the islands are inhabited with about 17 or so of the islands having a population exceeding 30. The others are either uninhabited or have very small or transient populations. The total population just exceeds 255,000 (1990 population census). Around 67% of the population live on New Providence Island, on which is situated the capital city of Nassau. Another 16% of the population live on Grand Bahama Island (site of the nation's second city). The remaining 17% are scattered throughout the other islands. The populated islands other than New Providence are known as the Family Islands.

Geology

Geologically, the archipelago comprises a low lying, undulating limestone platform derived from coral. The highest point (Mount Alvernia in Cat Island) is only 62.8 m above sea level. Only about 10% of the total land area is considered to have good agricultural potential and 90% of these lands are located on the three major islands of Abaco, Andros and Grand Bahama.

Economy

The economy is dominated by the tourism sector; agriculture has historically never been of major importance. The agricultural sector accounts for only about 5% of economic output, whilst food imports account for 25% of non-petroleum imports. About 90% of the food consumed in the Bahamas is imported. Agriculture employs just over 3,000 persons – less than 3% of the total work force.

Agricultural production

Recently, there has recently been an increase in agricultural activity in the northerly islands. Much of this is large-scale production of citrus, other fruit crops and vegetables, for export. Large-scale agriculture requires heavy tracklaying tractors with rock ploughs and crushers for land preparation. The resultant soils are stony, free-draining and highly alkaline. The underlying limestone contains extensive fresh-water aquifers, often at a depth of only a few feet. These provide water for irrigation, and for domestic and industrial use.

Pesticide usage

Disposal of pesticides and pesticide containers has been, and still is, a very serious constraint to the widespread use of pesticides in the Bahamas. This is particularly so as some of the Bahama Islands have very high water tables, and because a generous supply of potable water is vital to the tourism industry.

Integrated pest management

Due to the above, the authorities are acutely aware of the need to prevent contamination with pesticides. It is, therefore, advantageous to encourage the use of alternative measures for pest control. The smaller – subsistence – farmers engage primarily in 'pothole' farming and generally do not have the financial capability to venture into modern methods of integrated pest management. It is the larger farmer and some plant nurseries (particularly those involved in the tourism sector – in hotel decoration and landscaping) who involve themselves in integrated pest management.

Crop rotation, field sanitation and use of resistant varieties are the alternative measures to chemicals most widely

practised by subsistence farmers. Additionally, larger farmers utilize discing and ploughing of fields as well as biological control along with chemical pesticides to form an integrated pest control.

Biological control

Presently, *Bacillus thuringensis* is commonly used for the control of cabbage looper.

Cryptolaemus montrouzieri (lady bird beetle) has been used to control *Plannococcus citri* (mealybug) in citrus grown for export.

Encarsia opulenta and *Amitus hesperidum* (parasitic wasps) are used in the control of *Aleurocanthus woglumi* (citrus blackfly).

Steinernema carpocapsae nematodes are being injected into the soil through the irrigation system to control the citrus blue-green root weevil *Pachnaeus litus* in its larval form. The nematode is marketed under the name of BioVector®.

Both the citrus blackfly and mealybug are being successfully controlled. One release of parasitic wasps has shown very good results (the wasps occur naturally in the environment). The nematode release is fairly recent and is still being monitored for performance.

Interiorscapes

Phytoseiulus persimilis (predatory mites) have been used inside hotels to control red spider mites.

Similarly, *Aphidoletes aphidomyza* (aphid midge) has been used to control aphids.

Chhrysoperla spp. (lacewing) has been used to control mealybugs and whiteflies.

varieties of avocado which had lower tolerance to pests and diseases than local varieties.

The banana boom in the 1980s, while being of major economic benefit to farmers of this country, began a new phase in plant protection. Within this structure, the market demanded a particular product of a particular quality and to attain this quality, a 'menu' of practices was presented to farmers. It was essential for the successful marketing of these products not only that they be of the highest quality but that they be free from pests and diseases. These practices, more often than not, did not take into consideration the pest population, beneficial organisms and the economic thresholds of pest populations.

As far as farmers could see, the practices employed in the banana industry, proved fruitful and thus the same 'menus' and menu mentality were applied to different crops with devastating results. Relatively small holdings, soil type (clay loam) and topography make it quite impossible for individual farmers who don't adopt the menu to maintain a field that is pesticide-free.

Extensive experimental work is presently being employed to control the mango fruit fly. This includes trapping and population monitoring (using field traps). Zoning of mango to the west coast of the island, which is extremely dry, seems to have a negative effect on the population of the above pest.

Quarantine measures are also in place to ensure that this pest and other pests are not imported or exported out of the country. This effort, however, has met some short-comings and it is further frustrated by a booming huckster trade. There is also a post-harvest aspect to the control of this pest. Hot water dips are also done.

Within the vegetable sector emphasis is being placed on disease -resistant varieties, good land preparation, good rotation programmes, good fertilizer programmes, suitable cultivars of crops and general practices suitable to producing healthy plants, and, if there is an absolute need, the safe and effective use of pesticides. A number of training workshops have been held to transfer the need to evaluate crops carefully before the pesticide is used. Preventative sprayings in many cases are not encouraged within this sector.

Work has also been done on coffee borer, rodent control in cocoa, coconut mite grubs and citrus weevil.

The idea of 'organic farming' is slowly filtering to farmers in the country. This is especially true of housewives who are no different from housewives in the developed countries and are looking towards the well-being of their families. In many cases, farmers who are involved in organic farming have livestock which make use of material unfit for human consumption.

Degree of success

An IPM programme requires a very high level of management. While it has been argued that the chemical control regime cost more, one must agree that the cost that will have to be associated with the management of such a programme will be phenomenal.

Farming in the tropics requires considerable managerial ability, especially where diversified ecologically sophisticated agro-ecosystems are involved. Small farmers usually manage a mix of annual and perennial crops as well as animals on small plots of marginal land under highly variable conditions within an adverse socio-economic context. However, the management abilities of a small-scale farmer, such as ours, may already be stretched to their limits. The modem world makes all kinds of new demands on the traditional system and the quantity and quality of natural resources available to the traditional farmer are rapidly decreasing, e.g. top soil, water, trees etc.

Any crop protection methodology that requires a high level of management skills and critical decision-making based on data collection by monitoring crops is less likely to be accepted and implemented by small farmers.

It is less commonly acknowedged but no less true that the social and economic laws

which govern human interactions must be recognized and accepted if we are to institute technological change. Socio-economic and political considerations affect what can and cannot be done at the farm level. An understanding of these 'non-technical' parameters is essential if crop protection is to be relevant and applicable, particularly to small-scale resource-poor farmers like ours.

In Dominica, all of our trained personnel who are responsible for transferring management skills to farmers have been trained at institutions which did not take our socio-economic factors and on-farm situation into consideration. As a result, these personnel are left to form their own convictions about the existing situations and adapt as best as possible. The transfer process therefore is not uniform and varies from one technician to the next.

Technology transfer can only be effective if there is a receptive audience. The degree of receptivity on the part of the farmer will depend on the crop in question and the market situation of this crop. In Dominica, apart for the banana industry which has a guaranteed market, few crops offer a very attractive package. While diversification is being stressed, the marketing aspect of the crops being pushed is not well-established. Farmers are unwilling to accept extra responsibility without having some assurance of being able to market the crop being considered. Thus the concept of the IPM programme has not been followed to the letter by local farmers. While some aspects are still adhered to according to the crop being considered, the acceptance process is very slow.

Conclusions

It has been maintained by plant protection specialists that a more holistic approach must be employed in the control of pests. While this may be the case, it is obvious that a re-thinking of the strategies that will effect better protection is needed. Work needs to be done in the region to investigate pest populations with regards to their economic threshold level and the predators and other parasitoids that help control these pests. Planned strategies must be within the limitations of existing local socio-economic boundaries and must reflect a close marriage to the marketing of the crops involved.

INTEGRATED PEST MANAGEMENT IN GUYANA

L A Munroe
National Agricultural Research Institute, Guyana

The concept of integrated pest management (IPM) is usually interpreted as the application of a system that utilizes multiple control tactics integrated into a single strategy. Occasionally, the concept of applying optimal control of the pest complex within a given crop is exploited. This latter interpretation of the word 'integrated' considers the combined effects of insects, weeds, plant pathogens and nematodes in an integrated package.

The IPM strategy which is evolving in Guyana is reliant on the approach which integrates several control practices. Invariably, however, a combination of the two approaches is practiced.

The first structured IPM programme in Guyana began in the sugar industry with the introduction of biotic agents for the control of the small moth borers, *Diatraea* spp. (Pyralidae: Lepidoptera). Since there are no discrete generations of the pest, control by the application of pesticides was not considered feasible nor economic, thus the move to biocontrol.

Metagomistylum minense (Townsend) introduced from the Amazon in 1933 quickly became established and is today still effectively controlling this pest.

The sugar industry continued to apply the principles of IPM in its effort to reduce crop damage due to the effect of pests. The concept of IPM, even though in its most rudimentary form, is now applied to the control of pests in other crops. The thrust of pest control research in Guyana now revolves around the application of multiple control strategies.

One of the principal moves towards the institutionalization of IPM is the enactment of pesticide control legislation. Such a piece of legislation will regulate the importation and use of chemical pesticides. Another important component of the IPM programme must be the mass education of farmers, without whose willing and knowledgeable involvement the programme will fail. Research emphasis is placed on pest control strategies which rely less on the use of chemical pesticides, use of resistant varieties and the use of biotic agents and cultural practices.

This paper assesses the status of IPM in Guyana. It gives an overview of the current pest management practices in sugar cane, rice, coconut, pineapple and vegetables generally. The paper discusses how the concept of IPM is being developed into the main strategy for dealing with the pest problems in the agro-ecosystem.

Pesticide legislation

The existence of pesticide legislation is critical to the success of an IPM programme. The absence of such legislation has contributed to the injudicious use of pesticides. The importation of pesticides has been unregulated, resulting in the introduction of extremely and highly hazardous chemicals and the widespread indiscriminate use of these pesticides.

Some pesticides come in different concentrations and very often farmers are not aware of this. This leads to misuse of the product.

The philosophy guiding the use of chemicals will be the replacement of extremely and highly hazardous substances with moderately and slightly hazardous ones. Another principle to govern the use of chemical pesticides will be the importation of an invidual pesticide in one concentration only, preferably the higher concentration, except where this may pose a greater health risk. Ideally a minimum number of pesticides must be selected that can meet the needs of the country.

Complementing the pesticide legislation must be a mass education programme which targets all pesticide users.

Crop protection research

Crop protection in Guyana still depends greatly on the use of chemical pesticides. Although the sugar industry has made tremendous strides in the application of IPM in its crop production system, it still relies to a great extent on the use of chemical pesticides. The rice industry has not made the same progress as the sugar industry in the sphere of IPM. That industry places inordinate emphasis on chemical control. The concept of prophylactic treatment pervades the industry. A similar situation exists in the vegetable sub-sector, where routine pesticide application is administered as a matter of course.

Crop protection research is aimed at reducing the use of chemical pesticides and using only those pesticides which are classified as moderately or slightly hazardous. More emphasis is being placed on the utilization of biotic agents, including botanical pesticides. Varietal evaluation of crops for their resistance to specific insect pests and diseases forms an important component of the IPM research. Research is also being directed towards the development of economic thresholds for specific pests.

Sugar cane

Sixty insect pests have been recorded in sugar cane in Guyana, ten of these are considered important (Table 1). In addition to the insects, another major pest is the rodent, *Holochilus brasiliensis*. Cane stalks at all stages of development, from seed cane to harvested stalks, are damaged by this pest. Control is effected at 1% fresh stalk damage. Baiting with the anticoagulant wax blocks, Klerat® and Storm®, is the method applied. Hunting is practiced on some estates. Proper field sanitation keeps populations at low levels therefore this strategy is promoted.

Management of insect pests is achieved through the application of chemical, cultural and biological control. The sugar industry has an active biological control programme which involves the routine rearing, release and recovery of parasitoids of *Spodoptera* and other pests. Plans are presently being made for the evaluation of the fungus *Metarhizium anisopliae* as a control agent against *Aeneolamia flavilatera*.

Rice

IPM is not consciously practised in the rice industry. Crop production relies on the use of chemical pesticides. Forty-six insect pests have been recorded on rice in Guyana. However, the important ones are shown in Table 2. Of those listed *Oebalus poecilus*,, the paddy bug, is the most important. Parasitoids known to regulate this insect's population are shown in Table 3.

The widespread indiscriminate use of chemical pesticides for the control of the paddy bug and other insects in the rice ecosystem has decimated the parasitoid population. Recent surveys to determine the status of these parasitoids failed to recover either of the two species.

Rice disease

The major disease of rice in Guyana is blast, caused by the fungus *Pyricularia grisea (oryzae)*. The management of this disease is effected through the application of multiple control strategies. Those strategies include chemical control, cultural control (reduced use of nitrogen fertilizer and reduced seeding rate) and the use of resistant varieties. The area of emphasis presently is the breeding or evaluation of lines/varieties for their resistance to the disease.

Weeds in rice fields

Weeds are a major problem in rice production, and here again there is dependence on chemical pesticides for control.

Among the alternative management strategies which farmers are encouraged to apply for the control of weeds, are proper land preparation and water management. With the emergence of red rice as the major weed in paddy fields, the emphasis on cultural practices in the weed management package is well placed.

Table 1. Important sugar-cane pests in Guyana and their control

Pest species	Damage	Native natural enemies	Current method of control
Aeneolamia flavilatera (Urich) [Homoptera: Cercopidae]	Death; retarded growth	*Salpinogaster* sp.	Chemical: BHC, Sevin® against nymphs; Sevin®, Malathion®, Dipterex® against adults. Cultural: Weed control; drainage
Castnia licoides (Drury) [Lepidoptera: Castniidae]	Stem borer		Flooding fields for 48 hours after harvest
Cyclocephala amazona signata (F.) [Coleoptera: Scarabaeidae]	Feeds on tillers		Flooding fields for 24 hours
Diatraea centrella (Moschler) [Lepidoptera: Pyralidae]		Stem borer	None
D. saccharalis (F.)	Stem borer	*Telenomus* sp.; *Palpozenilla palpalis*; *Paratheresia claripalpis*(Walp); *Agathis stigmaterus* (Cresson) *Bracon* sp. *Ipliaulux medianus* (Cameron) *Ipobracon puberuloides* Myers *Imponbracon saccharelis* Turn.	Biological: Amazon fly; *Metagonistylum minemse*
Mocis latipes (Guenee) [Lepidoptera: Noctuidae]	Feeds on leaves		Chemical: Sevin® or Malathion® only when population very high
Nasutitermes costalis (Holmgren) [Isoptera: Termitidae]	Attacks planted setts. Nests on cane		Removal of nests; spraying nest sites with Sevin® or Malathion®
Spodoptera frugiperda J E Smith [Lepidoptera: Noctuidae]	Feeds on leaves	*Archytas piliventris* Walp. *Pseudoarchytopis* sp. *Coleomegilla maculata* (De Geer) *Telenomus rminunssimus* Ashmeed	Same as for *Mocis*
Strategus aloeus (L.) [Coleoptera: Scarabacidae]	Feeds on young tillers; occasional pest		No control
Dyscenetus geminatus [Coleoptera: Scarabaedae]	Attacks planted setts. Feeds on young tillers		Flooding fields for 24 hours

Table 2. Important insect pests of rice in Guyana and their control

Pest	Damage	Native natural enemies	Method of control
Helodytes foveolatus (Duval) [Coleoptera: Curculionidae]	Adult feeds on pregerminated seeds; larvae on roots and seedlings		Chemical pesticides
Hydrellia deonieri Rambajan [Diptera: Ephydridae]	Larva mines leaves		Chemical pesticides
Mocis latipes (Guenee) [Lepidoptera: Noctuidae]	Larva defoliates plants		Chemical pesticides
Oebalus poecilus Dallus [Hemiptera: Pentatomidae]	Sucks sap from grain	see Table 3	Chemical pesticides
O. ypsilongrisecus (De Geer)	Sucks sap from grain		Chemical pesticides
Rupela albinella (Cramer) [Lepidoptera: Pyralidae]	Stem borer	*Polycrytidea flavopicta* *Hecabolus* sp. *Idecthis* sp.	Chemical pesticides; water management
Spodopterafrugiperda J E Smith [Lepidoptera: Noctenidae]	Larva defoliates plant		Chemical pesticides; water management
Diatraea spp.	Stem borers		Bio-control
Sogatodes oryzicola Meir [Homoptera: Delphacidae]	Vector of hoja blanca		Of minor importance

Table 3. Parasitoids of the paddy bug *Oebalus poecilus*

Parasitoid	Host stage parasitized
Telenomus mormideae Costa Lima [Hymenoptera: Scelionidae]	Eggs
Beskia cornuta B.B. [Diptera: Tachinidae]	Nymphs

Table 4. Important insect pests of coconut in Guyana and their control

Pest species	Damage	Native natural enemies	Method of control
Aspidiotus destructor Sign. [Homoptera: Diaspididae]	Sucks sap	*Azya trinitatis* *Cryptognatha nodiceps* *Pentilia insidiosa* *Aphelinus chrysomphali* *Aspidiotiphagus citrinus*	Chemical
Azreca sp. [Hymenoptera: Formicidae]	Nuisance to harvesters		Chemical
Brassolis sophorae (L.) [Lepidoptera: Nymphalidae]	Defoliates palms	see Table 5	Chemical
Eupalmidae cyparissics (F.) (*Castnia daedalus*) (Cramer) [Lepidoptera: Castniidae]	Larvae bore trunk		Chemical
Hispoleptis diluta (Guer.) [Coleoptera: Chrysonelidae]	Larvae mine leaves		Natural and occasionally chemical
Nipaecoccus nipae (Mask) [Homoptera: Pseudococcidae]	Sucks sap		Chemical
Rhynchophorus palmarum (L.) [Coleoptera: Curculionidae]	Larvae tunnel trunk. Adults transmit red ring nematode		Cultural and chemical
Strategus spp. [Coleoptera: Scarabaeidae]	Adult bores into young palms		Cultural and chemical

The crop protection component of technology development for the rice industry is now being built on optimal control of the pest complex (i.e. insects, diseases and weeds). Lines/varieties are being evaluated for resistance to paddy bug and rice blast, the most important insect pest and disease respectively. Weeds which have a positive effect on insect pest population will be managed by a combination of control strategies. Evaluation of pesticides for control of specific pests/diseases is ongoing. A major objective of these evaluations is to identify Hazard Class II and III pesticides which give effective control and which have no adverse effects on beneficial organisms in the rice ecosystem

Training of extension officers and farmers is a vital link in the approach being adopted.

Coconut

Guyana still depends on coconut for a substantial proportion of its edible oil needs. The crop is severely affected by insect pests and diseases. Thirty-six insect pests have been recorded on coconut in Guyana; of these nine are considered important (Table 4)

The two most important pests are *Brassolis sophorae* and *Eupalmidae cyparissics (Castnia deadalus)*. Both pests are controlled by the injection of monocrotophos into palms. A conscious effort was made in 1982 to reduce the use of monocrotophos especially for the control of *B. sophorae* the more important of the two pests.

A biological control project with assistance from the Food and Agriculture Organization (FAO) was initiated at that time. Its objectives were to:

- evaluate indigenous natural enemies of *B. sophorae*
- introduce, breed and release exotic natural enemies
- evaluate the establishment and control after release of natural enemies.

The indigenous parasitoids are shown in Table 5.

The parasitoids are thought to be exerting some amount of control on the pest and may be responsible for keeping the pest population in check for 5–7-year periods (*Brassolis* outbreaks have been observed to occur in 5–7-year cycles). Exotic parasitoids (see Table 6) were introduced from Brazil to augment the native parasitoids.

Multiplication of parasitoids was not very successful and this limited the amount released. Totals of 6,612 *Brachymeria* and 121 *Spilochalcis* species were released. There was no evidence of the establishment of *Conura (= Spilochalcis)* sp. nr. *mariae*. Although *Brachymeria annulata* was recovered there is no evidence of the Brazilian strain being established in Guyana, since there is no way to differentiate between the native and introduced strains.

An entomopathogen, *Beauveria brongniartii* (Saccardo) was imported at the same time as the entomophagus insects; however, this was never used. Investigations on the use of this fungus for the control of *B. sophorae* is planned for the next phase in developing biological control of the pest.

Field sanitation is being advocated as an important method for control of the pest.

The only other coconut insect pest which is regularly controlled by the use of pesticide is *Azteca* ant. A Mirex®-based bait is used. Ant populations proliferate in poorly-kept estates, thus regular weed management is stressed as an important insect pest control measure.

Diseases also play havoc in the coconut industry: Cedros wilt which is caused by the protozoan *Phytomonas elmassiani* is the major disease. Two insect vectors and a weed are thought to be associated with the disease. The weed serves as a reservoir of the disease organism. Further, disease spread is enhanced by close spacing which causes branches of adjacent plants to overlap.

Management of the disease revolves around the adherence to proper agronomic practices, field sanitation and weed management.

INTEGRATED PEST MANAGEMENT IN THE COMMONWEALTH OF DOMINICA

B Nation
Division of Agriculture, Commonwealth of Dominica

In order to implement an integrated pest management programme, one needs to have a great deal of fundamental biological data, selective pesticides, adequately trained specialists and technicians, farmers who are receptive to new concepts and ample statistics on crop losses and economic threshold levels for each crop.

The agricultural sector in the Commonwealth of Dominica has been dominated by a few crops, leading practically to monoculture from colonial times. The principal crops are export-oriented and marketed to only a few foreign countries.

These crops have been introduced into the region together with production technologies – how to prepare land, plant, cultivate, harvest, process and how to control pest and diseases. There was little scope or time for the development of traditional and indigenous crop protection strategies because the imported plant protection technologies, which came with the crops, were essentially plantation-based and more importantly were transferred to smallholdings.

With rising costs of production and a retarding economy farmers face a serious dilemma, revolving around expensive crop protection practices that are limited by farming systems.

Many of the basic crop protection methodologies are incompatible with the agro-ecological or socio-economic conditions in the islands or are technically difficult and economically impossible to implement effectively

Status

Over the last 20 years, a conscious effort has been made on the part of the Ministry of Agriculture, to move farmers away from the injudicious use of chemicals and to adapt more scientifically and ecologically sound practices. This effort has met with varying degrees of success.

In the early 1970s in an attempt to control diamond-back moth, quantities of parasitoids were released into fields of cabbages. Control over this pest was not effective however, due to the fact that this parasitoid was not cultured in the region and thus supplies were infrequent and small in quantity. This was further compounded by the fact that cabbage plots were small and far apart, making it extremely difficult for this organism to establish itself. This effort was later abandoned.

While the 1980s can be described as a heavy chemical phase, the latter part of this period saw a change in the type and ways in which these chemicals were used. Attempts were made to attain more specific pesticides, and surveys were carried out to evaluate pest populations before and after treatment. This effort was again short-circuited by the introduction of extra-regional production methods which were imported together with projects which received external funding.

While suppressing one component of a possible strategy for an IPM programme, this programme brought about another aspect in terms of proper zoning of crops. During the Tree Crop Diversification Programme, attempts were made to put crops into areas for which they were best suited. The north-eastern part of the island was targeted as the main passion fruit area, whereas, the north and south of the island were targeted for the main clove and nutmeg areas.

These programmes however, replaced indigenous pest-tolerant varieties of certain crops, e.g. higher yielding grafted

Pineapple

Pineapple is the third most important export crop. It is severely affected by a disease, gummosis, which lowers the fruit quality. This has restricted the level of export of fruits.

Gummosis is facilitated by an insect vector, the mealybug, *Dysmicoccus brevipes* (Cockerell), which is one of nine insect pests found in the pineapple ecosystem (see Table 7). The mealybug is found in association with an ant, *Solenopsis* sp., and the control is targeted towards this complex. A combination of chemical and cultural control is recommended. Proper selection of planting material and the use of tissue-cultured plantlets also contribute to manage the pest population level.

Table 7. Six of the important insect pests recorded on pineapple in Guyana

Pest species	Damage done
Crematogaster sp. [Hym.: Formicidae].	Associated with mealybugs
Solenopsis spp. [Hym.: Formicidae]	Principal ants associated with mealybugs
Dysmicoccus brevipes (Cockerell) [Homoptera: Pseudococcidae]	Transmits wilt and gummosis
D. bromeliae	
Thecla basilides (Geyer) [Lepidoptera: Lycaenidae]	Larva bores fruit
Thlasticoris lactus (Mayr.) [Hemiptera: Coreidae]	Sucks fruit

Vegetables

Vegetable production is one area of great concern with regards to the use of pesticides. It is an area in which pest control practices are almost exclusively pesticide-dependent.

The most important insect pests of vegetables are:

Hellula phidilealis (Walker) [Lepidoptera: Pyralidae]

Plutella xylostella (L.) [Lepidoptera: Plutellidae]

Thrips palmi (Fitch) [Thysanoptera: Phlaeothripidae]

Liriomyza trofolii (Burgess) [Diptera: Agromyzidae]

These are the pests which have proved most difficult to control and for whose control farmers utilize large volumes of pesticides throughout the crop growing period.

The biopesticides, *Bacillus thuringiensis* de Barjac and Lemille and neem, *Azadirachta indica* A de Jussieu, have now been included in the arsenal to reduce the use of chemical pesticides. Cultural practices including crop rotation are being advocated. Proper pesticide application techniques are also being emphasized.

Simultaneous with these initiatives is the continual farmer education programme.

Table 5. Parasitoids of *Brassolis sophorae* in Guyana

Parasitoid	Host stage attacked
Telenomus nigrocoxalis Ashn. [Hym.: Scelionidae]	Egg
Anastatus reduvii How. [Hym.: Eupelmidae]	Egg
Chaetolypa pyrrhopyga Weid [Diptera: Tachinidae]	Larvae
Paraphrissopoda chrysostoma Weid [Diptera: Sacrophagidae]	Pupa
Sarcodexia innota (Walk.) [Diptera: Sarcophajidae]	Pupa
Brachymeria annulata (F.) [Hym.: Chalcididae]	Pupa
Brachymeria incerta (Cresson) [Hym.: Chalcididae]	Pupa
Spilochalcis morleyi Ashm. [Hym.: Chalcididae]	Pupa
Spilochalcis sp nr *burmeisteri* (Kirby) [Hym.: Chalcididae]	Pupa

Table 6. Exotic parasitoids of *B. sophorae* introduced into Guyana

Parasitoid species	Host stage attacked
Blaecipha (kellymia] plinthopyga (Wied.) [Diptera: Sarcophagidae]	Pupa
Brachymeria annulata (F.) [Hym.: Chalcididae]	Pupa
Spilochalcis sp. .nr. *erythrina* [Hym.: Chalcididae]	Pupa
Spilochalcis sp. nr. *mariae* [Hym.: Chalcididae]	Pupa
Unidentified [Diptera: Tachinidae]	Larva/pupa

Leaf-cutting ants

Leaf-cutting ants (*Atta* and *Acromyrmex* spp.) are the most serious general insect pest in Guyana. A recent survey has established that *Atta cephalotes* and *Atta sexdens* are the most important species in the country.

Management of this pest is achieved through the application of various methods, the major one being the use of Mirex®-based baits. Farmers utilize other pesticides among their control practices. One cultural method advocated is the use of mechanical barriers for perennial trees.

The survey alluded to earlier, is the first stage in the development of a new ant management strategy. Mirex®, a chlorinated hydrocarbon, must be replaced. The new strategy envisaged will use pheromones of the specific ant species in combination with an entomopathogen in a new bait

Conclusions

IPM in Guyana is now evolving as the main plank to tackle the country's pest problems. There already exists elements of integrated management of specific pests of most of the major crop commodities, although the emphasis has always been on chemical control. For the immediate future, those elements other than chemical control which are already being utilized for pest management will be emphasized.

Rice is targeted for immediate attention utilizing the multidisciplinary approach for management of the major rice insect pests, weeds and diseases. A similar approach will be applied to the other major commodities.

The success of IPM will hinge on the enactment of pesticide legislation, farmer education and appropriate research.

THE CONTROL OF IMPORTANT PESTS AND DISEASES OF MAJOR CROPS IN JAMAICA: THE STATUS OF IPM

R C Murray
Ministry of Agriculture, Jamaica.

An examination of the control measures being used for 26 crop–pest associations in Jamaica reveal an emphasis on pesticides (20 instances). Cultural control measures ranked second in importance, being combined with pesticides in 15 of 17 instances. Resistant varieties were used in only two cases while biological control agents play an important role in eight instances. In general, the results of the control packages have been good but excellent where economic threshold levels have been determined, and where resistant varieties, natural agencies and cultural control measures play major roles in the suppression of the pests. It is concluded that despite some weaknesses viable IPM programmes have been developed for the pests in banana, cocoa, coconut and sugar cane. There is too much emphasis on pesticides in mango and papaya. Finally, despite very good to excellent results in coffee, environmental considerations dictate the need for even greater caution in the use of pesticides in the sector.

Considering the popularity of agricultural pesticides in Jamaica and farmers' unfamiliarity with the term 'integrated pest management' (IPM) one may be tempted to conclude that IPM is restricted to the agricultural scientists in the country. It is often said that IPM as an approach to dealing with pest and diseases in Jamaica is new. The term may be new but certainly not the concept. For example, Gowdey's (1924) recommendations for controlling the sweet potato weevil, *Cylas formicarius elegantus*, constitute an IPM package. The same is also true for many of the pest control programmes recommended by the Department of Agriculture up to the 1950s. Not suprisingly, it is in the many publications of the 1960s and 1970s that the use of chemicals was emphasized and other measures largely forgotten, or at best taken for granted. In order to get a reliable picture of the status of IPM in Jamaica the author examined the pest control methods being used for important pests of major crops in the country. The findings are reported below and summarized in Table 1.

Banana

Thrips

The banana flower thrip (*Frankinella* sp.) is of primary importance in banana production in Jamaica. The red rust thrip (*Chaetanathothrips orchidii*) is a problem in scattered localities. These insects are important mainly because they damage the fruit and most commercial growers produce for an export market which places a high premium on unscarred fruits. The extent of losses caused by thrips have not been quantified. However, farmers are penalized by fruit rejection at the boxing plants, and thrips damage is one of the main reasons for rejection.

Cultural measures are used to reduce damage by thrips and to maintain low populations of the pest. The fingers are deflowered and the navel or buds of the bunches removed promptly after the last hand has differentiated. The navel is chopped up to encourage rapid desiccation in the field. Normally the only pesticide used is contained in the plastic covers impregnated with insecticides. These are used to sleeve the bunches from as early as 4 days after shooting (Anon. 1993). Usually chloropyrifos is the insecticide used. These sleeves cost US$0.12 – 0.14 each.

The measures used to control thrips and reduce their damage are highly successful when diligently implemented. However, the rate of fruit rejection because of thrips damage suggests that farmers are having

Table 1. Summary of control measures for important pests and diseases of Jamaica's major crops.

Crop Pest & diseases	Control measures * B	C	P	R	Results
Banana					
Thrips		X	X		Very good
Banana weevil borer		X	X		Satisfactory
Nematode		X	X		Satisfactory
Yellow sigatoka		X	X		Excellent
Citrus					
Fiddler beetle	X		X		Fairly good
Scales & related insects	X		X		Excellent
Fungal diseases		X	X		Satisfactory
Cocoa					
Black pod		X			Excellent
Rats		X	X		Excellent
Coconut					
Lethal yellowing				X	Excellent
Rats		X	X		Excellent
Bud rot and premature nut fall			X	X	Satisfactory
Mites			X		Fair
Leaf spot		X	X		Good
Coffee					
Coffee berry borer		X	X		Excellent
Coffee leaf miner	X	X	X		Normally very good
Coffee leaf rust	X	X	X		Excellent
Mango					
Fruit fly			X		Dubious
Anthracnose		X	X		Satisfactory
Papaya					
Bunchy top		X	X		Fairly good
Mites			X		Satisfactory
Sugar cane					
Cane fly	X	X	X		Excellent
Looper caterpillar	X				Satisfactory
Mealybugs	X	X			Satisfactory
Sugar cane stalk borer	X				Fairly good
Fungal diseases				X	Excellent

* B = Biological, C = Cultural, P= Pesticide, R= Resistant varieties

difficulties implementing them in the field.

Banana weevil borer

Foreman (1972a) described the banana weevil borer (*Cosmopolites sordidus*) as one of the most serious problem facing Jamaica's banana industry. He attributed low banana yield to inattention over a number of years to the 'immense damage' caused by the borer. Although losses due to the borer have not been quantified, it is generally agreed that it is a pest of major economic importance (Anon. 1972).

Twenty to thirty years ago, the most popular method of controlling the borer was with chemicals (Foreman 1972a). Today cultural measures are emphasized (Anon. 1993). This is largely a result of (i) the high cost of the chemicals, (ii) their high mammalian toxicities, (iii) the development of resistance to the pesticides by the borers (Foreman 1972a), and (iv) the adverse environmental consequences of their usage. The most important cultural control measures are the use of uninfested planting materials and field sanitation. Pseudostem traps set randomly throughout the field at approximately 35/ha are used to trap adult borers and to monitor their numbers. The traps are set every 6 months and any borer caught is killed (Anon. 1993). Insecticide treatment is advised if more than one borer per trap is caught. The wisdom of this threshold seems dubious in light of Foreman's (1972a) observation that adult counts bear little relationship to actual damage. Vilardebo's method for determining infestation was recommended (Foreman 1972a) but has not been broadly adopted, probably because it is more complicated than pseudostem trapping. The cultural measures employed against the banana weevil borer are obviously very useful. However, because many nematicides used in banana have strong insecticidal properties it is difficult to conclude that the cultural measures are adequate by themselves.

Nematodes

The burrowing nematode (*Radopholus similis*), the spiral nematode (*Helicotylenchus multicintus*) and the reniform nematode (*Rotylenchulus reniformis*) are the most important nematodes found on banana in Jamaica (Foreman 1972b). The losses caused by these and other species of lesser importance have not been quantified. However, Foreman (1972b) puts it at thousands of dollars each year. Quantifying the cost of loss due to parasitic nematodes is complicated by the fact that they and *C. sordidus* are commonly found together (Foreman 1972b).

Cultural measures form the basis of sound nematode control: planting only nematode-free suckers of not less than 15 cm diameter; planting in nematode-free soil; and preventing contamination of fields from outside sources. However, the emphasis seems to be on the use of nematicides. These are applied up to three times per year and give good control. The decision to use chemicals or not is largely subjective – primarily because no economic threshold level has been agreed on. The factors taken into consideration include the number and distribution of plants toppling as a result of nematode damage and the results of field surveys for the nematodes – species, numbers, male to female ratio and ratio of juveniles in the population.

Yellow sigatoka

Sigatoka disease (banana leaf spot), caused by the fungus *Mycosphaerella musicola*, is the most economically important malady of bananas in Jamaica. One source claims that its effect in a cultivation can be 'devastating' (Anon. 1993). Aside from the reduction in gross yield, poor quality fruits are produced (Hill and Walker 1990). Therefore, traditionally farmers spend a considerable amount spraying to control this disease – up to 26 cycles per year. Based on January 1992 estimates, spraying against Sigatoka disease cost US$17.30–34.60/ha per spray cycle for mobile (mist-blower) spraying, depending on the fungicide used. The cost of aircraft spraying then was US$22.86–40.77/ha per cycle.

Aside from the high cost of spraying chemicals other disadvantages were noted. The popular oils proved to be phytotoxic under dry conditions and the fungus started to develop resistance to some other fungicides. These problems prompted the Research Department of the Banana Board to improve the chemical application

technology. To this end a highly effective management programme has been developed and is being extended to farmers. The key step in the programme is fortnightly monitoring of the fields to establish the severity of the disease based on a youngest leaf spotted (YLS) score. The actual score is used to determine spray cycles, which may be from 14 to 28 days, whenever spraying is necessary. A number of fungicides are used in rotation to reduce the rate at which resistance may develop. The net result is better control of yellow sigatoka with as few as nine spray cycles per year. Notwithstanding, it is recognized that good cultivation practices are necessary for effective and efficient leaf spot control.

Citrus

Viruses

Of the major virus diseases of citrus, psorosis, tristeza and exocortis are known to be present in Jamaica (Weir 1974). At this time, tristeza is of major concern, particularly since the discovery of its most efficient vector, *Toxoptera citricidus*, in the country last July. A 1982 World Bank report put losses due to pests and diseases on citrus at about 45% (Ellis and van Whervin 1986). This figure is expected to pale if the full devastating potential of tristeza reaches the industry. Unfortunately the plans for a citrus budwood certification programme, to produce certified virus-free budwood, reported by Ellis and van Whervin (1986) were not implemented – largely because of financial constraints. The Citrus Growers Association (CGA) is now actively implementing measures to use cross protection from grafts infected by mild strains of tristeza against the severe strains of the virus.

Fiddler beetles

The fiddler beetles or root weevils (*Exopthalmus* spp., *Pachnaeus citri* and *Lachnopus* sp.) are the most important insect pests of citrus in Jamaica (Weir 1974). For several years the industry relied almost exclusively on dieldrin, applied to the soil under the trees, for control of these insects. The beetles developed resistance to the chemical. By the late 1980s it was clear that dieldrin was becoming useless against the pest; moreso in areas where the insecticide was used most diligently. New methods are being developed for dealing with fiddler beetles. Insecticide use is more restricted to spraying the adults and foliage in 'hot spots'. The chemical of choice is carbaryl. With respect to biological control, Weir (1974) reported that there are a number of active and effective egg parasites in many areas. It is doubtful that the measure he recommended for conserving these natural enemies was widely adopted. Recently the Caribbean Agricultural Research and Development Institute (CARDI) has been working with the CGA on other insect parasites and entomophagous nematodes for control of these weevils. Preliminary results are favourable.

Scales and related insects

Several species of Homoptera attack citrus in Jamaica. Generally they have been kept in check by natural enemies. Outbreaks are known to occur when external agencies disrupt the natural balances. For example, in 1962 a devastating outbreak of citrus blackfly (*Aleurocanthus woglumi*) followed the regular spraying of copper sulphate on grapefruit, to control scab (*Elsinoe fawcetti*) and melanose (*Diaporthe citri*), at Wakefield in St Catherine. Several spray cycles using oil and malathion failed to control the blackfly. Shortly after the decision to stop all spraying, populations of the pest subsided to sub-economic levels. Investigations revealed a high rate of parasitism by the wasps, *Encarsia opulenta* and *Amitus hesperidum*. Also, pupae of the insect were being heavily attacked by the entomogenous fungus, *Aschersonia sp.*

Of course, the natural balances are not only disrupted by the intervention of man. For example, the citrus snow scale (*Unaspis citri*) became a serious problem after Hurricane Gilbert in 1988. It is only recently that the problem has been subsiding. With these experiences pesticides are not frequently used to control scale insects and related species in citrus in Jamaica. The norm is the inclusion of oil in the post-bloom spray (Weir 1974). In general the results have been satisfactory.

Fungal diseases

The most important fungal diseases of mature citrus in Jamaica are scab; melanose; anthracnose caused by *Gloeosporium limetticolum* and *Colletotrichum gloeosporoides*; citrus knot caused by *Sphaeropsis tumefaciens*; phythopthora foot rot caused by *Phythopthora nicotignate* and *P. citrophthora*; and greasy spot caused by *Cercospora citri-grisea* (Weir 1974). Under normal conditions cultural control measures involving good field sanitation and pruning give adequate control of these diseases. An exception is premature fruit drop (PFD) which is caused by *Colletotrichum gloeosporoides*. PFD losses may be insignificant to severe depending on the free moisture conditions immediately preceding and going into the flowering period. Plenty of rainfall or heavy dew favours the fungus and leads to severe losses. In the drier areas, a second flowering often produces a late crop which though smaller in volume compensates for the loss because of the better price received. In the wetter areas even this second crop of fruit may be lost. Therefore, regular spraying prior to flowering is recommended.

Cocoa

Black pod

The black pod disease, caused by *Phytophthora palmivora*, is the only serious disease known to affect cocoa in Jamaica (Topper 1979). Under conditions favourable to the disease over 75% of a crop may be lost (Naylor 1974). Cultural measures as elaborated by Naylor (1974), Topper (1979) and Dunbar (1990) are normally adequate for controlling this disease. Naylor (1974) also recommended the planting of resistant varieties. The package of cultural control measures is so effective that chemicals are considered unnecessary for controlling this disease. Moreover, they are discouraged by the Cocoa Industry Board for fear that residues will persist in the cocoa beans. The use of chemicals is recommended only: after all cultural control measures have been implemented; production exceeds 100 boxes per ha; and when the level of infection exceed s10% of pods (Dunbar 1990).

Rats

Presently rats (*Ratus ratus*) are the major pests of cocoa in Jamaica. Nationally they destroy 10–15% of the crop. They are most serious in poorly managed cultivations. Therefore, the first step in controlling them is improving field sanitation. Dunbar (1990) suggested that removing and destroying their living and breeding places will eliminate them. In addition to field sanitation measures rats are killed by poisoned baits, anticoagulants (Topper 1979; Dunbar 1990). The bait is distributed throughout the cultivation in 25–125 stations per ha, depending on the severity of the problem. The resultant control is excellent.

Coconut

Lethal yellowing

The lethal yellowing disease almost wiped out the coconut industry in Jamaica when it decimated the Jamaica Tall variety, up to the early 1970s. It is being successfully combated with less susceptible varieties: Red, Yellow and Green Malayan Dwarfs and the Maypan hybrid. The response of these varieties to the disease has been variable. Thus 13% of the Maypan planted in 1980 have since succumbed to the disease and 2–3% of Malayan Dwarf plants also. The severity of the disease in these new varieties also varies with location. For example only 1% of the palms are lost in the eastern parishes where over 90% of the coconut is grown. On the other hand, in the Smithfield area of Westmoreland, in the west, up to 20% have been lost. The Coconut Industry Board is continuing its research to find answers to this disease.

Rats

Ratus ratus destroyed at least 5% of Jamaica's coconut crop, worth some US$250,000 annually, based on 1970 estimates (Anon. 1970). However, losses sometimes reach as high as 70% (Anon. 1970; Royes and Baccus 1988). Baiting with anticoagulant impregnated food blocks is normally used to control rats in coconut. Using a protocol developed by the Coconut Industry Board (Anon. 1970) growers are

able to measure the level of rat damage and decide when to apply baits. To avoid the build up to resistance as observed in some countries (Hill and Waller 1988) it is recommended that baiting be done only when damage is observed and not more than twice in any year (Royes and Baccus 1988).

Bud rot and premature nut fall

Bud rot, caused by *Pytophthora* sp. is most severe in low lying humid areas and is responsible for less than 1% loss in coconut island-wide. However, in certain localities it kills up to 20% of the trees. Bud rot is usually found in association with premature nut fall, also caused by *Phytophthora* sp. The latter condition does not kill affected trees. However, the incidence of nutfall increases considerably during periods of prolonged rainfall (Steer 1990). The use of fungicides (metalaxyl and fosetyl-Al), is recommended where cultural measures fail to control these diseases. If the 'bitten leaf' condition appears (a symptom of bud rot) then spraying is recommended. If however, the youngest leaf is wilted then the palm is already lost. Removing and burning it is recommended. Also, adjacent trees should be sprayed. These measures have given adequate control of the two diseases when supported by certain cultural control measures. The most important are the removal of shade over young trees, good field sanitation and avoiding planting in wet areas.

Mites

The coconut mite, *Eriophyes guerreronis*, has been growing increasingly conspicuous in Jamaica in recent years. Its damage has not been quantified but in severe cases all the nuts on affected trees are distorted. The mite is considered important enough that the Coconut Industry Board has financed studies on its status and control – by a graduate student at CARDI (Been 1990). The Board recommends spraying with white oil to control the pest. The Ministry of Agriculture advise that spraying may not be necessary in the rainy seasons or if the problem starts to develop towards the end of the dry season.

Leaf spot

Leaf spot is generally of low incidence, being serious on less than 1% of coconut palms. It is caused by a fungus, *Dreschera* sp. and is most threatening to young coconut in areas where coconut is intercropped with vegetables to which high levels of nitrogen are applied in fertilizer. Chlorothalonil is the fungicide recommended for use against this disease.

Coffee

Coffee berry borer

In Jamaica the coffee berry borer, *Hypothenemus hampei*, causes losses as high as 70–100% where no control is practiced (Budhlal 1986). The pest was first detected in the island in 1978. Within 4 years it was found in all coffee growing areas and bean damage averaged 33% (Williams 1992). This pest literally changed the nature of coffee production in the country as prior to its arrival the use of pesticides in the crop was minimal (Williams 1992). Pesticide spraying became a feature of coffee production subsequently.

A coordinated effort between the Ministry of Agriculture, CARDI, the Coffee Industry Board and the University of the West Indies developed a coffee berry borer control programme. Its objective was to reduce infestation levels to below 5% in 5 years; between 1982 and 1987 (Williams 1992). The cultural control elements of the programme were developed by CARDI. They form the main plank on which chemical control is built. Two well timed applications of endosulfan per year have proven sufficient to control the borer. The programme was highly successful. By the 1987/88 crop the mean bean damage level nationally was recorded as 4.3% (Williams 1992).

It is noteworthy that despite the success against the borer, the use of endosulfan in coffee in Jamaica has been the cause of much debate recently. The growth in importance of the previously relatively unimportant leaf miner, *Perileucoptera coffeela*, is blamed in part on the use of this

pesticide. Also, traces of the chemical have been found in streams originating from at least one major coffee growing area, the Blue Mountains. Sources in the Coffee Industry Board have blamed this on deliberate misuse of the chemical. It is quite possible however that the chemical is used excessively in the area. Firstly, because coffee tends to flower and bear year-round in the Blue Mountains. This and the high price paid for Blue Mountain coffee makes it difficult for farmers to implement certain cultural control measures such as stripping at the end of the crop. It is easier to spray. Secondly, agricultural labour is not always readily available in the area largely because of the considerable increase in coffee acreage over the last 10 years. The cultural control measures are labour-intensive. Finally, most of the private commercial group of coffee farmers are professionals who do not depend entirely on the income from coffee (Williams 1992). They are new investors who are unwilling to take 'unnecessary risks'. Pesticides are attractive to them because they act fast, the results are immediately obvious, they are easy to apply and labour is not a major constraint to their use.

In recognition of the problem posed by the use of pesticides in coffee in Jamaica a project proposal, seeking funding from the United Nation's Development Programme (UNDP), has been prepared. Among its objectives the project seeks to develop measures which rely less on chemicals for controlling coffee pests in Jamaica.

Coffee leaf miner

Prior to the discovery of the coffee berry borer in 1978, the leaf miner, *Perileucoptera coffeela*, was of little importance (Williams 1992) and never developed to any serious extent (Moss 1956) in Jamaica. By 1983 Rhodes and Williamson (1993) wrote that it was a major pest in coffee nurseries and plantations. Leaf miner damage reached its zenith in the 1991/92 crop year. This was an exceptionally dry year. A conservative estimate from the Coffee Industry Board puts the yield losses at over 41,000 boxes worth US$914,000. In addition 61.5 ha of plant coffee were destroyed. The first-year cost of re-establishing this acreage was US$113,000.

The use of pesticides to control the berry borer and later coffee rust has been partly responsible for the change in status of the leaf miner. Moss (1956) suggested that natural enemies, including at least ten species of parasitic wasps, normally control the pest. He reported that in a few instances fairly severe damage occurred where coffee was grown under bananas that were sprayed with Bordeaux mixture and opined that the copper in the spray either inhibited or destroyed the natural enemies. This is consistent with Schmutterer's (1990) observations.

Prior to 1991 satisfactory leaf miner control was obtained by placing granular systemic insecticides, particularly carbofuran, at the roots of coffee plants. Among the advantages of this method was that it had little effect on the natural enemies of the miner (Rhodes and Williamson 1993). However the method was inadequate in 1991/92. This was largely because sufficient moisture was not available for the chemical to become available to the plant from soil solution. Preliminary work done by CARDI in 1991 showed profenofos and a micro-encapsulated solution (CS) formulation of isozophos giving acceptable control (Reid 1991). Isozophos is preferred by the industry but its usage has been very limited because of the Pesticides Control Authority's concerns about possible adverse environmental effects of the chemical in the coffee country.

Coffee leaf rust

The coffee leaf rust disease caused by the fungus *Hemileia vestatrix* was first discovered in Jamaica in 1986 (Williams 1992; Brown 1993). The full devastation potential of coffee rust has not been realized in Jamaica, mainly because the industry was prepared for the disease when it was found. Following reports of the arrival of the disease in Cuba in 1984 an intensive rust education campaign was mounted in 1985 (Brown 1993). This campaign was helpful in enabling the early discovery of the disease and in the subsequent control programme.

The disease is controlled mainly by the use of copper oxide-based fungicides sprayed at the end of the dry seasons. Four to five spray cycles per year normally provide

adequate control. This approach recognizes that fewest viable spores of *H. vestatrix* are present at the end of the dry periods. It has minimal adverse effect on the natural enemies of the leaf miner. Also, an important naturally occurring verticillum fungus which parasitizes the rust in Jamaica, reducing spore counts by up to 50% (Brown 1993), is conserved. Together with cultural measures involving pruning, field sanitation and ensuring good plant nutrition these well-timed applications of pesticides keep the rust under control.

Mango

Fruit flies

The West Indian fruit fly (*Anastrepha obliqua*) is the only fruit fly known to attack mango in Jamaica (van Whervin 1974a; 1974b; 1976). It is rated as a serious pest of the crop by Henry (1975). He wrote that it may infest 9% of fruits at times. However, depending on the variety, location and season, up to 100% of the crop may be damaged (Murray 1987). One study in 1986 estimated that 25% of the annual mango crop worth US$5.7 million was lost because of fruit fly attack (FAO 1987).

Mango growers rely almost exclusively on pesticides for controlling fruit flies. Depending on the variety this may involve up to 12 spray cycles since spraying usually starts quite early, based on the results of van Whervin's (1976) work and Henry's (1975) recommendations. Generally the growers report that they get satisfactory control. However, it is dubious that this is due solely to the chemicals. Firstly, because Murray's (1987) work showed that fruit flies are least abundant in the areas where most of the commercial mangoes are grown. Secondly the most popular commercial variety, Tommy Atkins, is reported to show some resistance to the West Indian fruit fly (Weir et al. 1982; Soto-Manitu et al. 1987). Furthermore, even if the flies were plentiful, it is quite likely that the farmers are using too much insecticide because, based on the results of Soto-Manitu et al. (1987), their infestation levels in the new preferred varieties may be very low during most of the fruit's development period.

Anthracnose

Anthracnose, caused by the fungus *Colletotrichum gloeosporoides*, has long been the most important disease of mango in Jamaica. It is widely regarded as the most serious problem facing the industry. Even though the loss due to the disease has not been quantified the consensus is that it is considerable. Mango does not produce in certain areas because the fungus 'burns' off the inflorescences. Many fruits are lost early in the crop and whole shipments have been rejected in Europe because of post-harvest manifestations of the disease. Furthermore, the cost of post-harvest hot water treatment, which is now standard for the export trade, and monthly spraying as recommended by Naylor (1974) is quite high.

As for fruit fly control, mango growers rely almost exclusively on chemicals to control anthracnose in the field. Until recently the results have been satisfactory. However there are strong indications that the fungus has developed a lower sensitivity to benomyl, the preferred fungicide, in a number of areas.

Papaya

The pests and diseases of major concern in papaya production in Jamaica are bunchy top, distortion ringspot virus, papaya mosaic virus, thrips, mites and nematodes (Harvey et al. 1990). Distortion ringspot was only recently discovered and has been subject to eradication measures under the direction of the Ministry of Agriculture. Plants showing mosaic or bunchy top are removed and destroyed. Mites and thrips are kept under control with chemicals. Mites have been particularly problematic in certain areas. However growers are satisfied with the results when Stirrup-M® is added to the miticide mixture. Stirrup-M® is the trade name of a behaviour-modifying biochemical which causes increased movement of the mites (Sine 1990). This increases the pest's exposure to the chemical and hence ensures better control. Chemicals are also used to control the leaf hoppers which transmit the bunchy top disease (Royes and Baccus 1988).

Sugar cane

Canefly

In 1967 infestation of canefly (*Saccharosydne saccharivora*) reached its highest when almost 19,000 ha had to be sprayed. Prior to that the norm was 4,000 ha/year. According to Falloon (1984) that was the worst outbreak in Jamaica's history. Research into the biology and behaviour of the insect, by the Sugar Industry Research Institute (SIRI), and the development of better pesticide application technologies allowed for a dramatic reduction in the incidence of canefly. In the 1980s total spraying to control the pest never exceeded 400 ha and in most years of the decade the acreage sprayed was zero (Falloon 1990b). It was found that planting cane in the fall provided a natural bridge for the build-up of damaging populations of the insect (Falloon 1990b). This was actively discouraged. However the main plank of the success has been the rational use of proven pesticides, malathion and fenitrothion, as elaborated by Falloon (1990b). The chemicals are not used unless absolutely necessary; careful timing of spraying has made it possible to effect control with one rather than two treatments. Thereby the natural enemies of the insect are preserved.

Looper caterpillar

The looper caterpillar, *Mocis repanda*, is an occasional pest of sugar cane in Jamaica. In an infestation many leaf blades are eaten away to the mid-rib. However after a few months the plants recover (Frank 1970). A number of natural enemies, parasites and predators, keep the loopers under control and an outbreak does not normally last more than a single generation (Frank 1970. Therefore special control measures are not normally required.

Mealybugs

Two species of mealybugs attack sugar cane in Jamaica; the pink mealybug, *Saccharicoccus sacchari*; and the grey mealybug, *Dysmicoccus boninsis*, which is less common (Schaaf 1973). Losses caused by these insects have not been quantified. However the ants which are often found associated with them can be a nuisance to workers. Natural enemies and cultural control measures are relied on to keep these pests under control. The cultural measures include the use of clean planting material and replanting heavily infested fields after all trash and stubble is destroyed.

Sugar cane stalk borer

The sugar cane stalk borer (*Diatraea saccharalis*) has long been an important pest of the crop in Jamaica. Falloon (1985) wrote that, nationally, borer damage rarely exceeded 6% or 7% of internodes but that damage below 5% was the acceptable norm. Damage by this insect affects sucrose recovery at the factory and various estimates frequently put actual losses at 0.5–1.5% of sucrose for every 1% of internodes bored (Falloon 1985). Several factors made the search for an answer to the borer problem in chemicals undesirable. Instead suitable natural enemies were sought. A Tachinid, *Lixophaga diatraeae*, was known to exert some control over the pest (Falloon 1985; Royes and Baccus 1988) as well as the wasp *Agathis stigmaterus* (Falloon 1985). However they were believed to be inadequate and further work by SIRI led to the successful introduction and release of another wasp, *Apanteles flavipes*, in the early 1980s after many failures (Falloon 1985). By 1989 *A. flavipes* was exerting useful control over the borer, and being dominant to *L. diatraeae* and *A. stigmaterus* in the process (Falloon 1990).

Fungal diseases

Prior to the arrival of smut (*Ustilago scitaminea*) in late 1976 (McCatty 1977), and rust (*Puccinia erianthi*) in 1978 (Anon. 1978), Jamaica suffered relatively small losses from sugar cane pests and diseases (Royes and Baccus 1988). Before its arrival it was feared that losses from smut could reach proportions great enough to threaten the industry (Anon. 1975). The rapid spread of the two diseases caused farmers considerable losses and made it necessary for them to incur additional expenses for replanting affected areas (Royes and Baccus 1988).

However, the losses were minimized because it was promptly recognized that

only the planting of resistant varieties would give adequate control of the two diseases (Anon. 1978). The control measures recommended for smut involved regular surveys, getting rid of infected canes by roguing and replanting with resistant varieties (Burgess 1978). These measures were adopted and consistently followed and varieties resistant to both diseases were identified and planted. The responses to rust and smut have been successful.

Other crops

Most other crops grown in Jamaica (root crops, vegetables and pulses) are produced primarily by resource-poor farmers. Pesticide usage amongst these farmers in variable. Very little is used by the subsistence farmers in the hills. In contrast, considerable amounts of pesticides are used in those areas which specialize in certain crops. For example, in south Manchester and south St Elizabeth – major vegetable growing areas; in the Christiana area of north Manchester and Guys Hill in St. Catherine – Irish potato (*Solanum tuberosum*) growing areas; and in the Kellits/Douglas Castle area of north Clarendon – the main cabbage growing area. It is in these areas that pest outbreaks are most frequent. CARDI is doing useful work to identify effective biological control agents for use in these areas.

Ornamentals: In recent years the local ornamental industry has recorded substantial growth. Pesticide usage in the sector tends to be very heavy. Firstly, because the market demands blemish-free products and secondly, because investors are unwilling to take even reasonable risks with pests and diseases.

Weed control

In Jamaica, five of the ten most heavily used pesticides are herbicides (Murray 1992). They are used mainly by large farm operations in sugar cane, banana, citrus and coffee production (Murray 1992). Therefore it is not unfair to conclude that chemical control is the main method used in the plantation crops, even though much labour is employed by the large farms for weed control operations.

Observations and conclusions

The determination of actual losses and economic threshold levels (ETLs) are generally recognized as critical to the development of any pest control programme. In most cases the information regarding losses was not readily available. It is only in four cases of crop–pest associations that economic threshold levels were determined; for the banana weevil borer and yellow sigatoka on banana, for black pod on cocoa, and for rats in coconut.

Twenty-six important crop–pest associations were examined (Table 1). In 20 instances pesticides are used in the control package. In three of these instances the pesticides are relied on solely to do the job. Cultural methods rank second in popularity. They are combined with pesticides in 15 of 17 instances. In eight cases biological agencies are identified and relied on to effect some control. It is only in two instances – for fungal diseases of sugar cane and lethal yellowing of coconut – that resistant varieties are used. In general the control packages being used give satisfactory results for the pests and diseases targeted. It is noteworthy, however, that excellent control is obtained only where:

- resistant varieties are used
- ETLs have been determined
- natural agencies play an important role, for example in controlling scales and related insects on citrus and canefly
- cultural control measures play a major role, for example in controlling rats and the coffee berry borer.

Regarding the use of fully integrated control packages covering all pests, the main crops of concern are mango and papaya. The rapid expansion in production of these crops is fairly recent. Growers of these crops do not yet have the experience of say citrus or banana growers to compel them to adopt more diverse pest control

methods. Banana, coconut and sugar cane are serviced by, and benefit from, strong viable commodity organizations and research entities. Viable IPM programmes have been developed for these crops. They will be strengthened to the extent that ETLs are developed for the relevant pests and diseases. Cocoa has been strengthened because of this. The future of the citrus industry will be determined by the effectiveness of the response to tristeza, particularly the success or failure of the rootstock programme and efforts to use cross-resistance against the virus.

Coffee is a special case. The pest control programmes in this crop have been highly successful. Because of the fragility of the ecosystem in the main coffee growing areas the use of pesticides in the crop is of major concern. Coffee is an important and growing source of foreign exchange income It is the livelihood of over 25,000 farmers and their families (Williams 1992), and the investment in coffee is very substantial. On top of all this the pesticides have been working. The Jamaican coffee industry has all the elements for development of truly integrated pest manage-ment programmes. On the other hand all the forces to prevent this from being realized are involved and may succeed in doing so unless compromises are made.

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AN INTEGRATED PEST MANAGEMENT STRATEGY FOR THE CONTROL OF DIAMOND-BACK MOTH (*PLUTELLA XYLOSTELLA*) IN CABBAGE (*BRASSICA OLERACEA*) ON MONTSERRAT

D S Meade
Ministry of Agriculture, Montserrat.

Integrated pest management (IPM) emerged as a strategy for pest control on Montserrat as a result of significant changes in the attitudes prompted by the excessive use of chemical pesticides just a little over a decade ago.

During this time the success of chemical control with persistent insecticides was so efficacious that other control techniques received minimum support. These insecticides were used extensively whenever control was thought to be needed.

However, the escalating costs of pesticides to farmers, the widespread occurrence of pesticide-resistant insects in addition to the appearance of secondary pests and problems caused by pesticide residues, engendered a renewed interest in alternative methods of pest control.

An integrated pest management strategy for the control of diamond-back moth on cabbage

Cabbage (*Brassica oleracea*) is attacked by a number of insect pests of which the most widely distributed and important are the various lepidopteran insects. Included in this group are the diamond-back moth (*Plutella xylostella*), cabbage budworm (*Hellula phidiealis*), and the looper (*Trichoplusia ni*) which are regarded as the most damaging. One other pest of a more localized importance is the cabbage white butterfly (*Ascia monuste*) which causes serious losses at certain times of the year. Another pest of sporadic importance is the mole cricket (*Scapteriscus* spp.) which may cause some damage in the seedling stage of cabbage.

The diamond-back moth (DBM) is the most serious and widespread cabbage insect pest in Montserrat. Up until 4–5 years ago, there was no known effective chemical control for this insect. A wide range of conventional systemic insecticides was recommended by the extension services to farmers for the control of this pest. These included Decis®, Ambush® 50, Dipterex® 95%, and Lannate®, which all failed miserably because of too frequent applications at improper times and incorrect rates.

The injudicious use of insecticides resulted in the DBM becoming resistant to them, and an undesirable increase in the numbers of each successive generation. Widespread occurrence of this dreaded lepidopteran insect also caused a precipitous decline in total annual production as well as total marketable yields of cabbage.

The implication was that by the end of 1990, 92% of the island's consumption needs was satisfied by imports (see Table 2).

Based upon research conducted during the last 3 years on Montserrat, and in other countries, an integrated approach to control DBM on cabbage was designed and tested. The main components of this package of control techniques comprised:

- Cultural practices-field sanitation, scouting
- *Bacillus thuringiensis* (bt)
- Insect growth regulator (IGR)
- Broad-based systemic insecticide

The principal objective of this strategy was to evaluate the efficiency of this package to produce high quality heads and to determine the cost involved.

Results

The results are shown in Table 1.

Table 1. Effect of seven methods of control on marketable weight of cabbage – Montserrat 1992.
(** Selected observations)

*Treatment heads	Total wt. of heads	Stripped (marked) wt. of heads	% Marketable
Dipel® 2x	5.512	3.032	55
Condor®	4.890	2.675	55
Nomolt®	5.572	3.735	67
Cutlass	5.275	3.485	66
Nomolt® + Dipel®	6.520	4.610	71
Nomolt® + Condor®	6.615	4.575	69
Nomolt® + Cutlass	5.545	3.543	64

** Means of four replicates Sample of heads used from each plot

* Dipel 2x = Bacillus thuringiensis. var. kurstaki
* Condor = Bacillus thuringiensis subsp. kurstaki strain EG 2343.
* Nomolt = teflubenzuron

The results indicate that Nomolt® + Dipel®, the current recommended practice introduced by CARDI and the Ministry of Agriculture in October 1990, is superior to or as good as the other control measures.

Defacto, since farmers adopted Nomolt® and Dipel® as the standard practices, statistics show that imports of cabbage drastically shrunk while simultaneously local production expanded (Table 2).

Table 2 Change in cabbage trade since the introduction of insect growth regulators and *Bacillus thuringiensis* as a control of diamond-back moth in Montserrat: 1991/1992.

Year prodn.	Imports Value (kg)	(EC$)	Value (kg)	Local (EC$)
1990	25,200	81,000	2,220	14,670
1991	13,200	37,513	14,900	90,200

Source: Production Co-ordination Unit – Department of Agriculture, Montserrat.

Chemical control measures

When to spray	What and how much to use
In the nursery	Dipel®; 7 g/l of water or Nomolt®; 2.5 ml/l of water (if worms are present)

After transplanting

7 days	Dipel®; 7 g/l of water
15–20 days	Dipel®; 7 g/l of water
24–28 days	Nomolt®; 2.5 ml/l of water
32–35 days	Nomolt®; 2.5 ml/l of water
38-40 days	Nomolt®; 2.5 ml/l of water

Stop spray 7-10 days before harvest if other sprays are needed use Dipel®

Use Orthene® (7 g/l) to control adult diamond-back moth stink bugs and other insects.

Cultural practices

Much emphasis was placed on field sanitation and scouting. Farmers were encouraged to do the following:

- Get rid of all old cabbage stumps before planting, by piling outside of the field and then burning them.
- Check the plants every other day for worms. Spray Nomolt® immediately after the worms are seen.
- Manage weeds properly particularly 'white top' (*Parthenium hysterophorous*), since the adult diamond-back moth tends to be prevalent in cabbage producing areas infested with this weed. The contact herbicide, Reglone® (diquat) at 7 g/l was recommended to control white top prior to planting.

Conclusions

The data compiled in Table 2 indicate that in 1991, the amount of cabbage imported into the island fell by more than 50%, with a foreign exchange savings of 44%. Domestic production and farmers' income increased seven and sixfold respectively.

Under the old package, losses in marketable production varied between 60 and 70%. It is expected that the statistics would improve significantly in 1993 and beyond, as adoption rates improve.

DEVELOPMENT AND APPLICATION OF IPM IN SURINAME

M Dipotaroeno-Sakrama
Ministry of Agriculture, Animal Husbandry and Fisheries, Suriname

Agriculture in Suriname may be regarded as the second most important economic activity. It mainly practised in the coastal areas. There is a wide range of food crops grown in Suriname for both local consumption and for export. This range of food crops includes food legumes (beans, cowpea and peanut), cereal crops (rice and maize), root and tuber crops (cassava, sweet potato, dasheen and yam), vegetables (Cruciferae, Cucurbitacaea, Solanaceae) and oil crops (soya bean).

Among the food crops, rice is by far the most important – it is the staple food (100 kg per person per year) and contributes 55% to agricultural exports. Also the largest area of cultivation is covered by the rice crop. This is of great value to the country as an important foreign currency earning source.

On the other hand, vegetable crop production has always been important for local market supplies and also for domestic food. The export possibilities of vegetable products (Solanaceae and Crucifereae) to Europe (Holland) and French Guyana have led to the establishment of a large number of small-scale farms in Suriname. Tables 1, 2 and 3 show relevant data for annual and perennial crops between 1988 and 1992.

Current crop/pest situation

Apart constraints such as agricultural inputs hampering local foodcrop production, it was also recognized that the high cost of food crop production by small farmers is a result of inappropriate pest management techniques.

Over the past years, many pests have built up resistance to the available and over-used insecticides, so that farmers are becoming more careless in their demand for, and use of, pesticides. These and the unstable economic situation resulted in a decrease in food crop production in Suriname.
There are several pests and diseases in Suriname which are widespread and of great economic importance to farmers. Some of these pests are under a fair amount of control using integrated pest control methods (in bananas and to some extent rice), but the most widely practised control method is the use of chemical pesticides. These pesticides need to be changed frequently as the pests tend to change also.

Progress in IPM

In view of the problems encountered in the control of pests in food crops in Suriname – lack of agricultural inputs; untimely applications and incorrect dosages of pesticides; lack of knowledge of pest biology; and inadequate use of suitable agronomic practices – the long-term desire by the government to reduce the amount of pesticides and the world-wide pressure for what is perceived as 'safer produce', initial efforts have been made towards the development and imlementation of integrated pest mangement (IPM).

Table 4 indicates the current status of activities towards the development of IPM in food crops in Suriname.

Recognizing the negative effects of pesticides – to the farmer, consumer and the environment – efforts are being taken to introduce to small farmers the use of alternative control agents in combating pests. Some examples are:

- Preliminary tests were carried out with extracts of leaves of neem (*Azadirachta indica* A Juss) as a botanical insecticide against the diamond-back moth (*Plutella xylostella*) in cabbage, *Castnia* in coconut and rootknot nematodes (*Meloidogyne* spp.) in tomato. Also, extracts of seed kernels of neem were tested in the field against different insect species in rice. The results of these preliminary tests are presented in Table 4.

Table 1. Area (ha) of crops planted in Suriname

Description	1988	1989	1990	1991	1992
Annual crops					
Rice (paddy)	69,520	69,860	52,005	60,085	68,750
Maize	141	107	127	83	85
Cassava	156	170	195	198	244
Other tubers/root crops	27	34	40	66	157
Peanut	593	518	548	446	445
Cowpea	121	128	134	143	169
Other legumes	145	55	83	114	119
Cabbage	73	97	98	100	86
Tomato	194	172	197	243	194
Other vegetables	976	933	1.392	1.769	1.766
Melon	352	212	231	375	541
Total annual crops	72,290	72,286	55,050	63,222	72,556
Semi-permanent crops					
Sugar cane	2,523	2,495	2,273	2,291	2,245
Banana	1,986	2,076	2,073	2,216	2,131
Plantain	322	352	375	663	622
Others	49	12	24	60	125
Total semi-permanentcrops	4,880	4,935	4,745	5,230	5,123
Permanent crops					
Cacao	182	180	171	177	165
Coffee	239	242	239	235	237
Oilpalm	6,124	6,128	5,425	4,835	4,625
Orange	1,688	1,751	1,789	1,877	1,964
Grapefruit	162	191	180	183	176
Other citrus	234	297	306	365	366
Coconut	1,280	1,308	1,304	1,584	1,421
Others	583	600	533	607	486
Total permanent crops	10,492	10,697	9,947	9,863	9,440
Grand total	87,670	87,918	69,742	70,715	87,119
Small-scale cultivation	29,008	30,167	21,256	28,922	30,549
Large-scale cultivation	58,662	57,751	48,486	49,793	56,570

Source: Statistics Division, Ministry of Agriculture

Table 2. Agricultural production (tonnes) in Suriname

Description	1988	1989	1990	1991	1992
Annual crops					
Rice (paddy)	265,244	260,895	196,010	229,650	261,080
Maize	241	186	274	185	159
Cassava	1,843	1,995	2,450	3,058	3,517
Other tubers/root crops	128	178	298	473	1,846
Peanut	530	410	571	414	428
Cowpea	76	88	96	112	112
Other legumes	74	40	56	102	120
Cabbage	1,709	2,119	2,181	2,440	1,942
Tomato	1,344	2,087	3,023	5,705	3,466
Other vegetables	10,763	11,277	17,948	24,977	30,526
Melon	4,575	2,368	3,029	5,936	8,873
Total annual crops	286.528	281.643	225.937	272.662	312.069
Semi-permanent crops					
Sugar cane	18,875	18,492	725	770	-
Banana	52,894	45.943	47,943	49,971	49,886
Plantain	8,391	8,766	7,757	17,082	13,179
Others	744	216	225	581	1,006
Total semi-permt. crops	80,904	73,417	56,680	68,404	64,089
Permanent crops					
Cacao	18	20	17	27	21
Coffee	39	49	46	55	43
Oilpalm	11,609	13,953	7,645	7,814	10,640
Orange	10,013	12,638	13,405	13,335	14,130
Grapefruit	1,005	1,231	1,288	1,327	1,154
Other citrus	1,113	1,373	1,299	1,342	1,632
Coconut	8,698	11,270	10,956	12,086	9,522
Others	-	-	2,690	4,790	3,173
Total permanent crops	32,495	40,534	37,396	40,777	40,247
Grand total	399,927	395,594	320,013	381,852	416,405

Source: Statistics Division, Ministry of Agriculture

Note: 1 tonne grapefruits = 2,000 pcs. 1 tonne oranges = 4,000 pcs1 tonne other citrus = 6,350 pcs
1 tonne coconut = 1,000 pcs.

Table 3. Area (ha) and production (tonnes) of vegetable crops in Suriname

Description	Unit	1988	1989	1990	1991	1992
Total area	ha	1,235	1,202	1,687	2,112	2,046
Total production	tonnes	13,816	15,483	23,153	33,122	35,934
Tomato	ha	194	172	197	243	194
	tonnes	1,344	2,087	8,023	5,705	3,466
Cabbage	ha	73	97	98	100	86
	tonnes	1,709	2,119	2,181	2,440	1,942
Beans	ha	108	81	126	139	134
	tonnes	1,037	578	1,062	1,299	1,486
String beans	ha	164	149	215	191	295
	tonnes	1,674	1,222	1,836	1,730	3,898
Pak-choi	ha	60	59	71	96	53
	tonnes	177	342	685	732	808
Eggplant	ha	83	56	100	133	132
	tonnes	967	580	754	731	1,511
Cucumber	ha	80	71	145	154	140
	tonnes	2,037	2,034	2,952	5,342	4,491
Pepper	ha	77	117	144	215	168
	tonnes	1,309	2,076	2,516	4,286	4,747
Tayerblad (leaves of dasheen sp.)	ha	53,	54	78	143	137
	tonnes	436	661	1,539	4,130	3,409
Other vegetables	ha	351	346	513	698	707
	tonnes	3,126	3,884	6,605	6,677	10,176

Source: Statistics Division, Ministry of Agriculture

Table 4. Current status of activities towards the development of integrated pest management in food crops in Suriname

Activity	Crop concerned	Target pest/ disease/ weed	Compon- ents	Objective	Preliminary results	Completed study	Follow-up action	Limiting factors
I Screening of plants with biological impact on pests/diseases	Tomato	Nematodes (*Meloidog- yne* spp.)	Neem *Crotalaria* spp.	Reducing pesticide use; stimulating safer produce	Positive effect of neem leaves	Effect of *Crotalaria* spp. as rotation crop comparable with effect of Furadan® 5G in the field	Testing the effect of neem leaves in field on root-knot nematodes	Transport Staff Inputs
	Cabbage	Diamond- back moth (*Plutella xylostella*)	Neem	Alternative control methods	Effect of neem leaf extracts comparable to effect of Karate®		Testing in the field	Transport Staff Inputs
	Rice	Seed-borne fungi	*Phyllanthus amarus* *Solanum nigrum* *Ocimum sanctum*	Alternative control for seed-borne fungi	Positive effect with extracts		Continue the tests	Staff Inputs
		Several insect species	Neem seed kernels		No positive effect in field with extract			

Table 4. (continued)

Activity	Crop concerned	Target pest/ disease/ weed	Compon-ents	Objective	Preliminary results	Completed study	Follow-up action	Limiting factors
	Coconut	*Castnia*	Neem	Find alternative insecticide for Furadan® and Azodrin®	Indications of positive results of leaf extract on *Castnia*		Testing in the field	Transport Staff
		Coconut caterpillar (*Brassolis sophorae*)	egg and pupal parasites		76% egg parasitation by *Telenomus nigro-coxalis*		Search for limiting factors in the field	
II Weed inventory	Vegetables Cereals Rice	Different species		Reducing herbicide use using alternatives; reduced dosage	Initial phase			Transport Staff
III Selection of improved seed of different varieties	Vegetables			Improved seed quality, germination, disease-free				Transport Staff

Table 4. (continued)

Activity	Crop concerned	Target pest/ disease/ weed	Compon-ents	Objective	Preliminary results	Completed study	Follow-up action	Limiting factors
IV Evaluation of performance of different varieties under Surinamese environmental conditions	Vegetables			Selection of varieties with most valuable properties	Initial phase			Transport Staff
V IPM control methods practised in the field	Banana	Nemat-odes: *Radoph-olus similis* *Helicotyl-enchus multi-cinctus*				Hot water treatment of corms (55 °C, 20 min); wet flooding during 6 months		
		Banana weevil						
	Rice	Weeds Different insect species, e.g. root maggots		Reduced pesticide use; yield increase		Good tillage; soil levelling for water management; underwater sowing	Survey to determine key pests	Transport Staff Inputs

Table 4. (continued)

Activity	Crop concerned	Target pest/ disease/ weed	Compon-ents	Objective	Preliminary results	Completed study	Follow-up action	Limiting factors
VI FAO IPM proposals:								
Formulation of IPM in rice			Not yet initiated					
IPM in veget-able crops – prduction with emphasis on small-scale farmers								

- Preliminary studies have indicated that extracts of *Phyllanthus amarus*, *Solanum nigrum* and *Ocimum sanctum* seem to be effective against seed-borne fungi.

- A survey was carried out to determine the occurrence of parasites of the coconut caterpillar (*Brassolis sophorae*) at different locations. Parasitism was not high in every location, but figures of up to 86% parasitism have been found – 76% by the egg parasite *Telenomus nigrocoxalis*.

- Field studies (after positive preliminary tests) indicate that *Crotalaria* spp. also have significant reducing effects on populations of *Meloidogyne* spp., resulting in higher yields of tomato in a crop rotation scheme.

- With the breeding and release of the rice varieties Eloni and Ferrini, it has been possible for rice farmers to practise the so-called 'underwater sowing'. The advantage of this method is that, because of the physiological character and germination pattern of the seed and due to the 15–20 cm water layer, the growth of weeds is very much suppressed.

In terms of research activities in food crops, vegetables and legumes receive a considerable amount of attention in the field of agronomy (observation experiments of received varieties, improved seed production).

Future objectives and requirements

- Collaborative action is needed by the Agricultural Experiment Station and the Extension Division in conducting training programmes for farmers in areas such as pest management, pesticide management and safety use.

- Research findings in terms of new agronomical developments should be made more available through farm meetings, and the preparation and distribution of crop pest control pamphlets.

- Workshops need to be organized for extension workers and farmers in the identification and/or description of pests in food crops.

- Areas for assistance from international organizations include:

  - training in specialized fields, e.g. IPM methodologies in food crops.

  - help to coordinate pest management programmes as identified by the Ministry of Agriculture, e.g. biological control programmes.

  - financing research activities which are beneficial to small farmers towards the development and implementation of IPM in food crops.

- Exchange of research data and techniques with the countries in the sub-region to standardize IPM strategies in food crops.

INTEGRATED PEST MANAGEMENT IN TRINIDAD & TOBAGO

G L Rajnauth
Ministry of Agriculture, Land & Marine Resources, Trinidad & Tobago.

Trinidad & Tobago, the southernmost islands of the Caribbean, possess a humid, tropical climate with two seasons – a dry season and a bimodal rainy season. The major crops consist of the plantation crops – sugar cane, cocoa, coconut – and various food crops, vegetables, ornamentals, fruit crops and pasture crops. A review is presented of work on the integrated management of pests and diseases in some of these crops. In each crop situation, there exists a pest complex often with a dominant member. The pest complex, the dominant member and work on their integrated management are reviewed for sugar cane, cabbage, tomato, peppers, cucurbits, rice, soursop and miscellaneous fruits. Special pests – the Moruga grasshopper (*Coscinueta virens*) and armyworms (spp. of *Spodoptera*, *Agrotis*, and *Mocis*) – are also considered because of their polyphagous nature and tendency to occur in high density outbreaks. The major diseases of various crops and work on integrated disease management are then described. These diseases include those of cocoa, sugar cane, coconut, water-melon, legumes, pak-choi (Chinese cabbage), cassava and rice.

Integrated pest management (IPM), as a concept and a control strategy for pests, has received prominence since the late 1950s and early 1960s. The rise of IPM programmes occurred in the context of the heavy dependence of crop protection on synthetic chemical pesticides and problems consequent on this dependence. These problems included environmental contamination, detrimental effects on human health, and the loss of control of target pests due to pest resistance (Allen and Rajotte 1990).

Integrated pest management has been defined by Smith and Reynolds (1966) as 'a pest population management system that utilizes all suitable techniques in a compatible manner to reduce pest populations and maintain them at levels below those causing economic injury. However, although receiving much acclaim, many workers have noted the slow rate of adoption of IPM by farmers (Wearing 1988; Pollard 1991). Pollard (1991) has noted that, in many developing countries, pest control equals chemical control. In the specific context of Trinidad & Tobago, Pollard (1991) discussed the very heavy dependence on pesticides in tomato and cabbage production and noted the problems in introducing IPM in such situations. This paper looks at the recent IPM situation in Trinidad & Tobago at the level of the crop protection specialist and of the farmer and discusses its status in this country's crop protection programme.

Trinidad & Tobago

Trinidad & Tobago are the southernmost islands of the Caribbean, at 10–11° N latitude and 60–61° W longitude, with Trinidad located 15 km north-east of the coast of Venezuela. The islands possess a tropical climate with average temperatures in the day around 30 °C. There is a dry season from January to May and a rainy season from June to December, the latter season showing a bimodal pattern of rainfall.

The major crops are at present a mixture of:

- Traditional plantation crops – sugar cane (*Saccharum officinarum*), cocoa (*Theobroma cacao*), coconut (*Cocos nucifera*), oranges and grapefruit (*Citrus* spp.)
- Food crops – rice (*Oryza sativa*), bananas and plantains (*Musa* spp.),

cassava (*Manihot esculenta*), dasheen (*Colocasia esculenta*)

- Ornamentals – *Anthurium* hybrids, orchids (*Dendrobium* spp.) and heliconias (*Heliconia* spp.)

- Vegetables – tomato (*Lycopersicon esculentum*), sweet and hot peppers (*Capsicum* sp.), various cucurbits, cabbage and other crucifers (*Brassica* spp.), vegetable cowpea or bodi (*Vigna unguiculata*), pigeon pea (*Cajanus cajan*)

- Fruit crops – papaya (*Carica papaya*), mango (*Mangifera indica*)

- Pasture grasses.

In most of these crops, pests and diseases are major constraints in production.

Arthropod pests

Sugar cane

In this crop, like all the major crops in Trinidad & Tobago, one needs initially to note the existence of a pest complex. This is composed of the three small moth borers, the West Indian canefly, the sugar-cane thrips, the giant moth borer and the froghopper, the latter being the most important pest in the complex.

In the past, both the West Indian canefly (*Saccharosydne sacchivora* Westw.; Homoptera: Delphacidae) and the sugar-cane thrips (*Fulmekiola serrata* Kobus; Thysanoptera: Thripidae) have cost the sugar company (Caroni (1975) Ltd.) a significant amount in spraying. The former sucks the sap from leaves, excretes honeydew and the resulting sooty mould causes much blackening of plants; the latter's feeding damage prevents apices from opening (interlocked apices). This has led managers to spray pesticides to bring populations under control; in the former case costing approximately US$35,000 per year. However, studies have shown that neither pest should be sprayed with chemicals as indigenous natural enemies prevent the long-term build-up of large populations and hence prevent them becoming economically important (des Vignes 1987; 1992).

The giant moth borer (*Castnia licoides* Boisd.; Lepidoptera: Castniidae) can cause losses in sugar-cane crops at times. Studies have shown that losses are small in cane cut at 12 months but are much greater in standover cane, i.e. cane cut at 18–24 months. The approach adopted to control this pest is based essentially on cultural measures – the crop is cut at 12 months and not at 18–24 months.

The three pests examined so far are successfully controlled by programmes emphasizing the use of indigenous natural enemies and the use of cultural measures. The small moth borers of sugar cane, three species of *Diatraea* (Lepidoptera : Pyralidae), are controlled by an IPM programme emphasizing different components.

Following the introduction of aerial spraying for the froghopper in the mid 1960s, an upsurge in the population of these borers was observed in 1969/1970. A study indicated significant losses; 1974 figures show a loss of US$2.9 million, equivalent to 12–25% bored joints (des Vignes 1993a). An IPM programme to control this pest could consist of three components: insecticides; varietal resistance; and the use of natural enemies. However, insecticide application was considered to be difficult and costly as *Diatraea* does not reproduce in discrete generations in Trinidad (Hughes et al. 1982). In addition, there were few studies on varietal resistance. An IPM programme using natural enemies was established. However, the indigenous natural enemies were considered ineffective. The most important naturally occurring parasitoid was *Paratheresia claripalpis* (Van der Wulp) (Diptera: Tachinidae) and this could not distinguish between the three *Diatraea* spp.; moreover, *D. centrella* possessed natural immunity to attack. In addition, *Paratheresia* was itself subject to attack by a secondary parasitoid (Hughes et al. 1982). Further, another parasite, the egg parasite *Prophanurus*, was not found in sugar cane in recent times although it was common in the past (des Vignes 1982).

Exotic parasites were therefore sought (des Vignes 1982); several were identified,

brought in, reared and released into the field. *Cotesia flavipes* Cameron (syn *Apanteles flavipes* ; Hymenoptera: Brachonidae) established itself in the field and has provided a high degree of control of *Diatraea* spp. At the present time, the level of damage by *Diatraea* is 0–3% bored joints which is below the economic threshold of 5% (des Vignes 1993a).

The froghopper, *Aeneolamia varia saccharina* (Dist.) (Homoptera: Cercopidae) is the most important member of the pest complex of sugar cane in Trinidad & Tobago. Over 25–40% loss in yield has been attributed to froghopper attack (Evans 1973). Moreover, in its froghopper control programme, Caroni (1975) Ltd spends annually over US$1.8 million on synthetic insecticides and approximately US$0.9 million on labour. The control of this pest can be approached through a number of IPM components:

- Plant resistance. Few studies have been done in this area and this is not an effective component as yet.

- Cultural control. Ploughing and replanting of fields effectively reduces the froghopper population in those fields; this is an effective non-chemical means of froghopper control. Unfortunately, it is not economic to plough and replant each year.

- Chemical insecticides. The major component in the control of froghopper is the use of chemical insecticides which are aerially sprayed and rotated according to their mode of action. There is an ongoing programme of laboratory bioassays and field trials involving new chemicals and those in field use. A common rotation would involve organophosphates/carbamates (e.g. cyth-ion, triazophos, quinalphos, carbaryl, propoxur) with pyrethroids (e.g. lambda-cyhalothrin) with nereis toxins (e.g. thiocyclam) with nitromethylenes (e.g. imidacloprid) and with new categories of compounds (e.g. ethofenprox) (des Vignes 1993b).

- Biological control. Studies have shown that the froghopper is attacked in the field by the green muscardine fungus (*Metarhizium anisoplae* Metsch.). Spraying with spore suspensions has been effective in froghopper control in some cases and can lead to epizootics in subsequent years, reducing the use of insecticides. At present (in 1993), a field of 450 ha is being treated with fungal spore suspensions (R H Phelps, personal communication). Plans are to increase the area so treated.

Thus, the field control of froghopper is essentially a chemical control programme involving cultural means whenever fields are ploughed and replanted. However, control is moving towards a broader base depending on chemical and biological means with some cultural measures.

Vegetables

Among the economically important annual crops, pest pressure is greatest amongst the vegetables. The vegetables are grown by small farmers in intensively farmed areas for the local market or selected export markets (Jones 1985). Because of the great risk of crop failure, farmers have traditionally attempted to keep pest populations at very low levels and the major pest control strategy practised by these farmers has been the application of pesticides (Jones 1985). A large number of pesticides is used and in this situation, the implementation of IPM programmes is extremely difficult (Pollard 1991). However, it is believed (M Jones, personal communication) that it will be easier to implement IPM in vegetable crops at the present time than 10 years ago. This situation has arisen because of the emergence of *Thrips palmi* (Karny) and *Bemisia tabaci* Genn. as major problems; farmers no longer think that pesticides are the solution to all their pest control problems and are actively seeking alternatives to pesticides.

Cabbage

The pest complex in this crop is composed mainly of lepidopterans with the cabbage looper (*Trichoplusia ni* Hübner), the budworm (*Hellula phidilealis* Walker) and the ubiquitous diamond-back moth (*Plutella xylostella* (L.) (Jones and Ferguson 1988). In Trinidad, unlike many other cabbage growing areas, the budworm is the major pest. The budworm is a burrowing

larva and can damage the growing apex; one puncture of the apex by one *Hellula* larva can completely destroy a cabbage head. Hence, the damage threshold is very low and the larva, because of its burrowing habit is difficult to kill. The response of farmers has been to spray a range of insecticides at regular intervals (every 2–3 days). Large amounts of insecticide are used on cabbage in Trinidad – an island-wide survey in 1980 indicated that cabbage farmers were using the highest quantity of pesticides, most of which consisted of insecticides (Jones and Ferguson 1988).

The elements of an IPM programme for the control of pests in this crop have been studied over the period 1982–1988 (Jones and Ferguson 1988). The elements studied were:

- Varietal resistance
- Natural pesticides – neem and persian lilac.
- Insect growth regulators (IGRs) – teflubenzuron and fleufenoxuron.
- Natural enemies – a number of enemies is known on the pests in Trinidad.
- Microbial pesticides – preparations of *Bacillus thuringiensis*(Bt)
- Synthetic pesticides – profenfos/ cypermethrin; cartap; phosphamidon.

In their work, Jones and Ferguson (1988) demonstrated good control of cabbage pests utilizing synthetic insecticides, the microbial pesticide Bt, and the IGRs. However, at the farmer level, *Hellula* control is still a problem, a situation that is due to pesticide mismanagement and pest pressure but also because of the biology of the pest. Being a burrower, *Hellula* often escapes the effects of products deposited on the surface of cabbage leaves. It is believed (M Jones personal communication) that the weak natural enemies component is the missing one in this IPM package.

Tomato

The pest complex in this crop has changed significantly in recent years. In the 1970s and early 1980s, the main pests of the complex were the lepidopterans – the armyworm (*Spodoptera eridania* Cramer), the fruit worm (*Heliothis virescens* Fabr.) and the pinworm (*Keiferia lycopersicella* Busck) and the fruit-piercing bugs – the stink bug, *Nezara viridula* (L.), and the winged bug, *Phthia picta* Drury (Jones 1985). Studies were conducted on the losses due to these insects and an IPM programme was developed for their control (Jones 1985).

In recent years, the pest complex is now dominated by the sweet potato whitefly (*Bemisia tabaci*); an added dimension not present in the past is that this pest is transmitting an uncharacterized geminivirus causing a leaf curl disease, the most common disease of tomato in Trinidad & Tobago (Bala et al. unpublished).

Components of the IPM package for the sweet potato whitefly are being developed (Hall 1993; M Jones personal communication). They consist of:

- Insect growth regulators
- Microbial pesticides. Two major fungal pathogens have been identified in the field – *Paecilomyces fumoso-roseus* and *Verticillium lecanii* Zimm. (Hall 1993). Field observations and bioassays indicate that only the former may succeed as the ambient temperatures in Trinidad are more favourable for this fungus than *V. lecanii*. An aqueous formulation of spores is being developed for use in the rainy season; in the dry season, an oil-based formulation will be used.
- Natural enemies. A number of natural enemies is present in Trinidad & Tobago; for example, *Encarsia* sp. is present in farmers' fields. However, these have to be enhanced by mass-rearing and release, most likely in a commercial operation.

Peppers

Hot and sweet peppers, important commodities in the local and export markets, are adversely affected by a significant pest complex. The important members of this complex vary with the season of the year. In the rainy season, the broad mite *Polyphagotarsonemus latus* (Banks) (Acarina: Tarsonemidae) is the

dominant pest whereas in the dry season, the palm thrips, *Thrips palmi* (Thysanoptera: Thripidae) and the sweet potato whitefly are dominant. Losses due to the broad mite and palm thrips are substantial on these crops, especially hot peppers (Jones 1988; 1990).

Control programmes used by farmers for broad mite and palm thrips are based on synthetic chemical insecticides. With respect to thrips, such programmes are most often unsuccessful and an IPM package has been recommended (Jones 1990; personal communication) – use of insect growth regulators, overhead irrigation, minimal application of foliar fertilizers, complete non-use of fenthion as this kills natural enemies. However, this programme is not as effective as it should because of the absence of a strong biological control component. Work is in progress to develop microbial pesticides. Hall (1993) has indicated that a fungus *Hirsutella* sp. has been found in the field on *T. palmi*, apparently the first culturable pathogen of this insect found anywhere in the world; and in laboratory cultures *P. fumoso-roseus* and *V. lecanii* have been found on *T. palmi*. In addition, a range of predators has been found; these need to be studied and the most appropriate forms mass-produced and released (M Jones, personal communication).

Cucurbits (water-melon; cucumber)
In these crops, the major pest is also the palm thrips. An IPM programme, similar to the one in peppers and incorporating the use of mistblowers and mulching has been recommended.

Rice

Rice is a major food in the diet of people in Trinidad & Tobago and in the last few years production of the crop has increased greatly. In consort with this, the insect pest complex has been studied on small farms in various parts of Trinidad (Cooper 1991) and in large-scale cultivations (des Vignes 1991).

In late 1990, a survey was conducted of the major rice-growing areas in Trinidad and assessments made of the populations of various insect pests (Cooper 1991). Various insects were noted especially the rice bug *Oebalus prominulus* (Dallas) (Hemiptera: Pentatomidae), various grasshoppers (spp. of *Canlopsis*, *Conocephalis*, *Orphulella* and *Opshomala*), the stem borer (*Rupela albinella* (Cram) Lepidoptera: Pyralidae) and the leafhopper *Sogatodes oryzicola* (Muir) (Hemiptera: Delphacidae), the vector of the hoja blanca disease. However, the populations of these insects were generally low and did not indicate that economic losses were occurring. Farmers generally use little insecticide on rice; in some areas, they use one timed spray to control the rice bug *Oebalus* but further studies are needed to determine the economics of this practice.

With respect to the large-scale cultivations being undertaken by Caroni (1975) Ltd., des Vignes (1991) has indicated the insect pests found in these fields and the work being conducted on those considered to be of economic importance, especially *Sogatodes oryzicola* (see later), *Oebalus prominulus* and *Spodoptera frugiperda* (J E Smith) (see later). The rice bug damages the grain at the milky stage but data on economic importance are lacking. These studies are in progress but nevertheless, the insect is being controlled by insecticides – usually one critically timed spray of insecticides – either a systemic (vamidothion) or a contact/stomach insecticide (propoxur or thiocyclam). Natural enemies exist but these are not being enhanced at present.

Soursop

The soursop (*Annona muricata*) is a very popular fruit in Trinidad & Tobago and fetches high prices in local markets. Yet, there are no local orchards and most of the fruit consumed is imported from Grenada. The major reason for this is the depredations of two members of the pest complex of this crop, namely the soursop fruit borer (*Cerconata anonella* (Sepp); Lepidoptera: Stenomidae) and the soursop seed wasp (*Bephratelloides* sp.; Hymenoptera: Eurytomidae) (McComie 1987). Losses due to these two insects are estimated to be very high; data from a small orchard at Centeno indicated that over 96% of the harvested fruit were attacked (McComie 1987).

The components of an IPM programme for this crop were studied at Centeno (McComie 1987) as follows:

- Insecticide application. Various insecticides were used in trials at Centeno. Good control of the moth *Cerconata* was obtained in these trials but the wasp *Bephratelloides* still destroyed over 70% of the fruit. Unlike the moth, *Bephratelloides* oviposits into the fruit and the egg, larval and pupal stages are difficult to reach by insecticides; hence control can only be directed at the adult.

- Cultural control.
    - Sanitation. Infested fruit should be removed from fields.
    - Bagging. Trials at Centeno with plastic bags and mesh bags indicated that bagging was very effective in the control of these pests. Fruits, however, need to be bagged at a very early stage of growth (6 cm or smaller).

These studies need to be continued and expanded to develop an IPM package for this fruit crop.

Various fruits

Various fruit crops are attacked by numerous species of fruit flies, *Anastrepha* spp. (Diptera: Tephritidae). Over 20 species of this genus occur in this country and losses can be severe in many fruit crops. A recent survey has been conducted in Trinidad & Tobago over a 18-month period on fruit fly occurrence and distribution (F Hosein and Lewis, personal communication).

In papaya, the fruit fly *Toxotrypana curvicauda* Gerst. (Diptera: Tephritidae) is the major pest of this crop in Trinidad & Tobago (L McComie personal communication). Control is based on chemical insecticides.

IPM programmes need to be developed for the control of these pests.

Special pests

Considered here are two pests that are highly polyphagous, can develop high populations in the field in a short time, are quite unpredictable and can cause much crop damage in a very short time.

The Moruga grasshopper.
The Moruga grasshopper (*Coscinueta virens* Thun.; Orthoptera: Acridiidae), the most damaging grasshopper pest in Trinidad, is found in the heavily forested south-eastern section of Trinidad, in an area of 50,000 ha (McComie et al. 1989). This pest usually damages crops that are planted close to the forests. The nymphal stages (or hoppers) are gregarious and migratory; they are found in large, moving bands of many thousands of individuals with an average size of 500 insects/m^2 for 1st–5th stage instars and 100/m^2 for 6th stage instars (McComie et al. 1989). A single hopper band may cover up to 10 ha.

There have been records of damage due to this pest going back to 1919 (McComie et al. 1989). The pest can cause much damage in a short time and hence control measures must be quick and effective especially when hopper bands are near to or in cultivated areas. Control has been conducted on a regular basis as a region-wide operation by the Ministry of Agriculture since 1985 and involves the following (McComie et al. 1989):

- the application of synthetic insecticides – propoxur, fenithrothion and diazinon – by means of motorized mistblowers, airblast sprayers and fixed wing/rotary wing aircraft.

- the systematic searching and location of hopper bands and the direct treatment of these bands.

Studies are now being conducted on the use of insect growth regulators and the use of microbial pesticides (L McComie, personal commun-ication). These studies should lead to control measures that are more environmentally safe and effective in the forested environment of this pest.

Armyworms.
These are seasonal pests of numerous crops in Trinidad & Tobago. The larvae of *Spodoptera* spp., *Agrotis* spp. and *Mocis* spp. can build up to high populations in a very short time. They attack rice, corn,

plantains and bananas, numerous vegetables but the major attacks often occur on pasture and forage grasses – Pangola (*Digitaria decumbens*), Tanner (*Bracharia humidicola*) and Elephant (*Pennisetum purpureum*) grasses. Losses can be very high; fields can be defoliated in a few days.

Outbreaks are seen at two times of year. In the dry season, small, scattered outbreaks occur following short, showery periods. Major outbreaks occur one month in the rainy season following an extended dry season. Severe outbreaks are very difficult to control; they decline when the natural enemy populations build back up. It has been suggested (M Jones, personal communication) that, in the context of the insect being a major pest in those years when the populations of natural enemies decline significantly, that there be mass-rearing of natural enemies in such years and these be released with the first rains.

Diseases

Cocoa and sugar cane

The major disease in cocoa is black pod (causal agent, *Phytophthora palmivora* Butl.) and control is based on sanitation (removal of diseased pods) but mostly on fungicide application.

In sugar cane, on the other hand, disease control is based on the use of field-resistant varieties. This has proven to be a very effective control measure.

Coconut

Red ring is the major disease constraint of coconut in Trinidad & Tobago. The disease is caused by the nematode, *Rhadinaphelenchus cocophilus* (Cobb) Goodey, which lives mostly in the stems of young (3–10 year old) coconut palms inducing yellowing and wilting of the leaves and discolouration of the stem, which is seen as a red ring in a cross section of the stem (Griffith 1987). The disease is spread by the palm weevil, *Rhynchophorus palmarum* L., specifically by a segment of the population defined genetically (Griffith 1987).

Disease control (Griffith 1987) is based on:

- sanitation – destruction of red ring infected trees by injection with a herbicide.

- vector control by baiting – chunks of diseased coconut tissue sprayed with an insecticide (methomyl) are placed throughout the estate (guard baskets).

Vector control by generalized insecticide spraying of the trees has not provided any significant degree of control.

Vegetables

Water-melon

Gummy stem blight (causal agent, *Didymella bryoniae* (Auetrsw.) Rehm.; Ascomycotina) is the major disease constraint in the production of water-melon in Trinidad. Bala and Hosein (1986) noted significant yield losses on all commercial varieties cultivated with average yield loss being above 70% for all varietal groups. An integrated approach involving resistant varieties and fungicides was used by Bala et al. (1989) for the control of the disease. However, only fungicides provided any significant level of control of the disease.

Legumes and pak-choi (Chinese cabbage)

Web blight (causal agent, *Rhizoctonia solani* Kühn; Basidiomycotina) is the major disease constraint in the wet season production of legumes and pak-choi (Rajnauth 1987; Rajnauth and St Hill 1993). An integrated approach has been adopted for the control of this disease in pak-choi utilizing mulching and fungicides. Good control of the disease has been obtained under conditions of high disease pressure (Rajnauth and St Hill, in preparation).

In vegetable cowpea (bodi), cowpea severe mosaic (cowpea severe mosaic comovirus) is also a major constraint. Epidemiological studies have established the basis for an integrated control programme (Rajnauth et al., in press). More recently, resistant varieties have been bred and released (Umaharan 1993; Umaharan et al., in press).

Various vegetables
Root knot nematodes (*Meloidogyne* spp.) are common in many vegetable crops in Trinidad & Tobago. A programme involving biological control has recently been initiated to combat this problem (G Bala, personal.communication).

Food crops

Cassava
Cassava bacterial blight (causal agent, *Xanthomonas campestris* pv. *manihotis*) is the major disease of cassava in Trinidad (Rajnauth and Pegus 1987). An integrated programme has been recommended to farmers involving the use of clean planting pieces; crop rotation; and planting in the dry season if possible, following CIAT recommendations (Lozano 1986). More recently, two field-resistant cultivars were identified.

Rice
A survey of rice diseases recently conducted in small farmers' fields indicated that at least nine diseases could be found on rice. Generally, disease incidence was low in these fields except for sheath blight (causal agent, *Rhizoctonia solani*) and narrow brown leaf spot (causal agent, *Cercospora oryzae* Miyake) which occurred at moderate incidences (Cooper 1991).

However, in the large-scale cultivations of Caroni Ltd., brown spot (causal agent, *Cochiobolus miyabeanus*) and hoja blanca (causal agent, rice hoja blanca tenuivirus) can be major problems (Phelps 1991). Control of hoja blanca is based on the limited use of chemicals for control of the vector, *Sogatodes oryzicola*; the use of field-tolerant varieties (Oryzica 1 and 2 have replaced the susceptible Starbonnet); and the use of cultural measures where feasible – allowing 4–6 weeks between crops.

Conclusions

In Trinidad & Tobago, pests and diseases are major constraints to production in many crops and although a lot of work has been done, it is obvious that a lot remains to be done. In many crops, there is still a great dependence on chemical insecticides/fungicides and more work is required, particularly in the areas of natural enemies and microbial pesticides in the case of arthropod pests, and plant resistance, biological control and cultural measures in the case of diseases. In a year when the United Nations is emphasizing the harvesting of nature's biodiversity, we may wish to see our development of less chemically dependent control programmes as a way of harvesting that existing biodiversity.

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ANNEX II

REPORT OF THE PRELIMINARY SURVEY OF WHITEFLIES AND ASSOCIATED SYMPTOMS ON MAJOR ECONOMIC CROPS IN THE CARIBBEAN

In 1991 a plant virus workshop was held in Antigua. This workshop was coordinated by CARDI with funds provided by BDDC and USAID. One of the outputs of this workshop was the production of a questionnaire to assess the importance of whiteflies as pests and insect vectors in the English-speaking Caribbean. A copy of this questionnaire is attached to this report.

One questionnaire was sent to each CARDI Representative and Head of Unit with the request that the questionnaire be completed by the various Coopting Coordinators who had been selected to perform this task. Dr G Muller of CARDI, Trinidad & Tobago was responsible for this distribution and also for receiving the completed questionnaires. Ten questionnaires were returned from Barbados, Belize, Dominica, Grenada, Guyana, Jamaica, Montserrat, St Lucia, St Vincent and Trinidad & Tobago.

The completed questionnaires were passed to Mr F B Lauckner of CARDI, Trinidad & Tobago and the answers were computer coded and summarized. The results of these summaries follow. It will be seen from these results that all 10 countries which reported identified whitefly as a pest with a wide range of plants named as attracting this pest.

The paragraph numbers below refer to the question numbers on the questionnaire.

1. **Countries from which questionnaires returned:**

   Barbados, Belize, Dominica, Grenada, Guyana, Jamaica, Montserrat, St Lucia, St Vincent and Trinidad & Tobago

2. **All ten countries stated whiteflies reported or observed:**

3. **During thepast:**

During thepast:	> 10years	4
	10 years	0
	5 years	4
	3 years	0
	2 years	0
	1 year	2

4. **Species seen in country:**

Bemisia tabaci	2
Trialeurodes abutilonii	3
Bemisia tabaci/Trialeurodes abutilonii	1
Other	2
Bemisia tabaci/other	
Bemisia tabaci/other/*Trialeurodes vaporariorum*	1

5. **Whiteflies observed feeding or breeding on the following crops:**

	Feeding	Breeding
Eggplant	7	2
Cabbage	6	4
Pepper	9	4
Tomato	10	6
Squash	5	1
Pumpkin	5	0
Cotton	2	1
Cassava	3	2
Cut flowers	3	1
Tannia	3	0
Pigeon pea	3	2
Sorghum	0	0
Spinach	1	0
Cowpea	4	1
Peanut	2	1
Phaseolus	6	1
Soybean	0	0
Papaya	4	2
Annoa	3	1
Croton sp.	2	0
Corn	0	0
Weeds	7	3
Banana	0	0
White potato	2	0
Carrot	2	0
Lettuce	3	2
Pak-choi	0	1
Okra	2	1
Amaranthus	2	0
Musk melon	3	3
Pineapple	1	0
Citrus	5	3
Sweet potato	5	2
Tobacco	2	1
Passion fruit	1	1
Water-melon	1	1

6. **1st major plant as whitefly host:**

Monaceae	3
Cabbage	3
Tobacco	1
Cotton	1
Peanut	1
Citrus	1

2nd major plant as whitefly host:

Monaceae	3
Cabbage	2
Cucurbits	1
Beans	1
Sweet potato	1
Carrot	1
Coconut	1

3rd major plant as whitefly host:

Solanaceae	6
Pigeon pea	1
Lettuce	1
Melon	1
Citrus	1

4th major plant as whitefly host:

Solanaceae	2
Sweet potato	2
Phaseolus	1
Melon	1
Papaya	1
Ornamentals	1
Cauliflower	1
Guava	1

5th major plant on whitefly host:

Solanaceae	2
Phaseolus	1
Cotton	1
Tannia	1
Papaya	1
Citrus	1
Root crops	1
No answer	2

7. **Are you aware of any specific virus-like symptons associated with whiteflies ?:**

Yes 7 No 3

7a. **Which crops?:**

Tomato	2
Beans, Phaseolus	1
Beans, Phaseolus and weeds	1
Beans, Phaseolus, tomato, pigeon pea	1
Beans, Phaseolus, tomato, pigeon pea, papaya	1
Tomato, pumpkin	1
Tomato, hot pepper	1
Not applicable	2

8. **Major plant type imported:**

Fruit trees	1 (years not known)
Woody ornamentals	1 (years not known)
Fruit trees/woody ornamentals	1 (years not known)
Fruit trees/vegetable seedlings/woody ornamentals	1 (years not known)
Fruit trees/vegetable seedlings/foliage plants	1 (2–5 years)
Woody ornamentals/foliage plants	3 (2–5 years; 5–10 years; 2–5 years)
Fruit trees/woody ornamentals/foliage plants	2 (2–5 years; years not known

8e **See Appendix for list of imported plants**

8f **Year whitefly seen on any plant:**

This year	Poinsettia, Gerbera
2–5 years	*B. tabaci,* Poinsettia)
5–10 years	No plant mentioned

(NB: No response to this question from seven countries)

9. **The following countries were mentioned:**
(Two of the ten respondents did not identify any countries of origin).

Country	No. of respondents mentioning at least once
United States of America (including Hawaii)	6
United Kingdom	4
St Lucia	3
Trinidad & Tobago	3
Antigua & Barbuda	2
Barbados	2
Guadeloupe	2
Jamaica	2
Netherlands	2
Puerto Rico	2
Thailand	2
St Vincent & the Grenadines	2
Venezuela	2

The following countries were mentioned by one respondent:

Australia, Bahamas, Brazil, British Virgin Islands, Canada, China, Columbia, Costa Rica, Denmark, Dominica, Ecuador, France, Grenada, Guyana, Hong Kong, Malaysia, Martinique, Mauritius, Montserrat, Peru, St Kitts, Singapore, Suriname, Sweden, Taiwan, United States Virgin Islands, West Germany.

10. **Number of respondents reporting major crop types exported:**

	2 years	2–5 years	5–10 years	Over 10 years
Vegetable seedlings	0	1	0	0
Woody ornamentals	1	2	1	0
Foliage plants	3	5	2	1
Fruit trees	2	1	0	1

10a. **List of plant types exported and destination:**

Barbados:	
Croton, Ficus, Dracaena, Dragon Stick	West Germany
Belize:	
Cut flowers, Heliconia, Ornamental ginger	United States of America
Dominica:	
Anthurium	Guadeloupe, United Kingdom
Bananas	Antigua, United Kingdom,Virgin Is
Citrus	Destination not stated
Grenada:	
None	
Guyana:	
Croton	United Kingdom
Foliage plants	Antigua, St Lucia
Fruit trees	Antigua
Jamaica:	
Apple	Israel, United Kingdom
Agalea	United Kingdom
Avacado	Trinidad
Black pepper cuttings	India
Cherry	Japan
Gerbera	Netherlands, United Kingdom
Grape	Canada, Italy, United Kingdom
Neem seedlings	Hawaii
Orchids	Canada, Columbia, Curacao,
France,	Guatemala, Israel, Malaysia, Netherlands, Philipines, S Lucia, Singapore, Thailand, Trinidad
Passion fruit	Australia, New Zealand
Sweet pepper	Nigeria
Yam (tissue culture)	Nigeria
Montserrat:	
Foliage plants	United Kingdom
St Lucia:	
Foliage plants	United Kingdom
St Vincent:	
Anthurium	Antigua, Dominica
Citrus	Antigua, Curacao, St. Martin
Croton spp.	Destination not stated
Hibiscus	Trinidad
Mango	Barbados, St Martin
Trinidad:	
African violets, Chrysanthemums, Peperomia, Petunias, Poinsettia, Salvia	Barbados

11. **Pesticides most often used:**

Acephate	1
Carbophos	1
Tamaron®	1
Basudin®	1
Metasystox®	1
Diazinon®	1
Ambush®	1
Actellic®	1
None	2

Pesticides moderately used:

Carbophos	2
Pythrethroid, Karate®	1
Decis®	1
Karate®	1
Tambo®	1
Metasystox®	1
Vydate® L	1
None	2

Pesticides used only if 1 or 2 not available:

Carbophos	1
Pythrethoid, Karate®	1
Tambo®	1
Basudin®	1
Safer®	2
Systoate®	1
None	3

Appendix Imported plants listed at 8e

Barbados:

Adenium, Aechmea, African Violets, Agapathus, Agaves, Agerahum, Aglaonema, Air Plant, Alamanda, Allusion, Almond, Alocasias, Aloe, Alpinia Purpurata, Amaranthaceae, Amaryllidaceae, Amherstia, Ancanthacea, Anthurium, Apocynceae, Aporcactus, Apricot, Aracene, Araliaceae, Araucaria Excelsa, Arducaria, Areca, Ariocarpus, Aroids, Asparagus, Asplenium, Aurea, Azaleas, Bamboo, Barbados Cherry, Bay, Bearded Iris, Beaucarneas, Begonia, Bismarckia, Bluebell, Blue Daze, Bougainvilleas, Brighamia, Bromeliads, Busy Lizzie, Cactus, Caladiums, Calathea, Callaloo Plant, Campanula, Cananga, Carambola, Carnation, Catasetum, Cedar, Celosia, Chocolate Soldier, Chonile, Coladium, Condeaster, Crown of Thorn, Cuffia, Cynoches, Chalaenopsis, Chamaecereus, Cherry, Chrysanthemums, Cinnamon, Cissus, Cocoa, Coleus, Colocasia, Columneas, Composites, Conifers, Cordyine, Crassula, Criptanthus, Croton, Cycads, Cyclamen, Cyrtopodum, Dasheen Plant, Deiffenbachia, Deptospermum, Desert Rose, Dianthus, Dill, Dipladenia, Diversifolia, Dracaena, Dragon Sticks, Dutch Iris, Echinocereanae, Enchinoceredus, English Apple, Epiphyllum, Eranthenums, Eriocereus, Erythorina, Escleveria, Espician, Ettingera, Euphorbia, Euphorbiaceae, Ferns, Ficus, Fig, Fiitonia "Mini", Fiitonia "Red Percy", Flamingo Flower, Frangipani, Fuschia, Gardenias, Gazania, Geraniums, Gerbera, Gesneriads, Ginger, Gladiolus, Glory of the Snow, Gloxinias, Guzmania Minor, Gymnocalycium, Gynere, Gypsophila, Hebe Bush, Heliconia, Hibiscus, Holly, Horehound, Hoya, Hyacinth, Hydrangeas, Hypocyrta, Hypoestes, Impetrias, Incarvella, Iresine, Iris, Ivy, Ixora, Jade Vine, Japanese Bell, Japanese Tree, Jasmine, Jerusalem Cherry, Jump-Up-and-Kiss-Me, Juniperus Barbadensis, Kalanchoes, Kiwi Fruit, Labiates, Labiola, Lamb's Ear, Latarvia, Laurania, Leguminosae, Liliaceae, Limonium, Lisianthus, Macademia Nut, Mandevilla, Marantaceae, Marigold, Melastomaceae, Meyerii, Michaelia, Mint, Monstera, Morning Glory, Mosaceae, Muscipula, Mussaenda, Nephroleps, Niaranta, Nyctaqinaceae, Oleander, Ophiopogon, Orchids, Osmoxylon, Pachypodium Lamerii, Palms, Pandanus, Pansy, Paradise Nut, Passion Fruit, Peach, Pear, Pellionia, Pentas, Peperomia, Pepper (Ornamental), Petrea, Petunias, Philodendron, Pilea, Pinus, Pineapple, Piperaceae, Pittosporum, Plumbago, Podocarpus, Poinsettia, Pomeracs, Portulaca, Potentila, Pothos, Poui, Privet, Ptelia, Rhipsalis, Rhubarb, Rebutia, Rose, Rubiaceae, Salvia, Sapodilla, Sanseviera, Schefflera, Schismatoglotis, Sedum "Autumn Joy", Snapdragon, Snowdrop, Snow on Mountain, Solanaceae, South American Greenheart, Spathyphyllum, Spider Plant, Spirea, Spruce, Star Apple, Stephanotis, Strawberry, Streititza, Sugar Cane, Sunflower, Syngonium, Table Grape Vine, Tarragon, Thiya Ornamental, Thumbergia, Thyme, Tigridia Pavonia, Tradescantia, Tromota, Tropical Peanut, Tulip, Venus Fly Trap, Violets, Vitus, Vriesea, Wandering Jews, Warnekii, Watercress, White Butterflly, Wilcoxia, Xanthosoma, Yuccas, Zebrina, Zingiberaceae, Zinnia.

Belize:

Citrus tuckwood, Ornamentals and Foliage for home/hotel use, etc.

Dominica

Anthuriums, Begonia, Ferns, Orchids, Palms, Poinsettia, Orchids.

Grenada

Bougainvilla, Hibiscus, Roses, Begonia, Dieffenbachia, Gerbera, Pepperomia, Poinsettia, Schlefflera, Syngonium.

Guyana

Citrus, Roses, etc.

Jamaica

Apple plants, Avacado, Cherry, Grape plants, Passion Fruit, Black Pepper cuttings, Sweet Potato, Yam, Anthurium, Amaryllis (bulbs), Carnation, Dahlias, Gerbera, Gladiolias, Lily, Orchids, Poinsettia, Tulip (bulbs).

Montserrat

Citrus, Mango

St Lucia

Passion Fruit, Pineapple, Plantain, Poinsettia, Yam.

St Vincent

Banana (Sucrier), Casuarina, Chrysanthemum, Grape, Olives, Orchids, Pineapple, Rose, Travellers Palms.

Trinidad & Tobago

African Violets, Begonia, Bougainvillas, Chrysanthemum, Ferns, Gerberas, Hibiscus, Ixora, Petunia, Orchids, Poinsettia, Roses.

CARIBBEAN AGRICULTURAL RESEARCH AND DEVELOPMENT INSTITUTE

PRELIMINARY SURVEY OF WHITE FLIES AND ASSOCIATED SYMPTOMS ON MAJOR ECONOMIC CROPS IN THE CARIBBEAN

1. Name of Scientist ______________________ Country____________

2. Address of Organisation: ______________________________________

____

3. Have White flies been reported or observed in your country?

During the past ☐ >10 ☐ 10 ☐ 5 ☐ 3 ☐ 2 ☐ 1 years

4. Which of the following species have been seen in your country?

Bemisi tabaci ☐

Trialeurodes vaporariorum ☐ Trialeurodes abutilonii ☐

White flies not identified by genus ☐

Others ____

<u>Aleurothrixus</u> <u>floccosus</u> (Maskell)
" <u>myrtacei</u> (Bondar)
<u>Aleurotrachelus</u> <u>trachoides</u> (Back)
<u>Dialeurodes</u> <u>citrifolii</u> (Morgan)
<u>Aleurodicus</u> <u>capiangae</u> (Bondar)
" <u>cocois</u> (Curtis)
" <u>dispersus</u> Russell
<u>Hexaleurodicus</u> sp.
<u>Metaleurodicus</u> sp.
<u>Paraleyrodes</u> <u>goyabae</u> (Goldi)
" <u>urichii</u> Quaintance & Baker

5. Have white flies been observed feeding or breeding on any of the following crops?

	Feeding	Breeding		Feeding	Breeding
Egg plant	☐	☐	Croton sp.	☐	☐
Cabbage	☐	☐	Corn	☐	☐
Pepper	☐	☐	Weeds	☐	☐
Tomato	☐	☐	Bananas	☐	☐
Squash	☐	☐	White potato	☐	☐
Pumpkin	☐	☐	Yams	☐	☐
Cotton	☐	☐	Poinsettia	☐	☐
Cassava	☐	☐	Carrots	☐	☐
Cut flowers	☐	☐	Lettuce	☐	☐
Tannia	☐	☐	Pak choi	☐	☐
Pigeon pea	☐	☐	Okra	☐	☐
Sorghum	☐	☐	Amaranthus	☐	☐
Spinach	☐	☐	Musk melon	☐	☐
Cowpea	☐	☐	Pineapple	☐	☐
Peanut	☐	☐	Citrus	☐	☐
Phaseolus	☐	☐	Sweet potato	☐	☐
Soybean	☐	☐	Tobacco	☐	☐
Papaya	☐	☐	Passion fruit	☐	☐
Annona	☐	☐	Water melon	☐	☐

6. Please list the five plants in order of importance as white-fly hosts.

1 ____________ 2. ______________ 3.______________

4 ______________ 5 ________________

7. Are you aware of any specific virus-like symptoms associated with white flies?

Yes ☐ No ☐

7a. On which crop(s)? ____________________ ____________________

____________________ ____________________

THE FOLLOWING QUESTIONS CONCERN THE IMPORTATION OF PLANT MATERIAL - NOT SEEDS

8. Tick the major plant types imported in the last :

2 years 2 - 5 years 5 - 10 years over 10 years (if known)

8 a. Fruit trees

b. Vegetable seedlings

c. Woody ornamentals * See bottom of page

d. Foliage (indoor) plants

e. If you ticked 8a, 8b, 8c, 8d list as many of the types that you know about

____________________ ____________________ ____________________

____________________ ____________________ ____________________

____________________ ____________________ ____________________

f. Have white flies been seen on any of the plants in 8e, if so, please indicate which, and a number after the plant type:

1 (this year); 2 (2-5 years); 3 (5-10 years) e.g. Poinsettia (2)

No. See bottom of page (**)

9. Could you identify the origin of the plant consignments listed in 6e ?

____________________ ____________________ ____________________

____________________ ____________________ ____________________

____________________ ____________________ ____________________

e.g. Poinsettia - Florida, USA; Citrus - Brazil

* MAFF Plant Quarantine recommendations: Importation of woody ornamentals - specimens should arrive free of leaves.

**B. tabaci intercepted on cabbages imported from Guyana in December 1988 - MAFF Plant Quarantine Section, only record of interception of white flies.

10. Tick the major plant types exported last

	2 yrs	2-5 yrs	5-10 yrs	over 10 yrs
10 a Vegetable seedlings	☐	☐	☐	☐
b Woody ornamentals	☐	☐	☐	☐
c Foliage plants	☐	☐	☐	☐
d Fruit trees	☐	☐	☐	☐

e If you ticked any of the above, please list below and give country of destination

______________________ ______________________

______________________ ______________________

______________________ ______________________

______________________ ______________________

______________________ ______________________

______________________ ______________________

e.g. Tomato (St. Kitts)

11. What pesticides are used in your country for white fly control?
Name three in order of use i.e.

1. Most often used; 2. Moderately used;

3. Used only when 1 or 2 not available. (Not usually the case in Barbados)

Diazinon
Tambo
Safer

ANNEX III

LIST OF PARTICIPANTS

(in alphabetical order)

ABEL De la Rosa, Ramón Antonio
Enc. Control de Plagas
Depto. Normas y Calidad INESPRE
Av. Luperón
Santo Domingo
DOMINICAN REPUBLIC
Phone: (809) 530-6565 (office)
Phone: (809) 568-7424 (home)

ABUD Antún, Abraham
Enc. Entomología
Junta Agroempresarial Dominicana (JAD)
Euclides Morillo 51
Arroyo Hondo
Santo Domingo
DOMINICAN REPUBLIC
Phone: (809) 563-6178/6180
Phone: (809) 565-8291 (home)
FAX: (809) 563-6181

AGOSTINI, Alexis E
US Dept. of Agriculture/APHIS
c/o American Embassy
Leopoldo Navarro No.1
Santo Domingo
DOMINICAN REPUBLIC
Phone: (809) 685-9780
FAX: (809) 686-0979

ALAM, Muhammad Munir
CARDI
University of the West Indies
Mona Campus
Kingston 7
JAMAICA
Phone: (809) 927-1231

ALEXIS, Theresa
CAB International
Gordon Street
Curepe
TRINIDAD & TOBAGO
Phone: (809) 645-7628
FAX: (809) 663-2859

ALVAREZ, Porfirio
Encargado Proyecto MIP
Junta Agroempresarial Dominicana (JAD)
Euclides Morillo 51
Arroyo Hondo
Santo Domingo
DOMINICAN REPUBLIC
Phone: (809) 563-6178/80
FAX: (809) 563-6181

ANGELES Ramos, Rosendo
Fitopatólogo
Programa Pro-Frijol/CESDA
San Cristóbal
DOMINICAN REPUBLIC
Phone: (809) 528-7898 (office)
Phone: (809) 547-4765 (home)

ARIAS, Bienvenido
Productor de Aguacate
Calle Pablo Barinas 5
Lavapies
San Cristóbal
DOMINICAN REPUBLIC
Phone: (809) 528-7208

BAEZ, Hipólito y Juan María
Proyecto Cítrico Quirilio Vilorio
Luis Alberti esq. La Arboleda
Ensanche NACO
Santo Domingo
DOMINICAN REPUBLIC
Phone: (809) 544-0964/0997

BARROW, Ronald
Ministry of Agriculture
P. O. Box 389
Port-of-Spain
TRINIDAD & TOBAGO
Phone: (809) 622-0213
FAX: (809) 622-4246

BELLO Guerrero, Leovigildo
c/o INDOTEC
Núñez de Cáceres
esq. J. Amado Soler
Santo Domingo
DOMINICAN REPUBLIC
Phone: (809) 566-8121/29
Phone: (809) 533-3832 (home)
FAX: (809) 540-2809

BERNARD M, Filiberto Antonio
Asesor Dir. de Investigación
Sec. de Estado de Agricultura
Centro de los Héroes
Santo Domingo
DOMINICAN REPUBLIC
Phone: (809) 533-0928 (home)

BOGAERT Marra, Miguel
Administrador Rancho Madrigal
Sección Las Palmas
Paraje el Caobal
San Cristóbal
DOMINICAN REPUBLIC
Phone: (809) 529-2520/687-9787
Phone: (809) 531-4036 (home)

BONILLA Mejía, Mario
Vice-Rector Académico
Universidad CDEP
Prolong. Av. Independencia
Km.9, Carr. Sánchez
Santo Domingo
DOMINICAN REPUBLIC
Phone: (809) 533-8252/535-6455
Phone: 809) 596-2064
FAX: (809) 535-6424

BORBON, Diego Antonio
Sec. Prensa y Propaganda ADIA
Av. Independencia esq. Pasteur
Apto. 303
Santo Domingo
DOMINICAN REPUBLIC
Phone: (809) 686-8440 (office)
Phone: (809) 597-0086 (home)

BORBON, Julio
Entomólogo
Junta Agroempresarial Dominicana (JAD)
Euclides Morillo 51
Arroyo Hondo
Santo Domingo
DOMINICAN REPUBLIC
Phone: (809) 563-6178/6180
FAX: (809) 563-6181

BRECHELT, Andrea
Dir. Proyecto Neem-GTZ
Instituto Politécnico Loyola
San Critóbal
DOMINICAN REPUBLIC

BRITO H, Carlos José
Enc. de Seguros Agropecuarios
ADACA
I. la Católica 212
Santo Domingo
DOMINICAN REPUBLIC
Phone: (809) 685-6191/6192

CAO-VAN, Philippe
CIRAD-FLHOR
BP 153
97200 Fort de France
MARTINIQUE
Phone: (596) 71-92-01 (office)
Phone: (596) 60-28-77 (home)
FAX: (596) 63-07-24

CARRASCO E, Elvin de Js.
Sub-Director Sanidad Vegetal
Sec. de Estado de Agricultura
Centro de los Héroes
Santo Domingo
DOMINICAN REPUBLIC
Phone: (809) 532-7941 (office)
Phone: (809) 568-2051 (home)

CASTILLO Lachapelle, Ramón
Gerente CALOSA
Bernardo Pichardo 55, Gazcue
Santo Domingo
DOMINICAN REPUBLIC
Phone: (809) 688-5284
FAX: (809) 682-9927

CASTLETON, Carl
Director USDA/APHIS
Leopoldo Navarro esq.
C. Nicolás Penson
Santo Domingo
DOMINICAN REPUBLIC
Phone: (809) 685-9780
Phone: (809) 533-6542

CASTRO Escoto, José E
Consorcio Cítrico Dominicano, C. x A.
Basima
Villa Altagracia
DOMINICAN REPUBLIC
Phone: (809) 223-6440

CEDANO Mateo, Juan Ramón
Estación Experimental Arroyo Loro
Apartado Postal 188
San Juan de la Maguana
DOMINICAN REPUBLIC
Phone: (809) 557-5934

CESPEDES, Carlos Manuel
Encargado Proyecto Jamao
Direccieon General Forestal
Edif. ODC, 3er. piso
Centro de los Héroes
Santo Domingo
DOMINICAN REPUBLIC
Phone: (809) 533-5183

CLARKE, Dionne O
CARDI
University Campus
Mona
Kingston 7
JAMAICA
Phone: (809) 927-1231/4140
FAX: (809) 927-2099

CUEVA Moronta, Antonio
Laboratorio Control Biológico
Universidad Autónoma de Santo Domingo (UASD)
Estación Experimental Engombe
Santo Domingo
DOMINICAN REPUBLIC
Phone: (809) 537-9465 (office)
Phone: (809) 593-6339 (home)

CHRYSOSTOME, Myrlene
Centre de Recherche et de
Documentation Agricole (CRDA)
BP 680
Port-au-Prince
HAITI
Phone: 509) 22-4503 (office)
Phone: (509) 46-3647 (home)

DE LA CRUZ Frías, Patricio
Encargado Nac. Programa Nematología
Sec. de Estado de Agricultura/CESDA
Apartado 24
San Cristóbal
DOMINICAN REPUBLIC
Phone: (809) 528-7317 (office)
Phone: (809) 528-5866 (home)

DIAZ, Andrés
Enc. Sanidad Vegetal
Consorcio Cítrico del Este, C. x A.
Km.1, Carr. Hato Mayor
Sabana de la Mar
DOMINICAN REPUBLIC
Phone: (809) 553-2230/2478

DIAZ Céspedes, Fernando A
Entomólogo Depto. Técnico
FERSAN
Apartado Postal 1405
Santo Domingo
DOMINICAN REPUBLIC
Phone: (809) 562-2351 (office)
Phone: (809) 533-1452 (home)

DIAZ Thomas, Frank
Gte. Agrícola Zona Sur
Transagrícola, S. A.
Av. Luperón esq. Sarasota
Santo Domingo
DOMINICAN REPUBLIC
Phone: (809) 521-4598 (office)
Phone: 809) 521-2060 (home)
FAX: (809) 582-8171

DIPOTAROENO-Sakrama, Marijke S
Agricultural Experiment Station
Cultuurtuinlaan
Paramaribo,
SURINAME
Phone: (597) 472442
FAX: (597) 470301/478986

DOMINGUEZ, Manuel Luis
Bayer Dominicana
Zona Industrial de Herrera
Santo Domingo
DOMINICAN REPUBLIC
Phone: (809) 530-8086 (office
Phone: (809) 530-0341 (home)

DUPUY, Jerry
Barceló Industrial
PO Box 63
Santo Domingo
DOMINICAN REPUBLIC
Phone: (809) 593-3411 (office)
Phone: (809) 560-5917 (home)
FAX: (809) 593-4209

DURAN Angustia, Roberto E
Gerente de Reclamaciones
ADACA
I. la Católica 212
Santo Domingo
DOMINICAN REPUBLIC
Phone: (809) 685-6191/6192
FAX: (809) 688-9040

ESCARRAMAN H, Vinicio Antonio
Gerente Regional Norcentral
Programa MIP
Apartado 206
La Vega
DOMINICAN REPUBLIC
Phone: (809) 573-9611 (office)
Phone: (809) 574-4863
FAX: (809) 573-3657

FABELO M, José Antonio
Gerente Agrícola
Barceló Industrial
Las Clavellinas
Azua
DOMINICAN REPUBLIC
Phone: (809) 521-3374/3667
Phone (809) 521-4409 (home)

FELIZ Peralta, Manuel
Secretario Organización
ANPA
Ave. Independencia 24
Miramar, Santo Domingo
DOMINICAN REPUBLIC
Phone: (809) 533-7008/8430
FAX: (809) 532-9808

FERGUSON, Everest John
Pest Management Unit
Ministry of Agriculture
St George's
GRENADA
Phone: (809) 440-0301/3274
FAX: 809) 440-4191

GARCIA Encarnación, Leonardo
Técnico Programa Leguminosas
Sec. de Estado de Agricultura/CESDA
Apartado Postal 24
San Cristóbal
DOMINICAN REPUBLIC
Phone: (809) 528-7898/7317
Phone: (809) 542-1681 (home)

GARCIA Pérez, Juan José
Plantaciones Oscar De la Renta
Av. Máximo Gómez 182
Santo Domingo
DOMINICAN REPUBLIC
Phone: (809) 565-2151 ext.2156/7
Phone: (809) 682-3615 (home)

GARRIDO, Luis
Asist. Téc. Sanidad Vegetal
Sec. de Estado de Agricultura
Centro de los Héroes
Santo Domingo
DOMINICAN REPUBLIC
Phone: (809) 532-7941 (office)
Phone: (809) 533-9197 (home)

GENAO, Madera Alberto
Administrador General
Productora de Semillas Dominicans, C. x A.
La Herradura
Santiago
DOMINICAN REPUBLIC
Phone: (809) 583-7241/42
Phone: (809) 530-3646 (home)
FAX: (809) 583-7243

GEORGE, Rodney
Agricultural Extension Division
Ministry of Agriculture
Kentist Rd
ANTIGUA & BARBUDA
Phone: 809) 462-4962/1007
Phone: (809) 463-3024 (home)

GERLING, Dan
Department of Zoology
Tel Aviv University
Ramat Aviv, 69978
ISRAEL
Phone: (972) 3-640-8611
FAX: (972) 3-640-9403

GOMEZ, Emigdio
Gerente Regional Norte MIP
c/o ISA
PO Box 166
Santiago
DOMINICAN REPUBLIC
Phone: (809) 571-0821/581-6653
Phone: (809) 580-1599 (home)

GOUGLER, Robert and Lynda
General Delivery
San Ignacio
BELIZE
Phone: (501) 823093
FAX: (501) 822928

GUERRA, Carlos
Productor de Papas
Constanza
DOMINICAN REPUBLIC
Phone: (809) 539-2791

GUERRA Blanco, Alcadio
Productor
Tireo Arriba
Constanza
DOMINICAN REPUBLIC
Phone: (809) 539-2412

GUERRERO, Kelvin Antonio
Curador de Insectos
Museo Nacional de Historia Natural
Sección de Entomología — Phone: (809) 689-0106/687-5609
Plaza de la Cultura — Phone: (809) 688-3124 (home)
Santo Domingo — FAX: (809) 687-5766
DOMINICAN REPUBLIC

GUZMAN Cáceres, Francisco
Rel. Públicas Area Rural
Falconbridge Dominicana — Phone: (809) 682-6041/525-3106
Loma La Peguera — Phone: (809) 525-4634
Bonao — FAX: (809) 525-2335
DOMINICAN REPUBLIC

GUZMAN Santana, José Ramon
Sanidad Vegetal/Espaillat
Sec. de Estado de Agricultura
Prolongación Sánchez — Phone: (809) 578-6966 (office)
Provincia Espaillat — Phone: (809) 578-5758 (home)
DOMINICAN REPUBLIC

HALL, Richard
CAB International
Gordon Street — Phone: (809) 662-4173
Curepe — FAX: (809) 663-2859
TRINIDAD & TOBAGO

HAMMERTON, Ruth G — Phone: (809) 361-4370 (office)
PO Box N 8409 — Phone: (809) 325-5642 (home)
Nassau, Bahamas — FAX: (809) 361-4236

HAMMOND, Roger Antony
CAB International
Gordon Street
Curepe — Phone: (809) 645-7628
TRINIDAD & TOBAGO

HEFFES, Amnon
Presidente Fénix, S A
Leonardo Da Vinci 66
Urb. Real — Phone: (809) 562-8374/8375
Santo Domingo — FAX: (809) 562-8372
DOMINICAN REPUBLIC

HENRIQUEZ, Andrés Paíno
Hacienda Buchín Henríquez
San Teresa No.4 (Naco) — Phone: (809) 541-0777 (office)
Santo Domingo — Phone: (809) 563-6312 (home)
DOMINICAN REPUBLIC

HERASME C José de la Cruz
Enc. Lab. Fitopatolog'Ia
Sec. de Estado de Agricultura
Estación Post-entrada de Cuarentena Vegetal
Aereopuerto Int'l. Las Américas — Phone: (809) 549-0991 (office)
Santo Domingo — Phone: 809) 685-5735
DOMINICAN REPUBLIC

HICHEZ, Frias Eligio
Presidente Bioagro
Felix María Nolasco No.2
Los Prados
Santo Domingo — Phone: (809) 542-5106
DOMINICAN REPUBLIC

HUNT, Peter
NRI/ODA Plant Protection Project
c/o British High Commission
PO Box 91
Belmopan — Phone (501) 92-2640
BELIZE — FAX: 501) 82-3712

ILES, Malcolm
Natural Resources Institute
Central Avenue
Chathan Maritime
Kent, ME4 4TB — Phone: (44) 634-883054
UNITED KINGDOM — FAX: (44) 634-883377

JACKSON, Alan C
CTA, Postbus 380 — Phone: (31) 8380-60400 (office)
6700 Aj Wageningen — Phone: (44) 582-762742 (home)
THE NETHERLANDS — FAX: (31) 8380-31052

JIMENEZ, Héctor
Director Depto. de Café
Sec. de Estado de Agricultura
Centro de los Héroes — Phone: (809) 532-1038
Santo Domingo — FAX: (809) 537-3632
DOMINICAN REPUBLIC

JIMENEZ G, Alfredo A
Enc. Unidad Investigación
Plan Sierra — Phone: (809) 578-8249 (office)
Apartado Postal 1152 — Phone: (809) 578-8734 (home)
Santiago — FAX: (809) 578-8396
DOMINICAN REPUBLIC

JIMENEZ Ortiz, Odelis
Gerente Regional Este
Programa MIP
Calle San Antonio 47 — Phone: (809) 553-3989 (office)
Hato Mayor — Phone: (809) 553-3804 (home)
DOMINICAN REPUBLIC

JOHNSTON, Denyse Mariella
CARDI
University Campus — Phone: (809) 645-1205/1206/1207
St Augustine — FAX: (809) 645-1208
TRINIDAD & TOBAGO

JONES, Jeffrey
Ministry of Agriculture
Graeme Hall
Christ Church
BARBADOS
Phone: (809) 428-9980/9982
FAX: 809) 420-8444

JONES, Mona Theresa
Central Experimental Station
Centeno
Arima
TRINIDAD & TOBAGO
Phone: (809) 646-6049/662-4173
FAX: (809) 645-2643

KHAN, Ayub
Dept. of Plant Science
University of the West Indies
St Augustine
TRINIDAD & TOBAGO
Phone: (809) 662-2002, ext. 3087

LINK, John E.
Central Farm
PO Box 932
Belize City
BELIZE
Phone: (501) 92-2640
FAX: (501) 92-2640

LLUBERES, Juan Félix
Presidente Administrador
Agroindustria Lluberes, CxA
San Antonio 2
Hato Mayor
DOMINICAN REPUBLIC
Phone: (809) 553-2273

MANCEBO Méndez, Josefa
Depto. Extensión
Sec. de Estado de Agricultura
Centro de los Héroes
Santo Domingo
DOMINICAN REPUBLIC
Phone: (809) 535-4742 (office)
Phone: (809) 681-1923 (home)
FAX: (809) 535-6424

MARTINEZ Castillo, José A
Propietario Finca Ocoeña
Tetelo Vargas 25, Apto. 401
Edificio Duendy XII
Santo Domingo
DOMINICAN REPUBLIC
Phone: (809) 541-5835
FAX: (809) 563-2435

MARTINEZ Yorke, Reina Teresa
Enc. Unidad Virología
Sec. de Estado de Agricultura/CESDA
Apartado Postal 24
San Cristóbal
DOMINICAN REPUBLIC
Phone: (809) 528-7898/528-7317
Phone: (809) 531-0967

MATOS Casado, Luis Antonio
Laboratorio Fitopatología
Universidad Autónoma de Santo Domingo (UASD)
Estación Experimental Engombe
Santo Domingo
DOMINICAN REPUBLIC
Phone: (809) 537-9465 (office)
Phone: (809) 537-5512

MEADE, Dudley
Ministry of Agriculture
PO Box 272
Groves
MONTSERRAT
Phone: (809) 491-2546 (office)
Phone: (809) 491-5139 (home)
FAX: (809) 491-7275

MENDEZ Bautista, Rosa María
Enc. Sección Fitopatología CESDA
Sec. de Estado de Agricultura
Apartado Postal 24
San Cristóbal
DOMINICAN REPUBLIC
Phone: (809) 528-7898/7317
Phone: (809) 528-7532 (home)

MENDEZ G, Felipe de Js.
Director Proyecto MIP Diaprepes sp.
Autopista Duarte, Km 8
Santo Domingo
DOMINICAN REPUBLIC
Phone: (809) 544-2445/523-4428
Phone: (809) 566-2913 (home)

MIESES, Eugenio
Gerente Selecta Agroindustrial
Calle D Esquina G
Zona Industrial de Haina
Santo Domingo
DOMINICAN REPUBLIC
Phone: (809) 542-1070 (office)
Phone: (809) 521-4743 (home)

MINYETTY Pinales, Ramón Ant.
Federación Provincial de Organizaciones Campesinas Azuanas
(FEPROCA)
Calle 30 de Marzo 215
Azua
DOMINICAN REPUBLIC
Phone: (809) 521-3255

MORA Tavera, Ramón A
Técnico Instituto Agrario Dominicano
Ave. 27 de Febrero
Santo Domingo
DOMINICAN REPUBLIC
Phone: (809) 530-5591 (office)
Phone: (809) 593-8162 (home)

MOTA, Rolando
Enc. Unidad Técnica OFIROYA
Departamento de Café
Sec. de Estado de Agricultura
Centro de los Héroes
Santo Domingo
DOMINICAN REPUBLIC
Phone: (809) 532-1032 (office)
Phone: (809) 594-6843 (home)

MUNROE, Leslie Allan
National Agricultural Research Institute
Mon Repos
East Coast Demerara
GUYANA

MURRAY, Roy C
Ministry of Agriculture
Bodles Research Station
Old Harbour
St Catherine
JAMAICA
Phone: (809) 983-2267/2281/
983-2842/2843

NATION, Bernard
Division of Agriculture
Botanical Gardens, Roseau
COMMONWEALTH OF DOMINICA
Phone: (809) 448-82401

PARASRAM, Samsundar
Director, Research and Programmes
CARDI
University Campus
St Augustine
TRINIDAD & TOBAGO
Phone: (809) 645-1205/1206 (office)
Phone: (809) 663-1553 (home)
FAX: (809) 645-1208

PELLETIER, Luis E
AFIPA, Inc.
Gerente Prog. Manejo Seguro Plaguicidas
Abraham Lincoln esq. J Amado Soler
Edif. Concordia, Apto.302
Santo Domingo
DOMINICAN REPUBLIC
Phone: (809) 562-5404/532-2696
Phone: (809) 533-9062 (home)
FAX: (809) 535-3894

PEMBERTON, Carlisle
Dept. Agricultural Economics
The University of the West Indies
St Augustine
TRINIDAD & TOBAGO
Phone: (809) 663-1359 (office)
Phone: (809) 662-7297 (home)
FAX: (809) 663-9686

PEÑA, Angel Antonio
Laboratorio Control Biológico
Facultad de Agronomía
Univ. Autónoma de Santo Domingo (UASD)
Finca Experimental de Engombe
Santo Domingo
DOMINICAN REPUBLIC
Phone: (809) 537-9665/535-8300
Phone: (809) 597-4181 (home)

PEÑA Cornielle, Jehová
Kettle & Almeanzar, S A
Paseo de los Aviadores #4
Ensanche Miraflores
Santo Domingo
DOMINICAN REPUBLIC
Phone: (809) 566-0161/0164
FAX; 809) 566-9885

PEREZ Otañez, Lillian E
Gerente General ADACA
Isabel la Católica 212
Zona Colonial
Santo Domingo
DOMINICAN REPUBLIC
Phone: (809) 685-6191/92
Phone: (809) 567-3850 (home)
FAX: (809) 688-9040

PEREZ Solano, Evaristo
Cons. Agroindustrial Delta, SA — Phone (809) 561-7373 (office)
Prolong. 27 de Febrero No. 1500 — Phone: (809) 528-6188 (home)
Santo Domingo — FAX: (809) 561-6033
DOMINICAN REPUBLIC

PERFECT, Trevor John
Natural Resources Institute
Central Avenue
Chatham Maritime
Kent ME4 4TB — Phone: (44) 634-883393
UNITED KINGDOM — FAX: (44) 634-883386

POLANCO R, Héctor Emilio
Productor de Cítricos
Calle 27 de Febrero 33
Hato Mayor — Phone: (809) 553-3957/532-1872
DOMINICAN REPUBLIC

POLLARD, Gene V
FAO Representation
P O Box 822
134-138 Frederick Street
Port-of-Spain — Phone: (809) 625-0467/04688
TRINIDAD & TOBAGO — FAX: (809) 623-0995

PORTALATIN B, Frank J
Propietario Cítricos Frank
Pedro A Bobea, Apt. 147
Edif. 4, Jardines del Embajador
Urb. Bella Vista — Phone: (809) 553-3361 (office)
Santo Domingo — Phone: (809) 535-3874 (home)
DOMINICAN REPUBLIC

RAJNAUTH, Garth L
Ministry of Agriculture Land & Marine Resources
Central Experiment Station
Centeno, via Arima PO — Phone: (809) 646-1645 (office)
TRINIDAD & TOBAGO — Phone: (809) 642-7955 (home)

RAMIREZ Coronado, Rafael Antonio
Director Depto. Sanidad Vegetal
Sec. de Estado de Agricultura
Centro de los Heroes — Phone: (809) 532-7941
Santo Domingo — Phone: (809) 593-2760
DOMINICAN REPUBLIC

RAMON Beriguete, Juan
Asistente Investigación FERQUIDO
Ave. Luperón — Phone: (809) 530-5598 (office)
Santo Domingo — Phone: (809) 521-0822 (home)
DOMINICAN REPUBLIC

REDDY, Peddigari Srinivasa
Citrus Growers Association — Phone: (501) 5-22442 (office)
Dangriga — Phone: (501) 5-23354 (home)
BELIZE — FAX: (501) 5-22686

REID, Janice Celia
CARDI
PO Box 113
Mona
Kingston 7
JAMAICA

Phone: (809) 927-1231/4140
FAX: (809) 927-2099

RIVAS, Felipe de Js.
Productor de Bananos
Bajo Yaque
DOMINICAN REPUBLIC

Phone: (809) 579-2771
FAX: (809) 579-2771

RODRIGUEZ Sosa, Amaury
Supervisor General Sanidad Vegetal
Sec. de Estado de Agricultura
Centro de los Heroes
Santo Domingo
DOMINICAN REPUBLIC

Phone: (809) 530-6140 (home)

ROGER, Tony
US Peace Corps
Calle 1ra. No. 84
Los Peralejos
Santo Domingo
DOMINICAN REPUBLIC

Phone: (809) 560-0047 (home)

ROSARIO, Juan
Sec. de Prensa y Propaganda
ANPA
Arz. Meriño esq. Luperón
Edif. Ocaña, 3ra. planta
Santo Domingo
DOMINICAN REPUBLIC

Phone: (809) 686-8480 (office)
Phone: (809) 593-0373 (home)

SANCHEZ, Miguel
Vicepresidente Transagrícola
Ave. Duarte 269
Navarrete
Santiago
DOMINICAN REPUBLIC

Phone: (809) 582-8171 (office)
Phone: (809) 581-0738 (home)

SANCHEZ Andujar, Fidel Esmelin
Director Centro de Investigaciones Aplicadas a Zonas Aridas
(CIAZA)
Proyecto Ysura El Sisal
Azua
DOMINICAN REPUBLIC

Phone: (809) 521-2611 (home)

SANCHEZ de Pérez, Alfonsina
Encargada Sanida Vegetal
Sec. de Estado de Agricultura
Anacaona No. 112
San Juan de la Maguana
DOMINICAN REPUBLIC

Phone: (809) 557-2916
Phone: (809) 557-6163

SANCHEZ J, Humberto R
Sec. de Estado de Agricultura
CESDA
San Cristóbal
DOMINICAN REPUBLIC
Phone: (809) 532-4626 (office)
Phone: (809) 531-7301 (home)

SANCHEZ P, Juan
Enc. Capacitación FUNDEJUR
Ramón Santana 37B
Zona Universitaria
Santo Domingo
DOMINICAN REPUBLIC
Phone: (809) 885-7057 (office)
Phone: (809) 593-7726 (home)
FAX: (809) 686-7208

SANCHEZ Schwarz, Pablo Miguel
Asistente Agrícola
Transagrícola, SA
PO Box 02-5360
Miami
Florida 33102-5360
USA
Phone: (809) 582-8171
FAX: (809) 582-8171

SANQUINTIN B, Carlos
Gerente Agroquímicos
ICI Dominicana, SA
Fantino Falco 7, NACO
Santo Domingo
DOMINICAN REPUBLIC
Phone: (809) 565-8479/567-2117
Phone: (809) 530-0249 (home)
FAX: 809) 567-9310

SANTANA C, Julio César
Enc. Depto. Agrícola
Juan Barceló, C. x A.
Km 1, Carr. Sabana de la Mar
DOMINICAN REPUBLIC
Phone: (809) 553-2230 (office)
Phone: (809) 553-2743 (home)

SANTANA C, Miguel Angel
Gerente Div. Agrícola
Hacienda Romelia, SA
Edif.No.4, Apt.1-A
Barrio Savica
Hato Mayor
DOMINICAN REPUBLIC
Phone: (809) 553-2230/2478
Phone: (809) 553-4025 (home)

SANTANA S, José D
c/o FERSAN
Ave. J F Kennedy
Santo Domingo
DOMINICAN REPUBLIC
Phone: (809) 562-2352 (office)
Phone: (809) 594-1330 (home)

SANTONI Stroffer, Carlos F
Sub-Administrador
Pascual Santoni y Sucs., CxA
Av. Santa Rosa 136
La Romana
DOMINICAN REPUBLIC
Phone: (809) 556-3179/2332
Phone: (809) 523-8344 (home)
FAX: (809) 556-4936

SAVIÑON, Manuel Antonio
Div. Asistencia Técnica
Sec. de Estado de Agricultura
Centro de los Héroes
Santo Domingo
DOMINICAN REPUBLIC
Phone: (809) 535-4742 (office)
Phone: (809) 530-6403 (home)
FAX: (809) 535-6424

SENCION S, Luis Manuel
Enc. Sanidad Vegetal
Barceló Industrial
Las Clavellinas
Azua
DOMINICAN REPUBLIC
Phone: (809) 521-3374/3558
Phone: (809) 521-3525 (home)
FAX: (809) 521-4333

SERRA A, Colmar A
Instituto Superior de Agricultura (ISA)
Entomólogo/MIP
Ave. Antonio Guzmán
La Herradura
Santiago
DOMINICAN REPUBLIC
Phone: (809) 582-8011
FAX: (809) 582-6626

SHIRAISHI, Masaaki
SESDA/JICA
Av. Bolivar 818
Santo Domingo
DOMINICAN REPUBLIC
Phone: (809) 682-4703

SINGH, Ranjit H
Dept. of Agricultural Economicsand Farm Management
The University of the West Indies
St Augustine
TRINIDAD & TOBAGO
Phone: (809) 663-1364 , ext. 3275
FAX: (809) 663-9686

SMALL, Winston Lyall
Ministry of Agriculture
Graeme Hall
Christ Church
BARBADOS
Phone: (809) 428-4150
FAX: (809) 420-8444

SOSA, Luis Rafael
Gte. de Producción
Camelia Agroindustrial SA
Bartolomé Colón esq. Metropolitana
Santiago
DOMINICAN REPUBLIC
Phone: (809) 582-1151/1153

SPONAGEL, Karl Wilhelm
Encargado Entomología
Fundación Hondureña de Investigación Agrícola (FHIA)
La Lima
HONDURAS
Phone: (504) 682078 (office)
Phone: (504) 682373 (home)

SQUIRES, Gregory
Ministry of Agriculture
NIS Building
Castries Waterfront
ST LUCIA
Phone: (809) 450-2375/452-2526
FAX: (809) 453-6214

STANSLY, Philip
Associate Prof. of Entomology
University of Florida/IFAS
PO Drawer 5127
Immokalee
Florida 33934
USA
Phone: (813) 657-5221
FAX: (813) 657-5224

STARR, Christopher K.
Dept. of Zoology
The University of the West Indies
St Augustine
TRINIDAD & TOBAGO
Phone: (809) 663-1334 ext. 3096
FAX: (809) 663-9684

TAVAREZ Rodríguez, Héctor
Supervisor Regional Sanidad Vegetal
Sec. de Estado de Agricultura
Restauración esq. España
Santiago
DOMINICAN REPUBLIC
Phone: (809) 241-4206 (office)
Phone: (809) 583-4202/582-9787

TAVERAS Taveras, Francisco Js.
Proyecto NIM
Fabricación de Insecticidas Naturales
Instituto Politécnico Loyola
San Cristóbal
DOMINICAN REPUBLIC
Phone: (809) 528-4786 (office)
Phone: (809) 528-4381 (home)

TEJADA, Santiago
Gerente General Banco de Desarrollo
Agropecuario, SA
Ave. Independencia 801
Santo Domingo
DOMINICAN REPUBLIC
Phone: (809) 686-0984 (office)
Phone: (809) 533-3947 (home)
FAX: (809) 687-0825

TINEO H, Fco. Osvaldo
Enc. Programa Preaviso Biológico Control Sigatoka
Cooperativa de los Bananeros
Av. J F Kennedy 10
Mao, Valverde
DOMINICAN REPUBLIC
Phone: (809) 572-6205 (office)
Phone: (809) 572-4684 (home)
FAX: (809) 572-5747

TORAL Córdova, Fco. José
Vice-Presidente Administrador
Agroindustria de Barahona, CxA
Carr. Barahona-Pedernales
Km 2 1/2
Barahona
DOMINICAN REPUBLIC
Phone: (809) 524-2444/687-7984
Phone: (809) 524-3242 (home)
FAX: (809) 524-2662

TORIBIO Díaz, Benito
Profesor Entomología
Instituto Agronómico Loyola
Dajabón
DOMINICAN REPUBLIC
Phone: (809) 579-8765

TORRES, Víctor
Gte. Depto. Agrícola
Cía. Angloamericana
Autopista Duarte, Km 6 1/2
Santo Domingo
DOMINICAN REPUBLIC
Phone: (809) 562-1333 (office)
Phone: (809) 530-1459 (home)
FAX: (809) 544-3145

TORRES Beato, Diego
Director Depto. Ingeniería Agronómica
Universidad Autónoma de Santo Domingo (USAD)
Engombe
Santo Domingo
DOMINICAN REPUBLIC
Phone: (809) 537-5330/4218
Phone: (809) 531-1232 (home)
FAX (809) 533-1106

TORRES Herrera, Juan Gilberto
Asistente Investigacions
Plan Sierra
San José de las Matas
DOMINICAN REPUBLIC
Phone: (809) 578-8249/8370
Phone: (809) 579-0874 (home)

ULLOA Figuereo, Marcos
Encargado Div. Desarrollo y Promoción, FERQUIDO
Ave. Luperón esq. Central
Zona Industrial Herrera
Santo Domingo
DOMINICAN REPUBLIC
Phone: (809) 530-5598 (office)
Phone: (809) 566-5564 (home)
FAX: (809) 530-6586

VALLEJO Cayo, Mauricio
Gerente de Producción
Fénix, S A
Leonardo Da Vinci 66
Urb. Real
Santo Domingo
DOMINICAN REPUBLIC
Phone: (809) 562-8374/8375
FAX: (809) 562-8372

VAN LENTEREN, Johan C.
Dept. of Entomology
PO Box 8031
6700 EH Wageningen
THE NETHERLANDS
Phone: (31) 8370-82327
FAX: (31) 8370 84821

VELOZ Cepeda, José Miguel
Administrador General
Jardín Fiesta, C. x A.
La Joya Jarabacoa
DOMINICAN REPUBLIC
Phone: (809) 574-6383

VIDAL Montero, José Miguel
Dirección General Forestal
Centro de los Héroes
Santo Domingo
DOMINICAN REPUBLIC
Phone: (809) 532-4128 (office)
Phone: (809) 561-3645 (home)

WALMSLEY, Donald
PO Box 4757
Arima
TRINIDAD & TOBAGO
Phone: (809) 642-2248 (home)

ZOQUIER, Luis
Gerente de Producción
Famosa Agrícola
Calle Canela Mota
Altos de los Melones
Baní
DOMINICAN REPUBLIC

Phone: (809) 522-3842 (office)
Phone: (809) 522-7744 (home)
FAX (809) 522-5632

ANNEX IV

ACRONYMS AND ABBREVIATIONS

ACP	African-Caribbean-Pacific (group of signatories to the Lomé Convention)
BCGA	Belize Citrus Growers Association
BDDC	British Development Division for the Caribbean
BGMV	Bean Golden Mosaic Virus
CAB	Commonwealth Agricultural Bureaux (UK)
CABI	CAB-International
CaIB	Cocoa Industry Board (Jamaica)
CARAPHIN	Caribbean Animal and Plant Health Information Network
CARDI	Caribbean Agricultural Research and Development Institute
CARICOM	Caribbean Community
CATIE	Centro Agronomico Tropical de Investigacion y Ensenanza (Costa Rica)
CD-ROM	Compact Disc – Read Only Memory
CDB	Caribbean Development Bank
CES	Central Experiment Station (Trinidad & Tobago)
CESDA	Centro Sur de Desarrollo Agropecuario (Dominican Republic)
CFC	Caribbean Food Corporation
CfIB	Coffee Industry Board (Jamaica)
CGA	Citrus Growers Association (Jamaica)
CGIAR	Consultative Group on International Agricultural Research
CIAT	International Centre for Tropical Agriculture (Colombia)
CIAZA	Centro de Investigaciones Aplicadas a Zonas Aridas (Dominican Republic)
CIDCO	Coffee Industry Development Company (Jamaica)
CIMMYT	Centro Internacional de Mejoramiento de Maiz y Trigo (Mexico)
CIP	Centro Internacional de la Papa (Peru)
CIRAD/FLHOR	Centre de Coopération Internationale en Recherche Agronomique pour le Développement/Département de Productions Fruitières et Horticoles (France)
CoIB	Coconut Industry Board (Jamaica)

CPPC	Caribbean Plant Protection Commission
CRDA	Centre de Recherche et Documentation Agricoles (Haiti)
CRIN	Caribbean Rice Information Network
CRW	Citrus Root Weevil
CTA	Technical Centre for Agricultural and Rural Cooperation (ACP–EEC Lomé Convention) (The Netherlands)
CTV	Citrus Tristeza Virus
DBM	Diamond-back Moth
EC	European Community
EDF	European Development Fund
EEC	European Economic Commission
EIL	Economic Injury Level
EPPO	European and Mediterranean Plant Protection Organization
ET	Economic Threshold
ETL	Economic Threshold Level
FAO	Food and Agriculture Organization of the United Nations
FAO/RALC	FAO/Regional Office for Latin America and the Caibbean
FDA	Fundación de Desarrollo Agropecuario Inc. (Dominican Republic)
FEPROCA	Federación Provincial de Organizaciones Campesinas Azuanas (Dominican Republic)
FHIA	Fundación Hondureña de Investigación Agrícola (Honduras)
FIC	French Inter-Ministerial Fund for Regional Cooperation
GATT	General Agreement on Tariffs and Trade
GBCS	Grenada Banana Cooperative Society
GTZ	Deutsche Gesellschaft für Technische Zusammenarbeit (Germany)
IACNET	Inter-American Citrus Network
IAL	Instituto Agronómico Loyola (Dominican Republic)
IARC	International Agricultural Research Centre
IBPGR	International Board for Plant Genetic Resources
ICTA	Imperial College of Tropical Agriculture

IFAS	Institute for Food and Agricultural Science University of Florida)
IGR	Insect Growth Regulator
IIBC	International Institute of Biological Control
IICA	Inter-American Institute for Cooperation on Agriculture
IITA	International Institute of Tropical Agriculture (Nigeria)
INRA	Institut National de la Recherche Agronomique (France)
IPL	Instituto Politécnico Loyola (Dominican Republic)
IPM	Integrated Pest Management
IPMWG	IPM Working Group
IPPC	International Plant Protection Convention
IRRI	International Rice Research Institute
ISTH	Inter-American Society for Tropical Horticulture
JAD	Junta Agroempresarial Dominicana Inc. (Dominican Republic)
LDC	Less Developed Country
MAB	Man and the Biosphere (UNESCO)
MB	Mosca Blanca
MALMR	Ministry of Agriculture, Land and Marine Resources (Trinidad & Tobago)
MDC	More Developed Country
MoA	Ministry of Agriculture
MSW	Mango Seed Weevil
NAPPO	North American Plant Protection Organization
NARI	National Agricultural Research Institute (Guyana)
NARS	National Agricultural Research System
NGO	Non-Governmental Organization
NIHERST	National Institute for Higher Education, Research, Science and Technology (Trinidad & Tobago)
NRI	Natural Resources Institute (UK)
OAS	Organization of American States
ODA	Overseas Development Administration (UK)

OECS	Organization of Eastern Caribbean States
PRA	Plant Risk Analysis
RPPO	Regional Plant Protection Organization
RRC	Regional Research Centre (Caribbean)
SCMA	Standing Committee of Ministers Responsible for Agriculture (CARICOM)
SLBGA	St Lucia Banana Growers Association
SPW	Sweet Potato Whitefly
TGMV	Tomato Golden Mosaic Virus
TMoV	Tomato Mottle Geminivirus
UASD	Universidad Autónoma de Santo Domingo
UN	United Nations
UNDP	United Nations Development Progamme
UNEP	United Nations Environment Programme
UNESCO	United Nations Educational, Scientific and Cultural Organization
USAID	United States Agency for International Development
USDA	United States Department of Agriculture
USDA/APHIS	USDA Animal and Plant Health Inspection Service
UWI	The University of the West Indies
WINBAN	Windward Islands Banana Association

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CTA
Technical Centre for Agricultural
and Rural Co-operation
(ACP-EEC Lomé Convention)

Visiting address
'De Rietkampen', Galvanistraat 9
6716 AE Ede, The Netherlands

Postal Address
Postbus 380
6700 AJ Wageningen
The Netherlands

Tel. (31)8380 - 604-00
Telex (44)30169 cta nl
Fax (31)8380 - 31052

Brussels Branch Office
Rue de l'Industrie 4
1040 Brussels, Belgium

Tel. (32)2 5137435/6
Telex (46)20577 cta bxl b
Fax (32)2 - 5113868

CTA
Centre Technique de Coopération
Agricole et Rurale
(Convention ACP-EEC de Lomé)

Adresse physique
'De Rietkampen', Galvanistraat 9
6716 AE Ede, Pays-Bas

Addresse Postale
Postbus 380
6700 AJ Wageningen
Pays-Bas

Tél. (31)8380 - 604-00
Télex (44)30169 cta nl
Fax (31)8380 - 31052

Antenne de Bruxelles
Rue de l'Industrie 4
1040 Bruxelles, Belgique

Tél. (32)2 5137435/6
Télex (46)20577 cta bxl b
Fax (32)2 - 5113868

CTA publication no. 607