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"Food Production, Marketing, and Safety: Strategies for Caribbean Food Security"

United States Department of Agriculture, T-STAR Sponsored Symposium

Challenges and Opportunities in Protecting the Caribbean, Latin America, and the United States from Invasive Species

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TABLE OF CONTENTS

Proceedings of the Caribbean Food Crops Society. 39(1):1-5. 2003

CHALLENGES IN SAFEGUARDING THE GREATER CARIBBEAN BASIN AGAINST INVASIVE PESTS, DISEASES, WEEDS, AND OTHER AGENTS: A FLORIDA PERSPECTIVE

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ABSTRACT: There is a clear and significant problem with the invasion of basin ecosystems by a wide array of biological agents impacting the social and economic systems, food supply, and unique environments. Basin members share both an interest in and dependency on trade with a great vulnerability to the inherent risks associated with it. Moreover, what threatens one generally is a threat to all. Mostly unilateral, occasional bilateral and few multilateral initiatives have been taken to cope with invasive alien species and more are in the planning stages. Now the challenge is how to take advantage of these initiatives and weave them into a strategic, coordinated set of actions to enhance prevention, exclusion, detection and management of high-threat agents basin-wide. Through this collective security approach, initiatives in regulation development, institution building, training, research, public affairs, and pest/disease/weed management would serve to strengthen safeguarding systems basin-wide.

KEY WORDS: Regional safeguarding strategy, ecological and economic impacts, trade, invasive alien species, interdiction, collective security, Caribbean

INTRODUCTION

Florida, as a neighbor of countries within and adjacent to the Caribbean Sea, has a major stake in the effectiveness of safeguarding throughout this entire region against invasive alien species. I wish to briefly describe the enormous problem that invasive indigenous species pose to the political and ecological community described as the "Caribbean Basin", and to suggest a more strategic approach to addressing it. Whereas invasive species problems tend to be framed and attacked on an individual basis by each political jurisdiction, they impact the entire ecology, social structure, and economy of the region. As such, they would be more effectively attacked with our collective resources, as the collective priority they really are. Herein lies the relevance to the Caribbean Food Crops Society in providing this forum for focusing science and research directed to the prevention, detection, and management of key invasive species threats. This is the key outcome needed from this symposium.

THE FLORIDA PERSPECTIVE

As a member of the Caribbean Basin ecological community, the state of Florida, with its $6 billion agricultural industry, substantial marine and freshwater fisheries, major terrestrial and marine parks, extensive forests and naturalized areas, various unique ecosystems, and 15 million people, is presently faced with a tremendous amount of pressure from unwanted species introductions conveyed by international commerce. Florida receives 80% of all propagative plant material and 70% of all cut flowers imported into the United States. The port of Miami is the third largest cargo port in the world, and it is estimated that over 70 million passengers will pass through Miami by the year 2010. In addition, 70% of passengers traveling between the

United States, the Caribbean, and Latin America pass through Miami. During the past decade, the tonnage of trade through Florida's sea- and airports has been doubling every 5 to 6 years. The number of interceptions of quarantine pests intercepted at Florida's ports-of-entry has been doubling every 4-5 years.

Florida's proximity to the Caribbean makes it especially vulnerable to exotic pest introductions. This high-risk pathway has been confirmed year after year with repeated detections of exotic pests that make their way from the Caribbean islands to Florida's shores. We have witnessed the introduction and establishment of the Diaprepes Weevil, Black Parlatoria Scale, Brown Citrus Aphid, Tomato Yellow Leaf Curl Virus, a Geminivirus complex with associated whiteflies, and variety of thrips, Pink Hibiscus Mealybug, scale insects, and various termites.

We are now facing the imminent introduction of Stellate Scale, and damaging sugarcane and citrus root weevils, Africanized honeybee, Bont tick, Swine fever, Giant African Snail and various invasive plants –to name a few. More invaders are poised to attack the Caribbean ecosystem: Medfly, Carambola Fly, Citrus Greening Disease.

In recent two decades roughly 55% of the harmful alien species that established in Florida were of neotropical origin; about 40% originated in Asia, but established in the Caribbean before entering Florida, and about 5% come from Europe, Africa, and our more northerly states. We are acutely aware that a number of damaging pests have entered the Caribbean region from Florida and other parts of the U.S. Mainland. The key point is that neither Florida nor anyone of Florida's Caribbean neighbors has been able to safeguard completely, or even adequately, against damaging species originating within the region or from as far away as Asia.

ADEQUACY OF CURRENT MEASURES

It is readily apparent that current inspection, detection, and eradication efforts are currently being challenged to address the increasing volume of international trade and associated pests. In managing the repeated outbreaks of exotic pests, Florida has had to incur an enormous financial and social burden, and deal with increasing environmental and public concerns. In addition, the introductions of these damaging pests compromise our efforts in facilitating exports with our trading partners who are equally concerned that these pest species may cause massive ecosystem disruption and other impacts. Florida can be viewed as a beachhead for exotic pest threats to the rest of the U.S., both as a key entryway for imported goods destined to other areas and as a place where non-indigenous species first establish on the continent.

The United States has in place a program funded at over $100 million annually to identify and control the risks associated with international trade. These funds are obtained through user fees assessed to passengers and carriers and must be used for port-of-entry-related activities. This pest exclusion network is neither infallible nor impermeable and some exotic organisms gain entry in spite of our best efforts. To ensure we have the strong, effective, and responsive safeguarding system in the U.S., APHIS asked our State counterparts at the National Plant Board to form a stakeholder team, review the primary components of the safeguarding system and make recommendations for enhancement. In total, 310 recommendations resulted and are currently being addressed. One highly relevant recommendation of special note was that the U.S. safeguarding system should shift primary reliance from port-of-entry inspection to off-shore actions, including risk mitigation in production areas, certification of pest-free status at point of origin, and preclearance at the port of export.

In addition, the system in the Caribbean Basin was addressed at a 1999 Workshop, "Mitigating the Effects of Exotic Pests on Trade and Agriculture," sponsored by the USDA

Tropical and Subtropical Agriculture Research (T-STAR) program and convened by the University of Florida.

Although the workshop's purpose was to identify economic and biological research needs, the Proceedings have been quite valuable in defining strategic problems in the basin that badly need to be addressed. Some of the key issues that emerged:

1. The array of unwanted species is scientifically diverse.
2. The number of successful invasions by unwanted species is increasing, as is the trade that moves them.
3. The impact of individual species affects not only agricultural sustainability, but also public health, environmental diversity, tourism, economic viability, and, in the end, the quality of life of individual citizens.
4. Close linkages between Basin members contribute to rapid spread by successfully invading species.
5. Environmental vulnerability and trade connections define the basin community plagued by this problem as 35 political entities, including the state of Florida.
6. Although there are some excellent examples of strategic, coordinated action on unwanted species problems there are too few, given the known scope of these problems.
7. A diverse array of organizations and institutions are investing considerable resources on various aspects of the problem; however, the strategic direction and coordination of efforts needed to obtain maximum impact on the problem appear to be lacking. Mechanisms to facilitate this coordination have not been up to the task.

Earlier this year CAB International conducted a review of invasive species threats in the basin, under the sponsorship of the Nature Conservancy. The issues emerging during this process appear to be similar to those listed above; however, the CABI review adds great value in validating, analyzing, and defining the many opportunities and barriers to managing these issues more effectively in a deeper, more systematic way.

NATURE OF SAFEGUARDING SYSTEMS

In the context of this discussion, a safeguarding system can be viewed as a set of interdependent, science based actions implemented to manage the risk posed by an unwanted biological agent or group of agents to an acceptable level. The quest to enhance safeguarding systems in the Caribbean could benefit from being addressed in such a systematic way, rather than the current approaches, which appear to be the placement of patches in response to crises, or short term funding opportunities that have no significant strategic impact.

All of our countries have a safeguarding system of some type in place, but the nature and extent of these government programs are driven by political and public policies and priorities, and even cultural considerations of each sovereign nation which dictate:

1. What particular invasive species are the most important;
2. Fiscal and human resource availability;
3. Nature and content of regulatory authorities and mandates;
4. Stakeholder involvement and influence;
5. Availability and focus of science and technology to manage issues;
6. Definition of tolerable levels of risk.

This complex patchwork of factors make addressing the safeguarding of the Basin such a daunting task, and explain why identification of threats, those most important to all, is the key first step to having a strategically sound basin safeguarding plan. This and the quality of scientific knowledge about individual problems is what fuel the 5 components of an effective safeguarding system, namely:

1. Prevention-regulatory restrictions (prohibitions, permits, best management practices, etc.) that reduce risk at the point of origin.
2. Port of entry measures-control at point of arrival of entry risk from passengers, cargo, carriers, and application of appropriate mitigative actions.
3. Detection-formal programs in place focused on early detection of key invaders.
4. Eradication-elimination of introductions where it is technically, economically, socially and environmentally feasible.
5. Management-development and transfer of technology to live with invasive species that cannot be eradicated.

There are many organizations doing high quality work towards enhancing capacities to safeguard the Caribbean basin from unwanted species. The infrastructure discussions cited above identify the need for training, regulatory frameworks, science and research, and information systems that are subjects for this work. Nevertheless, without a commonly accepted set of threat targets, framework for their management, and agreement on the outcomes needed, we may simply be shoring up and patching the system while missing opportunities to achieve the maximum return on the resources invested. Moreover, in some cases we may be falling prey to the paradigm of defining the problem in terms of the particular training, research, or other solutions we individually have to offer. Some examples may illustrate these points.

Citrus greening disease is recognized as a key exotic threat to new world citrus production. Its primary vector has recently been introduced, and has spread to certain Basin members. The most likely pathway of introduction of the pathogen is the inadequately restricted propagative material imports. As was recently reported at the 13th Session of the Intergovernmental Group on Citrus in Havana, Cuba, in May 2003, this disease, along with a number of other exotic agents affecting citrus, needs to be addressed in a regionalized approach that addresses preventive actions at the source (budwood), interdiction and action at time of entry, detection and development of the legal, regulatory, and scientific capacities to manage these agents when they are introduced. From a practical standpoint it is impossible to achieve this on a country-by-country basis.

Exotic fruit flies, as a broad group of pests, have long been recognized for their potential to spread and colonize new ecosystems. Their pathways of entry are passengers, carriers, and inadequately regulated cargo. The carambola fruit fly is one species currently threatening the Region. Introduction of any of these exotic species would thwart economic development initiatives and pose an immediate threat to the entire Region. The significance of this impact warrants a close look at all 5 components of the safeguarding systems in place in each basin member to reduce the potential for introduction, provide for timely detection, and effectively respond to invasion incidents. This major threat cannot be effectively addressed one country at a time, but requires a basin wide approach to protect our mutual interests.

Classical swine fever is a key disease threat to the basin that has been introduced multiple times, and subjected to eradication efforts. It can enter not only with live animals, but also with passenger-carried meat products, and with vessel and air carrier waste that may be fed to swine. It is worth noting that these same pathways move exotic fruit flies and other unwanted species. The basin infrastructure discussions cited earlier describe current inadequacies in the control of carrier waste materials as a major point of weakness.

Eradication programs are difficult, expensive, disruptive and unpleasant, and sometimes they fail. Where the risks are clear, as they are here, a consistent basin-wide strategy would be a good business decision.

TOWARD A REGIONAL STRATEGY

The key step in moving towards a regional strategy is to accept that prevention and point-of-entry interdiction are far from infallible, although empirically they can be demonstrated to have significant impact on the problem. Clearly, if there were no border controls, our problems would be much worse.

The term "Caribbean Basin" has been defined in many ways on political, sociological, and economic bases. However, all of these definitions tend to divide us in managing this problem. When one looks closely at the history of invasive species problems, it is clear that we are joined in our vulnerability to the economic, social, and environmental impact of invasive species. What effects one of us eventually impacts us all. The realities that confront us are:

1. Intense trade, agricultural production, linkages, and geographic proximity facilitate the spread of invasive species within the community.
2. Invasions by highly disruptive organisms of many types appear to be increasing.
3. With some exceptions, individual political entities act independently to exclude, detect, and manage invasive species.
4. Speaking as a public servant, I maintain that it does not appear to be most effective for the public interest to continue addressing these shared threats to our common ecosystems on an individual, country-by-country basis.

Assuring safe trade in a globalized trading environment requires an international coalition. Indeed, what may be needed is development of a Caribbean Basin Safeguarding Strategy that would include the following components:

1. Identify the nature and significance of invasives in the "Basin".
2. Identify key external biological threats to "Basin" ecosystems.
3. Build public and private coalitions around those problems, and implement appropriate actions (preventive, but, if necessary, curative).
4. Establish equivalent risk management and safeguarding systems among "Basin" members.
5. Establish appropriate surveillance strategies for key organisms.
6. Provide enhanced scientific and research support on high priority invasive issues.

The capacity to manage this problem is absolutely dependent on sound science and technology that is transferable to the problem. The above strategy is meant to provide a context that can maximize the possibility of this happening.

The Caribbean Region is fortunate to have in place several regional organizations positioned to provide the leadership for such a strategy to emerge.

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A REGIONAL MECHANISM FOR AGRICULTURAL HEALTH AND FOOD SAFETY IN THE CARIBBEAN

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ABSTRACT: The demands of globalization, commitments under the World Trade Organization (WTO) Agreements on Sanitary and Phytosanitary (SPS) Measures, the Free Trade Area of the Americas (FTAA) and greater public scrutiny of quality and safety of produce are forcing countries to rethink their agricultural health and food safety policies and actions. Agricultural Health and Food Safety (AHFS) must now reflect a broader mandate and an expanded vision building on traditional agricultural health services within the Ministries of Agriculture to include stronger alliances and integration with Ministries of Health, Trade, and External Affairs and adopting a systems approach which involves links with producers, operators of agribusiness and food industries. Actions taken not only, should assure a strong and productive agricultural economy, but also increase trade and competitiveness, improve food safety, promote health, advance food security and tourism, and enhance environment stewardship. AHFS organizations must obtain the confidence of those they serve and that of their trading partners. To obtain this confidence requires the active participation of all parties across the entire agri-food chain. There must be a shared responsibility and coordinated approach on the part of public and private sectors to ensure that all of the stages in the agri-food chain are identified, that decisions are based on scientific criteria, that regulations are consistent with international standards, and that all parties recognize the impact of AHFS policies and actions. In this paper, we discuss a modern national agricultural health and food safety system and suggest an approach to regional cooperation and coordination which will contribute to the Regional discussions.

INTRODUCTION

Agricultural health and food safety (AHFS) programs have in the past been geared towards the protection of domestic production through the prevention of entry of exotic pests and diseases (pests), implementation of emergency actions in the event that these exotic pests enter the country, and the conducting of treatment strategies to control or eradicate already established pests. Overall responsibility for implementing the programs rested on the Government with limited or indirect support from the private sector.

The new trends toward globalization, greater public scrutiny of quality and safety, concern for the environment, and the expanded role of AHFS are forcing countries to rethink their AHFS policies and actions. This paper describes the new environment and its implication to AHFS services. It notes the current status of AHFS institutions in the region and promotes the concept of a modern National AHFS system suggesting an approach to regional cooperation and coordination to add to the ongoing discussions in the region.

THE NEW TRENDS

Developments in international trade brought about by agreements under the World Trade Organization (WTO) aim at facilitating trade. The WTO Agreement on the Application of Sanitary and Phytosanitary (SPS) Measures gives countries the right to protect their human, animal and plant health but in a manner that will not inhibit trade. It also requires that countries base any SPS trade restrictive actions on scientific principles. SPS measures are being discussed at other trade negotiations such as the Free Trade Area of the Americas (FTAA), the Cotonou Agreement between the European Union and Africa, Caribbean, and Pacific Group, and the CARICOM Single Market and Economy (CSME), which seeks to deepen and widen Caribbean Integration.

There is greater scrutiny by the public of the quality and safety of foods for human consumption. Production is geared toward what the market demands rather than toward expecting customers to consume what is produced. Consumer and advocacy groups are seeking for more to be done to protect the environment and minimize the risk to human health from inputs used in agricultural production. Increased recognition is being given to the environmental impact from agricultural practices including pest control methods in plants and animals. Agriculture as a result has to seek and adopt the most environmentally compatible pest control technologies available.

Advances in technologies are also to be noted. The growth in information technology has allowed for greater understanding and precision in conducting risk assessments and making policy decisions when dealing with pests. At the same time, biotechnology promises to increase the quality and quantity of the food supply by reducing the levels of pest damage and residues of chemicals. However, these benefits for health and the environment are being met with uncertainty and doubt as to their long-term adverse effects.

Increasingly demands are being made on the AHFS, but countries are conscious of the need to reduce public expenditure. The private sector is being asked to get involved to reduce that dependence on direct public sector funds. Cost recovery systems are becoming a necessity.

THE IMPORTANCE OF AHFS INSTITUTIONS

The importance of AHFS programs in agricultural production has been well recognized but the impact of effective AHFS programs extends beyond production to other areas such as food security, trade, agricultural competitiveness, tourism, public health, and the environment.

In the area of food security, many of the countries are net importers of food and this is expected to increase as the countries try to meet growing domestic demands. AHFS institutions must be able to facilitate imports to meet domestic demand while not putting domestic production at risk. Trade and AHFS are interdependent. AHFS regulations, standards, and actions should serve to facilitate imports and exports of agricultural goods.

The level of agricultural competitiveness of a country can often be measured by the level of investment in the AHFS institution. A country with a weak AHFS institution will be unable to protect itself and its trading partners. This inability will affect the level of production and the confidence of the trading partners in the produce they receive.

Tourism is also closely linked to AHFS programs. IICA (2003), citing a report by the Caribbean Epidemiological Centre (CAREC) of outbreaks of food borne illness in various Caribbean tourist destinations, indicated that a Salmonella outbreak in a certain Caribbean country in 2000 affected six hotels with temporary closure of one hotel and a threat of United States travel advisory. There are reports that Pink Hibiscus Mealybug was first introduced on the island of Margarita and unknowingly carried by tourists to the South American Continent.

AHFS can also affect public health from problems that can emerge at any point along the production, processing, transportation, and storage stages of the agri-food chain. For example, food borne diseases may occur if produce is washed with microbial contaminated water and then eaten raw. Produce may be harvested with high residue levels of pesticides if the harvest period is not adhered to after the application of a pesticide.

The type of AHFS programs can have an impact on the environment. Pesticides for example, have been known to contaminate ground water. Organisms which were not considered pests can achieve pest status when the natural enemies are killed by the indiscriminate use of chemicals.

STATUS OF AHFS INSTITUTIONS IN THE CARIBBEAN

IICA (2002) reported on various studies (IICA Surveys in 1997 and 2000 and USAID/CARICOM Study 1999/2000) conducted to assess the status of compliance of the national AHFS systems with the WTO Agreements on SPS Measures in the Caribbean. The studies focused on the following:

a) Capabilities and capacities of national AHFS delivery systems.
b) Capabilities and capacities to identify and respond to emergencies and emerging issues.
c) Agricultural health and food safety legislative framework in compliance with international standards.

The report (IICA, 2002) concluded that the assessment of the countries' AHFS showed a fairly good level of effort in all three areas of human, animal or plant health, but in general programs are not all up-to-date with international standards. In order to conform with and benefit from international standards, AHFS institutions must be modernized. This modernization will require making fundamental changes in these institutions and enhancing their capacity and capabilities in AHFS. Unless changes are made, the outcome of poorly performing AHFS programs as measured in terms of loss of market opportunities and adverse effects on the animal, plant, and human health of the countries will increase.

A MODERN NATIONAL AHFS SYSTEM

Traditionally, AHFS Programs have been focused only at the national level. The objectives have been to protect domestic agriculture with resources being channeled into controlling pests that could adversely affect primary production. AHFS programs were evaluated on the basis of the efficiency of its inspection, surveillance, and emergency response to unexpected entry.

It has been recognized that this traditional approach is not always sufficient to meet today's challenges. It has been shown that problems manifested at the consumer level can be traced back further down in the agri-food chain. Programs are developed and implemented that go beyond the farm level to encompass the entire agri-food chain. Therefore, AHFS institutions must operate with an expanded international vision and broader mandate. The traditional agricultural health institution within the Ministry of Agriculture must be restructured to include stronger alliances with the ministries of health, trade, environment, and foreign affairs. The private sector must join forces with the public sector to define complimentary roles for which each has specific responsibilities in order to enhance AHFS.

The members of a modern National AHFS System are the Ministries of Agriculture, Health, Environment, Trade, and official services of other Government Agencies responsible for decision making, provision of services, and verification and certification in matters related to plan and animal health and food safety; the associations of producers, agribusiness operators, chemists, veterinarians, agronomists, and other related professionals; public and private sector laboratories which diagnose pests, conduct analyses for residues and verify and certify agricultural chemicals, veterinary products, animal feed, and conduct microbiological and toxicological analyses of agricultural products; laboratories for quality control of agricultural products; agricultural input suppliers and service providers and importers and exporters of agricultural products.

ESTABLISHMENT OF A MODERN NATIONAL AHFS SYSTEM

Establishing a modern national AHFS system begins with the articulation of the complementary roles of the public and private sectors. There must be a coordinated approach as success or failure of the AHFS programs is a shared responsibility. There are certain public sector roles that cannot be delegated and have to be kept by the respective Ministries of Agriculture, Health, and Trade. These non-delegated roles include establishing laws and standards based on international legislation; overseeing and ensuring compliance by applying sanctions in cases of non-compliance; and actively negotiating in the country's best interest within the relevant international organization and standard setting fora.

The delegated roles can be played by producers, agribusiness operators, professionals, universities, and private laboratories. Capabilities of other national institutions can be used as needed as well as those of universities and institutions of other countries through alliances or cooperative agreements with a view of enhancing existing capabilities. A national advisory council consisting of representatives of the private and public sectors involved in AHFS at the national level should be established. Additionally, advisory committees on animal health, plant health, pesticide control, and food safety involving representatives of the participating institutions and the private sector should be formed and serve as a forum for discussions and planning on various issues related to AHFS. Other national sub committees may be established as necessary. At the local district level, it may be necessary to establish district committees involving representatives of associations of producers and local government personnel for funding and execution of AHFS programs in the area. The public should be informed of SPS measures through the national enquiry points. Training programs should be implemented for producers and other persons who could be accredited to carry out the functions.

Financial support to AHFS institution must focus not only on building technical capacity but also on strengthening regulatory mechanisms and institution sustainability. Therefore self-financing mechanisms must be established for the operations of the animal health, plant protection, and food safety services. Technical assistance must be planned within the countries and areas and based on their determined priorities. The contents of training programs and the approaches used in providing training and technical assistance must be jointly evaluated and the products and delivery methods modified accordingly. Technical cooperation agencies must make a concerted effort to work together.

THE REGIONAL MECHANISM

There is no doubt that not all the technical expertise, information, laboratories, and other necessary facilities can be found in one country but it is possible to draw on the required expertise and facilities in other countries. This calls for effective cooperation and efficient coordination.

Structure. The structure proposed consists of four separate regional committees (plant health, pesticide control, animal health, and food safety). Membership of each of these committees should comprise the Chairmen of the National Committee for plant health, pesticides control, animal health, and food safety. There will be annual meetings of each of the Committees rotated among the countries. The Chairman of the host country's Committee will serve as Executive Chairman for one year or the duration of the period between annual meetings.

Meetings of Special Regional Sub-Committees or networks within a Regional Committee may be convened as necessary.

Countries will be responsible for funding their participation in the annual meetings. Regional organizations, agencies, and regional private sector interests will be invited to participate in the meetings.

Coordination of Committees can take place through a Coordinating Secretariat consisting of a professional for the four Regional Committees housed in an existing regional organization or agency and funded by that body and others in the short-term. The person is a member of staff of the organization or agency, and the Secretariat forms a part of the duties. Alternatively, the Secretariat can consist of a professional for each Regional Committee who is a member of staff of a regional organization or agency, and the Secretariat is part of the duties. Funding in the short-term will be from the organization or other agencies. In both cases in the long-term, the countries would be expected to fund the Secretariat.

Function. The Regional Committees should be a mechanism of collaboration and cooperation among the National AHFS systems to promote a common understanding through sharing of information, resources, technology, and expertise. There should be good communication among the countries, the Secretariat and regional and international organizations. There should be a harmonized system of technical procedures, information, and exchange legislation. Some functions may be discrete and will have specific life phases. Some of these functions include:

- Training, education, and public awareness
- Coordination of resources, networking
- Development of projects for funding
- Interfacing with regional and international organizations
- Any other activity that may be approved

Financing. Financing should be through contributions from technical agencies and other corporate groups in the short run, but in the long run funding should be from the various countries. This finance should be from contributions and payments for services. Additionally, the secretariat will develop specific projects for which funding will be sought. The necessary mandate should be given to accept funds and gifts from accredited donors including private sector organizations to assist in execution of functions.

CONCLUSION

Effective AHFS programs are important to the level of agricultural economic growth of a country. As countries are heavily dependent on agriculture, it is necessary to build and sustain efficient and effective AHFS institutions to achieve prosperity. The scope and operation of AHFS institutions and the risks and rewards to a country as a result of globalization, are much greater than before. A concerted effort at collaboration between the public and private sector together with assistance of financial agencies and technical cooperation agencies will enable countries to take advantage of the opportunities not realized before. An AHFS system must earn the confidence of its citizens and its trading partners through its policies and the actions taken. Strong AHFS Systems will guide the Regional Mechanism.

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A PEER REVIEWED PAPER

DANGEROUS INVASIVE SPECIES THREATENING OR WITH A FOOTHOLD IN THE CARIBBEAN

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ABSTRACT: In recent years, a spate of dangerous invasive alien species (IAS) have become established in the Caribbean, and many others threaten the region. Some established species continue to spread, causing economic and environmental damage. This paper reviews the status and significance of IAS in the Caribbean. Factors contributing to the upsurge of new problems and pathways are discussed from a perspective of prevention. Steps recently taken to prevent or mitigate the impact of these species are also discussed. On the basis of these experiences, suggestions are made for the future direction of efforts to prevent or manage such invasive species within the Caribbean context.

KEY WORDS: Invasive alien species, Caribbean

INTRODUCTION

Globalization of trade, transport, and travel during the last century has led to an unprecedented movement of species, intentionally and unintentionally, across natural biogeographical barriers. For instance, based on estimates by Holt (1996, cited in Wittenberg and Cock, 2001), one new alien invertebrate becomes established in Hawaii every 18 days compared to the estimated natural rate of one every 25-100,000 years. Such accelerated movement of species is not without consequences, especially when they become invasive; that is, when they become established and spread, causing economic or environmental damage, or posing a risk to human health.

The damage caused by such invasive alien species (IAS) (referred to as exotic pests in most agricultural literature) to agricultural production has long been recognized. Beyond agriculture, however, it is only in the last few decades that the threats posed by IAS to the environment have become increasingly recognized. These threats include loss of biodiversity and interference with ecosystem processes and services. The 1992 United Nations Convention on Biological Diversity recognized these threats, and called on signatory nations to 'prevent the introduction of, control or eradicate those alien species which threaten ecosystems, habitats or species' (Article 8h).

The Caribbean has not been immune to IAS. Indeed, their incidence has increased considerably in recent years. The growing importance of IAS has been acknowledged in several recent regional meetings (e.g., Klassen, 1999; Hernandez et al., 2002) including the present one. Furthermore, it is known that evolutionarily and/or geographically isolated ecosystems, such as the islands of the Caribbean, are particularly vulnerable to the negative impacts of IAS. Against this background, this paper gives an account of IAS in the Caribbean. Specific attention is given to the broader nature of the IAS problem, particularly environmental effects, vulnerability of the region, scope of the problem, and measures to address the problem. Examples of invertebrate IAS in agriculture are used as case studies.

Invasive alien species and Caribbean biodiversity. Caribbean islands support many rare, declining and threatened species, across a range of taxa, as do the surrounding seas. Mittermeier et al. (2000) and Myers et al. (2000) recognize the wider Caribbean as one of the world's biodiversity "hotspots," supporting some 7000 species of endemic plants and 779 endemic vertebrates. Invertebrate endemism is also extensive but is relatively poorly documented. Thus, it is not surprising that Caribbean habitats are of international importance for their biodiversity and conservation value. Direct removal for instance through hunting, habitat destruction, and IAS impact have resulted in rapid species extinctions on islands. While these mechanisms often act in combination, on many islands, introduction of IAS is the most important factor in the loss of indigenous biodiversity (Whittaker, 1998). Experimental work in the Caribbean has demonstrated that invertebrates, as well as plants and vertebrates, are vulnerable to the impact of IAS (Schoener and Spiller, 1996).

Why the Caribbean is vulnerable to IAS? Several ecological as well as human-derived factors serve to increase the vulnerability of the insular Caribbean. Many of the biological characteristics that make islands special, and of substantial conservation value, also render them particularly vulnerable to the establishment and impact of invasive species (Cronk and Fuller, 1995; D'Antonio and Dudley, 1995). The relative paucity of indigenous species per unit area, for instance, provides greater vacant niche space and less competition for potential invaders than would be found on the mainland, and small size of indigenous island populations renders them prone to extinction. Additionally, evolution of island species in isolation leads, for example, to loss of defensive behaviors and consequent vulnerability to introduced predators. A single non-native species can drive numerous indigenous species to extinction, as witnessed by the effects of introduction of the brown tree snake, *Boiga irregularis* (Merrem) into Guam, or the invasive shrub, *Miconia calve*scens Schrank & Mart. ex DC to Tahiti (Whittaker, 1998).

The vulnerability of the Caribbean is exacerbated further by the wide range of deliberate or accidental pathways for species introductions (Table 1). Growing numbers of tourists, as well as high volumes of traded commodities, are among the most important of these. Many of the island nations have inadequate capacity for implementing preventative measures, further increasing the risk of potential IAS introductions. Close cultural and economic ties also mean that (once established) an IAS is likely to move rapidly through the insular Caribbean and may subsequently threaten North, South, and Central America. The converse is also true, IAS established in Florida, for example, are relatively likely to spread into and through the Caribbean. These facts are well illustrated by the recent spread of the pink hibiscus mealybug, *Maconellicoccus hirsutus* (Green) through the Caribbean Basin (Figure 1). Sugarcane smut and sugarcane rust spread through much of the Caribbean Basin over periods of less than six years during the 1970-80s provide further examples (Shaw, 1982).

Quantifying the IAS problem in the Caribbean. Few efforts have attempted to document the wide range of IAS affecting or threatening the Caribbean. Cock (1985) discusses a range of IAS from the perspective of management, while Pollard (1986) developed a list of major pests of quarantine importance. Hernandez et al. (2002) noted that an inventory of IAS present in and/or threatening the region was lacking. Whereas problems in agriculture surface very quickly, especially when they constrain production or negatively affect trade, IAS impact on the environment is not so obvious. Thus, an important starting point for the development of efforts to deal with IAS is an inventory and specification of the problems.

Towards this end, CAB International and The Nature Conservancy are developing a database of IAS as part of an effort to capture as much information as possible on established IAS within the insular Caribbean. The information in the database is arranged by species, each entry comprising a number of fields as listed in Box 1.

Box 1. The key elements of the invasive alien species database.

• Identity - species name, synonyms, and common names by country.
• Type of organism - plant, bird, mammal, etc.
• Broad natural community type affected - terrestrial, marine or freshwater.
• Distribution - native distribution and non-native distribution in the Caribbean including information on non-native distribution in Caribbean below country level.
• Entry pathways - means of spread (e.g., contaminants in agricultural produce).
• Dates of introduction by country.
• Caribbean countries where each species is present as an exotic, or naturalized and invasive.
• Factors contributing to spread.
• Habitats at risk.
• Impact in different locations.
• Key aspects of species biology.
• Information on risk assessments.
• Agencies involved.
• Programs targeted at each species.
• Approaches to management.
• Any other relevant information.

An initial report from the database lists a total of 552 alien species in the insular Caribbean region (Kairo et al., 2003a). Most occupy terrestrial habitats, with fewer species reported from freshwater and marine environments (Table 2). It is clear, however, that there are serious gaps in our knowledge of these aquatic ecosystems. It should be noted that this is work in progress, and as information is gathered the total number of alien species recorded in the database is likely to more than double. Of the 552 alien species initially reported, 75% were regarded as naturalized (established in the wild) and/or invasive (established, spreading, and constituting a biological, environmental or socio-economic threat). The remaining 25% were known to be present, but had not been reported as naturalized or invasive in any of the territories in the region. Knowledge of the ecological and economic impact of those species identified as invasive is largely lacking. Such information will be useful in the development of priorities for action.

Genesis and spread of recent invertebrate IAS problems in agriculture. Table 3 gives some examples of non-native invertebrates, which have emerged as serious pests in Caribbean agriculture during the last decade. The majority originated from the Old World, but there are also examples from the New World. Some of the species are strictly pests affecting agricultural production, such as the citrus blackfly, *Aleurocanthus woglumi* Ashby. However, a few have had a wider ranging impact, including effects on natural environments, such as *M. hirsutus*.

An appraisal of the pattern of emergence of the various IAS problems reveals a number of important trends:

- New IAS can become established and spread rapidly across the region.
- Some long-established alien species with limited distribution can quickly extend their distribution.
- Some long-established alien species continue to expand their ranges only gradually.

There are several examples of new IAS, which have become established and spread rapidly across the region, for instance *M. hirsutus*. Since its first appearance in the Caribbean in 1994, the insect has now spread throughout most of the region (Figure 1). Of greater concern is the fact that, despite specific and heightened preventative measures, the pest continued to spread. The spread of *Thrips palmi* Karny and *Bemisia tabaci* (Gennadius) (B biotype) during the 1980-90s, and that of *Phyllocnistis citrella* Stainton during the 1990s, are other examples. The high populations during the explosive invasion phase may have contributed to the rapid rate of spread.

Also during the last decade, several IAS, which have been present in the region for a long time, have extended their ranges in a similarly dramatic pattern. The most notable are *A. woglumi* and the imported red fire ant, *Solenopsis invicta* Buren. *A. woglumi,* which is native to Asia, first appeared in the Caribbean in the early part of the last century, and then spread to the mainland and effectively controlled by using classical biological control. During the mid-1990s, the pest re-emerged as a serious problem in Dominica. Although recorded there as early as 1969, it had never been observed as a serious pest, and there are no records to indicate that specific control measures were undertaken at the time. While it is possible that natural enemies were fortuitously introduced with it, there are no adequate explanations why, 30 years later, very damaging populations have built up. Since its emergence as a serious pest in Dominica, recent years have seen *A. woglumi* extend its range to several other countries, including Trinidad & Tobago and St Kitts & Nevis.

S. invicta is native to South America and has been present in the United States since the early part of the last century. Despite its close proximity to the region, it is only in the last two decades that this insect has rapidly extended its range to many islands in the Caribbean (Davis et al., 2001). In contrast, the spread of the coffee berry borer, *Hypothenemus hampei* Ferrari through the region has happened only gradually.

Whereas many of the most serious pests of Caribbean agriculture have their origins in Asia or Africa, a number originate from within the western hemisphere. Examples include papaya mealybug, *Paracoccus marginatus* Williams and Granara de Willink and coconut whitefly, *Aleurodicus pulvinatus* Maskell, as well as *S. invicta. P. marginatus* is probably native to Mexico or Central America (Miller and Miller, 2002). It was not recorded from the Caribbean islands before 1994, but has been extending its range in the region. *A. pulvinatus* is widely distributed in warmer parts of the New World, and has been reported as a serious pest in Nevis (Martin and Watson, 1998).

Dealing with IAS. These examples emphasize the regional nature of many IAS problems and, therefore, the need for concerted cooperative efforts if effective counter measures are to be developed and implemented. Many previous efforts to deal with IAS have been reactive, but a more comprehensive approach is now required.

At the global level, there are more than 40 international instruments that deal with some aspect of IAS. These include the Convention on Biological Diversity, World Trade Organization Sanitary and Phytosanitary Standards Agreement, and The International Plant Protection Convention. While these provide an international framework for action and cooperation, many countries have not developed coordinated policies and strategies to address IAS problems. Even where countries are willing to take action, efforts have often been hampered by insufficient technological, scientific, and financial resources. Recognizing that ecosystem boundaries have nothing to do with political borders, greater cooperation at both the regional and international levels is necessary. McNeely et al. (2001) provided an overview of a global strategy to deal with IAS, while Sherley (2001) gives an example of a regional strategy adopted by the Pacific Islands. These publications provide a good starting point for the development of a strategy for the Caribbean. At the technical level, Wittenberg and Cock (2001) provide a generalized account of tools and approaches for dealing with IAS. They identify four key steps: prevention, early detection, eradication, and control.

Prevention and early detection. In tackling IAS, eradication attempts are likely to succeed only if they are applied at an early stage, or on sites that can be relatively well protected against reinvasion. Prevention, rather than control, is likely to be more cost-efficient and effective. Some of the measures, which need to be adopted, include effective public awareness and outreach, rigorous implementation of risk assessments, and appropriate screening of imported commodities. Adoption and enforcement of national and international regulations will be essential. Effective technologies to allow early detection of many potential IAS are still lacking. Additionally, the dearth of taxonomic expertise has to be addressed. Public awareness and a high state of alert certainly contributed to the early detection of *M. hirsutus* in most Caribbean countries, enabling timely implementation of control measures. These actions saved many countries from the levels of damage seen earlier in Grenada, and probably reduced the rate of spread of the pest.

Eradication efforts. Islands, by virtue of the strong dispersal barrier that the surrounding ocean represents, are relatively promising sites for IAS eradication attempts. Details of many such projects on islands are given in Veitch and Clout (2002). There have been several eradication projects in the Caribbean, and one current example targets the tropical bont tick (TBT), *Amblyomma variegatum*. This species was first introduced from Senegal into Guadeloupe in 1828. During ensuing years, the tick became a serious constraint to livestock production in the Caribbean, and now threatens North and South America. The Caribbean Amblyomma Program was initiated in 1995 to eradicate the tick from all infested islands (Pegram et al., 2002). The program is ongoing and several of the infested islands have been declared provisionally free of TBT. While progress has been made on individual islands, it is clear that the regional effort must be maintained to ensure that TBT is eradicated from the Caribbean as a whole, especially as the vector (the cattle egret) moves freely between islands. This program has highlighted the importance of concerted regional action, and it is clear that long-term commitment is required if eradication is to succeed. Other potential targets for eradication programs in the region include various fruit fly pests and the giant African snail.

Control of IAS. Inevitably, some IAS will escape early detection, and eradication attempts might not be feasible. A range of control measures is available, including chemical, mechanical, and biological means, as well as habitat management or the integration of various approaches. Biological control is a very attractive technique for the management of species invasions, providing a potentially low-cost, self-sustaining mechanism for controlling populations of damaging non-native species. However, to many people it is counter-intuitive to fight an invasion by one exotic species by introducing yet more non-native biodiversity.

Concerns are exacerbated by the damage caused by a number of early attempts at biological control. Coblentz (1998) cites a widely-known example: The small Indian mongoose, *Herpestes javanicus*, which was released on many islands, in order to control rats in fields of sugar cane, and is now found on many Caribbean islands, Hawaii, and Fiji. Rats are nocturnal, but had become active in cane fields during the day in the absence of any significant predators. The mongoose is a diurnal predator, and following its arrival rats simply reverted to a nocturnal habit, leaving the mongoose to feed on indigenous (often endemic) small vertebrates and invertebrates, and in some cases on the eggs and young of nesting sea turtles (Coblentz, 1998). Rigorous screening for potential impacts on non-target organisms is clearly an essential part of any responsible current biological control program in the modern age (Thomas and Willis, 1998), and international guidelines are now available (FAO, 1996; Kairo et al., 2003b).

The recent regional efforts against *M. hirsutus* serve to emphasize the usefulness of biological control against IAS. This pest first appeared in the region in 1984 in Grenada (Kairo et al., 2000). Rapidly, it spread across countries in the Caribbean Basin, including some localized infestations in northern South America, Central America, and North America (Florida and California). Within the insular Caribbean, Cuba and Jamaica are the only major islands, which are still free of the pest. Its spread has clearly demonstrated the difficulty of containing pests within individual countries. However, throughout the region, this pest has been effectively managed through the introduction of natural enemies, principally, *Anagyrus kamali*, *Cryptolaemus montrouzieri*, and *Gyranusoidea indica*. The biological control efforts largely followed the international guidelines set out in the Code of Conduct for the Import and Release of Exotic Biological Control Agents (FAO, 1996). Success was the result of concerted cooperative efforts between national, regional, and international institutions. Furthermore, once developed, the technology was easily transferable to new countries as they became infested.

Predicting IAS threats in the Caribbean. It would be desirable to be able to predict IAS threatening the region. Some information can be surmised from distributional data on known problem species. For example, Watson and Chandler (1999) discuss potential mealybug IAS threats from a global perspective, and at the regional level, for species with limited distributions. From an agricultural standpoint, it is unfortunate that there is no reliable list of quarantine pests for the Caribbean. Pollard (1986) attempted to develop a list of the most important pests, but this clearly needs updating. The Caribbean Plant Health Information Network (CARAPHIN) database compiles reports from national programs, but this is not comprehensive. There are even fewer information resources that relate to actual and potential IAS whose principal threat is to the environment (and indigenous biodiversity) rather than agriculture. Efforts are therefore required to develop comprehensive inventories, as well as lists of key potential problem species, in relation to agriculture and the wider environment if predictive tools are to be developed.

CONCLUSIONS

Prevention and control measures are clearly critical to the effective management of IAS threats. However, efforts to develop management strategies require the collation and on-going management of relevant data so that informed decisions can be made. The development of predictive tools requires similar investment in information gathering and analysis. At the national and regional levels, knowledge of the ecological and economic impacts of IAS in the Caribbean is still less than adequate. Indeed, there is a lamentable absence of national or regional pools of information.

Kairo et al. (2003a) provides the first concerted attempt at data gathering on IAS threats in the Caribbean. It is intended that this database should be further developed as the foundation for a regional information resource. There is also good scope for capitalizing on other regional or hemispheric initiatives, for instance the Inter-American Biodiversity Network (http://iabin.ucdavis.edu/index_eng.html), and the US Federal and State Invasive species activities and programs (http://www.invasivespecies.gov/geog/nrthamerica.shtml). Clearly, such efforts will need to be coordinated, as far as possible, to enhance complementary effort and to avoid duplication.

Awareness of the importance of invasive species issues among policy-makers and other stakeholders also needs to be raised. All levels of society need to be made more aware of the importance of the issue, in order that political will to address the problem is generated. At the political level, one of the most useful areas to emphasize will be the benefit of increasing integration between agricultural and environmental sectors. This would serve many aspects of the wider sustainable development agenda, as well as supporting concerted efforts against IAS threats.

Sharing of experience will also be vital, to minimize duplication of effort, enhance co-operation and increase the speed with which effective strategies can be developed and implemented. An informal electronic network, in which resides vast knowledge in all areas of invasive species, has been formed by experts and practitioners from within and outside the region as part of the project described by Kairo et al. (2003a). Such networks provide a means for information gathering and exchange and need to be maintained and enhanced to maximize the benefits of sharing experience in this rapidly developing field.

Invasive species problems are complex and on the increase. Ad hoc reactive interventions no longer provide effective solutions. A coordinated, multi-stakeholder (national, regional, and international) cross-sectoral effort is required.

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Table 1. Examples of pathways for the introduction of IAS (adapted from Wittenberg and Cock, 2001).

Accidental introductions	Deliberate introductions
1. Contaminants in traded commodities including industrial equipment. 2. Hitch-hikers in other consignments including passenger baggage. 3. Ballast material from ships. 4. Hull fouling. 5. Escaped pets, or other captive species.	1. Plants introduced for agriculture/forestry. 2. Animals introduced as livestock or for sport. 3. Ornamental plants. 4. Other aesthetic introductions. 5. Biological control.

Table 2. Broad categorization of alien species by broad habitat type (adapted from Kairo et al., 2003).

Broad habitat type	Exotic	Naturalized and/or invasive*
Terrestrial	479	390 (81%)
Marine	18	16 (89%)
Fresh water	55	10 (18%)
Total	552	416 (75%)

*Naturalized and/or invasive as a percentage of all alien species in each category

Figure 1. Spread of the pink hibiscus mealybug, *Maconellicoccus hirsutus,* in the Caribbean shown as new islands infested each year.

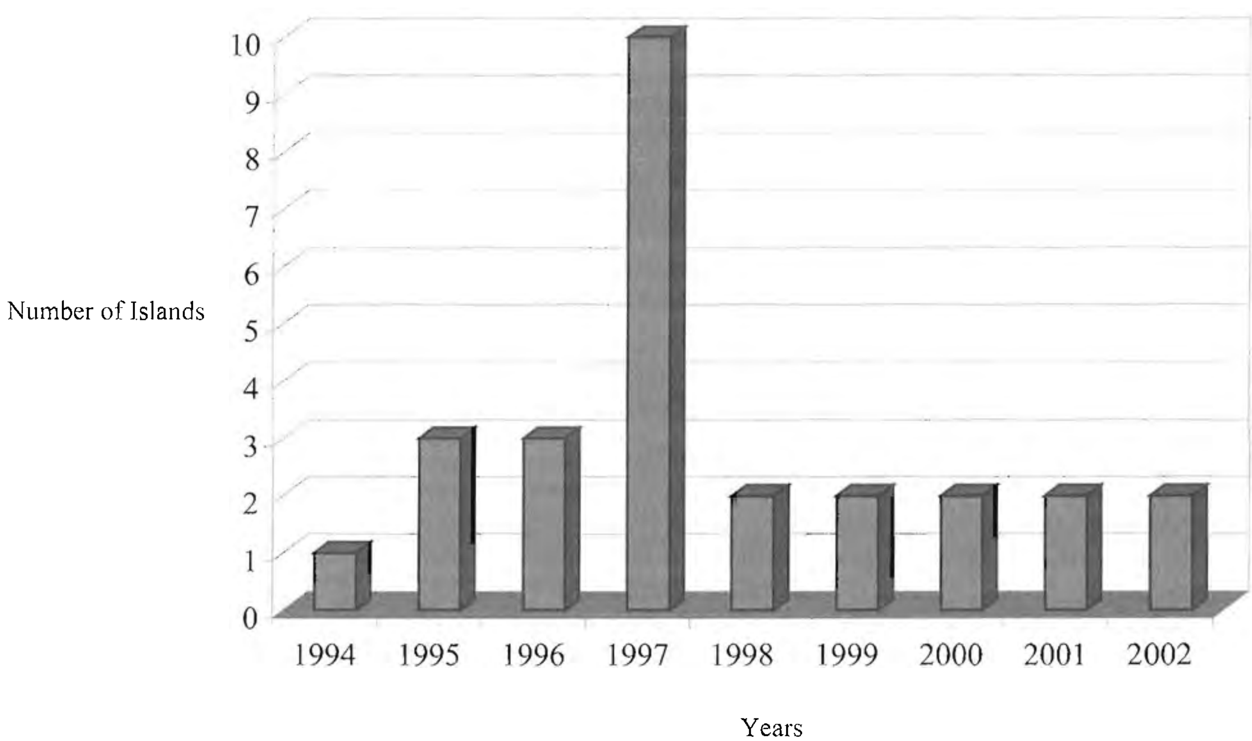

Table 3. Agricultural invertebrate IAS problems which have become introduced or expanded their range in the Caribbean since 1990 (distribution data based on CABI-CPC, 2003 unless otherwise stated).

Genus species	Family	Origin	Year*	Notes on distribution in countries bordering the Caribbean Sea
Aleurocanthus woglumi Ashby	Aleyrodidae	Asia	1913	Antigua and Barbuda, Bahamas, Barbados, Belize, Bermuda, British Virgin Islands, Cayman Islands, Colombia, Costa Rica, Cuba, Dominica, Dominican Republic, Ecuador, El Salvador, French Guiana, Guatemala, Guyana, Haiti, Jamaica, Mexico, Netherlands Antilles, Nicaragua, Panama, Puerto Rico, Saint Kitts and Nevis, Saint Lucia, Suriname, Trinidad and Tobago, USA, Venezuela (Serious problem in Dominica in the mid 1990s. Expanded its distribution to include, St Kitts and Nevis, Trinidad and Tobago)
Aleurodicus pulvinatus (Maskell)	Aleyrodidae	Neotropical		Belize, Bolivia, Brazil, Colombia, Costa Rica, Ecuador, El Salvador, Guyana, Honduras, Mexico, Nicaragua, Panama, Saint Kitts and Nevis, Suriname, Trinidad and Tobago, Venezuela (Currently extending its range.)
Toxoptera citricidus (Kirkaldy)	Aphididae	Asia	1985-86	Antigua and Barbuda, Aruba, Belize, Bermuda, Brazil, British Virgin Islands, Cayman Islands, Colombia, Costa Rica, Cuba, Dominica, Dominican Republic, Ecuador, French Guiana, Grenada, Guadeloupe, Guyana, Haiti, Honduras, Jamaica, Martinique, Mexico, Netherlands Antilles, Nicaragua, Panama, Puerto Rico, Saint Kitts and Nevis, Saint Lucia, Saint Vincent and the Grenadines, Suriname, Trinidad and Tobago, USA, Venezuela
Achatina fulica Bowdich	Archatinidae	Africa	1989	Present in Barbados, Brazil, Guadeloupe, Martinique and Saint Lucia. Eradicated in Florida by 1975 after having been introduced in 1966.
Sternochetus mangiferae (Fabricius	Curculionidae	Asia	1984	Barbados, British Virgin Islands, Dominica, French Guiana, Grenada, Guadeloupe, Martinique, Montserrat, Saint Lucia, Saint Vincent and the Grenadines, Trinidad and Tobago, United States Virgin Islands
Solenopsis invicta Buren	Formicidae	South American	1918	Antigua and Barbuda, Bahamas, British Virgin Islands, Florida, Turks and Caicos, United States Virgin Islands, Trinidad and Tobago, Venezuela (Still expanding its range with many new islands becoming infested in last 10 years (Davies et al., 2001))
Phyllocnistis citrella Stainton	Gracillariidae	Asia	1993	Antigua and Barbuda, Bahamas, Barbados, Belize, Bermuda, Brazil, British Virgin Islands, Cayman Islands, Chile, Colombia, Costa Rica, Cuba: present, Dominica, Dominican Republic, French Guiana, Grenada, Guyana, Honduras, Jamaica, Martinique, Mexico, Netherlands Antilles, Nicaragua, Panama, Puerto Rico, Saint Kitts and Nevis, Saint Lucia, Trinidad and Tobago, USA
Amblyomma variegatum (Fabricius)	Ixodidae	Africa	1828	Anguilla, Antigua and Barbuda, Barbados, Dominica, Guadeloupe, Martinique, Marie Galante, Montserrat, Saint Kitts and Nevis, Saint Martin, Saint Vincent (Barre et al., 1995)
Maconellicoccus hirsutus (Green)	Pseudococcidae	Asia	1994	Anguilla, Antigua and Barbuda, Aruba, Bahamas, Barbados, Belize, British Virgin Islands, Curacao, Dominica, Dominican Republic, French Guiana,

				Grenada, Guadeloupe, Guatemala, Guyana, Haiti, Jamaica, Martinique, Montserrat, Puerto Rico, Saint Kitts and Nevis, Saint Lucia, Saint Vincent and the Grenadines, St. Martin, Suriname, Trinidad and Tobago, United States Virgin Islands, Venezuela
Paracoccus marginatus Williams & Granara de Willink	Pseudococcidae	Mexico or Central America	1995	Antigua and Barbuda, Barbados, Belize, British Virgin Islands, Cayman Islands, Costa Rica, Cuba, Dominican Republic, French Guiana, Grenada, Guadeloupe, Guatemala, Haiti, Montserrat, Netherlands Antilles, Puerto Rico, Saint Kitts and Nevis, St. Martin, USA (Florida and Montana), United States Virgin Islands
Hypothenemus hampei Ferrari	Scolytidae	Africa		Brazil, Colombia, Costa Rica, Cuba, Dominican Republic, Ecuador, El Salvador, Guatemala, Haiti, Honduras, Jamaica, Mexico, Nicaragua, Puerto Rico, Suriname
Stenotarsonemus spinki Smiley	Tarsonemidae	Asia	1990s	Central America, Colombia, Cuba, Dominican Republic – potential to increase its range
Anastrepha obliqua (Macquart)	Tephritidae	Tropical Americas		Bahamas, Barbados, Belize, Bermuda, Brazil, British Virgin Islands, Chile, Colombia, Costa Rica, Cuba, Dominica, Dominican Republic, Ecuador, Grenada, Guadeloupe, Guatemala, Guyana, Haiti, Honduras, Jamaica, Martinique, Mexico, Montserrat, Nicaragua, Panama, Puerto Rico, Saint Kitts and Nevis, Saint Lucia, Suriname, Trinidad and Tobago, United States Virgin Islands, Venezuela (In recent years it has expanded its range to Barbados, and Grenada.)
Bactrocera carambolae Drew & Hancock	Tephritidae	South East Asia	1975	Brazil, French Guiana, Guyana and Suriname. This pest is the target of an eradication program.
Thrips palmi Karny	Thripidae	Asia	1985	Antigua and Barbuda, Bahamas, Barbados, Bermuda, Brazil, British Virgin Islands, Colombia, Cuba, Dominica, Dominican Republic, French Guiana, Grenada, Guadeloupe, Guyana, Haiti, Jamaica, Martinique, Netherlands Antilles, Puerto Rico, Saint Kitts and Nevis, Saint Lucia, Saint Vincent and the Grenadines, Suriname, Trinidad and Tobago, USA, Venezuela countries

*First reported in the region

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STRATEGIES FOR PEST SURVEY: TARGETS, METHODOLOGIES, AND DIAGNOSTICS

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ABSTRACT: USDA, APHIS, Plant Protection and Quarantine (PPQ) conducts cooperative nationwide surveys for invasive species. The PPQ Center for Plant Health, Science, and Technology maximizes the survey element of the safeguarding continuum by applying the best available science. For example, predictive modeling projects direct pest surveys to areas of greatest risk. Spatial analysis technologies provide managers with powerful new survey tools. Survey methodologies blend emerging technologies from other disciplines with more traditional trapping programs. Pest identification is enhanced through molecular diagnostics and LUCID software keys. This application of science-based strategies, optimizes the possibility of early detection and identification of invasive species, and contributes to an overall more successful safeguarding program.

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THE U.S. SOUTHERN REGION ANIMAL DISEASE AND PEST SURVEILLANCE AND DETECTION NETWORK AND ITS POSSIBLE EXTENSION INTO THE CARIBBEAN AND LATIN AMERICA

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Our agriculture and natural resources are highly vulnerable to attack (whether intentional or accidental) by pests and pathogens because of large acreages, the use of monocultures, and global movement or travel. In 2002, funds were appropriated for Emergency Supplement for Recovery and Response to Terrorist Attacks on the United States. The National Plant Diagnostic Network (NPDN) has designated five plant and animal centers in the United States on the basis of their common agriculture.

Our mission for the southern plant diagnostic network (SPDN) is to promote the health and security of plants by intercepting, preventing, and managing plant diseases and pests that could threaten our agriculture. The Regional Diagnostic Networks will seek to accomplish their missions by working with partners throughout the U.S. to:

(a) enhance diagnostic capabilities and establish a secure, regional network for the detection and diagnosis of plant health problems, and better track the health of crops and/or the spread of pests;
(b) extend and support sound public policies, implement rapid and accurate diagnoses; and
(c) provide leadership and training to key stakeholders, county faculty, and farmers.

This network can enhance the task of safeguarding against harmful exotic organisms through digital diagnostics utilizing a web-based system.

The Distance Diagnostic and Identification System (DDIS) for Extension was developed jointly by extension agents, specialists, and the faculty of UF/IFAS Information Technologies (http://ddis.ifas.ufl.edu/). This system allows users to submit digital samples obtained in the field for rapid diagnosis and identification of pests, plants, diseases, insects, and animals. DDIS provides an environment for agricultural extension agents and specialists to share information on plant insects and diseases.

Through interactions on the Internet, problems can be quickly communicated and assessed. Specialists can perform diagnosis and identification to provide best management practice recommendations to the users and determine quick response strategies. The system creates a digital image library with associated site, crop, and pest or disorder data that could be used in educational programs to assist diagnosis. Efforts are also underway in the southern region to connect all state universities and agriculture labs through a secure computer network and to link to all experts in their fields for these purposes.

To date, all diagnostic clinics in the 12 states of the SPDN, with the University of Florida as the coordinator, are connected, and are transmitting diagnostic data to the National Agricultural Pest Information System (NAPIS) at Purdue, a real time repository for diagnostic data. The DDIS and DDDI (University of Georgia) are just two of the digital diagnostic systems utilized among the 12 southern states. Within the next month, the University of Puerto Rico will also be networked and will be transmitting and receiving diagnostic data.

Educational materials are being developed, based on a plan for a national curriculum for crop biosecurity. The national curriculum topics are based on what a first responder should be able to do and understand:

- NPDN Mission and Biosecurity
- Art and Science of Diagnosis
- Quality and Secure Sample Submission
- Monitoring for High Risk and Unknown Pests
- Digital Imaging for Diagnostics

Initially, training materials will be based on current capabilities, including PowerPoint and narratives. However, future plans for training programs are based on the new learning management systems that will allow for a shared, reformattable set of materials for many types of training venues.

Scenarios for the soybean rust (SBR) pathogen, *Phakopsora pachrizi*, have been conducted in 10 states in the United States. The purpose of these scenarios is to be fully prepared in the event of a SBR introduction, whether intentional or accidental. The scenarios include the diagnosticians from the respective land-grant university and members of the State and Federal regulatory agencies. The mock samples are sent to the diagnosticians in Beltsville, Maryland, for final confirmation. In addition to the scenario training, representatives from the NPDN where SBR is considered to be the most significant threat have been trained at the Ft. Detrick federal quarantine facility for diagnostic protocols. These individuals will obtain security clearance to receive positive control samples to conduct the necessary molecular tests. Scenario training will be developed for all the pathogens on the target list.

In addition to the USDA list of target pathogens, each regional network is in the process of establishing its respective lists of pest and pathogens for its most economically important crops. Training programs will be developed for each of the target pathogens for national prevention and diagnostic programs. As part of the network, a list of experts and reference collections are being developed. This will be an essential component of the network as the digital imaging is developed. Those clinics that do not have the expertise to identify or make a diagnosis can more easily access the experts needed. The goal of the network is to prevent and respond properly to pests and pathogens that threaten our agriculture and economy.

Now that the network has been extended to Puerto Rico, other locations in the Caribbean and elsewhere should be connected as a means of international agricultural protection.

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PEST TARGETING EFFORTS AND THE DEVELOPMENT OF AN OFFSHORE PEST INFORMATION SYSTEM (OPIS)

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ABSTRACT: International trade is rapidly expanding and the relevance of international borders as barriers to pest movement is diminishing. As trade expands, so does the risk of accidentally or intentionally spreading exotic plant pests. The Offshore Pest Information System (OPIS) is a process designed to collect, analyze, communicate, and use relevant international information concerning pests that are not known to occur in the U.S. Using OPIS will enable USDA, Animal and Plant Health Inspection Service (APHIS) to meet its mission. That mission is to "safeguard American resources from exotic invasive pests and diseases." By using OPIS, the Agency can quickly and effectively respond to imminent pest threats. OPIS requires information collection, synthesis, communication, and supporting research. Exotic pests of concern to the U.S. have been ranked by order of importance by numerous professional societies and other sources. These rankings allow APHIS to focus on significant pests or pathways. Disclosure of these pests and their pathways helps U.S. trading partners to become aware of U.S. concerns, and to desire to work with those countries to keep such pests out of their countries as well. U.S. safeguarding response may be triggered by outbreaks of a pest, pesticide resistance, and loss of a pesticide or its cancellation.

The OPIS consists of the following components:

- (i) Global Pest and Disease Database: a reference tool on pests.
- (ii) Target pest list—A list that is reviewed and updated periodically.
- (iii) Pest/Pathway status in foreign countries: monthly reports on target pests.
- (iv) Pest interception data from U.S. ports: information reported into the system.
- (v) Communication through monthly or emergency pest alerts and news releases.
- (vi) Initiation of protective and mitigation measures: actions by U.S. and foreign countries

KEY WORDS: Pest surveillance, foreign pests, information collection, information reporting, targeted pests

INTRODUCTION

The mission of USDA's Animal and Plant Health Inspection Service Plant Protection and Quarantine Program (APHIS PPQ) is to safeguard agricultural and natural resources from the risks associated with the entry, establishment, and spread of animal and plant pests and noxious weeds for the overall benefit of the United States, the world's environment, and domestic and international trade.

A stakeholder review of the USDA's plant safeguarding system in 1999 found that a "broad range of highly reliable information on international pests is needed to enable APHIS PPQ to effectively safeguard America's plant resources." Likewise, the Animal Health Safeguarding Review found in 2001 "that the U.S. cannot achieve exclusion, detection, assessment of risk or eradication, and control of foreign animal diseases without adequate, scientifically sound, rapidly accessible, and completely communicated international animal health information." Both Reviews recognized the importance of identifying pest threats.

The International Services (IS) program of the USDA's Animal and Plant Health Inspection Service (APHIS) provides foreign services to the various units of APHIS. International Services employees in foreign countries assist U.S.-based safeguarding entities by providing inspection and information-gathering activities intended to protect U.S. plant and animal resources from foreign threats and to facilitate the movement of goods from foreign countries into the U.S. with minimal risk of pest and disease introduction. The Plant Protection and Quarantine Program and the Veterinary Services Program of APHIS provide guidance to the International Services Program on how to provide those offshore plant and animal protection services.

DESCRIPTION OF OPIS

The Offshore Pest Information System is designed to identify for International Services and our trading partners a maximum number of targeted plant pests and animal diseases which the Agency has determined represent a current and significant threat to the U.S. agricultural and natural resources. The components of an effective safeguarding system include offshore risk management, port-of-entry exclusionary measures, quarantines, pest detection, and emergency response. One of the most important of these is pest detection. The OPIS provides for the detection of pests on a global scale for specific targeted plant and animal pests. Communication of this information through the designed system complements the other components of the effective safeguarding system.

There are four basic elements of the OPIS. The first element is to collect the information. This data collection element of the system is used to collect and report into the system changes in pest distribution patterns, pest outbreaks, new trade patterns, and other factors which could threaten U.S. plant and animal resources. Data are collected by accessing the following sources:

- Collecting data from open sources on the internet.
- Monitoring and analyzing documents reporting the status of target pest populations in foreign countries and the pathways through which these pests could enter the U.S.
- Reporting by in-country safeguarding officers.

Such data collection or monitoring also facilitates pest risk mitigation in those countries of origin to reduce the risk of its spread into the United States.

The second element of the system is synthesizing and evaluating the collected information. The collected information must be credible and corroborated in order to protect those countries whose trade could be negatively impacted by the data. Also, since significant APHIS policy changes could be made on the basis of the information, there is a need to ensure its accuracy before costly U.S. safeguarding decisions are made.

The third element of the system is communicating the information. In cases where the information reveals a significant threat to the U.S. animal and plant resources or to our ability to conduct effective trade, the information must be disseminated with appropriate recommendations to safeguarding officials. Communication will thus result in pest detection or mitigation at coastal ports-of-entry or interior U.S. sites. This element focuses on the commodity inspection and pest detection activities of APHIS and its cooperators in priority areas with specific uniform processes developed with national and/or regional guidance from APHIS.

The fourth element of the system is supporting it with research and data collection. The basic pest information necessary to effectuate this system includes the following:

- Biological and taxonomic information.

- Control strategies or options.
- Geographic distribution of the pest.
- Known hosts or pathways.

Much of this type of information is already available. All that needs to be done is to retrieve the information and collate it in a simple, easy-to-use system. The development and continued repopulation of such a database is a major input and significant output of the pest information system. Pest risk analyses can be developed and improved by using information that is current and pertinent.

With the assistance of several professional scientific societies and industry groups, the USDA APHIS has developed a target pest list. This list is composed of more than 600 insects, mites, pathogens, nematodes, mollusks, and weeds that the cooperating groups identified as the most threatening to U.S. plant and animal health. Approximately 100 pests have been identified as "priority" targets. Disclosure of these pests of concern by the U.S. helps U.S. trading partners become aware of American concerns and the desire to work with those countries to keep such pests out of their countries as well; this awareness helps both the U.S. and its trading partners.

Information on the density and distribution of priority target pests is collected regularly in the foreign countries where they are known to occur. New detections of these organisms are also monitored and reported. As current status information is collected and reported on these priority target pests and diseases, safeguarding personnel in the U.S. and elsewhere adjust pest-and disease-risk management options. These options may include modifying the following:

- Initiating offshore pest management or risk mitigation.
- Organizing early-detection surveys for these pests and diseases in the U.S.
- Improving port-of-entry inspection procedures.
- Re-evaluating existing phytosanitary policies.

The information relevant to these pest issues is a basic item in the toolbox of those responsible for producing and protecting the health of a nation's plant resources. If a wood boring beetle population in a particular foreign country is at epidemic proportions, shipment of beetle host commodities into the U.S. could be a major pathway of borers into the U.S. Armed with this information, safeguarding officials can focus their port-of-entry inspection activities or even restrict the importation of such host commodities on the basis of phytosanitary principles. Information derived from U.S. port interceptions is also used to supplement offshore information.

To ensure timely, accurate, and secure management of this international pest and disease information, a web-based reporting and reference system has been developed. The system identifies and communicates to those who have a need to know, the target pests and diseases that have been identified by APHIS as a current potential threat to the U.S. Offshore safeguarding officers and others can report their findings immediately through the secure electronic system.

Reported information is evaluated by key scientists and policy making officials within APHIS to determine credibility, spatial and geographic impact on American plant and animal resources, and to determine risk mitigation procedures or policies to be undertaken by safeguarding officials here in the U.S. Following this analysis, the collected information and appropriate mitigation or advisory measures are electronically reported through a secure system as ranked pest alerts or pest news items to federal and state safeguarding officials for subsequent commodity inspection, pest detection or quarantine activities.

The electronic system provides a link to basic pest information contained in a USDA APHIS Global Pest and Disease Database. The information contained in this database includes geographic distribution, host commodities, animals, or other material, and taxonomy and identification information. The offshore pest and disease status information reported by safeguarding officials is also stored electronically for use by risk assessors and policy makers when needed for future decision-making.

During 2003-2004, APHIS will conduct a pilot program of the OPIS in three countries or regions. The Caribbean region has been determined to be a significant threat of exotic pest introduction because of its proximity to the U.S., developing pest populations, and existence of potential pathways identified by present or planned trading activities. Safeguarding officers will be hired by APHIS and placed in the Caribbean region specifically to cooperate with foreign officials to monitor the populations of the target pests and diseases in that region or in regions with which they conduct trade.

The Caribbean region is strategically suited for management of pest and disease risks threatening the southern U.S. Approximately 14 priority target pests and diseases have been identified as occurring in the Caribbean region. Several mutual benefits are anticipated from the pilot program in the Caribbean region. Included among those benefits is increased communication about specific pests with potential for disrupting U.S. - Caribbean trade. An example outcome of a pest monitoring system in the South American and Caribbean region would be the implementation of Caribbean regional exclusion measures designed to impede the northward spread of soybean rust from South America. Another mutual benefit from such as system would be the facilitation of pest mitigation or pest management programs for pests of concern. This benefit has already been demonstrated in at least one Caribbean country through the development and establishment of a biological control program for pink hibiscus mealybug.

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A PEER REVIEWED PAPER

MODELS FOR MINIMIZING OR ELIMINATING RISKS OF DANGEROUS PESTS: THE CARIBBEAN *AMBLYOMMA* PROGRAM

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ABSTRACT: The Caribbean *Amblyomma* Program is a multi-donor funded activity that involves both national governments and several technical organizations for the eradication of *Amblyomma variegatum*, the tropical Bont tick, from the Caribbean. The European Union and the United States Department of Agriculture are the major donors. The Food and Agriculture Organization is the lead technical agency, providing both technical and administrative support to the Caribbean *Amblyomma* Program Regional Coordination Unit. All collaborating agencies, donors, and national representatives are members of the *Amblyomma* Program Council, the overall governing body of the Caribbean *Amblyomma* Program. Historical aspects of the program are reviewed briefly, including the introduction of the tick from Africa in the 18th century, its subsequent spread during the 1970s, and the development of the concept of eradication. Conceptual characteristics for tick eradication programs are outlined using two brief case studies, one from Africa and one from the USA. The paper then focuses on the development of the model adopted for the eradication program, the achievements accomplished, and the constraints that the program faced during implementation.

KEY WORDS: tropical bont tick, acaricide, eradication, cowdriosis, dermatophilosis

INTRODUCTION

Amblyomma variegatum, the tropical Bont tick (TBT), became established on three islands in the Caribbean between 150 and 200 years ago. From the late 1960s, when it was first identified in St Croix (1967), and later in Puerto Rico (1974), it caused increasing concern (Pegram et al., 1997). The TBT gradually became widely dispersed over a period of 15 years causing devastation in St Kitts and Nevis, among other islands, in association with dermatophilosis (Pegram et al., 1996). In 1980, heartwater was reported in the Caribbean, and in 1984 the association between *A. variegatum* and the epidemiology of dermatophilosis was demonstrated (Jongejan and Uilenberg, 1994).

The Third Food and Agriculture Organization (FAO) Expert Consultation on Tick-Borne Diseases and their Vectors, held in 1983, made a recommendation urging Caribbean governments to cooperate and support the proposal to eradicate heartwater from Guadeloupe and Antigua. The First CARICOM Chief Veterinary Officers Meeting in Kingston, Jamaica, in May 1985 recommended a regional approach to eradication and encouraged countries to undertake a pilot project to test the feasibility of eradication. A "Technical Workshop on *Amblyomma variegatum* Eradication" was then convened in Barbados in 1987. Subsequently, a feasibility proposal, "Management of the Tropical Bont Tick *(A. variegatum*) and Associated Diseases in the Caribbean", was presented. The proposal included the creation of an *Amblyomma* Program Council (APC) to provide oversight to the program and to develop an eradication policy.

Several preparatory activities were initiated by FAO:

i. A Technical Cooperation Program (TCP) project, "Control of the Tropical Bont Tick in St Lucia" in 1986.

ii. A regional TCP project, "Eradication of the Tropical Bont Tick, Heartwater, and Dermatophilosis", based in St Lucia (1988). The project was responsible for the organization of a regional eradication proposal and for establishing the *Amblyomma* Steering Committee, the predecessor to the APC.

iii. Two further regional TCP projects: the first based in St Lucia, the then designated headquarters of the Regional Coordination Unit (RCU), "Surveillance and Prevention of the *Amblyomma variegatum* Tick", and the second relocated to Barbados, "Surveillance and Control of *Amblyomma variegatum*".

In 1990, a joint seminar on "Cowdriosis and Dermatophilosis of Livestock in the Caribbean Region" was sponsored by the Caribbean Agricultural Research and Development Institute (CARDI) and the Technical Centre for Agricultural and Rural Cooperation (CTA) in Antigua. In the proceedings, reference is made to the joint USAID/USDA pilot project in Antigua for US$ 4.8 million that could not be implemented because of the lack of agreement on the use of Bayticol, the acaricide used to control the tick.

During the early 1990s, a series of donor consultations were organized:

i. CARICOM – St Lucia, June 1991.

ii. FAO – Rome, 1992.

iii. FAO/CARICOM – Barbados, 1993.

iv. FAO – Rome, 1994.

After several years of negotiations, the impasse was eventually broken at the 1994 FAO-convened donor meeting, when USDA reconfirmed its commitment with an initial contribution of US$ 550,000 (Over the five years this was gradually reduced to about US$ 300,000) and a pledge for US$ 500,000 per year for 5 years. The British and German Governments agreed that residual SECNA funds (US$ 750,000) could be used for the Caribbean *Amblyomma* Program (CAP). Thus, the program started in late 1994 with about 10% of the required funding committed.

PROGRAM IMPLEMENTATION

Administrative Issues. There were numerous, complex international collaborative financing agreements, and several Memoranda of Understanding and Contractual Agreements.

However, each institution managed its funds independently:

i. USDA/IICA Contractual Agreement (IICA managed USDA funds during 1994 - 1998).

ii. FAO Government Cooperative Program Trust Fund Agreements (UK/ODA and GER/GTZ).

iii. IFAD/FAO (Technical Assistance Grant Agreement), the adaptive research component "Environmentally sustainable strategies for the control of the Tropical Bont Tick from the Caribbean" mainly investigated possible biological control methods using a juvenile growth inhibitor (Akatak) or myco-acaricides.

iv. FAO/TF Associate Professional Officer Agreements (Belgium, Italy, Netherlands).

v. FAO/TCP (FAO Management).

vi. EU (Direct purchasing via EU).

In addition to the financing agreements, there were also several agreements relating to coordination, management, and implementation:

i. USDA – IICA: Cooperative Agreement.

ii. FAO – IICA: Memorandum of Understanding.

iii. CARICOM – FAO – IICA: Memorandum of Understanding.

iv. FAO – EU: Memorandum of Understanding.

Unfortunately the various agreements were not always mutually compatible as they did not relate directly to each other, nor were they referred to in the overall program document that envisaged the APC as the overall management authority. There were two main areas of discrepancy. Firstly, there was generally no reference to the executive powers formally assigned to the *Amblyomma* Program Council. Secondly, funds were managed independently by the respective funding and implementing agencies (i.e., EU, FAO, IICA), and therefore, the clauses relating to collective management of funds were effectively meaningless. Consequently, the Regional Coordination Unit of the CAP often had little executive responsibility for management and disbursement of program funds, especially during the early years.

Technical Issues. It was realized at the onset of the program that there was a major defect in the design in relation to the proposed technical implementation of the field activities. It was stated that "... the acaricide will be applied in appropriate handling facilities for livestock. Accordingly, the animal handling facilities will be either permanent or mobile and will be distributed at strategic locations on each island." The proposal seemed illogical, as most livestock owners in the Caribbean are landless and only raise animals on a part-time basis.

There were several issues related to the handling facilities:

i. Just who was going to construct them?

ii. Where would they be located?

iii. Who would bring the livestock to them?

It was also apparent during the initial internal program review that inadequate attention had been given to the donor concerns relating to the calculations for operational costs for vehicles, for treatment teams, and costs for Bayticol. Notably, in the final version of the program document, external donor costs for the Antigua eradication program were estimated at less than US$ 0.5 million. This is in marked contrast to the estimated costs of the proposed USAID/USDA pilot project with an estimated budget of US$ 4.8 million.

Thus, in 1995, the program approach was reformulated. The new approach envisaged that the tick control treatments would be carried out by the livestock owners themselves at an opportunity cost, that is, the estimated monetary value of the time taken for treating their animals, of about US$ 8 million. The revised strategy, with devolution of responsibility for mandatory treatment to livestock owners, was in line with the global trend of privatization of government services. Government teams would then monitor farmers to ensure compliance with treatment schedules.

The "pour-on" technology using Bayticol is simple to transfer, but there remained considerable concern regarding compliance as it had been noted that, "*whilst the technology was available and eradication was considered to be feasible, the most important obstacle in attempts to eradicate the Tropical Bont Tick would be the human factor*" (Barre and Garris, 1989; Wilson, 1995). Thus, the strategy was to be reinforced through an intensive public information program directed to livestock owners and the general public. A communications and public information program was designed taking into account experiences from other large-scale animal disease-eradication programs (African swine fever, rinderpest, and screwworm). Supportive legislation was revised and enacted making it illegal for farmers to be in possession of tick-infested animals.

CONCEPTUALIZATION OF THE TICK ERADICATION MODEL

There are few, if any, global possibilities for tick eradication programs on which to base and develop a strategic model. Most countries in Africa, for example, remain dependent on tick control, although it is very expensive and generally considered to be unsustainable. Moreover, epidemiological and economic justification for intensive control remains questionable.

Pegram and colleagues formulated a comprehensive list of essential pre-requisites for pest eradication programs based on a literature review and the FAO/IAEA joint symposium on area wide eradication and control programs (Pegram et al., 2000a, 2000b; Tan, 2000). The essential components identified are as follows:

i. An economically viable livestock industry.
ii. Benefit-cost analysis to justify eradication and public conviction of the justification.
iii. Appropriate legislation.
iv. Adequate government, donor and/or industry finance for uninterrupted progression.
v. Scientifically based tick control/eradication strategies.
vi. An effective acaricide with no evidence of resistance to target species.
vii. Geographically defined distribution and host/habitat specificity.
viii. Adequate livestock handling facilities and infrastructure.
ix. Effective education programs, acceptance of the strategy, and farmer co-operation.
x. Adequate quarantine to prevent re-infestation.
xi. A statistically sound practical surveillance system for the tick.

The fundamental requirements were, in part, based on two brief case studies, one for eradication of the cattle tick in the southern USA, and a second for the eradication of a tick-borne disease, bovine theileriosis, in Zimbabwe.

Wilson (1995) concluded: "... *Zimbabwe probably had the most intensive, legally enforced, and best supervised dipping system in the world.*" It had been introduced in the early 1900s to control and subsequently eradicate theileriosis. Over a period of 90 years, the number of tick control facilities increased to 6,000 and the national cattle herd increased from 20,000 to 6 million. Regular tick control was compulsory; it was an offence to own tick-infested cattle.

Civil disturbances in 1975 – 1980 led to the cessation of dipping and to unauthorized cattle movements. Following independence in 1980, there was a gradual transition from intensive tick control to a strategic integrated approach.

Was the Zimbabwe national tick control program a success or failure? Our conclusion is that the Zimbabwe model was highly successful. Although the program broke down during the civil disruptions in the late 1970s, it seems futile to speculate that it was a failure on those grounds. Who would plan a disease control strategy based on the prospects of a civil war 75 years later?

In the southern USA, cattle tick fever was recognized as a major problem in the early 1700s and by the mid 1800s, cattle fever was identified as an important barrier to livestock development. In 1894, the authorities initiated a study on the distribution of the cattle tick and implemented research on the feasibility of tick eradication. Dipping was accepted as the most efficient and economical control method. Also exclusion of host animals from fenced pastures until all ticks had died of starvation was found to be effective.

In 1889, quarantine measures were implemented and the quarantine line extended from the Atlantic coast to the Pacific Ocean. When the eradication program began in 1906, it was estimated that *Boophilus annulatus* cost the cattle industry over US$ 130 million per year. The plan was for the eradication to progress from north to south. By 1909, cattle producers began reporting increased productivity in tick-free areas, but it was not until 1943 that the eradication of the tick was deemed to be complete except for a quarantine area along the Mexican border. Even today, 60 years later, problems of re-infestation still occur and acaricide resistance in Mexico continues to be a major challenge.

One can draw two conclusions from these two brief reviews:

i. Both efforts took an exceedingly long time (more than 30 years) to attain their respective goals.

ii. Governments, both of which showed long-term vision and financial commitment, administered the programs.

In contrast, in the Caribbean *Amblyomma* Program, there are ten national governments and several international agencies involved in the implementation of the program. There was also constant uncertainty over long-term financial assurances for the continuity of the program.

A critical analysis of the literature on both successful and unsuccessful tick control/eradication programs was then applied to the Caribbean *Amblyomma* Program countries to determine the parameters likely to impact on its success. The status of the key essential requirements for some of the islands is summarized in Table 1.

The basic field model. The application of the model in the field was dynamic for a number of reasons. It had been envisaged from the conceptual stages that the eradication effort must start simultaneously on all TBT infested islands. However, financial constraints prevented this from the beginning, and starting dates on individual islands were based more-or-less haphazardly, from north to south, on the temporal availability of funding.

It was further anticipated that all animals would be tagged prior to implementation of treatment, but this proved to be very time-consuming, especially to keep up-to-date with the prolific reproductive capacity of small ruminants, and proved to be expensive relative to the very limited funding available. Subsequently, tagging was discontinued in favor of animal owner registration and head counts of animals owned.

A further constraint was that on some islands there was no up-to-date livestock census. Antigua was the worst-case scenario. As the registration of livestock continued it was realized that animal populations had been seriously underestimated: cattle by 25% (16,000 compared to 12,000), and small ruminants showed a disparity of 400% (60,000 as opposed to 15,000 previously recorded).

The general model planned for implementation consisted of the following sequential activities:

i. Registration of livestock owners.

ii. Tagging of all livestock with specific color and number sequences.

iii. Data recording using the databases CAPstat and CAPdat specifically designed for the program, primarily for monitoring purposes. The second database made provision for subsequent TBT surveillance but proved unwieldy in that all negative findings had to be recorded individually.

iv. Treatment of all livestock every two weeks, for at least two years, by the livestock owners. The treatment schedule was based on a simulation model of tick survival, host preferences, and climatic data.

v. Quantitative, statistically validated surveillance for TBT was introduced after the first year of mandatory treatment. A user-friendlier database "TickINFO" was then developed with user involvement for the TBT surveillance component.

vi. Quarantine and livestock movement restrictions as areas or islands were certified provisionally free from the tick.

Each stage of the cycle was introduced and reinforced through an intensive public education and social marketing program. This input was continued throughout the program and included media (TV, radio, printed materials including posters, and calendars), signboards, promotional materials (including T-shirts, caps, key rings, calculators, pens, pencils, mugs, clocks, watches, and fanny packs), and sponsorship (softball, cricket, and football) as well as more traditional extension and field training for farmers and technical training for animal health staff.

Assessment of progress in the eradication was based mainly on analysis of quantitative surveillance for the TBT and associated diseases at the parish level on each island. In the initial stages of the program, the sampling strategy was based on a statistically representative sample of livestock throughout the island. The sampling design was reviewed after one year and the strategy changed to sample far more properties or premises, but fewer animals on each property. This design strategy was deemed necessary because of the diversity of the animal husbandry practices among the community.

Island wide treatment could be terminated only after at least 24 months of continuous application of the pour-on, and two consecutive surveillance cycles in which no TBT were observed. After the cessation of island wide treatment, certification of provisional freedom from the tick was dependent on no ticks being found on a statistically representative sample of properties during a further consecutive six-month period. Again, this scheme was modified in 2000 on the basis of USDA experiences in Puerto Rico, where it had been assumed that individual male ticks did not constitute an active infestation. Whilst there may have been some validity in this assumption under Puerto Rican conditions, *post-factum* assessment of the TBT simulation model that was used as a basis for the two-year treatment schedule (based on Puerto Rico data and experiences) is believed to be flawed.

RESULTS

During 2001-2003, six islands, St Kitts, St Lucia (November 2001), Anguilla, Montserrat (February 2002), and Barbados and Dominica (February 2003) were certified as provisionally free from *A. variegatum*. There are various administrative and technical reasons why the national eradication campaigns took much longer than the original model had projected. Thus, the final stages of eradication on most islands were "vague" and elimination of the residual infestations in hot-spot areas took a further 15 - 30 months, although TBT prevalence rates were maintained at very low levels.

Chronological, quantitative TBT surveillance data from 1998 to 2003, based on an analysis using the TickINFO database, are shown in Table 2 and Figures 1, 2, 3, and 4. It should be noted that data for several countries is not complete, especially in terms of infested farm prevalence rate. This is primarily due to the fact that earlier databases that were adopted under the program did not allow easy generation of this information.

Although all countries under CAP, except Nevis, Antigua, and St Maarten, have attained provisional freedom from TBT infestation, several countries continue to report the presence of ticks, both males and females. However, under the current protocol, they will maintain their provisional free status as long as extensive surveillance and appropriate control measures in the surrounding areas are carried out.

Farmers themselves have reported many of the recent sightings of ticks in several countries. The active participation of farmers in surveillance activities is of paramount importance if adequate levels of animal inspection are to be maintained.

DISCUSSION AND CONCLUSIONS

Constraints. The pour-on technology and the pyrethroid acaricide selected for the program were known to be the best technically available. The distribution of the tick was known. The legislation was in place but, unfortunately, not always enforced in a timely manner. On most islands, the animal handling facilities and quarantine measures were deemed to be adequate, but again they were not always effectively applied and some of the authorities were unable to pay adequate attention to important issues such as land ownership and lack of grazing rights. In the dry season and periods of prolonged drought particularly, there were serious problems when livestock owners either abandoned their livestock or let them wander anywhere in search of grazing. Antigua and Nevis were the two worst cases and this undoubtedly was one of the major constraints leading to inadequate progress.

It is doubtful in the overall context of the world economy in agricultural production that any of the countries had an internationally competitive, or viable, livestock industry, mainly because of cheaper imports of meat and dairy products. However, opportunities existed for niche markets, and prior to the devastation caused by the TBT, most islands had reasonably viable local and regional markets. The USDA benefit-cost analysis (Gersabeck, 1994) certainly justified the intervention at the wider continental level, but public-owner conviction was marginal on several of the islands because livestock owners were invariably only part-time. The regional approach to provide an effective education program was deemed to be effective although some countries did not sustain it consistently.

Funding. An overall problem was the uncertainty of continuity of funding for the regional inputs. Moreover, most countries found it difficult to maintain the long-term national annual inputs for staff and local operational costs. There were also several periodical donor-funding crises throughout the program. In late 1996, the EU released € 0.740 million (= US$ 850,000) for the purchase of Bayticol, and in 1997 the International Fund for Agricultural Development (IFAD) approved a Technical Assistance Grant for US$ 1 million for support of the adaptive research component. A constructive mid-term review (MTR) in 1997 concluded that the program had achieved substantial progress towards eradication, despite administrative, resource, technical, and personnel constraints.

The participatory approach, supported by a public information and communications strategy was highly commended. The MTR stressed that progress could be sustained only if additional funding were urgently secured to finance the eradication of the TBT from the entire Caribbean.

In mid-1998, the CAP again faced an acute funding problem. At that time the US Treasury had identified US$ 1.94 million originally committed to the SECNA program, and USDA approved these funds for the CAP. The EU/CARIFORUM provided a further € 1.5 million for the period 2000–2003.

Progress. Although there were constraints and complications, there was sufficient good will among most of the main collaborating agencies and the participating Governments to ensure substantial technical progress. Moreover, at the national level, there was generally a positive commitment and determination to succeed.

There are several lessons to be learnt from this program, although they are not necessarily new. Most of them were included in overview presentations at the IAEA/FAO Conference in Malaysia on "Area-wide Control of Pests" in June 1998 (Tan, 2000). These include:

i. Programmes should be independent of political and institutional bodies, i.e., managed by an autonomous body (It was noted that some programmes failed not because of inappropriate technologies, but because of conflicting political and institutional agendas). It was further noted, however, that independent management of eradication programs rarely, if ever, occurs. As outlined above, in this program there were no fewer than 10 international inter-agency agreements (excluding the French West Indies program) and 10 national governments involved in the implementation. Frequently, implementation delays occurred, and unilateral decisions on procedures and funding priorities were sometimes made without consultation with the technical managers. These led to inter-agency disagreements and lack of harmonization.
ii. Full support of producers and producer associations is essential.
iii. Appropriate legislation must be in place and agreed upon by all parties.
iv. Education and communication are very important.
v. Use only "proven" technical methods within the eradication areas. Applied or adaptive research should be carried out before the implementation of the eradication process (or in areas outside the eradication zone).
vi. Defined goals are also essential as well as standard systems to verify status.
vii. Research that could jeopardize success should not be carried out within the area of eradication or control.

The key issues leading to eventual success can be summarized as follows:

i. The important role played by the APC as an independent body, assisted in harmonizing the earlier differences among some agencies and governments.
ii. The flexibility of "informal ad hoc working groups" as defined and agreed on by the APC.
iii. The continuous informal contact and meetings particularly between the main technical and donor institutions (for example the USDA and the CAP-RCU).
iv. The gradual increase in confidence of, and flexibility on the part of FAO-HQ to decentralize operational and technical responsibilities more directly to the RCU.
v. The gradual trend towards more independent management of project funds.
vi. The commitment and support of the Ministries of Agriculture of the participating governments.
vii. The public information/social marketing aspects of the program.
viii. The positive response and compliance of the target livestock owners.

Ecological and Biological Factors. Simulation models were developed, using biological and ecological data for *A. variegatum,* to estimate the duration of the required treatment periods for the elimination of the tick in the Caribbean environment.

Key bio-ecological factors, including development and survival periods for *Amblyomma variegatum,* are summarized in Table 3. With the favorable climatic conditions in the Caribbean, the adult ticks may be present year round, although they are far more prevalent between July and September.

The tick usually completes its life cycle in one year, but with the long survival periods, the life cycle could be extended to up to four years. In contrast, in the more arid and harsh conditions in central Africa, the synchronization of various stages of the life cycle, and the much shorter periods of survival for all free-living stages, the cycle is usually completed in one year even though development periods are longer (Pegram et al., 1998; Pegram and Banda, 1990).

In the Caribbean, the only hosts for the tick other than domestic livestock, and rarely dogs, are the cattle egret and the mongoose. Studies in Guadeloupe showed that almost 95% larvae, 97% nymphs, and 100% adults feed on domestic hosts (Barre and Garris, 1989; FAO, 1993).

The two simulation scenarios developed were based on the following criteria:

i. The total accumulated maximum survival period for eggs, larvae, nymphs, and adults is 46 months.
ii. The survival period of adults only is 20 months.

This second scenario made two assumptions:

i. A concentration of all tick stages within the host grazing area or range.
ii. All livestock would be treated every two weeks.

The latter strategy was based on experiences in Puerto Rico for a successful intensive treatment duration of two years. It had been assumed that it would work throughout the Caribbean, but there are at least two reasons why this may not be so.

Firstly *A. variegatum* had not become well established in Puerto Rico by the time intensive treatment programs were implemented. It was most unlikely, therefore, that *A. variegatum* immatures had become adapted to feral hosts. In contrast, in most other Caribbean islands the tick had been present at least 10-15 years before the intensive treatment programs were implemented and the tick was well established.

Secondly a further factor influencing the widespread dispersion of the tick is related to livestock management systems. In Puerto Rico, most livestock are kept commercially and maintained in enclosed or fenced commercial properties. Thus, all stages of ticks would be "exposed" to hosts that have been treated with acaricide. In the other Caribbean islands, there are very few livestock managed commercially except on Government farms, and the majority of livestock are free ranging. Moreover, on some islands, for example Antigua and Nevis, there is a high proportion of feral or free-ranging livestock. In these situations, there could well be small pockets of residual infestations of *A. variegatum* that are not exposed to acaricide-treated animals, because of larvae and nymphs feeding on non-domestic small ruminant hosts for periods of up to 2 years.

Drought and other factors influence the grazing areas of domestic animals, especially goats, and as such, untreated, or infrequently treated hosts may pick-up residual adults some 24-48 months after the original depositing of eggs. It is also known that immature stages of *A. variegatum* are known to survive longer in bush scrublands than on well-managed pastures.

These rather complex and varied management factors have undoubtedly contributed to the prolonged persistence of infestations of TBT in the Caribbean islands.

At the administrative and political management level, the main conclusion drawn from these experiences is that international collaboration is a valuable tool in the implementation of such a multi-donor funded, and multi-institutionally managed program. It was stressed earlier in this paper that eradication programs should be independent of political and institutional bodies; i.e., managed by an autonomous body. Thus, rather than a multitude of individual, and possibly incompatible agreements being made, a single multi-organizational agreement must be considered essential to harmonize and coordinate operations under the leadership of a single technical, preferably independent, implementing agency. Democracy can be ensured through a body such as the *Amblyomma* Program Council, but it must be empowered with some legally binding and acceptable authority.

Further application of the model. The activities of CAP, in addition to controlling *A. variegatum* in member countries, have helped to foster a strong link between the farming communities and national veterinary services. Furthermore, under CAP the capabilities of veterinary services for data collection and analysis have been enhanced; a culture of livestock data management has started on many islands where before none existed. CAP hopes to build upon this and, using lessons learnt from the program, act as a model for widening and further strengthening animal disease surveillance in the region to include diseases other than just that of the Tropical Bont Tick.

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formally cited or accessed. To resolve this problem, the reader is referred to the Caribbean *Amblyomma* Program home page www.capweb.org and the document "Caribbean *Amblyomma* Program: History and Bibliography" 1999. pp. 14.

Table 1. Identification of potential constraints in Caribbean territories.

Pre-requisite/Factors	Anguilla	Antigua	Barbados	St Kitts	Nevis	St Lucia	Remarks
Appropriate Legislation	+	+	+	+	+	+	Legislation and methodology common to all islands
Geographically defined distribution	+	+	+	+	+	+	
Known effective acaricide	+	+	+	+	+	+	
Scientifically based strategies	+	+	+	+	+	+	
Adequate quarantine measures	+	±	+	+	+	+	
Adequate, un-interrupted finance	-	-	-	-	-	-	
Adequate livestock handling facilities	±	±	+	+	±	+	
A viable livestock industry	-	+	+	+	+	+	
Benefit-cost analysis / justification	-	+	+	+	+	+	
Effective education program	±	±	+	+	±	+	
Public/owner conviction	-	-	+	+	±	+	

Table 2. Tropical Bont Tick surveillance data 1998 to 2003.

	1998				1999				2000				2001				2002				2003		
NEVIS	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**	**1**	**2**	**3**
Properties Exam				699	234	231							429	356	355	305	347	304	285	117	392	279	365
Hosts Examined				14052	6938	7016							12478	8417	7163	5951	5257	5992	3426	1764	7917	6204	10496
No. TBT Positive				74	40	17							10	16	21	1	8	8	10	2	2	4	24
Prevalence (%)				1.80	0.58	0.24							0.08	0.19	0.29	0.02	0.15	0.13	0.29	0.11	0.03	0.06	0.23
Male TBT				-	55	20							24	23	60	1	16	22	103	9	2	16	61
Female TBT				-	15	3							14	1	34	0	0	5	11	1	0	5	17
ST KITTS																							
Properties Exam	80	80	9	34	88	83	174	197	207	178	194	147	180	148	147	109	98	93	48	61	100	122	186
Hosts Examined	969	916	70	427	984	1015	761	412	434	390	602	613	657	528	422	334	321	293	164	195	822	983	1355
No. TBT Positive	3	1	0	2	2	4	7	0	2	0	0	0	0	1	0	0	0	1	1	0	0	0	6
Prevalence (%)	0.31	0.11	0	0.47	0.20	0.39	0.92	0	0.46	0	0	0	0	0.19	0	0	0	0.34	0.61	0	0	0	0.44
Male TBT	5	2	0	4	1	4	11	0	2	0	0	0	0	1	0	0	0	1	11	0	0	0	23
Female TBT	3	0	0	0	1	3	12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5
ST LUCIA																							
Properties Exam	170	204	111	196	189	158	150	68	110	108	55	75	130	22	107	69	68	55	69	37	54	108	170
Hosts Examined	1101	1936	1068	1583	2416	2488	4068	[illegible]739	9611	17598	7147	12737	8728	1294	5583	5744	5971	2799	2057	924	2233	5246	5260
No. TBT Positive	0	0	5	2	2	0	4	2	0	1	1	2	0	0	1	0	0	5	0	0	2	8	22
Prevalence (%)	0	0	0.47	0.13	0.08	0	0.10	0.11	0	0.01	0.01	0.02	0	0	0.02	0	0	0.18	0	0	0.09	0.15	0.42
Male TBT	0	0	10	2	3	0	10	3	0	1	0	5	0	0	4	0	0	10	0	0	10	25	31
Female TBT	0	0	5	3	6	0	7	3	0	1	1	0	0	0	0	0	0	3	0	0	1	8	3
ANTIGUA																							
Properties Exam					-	-	-	-	103	34	73	200	388						114	121	138	86	89
Hosts Examined					195	280	1037	1578	2378	579	801	1821	4716						926	944	1401	880	1112
No. TBT Positive					1	7	3	1	2	0	12	8	4						3	2	0	0	0
Prevalence (%)					0.51	2.50	0.29	0.06	0.08	0	1.50	0.43	0.08						0.32	0.21	0	0	0
Male TBT					1	12	2	2	3	0	28	11	10						2	2	0	0	0
Female TBT					0	4	6	0	1	0	20	3	2						1	0	0	0	0

Table 3. Bio-ecological development and survival data for *Amblyomma variegatum* under quasi-natural conditions (in days).

Parameter	(FAO, 1993)	(Pegram et al., 1988) (Pegram and Banda, 1990)
Adult female feeding period	7 - 15	10 - 19
Pre-oviposition	9 - 21	10 – 63*
Oviposition period	17 - 50	56 - 97
Pre-eclosion (Incubation) period	43 - 62	53 - 111
Pre-moulting (Larvae to Nymph)	15 - 22	42 - 63
Pre-moulting (Nymph to Adult)	18 - 28	39 – 60
Larval survival	285 (max)	96 – 147
Nymphal survival	450 (max)	98 – 189
Adult survival	600 (max)	196 - 228
Total maximum duration (Development and survival)	4 years	1 year

*Usually 11 to 21 days. If longer than 21 days, engorged females were considered to undergo morphogenetic diapause.

Figure 1. Nevis: Prevalence of TBT infested farms and animals.

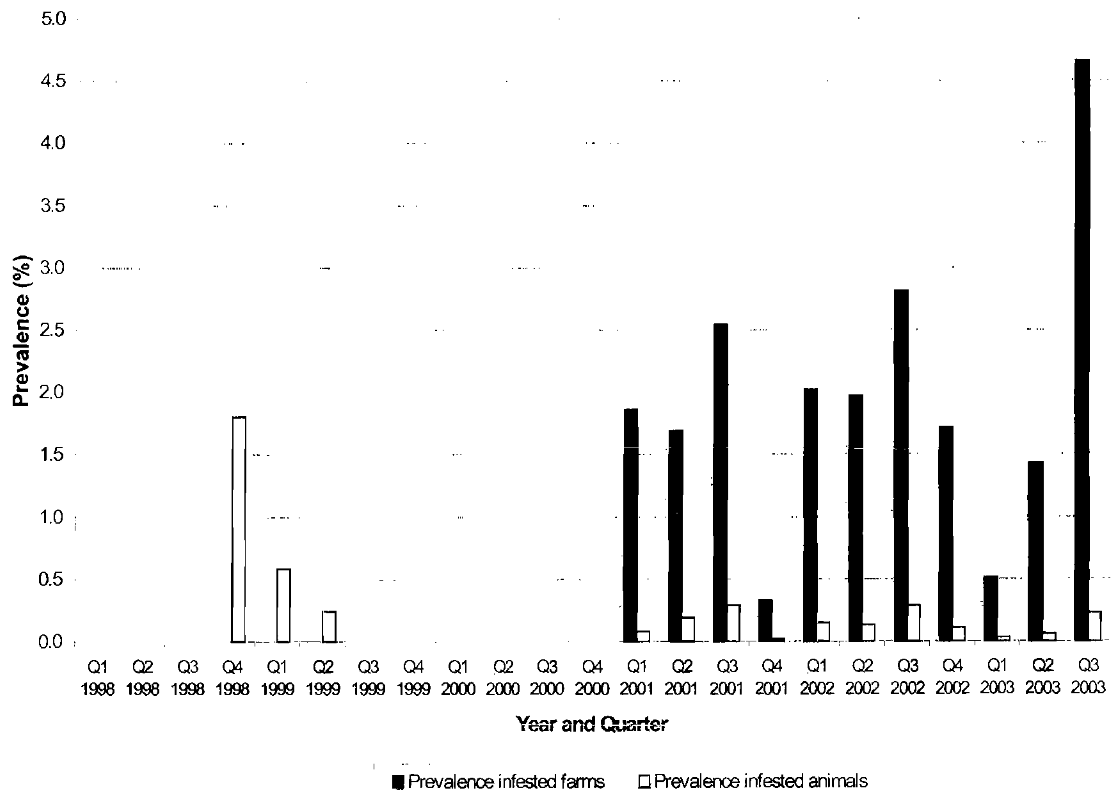


Figure 2. St Kitts: Prevalence of TBT infested farms and animals.

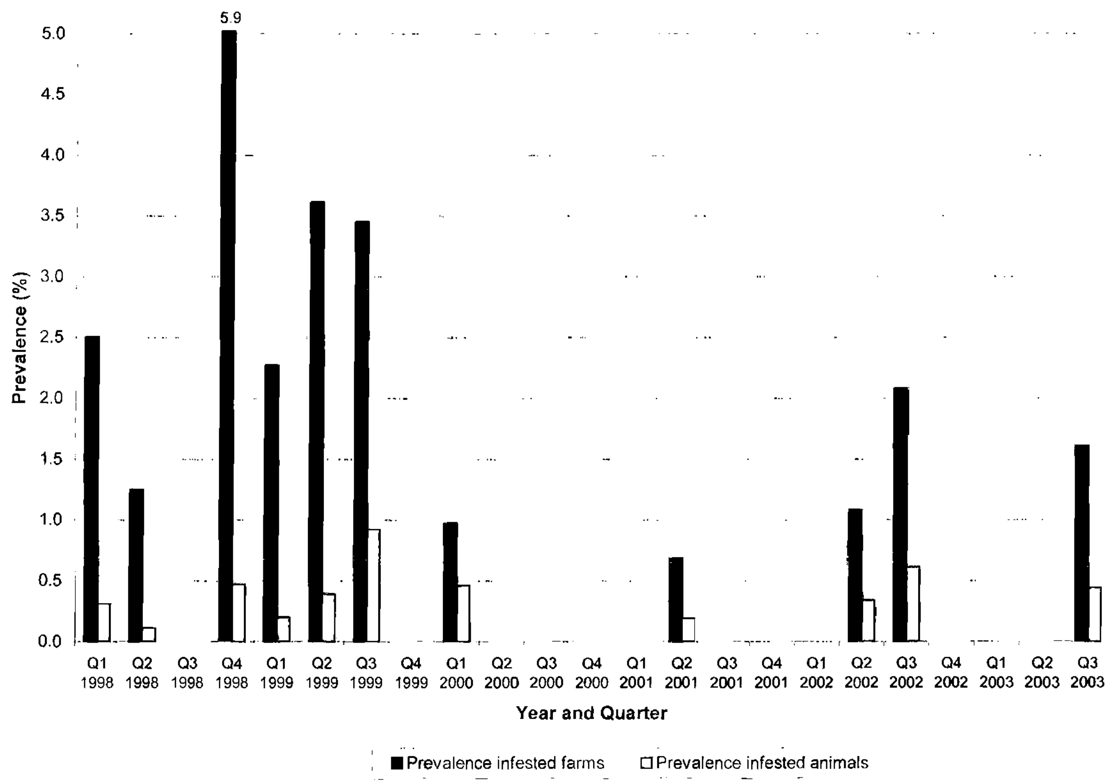


Figure 3. St Lucia: Prevalence of TBT infested farms and animals.

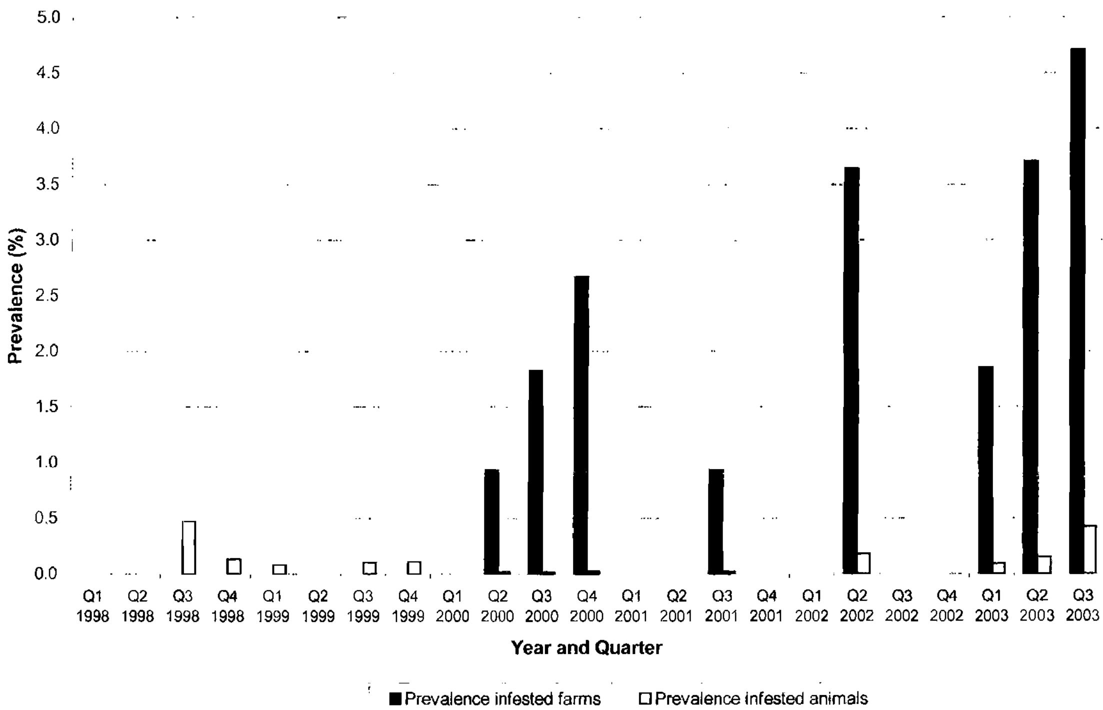
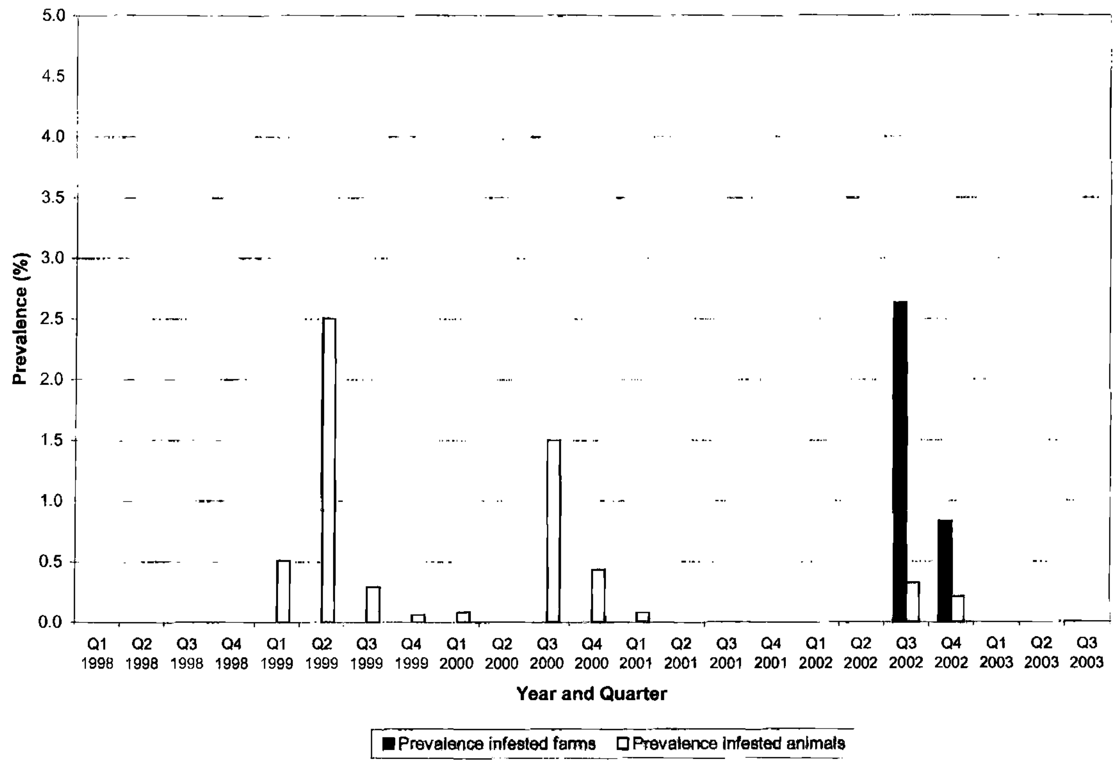


Figure 4. Antigua: Prevalence of TBT infested farms and animals.



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MODELS FOR MINIMIZING RISKS OF DANGEROUS PESTS: THE PINK HIBISCUS MEALYBUG AND PAPAYA MEALYBUG

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ABSTRACT: The pink hibiscus mealybug (PHM), *Maconellicoccus hirsutus* (Green), and the papaya mealybug (PM), *Paracoccus marginatus* Williams & Granara de Willink, biological control programs were cooperatively developed in the Caribbean by various local and international agencies and organizations. Both programs served as models of proactive program action in the early stages of each invasive pest's introduction into a Caribbean island, and for minimizing losses to the U.S. and neighboring countries. The biological control technology for the PHM developed in St. Kitts and Nevis, W.I., between 1995 and 1997, has been successfully transferred within the last six years to the US Virgin Islands, Puerto Rico, Bahamas, Belize, California, and most recently to Florida, Haiti, and the Dominican Republic. The PM biological control technology developed in the Dominican Republic in 1999 has been transferred to Puerto Rico, Florida, Bahamas, and Guam within the last four years. In both programs, the introduction of exotic parasitoid species resulted in mealybug population density reductions ranging from 82 to 97%. Early program development allowed for swift technology transfer to newly infested islands and to the U.S. Mainland (California and Florida) within thirty days of being found infested. This swift transfer in turn significantly reduced the potentially high rate of geographical dispersal and averted disastrous economic losses in the Caribbean countries, and in the U.S. and its island territories.

KEY WORDS: *Maconellicoccus hirsutus*, *Paracoccus marginatus*, biological control

INTRODUCTION

Invasive agricultural pests continue to invade the Continental United States in record numbers of species. The U.S. Department of Agriculture, Animal and Plant Health Inspection Service had intercepted over 70,000 agricultural pests alone at ports of entry in the US by the close of 2002 (Figure 1) (Anon. 2003). Once a new pest is found in the US, a decision needs to be made whether to take no action, to implement an eradication program, or to develop an integrated pest management (IPM), a cultural, a chemical, or a biological control program.

During this last decade, a model for minimizing the risks of dangerous pests in the US has consisted of addressing the control of some of these pests offshore in a proactive mode prior to their introduction into the U.S. One option may be to develop a classical biological control program in cooperation with neighboring countries. This cooperation has successfully been accomplished for the pink hibiscus mealybug (PHM), *Maconellicoccus hirsutus* (Green), and the papaya mealybug (PM), *Paracoccus marginatus* Williams & Granara de Willink (both: Hemiptera, Coccoidea, Pseudococcidae).

The advantages of implementing an offshore classical biological control program are that: (i) it becomes a self-sustaining control program; (ii) it has high cost efficiency; (iii) it is environmentally sound; (iv) it "buys time" to develop the technology abroad before the pest invades another country; (v) it evolves into a cost-shared program with other countries and international organizations; (vi) its level of control escalates as released exotic natural enemies increase in numbers and disperse geographically to new infested locations; and (vii) it reduces the population density of the pest, and thereby tend to slow its rate of dispersal, and thus defers the time when other countries in the region become infested; (viii) it is relatively easy to transfer to other countries; (ix) it reduces potential economic losses if ready to implement immediately upon detection of the pest after entry into a new country, i.e., no down time for a technology development phase; and (x) it takes advantage of resources and expertise in other countries.

THE PINK HIBISCUS MEALYBUG

The pink hibiscus mealybug was first found in the Western Hemisphere in Grenada in 1994. The economic risk to U.S. agriculture due to the invasion of the pink hibiscus mealybug was estimated by Moffitt (1999) to be approximately a US$ 750 million per year potential loss. Agricultural crops in the U.S. expected to bear most of the economic risk due to this pest included ornamental, vegetable and citrus crops, grapes, and avocados. The pest had spread rapidly to other Caribbean countries by 1999 (Figure 2) with the largest number of Caribbean countries confirming establishment of this pest by 1997 (Pollard, 1999). The infested area soon came to include more than 25 Caribbean Islands, and Guyana, and by August of 1999 southern California, by September 1999 Belize, and by November 2000 the Bahamas. The PHM was first detected and identified in Florida in June 2002, confirmed to be present in Haiti in May 2002, followed by the Dominican Republic in August 2002.

PHM attacks over 200 host plant species, but is most common on hibiscus and soursop (*Annona muricata*) in the Caribbean (Stibick, 1997). Hibiscus plants were used as a standard host for these studies except in California, where mulberry and carob trees were also studied. Two exotic parasite species were imported for control of PHM. One was *Anagyrus kamali* Moursi (Hymenoptera: Encyrtidae) imported from China, and a second was *Gyranusoidea indica* (Hymenoptera: Encyrtidae) imported from Egypt. Both parasites have a life cycle producing two generations for every one generation of the mealybug.

St. Kitts, W.I. *Anagyrus kamali* was initially released in St. Kitts in August of 1996. The second species, *Gyranusoidea indica,* was released in the spring of 1997. *Anagyrus kamali* became the dominant parasite and has been reported moving up to three miles from initial release points. By January of 1998, the parasites had reduced the PHM population density on hibiscus in St. Kitts by 92% (Figure 3).

US Virgin Islands. PHM was first found in the U.S.V.I. in St. Thomas and St. John in May 1997 and St. Croix in June 1997. The mealybug's population density on hibiscus shrubs at release study sites was reduced by an average of 91% in St. Thomas and over 97% in St. Croix during the period from July 1997 to February 1999 (Figures 4 and 5).

Puerto Rico. This same mealybug pest was first reported in Puerto Rico on the island of Vieques, June 24, 1997. Parasites were first released in Puerto Rico on January 8, 1998, first on Culebra; April 16, 1998 on Vieques; and May 22, 1998 on the main island. PHM densities were reduced by 96.3% on the main island during the period from May 1998 to January 2001 (Figure 6); 98% on Vieques from May 1998 to August 1999 (Figure 7); and 97.8% on Culebra from May 1998 to August 1999. Parasitization after the decline of the mealybug's population density remained at an average of 19.8% in Puerto Rico, 31.6% in Culebra and 24.8% in Vieques. The PHM has spread across Puerto Rico to date since the initial infestation in April 1998 moving from east to west much more slowly then anticipated, probably because of the early presence and impact of the exotic parasites.

Belize. The PHM was first reported in Belize, Central America, in September 1999. The above two parasite species were released by November 16, 1999, at a rate of 200 to 400 parasites per release site. Within one year (November 1999 to November 2000) the PHM population densities had been reduced by 96.6% on hibiscus shrubs (Figure 8). Parasitization increased from 0% in November 1999, when the parasites were first released, to a high of 74% by November 2000.

California. This same mealybug pest was also discovered in Imperial County, California, in August 1999. The infestation was predominantly in the city of Calexico. In a cooperative effort among the California Department of Food and Agriculture, and the USDA, APHIS, PPQ, and the Puerto Rico Department of Agriculture Insectary, the latter shipped approximately 3,000 parasites for release in September 1999, only one month after PHM detection. An insectary was soon established in El Centro by the California Department of Food and Agriculture (CDFA) to mass produce *A. kamali* and *G. indica.* These species were released in the local area at newly infested sites. CDFA provided these beneficial species to Mexico, and later to USDA, APHIS, PPQ for releases in the Bahamas and the Caribbean. The infestation has remained confined to the southern end of Imperial County. The PHM population density on mulberry trees remained low throughout 2001, averaging only 3.9 mealybugs per terminal in September 2001 with 30.7% parasitization. This was an overall mealybug population density reduction of 98.4% (Figure 9).

Bahamas. The Bahamas were found to be infested in November 2000 on the Island of New Providence in the Nassau area. The PHM population density levels averaged 242.4 mealybugs per terminal in January 2001 with no parasites present. Following the established parasite release protocol, the PHM population density by February 2001 had declined by 82% (Figure 10). Additional parasite releases were made across the island of New Providence as the mealybug dispersed.

Florida. The pink hibiscus mealybug was first detected and identified in Florida in June 2002. By the end of December a total of 240 sections in Broward County and 133 sections in Miami-Date County had been formally surveyed. After parasite releases, population density of PHM declined from July to October of 2002 by 94% and was further reduced to 98.7% by April 2003 (Figure 11). Cooler temperatures could have contributed to the lower numbers counted in January. Parasites have been detected at new PHM infestations that are at least 3-4 miles away from the closest parasite release site, thus indicating that efficient parasite dispersal is occurring naturally. Homeowners are expressing their satisfaction with the biological control program of the PHM. Their hibiscus shrubs are returning to normal growth cycles with fully extended leaves and many flowers.

Haiti. The PHM was initially collected in Haiti May 9, 2002. A PHM biological control program similar to that of St. Kitts, U.S. Virgin Islands, Puerto Rico, and Belize was initiated in Haiti in July 2002. All parasites were shipped from the Puerto Rico Department of Agriculture's Insectary Operation. By February 11, 2003, a total of 106,300 parasites had been released in Haiti. From July 2002 to June of 2003, the PHM population density was reduced by 97% at the study sites (Figure 12). The PHM continues to disperse and now occupies over 1/3 of Haiti where parasites have been strategically released.

Dominican Republic. The Dominican Republic Ministry of Agriculture confirmed the presence of PHM on August 1, 2002. Initially the infestation was more or less confined to the Santo Domingo area, San Cristobal, Yamasa, and Monte Plata, and has now slowly begun to disperse in all directions throughout the country. Initial parasite releases were made in August at nine study sites and throughout the infested region. By the end of January 2003, a total of 79,400 parasites had been shipped from the Puerto Rico Department of Agriculture Insectary and released in the Dominican Republic. The PHM population density had significantly declined by 96.6% by June 2003 (Figure 13).

The common denominator in the success of this biological control program against the PHM has been the effectiveness of *A. kamali* and *G. indica*, which have demonstrated the capability of successfully regulating PHM in tropical, subtropical, and semi-desert regions. Apparently the genetic variability of these two parasites has allowed them to adapt to a wide range of climatic habitats.

THE PAPAYA MEALYBUG

The papaya mealybug is believed to be indigenous to Central America and has been reported in Belize, Costa Rica, and Guatemala (Ben-Dov, 1994) and Mexico (Miller et al., 1999). In 1995, this mealybug species was first reported in the Caribbean in St. Martin. Since that time, it has spread to over 13 Caribbean countries as reported by Food and Agriculture Organization of the United Nations Office of the Sub regional Representative for the Caribbean. These include Antigua, Cuba, Guadeloupe, Montserrat, Puerto Rico, St. Kitts and Nevis, U.S. Virgin Islands, British Virgin Islands, Dominican Republic, Haiti, and St. Barthelemy (G. Pollard, personal communications; Ben-Dov, 1994). PM has also been found in the U.S., but only in Florida, where it was first detected and reported by the Florida Department of Agriculture in 1998 in Bradenton, Manatee County, and in Boca Raton, Palm Beach County. Both counties reported the mealybug on hibiscus plants in residential areas (Miller et al., 1999).

Over 55 host plants have been reported attacked by *P. marginatus* including: *Acacia* sp., *Acalypha* sp., *Ambrosia cumanensis*, *Annona squamosa*, *Carica papaya*, *Guazuma ulmifolia*, *Hibiscus rosa-sinensis*, *Hibiscus* spp., *Ipomoea* sp., *Manihot chloristica*, *Manihot esculenta*, *Mimosa pigra*, *Parthenium hysterophorus*, *Persea americana*, *Plumeria* sp., *Sida* sp., and *Solanum melongena*. The authors have observed heavy infestations on hibiscus and papaya.

Damage can be caused by direct feeding of the mealybug on the host plant resulting in defoliation, a bunching of the leaves at the terminal of the plant, distortion of the growing tip, heavy sooty mold, fruit discoloration, death of the plant, and heavy insect population densities on the fruit. It has been reported at times to cause damage to cassava in some areas of Mexico, and to papaya fruit, with so many mealybugs as to render the fruit inedible (Miller et al., 1999).

Field characteristics of an adult female of *P. marginatus* include body color that is yellow under a white waxy secretion; no longitudinal depressions; short waxy filaments around the body of the adult female; short caudal filaments; yellow body fluid; egg sac produced under the body of the female; and specimens in alcohol turn a bluish-black color.

The potential for developing a successful biological control program was high. One reason is that this insect is not a major pest in Mexico, all of which implies that effective natural enemies attack it in Mexico. Secondly, five primary parasites had been collected from this mealybug in Mexico in 1999. Thirdly, mealybugs are highly amenable to classical biological control.

Hymenoptera parasites reported attacking *Paracoccus* spp. are *Adelencyrtoides* spp., *Aenasius* spp., *Alamella* spp., *Anagyrus* spp., *Aphycus* spp., *Clausenia* spp., *Gyranusoidea* spp., *Leptomastix* spp., *Prochiloneurus* spp., *Pseudectroma* spp., *Psedococcobius* spp., *Rhopus* spp. and *Pseudleptomastix* spp. (Noyes and Hayat, 1994). Parasites recovered from *P. marginatus* prior to any release in the Caribbean included *Anagyrus* spp. from Florida, St. Thomas (U.S.V.I.), Dominican Republic, and St. Kitts; *Acerophagus* spp. from St. Thomas, Dominican Republic, and St. Kitts; *Pseudleptomastix* sp. from the Dominican Republic; and *Prochiloneurus* sp. (hyper parasite) from St. Thomas, Dominican Republic, and St. Kitts.

The four primary parasites collected in Mexico by the United States Department of Agriculture (USDA), Agricultural Research Service (ARS) and cooperators in Mexico in 1999 were *Anagyrus californicus* (Compere); *Anagyrus loecki* Noyes and Menezes; *Acerophagus papayae* Noyes and Schauff; *Pseudleptomadtix mexicana* Noyes and Schauff; and *Pseudaphycus angelicus* (Howard).

All five species were screened through the quarantine facility at the USDA, ARS Beneficial Insects Laboratory in Newark, Delaware. An environmental assessment was completed on all five species and specimens eventually shipped to San Juan, Puerto Rico, for field release. Here they were cultured and mass produced in a cooperative effort with the Puerto Rico Department of Agriculture and USDA, APHIS, PPQ.

Puerto Rico. Biological control programs were developed cooperatively in Puerto Rico with the Puerto Rico Department of Agriculture. Residential hibiscus and papaya plants were more commonly found to be infested in Puerto Rico. In Puerto Rico, prior to the release of any exotic parasites, the primary parasites already found attacking *P. marginatus* were *Anagyrus loecki* (90%); *Acerophagus* (unknown species) (10%); and an unknown species, which averaged 2.8% parasitization overall in May 2000. The *P. marginatus* population density at the study sites at that time averaged 447 mealybugs per hibiscus terminal and was not being effectively regulated by the local parasites. Within eleven months from the initial release of parasites, the mealybug population density decreased to an average of 16.3 mealybugs per terminal, a significant reduction of 96.3%. By February 2003 the PM population density had declined by over 99% (Figure 14). The parasite ratio shifted in two months with *Anagyrus loecki* at 18% and *A. papayae* at 75%. By December 2000, *A. papayae* was the only species recovered (100%), indicating a potential shift in parasite dominance by a potentially new exotic species from Mexico.

Dominican Republic. The PM biological control program in the Dominican Republic was a cooperative effort with the Ministry of Agriculture, USDA, APHIS, PPQ and IS and Junta Agroempresarial Dominicana (JAD). In the Dominican Republic, the parasite complex on *P. marginatus* prior to exotic parasite releases early in 1998 consisted of *Anagyrus loecki* (67%), *Acerophagus* sp. (11%) and *Pseudleptomastix* sp. (2%), and an unknown species (20%). Baseline data samples of the mealybug density on papaya initiated in May 2000 averaged 598 mealybugs per leaf with an average of 1% parasitization. After the release of the exotic species of parasites from Mexico, the parasite complex later shifted with *Acerophagus papayae* becoming dominant at 50% within six months, as compared to a reduction of *Anagyrus loecki* (11%). The percentage parasitization at that time reached 51%. The overall density of the mealybug on papaya over a nine-month period decreased to 16 mealybugs per leaf, a reduction of 97.3% (Figure 15), similar to that in Puerto Rico, and a 97% reduction on hibiscus.

Preliminary studies indicate that the newly imported and released parasite species from Mexico possess the potential for significant impact on the population density of *P. marginatus* in papaya. The preexisting parasite complex in both Puerto Rico and the Dominican Republic, which is still being studied, appears to consist of similar species and genera found attacking *P. marginatus* in Mexico. It is believed that new species and/or biotypes of the same species introduced from Mexico may be more specialized and more adaptive to *P. marginatus* than the preexisting parasite species. The new forms caused a significant population density reduction of *P. marginatus*.

Guam. The report of papaya mealybug in Guam is the first record of this pest in the Pacific. It has been spreading actively from the Caribbean towards the North and South American continents. There is a threat of this mealybug spreading to the Commonwealth of the Northern Mariana Islands in the north, Federated States of Micronesia and the Republic of Palau in the south, and the Marshall Islands and the Hawaiian Islands east of Guam. Whereas economic losses caused by PM have yet to be documented in Guam, there was adequate justification for controlling this pest in the Caribbean and the U.S. mainland and its territories.

Baseline data surveys for evaluation of PM population densities on *Plumeria* spp. and *Hibiscus* spp. and their local natural enemies were conducted June 24, 2002. The overall population density of the PM was significantly reduced by 83% over a three-month period from

24 June until September 25, 2002 at eight *Plumeria* spp. study sites, and reduced by 96% at four Hibiscus study sites. The percentage parasitization at the beginning of this program was zero at both *Plumeria* spp. and Hibiscus spp. study sites, all of which indicated that no local parasites were parasitizing PM in Guam in June when the baseline data was collected. By July and August, percentage parasitization had increased to 30.0% and 33.4% on Hibiscus spp. and 2.9% and 1.9% on *Plumeria* spp. respectively. The percentage parasitization on *Plumeria* spp. was low with this sampling technique, because of large PM populations and the inability of the sampling technique to detect low numbers of parasites. The actual density counts of samples per leaf revealed an average of 11.6% parasitization in September and an 82.5% reduction of the PHM population density since June (Figure 16).

By October, the percentage parasitization had reached an average of 43.6%. A major typhoon passed directly over Guam in December 2002 causing some damage and defoliation to the study sites, and delayed the timing of the next collection of the field samples for determining the density of the PM and the parasites. Both *Anagyrus loecki* and *Acerophagus papayae* have become established in Guam and appear to be the major biological control agents regulating the population density of the PM.

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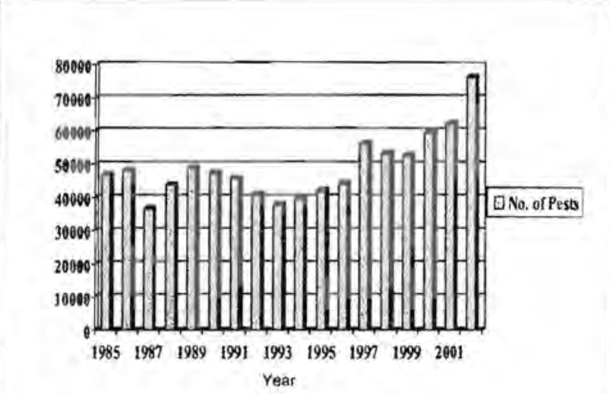

Figure 1. Reportable Interceptions of Agricultural Pests at US Ports of Entry

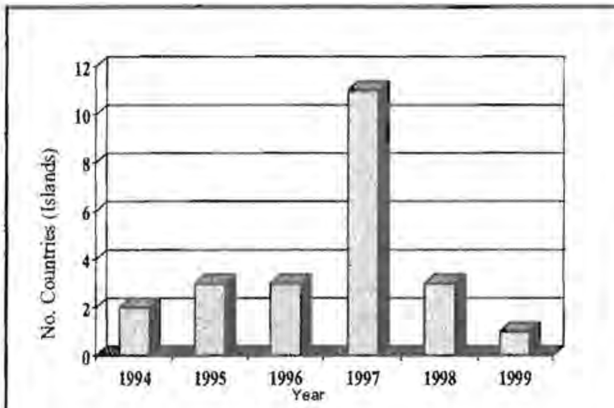

Figure 2. Spread of *M. hirsutus* in the Caribbean

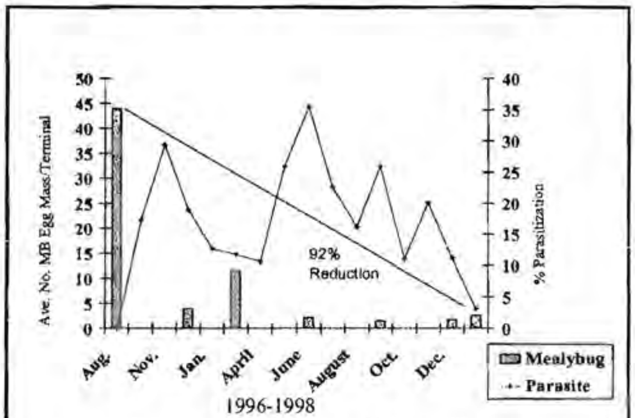

Figure 3. Impact of parasitoids on PHM in St. Kitts, West Indies (Hibiscus)

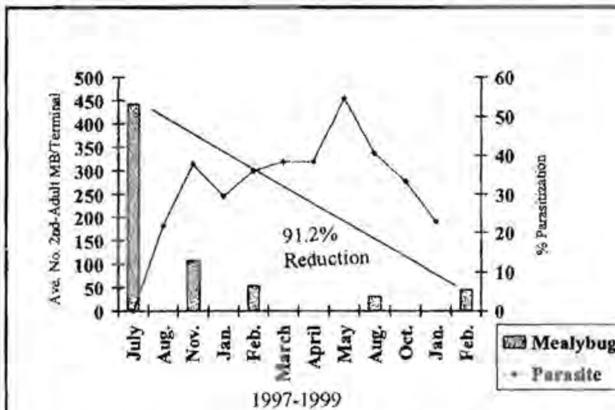

Figure 4. Impact of Parasitiods on PHM in St. Thomas, U.S.V.I. (Hibiscus)

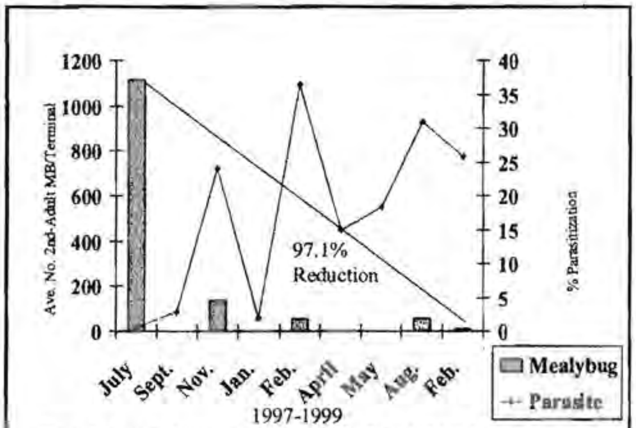

Figure 5. Impact of parasitoids on PHM in St. Croix, U.S.V.I. (Hibiscus)

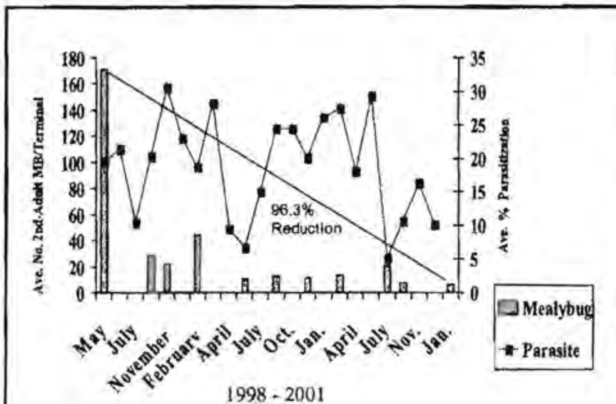

Figure 6. Impact of parasitoids on PHM in Puerto Rico (Hibiscus)

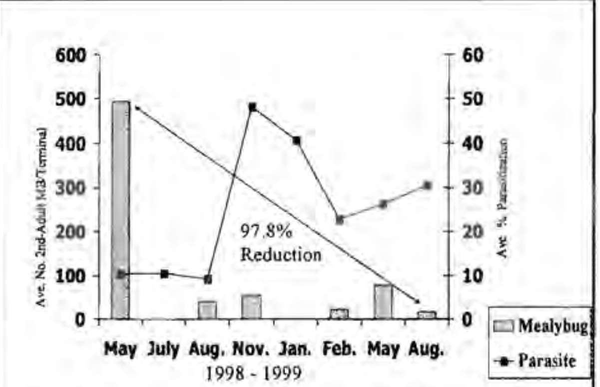

Figure 7. Impact of parasitoids on PHM in Vieques, Puerto Rico (Hibiscus)

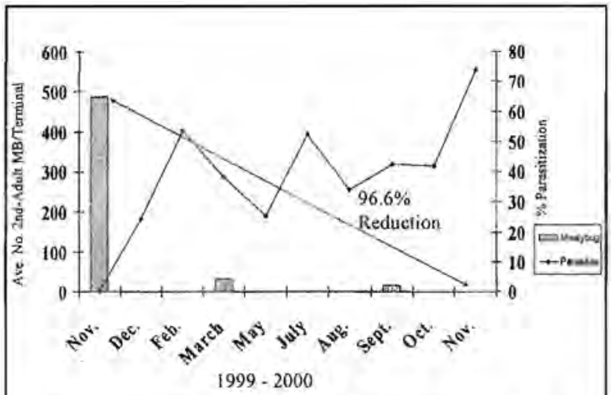

Figure 8. Impact of parasitoids on PHM in Belize, Central America (Hibiscus)

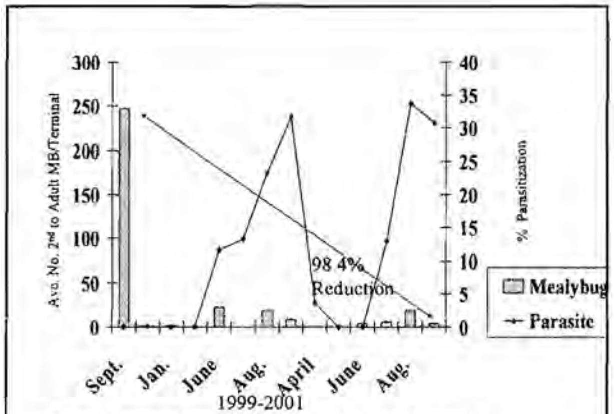

Figure 9. Impact of parasitoids on PHM in California (Mulberry)

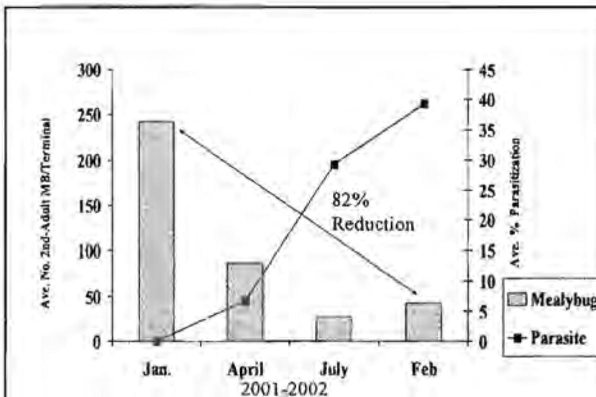

Figure 10. Impact of parasitoids on PHM in the Bahamas (Hibiscus)

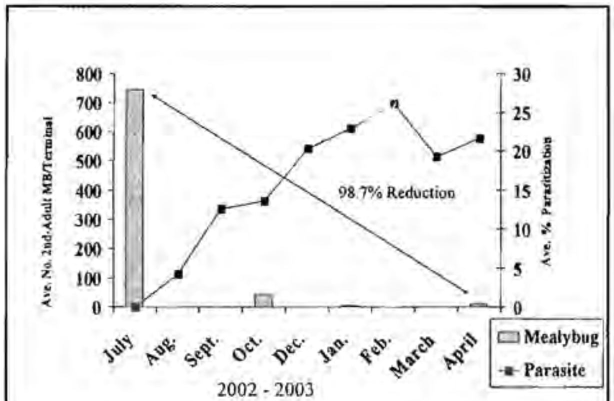

Figure 11. Impact of parasitoids on PHM in Florida (Hibiscus)

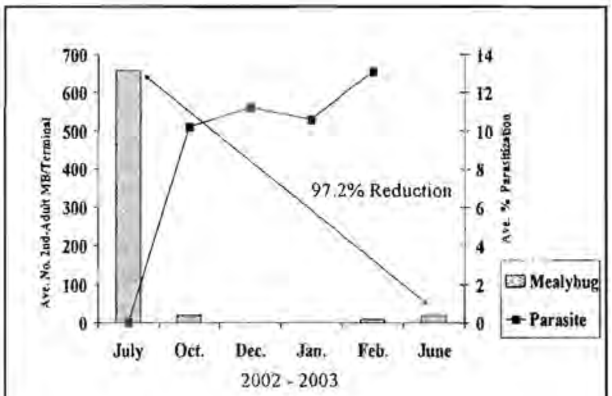

Figure 12. Impact of parasitoids on PHM in Haiti (Hibiscus)

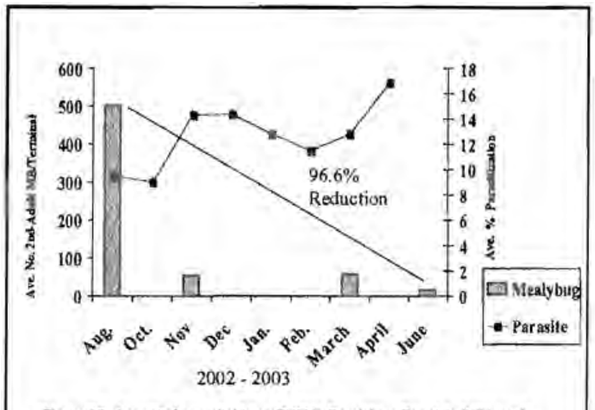

Figure 13. Impact of parasitoids on PHM in Dominican Republic (Hibiscus)

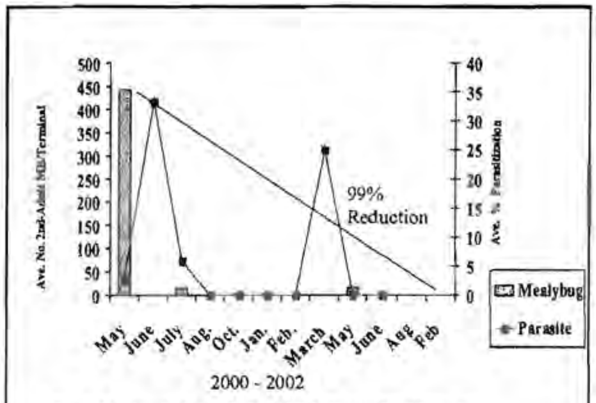

Figure 14. Impact of parasitoids on PM in Puerto Rico (Hibiscus)

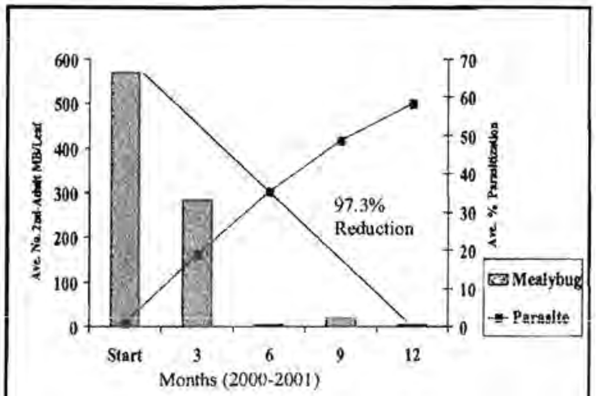

Figure 15. Impact of parasitoids on PM in the Dominican Republic (Papaya)

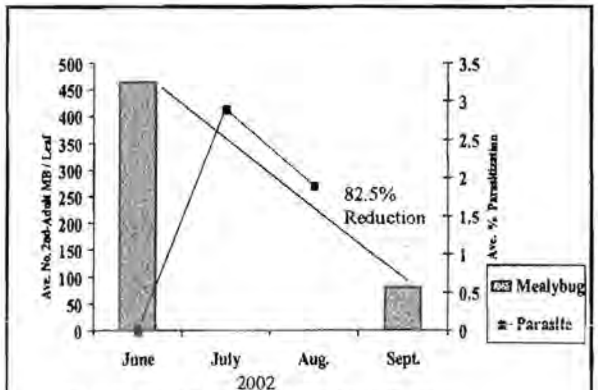

Figure 16. Impact of parasitoids on PM in Guam (*Plumeria* spp.)

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INVASIVE EXOTIC PLANTS IN NATURAL AREAS OF THE CARIBBEAN BASIN: QUANTIFYING ECOLOGICAL EFFECTS AND FORMING MANAGEMENT PARTNERSHIPS

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ABSTRACT: Invasive non-native plant species are causing worldwide economic and ecological damage. As an example, the State of Florida spends over 20 million dollars each year to manage just a few of the worst problem species. Many of the same plant species are also spreading into the Caribbean. Most of the introductions in Florida have been for agricultural purposes, including horticultural production. Only a few of these have become serious problems, but the consequences of these few are focusing state, national, and international attention on invasive pest issues. Invasive exotic plant research is underway within the U.S. Virgin Islands National Park to examine the effects these plants have on native flora. Research conducted in the U.S. Virgin Islands is being conducted through a grant from the U.S. Department of Agriculture's Tropical and Subtropical Agricultural Research (T-STAR) Program through the University of Florida. Specifically, the project is comprised of four components: 1) survey the invasive non-native plant species, including agricultural introductions, currently existing in the natural areas of the U. S. Virgin Islands and major Cays; 2) document the ecological effects of invasive exotic plant species on native plant cover, richness, and diversity; 3) examine the effect feral ungulates (donkeys) have on native and exotic plants as well as restored ecosystems and; 4) restore a section of protected natural Virgin Islands habitat within the Virgin Islands National Park by removing invasive non-native plant species and replacing them with native plant species from local propagules. Today, exotic plants infest nearly 2.6 million acres in the U.S. National Park System. In response to the degradation of native natural ecosystems service-wide caused by invasive exotic plants, the U.S. National Park Service has established nine tactical Exotic Plant Management Teams. Modeled after the approach used in wildland firefighting, the teams provide highly trained, mobile strike forces of plant management specialists to assist parks in the control of invasive exotic plants. Under the administrative and financial assistance of the Florida Partnership Team (created in 2000), the Caribbean team has been formulated this year. Work is coordinated through a liaison and contracted companies provide the labor for control.

KEY WORDS: Caribbean plants, invasive exotic plants, ecological effects, Virgin Islands National Park, National Park Service Exotic Plant Management Teams

INTRODUCTION

Invasive species are costing the world billions of dollars. In the U.S. alone, annual environmental damage and losses attributed to invasive species have been estimated at more than $138 billion (Pimentel et al., 2000). Pest plants in the continental U.S. include an estimated 5,000 introduced species (versus 17,000 native species) that have escaped and now maintain themselves in natural areas (Morse et al., 1995). In Florida, an estimated 900 species out of 25,000 species introduced have become established in natural areas (Frank and McCoy, 1995; Frank et al., 1997; Simberloff et al., 1997). This is about 23 percent of the total flora (over 4,000 taxa) of ferns, fern allies, and seed plants native to, or naturalized in Florida (Wunderlin, 1998).

The commercial importance of many agricultural introductions further complicates the issue (Stocker, 2001). For those introduced invasive species for which records exist, approximately 90% were introduced deliberately (Gordon and Thomas, 1997), and many of those were brought in for crop production and horticultural use.

Invasive non-native species displace native plant species (Callaway and Aschehoug, 2000; Morse et al., 1995), alter species proportions (Callaway and Aschehoug, 2000; Gould and Gorchov, 2000), alter nutrient (Evans et al., 2001; Mack et al., 2001; Scott et al., 2001) and fire patterns, modify geomorphology, hydrology, and biogeochemistry (Gordon, 1998), and reduce recreational use of resources (OTA, 1993). Florida spends about 20 million per year to control a small proportion of the total invasive non-native plant species in natural areas.

The beginnings of similar impacts are occurring in the Virgin Islands. The three islands of the U.S. Virgin Islands (St. Croix, St. Thomas, and St. John; 34,447 hectares total) are dominated by mountainous terrain and surrounded by coastal lowlands (Lewis, 1989). On the island of St. John alone, eleven vegetation types have been mapped, including mangroves, salt flats, pasture, upland moist forest, gallery moist forest, basin moist forest, dry evergreen forest, dry thicket and scrub, thorn and cactus, disturbed vegetation, and rock and coastal hedge. About 63% of the island is in the dry evergreen forest category and 17% in the combined moist forest category. The upland moist forest contains some virgin stands with minimal invasive non-native plant species impact (Virgin Islands National Park, 2001).

While several publications list the native plants of the Virgin Islands, little research has been published on the extent of the many species of non-native plants, and the ecological and economic consequences of their distribution and spread. To date, 747 species of vascular plants have been identified from St. John, 642 (86%) of which are native to the island. The species are found in 117 families, 12of which are introduced (Virgin Islands National Park, 2001). While the exact geographical origin and date of introduction of many plant species to Caribbean islands is disputed or unknown, several species with known origins are expanding their populations without cultivation into natural areas of the Greater Antilles. Some invasive exotic plant species within the Virgin Islands National Park, St. John are listed in Table 1.

Similar historically to other Caribbean islands, European settlement patterns and plantation systems significantly altered the biology and ecology of the Virgin Islands by removing native forests, building structures, terraces, rock walls and roads, and importing vegetation and mammals. The National Park Service Organic Act (16 U.S.C. 1 et seq [1988], August 25, 1916, sc. 408, 39 Stat. 535) mandates the parks to "conserve the scenery and the natural and historic objects and the wildlife therein...{to} leave them unimpaired for the enjoyment of future generations."

The park's internationally significant natural resources enabled the designation as an international biosphere reserve in 1976 and it is one of the few biosphere reserves that have both marine and terrestrial resources. The park was included in the United Nation's Biosphere Reserve System as a representative example of Lesser Antillean cultural and natural ecosystems (Virgin Islands National Park 2001). Changes to the natural communities from the human actions in the parks, including the continuous and unabated invasion of exotic and feral species, are contrary to the intentions of the National Park Service Organic Act (Virgin Islands National Park 2001). The Act authorizes the parks to eradicate exotic and invasive species. Many of the species introduced to the Virgin Islands are recognized as having "negative impacts on our indigenous species of plants and animals... {however} these impacts have never been quantified. Quantification would enable NPS to realistically prioritize species in terms of threats and guide us in the development of management measures to address the threats" (Virgin Islands National Park, 2001).

This research project proposes to categorize and to begin to identify ecological and economic impacts created by invasive non-native plants within the park and other Virgin Island natural areas, and may also serve to assist park managers in quantifying management priorities with regard to maintenance and control of these species.

Three U.S. Federally listed endangered species occur in the Virgin Islands, but it is not known to what extent these species are impacted by invasive non-native species. Forty-eight additional endangered species are listed by the government of the Virgin Islands (Gibney et al., 1991). While invasive non-native plants have been recognized as a significant impact to threatened and endangered plants (Ludlow, 1995) and wildlife (Gaudet and Keddy, 1988), nothing has been reported on impact in the Virgin Islands.

Of the 125 non-native species in Florida listed as threats to native habitats by the Florida Exotic Pest Plant Council (FL EPPC), at least eight are also invasive non-native species found in the U.S. Virgin Islands: *Abrus precatorius*, *Albizia lebbeck*, *Casuarina equisetifolia*, *Melia azedrach*, *Schinus terebinthifolius*, *Callisia fragrans*, *Murraya paniculata*, and *Terminalia catappa* (Acevedo-Rodriguez, 1996). Probably because of similar tropical/subtropical climates, at least nine of the most widely known invasive non-native plant species found in Florida natural areas are native to the West Indies: *Calophyllum antillanum*, *Hymenachne amplexicaulis*, *Lantana camara*, *Rhoeo spathecea*, *Solanum tampicense*, *Tectaria incisa*, *Solanum jamaicense*, *Wedelia trilobata*, and *Xanthosoma sagittifolium* (Langeland and Burks, 1998; Wunderlin, 1998).

In addition to the need for information about the distribution and impact of invasive non-native plant species, there are fundamental hypotheses about the reasons why some native plant systems are so easily invaded that deserve experimental testing. Many authors have suggested that escape from natural enemies is the primary reason why invading non-native plants succeed in novel habitats, but competitive use of nutrients may be equally, or more, important than absence of natural enemies (Callaway and Aschehoug, 2000). While numerous authors continue Charles Elton's (1958) hypothesis that increasingly diverse communities should be decreasingly susceptible to invasion by non-native species, several studies have suggested that species diversity alone does not affect plant community invasibility (Dukes, 2001). Nutrient analysis and spatial assessment of native and non-native species distribution will provide opportunities to support or refute ecological premises important to both Florida and the Caribbean islands.

After habitat loss, invasive or exotic species are considered the greatest threat to global biological diversity; they are implicated in the listing of 42% of all species protected by the Endangered Species Act. Additionally, approximately 2.6 million acres of National Park Service (NPS) lands are infested by invasive plant species (U.S. Department of Interior, 2003). The threat of invasive plant species has grave implications for the preservation of natural and cultural resources throughout the NPS system.

To effectively combat exotic plant species, the National Park Service's Biological Resources Management Division (BRMD) established the Exotic Plant Management Teams (EPMT) in 2000. The EPMTs are modeled after the coordinated rapid response approach used in the U.S. for wildland fire fighting. The first test of the EPMT concept was conducted in 1997 at Lake Mead National Recreation Area in Nevada and Arizona. The success of that EPMT led to the establishment of additional EPMTs funded by the Natural Resource Challenge Program.

EPMTs are part of the long-term control of invasive plants set by the Natural Resource Challenge and contribute to individual park goals by, "containing exotic plant disturbances." They also satisfy the need for implementation of Executive Order 13112 on invasive species.

The success of the EPMTs is based on the team's ability to adapt to local conditions and needs. Each team employs the expertise of local citizens and the capabilities of local agencies. Each EPMT sets its own work priorities based on the severity of the threat to high quality natural areas and rare species, the extent of a target infestation, the probability of successful control and potential for restoration, the opportunities for public involvement, and the park's commitment to follow-up monitoring and treatment. Thus, each EPMT provides a highly trained, mobile strike force of invasive plant management specialists to assist NPS units with limited resources and expertise in the control of invasive exotic plants.

METHODS

Three study sites have been established on the north shore of St. John Island within the Virgin Islands National Park. The study area is located in the Maho Bay Quarter in the Cinnamon Bay campground facility. The site is strategically located near existing park infrastructure to facilitate interpretation of the research and restoration. Vertical relief in the Park can be extreme (30 degrees or greater), and this site was selected to accommodate safe researcher, volunteer, and visitor access.

Each site is divided into three vegetation treatments: one vegetation treatment has existing vegetation, never to be touched; one vegetation treatment has invasive plants removed continually; the third vegetation treatment has invasive plants removed, continually, and native plants added. Each plot is approximately 10 meters (along the fence) by 7 meters. Each of the three vegetation treatments is divided in half by a fence designed to exclude feral donkeys from the campground (the final variable in the study - feral animal effects). Thus, each site has six plots - each of three vegetation treatments divided by the fence.

A transect is established 3.3 m away from the fence, paralleling the fence, and with a minimum of 1 m from the plot edge, and 2 m from other transects. The treatment is applied to all the area within the treatment plot, not just the sampling line (transect line), and including the buffer zones. Within each plot, sub-plots (50 cm X 20 cm) are placed at 1-m intervals along the transect. Canopy coverage is estimated, using size classes (>0-5%=1; >5-25%=2; >25-50%=3; >50-75%=4; >75-95%=5;>95-100%=6) for each species within each sub-plot. Canopy coverage follows Daubenmire (1959), visualizing a polygon surrounding the outer edge of the plant, and ignoring small gaps in canopy. Any vegetation that occurs in the plot is included, regardless of where it is rooted. A slight revision in technique has been incorporated to account for invasive exotic plants that are rooted several meters outside of the plot, yet extend over it; some of these are road-side trees that were not removed. Coastal dry forest habitats typify the study plots as defined by Woodbury and Weaver (1987). *Triphasia trifolia* (limeberry) and *Melicoccus bijugatus* (Genip) are cultivated and now naturalized plants (shrub and tree, respectively) found on all three U.S. Virgin Islands and throughout the West Indies, including the natural habitats of the study site.

A member of the Rutaceae family, *T. trifolia* is a relative of commercial citrus species and was apparently introduced to the U.S. Virgin Islands as an agricultural species for use as a food crop and/or ornamental shrub. *T. trifolia* has been used throughout the Caribbean for the production of jam from the small, fleshy fruit (University of Guam, http://www.uog.edu/cals/site/POG/triphas.html), and seeds for propagation remain commercially available from the U.S. (e.g., Tropilab Inc.; http://www.tropilab.com/lime-ber.html).

A member of the Sapindaceae family, *M. bijugatus* is native to northern South America but has been planted and naturalized throughout Central America and the West Indies. It was apparently introduced on St. John in the eighteenth century (Acevedo-Rodriguez, 1996).

Although *T. trifolia* and *M. bijugatus* were probably introduced in the past as beneficial agricultural products to the U.S. Virgin Islands, they have escaped cultivation and are spreading throughout the Island's natural areas. *T. trifolia* was listed as a 1999 Florida Exotic Pest Plant Council Category II pest plant in natural areas of Florida, indicating that professionals in the field determined the species to show a potential to disrupt native plant communities. It was dropped from the list in 2001 because of lack of research and identification of impact on the native plant communities invaded in Florida. Specific research on management and control of this species in natural areas is also lacking.

Restoration of the study site will include the physical removal of all *T. trifolia, M. bijugatus,* and other less abundant exotic species such as *Leucaena leucocephala* (tan tan), *Samanea saman* (rain tree), and *Delonix regia* (flamboyant tree) and maintenance of the site free of these species for the duration of the study, feral animal exclusion (primarily donkeys) by a fence dissecting the sites, and re-introduction of a suite of native plant replacements suitable for the site, which will be obtained from local propagules.

Numerous species of feral animals and their associated impact on native plant and animal communities in the U.S. Virgin Islands have been documented (Virgin Islands National Park, 2001). A change in forest structure and species composition can be attributed to the introduction of grazing feral animals such as goats, pigs, and donkeys. Without the continued supply of non-native food sources, the feral animals graze on native plant species such as the protected black mangrove, as well as introduce increased amounts of nutrients through their fecal material. Other impact on local threatened and endangered species such as native plant consumption and uprooting, shorebird and sea turtle predation, and distribution of invasive non-native plant seeds have been attributed to the host of feral animals inhabiting the U.S. Virgin Islands.

The fence dissecting the study area resulting in the exclusion of feral animals will hopefully facilitate the determination of impact on native communities caused by the presence of *T. trifolia* and donkeys. Using similar feral animal exclusion techniques, future research could include an in depth examination of the impact created by both feral animals alone and a combination of feral animals with invasive non-native plants on the native plant communities of the U.S. Virgin Island's natural areas.

RESULTS AND DISCUSSION

The study plots described above were sub-sampled in August of 2003 and the invasive exotic vegetation was subsequently removed from the two treatments in each plot in September of 2003. Additional sub-sampling of the plots is expected to occur in October of 2003. Anecdotally, the plots were comprised extensively with the exotic plants *T. trifolia* and *M. bijugatus* and stem densities reached a high of 38,000 per ha and 17,700 per ha, respectively. Established photo points revealed that the removal of the exotic vegetation from plots created a significantly different appearance since a relatively few native species remained post removal. The restoration of the third treatment in each plot (augmentation with native species grown from local propagules) is expected to occur in 2004 and subsequent sub-sampling will reveal the efficacy of this treatment.

Feral donkey exclusion has not been fully realized as several donkeys remain inside the fence. These are expected to be removed in October of 2003 and future sub-sampling on both sides of the fence will hopefully shed light on the role feral donkeys have on the vegetation existing in the plots.

Additional studies planned within the research plots include soil sample analysis and light attenuation studies. In addition to the applied research underway within the plots described, a survey of the natural areas of the three major U.S. Virgin Islands and associated Cays is underway to provide a cursory look at the abundance and distribution of invasive exotic plants in the territory. Surveys are being conducted by using a geo-referenced grid of the area with random points along the grid being sampled in each habitat type of the U.S. Virgin Islands. The results of these surveys will be available in 2005.

While applied research and area survey related to invasive exotic plants in the U.S. Virgin Islands is underway in 2003, The NPS has established a branch of the Florida Partnership Exotic Plant Management Team in the U.S. Virgin Islands. The new team was established in 2003 and the Florida Partnership EPMT name was changed to "Florida/Caribbean EPMT" to include the addition. The Caribbean extension of the team operates from the same organization and budget as the original Florida team, which was founded in 1999. A NPS staff liaison in Florida and one in the U.S. Virgin Islands coordinates with staff of area National Parks and expert local citizenry to organize and prioritize invasive exotic plant removal projects in the parks. Contracted labor is utilized to conduct the work on the ground and the liaison supervises the contractor by acting as a Contracting Officer Representative in the field to provide technical expertise in the exercising of the work contract.

The Caribbean parks in partnership with the Florida/Caribbean EPMT are the Virgin Islands National Park on St. John, and Christiansted National Historic Site, Buck Island Reef National Monument, and Salt River Bay National Historic Park and Ecological Preserve on St. Croix. The team will begin its first Caribbean project in the winter of 2004 on Buck Island off the northern coast of St. Croix. The 174-acre island comprises the terrestrial portion of the Buck Island Reef National Monument and contractors will systematically remove specific invasive exotic plants from the entire island over a six-week period. Removal methodology includes treating individual plants with specific herbicide basally and foliarly, as well as hand pulling.

The Florida/Caribbean EPMT is also embarking on the formation of international partnerships to share technical information and conduct joint projects with regards to the management and control of invasive exotic plants in natural areas throughout the Caribbean. Territories and nations that have shown interest in collaboration include Martinique, Puerto Rico, and the Dominican Republic. It is anticipated that through a U.S. Department of Agriculture (T-STAR) workshop in the near future concerning management and control of invasive exotic plants, additional nations will show interest in regional collaboration.

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Table 1. Some invasive exotic plants found within the Virgin Islands National Park

Family	Genus species	Common Name	Origin
Aloeaceae	*Aloe vera*	Aloe	Africa
Anacardiaceae	*Schinus terebinthifolius*	Brazilian Pepper	S. America
Araceae	*Syngonium podophyllum*	Arrowhead Vine	Mexico
Asclepiadaceae	*Cryptostegia grandiflora*	Rubbervine	Africa
Bignoniaceae	*Tecoma stans*	Ginger Thomas	Tropical America
Bromeliaceae	*Bromelia pinguin*	Wild Pineapple	Tropical America
Casuarinaceae	*Casuarina equisetifolia*	Australian Pine	Australia
Combretaceae	*Terminalia catappa*	West Indian Almond	Malaysia
Commelinaceae	*Callisia fragrans*	Basket Plant	Mexico
Dracaenaceae	*Sansevieria trifasciata*	Snake Root	Africa
Fabaceae	*Abrus precatorius*	Crab's Eye	Old-World Tropics
Fabaceae	*Albizia lebbeck*	Woman's Tongue Tree	Tropical Asia
Fabaceae	*Bauhinia monandra*	False Orchid	S.E. Asia
Fabaceae	*Leucaena leucocephala*	Tan Tan	C. America
Fabaceae	*Peltophorum pterocarpa*	Yellow Poinciana	Tropical Asia
Fabaceae	*Senna siamea*	Yellow Cassia	Burma, Thailand
Malvaceae	*Thespesia populnea*	Seaside Maho	Old-World Tropics
Meliaceae	*Azadirachta indica*	Neem	India, Asia
Meliaceae	*Melia azedarach*	Chinaberry	Old-World Tropics
Poaceae	*Urochloa maxima*	Guinea Grass	Africa
Polygonaceae	*Antigonon leptopus*	Coralita	Mexico, C. America
Rubiaceae	*Morinda citrifolia*	Noni	Asia, Australia
Rutaceae	*Triphasia trifolia*	Limeberry	Asia, Phillipines
Sapindaceae	*Melicoccus bijugatus*	Genip, Kenip	S. America

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EDUCATION, TRAINING AND TECHNICAL ASSISTANCE REQUIREMENTS FOR PROTECTING THE CARIBBEAN, LATIN AMERICA AND THE UNITED STATES FROM INVASIVE SPECIES

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ABSTRACT: Trends in market regionalization, market globalization, open trade policies, and market availability facilitates increased trade of agricultural commodities, but implies increased risk for pest introduction and increased levels of pest tolerance. These changes require that the countries examine their phytosanitary status and collaborate to standardize phytosanitary permits. The World Trade Organization Agreement on the Application of Sanitary and Phytosanitary Measures (SPS) mandates the adoption of guidelines and requirements for agricultural trade. A country's responsibility for protecting itself and its trading partners from pests becomes more demanding as the level of international trade in agricultural products increases in volume and complexity. Thus, countries are trying to ensure that measures are in place to meet these requirements. At the same time, the SPS agreement ensures that the requirements are based on accurate scientific data, which are not readily available in all countries. On the other hand, resource limitations, downsizing, and continuous reorganization of agricultural quarantine, surveys and inspection programs are not always in keeping with the increased market trends. The expected outcome could be an increase in the number of pests introduced and established in the region. In Latin America and the Caribbean islands this problem is underscored by abundance of entry points, low number of phytosanitary personnel, limited access to equipment, technology, the lack or limited access to literature, and insufficient information on presence and distribution of pests in the region. The creation of the U.S. Department of Homeland Security supports activities that improve pest surveillance, early detection, rapid diagnostic of animal and plant diseases and pest threats, but the problem of invasive species persists. Knowledge of Latin America and the Caribbean islands strengths, weaknesses, and training needs will help to determine where the threats to American plant resources exist and what impact they could have if they enter the United States. In this paper, we present an analysis of the education, training and technical assistance requirements for protecting Latin America and the Caribbean and the U.S. from Invasive Species. The analysis contemplates existing training resources, the need for pest surveys, risk potential and assessment, eradication and management programs, and the need for a regional approach for invasive pest management.

KEY WORDS: training needs, technical assistance requirements, phytosanitary status

INTRODUCTION

Developments in international trade brought about by agreements under the World Trade Organization (WTO) are designed to facilitate trade. The WTO Agreement on the Application of Sanitary and Phytosanitary (SPS) Measures mandates signatories to adopt guidelines and requirements for agricultural trade. Countries have a right to protect themselves and their trading partners and actions should be based on science. Additionally, trade liberalization is high on the agenda of the negotiations in the Western Hemisphere under the Free Trade Area of the Americas (FTAA), which is to be in place by 2005. There are also the arrangements under the Cotonu Agreement between the European Union and the Africa Caribbean and Pacific Grouping. In the CARICOM Region, the CARICOM Single Market and Economy (CSME) seeks to deepen and widen Caribbean integration.

With these policies for increased trade comes the increased movement of invasive species. There can be environment changes through loss of biodiversity and the entry of exotic pests, which can affect agricultural production, trade, food security and competitiveness, the environment, and public health.

National quarantine institutions must operate with an expanded vision and broader mandate. The ministries of health, trade, external affairs, and the private sector are recognized as cooperators. Decisions are based on risk analysis, harmonization, equivalence and other elements as outlined in the SPS Agreement. In this paper, the status of the countries' capabilities is discussed; and their education, training, and technical assistance requirements are identified. Knowledge of Caribbean islands strengths, weaknessess, and training needs will help to determine threats to the region, where they exist, and what impact these invasive species could have if they enter a neighboring country or trade partner.

STATUS OF PLANT HEALTH

All the countries have plant protection legislation, which requires the existence of a plant quarantine service. However, in some countries the legislation is not in keeping with WTO requirements. A model Plant Protection Act has been developed for the Caribbean by the Food and Agricultural Organization (FAO) and is presently being introduced. The concern though is that development of national legal instruments takes a very long time in these countries.

The Plant Health Service varies in structure in the various countries. In some, Plant Health Service comprises the Plant Protection and Quarantine Units, in which the same staff is responsible for quarantine and general plant protection. In others, the two are separated and plant protection staff provides research support to plant quarantine, which performs a purely regulatory role. There is support from the Customs in all the countries even where a Customs Declaration Form is not in use. However, support from Immigration is not always available, as most countries do not consider it necessary to sensitize that Agency. Further, in some countries, the passenger is not obligated to have a form.

Surveillance at the ports of entry varies. In some countries, plant quarantine activity is separated from animal quarantine but there is excellent collaboration between them. In some countries the quarantine officers are cross-trained so that one officer is stationed at a port of entry and the appropriate entity is alerted when required. The number of designated ports of entry varies per country but not all the ports are manned; thus the collaboration of other agencies (customs, police, port authority, coast guard) and the public, including shipping agents, is solicited for effective quarantine operations. In this situation, the plant quarantine officer visits the port at specific times or on request. Additionally, in some countries, the plant quarantine officer may receive a copy of the carrier's manifest in order to time port visits. However, there are many unofficial ports in the countries where trading and smuggling can take place.

All countries try to control international garbage disposal. However, inspecting all tourist boats and yachts is not possible. Where accepted, garbage generated by the international vessels is destroyed by burning or burying at a landfill. A problem, however, is that in some countries the quarantine officer does not board carriers and international garbage may be off loaded, stored, and transported without supervision. Additionally, burning or burying may not be done immediately thus creating opportunity for scavenging. Also it is difficult to monitor the yachts whose garbage may not be disposed of into the bins provided.

All countries issue phytosanitary certificates, but some trading partners have no confidence in these certificates as there is the suspicion that produce inspections are either not done or are not done properly. All countries require import permits for the importation of planting material. Some countries require permits for all plant material entering the country. Inspectors at the ports of entry do not have an inspection manual thus indicating insufficient uniformity in inspection procedure in a country. The high volume of inspections or the lack of access to experts in the relevant discipline prevents consultations with taxonomists for a rapid response once a pest or disease is detected. Few countries have reference collections for rapid consultation by the inspectors.

Port facilities vary amongst countries. At all ports where personnel are stationed, there is an office with equipment varying from a desk and a chair to a fully equipped office with refrigerator, workbench, and examination equipment including a stereoscope. Most countries have security bins for storing or disposing of confiscated plant material.

Not all quarantine officers have the basic equipment. If a quarantine treatment is required as a condition of entry by a country, the treatment may be done by the quarantine service, or a company is contracted and supervised by plant quarantine. However, that capability is not available in all countries, or the pest has escaped by the time the proper response/treatment is applied.

In most countries, there is a diagnostic laboratory located at the Ministry of Agriculture, but it is not always fully equipped or staffed. In addition to the Ministry of Agriculture's laboratory, a plant protection laboratory may be present at a University or a commodity organization, but it may not always be available for consultation.

Funding for the operations and maintenance of the plant quarantine service is from Government. In all cases, the amount is insufficient to support the activities and requirements for plant protection and quarantine services. Some countries charge fees for issuing of import permits and phytosanitary certificates but these fees are only for the paper work and not for the services provided. A fee for other plant quarantine duties is not common in most countries. Usually, the plant protection officers do not participate in negotiations of international standard setting. Recent participation at the meetings has been as a result of external funding, which is not sustainable.

Survey and detection programs are being undertaken for some major pests at the time of declaration of detection in other countries. Despite that, in many cases, pest detection is only after the pest has been established; therefore only containment or control can be affected. Most countries have a pest list, but this is generally incomplete and does not include quarantine pests.

The database of plant pests for the Caribbean, which was developed by FAO, is now out of date. Reference collections, where present, are generally incomplete, not properly maintained and in most cases consist only of specimens of an entomological nature. The collections are usually associated with universities, thus unavailable to inspectors at the point of entry. Database for invasive weeds and other organisms such as snails, viruses, and nematodes is lacking. Furthermore, there are few comprehensive lists or databases for pests present in each country. Additionally, even for strategic pests present in the region, there is evident lack of biological data, life history, host list, natural enemies, pest status, and geographical distribution.

All countries undertake some form of pest risk analysis to make decisions for entry of plant products, but do not record these despite the fact that some persons have been trained in recording of pest risk analysis. Although a model emergency action plan for the entry of exotic pests is available and has been introduced in most countries, only few now have a written plan. Those with a plan do not undertake emergency simulation exercises. Furthermore, none of the countries have a written emergency plan for any major quarantine pest. Information on pest interceptions and detections is provided to countries mainly through the FAO Newsletter, the IICA Plant Health Reports (IICA-PHR) based on reports received from other countries, and by professional organizations networks. Publication of the FAO newsletter is irregular and IICA-PHR is biannually. Therefore, dissemination of information on new pests is never timely. Additionally, there is a lack of relevant literature on exotic and endemic pests in the region.

The inspectors usually have training for preliminary diagnostics, but cannot provide positive pest identification, especially on exotic pests. Some of the countries have personnel in entomology and pathology to address plant health problems and to provide adequate and timely identifications. However, specialists in disciplines such as virology, weeds, nematology, and wild animal diseases are very limited in the region. Usually experts with an advanced degree in a relevant discipline are associated with universities, experiment stations and research centers. The experts provide "consulting services" to quarantine personnel, but the response may not be timely. Additionally, experts are scattered at different locations, thus increasing the difficulty of arranging a consultation. On many islands, there is lack of personnel with degrees in relevant disciplines.

The Caribbean Loop of Bionet International (CARINET) provides biosystematics support to the countries as required, but countries have complained about the high costs for pest identification and the non-timeliness of the results of these identifications. Training programs for identification of specific genera of concern have been organized through CARINET but additional training is required.

Most countries consider the number and level of training of quarantine staff to be inadequate. Some countries have all plant protection staff trained at least at the diploma/certificate level in agriculture. In a few others, only in-service training has been received by personnel, and their basic education is a high school certificate. Public awareness programs are being conducted annually in some countries to sensitize the public and related agencies and to solicit their support for plant health decisions.

EDUCATION, TRAINING, AND TECHNICAL ASSISTANCE REQUIREMENTS

Countries in the region face several significant challenges of maintaining an umbrella of protection and at the same time not impeding trade. These challenges will require plant health officials and inspectors to become increasingly involved in negotiations with other countries and in international arenas where sanitary import/export standards are being developed and applied.

The challenge requires training, education, and technical assistance to ensure the safe research, release, and movement of agricultural biotechnology and products. Areas such as emergency preparedness and response, international trade to resolve trade barriers related to sanitary and phytosanitary issues, threat assessment, risk analysis, and risk-reduction activities require attention.

The failure or success of plant quarantine programs and services is greatly dependant on the cooperation among public and private sectors and countries in the region. The cooperation and collaboration of the associated agencies should be solicited to ensure that national and international stakeholders and the global public have full confidence that it is safe.

In general, there are educational, training, and technical assistance needs in all aspects of quarantine, but a few critical areas are listed below:

1. Surveillance and early detection. State, academic, and private industry resources and coordination are needed. The incorporation of modern techniques for pest detection is needed in most countries.
2. Emergency response: how to prepare and implement response plans.

3. Eradication procedures for tropical agricultural threats in the event of an emergency.
4. Setting scientific standards upon which sanitary and phytosanitary issues can be more easily resolved.
5. Setting up reliable plant and animal pest, disease, and pathway information systems (database).
6. Identification and eradication of specific exotic pests and wildlife diseases, particularly those that are transmissible to humans and domestic livestock, and invasive species that impact ecosystems.
7. Developing/strengthening risk analysis capabilities, including assessment, management, and communicating risk factors to justify regulatory actions.
8. Specialized training programs for professionals to improve their capability and to provide the region with the necessary expertise. The integration of agricultural economists, statisticians, and pest managers is imperative.
9. Inspection methods and pest diagnosis.
10. Handling specimens for identification.
11. Collection and maintenance of reference material.
12. Creation and maintenance of a reliable database for all pests in the region, including all organisms and wild animal diseases.
13. Establishment and maintenance of pest-free areas and area-wide pest management.
14. Development of protocols for post-entry evaluation.
15. Development of a regional network of experts for rapid response and action.
16. Improvement of regulation and management of intentionally introduced organisms by universities, growers and other groups. Usually, there is little post-entry evaluation of organisms introduced by universities and research centers.
17. Establishment of networks in the region to identify needs, prioritizing, and evaluating approaches and methods as appropriate.
18. Protocol for inspection at ports of entry, including handling of international garbage, storage areas on carriers.
19. Development of sustainable quarantine system, including the development and use of appropriate quarantine forms, and cost recovery mechanisms.
20. Mechanisms for support and building institutional sustainability of quarantine system in particular and agricultural health and food safety in general.
21. Collaboration amongst Technical Cooperation Agencies to avoid duplication.
22. Pre-departure clearance procedures.

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A PEER REVIEWED PAPER

BRIDGING THE COMMUNICATION GAP BETWEEN ECONOMISTS AND BIOLOGICAL SCIENTISTS IN THE MANAGEMENT OF INVASIVE SPECIES

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ABSTRACT: Traditionally, the problem of invasive species, along with the decision-making framework established to prevent their introduction and spread, has been the domain of the biological scientific community. However, the scientific community is now calling for input by economics and other social science disciplines. The economic dimension of the problem of invasive species is growing from at least two perspectives. First, there is a greater awareness that economics is central to the causes of biological invasiveness, and that the consequences of pest incursions go far beyond direct damages or control costs. Second, modeling the economic and trade impact of regulations to combat the increased incidence of exotic pests and diseases, is becoming more important. This paper discusses the problem of invasive species from an economic perspective. It focuses on what economics has to do with the problem of biological invasiveness, and how the discipline can contribute to improving the decision-making framework.

KEY WORDS: invasive alien species, economics of invasive species, exotic pests and diseases, inter-disciplinary collaboration

INTRODUCTION

Although the subject matter of economics appears to be quite different from that of biology, there are considerable similarities between the two disciplines in terms of the fundamental analytical structures employed and the terminologies used. Concepts such as scarcity, competition, equilibrium, and specialization are common to both fields. Terms used in economics, such as industry, innovation, progress, exchange, and long run, have their counterparts in terms used in biology, such as species, mutation, progress, exchange, and natural selection (Hirshleifer, 1977). The striking similarity between the two disciplines is no mere coincidence since economics focuses on understanding and analyzing the social behavior of the most dominant species (*Homo sapiens*) in the animal kingdom. As famed economist Alfred Marshall wrote in the 1920s, "...it [economics] is a branch of biology broadly interpreted".

However, despite such similarities and evidence suggesting that at one time there was considerable communication between the disciplines[1], with the passing of time and with increased knowledge leading to greater specialization, the disciplines appear to have grown apart. A manifestation of this drift has been a tendency within the biological scientific community to treat the problem of biological pollution (i.e., the undesirable introduction and spread of invasive species) exclusively from an ecological perspective. Accordingly, the established decision-making framework for dealing with such issues is usually based on a set of

[1] Economist Thomas Robert Malthus was credited by biologists Charles Darwin and Alfred Russell Wallace for crucial insights leading to the discoveries of the idea of natural selection.

biological strategies centered on prevention/exclusion, early detection, eradication, containment, and suppression. There has been little or no involvement of economists in the decision-making process. Where economic analyses have been carried out, they are either peripheral to the biological study or conducted by non-economists, and as such are of limited use (US GAO, 2002)[2].

However, as management systems have become overwhelmed by increases in economic activity and the introduction and spread of invasive species, there appears to be a paradigm shift. The scientific community is once again calling for input by economics and other social science disciplines to answer questions and to assist with designing and carrying out strategic actions to address the problems.

The purpose of this article is to examine this change in paradigm by highlighting the economic dimensions of the problem of invasive species and demonstrating some of the key roles that economics can play in the fight against the growing incidences of biological pollution (invasions).

SHIFT IN PARADIGM

As mentioned earlier, whereas traditionally the problem of biological pollution has been considered the sphere of biological scientists, several factors appear to be causing a shift in this paradigm. These factors include:

1. Increased incidences of biological invasions linked directly to trade in agricultural commodities and movement of people.
2. Increased budgetary constraints and calls for greater public accountability—the need for trade-offs (Cost Benefit Analysis).
3. Increased demand for greater transparency of decisions taken and the growing influence of interest groups.
4. Increased need for better communication to implement desired strategies.

All of the above are more readily addressed within a social science framework. As a result, there have been calls for input by economics and other social science disciplines to contribute to improving the decision-making framework and to answer questions and carry out strategic actions to address the problem of biological invasions[3].

WHAT ECONOMICS HAS TO CONTRIBUTE TOWARD RESOLVING THE PROBLEM OF INVASIVENESS

The apparent disconnect between economists and biologists in some regard stems from a failure on the part of biological scientists to fully appreciate the discipline of economics and likewise on the part of economists to effectively communicate what the discipline is.[i] Most biological scientists consider economics to be all about estimating costs and determining the cost effectiveness of different treatments. However, as Perrings et al. (2002) made quite clear, economics is not just about calculating costs; rather it is a framework for understanding the complex causal interaction between human behavior and natural processes and for finding

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[2] A notable exception is Australia, where there is a long history of bio-economic cooperation among scientists owning to the special concerns about the invasiveness in an island economy.

[3] See Incorporating Science, Economics, and Sociology in Developing Sanitary and Phytosanitary Standards in International Trade, 2000, *Proceedings of a Conference, National Research Council*, Washington D.C.: National Academy Press. (Also available on-line at: http://books.nap.edu/openbook/0309070902/html/index.html.)

institutional and behavioral solutions to seemingly intractable problems (Perrings et al., 2002)[4]. Consequently, economic analyses are not only essential in providing more accurate and comprehensive assessments of the benefits and costs of control alternatives to increase the effectiveness and efficiency of publicly funded programs (assist with the allocation of scare resources), but equally essential in understanding the invasive species problem and in fashioning meaningful solutions.

Economics has traditionally been concerned with decision-making, particularly with what decisions are made rather than how they are made—although to some extent the discipline has started to embrace the latter. This is based on the premise that economic agents (individuals, firms) are capable of making rational decisions (i.e., decisions that will maximize or minimize some objective function within the framework of a given set of constraints). The notion of economics as an efficient allocator of scarce resources has had universal appeal and is responsible for the spread of economics into non-traditional areas. The discipline has developed a set of analytical capabilities that can aid decision makers in arriving at a set of rational and consistent decisions. Analytical capabilities, as pertaining to the problem of invasive species, include rational decision-making over a range of pest threats and management interventions, monetary valuations, cost-benefit analysis as a tool to evaluate public intervention strategies, allocation of scarce resources, and formal consideration of risk and uncertainty.

The discipline has also developed several empirical techniques to assess the value of non-marketed environmental and health effects, hence providing additional insights into whether and to what extent resources are being allocated efficiently. With the increasing demand for transparency in decision-making due to commitments to international agreements and pressure from various interest groups, effective and convincing communication is essential to implement the desired strategies. When such communications are based on sound economic analysis, efficiency in bargaining can be greatly enhanced.

ECONOMIC DIMENSION OF THE PROBLEM OF BIOLOGICAL INVASIVENESS

The economic dimension and interest by economists in the problem of invasive species are growing from at least two perspectives. First, there is an increasing awareness that economics is central to the cause of biological invasiveness, and that the consequences of pest incursions go far beyond direct damages or control costs. Second, modeling the economic and trade impact of technical trade barriers is becoming more important.

Economics is central to the cause of biological invasiveness, since most cases of invasiveness can be linked to the intended or unintended consequences of economic activities (Perrings et al., 2002). The increased spread of invasive species reflects rapid globalization and trade liberalization-economic phenomena. These developments have spawned greater long-distance hitchhiking by invasive species of pests and diseases, especially in the trading of live animals and horticultural and raw animal products. The Animal and Plant Health Inspection Service of the United States Department of Agriculture (USDA/APHIS, 2001) has cited a dramatic increase in the incidence of invasive pests and diseases in the United States. Specifically, the study noted the increased outbreak of exotic fruit fly infestations in California and Florida, the entry of the Asian longhorn beetle into New York and Illinois, the introduction of the Asian gypsy moth in North Carolina and Oregon, and the infestation of citrus canker in Florida (USDA/APHIS, 2001).

[4] See Incorporating Science. Economics, and Sociology in Developing Sanitary and Phytosanitary Standards in International Trade, 2000, *Proceedings of a Conference, National Research Council*, Washington D.C.: National Academy Press. (Also available on-line at: http://books.nap.edu/openbook/0309070902/html/index.html.)

It is only now being widely recognized and acknowledged, the extent of the damage and cost for the eradication and control of invasive species. For example, invasive species can harm agricultural systems and native plants and animals, particularly endemic species because their natural predators and parasites are usually not present in the new environment. Thus, an invasive species that is not a pest in its native land could cause significant damage in a new environment. In the extreme, such damage could lead to the loss of biodiversity. One example is the Asian longhorn beetle, which was first discovered in the U.S. in New York, in 1996, and Chicago, in 1998. This beetle is expected to damage millions of acres of hardwood trees throughout U.S. forest and suburban landscapes. State and local governments have already invested more than $30 million to eradicate this pest and to protect 6.7 million trees in the infested regions. Another example is the eradication of citrus canker in Florida, which has cost the state over $300 million dollars since 1996 (Macdonald and Van Wilgen, 2002; FDAC, 2002).

Invasive species can adversely affect important environmental service flows such as cropping systems, livestock grazing, and water systems used for human consumption and recreation (e.g., when pests clog rivers, irrigation systems, and shorelines). In addition, invasive species can have negative impact on ecological services provided by one resource for other resources or an entire ecological system (Evans et al., 2002).

As noted earlier, modeling economic and trade impact of measures to stem the arrival and spread of invasive species is becoming an area of interest to many trade economists. While sanitary and phytosanitary measures are within the rights of a country for economic and social prosperity, they can also impose unnecessary social costs, thwart commercial opportunities, and reduce competition and economic growth. Sound economic analysis can assist with the design and implementation of these measures to ensure the benefits exceed the costs.

ASSESSING THE ECONOMIC CONSEQUENCES OF INVASIVE PESTS AND DISEASES

Considerable effort is being devoted to assessing the full economic impact of invasive pests and diseases. The goal is to develop effective management programs to help prevent, control, or mitigate such invasions. Previously, the focus was on identifying the most cost-effective means of treatment for outbreaks. Now the emphasis is on the benefits and costs of managing a particular pest and/or disease.

Assessing the economic consequences is both challenging and imprecise. As noted earlier, the full range of economic costs of biological invasions goes beyond the immediate impact on agricultural producers. Often included are secondary and tertiary effects such as shifts in consumer demands, changes in relative input prices, and loss of important biodiversity and other natural resource and environmental amenities.

The range of economic impact can be broadly classified into two categories: direct and indirect (Bigsby and Whyte, 2001). Direct impact is host specific and affects a particular pest or host disease. Indirect impact is non-host specific, since it is created by the presence of a pest rather than by the pest-host dynamics/public health issues such as compromising key ecosystem functions, general market effects such as changes in consumer attitude toward a given product, research requirements, market access problems, and impact on tourism and other sectors of an economy.

In addition, there are six types of economic impact: (1) production; (2) price and market effects; (3) trade; (4) food security and nutrition; (5) human health and the environment; and (6) financial cost (FAO, 2001).

Production Impact—This is considered the most direct economic impact associated with the host, resulting in the loss or reduced efficiency of agricultural production (e.g., yield decline).

Even though production impact may be relatively easy to identify, it can be difficult to measure. Disease can have long-lasting effects on the host in ways that are not always obvious. In livestock, for example, there could be delays in reproduction, resulting in fewer offspring. Pesticides applied to treat a given pest could pollute soil and surface water. Sometimes it is hard to distinguish production impact from another impact, such as climate.

Price and Market Impact—Outbreaks of pests and diseases can directly affect the quantities of commodities demanded or supplied. The exact impact on the market and the duration of the impact depend on several factors, including the nature of the pest or disease, market size, and demand and supply elasticities. In cases where consumer health is involved, as in the recent outbreak of bovine spongiform encephalopahy (BSE), consumers' perception about an implicated product and a country's ability to produce safe food after an outbreak or illness can have a devastating effect on marketing. In addition, a range of secondary effects may result from the multiplier effect.

Trade Impact—The introduction and/or spread of invasive species can have major trade implications that could outweigh direct production losses. Trade impact depends on a number of factors, including the policy response of trading partners to news about outbreaks, the importance of traded commodities, the extent of the damage, and the elasticity of demand and supply. In addition, losing a competitive advantage in the export market or premiums from supplying disease-free products negatively impacts trade. These concerns are real because unaffected countries will either prohibit the entry of commodities from the affected country or establish a set of precautionary measures. In either case, competitive trade advantages could be lost.

Food Security and Nutrition Impact—The extent to which invasive pests and diseases reduce the domestic supply of foods directly or restrict a country's international trade could harm its food security, especially for developing countries.

Human Health and the Environment Impact—It is difficult to assess the human health and environmental impacts of invasive pests and diseases because the impact is not always fully understood. Available evidence suggests that the incidence of invasive zoonotic and parasitic diseases is growing and that their health and socio-economic impact are increasingly being felt in both developed and developing countries.

Financial Cost Impact—Measures taken at the individual, collective, and international levels to control, eradicate, or mitigate invasive pests and diseases may have budgetary implications. Such costs include inspections, monitoring, prevention, and response. Estimating this economic impact requires biological and non-biological information that involves considerable time and expense. Most studies have easily calculated financial cost impact such as costs for control, eradication, and prevention and expected losses in enterprise productivity. However, such an approach is shortsighted since, in several cases, the indirect effects arising from (say) the trade impact could easily outweigh production loss impact. A recent GAO report commented on this problem in its observation that:

"The scope of existing studies on the economic impact of invasive species in the United States ranges from narrow to comprehensive, and most are of limited use for guiding decision makers formulating federal policies on prevention and control. Narrowly focused estimates include analyses of past damages that are limited to certain commercial activities such as agricultural crop production and simple accounting of the money spent to combat a particular invasive species. These estimates typically do not examine economic damage done to natural ecosystems, the expected costs and benefits of alternative control measures, or the impact of possible invasions by other species in the future.... In general the more comprehensive the approach used to assess the economic impact of invasive species, the greater its potential usefulness to decision makers for identifying potential invasive species, prioritizing their economic threat, and allocating resources to minimize overall damages" (U.S. GAO, 2002, p. 3).

In addition, valuing non-market impact can be challenging because usually there is no direct market valuation. In order words, it is hard to identify any existing market, so there is no information on prices, costs, profits or quantities. Examples of non-market impact include environmental effects and loss of biodiversity. However, as noted earlier, economists have devised, and continue to refine, methods to quantify such impact. In this regard, use is made of techniques such as contingent valuation, contingent choice, contingent ranking, and conjoint analysis. These techniques utilize microeconomics, welfare economics, and econometrics in their analysis. Whereas a description of each of these techniques is beyond the scope of this paper, suffice it is to say the main intent of these approaches is to infer the value society ascribes to such non-market goods and services[5].

A more general measurement problem is the unavailability of data, especially when there is no disease history. Complications may also arise from the uncertainty of the scientific evidence about the probability of entry and establishment of a pest or disease, the rate at which it spread, and the extent of the damage. Closer collaboration between economists and biological scientists, as well as the increased availability of computer software programs (such as the Excel @RISK program that combines dynamic simulation procedures with probability distribution), allows analysts to combine actual, but limited, data with theoretical modeling in determining potential impacts.

MODELING THE IMPACT OF SANITARY AND PHYTOSANITARY REGULATIONS

The need for a government to protect its citizens and environment against imported externalities (such as invasive pests and diseases) is embraced by the WTO Agreement[6], which promotes increased trade among countries. One way to safeguard a nation's welfare is to address legitimate externalities or other market failures through technical trade barriers. However, such measures are "welfare-decreasing" when they are imposed to isolate domestic producers from international competition. The dual nature of SPS measures, which provide externality-based protection versus economic-based protection, adds to the importance of comprehensive economic analysis of the issues of invasive pests and diseases.

As a consequence, economists are working to develop a framework for assessing both the trade and welfare implications of trading a particular commodity under different management options when there is the potential for the introduction of an invasive pest or disease (Krissoff et al., 1997; Sumner and Lee, 1997; Roberts et al., 1999; Bigsby and Whyte, 2001). Developing such a framework, however, is far easier in theory than in practice. Although not insurmountable,

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[5] The interested reader is referred to Hanley, N., J. F. Shogren, and B. White, 1997, *Environmental Economics in Theory and Practice*, Oxford, UK: Oxford University Press. Useful examples of cases where economics and biological information have been used in the decision-making framework can be found in Orden, David, Clare Narrod, and Joseph W. Glauber, 2001, Least-trade-restrictive SPS policies, in *The Economics of Quarantine and the SPS Agreement*, edited by K. Anderson, C. McRae and D. Wilson, pp. 183-215, Adelaide, Australia: Centre for International Economic Studies and Agriculture, University of Adelaide.

[6] A separate agreement governing sanitary and phytosanitary issues, Agreement on the Application of Sanitary and Phytosanitary Measures, was negotiated during the 1986-1994 Uruguay Round multilateral trade negotiations.

the involvement of externalities in the form of unwanted pests and diseases, and specifically the risks and uncertainty associated with them, complicate the standard economic policy analysis.

CONCLUDING REMARKS

The invasive species problem poses a serious challenge in an era of increased globalization and trade liberalization. The problem has as much to do with economics as it does with ecology. Any solutions advanced must be firmly grounded in both science and economics. The economic discipline possesses the capability of valuing various market and non-market impacts and provides a means for assessing important trade-offs among various management alternatives, which can greatly improve the decision-making process for managing such risks. In addition, it can improve the transparency of the decision-making process by providing justification for the measures implemented. The true value of economics should therefore not be seen solely in the precision of the numbers generated, albeit this is important, but the extent to which the discipline aids decision makers to formulate consistent and rational decisions.

Although the focus of the article was on invasive species, this is just one case of the more general issues of communication between economists and scientists. Economists and scientists must also communicate in fields of food safety, global warming and ozone protection, and nutrition.

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CIAT'S CONTRIBUTION TO THE DETECTION AND CONTROL OF INVASIVE PESTS IN THE GREATER CARIBBEAN REGION

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ABSTRACT: The movement of invasive species is exacerbated by inadequately inspected massive shipments of agricultural products and propagating materials to and from developing countries. Drastic reductions in government spending in developing countries have weakened their research, extension and regulatory capabilities needed to cope with new pests and pathogens. CIAT has modified its commodity-oriented programs to include research on solutions to harmful new invasive species. Invasive viruses studied by CIAT include, rice hoja blanca, rice stripe necrosis, a naturally occurring seed-borne recombinant virus of common bean, bean severe mosaic, bean calico mosaic, peanut stripe, Frogskin disease of cassava, African cassava mosaic, African oil palm ringspot virus, African oil palm chlorotic ring virus, various unidentified exotic viruses of tropical fruits and vegetables. Insect vectors studies include *Bemisia* spp., the rice mite, *Steneotarsonemus spinki,* and the rice thrips, *Stenchaetotrips biformis, Thrips palmi, Trialeurodes* spp., *Aleurotrachelus socialis, Tetraleurodes* sp. and *Aleurodicus* spp. and natural enemies of these vectors.

KEY WORDS: invasive species, CIAT programs, viruses, insect vectors, natural enemies

INTRODUCTION

I was trained and had a research career as an entomologist, but my current administrative responsibilities have not allowed me to practice for several years. Thus, it was not without reservation that I accepted to speak in this symposium on behalf of the "Centro Internacional de Agricultura Tropical" (CIAT) on the topic of invasive pests. My presentation today is based on the paper written by Dr. A. Bellotti and myself on invasive pests, presented three years ago in the T-STAR Workshop. Copies of this paper are available for anyone interested. I will try to offer some points of view regarding the increasing number of invasive and emergent pests that threaten our food security every year. The second part of the paper contains updated information on some of the invasive pests we have encountered and researched in Colombia.

SOME RECENT HISTORY

To better understand the constant emergence of new invasive pests and the significant damage they cause in various agricultural regions of the world, we should review some recent economic developments in the world, particularly the globalization of the economy and its impact on the global trade of agricultural commodities.

The first two factors I want to highlight are the liberalization of trade, and the existence of surpluses of several agricultural commodities subsidized in various industrialized nations. These two factors have greatly increased the volume of agricultural commodity exchanges and the speed at which they are traded, as most of the quarantine barriers previously in place have been removed. Thus, tons of seed of various food staples and industrial crops arrive in developing countries, depriving local farmers of markets for their traditional crops, such as maize and beans, in the case of Latin America. We should recall that the same farmers domesticated these crops. For example, Colombia used to be self-sufficient in maize; and last year, it imported two million tons. Ships loaded with cheap rice produced in Asia roam the oceans in search of ports to unload. Most of these massive grain shipments have not gone through proper pest control and quarantine procedures.

Moreover, affected farmers and governments have had to develop a competitive agriculture through crop diversification. In Latin America, the emphasis has been on horticultural and fruit crops, because of their intensive labor demand available in developing countries. This drive for competitiveness in a world with a more liberalized trade has resulted in an intensive exchange of seed and vegetative materials. In addition, international trade in ornamentals and cut flowers has facilitated the spread of leafminers, aphids and thrips species. These shipments of planting materials and export of traditional and non-traditional agricultural products have increased the movement of invasive pests in the Americas and other agricultural regions of the world. The international movement of pests is further facilitated by the current WTO regulations, which replaced the old quarantine procedures with new time-consuming and costly pest risk analyses for every group of commodities. Not all national systems can comply with these rules; the result is introductions of plant material which would not have occurred previously. The rapid rise of tourism in developing countries has undoubtedly contributed to the increased pest distribution.

The third factor I want to highlight is the following. The impact of the globalization of the economy was magnified by the recession of the western world in the 1980s, and the so-called structural adjustments, which were later implemented by the IMF. This recession involved a drastic reduction in government spending and employment. Agricultural research and extension were particularly affected. National research organizations in Latin America have been reduced to a fraction of their previous strength, and attempts were made, with very little success, to privatize research. A few extension services have survived, but there is very little indigenously generated technology to be transferred. For example, when I left CIAT in 1986, Guatemala had 11 bean research scientists; when I returned ten years later, only one bean researcher remained. The pressure to address environmental issues related to agriculture in developing countries has further aggravated this disastrous trend.

Thus, there is little or no research done in developing countries on new crops and their pests, some of which have been introduced or have emerged as cropping systems have changed. These pests are not managed by well-supported research and extension systems, which have been debilitated by the structural adjustment programs. The only extension service still available to farmers is the pesticide sales force, and this has resulted in the current horrific abuse of pesticides. With beneficial insects tending to be more susceptible to pesticides than the pests, this problem is further aggravated. Moreover, donor wisdom that research must be financed through finite three-year projects does not provide for the flexible deployment of resources needed to develop a concerted research strategy to combat incipient or newly established invasive pests and pathogens.

CIAT'S RESPONSE

The above developments are of considerable concern to CIAT. The Center traditionally focused its research on beans, rice, forages and cassava. With beans and rice now out-competed by subsidized imports, CIAT's original mandate became less relevant. Yet the Center had to respond to the constant emergence of new invasive pests, such as the B biotype of the whitefly *Bemisia tabaci*, *Thrips palmi*, the pink hibiscus mealybug (*Maconellicoccus hirsutus*), rice stripe necrosis, and many other pests and pathogens. These new pests have also occurred on the crops presently research at CIAT. Examples include the introduction of the cassava mealybug and the cassava green mite into Africa. Combined research by CIAT, IITA, and EMBRAPA resulted in the identification of their natural enemies in the centers of origin of these pests. Subsequently these natural enemies were introduced into Africa. These parasitoids and predators rapidly established themselves and saved African farmers from famine.

Another example is the development of moderate levels of resistance in beans to the recently arrived *Thrips palmi*. But this research capacity was not available in CIAT to support research in non-mandated crops, such as tomatoes, cucurbits, and broccoli.

CIAT, in an effort to improve its relevance, reorganized its research drastically around competency areas centered on the improvement of cropping systems. The five research competency areas are Integrated Pest and Disease Management; soil fertility management; land use (with GIS); biodiversity (plant breeding, genetic resources and biotechnology tools); and socio-economics. Each of these five competencies remained active in the traditional crops, but they are increasingly responding to the needs of major pest problems in other crops. In this way research could now focus also on tomato, African oil palm, asparagus, and fruit crops. Currently, CIAT's research activities cover ornamental, fruit and horticultural and industrial crops. In addition, CIAT undertook research in the management of natural resources.

Another parallel development occurred. CIAT realized that given the magnitude of the research task (more crops and natural resources) and the small size of the institute, it could only make an impact by doing cooperative research together with others. Therefore, CIAT organized a science park, called Agronatura. This is not an assembly of individuals that merely share the same infrastructure without common objectives. Instead, all members of the science park, in order to gain entrance, must have the same goal and mission as CIAT, i.e., how to make the small farmer competitive, and to make agriculture less damaging to the environment. Thus all 23 institutionsentities, including the private sector that share the park at this moment, all work on one general theme. This cooperation results in much synergism and increased relevant impact. It is CIAT's sincere wish that the University of Florida, with its tropical research program, particularly on tropical fruits and pest management, will one day be an important member of this science park.

This new structure and broader vision has permitted the rapid formation and dismemberment of new research associations. The geographic position, culture, infrastructure, experience in networking, and scientific expertise to monitor and carry out innovative research enabled CIAT to assume a significant role in the study and management of invasive pests in a wide range of cropping systems. When the whitefly problem became severe, CIAT with other centers, both national and international coordinated the creation of the Tropical Whitefly Project, probably one of the most ambitious global pest management projects, currently covering Latin America and the Caribbean, Sub-Saharan Africa, and South-East Asia. This project has contributed to the identification of the main viruses transmitted by whiteflies, as well as to the characterization of the main whitefly species and biotypes of *Bemisia tabaci*, the main pest and plant virus vector worldwide.

AN UPDATE ON INVASIVE PESTS

In the remainder of the article I would like to expand briefly on recent information generated in CIAT, often through collaborative projects, on invasive pests and to conclude with a summary of research on natural enemies of whiteflies.

A. Invasive viruses, particularly the highly threatening whitefly-transmitted viruses

Rice. *Rice hoja blanca* is the main viral disease of rice in tropical America, and has attacked rice in the United States (Louisiana and Florida) in the past. CIAT characterized the causal virus in the 1980s and has since developed an efficient rice improvement program to control this disease. If there is a warming trend in the Caribbean, this disease may reemerge in the southern USA.

Rice stripe necrosis is the only other virus disease of rice known to occur in the Americas. The causal virus and its fungus vector were probably introduced in contaminated rice seed imported into Latin America from West Africa in the early 1990s. The fungus vector was originally described on cereal crops in temperate countries, and it has now moved up from South America through Central America, probably all the way to Nicaragua. This virus has the potential to move into North America, considering its seed-borne nature and the adaptation of the fungus vector, *Polymyxa graminis*, to temperate environments. CIAT has developed diagnostic materials and disease management practices that have greatly reduced the economic and environmental impact of this exotic disease.

In June 2003, we received notice of a new whitefly-transmitted virus outbreak in El Salvador. Symptoms coincide with preliminary reports from Cuba and the Dominican Republic. The virus causes leaves to turn orange, followed by necrosis. We are monitoring this potential new pest with great concern, as reports come in on whitefly damage to grass species.

Common bean. In Latin America, common beans are grown in both temperate and tropical countries. This diversity of environments facilitates the recombination and dissemination of plant pathogens in different regions. For instance, a highly pathogenic new virus was detected in Chile attacking common beans. The causal virus was later shown to be a natural recombinant virus from a cross between *Cucumber mosaic virus* and *Peanut stunt virus.* The seed-borne recombinant virus is a threat to common bean production worldwide.

Bean severe mosaic is caused by some comoviruses transmitted by chrysomelids in Central America. These viruses cause systemic necrosis in bean genotypes possessing I gene resistance to bean common mosaic, a common gene found in most North American bean cultivars. Whitefly-borne *Bean calico mosaic virus* attacks legumes and cucurbits in northwestern Mexico, and could easily travel east to affect the snap bean industry in Florida.

Tropical and subtropical forage grasses and legumes are susceptible to different viruses found in temperate and tropical regions of the world. *Peanut stripe* was originally introduced in the U.S. from Asia, and later transported into Latin America. Although the virus was successfully eradicated from S.E. United States, its emergence in northern South America might lead to its re-introduction into the U.S. In tropical forage grasses, such as *Brachiaria* spp., exotic viruses, probably of African origin, have been detected in Latin America.

Cassava. Frogskin disease in the Americas (causal agent and vector are unknown), and *African cassava mosaic* in Africa and some Asian countries are major threats to cassava production worldwide.

African oil palm. Colombia is the largest producer of African oil palm in the Americas, and consequently is concerned about the slow but continuous spread of exotic viral diseases probably introduced to the Americas from West Africa. The CIAT Virology Unit identified these elusive pathogens in 1999, and succeeded in the isolation of two different viruses. The new viruses are *African oil palm ringspot virus* (vector unknown) and *African oil palm chlorotic ring virus* (aphid-borne). These are the first viruses ever identified in this globally important oil crop.

Tropical fruits. Unidentified exotic viruses have been detected at CIAT in most tropical fruit crops assayed to date. These tropical fruit crops include tree tomato (tomate de árbol), naranjillo (lulo), feijoa, passion fruit (maracuja), pitahaya cactus, and banana. Some of these viruses can be disseminated directly from fruits sold in foreign markets through insect vectors.

Vegetables. Some 20 uncharacterized new viruses have been detected in the past six years in tomato, sweet and hot peppers and cucurbits. Interesting research is being carried out in El Salvador with farmers using nylon mesh tunnels to exclude the vector as one component of an IPM package.

B. Severity of invasive insects as vectors of virus diseases

Whiteflies. CIAT's research activities with invasive insect pests include several whitefly species, including *Bemisia afer* sensu lato, a species native to Africa. It was first reported on sweet potato in the Canete Valley in coastal Peru and has been seen on cassava as well. By 2000 it was reported in damaging populations, although it may have been present in the Americas much earlier.

The role of *Bemisia afer* as a virus vector of Solanaceous crops is being investigated, particularly as related to the *Solanum muricatum* exported to Europe. *Aleurocanthus woglumi* (the citrus blackfly or spiny citrus whitefly) is another threatening whitefly species. Other important species include the *Bemisia tabaci* complex.

Rice insects. The rice mite (*Steneotarsonemus spinki*) and the rice thrips (*Stenchaetotrips biformis*) are threatening several grass species.

Others. *Thrips palmi* arrived in the Caribbean about 1990, and resistance to this exceedingly damaging pest has been identified in beans.

Other important indigenous arthropod pests with somewhat restricted distributions that could potentially spread to other areas, or crops, include the tropical fruit flies (*Anastrepha grandis* and *A. suspensa*), the apple maggot (*Rhagoletis pomonella*), the pink hibiscus mealybug (*Maconellicoccus hirsutus*), the Guatemalan potato moth (*Tecia solanivora*), and the citrus leafminer (*Phyllocnistis citrella).*

Whiteflies and their Natural Enemies. Surveys in recent years in the neotropics - especially in Colombia, Venezuela, Ecuador and Brazil, have identified a large complex of natural enemies associated with the whitefly complexes found on cassava, vegetable legumes, and other crops. This complex of natural enemies includes parasitoids, predators and entomopathogens. Agro-ecological zones have been defined for two whitefly species, *Bemisia tabaci* and *Trialeurodes vaporariorum*, feeding on numerous crops in Colombia and Ecuador. Three genera of whitefly parasitoids, *Amitus, Encarsia,* and *Eretmocerus* were collected from *B. tabaci* and *T. vaporariorum* feeding on these crops. Surveys in Colombia and Ecuador confirm the following five whitefly species feeding on cassava, *Aleurotrachelus socialis, Bemisia tuberculata, Trialeurodes variabilis, Tetraleurodes* sp. and *Aleurodicus* spp. Surveys on cassava in Colombia have resulted in the identification of at least 10 parasitoid species associated with the whitefly species, four from Ecuador, and seven from Venezuela. Several of the parasitoids are unrecorded species, and they have been submitted to taxonomists in USA universities for identification.

Whitefly species and their natural enemies have also been collected in the aforementioned countries from eggplant, tomato, cabbage, cucumber, snap bean, cotton, bell pepper, soybean, lima bean, watermelon, peanut, melon and field beans. Two whitefly species were identified from these hosts, *Bemisia tabaci* and *Trialeurodes vaporariorum. T. vaporariorum* was the species most often collected in Colombia, whereas *B. tabaci* predominated in Ecuador. *B. tabaci* was most often collected from sites below 400 m.a.s.l., and *T. vaporariorum* from sites above 1000 m.a.s.l. At altitudes between 400-800 m.a.s.l., the two biotypes of *B. tabaci* as well as *T. vaporariorum* can be found.

The parasites collected from these surveys from whiteflies feeding on the above mentioned hosts belong to the genera *Encarsia, Eretmocerus* and *Amitus.* Several of the parasitoids collected have now been identified to species including *Amitus fuscipennis, Encarsia sofia, Encarsia hispida, Encarsia nigricephala* and *Encarsia tabacivora*. Numerous other species, especially of the genera *Eretmocerus* and *Amitus* are still awaiting identification by US taxonomists; several of these are unrecorded species.

This species complex of natural enemies associated with whiteflies on cassava and on other hosts in the neotropics needs to be further evaluated and investigated to determine their role and importance in biological control programs.

Clearly the mounting threat of invasive species calls for greatly expanded research to safeguard the Greater Caribbean Region, and CIAT is seeking serious and effective partners in this critically important task.

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STRATEGIES AT THE SUBTROPICAL HORTICULTURE RESEARCH STATION (USDA/ARS) FOR MITIGATING INVASIVE INSECT PESTS

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ABSTRACT: In 1999, entomology at the USDA/ARS, SHRS was directed to take a proactive approach to the mitigation of invasive insects from the Caribbean, Central and South America that threaten U.S. agriculture. The objective of this research is to develop environmentally safe methods to diminish the risk of introducing foreign pests into the U.S. This includes reducing the pest pressure at the source and/or improving detection upon entry into the U.S. Studies on the life history, host range, behavior and chemical ecology will provide information that can be used in the development of management strategies for these pests.

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A PEER REVIEWED PAPER

DEVELOPMENT OF LURES FOR DETECTION AND DELIMITATION OF INVASIVE *ANASTREPHA* FRUIT FLIES

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ABSTRACT: Development of female-biased synthetic attractants for fruit flies offers considerable opportunities for fruit fly management programs. Traps baited with a food-based synthetic attractant composed of ammonium acetate, putrescine and trimethylamine are being used to detect and delimit populations of the Mediterranean fruit fly, *Ceratitis capitata*. Current research is being conducted in 14 countries via an FAO/IAEA-sponsored Coordinated Research Project to determine the utility of this synthetic attractant for detection of other fruit flies, particularly those in the genus *Anastrepha*. These include tests of four species of concern to the Caribbean basin: the Mexican fruit fly, *A. ludens*; the West Indian fruit fly, *A. obliqua*; the guava fruit fly, *A. striata*; and the sapote fruit fly, *A. serpentina*. Results of tests conducted in Columbia, Costa Rica, Honduras, and Mexico found that the highest capture tended to be in traps baited with liquid protein (11 out of 15 tests); in the other four tests highest capture was in traps baited with ammonium acetate-based synthetic attractants. The role of ammonia release rate from preferred baits and the development of improved attractants for these species are discussed.

KEY WORDS: trapping, synthetic attractant, *Anastrepha ludens*, *Anastrepha obliqua*

INTRODUCTION

The Mediterranean fruit fly (medfly), *Ceratitis capitata* (Wiedemann) and *Anastrepha* spp. fruit flies are pests of major economic importance that threaten fruit and vegetable production and export. The medfly is considered a major economic pest worldwide because of its wide distribution and large host range, encompassing over 240 species of fruits and vegetables (Liquido et al., 1991). California, Texas, Arizona and Florida maintain traps for detection of Mediterranean, Mexican and other exotic fruit flies. *Anastrepha* species of particular importance to the Caribbean Basin include the Caribbean fruit fly (caribfly), *A. suspensa* (Loew); the West Indian fruit fly, *A. obliqua* (Marquart); the Mexican fruit fly (mexfly), *A. ludens* (Loew); the guava fruit fly, *A. striata* Schiner; and the sapote fruit fly, *A. serpentina* (Wiedemann). Geographic distributions and host plant lists have been published (e.g., Stone, 1942; Hernández-Ortiz and Aluja, 1993; Zucchi et al., 1996) and recent detection of pest fruit flies is documented in the United States Department of Agriculture, Animal Plant Health Inspection Service (USDA/APHIS), National Agricultural Pest Information System (NAPIS, http://www.ceris.purdue.edu/napis).

Specifically, the caribfly occurs in Puerto Rico and Florida. Its presence impacts guava production in Florida and questions of host status impact marketability of other tropical fruit crops (Simpson, 1993). The West Indian fruit fly occurs in Puerto Rico and Mexico, and is detected periodically in Texas and California. Establishment of this fly in the continental US would pose a serious threat to mango production as well as cause quarantine restrictions for affected States. This fly was first detected in Grenada, West Indies, in the spring 2002 and has now become established in that country (Pest Management Unit, Ministry of Agriculture, St. George's, Grenada). Mexflies occur in Mexico and throughout Central America. Presence of breeding populations of mexfly in southern California in 2003 resulted in widespread quarantine and control activities to eradicate flies in areas currently infested as well as to prevent movement to other agricultural regions of California and the US. Mexfly larvae were intercepted in infested peppers in Florida in 2003 (Steck, 2003). This species poses a direct threat to citrus production and, as with presence of medfly, would cause widespread quarantine measures that greatly concern growers in potentially affected areas. The guava fruit fly and the sapote fruit fly occur in Mexico, Central, and South America and are occasionally detected in southern Texas.

Availability of highly effective traps for these and other exotic fruit flies is essential for suppression of fruit flies in areas in which they occur and for early detection in areas currently free of these pests. The earliest trapping systems for pest fruit flies relied on the use of baits made from proteins (needed by flies for reproductive maturation) and fermenting sugar (Gurney, 1925). Traps baited with these substances capture both females and males of a number of pest tephritid species, with the same as or greater numbers of females captured than males. These baits are usually deployed in McPhail traps (Newell, 1936), which are bell-shaped invaginated glass traps with a water reservoir, or other bucket-type traps (Cunningham, 1989a). Aqueous solutions of the corn hydrolysate Nulure and borax (Gilbert et al., 1984) and of torula yeast and borax (Lopez-D. and Becerril, 1967) are liquid protein baits used for medfly and *Anastrepha* detection. Several compounds were found that are potent lures for male medflies (Cunningham, 1989b). This finding culminated in the development of trimedlure (TML; Beroza et al., 1961). TML dispensers are typically mounted in Jackson traps (Harris et al., 1971), which are triangular cardboard traps that contain a sticky insert, or are attached to yellow panels that are coated with sticky material (Cunningham, 1989a).

In research of female-targeted trapping systems, the International Pheromone's McPhail trap (International Pheromone Systems, South Wirral, England) baited with liquid protein bait was found to be as effective as any of the McPhail-type traps tested (Katsoyannos, 1994). A food-based synthetic attractant that uses ammonium acetate (AA) and putrescine (Pu), a cylindrical closed-bottom plastic trap used with a toxicant panel (Heath et al., 1995; Epsky et al., 1995) and a cylindrical open-bottom plastic trap used with a sticky insert (Heath et al., 1996) were developed for pest fruit flies that are captured with liquid protein-baited traps. These female-targeted trapping systems were as effective as liquid protein baited traps for capture of medfly females. This synthetic lure also captures mexflies and caribflies (Thomas et al., 2001), although results for *Anastrepha* spp. tend to be more variable. Subsequent research found that trimethylamine (TMA) synergized capture of female medflies in traps baited with ammonium acetate and putrescine (Heath et al., 1997), and captured fewer non-target species than liquid protein baited traps (Katsoyannos et al., 1999). TML-baited traps have been used world wide for detecting and monitoring populations of male medflies; however their use for detection and delimitation trapping is no longer recommended because female-targeted trapping systems are more effective in detecting the presence of very low medfly populations (Papadopoulos et al., 2001).

Although the three-component synthetic food-based attractant (AA+Pu+TMA) is highly effective for capture of medflies (Epsky et al., 1999), studies are ongoing in several countries with endemic populations of *Anastrepha* and *Bactrocera* fruit flies under a Coordinated Research Project (CRP) funded by FAO/IAEA to optimize female-biased lures for these flies. Reported herein are results of initial field tests of several species of *Anastrepha* that were conducted as part of the CRP.

MATERIALS AND METHODS

Traps and Lures. Multilure McPhail traps (Better World, Miami, FL) were used in all studies. Liquid protein-baited traps had 300 ml of an aqueous solution of 9% Nulure (vol/vol; Miller Chemical & Fertilizer, Hanover, PA) + 3% borax (wt/vol; sodium tetraborate decahydrate) or torula yeast/borax (3 pellets in 300 ml water; ERA Intl., Baldwin, NY). Synthetic attractants included a solid formulation of ammonium bicarbonate (AB; Agrisense-BCS Ltd, UK) and individual membrane-based formulations of ammonium acetate, putrescine and trimethlyamine (BioLure, Suterra, LLC, Bend, OR). Traps baited with synthetic lures contained either 300 ml of water with 1-2 drops of Triton X-100 or 275 ml water with 25 ml polypropylene glycol (environmentally-safe car antifreeze). Comparisons were made among traps baited with Nulure/borax solution, torula yeast/borax solution, AA+Pu+TMA with water/triton, AA+Pu+TMA with water/polypropylene glycol, AA+Pu with water/triton, or AB+Pu with water/triton.

Protocol for Field Tests. Field tests were conducted in Columbia, Costa Rica, Honduras, and Mexico. The field plot design was a six treatment by six-trap Latin square in an area with a fairly uniform stand of host trees. No tests were conducted in areas where insecticide was being applied. There was at least 10-15 m between rows and 10-15 m between traps within a row. Tests were conducted for 8 wk, with fresh protein bait solutions made each week and the synthetic lures replaced after 4 wk. These tests were conducted in March-April in mango (Columbia and Costa Rica), in July-August in mango (Costa Rica), in April-June in mango and in August-September in grapefruit (Honduras), and in April-June in mango and in mamey (Mexico) in 2001. Traps were checked twice a week, and numbers of male and female flies recorded by species. Data for each species and each test were summarized separately by number of flies (males plus females) per trap per day, and the percentage of that total capture that was females was determined.

RESULTS AND DISCUSSION

The best lure for each species in each host/country tested is given in Table 1. Multiple lures are listed if two tied in number of flies captured, or if additional lures performed almost as well. Number of flies captured ranged from 0.3 to 19.7 per trap per day, and the percentage females ranged from 39.0 to 88.2% for the best of the lures in each test. Most of the captures were female-biased except for a male-bias in capture of *A. striata* in mango in Columbia, and little bias in capture of *A. serpentina* and *A. striata* in the spring tests in mango in Costa Rica, and *A. obliqua* in grapefruit in Honduras, and in mango in Columbia. The results from these tests showed considerable variation in lure effectiveness both within and among the different species. One of the liquid protein baits, however, was as good as, or better than, any of the synthetic lures in most of the studies. The ammonium bicarbonate plus putrescine lure was not the most effective in any test.

Among the many differences in volatile chemicals emitted from these baits, there are differences in release rates of ammonia. The Nulure/borax releases the highest amount of ammonia; the AA and AB lures intermediate amounts, and the torula yeast/borax releases the lowest amount (Heath et al., 1995; Heath unpublished). However, ammonia release rate alone does not explain the differences, and for several of the tests the highest capture was in both the Nulure/borax- and the TY/borax-baited traps, which represented the highest and lowest release of ammonia (Table 1). AA lures also release acetic acid, AB lures release carbon dioxide, and numerous other chemicals are released from the liquid protein baits. Therefore, differences in capture among these lures may be due to attraction or repellency of any of these chemicals.

Field tests are ongoing by the CRP collaborators to further evaluate the role of ammonia release rate and synthetic formulation. In research being conducted at USDA, ARS, SHRS (Miami, FL), electroantennogram (EAG) techniques are being used to measure chemoreceptive response of antennae, using the caribfly. Antennal responses are a prerequisite for behavioral responses, making EAG a useful tool for screening potential attractants. We are quantifying antennal sensitivity to ammonia, the primary attractant released from liquid protein baits and commercial lures.

Since the protein baits have higher capture rates than ammonia-based lures, it seems likely that additional food-based attractants remain to be identified. For this identification, EAG coupled with gas chromatography (GC-EAG) will be conducted to screen volatile chemicals emitted from liquid protein baits. This method uses GC to separate complex mixtures of volatiles into component peaks, and then uses EAG to determine the physiologically active peaks. This strategy will facilitate isolation and identification of new attractants. The best candidates determined by GC-EAG will then be evaluated as attractants in flight tunnel bioassays (Heath et al., 1993) with caribflies and subsequently field tested in combination with other known synthetic attractants for effectiveness for the other *Anastrepha* pest species.

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Table 1. Lures used in McPhail traps that resulted in the highest captures of the fruit fly species in field tests conducted in several countries, the average number of flies (males plus females) per trap per day captured in that trap, the percentage of those flies captured that were female, and the relative release rate of ammonia from those baits.

Species	Country	Host	Fruit Fly Lure[a]	Flies/Trap/Day	Percent Females	Ammonia Rate
A. obliqua	Columbia	Mango	Nulure/borax	7.2	53.9	High
A. striata	Columbia	Mango	Nulure/borax, TY/borax	0.6, 0.5	39.0, 42.8	High, Low
A. ludens	México	Mango	Nulure, AA+Pu, TY/borax	0.3	83.3, 55.6, 88,2	High, Medium, Low
A. serpentina	México	Mango	Nulure, AA+Pu+TMA	1.0	73.7, 60.7	High, Medium
A. serpentina	México	Mamey	AA+Pu+TMA, TY/borax	5.5, 3.9	64.8, 69.5	Medium, Low
A. obliqua	México	Mamey	AA+Pu+TMA, AA+Pu	0.5, 0.4	65.5, 70.4	Medium
A. striata	Costa Rica	Mango, summer	AA+Pu+TMA	0.4	61.9	Medium
A. obliqua	México	Mango	AA+Pu, Nulure/borax	19.7, 15.2	63.8, 64.0	Medium, High
A. ludens	Honduras	Grapefruit	TY/borax	0.6	68.7	Low
A. ludens	Costa Rica	Mango, summer	TY/borax, Nulure	3.8, 3.5	63.8, 71.7	Low, High
A. obliqua	Honduras	Mango	TY/borax, AA+Pu	1.1, 0.9	61.2, 57.9	Low, Medium
A. obliqua	Honduras	Grapefruit	TY/borax	0.07	54.5	Low
A. obliqua	Costa Rica	Mango, spring	TY/borax	6.0	61.6	Low
A. serpentina	Costa Rica	Mango, spring	TY/borax	0.5	48.3	Low
A. striata	Costa Rica	Mango, spring	TY/borax	1.2	52.9	Low

[a]Lures include aqueous solutions of the liquid protein baits Nulure/borax and torula yeast (TY)/borax; and the food-based synthetic lure of ammonium acetate (AA), putrescine (Pu) and trimethylamine (TMA).

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CURRENT STATUS OF EXOTIC TERMITES AND ANTS IN THE WEST INDIES AND FLORIDA

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ABSTRACT: In the last decade, pest termite and ant species have increased their range and threaten further expansion in Florida and the West Indies. A particularly damaging subterranean termite, *Coptotermes gestroi*, is now established in Antigua, Caymans, Florida, Guadeloupe, St. Kitts & Nevis, and the Turks & Caicos. A drywood termite, *Cryptotermes havilandi*, now occurs on Antigua, Barbados, Guadeloupe, and St. Croix. The West Indian drywood termite, *Cryptotermes brevis*, is now established on all inhabited islands and mainlands of the Caribbean Basin. The arboreal termite, *Nasutitermes costalis*, was recently introduced into Florida and St. Martin. Among ants, the red imported fire ant, *Solenopsis invicta*, now occurs in the Bahamas, Antigua, and Trinidad. The Caribbean crazy ant, *Paratrechina pubens*, has been moved from the Lesser Antilles into Florida. The white-footed ant, *Technomyrmex albipes*, is well established in Florida and will likely be introduced into the Caribbean region. Movement of plant materials, cargo containers, or infested boats, all of which are potential harborages for these social insects, is probably responsible for almost all of these inadvertent introductions.

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A PEER REVIEWED PAPER

THE LOBATE LAC SCALE INSECT, A NEW PEST OF TREES AND SHRUBS IN FLORIDA: IMPLICATIONS FOR THE CARIBBEAN REGION

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ABSTRACT: The lobate lac scale insect, *Paratachardina lobata* (Hemiptera: Coccoidea: Kerriidae), a species native to India and Sri Lanka, was found for the first time in Florida in 1999 and it appears to be widespread in the Bahamas. In Florida, it has already spread over an area of about 6400 km^2. It has been reported on more than 150 species of woody plants. Most host plants that are native to southern Florida are also native to the Caribbean Region, implying that the pest threatens natural areas in the whole Region. These scale insects infest the woody portions of small branches, causing branch dieback. Severe infestations of some plants are lethal. The duration of development from egg to adult is under investigation. Two species of Encyrtidae (Hymenoptera), *Metaphycus* sp. and *Ammonoencyrtus* sp., both probably undescribed, were reared from lobate lac scales. Only a few specimens were reared from thousands of lobate lac scales held in emergence containers. Application of imidacloprid as a root drench to infested trees is effective in controlling the scale insect, but biological control is viewed as the only practical option in the long term to control this pest, especially in natural areas. Therefore, a program to obtain natural enemies of this scale insect from India has been initiated.

RESUMEN: La escama lobada de laca, *Paratachardina lobata* (Hemiptera: Coccoidea: Kerriidae), una especie oriunda de la India y Sri Lanka, fue encontrada por primera vez en las Bahamas en 1992 y en la Florida en 1999. En la Florida, el insecto ya está distribuido sobre un área de 6400 km^2. Se le ha reportado en más de 150 especies de plantas de madera. Las infestaciones severas son mortales para algunas especies de plantas. Casi todas las plantas hospederas nativas de la Florida meridional son también nativas de la región del Caribe, implicando que la plaga amenaza a las áreas naturales de toda la región. Estas cochinillas infestan a la madera de ramitas pequeñas, causándoles la muerte. Se está investigando la duración del desarrollo desde huevo hasta adulto y al parecer ésta es mucho más larga que en la mayoría de las cochinillas. Se ha observado un índice muy bajo de parasitismo. Dos especies de Encyrtidae (Himenóptera), *Metaphycus* sp. y *Ammonoencyrtus* sp., ambas probablemente no registradas, se crearon de escama lobada de laca. Solamente unos pocos especímenes crecieron de millares de escamas en jaulas de crecimiento. La aplicación de imidacloprid en las raíces de árboles infestados controla con eficacia la cochinilla, pero el control biológico se ve como la única opción práctica a largo plazo para manejar esta plaga, especialmente en áreas naturales. Por eso, se ha comenzado un programa para obtener enemigos naturales de la India.

KEY WORDS: scale insect, host plants, invasive species, natural areas, chemical control, parasites

INTRODUCTION

The lobate lac scale insect, *Paratachardina lobata* (Chamberlin) (Hemiptera: Sternorrhyncha: Coccoidea: Kerriidae), a species native to southern India and Sri Lanka, was found for the first time in Florida in Broward County in 1999. Subsequent to its discovery in Florida, specimens of this scale insect collected in the Bahamas in 1992 were found in the Florida State Collection of Arthropods. This highly invasive species currently has a patchy distribution in urban and natural habitats within a total area of about 6400 km^2 in Broward, Palm Beach, and Miami-Dade counties, Florida and large areas of New Providence and Grand Bahama, Bahamas. *Paratachardina lobata* was recently collected for the first time on Christmas Island by Ms. Kirsti Abbott, Monash University, Australia (personal communications) and identified by Dr. Penny Gullan, University of California, Davis (personal communications).

DESCRIPTION OF LOBATE LAC SCALE

It is a very distinctive scale insect (Figure 1). The mature female, about 1.5-2 mm long, and of slightly less width, has two pairs of prominent lobes; its appearance has been likened to that of a bowtie. With some experience, the scale insect in this stage can be easily discerned with the naked eye. The first instars are maroon colored, elliptical, and about 0.4 mm in length. The lobed condition develops in the second instar. The covering of the third instar and mature female is extremely hard and brittle, glossy and of a dark reddish brown color, but is often coated with black sooty-mold. White wax bands are produced in the spiracular furrows. Males of this species have not been observed in Florida.

HOST RANGE AND PROPENSITY TO SPREAD

Nearly all the hosts of lobate lac scale are dicotyledonous trees and shrubs. It infests twigs, small branches, and stems of less than 2 cm in diameter. It is not found on foliage. Up to 46 mature females have been counted per 100 mm^2 of twig on highly susceptible hosts. Dense infestations may result in branch dieback of some plant species. High infestations have been lethal to some species of shrubs. Wax-myrtle (*Myrica cerifera*) is especially susceptible to the effects of dense populations of lobate lac scale insect. Some plant species appear to tolerate dense infestations, but this may be illusory, as the long-term effects of such infestations are not yet known.

As of October 2002, i.e., a few months after studies of this insect were initiated in Florida, host plants reported for lobate lac scale insect numbered more than 120 species in 44 families (Howard et al., 2002). These included more than 39 plant species native to Florida. Various observers in Florida have noted other hosts but these records have not yet been compiled, and additional host plants were recently detected during surveys for the scale insect on New Providence and Grand Bahama (Pemberton, unpublished). Almost 2/3 of the 108 native plants examined in that survey were infested, many of them heavily. Plants native to Florida and the Bahamas that are often highly infested include, in addition to wax-myrtle, cocoplum (*Chrysobalanus icaco* L., Chrysobalanaceae), buttonwood (*Conocarpus erectus* L., Combretaceae), myrsine (*Myrsine guianensis* (Aublet) Kuntze, Myrsinaceae), and wild-coffee (*Psychotria* spp., Rubiaceae). There is very little known about the susceptibility of most of the host species, and species that harbored only light infestations when first observed have often become highly infested later or at other sites. Several exotic fruit trees attacked by lobate lac scale insect in Florida are widely grown in the Caribbean Region, e.g., several species of *Annona* (Annonaceae), star-fruit (*Averrhoa carambola* L., Oxidalaceae), lychee (*Litchi chinensis*

Sonnerat, Sapindaceae), and mango (*Mangifera indica* L., Anacardiaceae).

The lobate lac scale insect may attack a high portion of the woody plants at a particular site. For instance, on one site sampled in 2002, 55% of the species in 63.3% of the plant families and 55% of the individual plants examined were infested (Pemberton, 2003a).

Invasion of natural areas is of paramount concern. A cursory examination of several tropical hardwood hammocks in southern Florida revealed that there were heavy infestations on diverse species over large areas. Most of the native host plants of *P. lobata* identified in Florida are also distributed in the Caribbean Region, and if the insect were to be introduced into Puerto Rico or other Caribbean countries, natural areas there would likewise be threatened.

The lobate lac scale insect is native to India and Sri Lanka, and introduced in the localities listed above. This implies a potential further spread of this species in tropical areas of the Western Hemisphere (Pemberton, 2003b). Vigilance should be exercised to prevent the introduction of this scale insect into Puerto Rico and other localities of the Caribbean Region, Texas, California, Hawaii, and other warm areas where plants are imported from Florida.

The lobate lac scale insect belongs to the lac scale insect family, Kerriidae, one of 28 families of the scale insect superfamily Coccoidea (Ben-Dov et al., 2003). The best-known species of Kerriidae is the true lac scale insect, *Kerria lacca* (Kerr). The scale of the true lac scale insect has been utilized since antiquity for making shellac and similar products. However, the lobate lac scale insect, like most species of Kerriidae, does not produce any material of known commercial value. Of the 87 described species of this family, 64 are distributed in the Eastern Hemisphere. Of the species native to the Western Hemisphere, 13 are reported from South America, six from Mexico (two of which are also reported in the southwestern U.S.), three reported only in the southwestern U.S., and one from Jamaica (Ben-Dov, 2003).

BIOLOGY AND CONTROL

The biology of lobate lac scale insect has not been studied in its native range. Studies are in progress in Florida to elucidate the bionomics of this scale insect and develop pest management methods for it.

The authors have initiated research to develop chemical control for this pest for the short term and biological control for the long term. An application of imidacloprid as a root drench on infested trees is effective in controlling the scale insect (Howard unpublished data). Biological control is seen as the best long-term option.

Biological control research on the scale insect is in progress. To determine whether natural enemies of this scale insect were already present in Florida, sections of branches infested with lobate lac scale were kept in plastic bags for rearing and identifying parasitoids. Two species of Encyrtidae (Hymenoptera), *Metaphycus* sp. and *Ammonoencyrtus* sp., both probably undescribed, were reared from lobate lac scales. These were identified by Michael W. Gates and Michael E. Schauff, respectively, both of the USDA, ARS, Systematic Entomology Laboratory, Beltsville, MD. They include *Ammonoencyrtus* sp. (identified by Schauff) and *Metaphycus* sp., (identified by Gates). The *Metaphycus* sp. is possibly undescribed and the *Ammonoencyrtus* sp. has been described previously, but its generic placement will be formally changed in a forthcoming paper (Schauff and Gates, Personal Communication). Only a few specimens of each were reared from thousands of lobate lac scales held on branches in plastic bags.

Promising natural enemies are known to attack the lobate lac scale insect in India, and few related native scale insects that could be non-targets of introduced biocontrol agents occur in Florida or the Caribbean, thus suggesting that the prospects are good for effective and environmentally safe biological control (Pemberton, 2003b).

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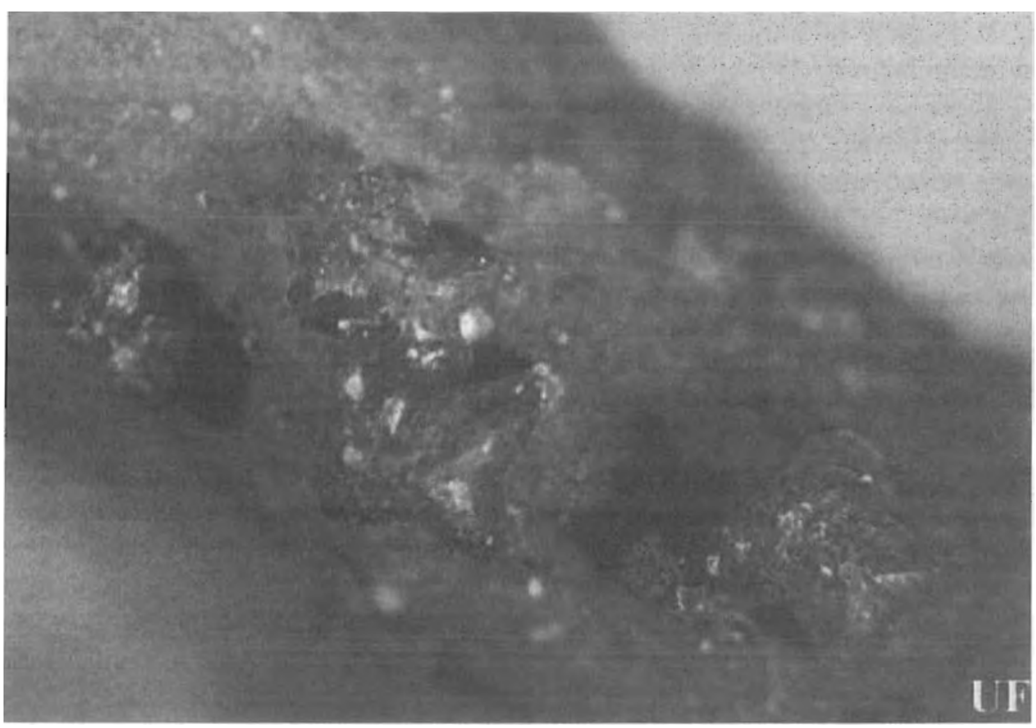

Figure 1. *Paratachardina lobata*, mature female scales on twig.

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THE NATURE CONSERVANCY'S CONSERVATION ACCOMPLISHMENTS AT RISK: ABATING THE THREAT OF INVASIVE SPECIES

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ABSTRACT: Whether in the coral reefs of the South Pacific, in native grasslands of the western U.S., in Brazil's Pantanal wetlands, in the hardwood hammocks of the Florida Keys, in coastal and tropical forests in the Caribbean, or across Mexican deserts, invasive species have been identified as one of the most serious and pervasive threats across all of The Nature Conservancy's Conservation Areas, threatening *all* our conservation accomplishments to date. Invasive species have been identified as one of the top two threats to global biodiversity, and this threat has economic consequences –estimated at $137 billion annually in the U.S. alone. In the long term, conservation success will depend greatly on the ability to prevent new invasions, and to manage "invaded" native systems for maximum benefit to native biodiversity and intact, functioning ecosystems. The prevention and early detection of new invasive species is not only important to natural systems, but can also save millions of dollars in control measures for agricultural systems. The Conservancy is actively promoting the implementation and scientific improvement of new prevention programs and methods, through capacity building and through the influence on policy. The steps for a comprehensive strategy include assessment and risk analysis, prevention, early detection, rapid response and eradication, control and management, restoration, and public education and awareness. The foundation for all these steps is science – but much more is needed and our ability to incorporate new information into management decisions in a timely fashion continues to be limited.

KEY WORDS: The Nature Conservancy; invasive species; threat; prevention; early detection; strategy

INTRODUCTION

The invasion of native ecosystems by non-native or alien organisms – animals, plants, insects, and pathogens – is now widely regarded as a top threat to biological diversity worldwide. In the United States, invasion negatively affects some 52% of all imperiled species (Wilcove et al., 1998). The scientific study of invasion is in its infancy. We know enough, however, to be confident that aggressive action is warranted to slow the flow of new invaders and to reduce the impact of established, habitat-altering species.

Some invasive species disrupt ecosystem processes, such as fire regimes, hydrology, and soil chemistry. Other invasive species have economic and social impact, costing millions of dollars to agricultural systems, the tourism industry, and utilities and highway maintenance, to name a few.

No habitat type or region of the globe is immune to biological invasion. From continental systems to oceanic islands, from the poles to the tropics, from evolutionarily ancient to youthful systems, and in marine, aquatic, and terrestrial habitats, all are experiencing important invasion impacts. Island ecosystems are especially vulnerable to invasions given that island species have evolved in relative isolation and often are not able to respond adequately to intense inter-specific competition.

Global trade and travel, climate change, habitat degradation and fragmentation, and the natural propensity of most species to disperse into available habitats will continue to drive invasion and threaten native species and ecosystems. Furthermore, many non-native species, particularly plants, exhibit a pronounced "lag effect" between their introduction in a new landscape and their first invasive expansion in that landscape. Even if all new introductions were stopped immediately, the existing pool of introduced species in most landscapes would still pose a threat requiring full attention.

POLICY CONSIDERATIONS IN THE PREVENTION AND CONTROL OF BIOLOGICAL INVASIONS

Within countries, farmers, health agencies, foresters, and conservation interests are understandably far more aware of the threat of invasive species than the general citizenry. Society-wide awareness and political action typically occur only where invasive species threaten public safety, health, or economic security in a dramatic way (e.g., the brown tree snake in Hawaii, or the Mediterranean fruit flies in California, Japan, or New Zealand). Some communities have utilized these high-profile pests to build political support for significant growth in invasive species management systems.

Awareness and engagement vary widely among countries. Australia, New Zealand, Great Britain, South Africa, and the U.S. stand out as leaders in invasive species management and public awareness. Most developing nations lack the personnel and technical capacity to carry out strong quarantine and mitigation work, even though many have basic quarantine laws in place.

Numerous international instruments, binding and non-binding, have been developed to deal with certain aspects of the invasive species threat. The most comprehensive is the 1992 Convention on Biological Diversity (CBD), which calls on its parties —178 governments as of 2000— to "prevent the introduction of, control or eradicate those alien species which threaten ecosystems, habitats, or species" (Article 8h). The 1952 International Plant Protection Convention binds 111 governments in a shared strategy to prevent the spread and reduce the impacts of plant pests. Other instruments deal with invasive alien species in specific regions (e.g., Antarctica), sectors (e.g., fishing in the Danube), or vectors (e.g., in ballast water, through the International Maritime Organization). Over 40 such instruments or programs are already in force, and many more are awaiting finalization and ratification.

The U.S. Federal government has begun showing stronger leadership on this issue, forming the National Invasive Species Council (NISC) in 1998 to prepare the first U.S. National Invasive Species Management Plan. Forty-three senators from both political parties issued a joint call in 1999 for stronger action against invasive species. The National Governors' Association has named invasive species a top policy concern, and several states are engaged in cross-sectoral strategies to reduce this threat. Some states and local governments have developed invasive species management programs that are more protective and pro-active than those overseen by higher levels of government, giving rise in some instances to jurisdictional disputes.

All of this action is dwarfed, however, by forces promoting free trade. The General Agreement on Tariffs and Trade (GATT), the North American Free Trade Agreement (NAFTA) and the World Trade Organization work explicitly to remove unnecessary trade restrictions, and have identified unjustified invasive species quarantines as a major focus for reform. All quarantines must be grounded in science, and the country restricting the import must demonstrate that it is actively controlling the pests that it seeks to prevent from entering. These rules put pressure on all trading countries to strengthen the technical aspects of their prevention systems, but few are currently capable of doing so.

THE NATURE CONSERVANCY'S INVASIVE SPECIES INITIATIVE

Whether in the coral reefs of the South Pacific, in native grasslands of the western U.S., in Brazil's Pantanal wetlands, in the hardwood hammocks of the Florida Keys, in coastal and tropical forests in the Caribbean, or across Mexican deserts, invasive species were identified as one of the most serious and pervasive threats across all of The Nature Conservancy's Conservation Areas, threatening all of our conservation accomplishments to date. The Nature Conservancy (TNC) is a non-profit organization dedicated to preserving the plants, animals and natural communities that represent the diversity of life on Earth by protecting the lands and waters they need in order to survive. The Conservancy has more than 1.1 million individual members and over 1,900 corporate sponsors, and currently has programs in all 50 states and in 27 other nations, including the Bahamas, Jamaica, Dominica, the Dominican Republic, and the U.S. Virgin Islands. To date, the Conservancy has protected more than 12 million acres worldwide, and has helped local partner organizations preserve millions of acres in other nations. The Conservancy itself owns more than 1,340 preserves in the United States –the largest private system of nature sanctuaries in the world. Its conservation work is grounded on sound science, strong partnerships with other landowners, and tangible results at local scale.

The Nature Conservancy determines where and how to do its work through a planning process that identifies areas in the country containing the most viable and important examples of plant and animal populations and communities. This process further identifies the principal threats to the integrity of the sites such as land conversion, non-point source runoff, or repression of natural fire regimes. And, in a bottom-up priority setting assessment in mid-2001, an overwhelming 94% of TNC sites identified invasive species as a significant threat to the native species and communities that we are working to protect.

In response to the pervasive threat of invasive species to the Conservancy's conservation achievements, TNC created an Invasive Species Initiative (ISI). The ISI's overarching goal is to reduce and manage the threat to worldwide biological diversity, and the concomitant social costs, caused by non-native organisms invading ecosystems. To achieve this goal, the Invasive Species Initiative developed a set of seven steps, which, when carried out in concert, will build a solid and adaptable foundation for any effective invasive species strategy. The steps for this comprehensive strategy include:

1. Adoption of governmental policies (on all scales) to prevent harmful new invasive species and control significant existing invasive species in a manner equivalent to the cutting-edge policies in New Zealand;
2. Availability of and use of tools, techniques, and information on invasive species prevention and management;
3. An accurate, all-taxa, baseline assessment of threats from invasive species;
4. Prevention of harmful new introductions on continental and local scales;
5. Early detection of, and subsequent rapid response to, newly established invaders;
6. Identification and control of all established invasions, including restoration of native ecosystems;
7. Awareness of the urgency and seriousness of the issue by the general public.

Although a comprehensive strategy includes all of these steps, the most effective invasive species efforts will focus priority attention on prevention and early detection, as once an invasive species becomes established, the time and money requirements needed for control of that species increase dramatically. The establishment of a new invader takes a similar toll on the ecosystem (Figure 1). In the absence of effective prevention and early detection systems, we are limited to the last remaining option for invasive species management, control. Below, we outline examples of the Conservancy's work on assessment, early detection and rapid response, and control strategies.

Before an early detection system can detect a new invasive species, it is necessary to have an all-taxa baseline assessment of invasive species threats already in place. The Nature Conservancy's Invasive Species Initiative and Northeast/Caribbean Division, in cooperation with CAB International, completed the first Caribbean Invasive Species Assessment in April 2003. This assessment has led to the creation of a database containing a list of contact information for invasive species experts in the Caribbean. In addition, the assessment discovered that invasive species policies and invasive species management techniques throughout the Caribbean are piecemeal in nature. This important baseline information will focus attention on the direction of future efforts in the Caribbean region; the region must develop comprehensive regional policies, control action plans, information exchange methods, and an early detection system.

No prevention system can be completely foolproof in keeping invasive species out of an area. This fact underscores the importance of maintaining an early detection and rapid response system to quickly eradicate new invasions. The following case studies illustrate The Nature Conservancy's commitment to abating invasive threats on local regional scales.

INTRODUCTION OF RACCOONS ON ABACO ISLAND, BAHAMAS

In 1992, raccoons were accidentally introduced to the Bahamian island of Abaco. This introduction threatens a number of species, in particular, an endemic, ground-nesting subspecies of the Cuban parrot (*Amazona leucocephala bahamensis*), the only significant remaining population being restricted to Abaco. In order to help the Abaconian community better respond to new invasive species, The Nature Conservancy's Bahamas Office is supporting and partnering with a local conservation organization called Friends of the Environment. Effective management of biological invasions requires consensus among all entities and decision makers, as well as affected parties. The Nature Conservancy is assisting this group in establishing a governing board to represent a diverse group of interests from the community, including a representative from the local Department of Agriculture. With help from The Nature Conservancy, the group is also developing a plan to control newly-detected invasive species, like the raccoon, and raising public awareness about the importance of preventing new invasive species from becoming established and threatening the island's biodiversity.

SPREAD OF CACTUS MOTH THROUGH THE CARIBBEAN AND FLORIDA

In 1988, officials in South Florida were alerted that the cactus moth (*Cactoblastis cactorum)* had been detected in Cuba. In the intervening fourteen years, the moth made its way to the Florida Keys and continued spreading northward at the rate of approximately 50 km per year, where it can now be found as far north as Charleston, South Carolina, on the East Coast and the panhandle of Florida on the Gulf Coast. Without a prevention or early detection plan, officials in Florida, as well as Conservancy staff, are now forced to try to control *C. cactorum* and stop it from spreading further.

The moth's larvae feed predominately on species of *Opuntia* cacti. The genus *Opuntia* is a diverse group in North America, with many endemic species. There are 31 likely host *Opuntia* across the United States (9 endemic), 56 in Mexico (38 endemic), and additional native and endemic species found throughout the Caribbean and Central America. Additionally, *C. cactorum* has been documented on one species of *Cereus* in Argentina, and may threaten some species of this group as well.

The establishment of *C. cactorum* seriously affects not only biodiversity in natural areas, but is a significant threat to agriculture across the Americas. *Opuntia* cacti are the seventh largest agricultural species in Mexico, with 215,000 ha planted commercially, as well as 3 million ha in the wild (Soberon et al., 2001). The threat to *Opuntia* affects other economic and social sectors as well. *Opuntia* serve as the third largest staple food for Mexico's rural poor (Soberon et al., 2001), and in 2001, the horticultural industry in Arizona sold $9.5 million worth of *Opuntia* cacti for landscaping purposes (Irish, 2001). With the inclusion of consequences to biodiversity across the region, the moth has the potential to dramatically change the landscape across the Americas.

When *C. cactorum* was discovered to have killed one out of a population of fourteen remaining individuals of the rare *Opuntia corallicola* on a Conservancy preserve, The Nature Conservancy began research on control methods for *C. cactorum*. Research methods currently include outplanting of *O. corallicola*, covering at-risk cacti with cages to exclude moths, and collaboration with the U.S. Department of Agriculture's Animal and Plant Health Inspection Agency on the possible use of pheromone traps and a sterile male release program. The Conservancy participated in an International Atomic Energy Agency workshop to develop a proposal and funding for mitigating the threat from *C. cactorum* in 2002. Additionally, the Conservancy raised the issue to the intra-governmental level at the April 2003 Annual Meeting of the Trilateral Committee for Wildlife and Ecosystem Conservation and Management, which includes the Governments of Canada, the United States, and Mexico. TNC participated in the invasive species working group, which asked the Executive Committee to initiate a project under the Trilateral Committee that would address the threat of the spread of the cactus moth, using modeling, surveillance, and public education.

CONCLUSION

Fundamentally, managing the threat of invasive species is not just about ecological intervention; it is about social change. The public's behavior must change because it is unacceptable to our quality of life to enable the free movement and establishment of invasive species, whether in natural areas and biodiversity hot spots, in agricultural systems and forests, or in our own backyards. To this end, The Nature Conservancy's approach is built foremost upon partnerships, locally and globally. Without the support of partnerships between the Conservancy and local conservation groups, university researchers, and Federal agencies, the early detection system and invasive species control research described above would be severely hampered. Additionally, a significant ramping up of efforts and partnerships outside of North America will be critical to the overall success of The Nature Conservancy's Invasive Species Initiative, as international travel and trade continue to spread new invasive species around the world at an unprecedented pace. Putting The Nature Conservancy's seven-step strategy into action, along with an emphasis on creating partnerships with a variety of stakeholders and on a number of scales, will reduce the threat of invasive species, not only to the Conservancy's preserves, but to others as well.

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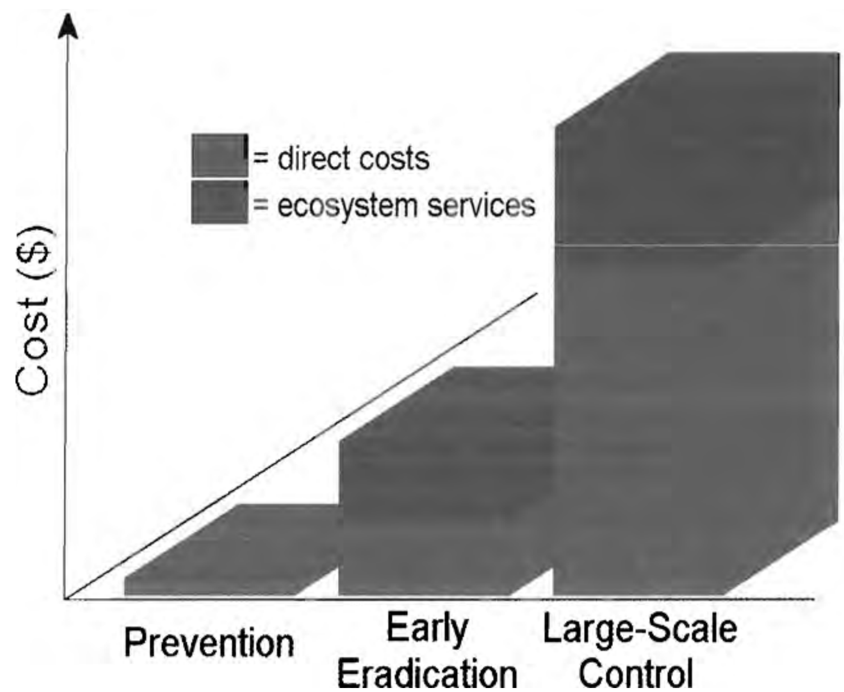

Figure 1. Direct and ecosystem services costs attributed to invasive species at different stages of invasion.

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ENTOMOFAUNA INVASIVA EN PUERTO RICO: HISTORIA Y POTENCIALES INTRODUCCIONES

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RESUMEN: Por sus condiciones ambientales y por ser uno de los centros de comercio y movilización de carga más grandes del Caribe, Puerto Rico se ve constantemente amenazado con la introducción de insectos exóticos. Estos generalmente son plagas de considerable riesgo económico para los cultivos y los productores de la Isla. Estos insectos se establecen en la mayoría de los casos debido a sus altos potenciales reproductivos, a la abundancia de sus hospederos y a la ausencia de sus enemigos naturales, que usualmente no se introducen simultáneamente. Entre 1963 y 1999 se introdujeron a la isla entre uno y seis insectos exóticos por año. En esta charla se presentará el impacto de la introducción de estas plagas en la isla y de otras plagas que causarían un serio impacto económico si fuesen introducidas al país. Puerto Rico debe mantenerse vigilante para impedir la entrada de especies devastadoras como la broca del café, *Hypothenemus hampeii*, el picudo del mango, *Sternochetus mangiferae*, los vectores del anillo rojo del cocotero, *Rhynchophorus palmarum* y *Rhinostomus barbirostris*, la mosca mexicana, *Anastrepha ludens*, la mosca del mediterráneo, *Ceratitis capitata*, así como *Myndus crudus*, el vector de amarillamiento letal del cocotero.

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A PEER REVIEWED PAPER

INVASIVE ALIEN SPECIES IN THE DOMINICAN REPUBLIC: THEIR IMPACT AND STRATEGIES TO MANAGE INTRODUCED PESTS

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ABSTRACT: The increased exchange of agricultural goods and people has unleashed the spread of alien species in the Caribbean. The Dominican Republic, as well, has been burdened with the introduction of dozens of alien species, including a substantial number with high invasive potential. Some of these have caused significant economic losses to affected crops within intensive agro-ecosystems, and others have displaced native species, and/or interfered with the functioning of susceptible ecosystems. Herein we list about 50 cases of introduced agricultural pests including arthropods, molluscs, and plant pathogens causing fungal, bacterial, viral or other diseases. We briefly review selected examples with respect to their detection, impact and countermeasures taken. In most cases involving introduced alien arthropods, the lack of specialized antagonists, and/or the ineffectiveness of native antagonists have permitted rapid dispersal of the introduced pests. This has occurred in the cases of vectors of plant pathogens (aphids, and whiteflies), mealybugs, thrips, fruit flies, the coffee-berry borer, and recently the pigeon pea pod fly. Thus far, no introduced pests have been eradicated from the Dominican Republic. On the other hand, intentional or accidental introductions of antagonists of some introduced insect pests have resulted in dramatic population decreases of these alien species, often to levels well below economic-damage levels. This decrease has been achieved in the cases of the citrus blackfly, the citrus leafminer, the brown rice bug, and the papaya mealybug. Regarding the pink hibiscus mealybug, the combination of parasitoid species, probably introduced together with the pest, and the predacious mealybug destroyer already present since the 1930s, and the implementation of classical biocontrol have not permitted damage at levels comparable to those caused by this pest in the Lesser Antilles during the last decade.

INTRODUCTION

In the last 25 years, significant increases in the international exchange of travelers and agricultural goods have caused a surge in both the risk, and actual introduction, of exotic plant and pest species, especially plant pathogens and arthropods, into the Dominican Republic, which covers the two eastern thirds of Hispaniola. The main factors contributing to this surge include:

- an improved, but still not sufficiently effective, quarantine system;
- sharing the island with Haiti, a politically unsettled country with a deficient safeguarding system, and a long border porous to pests;
- the occurrence of tropical storms and hurricanes, which can spread certain introduced pests and plant pathogens after their introduction into the Caribbean region.

The main implications of the introduction of alien invasive species are as follows:

- Many are major pests that cause direct yield losses to crops, and/or reductions in quality of harvested products, and increased costs of production. Consequently, production of some important crops has become unprofitable and unsustainable, and this has been accompanied with severe socio-economic distress. This situation occurred during the mid 1990s when the *Bemisia*-Geminivirus complex destroyed the production of tomatoes and other host crops.

- Loss of export markets. Alien pests often cause restrictions or bans on potentially infested or infected export products by countries that consider these pests or plant pathogens as quarantine-significant. These bans have severe economic implications to the producers, who risk the loss of competitiveness.
- Losses in biodiversity: In particular, invasive alien plant species tend to displace endemic and native species from protected natural areas.

Experience has shown that many introduced alien species become established, and in a relatively short period those with strong invasive potentials spread into agrarian or natural environments. Reports on introduced arthropods, plant pathogens, and invasive plant species seldom explain whether the pests were introduced deliberately, how the pests arrived, their countries of origin, their ports of entry, and their distribution. Often such information may be obtained only after these species have caused economic damage, or other serious problems. In many cases, the absence of specific antagonists has allowed highly damaging introduced alien species to spread rapidly throughout the country.

Examples of invasive alien plant species are presented in Tables 1 and 2. However, the problem of invasive species is enormous and complex, and this account does not treat many established alien invasive vertebrates (mammals, birds, reptiles, amphibians and fishes), nor plants, nematodes and other taxa. Many of the latter were introduced decades or even centuries ago, often intentionally, and their spread and negative impact have already been reported in other countries of the Caribbean.

Few records on the introduction of exotic plant species, and of the reasons for their often planned introduction are available. Most of the perennial species were introduced as fruit trees, ornamentals, reforestation to prevent soil erosion or to produce timber or fuel. Some species introduced centuries ago, now play an outstanding role in the native landscape, including the coconut palm (*Cocos nucifera* L., Palmaceae) from the southern Pacific, the tropical almond (*Terminalia cattapa* L., Combretaceae) in the coastal landscapes from Malaysia and Southern Asia, breadfruit trees (*Artocarpus altilis* (S. Park.) Fosb., Moraceae) in humid environments, and *Pinus caribaea* Morelet (Pinaceae) in mountain areas.

Some of the perennial alien species with invasive potential listed in Tables 1 and 2 are spreading into protected areas, and are displacing native endemic flora. The management of invasive plant species has been discussed recently with respect to protecting natural reserves. Nevertheless, special strategies for the management of those plant species in endangered environments either have not been implemented, or have been implemented only where they are problematic for annual and perennial crops and pastures.

Water hyacinth, *Eichhornia crassipes* (Mart.) Solms, is an economically serious problem in the Dominican Republic. It has invaded numerous aquatic environments, and has disrupted irrigation and navigation on rivers. Studies on the classical biological control of the water lily are planned with the support of the University of Puerto Rico. Successful classical biological control of *E. crassipes* would encourage similar thrusts against other weed species.

Numerous agriculturally significant arthropod pests and plant pathogens were introduced into the Dominican Republic and reported between 1975 and 2003 (Table 3).

IMPORTANT INTRODUCED PLANT PATHOGENS IN THE D.R.

Among 37 listed agricultural pests listed in Table 3, the plant pathogens most frequently reported as causes for severe diseases in agricultural crops in the Dominican Republic belong to the fungi (6), bacteria (2), viruses (4) and phytoplasmas (1).

Selected diseases and plant pathogens are discussed below.

a. Coconut Lethal Yellowing Disease (CLYD, Phytoplasma) has been reported in the Caribbean since the 1960s (Jamaica, Florida). It was reported in the D.R. by Schmutterer (1990), and was re-confirmed in 1995. It is caused by a phytoplasma transmitted by the 'palm cixiid', *Myndus crudus* (van Duzee) (Hemiptera [Auchenorrhyncha]: Cixiidae) as vector. To meet this danger, all detected infected and surrounding plants were destroyed in 1995. International authorities have recognized the commercial coconut growing regions in the Northeast as a disease-free area.

b. Bean Golden Mosaic Virus (BGMV, Begomovirus) was reported in 1978. This whitefly (*Bemisia tabaci*) - borne viral disease has been considered as a serious limiting factor for bean production in the D.R., the Caribbean, Central America and Florida. Numerous studies have focused on managing the whitefly/virus complex, but only the selection and introduction of tolerant varieties has permitted sustainable bean production. Since more than 10 years ago, the National IPM Program (SEA-JAD) has been implementing a host plant-free period in the most important tomato and bean growing areas, especially in the irrigated valleys of the south, southwest and northwest.

c. *Peronospora hyoscyami* de Bary (Peronosporales), blue mold of tobacco, or tobacco mildew was identified in 1981. This fungal disease was the main cause for the reduction of the tobacco-growing area. Monitoring systems were implemented in the 1980s, and effective chemical control has reduced the importance of the disease.

d. *Hemileia vastatrix* Berk. & Br. (Uredinales), coffee rust was introduced in about 1989. This fungal disease spread quickly throughout lowland coffee plantations. Although initially devastating, coffee rust with its economic impact has been reduced through strategic use of chemical controls.

e. Citrus Tristeza Virus (CTV, Closterovirus) was reported in 1990 by R.F. Lee. Etienne et al. (1992) identified its most efficient vector *Toxoptera citricida* (Kirkaldy). The main problem is that most citrus trees in plantations are grafted onto susceptible sour orange rootstocks. Management of the disease is based on grafting onto tolerant rootstocks, i.e., *Citrus* 'Volkameriana', Carrizo, and others. A program to produce CTV-free plants has been initiated recently with co-operation between (Instituto Dominicano de Investigaciones Agropecuarias y Forestales (IDIAF) and the Centre de Coopération Internationale en Recherche Agronomique pour le Développement (CIRAD).

f. Tomato Yellow Leaf Curl Virus (TYLCV, Begomovirus). This whitefly (*B. tabaci*)-borne virus, identified as TYLCV-Israeli strain, was observed first in 1991 in single tomato plants. This was the first reported introduction of this virus in the Western hemisphere (Nakhla et al,. 1994; Polston et al., 1994). Since 1992 this virus has caused devastating yield losses. Seminal studies on the epidemiology, host plant range of the virus and its vector have been conducted (see silverleaf whitefly). The system to manage this problem includes the area-wide use of systemic insecticides and host-free periods.

g. *Ralstonia solanacearum* (E.F. Smith) (Proteobacteria), this bacterial wilt of potato bacterium was confirmed in the D.R. in 1994 by P. Jorge and contributors (unpublished). Only limited management is possible at this time because of low quality plant propagation material. A program to produce certified potato planting material is planned by the IDIAF. Several strains are present in the country, some of which also attack tomato.

h. *Mycosphaerella fijiensis* Morelet (Ascomycetes: Mycosphaerellales), Black Sigatoka of *Musa* species was identified in 1996 and confirmed by scientists at CIRAD, Montpellier. This severe fungal disease destroys leaves of banana and plantain. Management is based on removal of infected leaves, fungicide applications, limited biological and climatic forecasting, and limited planting of tolerant hybrids (FHIA 20, 21, 25) (T. Polanco and P. Jorge 2002, unpublished). A nationwide extension program to meet this acute threat has been implemented by SEA.

i. Bean Common Necrotic Mosaic Virus (BCNMV, Potyvirus) was identified in 2000 in San Juan de la Maguana Valley, the main bean-producing area. Bean seed lots are tested to prevent the spread of the disease through infected seeds, and molecular genetic studies are being carried out by G. Godoy de Lutz (IDIAF).

j. Banana Streak Virus (BSV, Badnavirus) was identified in 2001 and confirmed by scientists at CIRAD – Montpellier, France. The distribution and incidence of the virus are still limited, according to a survey begun in 2001 by R.T. Martinez (IDIAF).

IMPORTANT PLANT PATHOGENS WITH POTENTIAL TO ENTER THE DOMINICAN REPUBLIC

If introduced into the D.R., the pathogens discussed below would be highly damaging.

a. *Ralstonia solanacearum* (E.F. Smith) (Proteobacteria), bacterial wilts, caused by diverse strains of this pathogen are present in the Caribbean area, and could threaten tomato and flower production. Uncharacterized biovar I strains with a wide host range including *Anthurium andreanum*, *Heliconia caribaea*, *Canna indica*, cucurbits, and several weeds have been reported from Martinique (Mian et al., 2003).

b. Tomato spotted wilt virus (TSWV, Tospovirus) has a wide host–plant range. Its most efficient vector, the thrips *Frankliniella occidentalis* (Pergande) is already present, but the TSWV has not been reported in the D.R.

c. *Liberobacter asiaticum* (L.) Jack (Proteobacteria), cause of 'citrus greening disease' (CGD) is a serious malady. It has not been reported in the Caribbean. Its most efficient vector, the psyllid *Diaphorina citri* Kuwayama, is already present (Abud, 2001).

d. Leprosis of *Citrus* (Rhabdovirus) and the associated mite vectors, *Brevipalpus* spp. complex (Acari: Tenuipalpidae), have caused significant economic losses in Brazil, Argentina and Panama. Leprosis was present in Florida, but has not been reported since 1961 (Childers et al., 2002).

e. *Moniliophthora roreri* (Ciferri) H.C. Evans *et al.* (Basidiomycetes) causes 'frosty pod rot'. It has caused more than 60% loss of the cocoa crop in Ecuador and Costa Rica.

f. *Crinipellis perniciosa* (Stahel) Singer (Basidiomycetes) causes 'witches broom disease' of cocoa (WBDC). It is present in South America.

The absence of the latter two very severe diseases on Hispaniola is one of the main reasons that the D.R. is the leading worldwide producer of organic cocoa.

IMPORTANT INTRODUCED ARTHROPODS AND OTHER PESTS IN THE D.R.

a. *Bemisia tabaci* (Gennadius) (Hemiptera [Sternorrhyncha]: Aleyrodidae), Biotype A, sweet potato whitefly, was reported in 1975. It showed a wide host range, and caused severe yield losses in bean fields due to direct damage, and as the vector of the Bean Golden Mosaic virus (BGMV). Improved chemical control, and the use of tolerant varieties developed by CIAT and in a USAID program minimized this problem for many years. Biotype A of *B. tabaci* has not been found since 1994, because it appears to have been displaced entirely by the **Biotype-B**, also known as ***B. argentifolii*** (Bellows and Perring) (Serra et al., 1994b; 1996).

b. *Trialeurodes vaporariorum* Westwood (Hemiptera [Sternorrhyncha]: Aleyrodidae), the greenhouse whitefly, was reported in 1978 in mountain valleys. This whitefly has a wide host range. Studies on natural enemies have been achieved. Parasitoids have been released and are established. Nevertheless, the high spray frequencies employed in intensively managed vegetable growing areas have induced high levels of resistance to insecticides, and have prevented biological control.

c. *Eriophyes guerreronis* Keifer (Acari: Eriophyidae), the coconut flower and nut mite, was identified in 1979. It has spread throughout the coconut growing areas, and it degrades coconut quality. Fungal pathogens associated with the mite have been detected. Recently, studies were undertaken on the management of the pest.

d. *Thrips palmi* Karny (Thysanoptera: Thripidae), the melon thrips, was identified in 1988 on eggplant. It attacks several cucurbits, pepper and other vegetables. From 1989 to 1996 the U.S. authorities banned of importation of Chinese vegetables from the D.R. because of impermissible pesticide residues and the occurrence of *T. palmi*, a quarantine pest. Consequently, an IPM program was implemented from 1991-92 based on monitoring, and cultural and postharvest measures, and in 1997 the ban was lifted.

e. *Bemisia tabaci* (Gennadius), Biotype B, or *B. argentifolii* Bellows & Perring (Hemiptera [Sternorrhyncha]: Aleyrodidae), the silverleaf whitefly, was identified in 1988. Unlike Biotype A, it reproduces on tomato. Initially Biotype B caused severe damage as a result of sap sucking, the growth of sooty mold on discharged honeydew, and uneven ripening in tomato, or the silvering of leaves of cucurbits. Between 1989 and 1995 losses to the tomato industry in D.R. were estimated at US$ 60 million (Polston and Anderson, 1997). Conventional chemical control was not effective, and even caused excessive increases in populations. On the other hand the management of the whiteflies was possible by the use of selective insecticides (Serra, 1992). In 1991, a geminivirus, TYLCV (see above) was detected in tomato fields. With its dissemination, yield losses increased catastrophically. Seminal studies on the host range of both the vector and the virus, as well as chemical, biological and integrated management have been achieved (Serra et al., 1994a, 1994b, 1996). An IPM program including legal measures (an annual 3-month host-crop-free period enforced by PNMIP-SEA-JAD), tolerant varieties, the use of protected nurseries, and systemic insecticides was implemented. It greatly reduced yield losses. Nevertheless, recently the importance of the complex has again increased.

f. *Rhizoglyphus robini* Claparede (Acari: Acaridae), the bulb mite, was reported in 1989 on garlic in a mountain valley of Constanza. This species was probably introduced with bulbs from China. Chemical control has not been very effective. In the 1990s a program (FST-Ciba Geigy) focused on reducing the spray frequency, and on the use of selective pesticides. Studies have been conducted on infestations in fields and in storage, and these included comparisons of conventional, botanical and selective pesticides (Serra et al., 2003).

g. *Pseudacysta perseae* (Heidemann) Blatchley (Heteroptera: Tingidae), the avocado lacebug, was reported in 1990. Causing defoliation, the pest has since spread throughout all avocado growing areas. Surveys for effective natural enemies have not been fruitful. Extension work has been achieved by the National IPM Program. The lacebug is commonly associated with *Colletotrichum* sp. (P. Jorge and R. Mendez, unpublished).

h. *Frankliniella occidentalis* (Pergande) (Thysanoptera: Thripidae), the western flower thrips, was identified in 1990. This thrips threatens the flower industry, since it is an efficient vector of the Tomato Spotted Wilt Virus (TSWV). TSWV has a wide host-plant range, but has not been reported in the D.R.

i. *Pomacea canaliculata* (Lamarck) (Stylomatophora: Ampullaridae), the golden or Channeled snail, was initially misidentified in 1991 as *Ampularia* (syn. *Pomacea*) *glauca* (L.), the Apple snail. The snail probably was introduced to clear algae from ponds, and subsequently escaped into irrigated-rice fields, spread through the irrigation systems, and now damages young plantings of rice. In 1996 the Ministry of Agriculture started a chemical control program, and in 1997 the Ministry offered a bounty for snails and snail eggs, but this latter approach failed. In 2001 a program combining trapping and chemical control was initiated.

j. *Aleurocanthus woglumi* Ashby (Hemiptera [Sternorrhyncha]: Aleyrodidae), the citrus blackfly, was reported in Haiti in the 1930s by Ashmead. Subsequently heavy infestations of the citrus blackfly were reported in Santo Domingo (Abud, 1992). The problem was overcome through the introduction of parasitoids, their mass rearing and successful releases by the JAD, so that now the pest is unimportant.

k. *Toxoptera citricida* Kirkaldy (Hemiptera [Sternorrhyncha]: Aphididae), the brown citrus aphid, was identified by Etienne et al. (1992). This aphid is considered the most efficient vector of the citrus tristeza virus (CTV) present in the D.R. A parasitoid, *Aphidius colemanii* Viereck, was imported from Argentina through Florida, but has not been recovered. However efficient parasitoids are present.

l. *Phyllocnistis citrella* Stainton (Lepidoptera: Gracillariidae), the citrus leafminer, was identified in 1994. An IPM program consisting in extension work to avoid spraying has been implemented. A survey of native parasitoids has been accomplished (Tavares, 2000). Effective parasitoids are present and are widely found.

m. *Varroa jacobsoni* Oudemans (Acari: Varroidae), the Varroa mite, was identified in 1995. The Varroa mite has caused serious losses to the national production of honey and other bee products. The situation has been improved through a program consisting in extension work and chemical control conducted by the Animal Health Dept., Redapi/CEDAF.

n. *Hypothenemus hampei* Ferr. (Coleoptera: Scolytidae), the coffee berry borer, was identified near Cotuí in 1995. Heavy yield losses have been limited to coffee grown at low altitudes. Biological, manual and chemical control has been implemented. A trapping system (Brocap®-CIRAD) has been tested in combination with manual practices (Pérez, 2003).

o. *Tibraca limbativentris* (Stål.) (Heteroptera: Pentatomidae), the rice stalk stinkbug, was re-identified in 1997. It might have been present since the 1980s (Pantoja, pers. com.). A survey of natural enemies was conducted, and was followed by the successful implementation of biological control with mass releases of a native egg parasitoid (*Telenomus* sp.) by the PNMIP-SEA-JAD.

p. *Paracoccus marginatus* Williams & Granara de Willink (Hemiptera [Sternorrhyncha]: Pseudococcidae), the papaya mealybug, was identified in 1997 on papaya, mandioca and ornamentals. In 2001, a successful program of classical biological control with 4 imported parasitoids was carried out jointly by USDA-APHIS, the National IPM Program, and SEA-JAD. Within 6 months the density of the pest's populations dropped by more than 95% (Meyerdirk and De Chi, 2003).

q. *Steneotarsonemus spinki* Smiley (Acari: Tarsonemidae), the rice tarsonemid mite, was identified in 1998. It was probably introduced from Cuba. The mite appears associated with the fungal pathogen, *Sarocladium oryzae* (Sawada) W. Gams & D. Hawksworth. Research on tolerant varieties and chemical control has been carried out. As a consequence, a tolerant variety was planted in more than 80% of the wetland-rice areas. New materials are being tested, but the problem still persists.

r. *Melanagromyza obtusa* (Malloch) (Diptera: Agromyzidae), the pigeon pea pod fly, was identified in 2000. This fly of Asian origin has already reached nationwide dissemination. Surveys showed damage levels exceeding 50% in the absence of effective natural enemies.

Studies on chemical control are being undertaken by the IDIAF (Cedano et al., 2003; Serra et al., 2003). Since the profitability levels of the pigeon pea crop are low, and since many producers belong to the subsistence sector, the implementation of classical biological control has been requested. Consequently, foreign exploration for parasitoids will be carried out in Asia during 2003 by USDA-APHIS.

s. *Diaphorina citri* Kuwayama (Hemiptera [Sternorrhyncha]: Psyllidae), the Asiatic citrus psyllid, was reported in 2001. This species is a potential vector of the 'citrus greening disease' (CGD), which is still absent from the Caribbean. Parasitoids and fungal pathogens of this vector have been detected.

t. *Contarinia maculipennis* Felt (Diptera: Cecidiomyiidae), the 'blossom midge', was identified in 2001. This midge is widely distributed, and attacks orchids, tomato, *Hibiscus* spp., and other ornamentals. It is already widely distributed throughout the country.

u. *Maconellicoccus hirsutus* (Green) (Hemiptera [Sternorrhyncha]: Pseudococcidae), the pink hibiscus mealybug, was reported in 2002. This mealybug has a wide host range, and has been very destructive on other Caribbean islands. Studies have been conducted on natural control by an established predator and introduced parasitoids, population dynamics, host plant range, and geographic distribution (Nuñez et al., 2003; Serra et al., 2003). A successful program of classical biological control with two parasitoids was started in August 2002, and has since been monitored by APHIS, SEA, National IPM Program, IDIAF-UNPHU, and UASD.

v. *Cyrtophora citricola* (Forsköl) (Aranae: Araneidae), the tropical tent-web spider, was identified in 2002. This spider originated in southern Africa, and spread through the Middle East and Mediterranean. It occurs on *Citrus*, other trees and shrubs, and is spreading throughout the D.R., Florida, Venezuela and Colombia. Observations to understand the cause of the damage and how the spider is involved have been initiated by Serra. The spider produces indirect damage through a dense web that can kill the host plants. Chemical control by localized spraying is effective, but risks disturbance of the ecosystem in perennial fruit orchards.

LESS WELL KNOWN INTRODUCED ARTHROPOD PESTS IN THE D.R.

A number of arthropod pests that probably entered the Dominican Republic during the last three decades, but which are poorly known, are described below.

a. *Tetranychus* sp. (Acari: Tetranychidae), an unidentified spider mite was detected in the Northwest. It covers tomato and other plants with an extra-dense web (Serra et al., 1994b).

b. *Eriophyes hibisci* (Nalepa) (Acari: Prostigmata: Eriophyidae) attacks *Hibiscus* spp., and is disseminated in many parts of the country (determined by M. Pellerano, pers. commun.).

c. *Eriophyes annonae* Keifer (Acari: Eriophyidae) is found on *Annona* spp.

d. *Anastrepha obliqua* (Macq.) (Diptera: Tephritidae), the West Indian fruit fly, attacks guava, mango, and other fruits.

e. *Anastrepha suspensa* (Loew) (Diptera: Tephritidae), the Caribbean fruit fly, has been trapped by Cuevas et al. (2002) and Abud (unpubl. data). It infests guava, mango, *Eugenia* spp., and tropical almond (*Terminalia cattapa L.*).

f. *Anastrepha dissimilis* Stone (Diptera: Tephritidae) has been trapped by Cuevas et al. (2002) and Abud (unpubl. data). It attacks the passionfruits, *Passiflora edulis* and *P. quadrangularis*.

g. *Anastrepha ocresia* (Walker) (Diptera: Tephritidae) has been trapped by Cuevas et al. (2002) and Abud (unpubl. data). It attacks sapodilla, *Manilkara zapota* (L.) van Royen, *Achras zapota* (L.).

h. *Anastrepha* sp. (syn. *hambletoni*?) (Diptera: Tephritidae) has been trapped (Cuevas et al., 2002; and Abud, unpubl. data). It attacks cashew, *Anacardium occidentalis*.

i. *Liriomyza trifolii* (Burgess) (Diptera: Agromyzidae), the American serpentine leafminer, attacks many vegetables, flowers and ornamental plants. Its introduction has not been reported, however the pest probably has occurred in the D.R. since the late 1970s.

j. *L. huidobrensis* (Blanchard) (Diptera: Agromyzidae), the pea leafminer, has been reported by Abud (1992).

k. *Hypsipyla grandella* Zeller (Lepidoptera: Pyralidae), the mahagony shoot borer, has been causing damage to *Swietinia* and *Cedrela* for years.

l. *Cactoblastis cactorum* (Bergroth) (Lepidoptera: Pyralidae), the cactus moth, has been present in the D.R. at least since 1970. It has been purposely released in the Caribbean since the 1950s for biocontrol of *Opuntia* spp., a forage. Studies on natural enemies and biocontrol have been conducted by the IDIAF (Wagner and Colón, 2002).

m. *Gynaikothrips ficorum* (Marchal) (Thysanoptera: Phlaeothripidae), the Cuban laurel thrips. Its population exploded into a nation-wide outbreak on *Ficus benjamina* in 2002. Apparently the pest has been present for many years.

n. *Myndus crudus* (van Duzee) (Hemiptera [Auchenorrhyncha]: Cixiidae) is a vector of the coconut lethal yellowing disease (CLYD). It has not been reported to be established, but this has not been confirmed recently.

o. *Planococcus lilacinus* (Cockerell) (Hemiptera [Sternorrhyncha]: Pseudococcidae). This mealybug has been reported to be present in the D.R. (Miller and Miller, 2001). Nevertheless its presence has not been confirmed by local authorities. It has the potential to cause economic losses to cocoa, citrus, guava and mango.

p. *Oxycarenus hyalinipennis* (Costa) (Heteroptera: Lygaeidae), the cottonseed bug, was reported in the D.R. by Slater and Baranowski (1994), but no local confirmation is available.

INVERTEBRATE PESTS WITH POTENTIAL TO ENTER THE D.R. IN THE NEAR FUTURE

a. African giant snail (*Achatina fulica* (Bowdich), Stylomatophora: Achatinidae) is present in Guadeloupe, Martinique and other islands in the southern Caribbean. It destroys native snail species through competition, but not by preying on them.

***b. Amblyomma variegatum* (Fabr.) (Acari: Ixodidae)**, the 'tropical bont tick', is an important vector of heart water disease (tick-borne rickettsial disease of ruminants) in Africa. It is present on Guadeloupe, Martinique and other islands in the Caribbean (Pegram and Indar, 2003).

c. *Planococcus minor* (Maskell) (Hemiptera [Sternorrhyncha]: Pseudococcidae). This mealybug has a wide host range, and the potential to cause economic losses to the cocoa industry. It is present in the Caribbean, and has been reported to have entered Haiti (Miller et al., 2002).

d. *Aulacaspis yasumatsui* Takagi (Hemiptera [Sternorrhyncha]: Diaspididae), the 'sagopalm scale', or *Cycas aulacaspis* scale, originated in Asia. It is present in Florida and Puerto Rico, where it has caused very severe damage to cycads (Pena and Baranowski, 1999; Aixa Ramírez, pers. com.).

e. *Paratachardina lobata lobata* (Chamberlin) (Hemiptera [Sternorrhyncha]: Kerriidae), the 'lobate lac scale', is present in the Bahamas and Florida. It attacks more than 150 woody species (Howard, 2003).

f. *Rhynchophorus palmarum* (L.) (Coleoptera: Curculionidae), the 'South American palm weevil', attacks coconut palms and palms belonging to the genera *Elaeis*, *Livistonea* and *Phoenix*. The weevil vectors the nematode, *Rhadinaphelenchus cocophilus*, which causes the serious red-ring disease of coconut palms (RDCP) (Schmutterer, 1990).

g. *Rhinostomus barbirostris* F. (Coleoptera: Curculionidae), the 'bearded coconut weevil' attacks several palm species, and is an effective vector of the RDCP (Franqui, 2003).

h. *Sternochetus mangiferae* (F.) (Coleoptera: Curculionidae), the 'mango seed weevil', is already present in the southern Caribbean.

i. *Anthonomus eugenii* Cano (Coleoptera: Curculionidae), the 'pepper weevil', is a serious pepper pest present in Florida, southwestern U.S.A. and Puerto Rico.

j. *Stenoma catenifer* Walsh (Lepidoptera: Oecophoridae), the 'avocado seed moth', is present in northern South America, Panama, and Mexico (ESA, 2001).

k. *Anastrepha ludens* (Loew) (Diptera: Tephritidae), the 'Mexican fruit fly', is already present on Grenada and other islands.

l. *Bactrocera carambolae* Drew & Hancock (Diptera: Tephritidae), the 'carambola fly', is present in northeastern South America.

m. *Bactrocera* spp. (Diptera: Tephritidae). Of special concern are the 'oriental fruit fly', ***B. dorsalis*** Hendel, and the melon fly, ***B. cucurbitae*** Coquillett.

n. *Ceratitis capitata* (Wiedemann) (Diptera: Tephritidae), the 'Mediterranean fruit fly', is established throughout Central America, and has to be considered one of the most dangerous quarantine pests, because of implications for fruit exportation to the U.S.A.

CONCLUSIONS AND DISCUSSION

During recent years, establishment of alien invasive species in the Dominican Republic has been reported with increased frequency, especially arthropods and plant pathogens. Unfortunately, the time of arrival of a relatively high number of these species, especially arthropods, cannot be ascertained. We assume that the introductions of many of them occurred long before their populations reached outbreak levels. The 37 most important exotic pest species reported between 1975 and 2002 (Table 3) belong to the following taxonomic groupings:

a) 23 arthropod species: 16 insect species: 8 Homoptera spp., 2 Hemiptera spp., 2 Thysanoptera spp., 2 Diptera spp., 1 Coleoptera sp. and 1 Lepidoptera sp.; 7 arachnid species: 6 mite species, and 1 spider species;
b) 1 mollusc species;
c) 13 plant pathogens: 5 fungi species, 2 bacterial species, 1 phytoplasma, 5 viruses

In addition to this list, more than a dozen arthropod species were mentioned as introduced, but no information on the year or period of entry or official confirmation of their presence was available. In general, there has been an increase in the number of reported exotic pests during the last decade. This is partly due to improved quarantine, taxonomic and diagnostic services for quick detection, backed by regional pest alert services (APHIS, CABI, IICA, etc.). On the other hand, the movement of alien pests into and within the Caribbean area, and risks of their accidental introduction, have increased because of the steadily growing importance of tourism and international trade of agricultural products. This problem can be expected to intensify further, especially as the Free-Trade Area of the Americas Agreement and other agreements with countries on other continents are concluded during the coming years.

Measures to stem the introduction of additional invasive pest species. The superiority of area-wide pest suppression over conventional field-by-field suppression, with the power of area-wide pest management as a phytosanitary measure, has been asserted by Klassen et al. (2002), citing the works of different authors (Meyerdirk, 1999; Klassen, 2000; Lindquist and Mumford, 2000), as well as by Griffin (2000). For the U.S.A. this means a greater shift to offshore strategies (a. prevention; b. preclearance) to supplement in-country strategies (a. exclusion; b. detection/ containment/ area-wide pest management or eradication; c. conventional Integrated

Pest Management; d. biological control) for meeting exotic pest threats (Klassen et al., 2002). The Dominican Republic, as well as many other countries of the Caribbean area, cannot aspire to build up such an effective system to assure exclusion of invasive pest species, as the one presented by Klassen et al. (2002), especially with respect to implementing its own offshore strategy. Nevertheless, it is necessary to revise existing protocols for strengthening possibly deficient aspects of the in-country strategy, and to find ways to support regional efforts.

Various topics on invasive species across the islands of the Caribbean have been selected and discussed during the last month in the form of an electronic workshop. The workshop was part of a new regional initiative supported by The Nature Conservancy and implemented by CAB International, as well as other national or regional organizations including the Inter-American Institute for Cooperation on Agriculture (IICA), Caribbean Agricultural Research and Development Institute (CARDI), CIRAD, University of Florida, University of Puerto Rico, and forums, such as the present USDA/T-STAR sponsored Symposium, including neighboring regions as northern South America, Central America and the southern United States. These and other more specific topics should be debated on a national level in the Dominican Republic by competent authorities, and by affected and interested sectors of the society in order to develop a national agenda, which should include the following topics:

- Characterization of the threats and impact of invasive species.
- Prioritization of invasive species on a national and regional level concerning food production, biodiversity, tourism and marine health.
- Examination and assessment of existing legislation on the management of invasives, identification of gaps, and opportunities for improvement.
- Development of recommendations for improvements and opportunities for partnerships to reduce the threat of invasives, especially those with multiple-site impact.

Specifically, discussions should focus on ways to do the following:

- Strengthen the quarantine systems of the Dominican Republic and Haiti, and improve cooperation between the two countries;
- Strengthen the forecasting system for the Caribbean through a wide participative network;
- As part of a regional effort, strengthen support of biological control programs and foreign exploration for natural enemies of potential pests before the pests have entered the Region.

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Table 1. Examples of alien invasive herbaceous plant species established in the D.R.

Family and -Genus species	Introduced as	Status (region)
Apocynaceae:		
-*Catharanthus roseus* (L.)	ornamental?	coastal areas (S)
-*Cryptostegia grandiflora* (Roxb.)	ornamental?	invading dunes (Baní, S)
-*C. madagascariensis* Boj.	ornamental?	invasive (Azua, S);
Asteraceae:		
-*Erechtites hieracifolia (L.)*	medicinal?	
Balsaminaceae:		
-*Impatiens walleriana* Hook.	ornamental	invading coffee at higher altitudes
Poaceae:		
-*Echinochloa crus-galli* L.	with rice seeds	intractable weed in rice fields
-*E. crus-pavoni* (H.B.K.)	With rice seeds	very invasive, aquatic environments
-*Melinis minutiflora* Beauv.	forage (C)	very invasive in crops (S)
-*Themeda quadrivalvis* (L.) Ktze.	?	very invasive (S)
Polygonaceae:		
-*Antigonon leptopus* H. & A.	ornamental	invasive in dry areas (S-SW)
Pontederiaceae:		
-*Eichhornia crassipes* (Martius) Solms	accidental, ornamental?	very invasive, aquatic environments
Nephrolepidiaceae (ferns):		
-*Nephrolepis multiflora* (Roxb.) Jarret	ornamental?	very invasive in pastures

Abbreviations: Regions: C, Central; N, Northern; S, Southern; W, Western; E, Eastern; SW, Southwestern; and NE, Northeastern.

Table 2. Important alien invasive tree and shrub species established in the D.R.

Family and -Genus species	Introduced as	Status (region)
Bignoniaceae:		
-*Spathodea campanulata* Beauv.	ornamental tree	very invasive in humid secondary vegetation (N, NE)
Leguminosae-Mimosoideae:		
-*Acacia mangium* Willd.	wood, reforestation	starting to invade
-*Albizia lebbeck* (L.) Benth.	ornamental tree	starting to invade
-*A. procera* (Roxb.) Benth.	?	invasive in pastures, as in P.R.
-*Calliandra calothyrsus* Meisn.	~1985, forage, living barrier	very invasive in humid regions
-*Leucaena leucocephala* (Lam.) De Wit	cv. K24+K28 for reforestation	very invasive in dry areas (S)
Leguminosae-Papilionoideae:		
-*Flemingia strobilifera* (L.) R. Br.	1980s: ornamental?	very invasive in pastures (N, NE)
Meliaceae:		
-*Azadirachta indica* (A. Juss.)	1980s: reforestation, botanical insecticide	starting to be invasive in dry forests (Haiti, *Prosopis*)
Moraceae:		
-*Castilla elastica* Cerv.	?, provides a gum	very invasive in humid forests (NE)
Myrtaceae:		
-*Syzygium jambos* (L.) Alst.	fruit tree	invades shores of creeks in the 'Cordillera Central'
Rubiaceae:		
-*Morinda citrifolia* L.	uncertain	very invasive in coastal areas (E)
-*Vangueria madagascariensis* Gmel.	fruit tree, medlar	invasive in humid areas
Verbenaceae:		
-*Gmelina arborea* Roxb.	reforestation, ornamental.	invasive in humid areas

Table 3. Examples of important agricultural arthropod pests and plant pathogens reported in the Dominican Republic during the last three decades.

Year	Pests/Plant Pathogens	Common English name	Important host plants
1975	*Bemisia tabaci* 'Biotype A'	Sweetpotato whitefly	vegetables, ornamentals, vectors BGMV
1978	BGMV (begomovirus)	Bean Golden Mosaic Virus	bean, leguminous and other weeds
1978	*Trialeurodes vaporariorum*	Greenhouse whitefly	bean, vegetables, vectors begomovirus
1978	*Rhizoglyphus robini*	Bulb mite	garlic, onion, flowers with bulbs
1979	*Eriophyes guerreronis*	Coconut flower & nut mite	coconut palm
1979	*Puccinia melanocephala*	Sugarcane rust	sugarcane
'80's	*Polyphagotarsonemus latus*	Broad mite	*Capsicum* spp., citrus + other crops
1981	*Erwinia carotovora*	Blackleg of potato	potato and other vegetables
1981	*Peronospora Hyoscyami*	Blue mold of tobacco	tobacco
1987	*Sclerophthora macrospora*	Downy mildew of corn	corn
1988	*Bemisia tabaci* 'Biotype B'	Silverleaf whitefly	+500 hosts, vectors begomoviruses
1988	*Thrips palmi*	Melon thrips	eggplant, pepper, oriental veget., etc.
1989	*Hemileia vastatrix*	Coffee rust	lowland coffee plantations
1990	CTV (Closterovirus)	Citrus Tristeza Virus	citrus species (orange + Persian lime)
1990	*Pseudacysta perseae*	Avocado lacebug	avocado
1990	*Frankliniella occidentalis*	Western flower thrips	flowers, vegetables, vector TSWV°
1991	TYLCV (Begomovirus)	Tomato Yellow Leafcurl Virus	tomato, tobacco, bean, weeds
1991	*Pomacea canaliculata*	Apple snail	irrigated rice
1992	*Aleurocanthus woglumi*	Citrus blackfly	*Citrus* spp.
1992	*Toxoptera citricida*	Black citrus aphid	citrus trees, vector CTV
1993	*Tetranychus* sp.	Spider mite	tomato
1994	*Ralstonia solanacearum*	Bacterial wilt of potato	potato
1994	*Phyllocnistis citrella*	Citrus leaf miner	*Citrus* spp.
1995	CLYD (Phytoplasma)	Coconut Lethal Yellowing Dis.	disease of coconut palm
1995	*Hypothenemus hampei*	Coffee berry borer	coffee
1995	*Varroa jacobsoni*	Varroa mite	honey bees
1996	*Mycosphaerella fijiensis*	Black Sigatoka	banana and plantain
1997	*Tibraca limbativentris*	Brown rice bug	rice
1997	*Paracoccus marginatus*	Papaya mealybug	papaya, mandioca, ornamentals, etc.
1998	*Steneotarsonemus spinki*	Rice tarsonemid mite	rice
2000	BCNMV (Potyvirus)	Bean Comm. Necrot. Mosaic V.	beans
2000	*Melanagromyza obtusa*	Pigeon pea pod fly	pigeon pea
2001	BSV (Badnavirus)	Banana Streak Virus	banana and plantain
2001	*Diaphorina citri*	Asiatic citrus psyllid	citrus trees, vector CGD°
2001	*Contarinia maculipennis*	Blossom midge	orchids, tomato, ornamentals
2002	*Maconellicoccus hirsutus*	Pink hibiscus mealybug	*Hibiscus* spp., >200 spp.
2002	*Cyrtophora citricola*	Tropical tent-web spider	trees and shrubs, incl. *Citrus* spp.

° TSWV and 'Citrus Greening Disease' are not present in the D.R.

Proceedings of the Caribbean Food Crops Society. 39(1):119-127. 2003

PROPOSED INVASIVE SPECIES PROJECTS FOR THE CARIBBEAN

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Byron Blake -	Caribbean Community Secretariat
William F. Brown -	University of Florida
Arlington Chesney -	Inter-American Institute for Cooperation on Agriculture
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Bruce Lauckner -	Caribbean Agricultural Research and Development Institute
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Charles Pierre -	SAQS
Claude Vuillaume -	French Caribbean Regional Cooperation Representative (CIRAD-INRA)

1.0 INTRODUCTION

This list of recommended projects was developed by a Working Group following the symposium on Invasive Species held during the 2003 Caribbean Food Crops Society Meeting in Grenada. The working group was appointed by Mr. Byron Blake, Deputy Secretary General for Regional Trade and Economic Integration, CARICOM.

2.0 PROJECTS

1. Early Detection of Carambola Fruit Fly

Problem: The Carambola fruit fly, *Bactrocera carambolae*, is present in Suriname, French Guiana, and Suriname. It poses a serious threat to the Caribbean, Central America, Mexico, and the southern USA.
Solution: Design and implement a Carambola fruit fly early detection program in the islands from Trinidad in the south through St. Martin in the north.
Comments: At this moment USDA-APHIS can allocate limited resources to provide traps and lures, and to arrange for training. Expeditious action is needed since the funds must be allocated by 30 September 2003.
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2. Timely Internet-based tracking of invasive pest interceptions and introductions

Problem: Timely information is a critical need in taking effective countermeasures against dangerous invasive species.
Solution: Develop an internet-based capability to record and keep track of invasive pest interceptions/introductions throughout the Caribbean region. Generate and post pest alerts. Maintain an updated listing of key invasive species threatening the region.
Comments: The SAQS systems analyst will review all relevant databases and web sites, and recommend the structure of an Internet site including links and who should set it up and maintain it. Each country will identify a contact with responsibility to provide forthright and timely information to the Internet site, and/or appropriate links.
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3. Restoration of natural areas infested with non-native invasive plants

Problem: Determine the most effective and efficient methods of restoring the original vegetation in natural areas taken over by invasive plants in various sites in the Caribbean region.
Solution: Conduct a training session and/or workshop, involving key personnel from various Caribbean islands, who would provide hands-on experience at removal of invasive species, and restoration of one or more sample natural areas.
Comments: Appropriate sites are available on numerous islands. For example sites could be readily selected on St. Croix. If so, the program might be supervised by the Faculty of The University of the Virgin Islands, Agricultural Experiment Station, and the U.S. National Park Service would coordinate the provision of labor. In addition, The Nature Conservancy probably would provide assistance.
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US National Park Service, Biological Resources Management Division

Florida Partnership/Caribbean Exotic Plant Management Teams
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4. Develop a Caribbean pest and disease diagnostic system based on distance digital imaging and internet-based communications

Problem: Diagnostic capabilities need to be strengthened and made more accessible.
Solution: Develop a Caribbean Pest and Disease Diagnostic System based on distance digital imaging and internet-based communications involving a network of experts throughout the Caribbean Region. Provide funding for equipment, travel, and training. Find solutions to bandwidth and other technical constraints. Possible funding sources include the Interamerican Development Bank, U.S. Department of Agriculture, USAID, etc.
Comments: A draft grant proposal being developed by Leppla & Klassen was distributed. The chances of funding of this proposal are small.
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5. Arouse public awareness of the invasive species crisis

Problem: The public is insufficiently aware and excessively indifferent to the invasive species crisis.
Solution: Develop an array of public information interventions tailored to specific interests. Consider establishing an annual Caribbean-wide "*Invasive Species Awareness Week*". Develop news releases, posters, catchy slogans, etc. for use on radio, TV, posting in ports, and airports, etc. Involve extension services and opinion leaders in communities.
Comments: Action has been initiated by USDA and IICA on the Giant African Snail. Surveys have been carried out in Saint Lucia, Barbados, Antigua, Dominica, and St Vincent and the Grenadines
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Email: Evans@fred.ifas.ufl.edu

6. Engage non-USA scientists in the Caribbean in T-STAR-funded research on invasive species

Problem: Since invasive species present anywhere in the Caribbean region are a threat to the U.S.A, there is a need to modify the T-STAR research program to address invasive species problems on Caribbean islands not under U.S. jurisdiction.
Solution: T-STAR Administrators should encourage their faculty to involve scientists in various Caribbean countries in developing and submitting joint proposals to the T-STAR Program.
Comments: To facilitate development of joint proposals, T-STAR-funded faculty members will

be encouraged to attend professional society meetings and other strategic events in the Caribbean region.

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Dr. Eric Young, SAAESD; email: eric_young@ncsu.edu

7. Assure region-wide adoption of the General Invasive Species Emergency Plan, and develop Specific Emergency Action Plans for key threats

Problem: Need to assure that all countries in the Caribbean Region have adopted a General Invasive Species Emergency Plan. In addition, Specific Emergency Action Plans need to be developed for use by all Caribbean countries against each of the key threats.

Solutions:

(i) The SAQS secretariat is requested to provide a copy of its model General Invasive Species Emergency Plan to appropriate government officials in each country in the Caribbean Region, as well as to colleagues in various institutions in these countries.
(ii) IICA, USDA-APHIS, INRA, and FAO are requested to assemble all available Specific Emergency Action Plans, and to identify the threats for which Specific Emergency Action Plans need to be developed.

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8. Appoint a Caribbean Region Standing Committee to serve as a watch-dog on the arrival of new invasive species, or on alarming developments in the spread of invasive species with foot-holds in the region

Problem: In many instances the individual countries in the Caribbean lack the resources needed to meet problems posed by the arrival of new invasive species, or to address developments in the continuing spread of invasive species with foot-holds in the region.
Solution: Appoint a Standing Invasive Species Watch-Dog Committee to discuss developments, and to determine whether formation of regional coalitions of public and private sector interests should be recommended to establish regional bodies in order to mount appropriate and effective countermeasures.
Comments: After considerable discussion, there appeared to be no prospect of reaching consensus on this proposal by Dr. Rosa Franqui. Therefore, the chair (Klassen) tabled the proposal for possible discussion at some future date.
Such a strategy may be considered with the establishment of CAHFSA.

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9. Take advantage of opportunities to obtain funding of critical invasive species R&D needs from USDA-APHIS and USDA-AR.

Problem: Critically important information on the biology and control of invasive pests is often needed in order to mount or improve the efficiency and or effectiveness of countermeasures. However, funds to support the needed R& D are frequently not available.
Solution: USDA-APHIS and USDA-ARS, although not granting agencies *per se*, often have limited sums, which can be made available to support extramural research to fill critically needed information and/or technology gaps in the systems for combating specific invasive species. Allocation of such funds must be based on mutual benefits to the USA and one or more Caribbean countries. Brief project proposals should be prepared and submitted to these agencies.

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10. CIRAD-1 Traditional Crops - Banana and Plantains

Title project: " Impact of the introduction of new hybrid varieties of bananas and plantains on the dynamic balance of the populations of some pathogenic agents and pests: nematodes, fungus, and virus."
Countries: Cuba, Haïti, Dominican Republic, Guadeloupe, Martinique, Windward Islands
Problem: There are two problems:

1. Progression of spread of Black Sigatoka disease in the Caribbean area, and
2. Introduction into this area of new hybrids containing BSV genomic sequences in their genomes.

Objective of the study and proposal solutions: This project aims to evaluate (i) the durability of resistances to the cercosporioses - black and yellow (*Mycosphaerella fijiensis* and *M. musae*) - obtained in interspecific hybrids of banana trees, (ii) the impact of the diffusion on a large scale of these hybrids on the populations of nematodes affecting the banana culture and (iii) potential risks of diffusion of the banana streak virus (BSV) resulting from the presence of genomic sequences of this virus that can be activated in the genome of these hybrids. The realization of this project will allow a better management of the resistances obtained in the hybrid varieties, and of the virological risk related to the BSV, by the establishment or the reinforcement of scientific exchanges and the transfer of methodologies.

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11. CIRAD-2 Traditional Crops - Sugarcane

Title: "Support of a sugar and rum sustainable production, and preservation of the agricultural landscape in the Caribbean by optimizing the processes of variety selection".
Countries: Belice, Cuba, Haiti, Dominican Republic, Trinidad, Guadeloupe, and Barbados.
Problems: New or undetected diseases can have a negative impact on Caribbean sugarcane production.

Objective of the study and proposal solutions:
The studies to be integrated in the project:

1. Characterization of the genetic resources, study of their diversity (microsatellite, and other tools), identification of new QTL;
2. Impact study of the emergent diseases and the major diseases on the production and selection (SCYLV phytoplasmas, RSD, etc.);
3. Impact study of the variability of pathogenicity on the durability of varietal resistance (leaf scald);
4. Database on genetic improvement.

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12. CIRAD-3 Diversification Crops – Citrus

Title: "Promotion of a sustainable citrus fruit cultivation and plant health observatory".
Countries: Cuba, Dominica, Haiti, Jamaica, Dominican Republic, Trinidad, and Guadeloupe.
Problems: Progress of the spread of the tristeza virus in the Caribbean area. Risk of additional invasive pests (CVC, bacterial canker and citrus greening disease).

Objective of the study and proposal solutions:
The citrus growers must engage in a project of rehabilitation, which would consist of establishing durable citrus fruit cultivation within an integrated fruit-bearing and production system.
This regional project will be based on research projects developed in the field of the varietal development and plant protection (plant health observation), involving integrated pest management and agronomic programs, training and technology transfer, and socioeconomic studies.
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13. CIRAD-4 Diversification Crops – Tomato and Pepper

Title: "Improvement of the market-gardening productions: creation of diseases and pests resistant tomato and peppers adapted to the Caribbean environment".
Countries: Cuba, Haiti, Dominican Republic, Trinidad, and Guadeloupe
Problems: The presence and development of different strains of begomovirus, and of bacteria causing loss of yield in tomatoes and peppers, and in certain cases, preventing the development of a profitable cultivation in the countries of the Caribbean.

Objectives of the studies and proposed solutions:
Identification of climatic and parasitic constraints on cultivation of tomato and pepper (sweet peppers), through collaborative Caribbean research teams and to highlight the genetic resources present in the Caribbean with resistance to these constraints. This project proposes the followings studies:

- Characterization in network of the useful genetic factors and introduction into the varieties of tomato and peppers by selection;
- Genome analysis (training of Caribbean researchers);
- Molecular marking of genes (QTL) conferring resistance to the begomovirus in tomato, and conferring resistance to bacterial fading (caused by the bacterium, *Ralstonia solanacearum*) in pepper.

The selection will be based on the evaluation of resistance and quality in growth conditions to create new varieties of tomato and pepper (experimentation over three years of their descendants: three generations in the field at selected sites, and utilizing selection by means of markers of plant traits to the desired resistances in the populations under selection).

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14. CIRAD-5 Diversification Crops – Coconut

Title: "Towards a global research program on integrated control of the coconut lethal yellowing disease in the Caribbean".
Countries: Cuba, Haiti, Jamaica, Dominican Republic, and Guadeloupe
Problems: Lethal yellowing of coconut is one of the most devastating diseases. To date, the French West Indies and lower Caribbean have not been touched by this dreaded scourge. As for the coconut production areas of Cuba, Haiti, Dominican Republic, and Jamaica, they are now partially devastated, and the disease in progressing relentlessly in the Caribbean. Its repercussions are particularly serious with respect to employment in rural areas, conservation of biodiversity, impact on ecosystems, degradation of landscapes, and reduction in visits of tourists to typical Caribbean countrysides and beaches.

Objectives of the study and proposed solutions:
The project will aim at characterizing the diversity and the variability of the phytoplasmas associated with this disease, identifying its vectors, defining their etiologic role and at identifying resistances in the plants hosts. Acquired knowledge will make it possible to establish recommendations for the varietal selection and methods of a rational struggle for the control of the disease, and for halting its diffusion in the Caribbean.

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15. Assessment of the Agricultural Health and Food Safety System in the Countries

Problem: It has been shown that certain problems manifested at the consumer level can be traced back further down in the agri food chain. The traditional approach focusing efforts only at the national level is not always sufficient to meet today's challenges.
Solution: The Agricultural Health and Food Safety Systems in the countries need to be modernized in order to conform with and benefit from international standards.

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Proceedings of the Caribbean Food Crops Society. 39(1):128-130. 2003

INVASIVE SPECIES POLICY RECOMMENDATIONS

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Arlington Chesney	-	Inter-American Institute for Cooperation on Agriculture
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Task:

The group was charged with the following responsibilities:

- Outlining the main components of a Caribbean Regional Invasive Species Strategy (CRISIS).
- Setting up a schedule for completing a draft summary and detailed documents for submission to relevant national authorities.

***Purpose*:**

The overall purpose of the Strategy is to safeguard the wider Caribbean from the threat of invasive alien species that could limit the future expansion of trade and tourism. Specifically, the Strategy would outline a plan of action that would assist the region in preventing and mitigating the introduction and spread of invasive alien species, increase awareness, provide a framework within which individual country and regional projects could be developed or strengthened, and facilitate sourcing of funds.

Goals of a Caribbean Regional Invasive Species Strategy (CRISIS):

1. Develop and maintain effective coordinated networks of information and technical expertise.
2. Prevent the introduction of new invasive species into the Caribbean region.
3. Reduce the impact and further spread of invasive species already existing in the Caribbean region.
4. Raise awareness.
5. Build the capacity required to manage the threats posed by invasive species.

***Scope*:**

- All English, French, Dutch, and Spanish speaking countries/territories in the Caribbean.

- All invasive species with the potential of being harmful to agriculture, natural ecosystems, and human health.

***Rationale for Strategy*:**

The rationale should include, but not be limited to, the following:

- Because of the importance of cost sharing, the near proximity of the countries in the region, and the fact that the strength of any regional safeguarding mechanism depends on the weakest link, a regional approach is justified. Moreover, such an approach would ensure that no one country would have to bear a disproportionate share of the burden, nor would a threat to the region, with a foothold in a country lacking means, go unattended.
- The economic impact of invasive species goes beyond direct damage and control costs, and could adversely affect trade, and environmental quality, and human health.
- A direct correlation has been established between the increased incidences of invasive species and the increased trade in agricultural goods and movement of people. With further trade liberalization on the horizon, as a result of regional and multilateral agreements such as WTO, FTAA, and the Caribbean Single Market and Economy (CSME), there is an increased likelihood for further introduction of unwanted pests and diseases.
- Most invasive species, once they have become established, are extremely costly to eradicate or to control; hence the need to take a proactive or at least a timely stance. Examples of well established invasive species include the coffee berry borer, the silverleaf whitefly, *Thrips palmi*, tropical fruit flies, Black Sigatoka disease, bean golden mosaic virus, soybean rust, Brazilian pepper, Australian pine, Melaleuca paperbark tree, classical swine fever, foot-and-mouth disease, and the tropical bont tick.
- Some invasive species, such as the pink hibiscus mealybug, have the potential to destroy many useful ornamental and food plants and to damage the natural environment. In the case of the pink hibiscus mealybug, the damage within the Caribbean basin has been greatly mitigated through basin-wide biological control, and the immediate availability of this technology has proven to be critically important in suppressing the pest shortly after it reached California and Florida. Clearly, collective action against this very damaging pest has proven to be highly advantageous to the entire Caribbean basin and to other states in the Western Hemisphere.
- Invasive species threaten the livelihood of the region since they have the potential to adversely affect the region's agricultural export trade and tourist industry, and hence have implications for sustainable development in the region.
- Invasive species are a form of "biological pollution" with the potential to spread and mutate.
- Global environmental changes may impact the rate of the spread of invasive species.
- Sustained (programmatic) efforts are needed to minimize the risk of re-infestation.
- Small island states are particularly vulnerable to the threat of invasive species.
- A clean Caribbean is not only essential to the expansion of agricultural trade from the Caribbean, but also to safeguarding the interests of the Americas, particularly Florida. Recall U.S. Secretary of State Colin Powell's statement that the Caribbean is the "third border" of the United States.

Major Components of Strategy (see handout on South Pacific Invasive Species Strategy)

1. *Information*: Need for greater coordination of information in the region, the need to include farmers and other key operators in various commercial sectors in the decision making process, and the need to conduct R&D to generate information and technologies to combat invasive species.

2. *Awareness*: Need to better inform all stakeholders (public, private, farmers, etc.) of the major threats and costs posed by the various invasive pests and diseases.
3. *Infrastructure*: Need to build on what we currently have; need to create linkages within and outside the region for future growth; and need to improve human, as well as physical, resources (i.e., capacity building).
4. *Protocols*: Need to update existing protocols and develop new ones, need a Caribbean Pest Alert System, and need assistance to carry out risk assessments.
5. *Legislation*: Need to review national laws to determine whether they are adequate and/or appropriate for safeguarding national and regional interests.
6. *Funding*: Need for base funds for start-up and to cover certain basics that should be sustainable. Possible funding sources include the Inter-American Development Bank and the Caribbean Development Bank. Funds also might be sought on the basis of special and differential treatment for small countries within the framework of the FTAA and the Barbados Plus-Ten Initiative.
7. *Policies*: (related to number 5 above) Need for economic policies that provide the necessary incentives/disincentives to impact peoples' behavior and to obtain their cooperation where needed.

***Other Considerations*:**

Because of the geo-political situation of the Caribbean (numerous islands, and several countries, which are disparate in size, patterns of trade and tourism, complexity of physiogeography, ethnic diversity and economic strength), a coordinated approach to safeguarding against invasive species appears to be essential for the Caribbean region. This diversity suggests the following imperatives:

- Need to have a safeguarding model (e.g., the CRISIS could be modeled on the basis of the South Pacific Invasive Species Strategy).
- Need to get member governments to buy into the strategy. Hence, the strategy should be written from the perspective of the Caribbean countries.
- Need to effectively use institutional linkages as well as current resources.

Implementation Schedule: Developing a Caribbean Regional Invasive Species Strategy (CRISIS)

Activity	**Due Date**	**Person(s) Responsible**	**Remarks**
Preparation and distribution of notes	July 18, 2003	Evans	Notes should be sent via email
Preparation and distribution of draft briefing strategy Document	August 1, 2003	Ambrose	Document should be no more than five pages (double spaced) Members should submit their comments no later than August 15th
Preparation and circulation of first draft of CRISIS	August 1, 2003	Ambrose & Kairo	Committee must submit comments no later than September 15th
Finalized draft of CRISIS	Sept. 22, 2003	Ambrose & Kairo	Submit for meeting of CARICOM ministers

Proceedings of the Caribbean Food Crops Society. 39(1):131-141. 2003

CARIBBEAN REGIONAL INVASIVE SPECIES STRATEGY (CRISIS)[1]

CONTENTS PAGE

[1] Subsequently Everton Ambrose and Moses T.K. Kairo developed the CRISIS based on the CFCS policy recommendations.

Executive Summary

- Invasive alien species (IAS) pose a serious threat to the region's economic and environmental well-being.
- The problem of IAS is growing at an unprecedented rate fueled by globalisation of trade, tourism and rapid means of transport.
- For various economic and biological reasons, islands are particularly vulnerable to IAS.
- An urgent and concerted cooperative effort is required if the region is to effectively deal with this threat.
- This document outlines a framework for regional cooperation and action to deal with IAS aimed at safeguarding the wider Caribbean from IAS.
- IAS do not recognize political borders, and an effective strategy must link the various countries within the Caribbean Basin.
- The goals of the strategy are to link all stakeholders and provide a coordinated approach to prevention, management, capacity building and, awareness and education.
- Specific activities to stem the problem of IAS are also identified.

2.0 Introduction

Alien species that become established in a new environment and then proliferate in ways that are destructive to human interests are considered to be invasive alien species (Mc Neely et al., 2001). Invasive alien species (IAS) threaten food security, human health and economic development. They also seriously threaten biodiversity, productive agricultural systems and natural ecosystems. At the global level, IAS are recognized as the second greatest threat to biodiversity conservation next to habitat destruction.

The economic impact of invasive species goes beyond the direct damage and control costs, and adversely impacts trade, environmental quality and human health. Once well established, IAS are extremely costly to eradicate, or to control; hence the need to take a proactive or at least timely stance to prevent introductions and subsequent establishment. Moreover, the ecological, economic and socioeconomic impact of invasive species is complex, and difficult to quantify. They damage buildings and other structures, obstruct waterways and disrupt transportation. Their effects can negatively impact agriculture, aquaculture, forestry and tourism, and reduce the amenity and other values of land. They impact human health, through the spread of disease agents and their vectors, and by decimating crops, livestock and fisheries they cause malnutrition and poverty.

The frequency of occurrence of new invasive species problems has increased sharply in recent years, and is likely to continue to mount with the continuing expansion of global trade and international movement of people, biological material and other commodities. With further trade liberalization at hand as a result of multilateral and regional agreements such as the World Trade Organisation (WTO), Free Trade Area of the Americas (FTAA) and the Caribbean Single Market and Economy (CSME), there is increased likelihood for even greater frequencies of introductions of invasive species. This burgeoning problem is recognized in Article 8(h) of the United Nations Convention on Biological Diversity (CBD) which calls on member governments, to, as far as possible and appropriate: *"Prevent the introduction of, control or eradicate those alien species which threaten ecosystems, habitats or species."* This need was reaffirmed at the Sixth Conference of Parties Meeting at the Hague in 2002 which calls for action to prevent and mitigate the impact of IAS in Decision VI/23 http://www.biodiv.org/decisions/default.asp?lg=08dec=vi/23).

There is no doubt that the best way to limit the impact of invasive species is to prevent them from invading the land and waters of the Caribbean and becoming established. Eradication programs, though possible, can be expensive, and in many cases are not practical unless initiated upon early detection. If eradication fails then perennial control is the only remaining option.

Invasive species represent the greatest threat to biodiversity conservation in island territories or countries. The Caribbean has a high endemism and therefore is an invaluable center of biodiversity. However, islands are very vulnerable to invasion and the rate of extermination of native species can be rapid because of the small size of the populations.

Many species of animals, plants and even microorganisms have been introduced to the Caribbean, either accidentally or deliberately, for a variety of reasons. In recent years, the accidental invasion of the pink hibiscus mealy bug, a species native to Asia, has provided a vivid example of the potentially massive consequences to agriculture and forestry. However, this problem also highlighted the benefits of cooperative efforts to bring it under biological control. The negative impact on non-target organisms caused by the small Indian Mongoose (*Herpestes aucropunctatus*), which was deliberately introduced in 1872 to control rats in sugar cane fields in Jamaica, serves as a vivid warning of the dangers when species become invasive.

This and other such experiences which have led to substantial refinements in the practice of biological control, provides an exceptionally cost effective and sustainable means of managing invasive species as evidenced in the case of the pink hibiscus mealy bug. The immediate availability of this technology to all affected countries proved to be critically important in suppressing the pest shortly after it reached California and Florida. Clearly, collective action against this very damaging pest has proven to be highly advantageous to the entire Caribbean basin and to other states in the Western Hemisphere. Thus a coordinated regional approach to the invasive species problem is highly recommended.

Recent years have seen a number of serious threats to agriculture via the introduction of invasive species. These include the coffee berry borer, silver leaf whitefly, *Thrips palmi*, tropical bont tick, tropical fruit flies, classical swine fever, foot and mouth disease, bean golden mosaic virus, tomato yellow leaf curl virus, soybean rust, black sigatoka disease of banana, Brazilian pepper, Australian pine and the Melaleuca paperback tree. The concerns about the impact of invasive species are shared throughout the Caribbean Basin. The United States is also concerned and has tasked the USDA-Animal and Plant Health Inspection Service (APHIS) to develop cooperative offshore programs to counter the threat.

In response to the need for action, several initiatives have begun to address the problem. In 2001, a workshop organized by the World Conservation Union, the United States Government, the Swiss Agency for Development and Cooperation and the Global Invasive Species Programme, brought together participants from the region to address the challenges posed by the presence of invasive alien species in the Meso-America and the Caribbean. This workshop identified a number of priorities, including the need for a regional concerted action (Hernandez, 2002). A more recent initiative by CAB International and The Nature Conservancy has begun accumulating information on invasive species threats in the region. As part of this effort, an electronic workshop involving more than 100 participants from within and outside the region also discussed priorities for action and identified similar issues (Kairo et al., 2003).

The urgent need for action and for a coordinated regional approach to this problem led to the organization of a symposium on Invasive Species, which was held during the 2003 Caribbean Food Crops Society Meeting in Grenada. Following the Symposium, two working groups were given responsibility for outlining the components of a Caribbean Regional Invasive Species Strategy (CRISIS), setting up a schedule for completing a draft summary and detailed document and for recommending related projects to be undertaken.

3.0 Capability to Address the Problem

The use of quarantine intended to prohibit organisms from entering a new area has a long history in combating invasive species. It is noted that for exclusion measures to succeed, they require cooperation from both source and recipient countries. Most invasions begin with the arrival of a small number of individuals. At this point, the cost of exclusion is relatively small compared to the cost and effort of eradication and control after the populations have established and grown. Nevertheless thorough inspection of arriving cargo and people is a challenging responsibility. Interception and identification of future invaders, however difficult, could allow marshalling of resources to prevent their subsequent entry or dispersal, or the destruction of founder populations soon after entry.

The ability of a nation to protect itself from the movement of invasive species is ostensibly governed by international treaties, especially the Agreement on the Application of Sanitary and Phytosanitary Measures (SPS) of the WTO. Under this agreement Members of WTO have a right to protect their animal, plant and human health so long as these decisions are based on science. Eradication of an invasive species is feasible with early detection, provided that the resources needed to act quickly are at hand. If eradication fails, then perennial control is the only remaining option. The latter option may require costly treatments during production, post harvest treatments of exports, pre-clearance at the port of export, production in pest-free areas, or loss of access to certain foreign markets. The challenge is equally great in natural habitats as well.

The capacity to grapple with invasive species issues at a national level varies considerably across the region. Surveys conducted in the English Speaking Caribbean to assess the status of compliance of national agricultural health and food safety systems (IICA, 1997; Ambrose, 1999; Pantoja, 1999; IICA, 2000; USAID/CARICOM, 1999/2000) reported that the overall status of compliance to WTO/SPS was not very high. A number of deficiencies were identified, including a shortage of, and inaccessibility to, scientific information. Generally, legislation is not up to date, and enforcement is many times inadequate. There is a shortage of technically trained personnel, and inadequate infrastructure to support decision-making. The private sector is not adequately involved in the decision-making process and implementation of the activities. Many of the countries have limited human and financial resources, and hence will never be able to have all that is required for prevention of entry, early detection, eradication, or control. Therefore, much stronger safeguarding capabilities must be created amongst trading partners, and in the region as a whole.

In order to conform with and benefit from international standards the agricultural health and food safety systems of the countries must be modernized. This modernization will require fundamental changes in these institutions enhancing their capacity and capability.

The countries are in close proximity, and the fact that the strength of any safeguarding mechanism depends on the weakest link makes a regional approach a supplement to efforts of individual countries. Moreover, such an approach would ensure that no single country has to bear a disproportionate share of the burden. A clean Caribbean is not only essential to the expansion of agricultural trade from the Caribbean, but also will contribute to safeguarding the interest of the Americas, the French and the Dutch countries.

The geo-political situation of the Caribbean (numerous islands and several countries which are disparate in size, pattern of trade and tourism, complexity of physical geography, ethnic diversity and economic strength) means that a coordinated approach to safeguarding against invasive species is essential for the region if the problem is to be addressed in a comprehensive, effective and practical manner. This approach is consistent with approaches taken in other regions. International support is available for development and implementation of regional strategies against island invasive species. The Invasive Species Group of the International Union for the Conservation of Nature (IUCN)/Species Survival Commission (ISSG) assisted in the review and strategy development process for the Pacific. The Global Invasive Species Programme (GISP) counts amongst its specific objective the facilitation of regional initiatives against invasive species.

A regional strategy for addressing the island invasive species problem has been prepared for the Pacific (REF). In developing the strategy, the South Pacific Regional Environmental Programme (SPREP) recognized the following key generic issues underpinning the invasive species problem in that Region (Sherley and Low, 1999):

- Shortage and inaccessibility of scientific information on basic biology (for prevention, early detection, risk assessment and development of management strategies).
- Lack of awareness of the impact of invasive species on indigenous biodiversity, and on economic activity.
- Insufficient networking mechanisms for dissemination of information (particularly to relevant decision makers and governmental officials).
- Poorly developed mechanisms for coordinated and collaborative action on invasive species detection and management across the region.
- Failure to address invasive species impact on biodiversity in existing legislative and regulatory frameworks and cross-sectorial policies.
- Inadequate enforcement of existing legislation.
- Shortage of technically trained personnel.
- Inadequate quarantine and risk assessment infrastructure.
- Insufficient funding to develop infrastructure, train personnel and develop risk assessment and invasive species management mechanisms. Also the need to maximize funding self-sufficiency by promoting full participation of private sector and local communities in project development, management, and implementation to ensure a long-term local commitment.

The SPREP Strategy for Invasive and Alien Species outlines the measures necessary to overcome these impediments and to implement or coordinate at a regional level wherever possible. There is no doubt that the generic issues outlined for the Pacific apply to the invasive species problem in the Caribbean. However, the safeguarding model for the Caribbean will undertake a more comprehensive and integrated approach.

A range of regional and international institutions and programs are already working on this issue, and they contribute to the implementation of the Regional Strategy. Therefore there is an immediate need for a coordinated and harmonized approach to the input of various institutions in order to maximize the scant resources available by avoiding duplication of efforts.

4.0 Strategy

4.1 Purpose

The overall purpose of the Regional Strategy is to safeguard the wider Caribbean from the threat of invasive alien species and to develop a framework for dealing with existing problems. Specifically, the Strategy provides a plan of action that would assist the region in preventing and mitigating the introduction, spread and impact of invasive alien species; increase awareness; provide a framework within which individual country and regional activities could be developed and strengthened; and facilitate sourcing of funds.

Goals of the Strategy:

- Develop and maintain effective coordinated networks of information and technical expertise
- Prevent the introduction of new invasive species
- Reduce the impact and further spread of invasive species already present
- Raise awareness of the dangers posed by invasive species with economic interests (operating in agriculture, fisheries, forestry, environment, public health, export/import, banking), military, local non-government organizations, policy makers and the general public
- Build the capacity required to manage the threats posed by invasive species
- Access and retention of markets
- Promote interaction among all stakeholders including the private sector, national, regional and international entities.

4.2 Scope

The Strategy is to encompass all English, French, Dutch, and Spanish speaking countries/ territories in the Caribbean basin and all invasive species with potential to be harmful to agriculture, natural ecosystems, and human health.

4.3 Major Components of the Strategy

It has been recognized that the traditional approach of focusing efforts only at the national level (where programs are based on inspection, surveillance and emergency response to unexpected entry) is not always sufficient to meet today's challenges. It has been shown that problems manifested at the consumer level can be traced back further down in the agri-food chain. Programs should be developed and implemented that go beyond the farm level to encompass the entire agri-food chain. Therefore, agricultural health and food safety (AHFS) institutions must operate with an expanded international vision and broader mandate. The traditional agricultural health institution within the Ministry of Agriculture must be restructured to include stronger alliances with Ministries of Health, Trade, Environment and Foreign Affairs.

The private sector must join forces with the public sector to define complementary roles for which each has specific responsibilities in order to enhance AHFS. The important role of active participation in international fora is recognized. Thus the term system, rather than service, is used to include all participants involved.

The SPREP strategy emphasizes IAS that threatens biodiversity and does not extend to agricultural pests. This present strategy encompasses not only changes in environment but also production, food security, trade, tourism, public health and agricultural competitiveness (IICA, unpublished). All of these impact on an effective AHFS system.

In a paper (IICA, unpublished) four major components on an AHFS are outlined these components listed below form the basis of the strategy:

- Human resources and capital
- Interaction with private sector
- Access to market
- Technical capability

4.3.1 Human Resources and Capital

4.3.1.1 Human Resource Capability

Ensure that technical personnel are trained and have the experience to effectively take action to prevent, mitigate, or control invasive species problems. Where necessary, this can be through short formal in-service training courses or by attachments. Horizontal technical assistance may also be necessary as action is already on the way in some countries (Kairo et al., 2003). Personnel should be provided with updated information and knowledge.

4.3.1.2 Policies and Programmes

Economic policies should be promoted to provide the necessary incentives/disincentives, to impact people's behaviour and secure their cooperation where necessary. Policies should adequately address problems of natural resource management. Duties and activities should be carried out autonomously without external interference attempting to influence technical decisions or results of management.

There is need to develop policies on appropriate property rights, estimation of social costs, assigning of liability, application of precautionary instruments and the like. Collaboration with other organisations and institutions is essential to develop appropriate policies to address the potential risks.

4.3.1.3 Financial Resources

There should be funds for the operation and sustainability of the system. Mechanisms should be developed to ensure that countries/territories are able to undertake work for the management of threats of invasive species. Possible sources of funding include the Inter-American Development Bank and the Caribbean Development Bank. Funds also might be allocated on the basis of special and differential treatment for small countries within the framework of the FTAA and Barbados Plus-Ten Initiative.

Make representations to Governments in order to have available improved long-term funding to address the pressing issues of invasive species conservation concern. Demonstrate the extent of the problem in economic cost/benefit terms and the necessity of taking action. Obtain support for management of invasive species among local communities as well as at national, regional and political levels.

4.3.2 Interaction with the Private Sector

4.3.2.1 Awareness

Active public engagement is critical to successful management of invasive species. All stakeholders (public, private sector, policy makers, farmers and the like) need to be better informed of the insidious and grave danger posed by invasive alien species. An informed public is more likely to support ongoing actions to mitigate the threat of invasive species, including accidental movement into new pest free localities within a country, and especially inter-island transfer. Represent invasive species issues at regional and national meetings and with funding organisations in order to increase awareness.

Promote awareness by educational programmes in identification. Establish effective communication networks on the effects of invasive species on biodiversity. Develop manuals of existing and potential invasive species, which would assist with identification, behaviour, where to look, how to exclude, eradicate and control them. Establish networking, international linkages, national working groups, regional technical groups and early warning databases.

It is necessary that there be active participation and follow up on technical committee meetings of international organisations related to enforcement of SPS and FTAA Agreements.

4.3.2.2 Information

Promote greater coordination of information and involve all stakeholders including farmers and other key operators in various commercial sectors in the decision making process. Promote sharing of information through the establishment of mutually accessible databases and websites taking into account existing sources of information nationally, regionally and globally. Develop a regional clearinghouse for information on invasive species that is easily accessible through a web-based information system.

4.3.3 Access to Markets

4.3.3.1 Protocol

In order to facilitate trade, trading partners must ensure that documentation is scientifically sound and is based on internationally recognised standards. They should be able to reach agreements on equivalents for products and processes so that although different, agree that they achieve the same objectives. They should notify each other of new laws or standards to be introduced and its status. They should be able to coordinate the execution of health programmes intended to obtain and maintain, with scientific evidence and international recognition, the status of free area or low prevalence for pests and diseases. A reliable due diligence mechanism should be in place to ensure documentation which will facilitate the tracing back of products to their origin.

Develop and strengthen procedures to process applications for species introduction and promote the use of existing risk assessment protocols with appropriate modifications. Develop early warning and response systems for invasive species including a Caribbean Pest Alert System. Develop guidelines for pest management that consider full biological and conservation consequences of eradication or control operations including restoration. Collaborate with institutions and organisations to develop appropriate policies to address the potential conservation/environmental risks of genetically modified organisms.

4.3.3.2 Legislation

Legislation should be reviewed to determine adequacy for protecting agriculture, forestry, fisheries, natural ecosystems and public health from threat of invasive species. Develop model legislation, which includes provisions for mitigating these threats, and which makes use of principles developed for invasive species by organisations, institutions and countries. Produce country specific recommendations for modifying or developing new legislation, which adequately regulates the following:

- Importation of all living organisms
- Surveillance for new incursions
- Risk analysis of import applications
- Assessment of environmental risks prior to introduction of genetically modified organisms
- Quarantine procedures
- Control or eradication of invasive species
- Export and transshipment of both harmful and endangered species

Strategies for enforcing legislation should be available.

4.3.4 Technical Capability

4.3.4.1 Access to Technical Innovation

Strengthen both basic and applied research and development on high priority problems. Emphasis should be placed on prevention and early detection and the evaluation of exotic species that are present or are potential problems. Establish long-term monitoring for incursions or recognised invasive species. Undertake inventory surveys in the countries/territories and monitor high-risk native areas of incursions of recognised invasive species. Strengthen linkages between countries and scientific institutions, sources of technical and research assistance or other bodies of information.

Determine and develop a regional source of public awareness materials that identifies the magnitude of the invasive species problems in the region. Information needed include:

- Know areas of natural ecosystems degraded by invasive species, their conservation impact and the consequences of not taking action
- Maximize funding of self-sufficiency by promoting participation of local communities in project development and implementation to ensure a long-term commitment

- Promote management of invasive species as a criterion in national, regional and international disaster management plans.

4.3.4.2 Infrastructure

Build on existing initiatives and facilities and thereby promote linkages within and outside of the region to enhance the capacity for management of invasive alien species. Improve and upgrade physical resources such as reference collections and special facilities for quarantine regionally and nationally. Develop training programmes in the area of species identification, field detection, monitoring and the like, and a network of resources that allow for the exchange of information between researchers and managers of invasive alien species. Develop rapid response mechanisms to deal with potential invasive species and strengthen initiatives that facilitate the use and sharing of existing regional facilities by Governments agencies in-country and between countries.

5.0 Way Forward

The Strategy may be used to initiate the modernization of the AHFS system, to seek funds, reinforce and guide natural biodiversity management plans, complement other invasive species programmes on the way both nationally and regionally and guide the Regional Invasive Species Programme. The technical group identified a number of joint projects. These projects are on plant problems but the integrated nature of the strategy creates the opportunity to develop projects in other areas and to upgrade the AHFS system in the countries.

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39

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TABLE OF CONTENTS

TECHNICAL SESSIONS Page

ANIMAL SCIENCE AND FORAGE CROPS

IPM AND PLANT PROTECTION

TROPICAL CROPS

VEGETABLE CROPS

NATURAL RESOURCES AND ENVIRONMENTAL QUALITY

SOIL SCIENCE AND PLANT NUTRITION

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SEASON EFFECTS ON FORAGE AND POD YIELD OF COWPEA GROWN ON HEAVY CLAY SOILS OF THE EASTERN CARIBBEAN ISLAND OF ST. CROIX

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ABSTRACT: Cowpea [*Vigna unguiculata* (L) Walp] cvs. Iron clay, Coolona, and Meringa performance on the heavy clay soils with the rainfall conditions of St. Croix, U.S. Virgin Islands is unknown. Studies were conducted in 2002 to assess season effects (wet versus dry), seedling vigor (plant height), forage dry matter (DM) yield, and pod yield (PY) of three commercial cowpea cultivars (Iron clay, Coolona, and Meringa). Field studies consisted of randomized complete blocks with four replicates. Field plantings were during July [dry season (DS)] and November [wet season (WS)]. Soil types were of the mildly alkaline Fredensborg clay (fine carbonatic, isohyperthermic, Typic Rendolls, Mollisol) with pH above 7.5. Mean seedling vigor differed ($P<0.0001$) across cultivars by season. Plant height during the DS at 2 wk post planting averaged 12.7, 7.3, and 7.1 cm for Iron clay, Coolona, and Meringa, respectively. This trend ($P<0.02$) was consistent among cowpea cultivars up to its physiological maturity at 12 wk post planting (46.3, 42.6, 36.5, cm for Iron clay, Coolona, and Meringa, respectively). For the WS, seedling vigor did not differ ($P>0.05$) for cowpea cultivars and averaged 46.3 ±9.4 at 12 wk post planting. Mean plant height by season for cultivar Iron clay was highest during the dry season and decreased during the wet season. During the DS, plant height averaged 30, 24.3, and 22.1 cm, and during the WS 25.4, 28, and 28 cm for Iron clay, Coolona, and Meringa, respectively ($P<0.01$). Forage yield also differed ($P<0.05$) for the DS, but not for the WS planting ($P>0.05$). Forage DM yields in the DS averaged 2.3, 1.0, and 1.5 Mg ha^{-1} for Iron clay, Coolona, and Meringa, respectively. In the WS, mean DM yield of the three cultivars averaged 2.2 Mg ha^{-1}. Pod yield differed ($P<0.05$) among cowpea cultivars for the DS planting. Highest pod yield was observed for Coolona cowpea (1.5 Mg ha^{-1}). Pod yield for WS did not differ ($P>0.05$) for cowpea cultivars and averaged 0.68 Mg ha^{-1}. These results indicate that in the DS, Iron clay is far superior to other cultivars for both plant vigor and yield, but in the WS exhibit decreased production to that of cultivars Coolona and Meringa. Yield performance during the WS was similar for all cultivars. Opportunities exist for the further development of cultivar Iron clay as a dry season forage legume in special purpose feeding and conservation systems in the U.S. Virgin Islands.

INTRODUCTION

The use of cowpea (*Vigna unguiculata*) in cultivated or improved pastures can provide positive attributes as a legume fed to ruminants and "Cowpea provides highly palatable succulent, nutritious fodder and improves soil fertility even when grown on light textured soils" (Sharma and Singhania, 1992). Early-growth cowpea has a mean crude protein (CP) level of 19.4% while more mature plants have CP levels of 11.3%, total digestible nutrient (TDN) levels reaching 59%, calcium at 1.40%, and phosphorus levels of 0.35% (Pinkerton and Pinkerton, 2001). Rouquette et al. (1990) found that the cowpea variety 'Iron and Clay' had a leaf CP level of 21%, while stems contained 9% CP. Results from the same study indicated that cowpea ranged from 2 to 3 feet in height and exhibited the ability to make sufficiently rapid growth to produce a canopy cover above Bermuda grass. 'Meringa' cowpea, when grazed by cattle in south-east Queensland, promoted much higher gain than tropical grass pasture as a result of its high quality (Holzknecht et al., 2000). Goat growth rate, feed intake, and feed conversion on an all-cowpea husk concentrate diet were significantly superior to those observed from a 40:60 concentrate: grass mixture (Adeloye, 1995). This suggests that cowpea husk could serve as an efficient fattening ration and dry-season feed for goats.

MATERIALS AND METHODS

Three cowpea lines (Iron clay, Coolona, and Meringa) were evaluated at the Agricultural Experiment Station, University of the Virgin Islands, St. Croix. Soil type was mildly alkaline Fredensborg clay (fine carbonitic, isohyperthermic, Typic Rendolls, Mollisol) with pH of 8.3. Replicated plots (complete block) were used for this study. Plot size was 3.5 x 5 m and distance between plots was 1 m and 2 m between blocks. Seven rows of each line (0.5 m between rows and 0.25 m within row/plants) were planted on July 9, 2002 and again on November 6, 2002. Plots were irrigated for 3 d to ensure uniform germination. Rainfall was sufficient thereafter, so no irrigation was needed.

Experimental variables included (i) stand germination (number seedlings per center row; on a percentage basis) 5 d after planting; (ii) weekly seedling height 2 wk after emergence up to 8 wk; and (iii) pod and forage yield ($g/1\text{-}m^2$). Forage from 1 m^2 -sections of the center rows of each plot was clipped to determine fresh weight. Sub samples (500 g) were obtained and dried in a 16° C forced air oven for 72 hrs. These samples were used for calculating percent DM and yield on a DM basis.

Data were analyzed using analysis of variance in the General Linear Model of SAS (1989). Seedling vigor was determined by using repeated measure analysis of variance to show time trend interactions (Little, 1986). All effects with probability levels >0.05 were considered not different. Mean comparison was made with F-protected LSD.

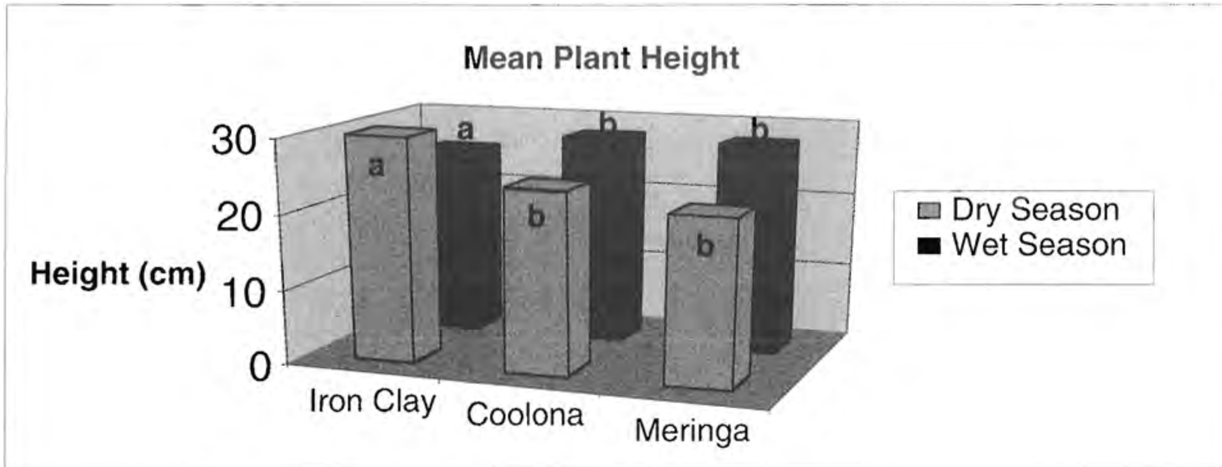
RESULTS

No differences across cultivars (cvs.) were observed for germination rate. All three cultivars exhibited uniform germination 3 days after planting as a result of sprinkler irrigation. Subsequent rainfall was adequate to provide enough moisture for normal plant growth and development in both the DS and WS. Rainfall during the DS totaled 23.8 cm and 29 cm during the WS.

There was significant difference between mean seedling vigor across all cvs. by season ($P<0.0001$). Mean seedling vigor for the DS and WS was 25.5 cm and 27.1 cm, respectively. This can be explained by higher rainfall observed in the WS vs. the DS.

There was a significant season by treatment interaction observed for cv. Iron clay ($P<0.01$). This can be viewed in Figure 1. In the DS mean plant vigor was 30, 24.3, and 22.1 cm and in the WS measured 25.4, 28, and 28 cm for Iron clay, Coolona, and Meringa, respectively.

Figure 1. Plant height of the three cultivars under two growing seasons.



Different letters within season indicate difference (P<0.01).

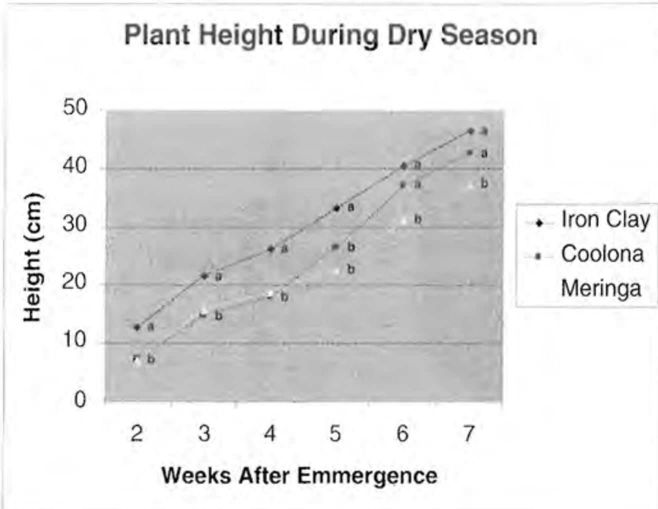
Plant vigor, when analyzed overtime during the DS, showed significant increased growth for cv. Iron clay over that of Coolona and Meringa in weeks 1, 2, 3, and 4, and over Meringa in weeks 5 and 6 ($P<0.02$). Plant vigor at week 6 was 46.3, 42.6, and 37.2 cm for Iron clay, Coolona, and Meringa, respectively (Figure 2). No significant difference was observed for plant vigor in the WS for weeks 1, 2, 3, and 4 across all cultivars. Weeks 5 and 6 showed increased growth for cvs. Coolona and Meringa over that of Iron clay ($P<0.05$) (Figure 3).

Forage yield differed in the DS ($P<0.05$). Iron clay yielded 2.3 Mg ha^{-1}, Coolona 1.0 Mg ha^{-1}, and Meringa 1.5 Mg ha^{-1}. For the WS there was no difference in forage yield across cultivars. Dry matter yield averaged 2.2 Mg ha^{-1} for the three cultivars. Pod yield differed ($P<0.05$) among cowpea cvs. for the DS planting. The highest pod yield was observed for cv. Coolona at 1.5 Mg ha^{-1}. Pod yield for the WS did not differ ($P>0.05$) for cowpea cultivars and averaged 0.68 Mg ha^{-1}.

CONCLUSIONS

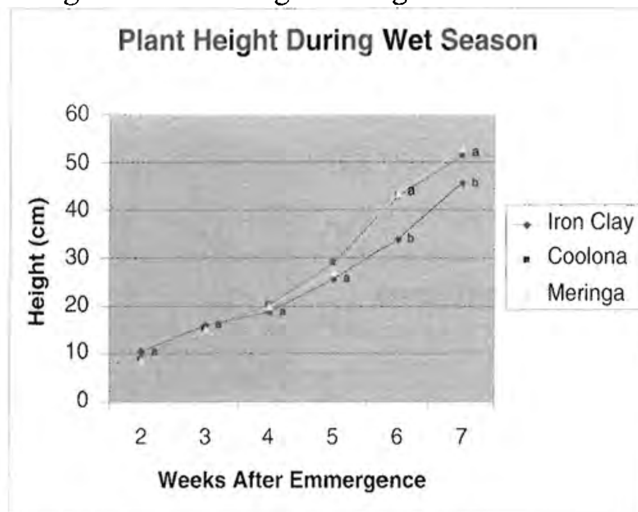
Cowpea cultivar Iron clay exhibited superior plant vigor and forage yield during the DS. This shows that cv. Iron clay has tolerance for high pH clay soils and can serve as an important forage crop for dry season production. In contrast to plant vigor and forage yield, pod yield was highest for cv. Coolona during the DS. Therefore, the importance of pod yield must be taken into account when selecting a dry season Cowpea cultivar. During the WS cowpea plant vigor is higher for cvs. Coolona and Meringa, but forage yield performance is similar for all cultivars tested. The three cowpea cultivars tested all have the potential to serve as valuable small ruminant forage resources in the U.S. Virgin Islands, but it is cv. Iron clay's overall dry season performance that exhibits the greatest potential as an alternative feed/cover crop resource.

Figure 2. Plant height during dry season.



Different letters within week indicate difference P<0.02.

Figure 3. Plant height during wet season.



Different letters within week indicate difference P<0.05.

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PERFORMANCE OF WEST AFRICAN SHEEP ON THE ISLAND OF TOBAGO, WEST INDIES

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ABSTRACT: Data on 245 lambs from 157 ewes of the West African breed, collected over 1982–1985 period at the Blenheim Sheep Station in Tobago (West Indies), were analyzed to study the effect of lambing season-year, sex, and type of birth on lamb birth weight (BWT), preweaning average daily gain (ADG), 56-day adjusted weaning weight (WWT), 6-mo weight (6MWT), and preweaning mortality. BWT was included as an additional source of variation in analyzing lamb mortality. The effect of the lambing season-year on measures of litter size (no. of lambs born total, born alive, and weaned per ewe lambing) and on total 56-day lamb weight weaned (TLWW) was also determined. The model for analyzing TLWW also included type of birth effects. The flock averages for BWT, ADG, WWT, 6MWT, and mortality were, 2.86 kg, 188 g, 11.9 kg, 20.0 kg, and 20.8%, respectively. Averages for number of lambs born total, born alive, weaned, and for TLWW were, 1.60, 1.56, 1.31, and 16.97 kg, respectively. The lambing season-year effect was highly significant ($P<0.01$) for measures of lamb growth but not for lamb mortality and litter size. Sex of lamb had a significant ($P<0.01$) effect on BWT only. The effect of type of birth was apparent for all lamb traits studied and for TLWW. Single born lambs weighed heavier than twins and higher multiplets from birth to 6 months of age. Ewes dropping triplets and higher multiplets weaned 20.72 kg lamb weight compared to 18.18 and 12.02 kg for ewes dropping twins and singles, respectively. Lambs with below average birth weight had significantly higher mortality than others (28.1 versus 13.4%).

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TRACEABILITY OF BEEF PRODUCTION IN MARTINIQUE: WHAT FOR AND WHOM FOR?

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ABSTRACT: The traceability of an agricultural product allows the follow up of a product from the farm to the table of the consumer. This tracing concerns the raw material as well as manufacturing preparations. In Martinique, traceability allows many useful operations such as: epidemiological surveys to avoid the incidence of pathological hazards; organization of commercial circuits; assist farmers in the production of better quality meat and recognition on the local market. This traceability provides the consumer products safe for his health and reliable information. By means of examples of their daily involvement in this matter, the authors will try to illustrate this traceability.

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IDENTIFICACIÓN DE PLANTAS CONSUMIDAS POR OVINOS Y CAPRINOS Y SU EFECTO EN UN ECOSISTEMA DE BOSQUE SECO EN LA REPÚBLICA DOMINICANA

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RESUMEN: Este trabajo se realizó con el objetivo de identificar las plantas consumidas por los ovinos y los caprinos en un ecosistema de bosque seco de la Línea noroeste del país. Esta zona cuenta con 29,623 cabezas de caprinos y 27,446 ovinos, y un total en el país de 163,489 caprinos y 105,454 ovinos (Datos SEA, 1998). Se utilizó como herramienta de trabajo la Unidad de Recursos para Planificación (URP), que describe las condiciones agroecológicas de la zona en estudio. En visitas diagnósticas a la zona se aplicó un formulario-encuesta preestablecido a los productores ovicaprinos. Se recolectaron las plantas que, según observaciones, estaban consumiendo los animales y aquéllas identificadas por los productores. Se identificaron 35 familias, 83 géneros y 97 especies, siendo la familia Fabaceae la de mayor aparición con 15 especies; Poaceae, 11; Mimosaceae, 8; y Cesalpinaceae, 6. Los resultados indican que esta zona presenta un gran potencial de plantas forrajeras que, utilizadas con racionalidad, pueden suplir las necesidades nutricionales de los ovinos y caprinos, así como de otras especies animales de la zona, tanto en época de sequía como en lluvia. Entre las plantas consumidas se encuentran: *Desmodium vaginalis*, *Gliricidia sepium*, *Acacia macracanta*, *Prosopis juliflora*, *Senna atomaria*, *Cassia grandis*, *Samanea saman*, *Macroptilium lathiroides*, *Guasuma tomentosa*, *Bothriocloa pertusa*, *Eleusine indica*, *Digitaria* sp., *Agave sisalane*, *Opuntia* spp. y otras cactáceas. Los animales consumen flores, tallos y hojas nuevas o brotes, frutos o corteza de árboles dependiendo de la época del año. Se recomienda: (1) La capacitación a productores sobre el uso racional de los recursos naturales disponibles, (2) Monitoreo constante de la vegetación primaria, ya que según estudios posteriores para validar estas informaciones, una gran parte de estas plantas está en vías de extinción, mientras están apareciendo nuevas plantas con características forrajeras bajas.

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POTENTIAL FOR YEAR-ROUND FORAGE PRODUCTION IN PUERTO RICO AND ST. CROIX

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ABSTRACT: Forage production can vary considerably during the annual cycle in Puerto Rico and St. Croix. Cool temperatures, low solar radiation, and low rainfall (Dec-Jan) are assumed to be the cause of substantial decreases in forage growth. To examine these hypotheses for low forage production, we used a forage growth model. Weather data were obtained from Puerto Rico and St. Croix. Minimum temperatures were always near or above 20° C year-round at all locations. Temperature did not appear to be a cause of the serious loss in forage production. The model predicted decreased forage production in the winter months due to decreased levels of solar radiation, but yields were still estimated to be 70 - 80% of summer yields. Although a shallow rooting depth of 45 cm resulted in decreased yields in some situations, it seemed unlikely to explain the large decreases observed in winter months. This research indicates that a factor other than the ones tested in this analysis contributes to the loss in winter forage yield. Short daylengths during winter months is suspected to cause the decrease in growth.

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IMPORTANCIA DEL MANEJO DE GARRAPATAS EN VAQUERÍAS DE PUERTO RICO

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RESUMEN: La presencia de garrapatas sobre el ganado tiene un impacto negativo y directo en la productividad de las vaquerías. El Ingreso Bruto Agrícola de Puerto Rico (IBAPR) ascendió a $724.1 en el 2002. La producción de leche aportó el 27% del IBAPR, con $193.4 millones, además, la Industria Lechera contribuye con 25,000 empleos directos e indirectos. Del 30 al 40% de la carne producida localmente proviene de las vaquerías. Se estima en 96,070 el número de animales en vaquerías en la isla. El control de garrapatas es de vital importancia para la salud del hato, éstas son un vector de Piroplasmosis y Anaplasmosis. Las picadas producen irritación, ansiedad, anemia, debilidad, pérdida de peso y reducción en la producción de leche. Desde 1936 el gobierno de Puerto Rico estableció un programa de control de garrapata en la isla (Ley Núm. 106 de mayo 1936). Actualmente el Programa Gubernamental de Control de Garrapatas se ha reducido al mínimo. El propósito de esta ley fue romper el ciclo reproductivo de las garrapatas con baños periódicos. La eliminación o reducción del programa ha tenido un impacto significativo en la salud animal y en el aspecto económico. Con el propósito de conocer la situación actual se entrevistaron el 85% de los ganaderos de la isla. El tamaño promedio de las fincas era de 180 cuerdas. El número promedio de vacas en ordeño era de 175, el 71% de los hatos tenía problemas con garrapatas. El 97% aplicaba el plaguicida sobre los animales. El 73% asperjaba para control de garrapatas con bomba en el cepo. La mayor incidencia de la plaga se reportó en vacas secas (horras), 72%. El 34% de los ganaderos indicaron que la mayor incidencia de garrapatas era en la época lluviosa. El 56% de los ganaderos contaba las garrapatas mediante observación visual. Se dividió la isla en dos zonas, noroeste y noreste. Los productores del noreste presentaron pérdidas mayores por efecto de la presencia de garrapatas. Esta zona no es la de mayor importancia económica para la industria lechera. En Puerto Rico, la zona noroeste es la de mayor concentración de vaquerías. Los ganaderos reportaron un gasto promedio anual en plaguicidas de $2,882 para controlar las garrapatas. El pago promedio a empleados en labores de control de garrapatas fue $1,937. El costo promedio del equipo fue de $1,324 y el gasto promedio en otras actividades relacionadas al control de garrapatas ascendió a $1,012. El gasto total anual promedio del programa de control de garrapatas establecido por los mismos agricultores ascendió a $7,155 por agricultor. El costo promedio por vaca, considerando un tamaño de 247.2 animales por vaquería ascendió a $28.09. El valor de las pérdidas en vacas ascendieron a $1,396,100. Si comparamos el costo de control de garrapatas por animal con el costo por la pérdida de animales debido a enfermedades producidas por Piroplasmosis o Anaplasmosis, concluimos que es recomendable para los agricultores el controlar las garrapatas en sus fincas para minimizar la pérdida de animales y garantizar la inversión que se hace en animales, así como la vida útil de las vacas en ordeño.

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RATIONAL PESTICIDE USE IN IPM OF PESTICIDE-RELIANT VEGETABLE CROPS IN THE CARIBBEAN

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ABSTRACT: Leafy vegetable production in the Caribbean is highly pesticide-reliant often using a calendar spray cycle to manage pests. This leads to unwarranted pesticide use and all the attendant problems of this practice. IPM proponents often promote the virtual elimination of pesticide use, which can lead to ineffective pest management. Despite the potential risks, pesticides continue to be valuable to agriculture; therefore, a reasoned approach to their inclusion in IPM is critical. Rationalization should include application thresholds, an efficient sampling plan, effective biorational pesticides and optimal spray application technology. Research on vegetable amaranth in Jamaica showed the potential of rational pesticide use to reduce pesticide input by 46-85%. Biorationals, ecdysone agonist (tebufenozide) and microbial metabolites (spinosyns, and emamectin benzoate), significantly reduced crop damage more effectively than commonly used pyrethroid (lambda-cyhalothrin). The approach also facilitates resistance management of new pesticides. Through regional collaboration under IPM CRSP, the approach is being tested more widely.

INTRODUCTION

The global concern about excessive use and frequent misuse of pesticides on food crops is growing and with new international requirements for safer foods, the Caribbean must be proactive. Vegetable production systems in the Caribbean, especially for leafy vegetables, are highly pesticide-reliant. Many farmers use prophylactic sprays on a calendar cycle to manage phytophagous pests and this invariably results in unwarranted pesticide use, the development of pesticide resistance and all the well documented attendant problems of this practice (IPM CRSP Annual Reports 1994 and 1995, Reid et al., 1998). IPM proponents in an effort to correct this problem, often move to the extreme of inadequate pesticide use (Bateman, 2000).

Despite their potential negative effects, pesticides continue to be valuable to agriculture and a reasoned approach to their inclusion as an option in IPM is critical. Rational pesticide use (RPU), was described by Brent and Atkin (1987) as the optimal use of pesticides through improvements in the selectivity of the products and precision of their application in space and time (cited by Bateman, 2000). This requires defined application thresholds, an efficient sampling plan, and effective biorational pesticides using optimal spray application technology.

This paper describes research experiences in Jamaica toward the development of such a system for vegetable amaranth production and discusses the potential role of this option.

Integrated Pest Management Collaborative Research Program (IPM CRSP)

In 1994, the USAID funded Integrated Pest Management Collaborative Research Support Program (IPM CRSP) was started in Jamaica with CARDI as the implementing agency. The goal of the project is to promote IPM through farmer participatory collaborative research among institutions in the United States and Lesser Developed Countries e.g. Guatemala, Jamaica, Mali, and the Philippines. These developing countries are regarded by IPM CRSP as primary host countries within defined geographical regions (Latin America, the Caribbean, Africa, etc.). The information generated from research activities conducted in these host countries would be extended to other countries within the corresponding region and globally, where relevant. The goal of the project is to reduce agricultural losses due to pests, damage to national ecosystems and pollution/contamination of food and water supplies.

Research efforts in Jamaica under IPM CRSP have been focussed on three commodities: vegetable amaranth, *Amaranthus viridis* and *A. dubius* (callaloo), hot pepper, *Capsicum chinensis* (Scotch Bonnet cv); and sweet potato, *Ipomoea batatas*. These commodities were selected on the basis that each production system presented different constraints to IPM system development. A range of benefits of IPM could therefore be readily demonstrated in these cropping systems.

Callaloo is a traditional vegetable in the Jamaican diet and during the last two decades it has gained importance as a non-traditional export crop on the U.S. market. However, various herbivorous pests including lepidopterans, beetles, mites and leafhoppers attack this crop (Clarke-Harris et al., 1998). To protect leaves from these ravaging pests, farmers commonly use synthetic pesticides on a calendar basis, every eight days. During heavy pest infestation pesticides are applied even more frequently. In the absence of any prior research data on this crop, work under IPM CRSP represents pioneer efforts, all of which allowed for the classical principles of IPM system development to be employed.

The Research approach to IPM system development in vegetable amaranth in Jamaica

The research approach used involved the following steps, many of which were geared towards developing a rational basis for pesticide application.

1. Determination of the taxonomy of major pests of the crop

The presence of various arthropods was recorded on the crop but not all were of economic importance. Deciphering the taxonomy of these species helped in the determination of their potential effects on the crop and their possible interrelationships as well as the identification of potential management tactics.

2. Development of Sampling Protocols

After identifying the major pests, research efforts were focused on reducing pesticide inputs by taking the following steps to develop decision-making protocols based on economic thresholds:

- Determination of an Action Threshold
- Monitoring of Pest Populations
- Development of a Model of Pest Frequency Distributions
- Development of a Sequential Sampling Plan
- Greater efficiency in sampling by using a sequential sampling plan
- Validation of Sequential Sampling Plan

3. Evaluation of the efficacy of new biorational pesticides

Calendar based spraying and other irrational methods of timing pesticide application have led to the development of insecticide resistance and consequent field failures of currently used synthetic pesticides (e.g., lambda cyhalothrin, methomyl diazinon, etc.). New biorational chemistries with their novel modes of action are more selective and often less toxic to the user/consumer and the environment and they have been shown to give greater protection from major pests, thus reducing insect-damaged rejects.

4. Development of a decision-making tool to guide pesticide applications

This tool is a practical guide for the farmer in deciding whether or not to take action on the basis of the pest density in his field at a given time.

5. On-farm validation and demonstration of IPM strategy

On-farm validation/demonstration plots are used in training farmers and extension officers in the developed techniques and other IPM practices and improved application technology (i.e., calibration of spray equipment and proper spray application techniques).

6. Evaluation of non-chemical alternatives

The mechanical method of exclusion of insect pests at the nursery and field level was well tested and has been found to be very effective. Cultural measures and good agronomic practices have also been incorporated.

Research achievements in the development of an IPM system for vegetable amaranth in Jamaica

The most limiting pests on callaloo were identified as a complex of lepidoptera species (three noctuids and two pyralids) whose density varies from one location to another and from one season to another. Given this variable density, a sequential sampling plan was developed to allow for efficient allocation of sampling input as warranted. The sampling plan was developed using a threshold of one larva per sample unit and the population distribution model of best fit (the negative binomial model) and a clumping parameter (k_c) of 0.645. When this sampling plan was compared with a fixed plan of 25 plants, sequential sampling recommended the same management decision on 87.5%, additional samples on 9.4%, and gave inaccurate recommendations on 3.1% of 32 farms, while reducing sampling effort by 46%. Insecticide application frequency was reduced 33 to 60% when management decisions were based on sampled data compared with grower-standards, without increasing crop damage. Crop losses remained high or variable (10-46%) with the weekly pyrethroid treatment (Clarke-Harris and Fleischer, 2003).

Despite farmers' frequent use of pesticides to control lepidopteran larvae on callaloo, field failures of insecticide applications have been observed (unpubl. data). Insecticide resistance is one known cause of reduced pesticide efficacy, and preliminary data suggest the presence of pyrethroid resistance in *Spodoptera exigua*, one of the lepidoptera on callaloo in Jamaica. Brewer and Trumble (1994) also reported resistance in *S. exigua* in the U.S.A.

Biorational materials have novel modes-of-action and some are selective to lepidopterans. These include ecdysone agonist, tebufenozide (Dhadialla et al., 1998), the semi-synthetic microbial metabolite from *Streptomyces avermitilis*, emamectin benzoate (Lasota and Dybas, 1991), microbial metabolites from *Saccharopolyspora spinosa*, spinosyns (DowElanco, 1997), and extracts from the neem tree, *Azadirachta indica* (National Research Council, 1992). These examples were tested and lepidopteran control was considerably improved with ecdysone agonists (tebufenozide) or microbial metabolites (spinosyns and emamectin benzoate). During periods of high pest pressure, larval populations in farmer-standard plots (weekly pyrethroid sprays) were 6-12 times greater than in plots treated with the biorationals (Clarke-Harris and Fleischer 2003).

Implementing a sequential sampling plan in conjunction with the introduction of newer modes-of-action for lepidopteran control in leafy vegetable production in the Caribbean can facilitate resistance management. Current studies using this combination show a reduction of 46-95% in pesticide input (CARDI, 2002).

Regionalization

Research, which has been conducted on the callaloo cropping system, has now come to fruition and the research model is thought to be applicable to other vegetable systems, in which high pesticide input is an important concern throughout the region. However, cabbage (particularly the pest diamond-back moth) which was named by 13 of 16 member countries of Caribbean IPM Network (CIPMNET) as a research priority (PROCICARBE CIPMNET 1998 unpubl.) was selected for the initial focus. Regionalization of the research approach to developing pest management systems for other pesticide-reliant vegetable crops is being carried out through regional collaboration under IPM CRSP.

As part of the regionalization effort in the Caribbean a two-day Regionalisation Workshop, Development of IPM in Leafy Vegetables that Currently Experience High Pesticide Input, which was held 12-13 June 2002, Centeno, Trinidad in collaboration with the Ministry of Agriculture, Trinidad and Tobago, was geared towards researchers and involved a total of nine participants from Barbados and Trinidad and Tobago, and resource persons included Scientists from Pennsylvania State University, Virginia Polytechnic Institute and State University, CABI, and CARDI.

Subsequent to this workshop initiative, some workshop participants were co-opted to collaborate in the IPM CRSP project by carrying out research activities, funded by IPM CRSP, in their respective countries. Parallel experimentation is now underway in Jamaica and Trinidad to evaluate the biorationals spinosad and lufenuron applied to cabbage on a threshold basis against major lepidoptera. This is being compared with current farmer practice of calendar sprays. The thresholds used were from the 2002 Commercial Vegetable Recommendations used in the mid-Atlantic states of the United States of America.

CONCLUSION

Based on the results described above, a focus on RPU can have far reaching effects to reduce pesticide input in Caribbean Agriculture. Among the benefits to be derived are reduction in pesticide and labour costs, improved user and consumer safety and reduced negative environmental impact. RPU will also help in resistance management to preserve the efficacy of new materials.

One of the tenets of IPM is minimized pesticide use; RPU ensures that optimal pest management benefits are derived from this reduced pesticide input. The importance of efficient application technology must be underscored as well as the continued need to incorporate other effective non- chemical approaches.

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EFFECT OF NEEM-BASED (*AZADIRACHTA INDICA*) PEST CONTROL METHODS ON OKRA YIELDS IN THE U.S. VIRGIN ISLANDS

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ABSTRACT: Neem (*Azadirachta indica*) products have been used as organic pesticide against a wide variety of agricultural pests in tropical areas of the world. A study was conducted to determine the efficacy of various neem treatments on the pests effecting okra in the U.S. Virgin Islands. A field trial was conducted at the UVI Agricultural Experiment Station incorporating six pest control treatments: diazinon, azatin, neem mulch, neem tea, neem hedge, and control. Okra was harvested three times per week for nine weeks. Marketable fruit weights and number of fruit were recorded. The diazinon, azatin, and neem mulch treatments produced statistically similar numbers of fruit and had similar yields (9.93, 9.74, and 8.36 t ha^{-1}, respectively). All three treatments were significantly ($P< 0.05$) better than the control (6.76 t ha^{-1}). Total yield and number of fruit were significantly less than the control for the 'home-made' neem tea treatment made from leaves. Production from the neem hedgerow treatment was significantly lower than all other treatments, most likely due to competition for light and moisture. This study indicates that azatin and neem mulch are organic pest control options that produce okra yields similar to those achieved when using the synthetic commercial insecticide, diazinon.

INTRODUCTION

The neem tree (*Azadirachta indica*) is a member of the mahogany family native to south Asia and naturalized throughout semi-arid areas in Asia, Africa and the Caribbean (Parotta and Chaturvedo, 1994). Neem has been used for centuries for its insecticidal properties against a myriad of insect pests (Schmutterer and Ascher, 1986). The tree has the potential of improving agriculture in the Virgin Islands as it represents an economical biological insecticide that can be collected and produced locally by small scale farmers (Ahmed and Grainge, 1986; Daly and Zimmerman, in press). Insecticidal extracts are made from both leaves and seeds (Navqi, 1986). In the U.S. Virgin Islands, a number of small farmers spray a "neem tea" (made from steeped neem) leaves on their crops. Although leaf extracts are known to have lower levels of active ingredients, they are probably utilized instead of the seed extracts because they are both easy to make and leaves are available all year. This study examines the effect that neem tea and other neem-based insect control methods have on production levels of okra.

Okra (*Hibiscus esculentus*) is a member of the Malvaceae (Mallow) family believed to have been introduced to the Caribbean sometime during the 1500s. The immature fruits are used as a vegetable in many Caribbean dishes and are served fried, curried, with peppery sweet corn and in countless other recipes (Bourne et al., 1988). Today it is grown throughout the Caribbean region.

In the Virgin Islands, okra is one of the most common crops grown during the summer months by small farmers. According to the National Agricultural Statistics Service (NASS), 50 farms planted 15 acres of okra, producing 11,745 harvested pounds in the Virgin Islands in 1993. In 1998, the most recent date for which data is available, the number of farms producing okra increased to 61 while total acreage decreased to 8 ac. and production fell to 8,156 (NASS, 1998). This data demonstrates the continued trend toward okra production on smaller farms and does not include the many other individuals producing okra in home gardens.

Large and small scale farmers alike in the Caribbean islands are heavily dependent on imported agrochemicals such as pesticides, which are not produced in the Virgin Islands. Shipping charges cause higher prices for Caribbean farmers and drive up operating expenses. In addition to being more costly, shipping is a process which often lasts several weeks from ordering to receiving goods. This makes farm management more complex by requiring accurate record keeping to ensure that materials are ordered well in advance. Although local farmers can ask a higher price for their produce and still remain competitive with imported goods, only \$2.8 million of the \$35 million expenditure on fresh agricultural products is locally met in the Virgin Islands (D'Souza, 2000). This fact can be partially explained by the expenses and complications associated with shipping agricultural products to the territory.

MATERIALS AND METHODS

This trial evaluated differences among six insect control treatments on okra and their overall effect on number of marketable fruit and marketable yield. Each treatment plot was 3.6 m x 7.3 m or 26.3 m^2, consisting of three rows spaced 1.2 m apart. Plant spacing within rows was 0.6 m or a total of 24 plants per replication. The field was irrigated with drip emitters every 0.6 m. The experimental design was randomized block design with four replications per treatment.

The okra variety used in the trial was Clemson Spineless. Plants were direct seeded with three seeds per hole and thinned to one plant after two weeks. Seeds were planted in June 2002 and sprayed for the first time when pests were observed 22 days later. One of the primary pests affecting okra in the Virgin Islands is the aphid, but mealy bugs, white fly and other pests are also a concern. The six pest control treatments tested in this study were traditional spraying (TS), neem-based spray (NS), neem mulch (NM), neem tea made from fresh cut leaves (NT), a neem hedge treatment (NH), and control.

Plants were sprayed as needed, usually once per week during initial stages and two times per week during the height of production. For the TS treatment either diazinon or malathion was applied only once per week. Azatin™ was used for NS treatment and was applied according to the label, usually twice per week. NT was made from fresh cut neem leaves (1kg leaves/7.6 L water) steeped in ambient temperature water for 48 hours, and then strained. The NT was applied as often as three times per week depending on the severity of the infestation. All commercial pesticides were applied in accordance with their labels. Spraying was conducted during early mornings to minimize drift and consequent cross contamination among treatments.

The non-spray treatments were NM, NH and control. The purpose of these treatments was to determine the insecticidal effect of un-processed green material from the neem tree. The hedge was comprised of neem seedlings planted 0.6 m apart in rows 10 m in length and 5 m between rows. The hedge rows were planted one year prior to the okra crop and were maintained at a height of 0.9 m and 0.6 m wide. The mulch for the NM treatment was applied green, in a 10-15 cm layer with woody stems over 3 cm removed. The mulch was applied only after the okra seedlings were tall enough (20 cm) to avoid being smothered.

The first harvest was 53 days after planting. Okra was harvested three times per week for 9 weeks for a total of 26 harvests. Field observations were recorded on the incidence of pests and diseases throughout the experiment. Data on number of fruit, fruit size and fruit yield were taken at each harvest. Data analysis was conducted by using the SAS System 8.00 for Windows. Analysis of variance was conducted for total number of fruits and total yield by using GLM procedure which indicated there was significant difference among treatments for both number of harvested fruits and total yield. Mean separation was completed using PDIFF (SAS 2001).

RESULTS AND DISCUSSION

White fly, mealy bug and aphids were the primary pests observed on plants within all treatments during the course of the study. Aphids were the only pests that caused serious damage to the plants and reduced yields. Severely infested plants went through a several-week process of increasing aphid population, development of sooty mold, leaf loss and, in severe cases, plant failure.

During the first three weeks of okra harvest only NH was visibly different from the other treatments, with noticeably underdeveloped plants. Insect pests were present in isolated patches and appeared to be spreading. Spraying regimes were increased for all three spray treatments. By week four, aphids were causing severe damage to isolated plants in NT and control, reducing yield. Spraying in NT was increased to three times per week but the aphid population continued to increase.

Total plot production by weight, number of fruit and average fruit size per treatment is shown in Table 1. Total marketable production weights ranged from 1.63 t/ha^{-1}, to 10.09 t/ha^{-1} (Figure 1). The results from the more productive treatments are in keeping with yields achieved in a previous variety trial conducted on an adjacent plot (Palada and Crossman, 1991). There were significant differences (P 0.01) in total marketable yield between all treatments except for TS and NM, which produced the highest total yields (10.09 t/ha^{-1} and 9.90 t/ha^{-1} respectively) and were the most successful treatments. The only other treatment that produced higher marketable yield than the control was NS.

Two treatments produced at significantly lower rates than the control (6.88 t/ha^{-1}). By far the lowest producer, NH (1.63 t/ha^{-1}) appeared to suffer from severe competition for moisture and nutrients from the hedgerow trees and produced well under the rate of the control (Figure 4). Plants in NH were the last to bear fruit and never reached the height of those from other treatments. Though this treatment was never sprayed, insect populations were not observed to be as great as in other treatments. NT (4.92 t/ha^{-1}) also had a negative effect on production as it produced significantly less than the control. It is not known why number of fruit and yield was reduced by this treatment, but the aphid infestation was observed to be more severe in this treatment than in any other.

In terms of number of marketable fruit produced per week, NS, TS and NM were not significantly (P 0.01) different. All three were significantly (P 0.01) better than control and were the top three producers (Figure 1). In terms of total production TS and NM were significantly (P 0.01) better than all other treatments, but were not different from one another (Figure 3).

SUMMARY AND CONCLUSIONS

This study has shown that okra production varied under the different pest treatments. Two treatments, NH and NT, had a negative effect, producing less than the control and, therefore, cannot be recommended. Three treatments, TS, NS and NM, had production levels significantly higher than that of the control. Growers of okra should note that it was possible to increase marketable yields with one of these three methods. The two spray treatments, TS and NS, improved yield through reduced insect damage. NM is a non-spray treatment that improved yields either through improved water conservation, insect repellant effect or a combination of the two. Future research should examine the possibility of further improving yields by combining NM with spray treatments. Additionally NM should be compared with traditional hay mulching to discover whether the neem mulch provides significant insect protection.

These results indicate that okra growers in the Virgin Islands may be able to improve their production systems with one of these two treatments. Furthermore, using neem leaves as mulch is a locally available, inexpensive, organic practice that offers results similar to those of more expensive and time consuming chemical application.

Table 1. Okra spray treatments and production from 96 plants over 9 weeks.

Treatments	Total yield (kg)	Total Number of Marketable Fruits	Average Marketable Fruit Weight (g)
Neem Spray	60.53	5697	10.59
Traditional Spray	71.45	6918	10.33
Neem Mulch	70.41	6298	11.18
Neem Tea	34.56	3303	10.46
Neem Hedge	11.44	1174	9.75
Control	48.64	4589	10.6

Table 2. Marketable yield of okra as affected by treatment.

Treatments	Marketable Yield (t/ha)	Average Number of Marketable Fruits per Plant
Chemical Spray	10.09 a	72.1 a
Neem Spray	8.50 b	59.3 b
Neem Mulch	9.90 a	65.6 ab
Neem Tea	4.92 d	34.4 d
Neem Hedge	1.63 e	12.2 e
Control	6.88 c	47.8 c

Figure 1. Total number of marketable okra produced per week with various insect control treatments over 9 week harvest.

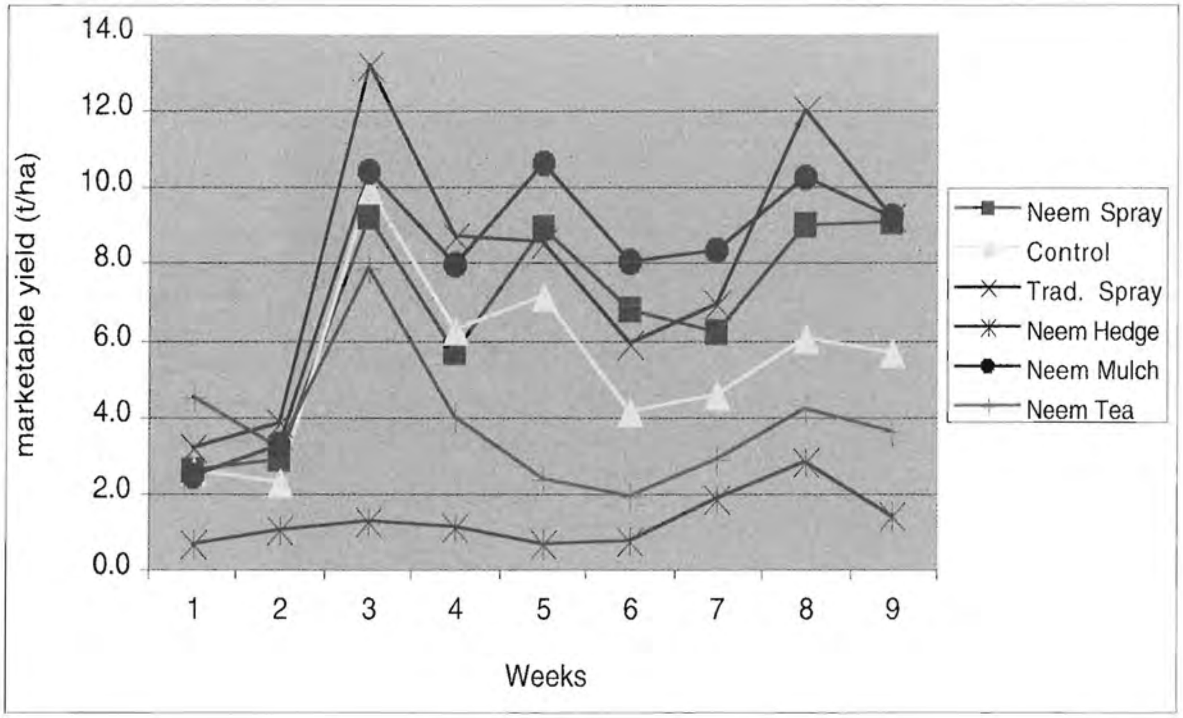


Figure 2. Weekly marketable okra yield per plot for various insect control treatments.

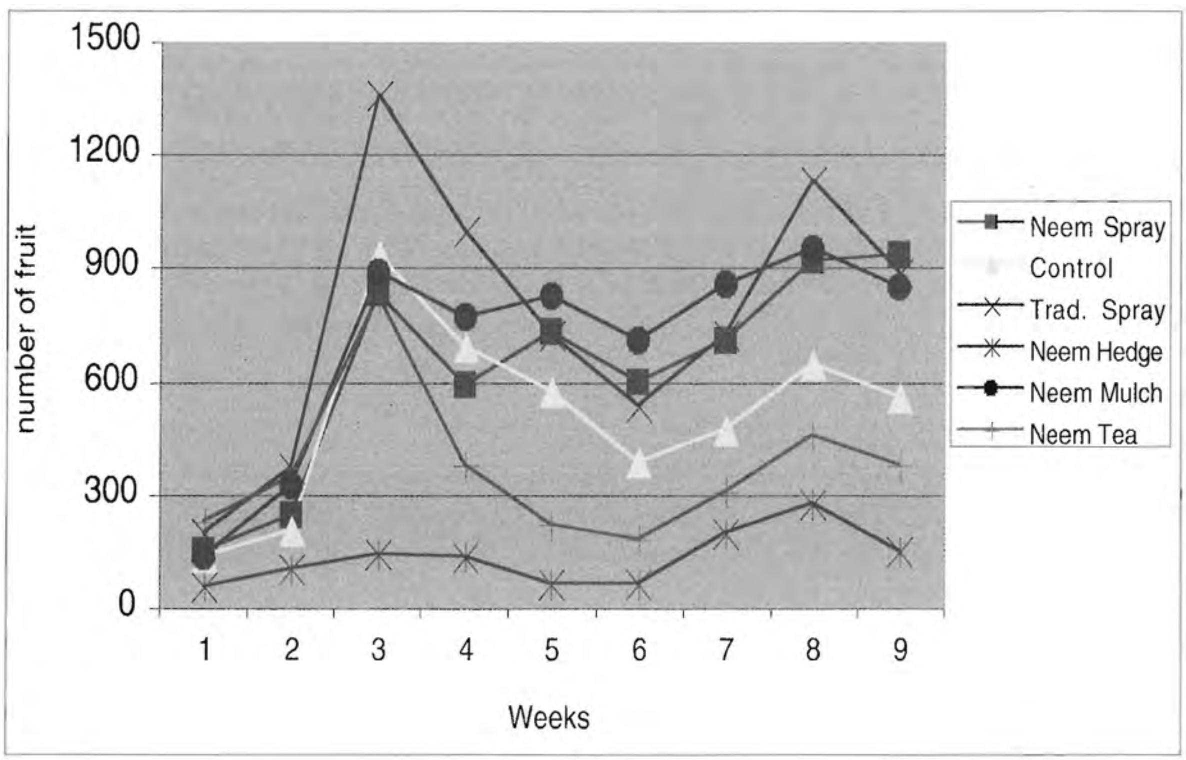
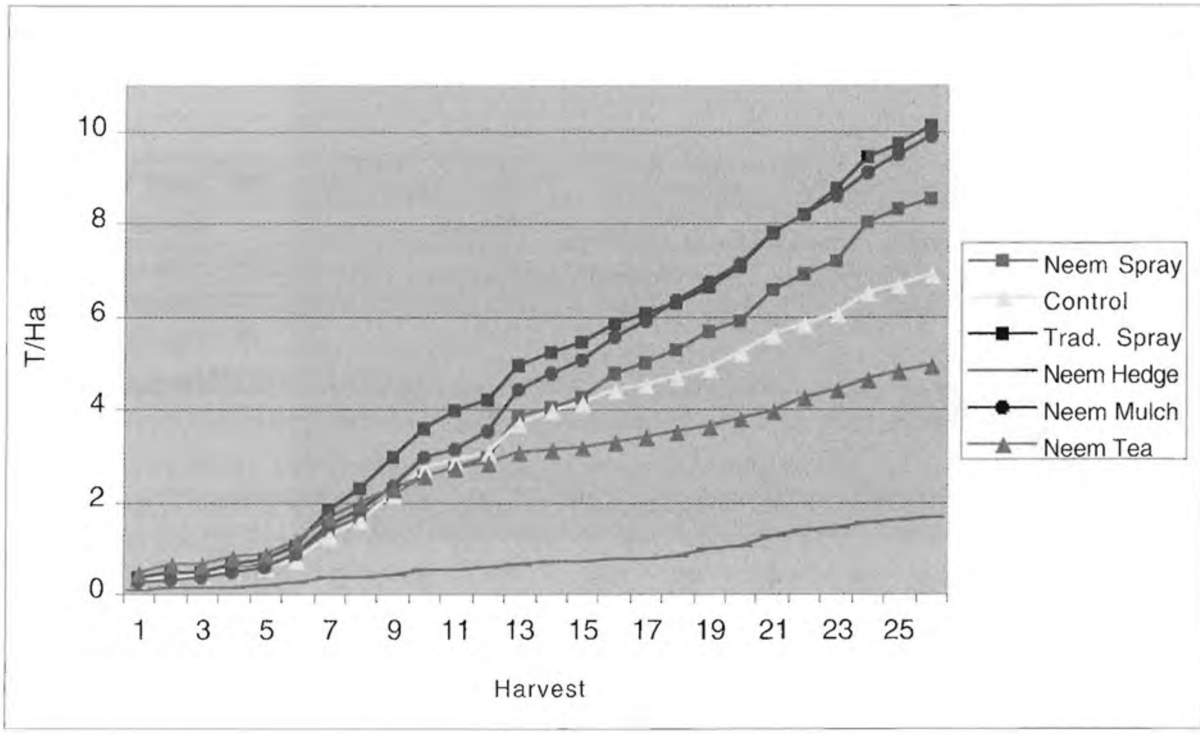


Figure 3. Cumulative marketable okra yield for various insect control treatments (t/ha).



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EVALUATION EN PLEIN CHAMP DE LA NUISIBILITE DE L'ANTHRACNOSE DE L'IGNAME *DIOSCOREA ALATA* SELON LA PERIODE DE DEVELOPPEMENT DE LA MALADIE

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ABSTRACT: Une expérimentation a été conduite pour évaluer l'impact de l'anthracnose, causée par *Colletotrichum gloeosporioides*, sur l'igname *Dioscorea alata*, selon la période de développement de la maladie par rapport au cycle de la plante. De petites parcelles de *D. alata*, cultivar Plimbite, variété sensible à l'anthracnose en Guadeloupe, ont été cultivées selon les pratiques culturales habituelles. Un certain nombre de parcelles a été maintenu hors attaques d'anthracnose par des traitements répétés d'un fongicide efficace. Les autres parcelles ont été inoculées à différentes dates, respectivement 76, 106 et 136 jours après plantation, par des souches très agressives de *Colletotrichum.* A la récolte finale (180 jours après plantation) le traitement témoin, protégé chimiquement, a eu une production de tubercules frais de 28 tonnes par hectare (T ha^{-1}). Le rendement pour la première date d'inoculation est par contre extrêmement faible (6 T ha^{-1}); il est respectivement de 20 et 27 T ha^{-1} pour les seconde et troisième inoculations. Les différences de rendement entre dates d'inoculation portent surtout sur le poids des tubercules et assez peu sur leur nombre. Comme les attaques d'anthracnose sont, dans nos conditions climatiques, très sévères surtout à partir du mois de septembre, il est possible d'envisager des dates de plantation précoces et des génotypes à cycle court comme moyens non génétiques de réduire l'importance des dégâts.

INTRODUCTION

La production d'ignames en Guadeloupe est voisine de 10.000 tonnes, mais cette production pourrait être accrue dans de fortes proportions, compte tenu de la demande sociétale forte, reposant sur un attachement culturel marqué à cette plante. La culture de l'igname blanche, *Dioscorea alata*, est la plus développée et elle profite de nouvelles techniques culturales : vitro-plants, culture à plat, mécanisation de la plantation et de la récolte, irrigation,... Mais la contrainte la plus forte au développement de cette production est une maladie fongique aérienne d'importance : l'anthracnose, due à *Colletotrichum gloeosporioides*. C'est une maladie qui peut être extrêmement sévère et quasiment empêcher toute tubérisation (Fournet et al., 1975); elle a rendu la culture de certains génotypes, très appréciés des consommateurs, irréalisable en Guadeloupe. L'anthracnose peut également se développer sur des tubercules en conservation (« dead skin », Green and Simons, 1994). La lutte chimique est possible mais elle est coûteuse (plus de 10 traitements par saison culturale; Toribio and Jacqua, 1978), dangereuse sur le plan environnemental et elle devient moins efficace. Il existe quelques variétés résistantes, dont certaines identifiées ou créées à l'INRA de Guadeloupe (Degras et al., 1984; Ano and Gamiette, 2002), mais la parade risque d'être temporaire, puisque leur résistance semble s'éroder plus ou moins rapidement. Il existe certainement, chez ce champignon qui présente une forme sexuée, un cortège de races de *Colletotrichum gloeosporioides* ce qui peut expliquer qu'un génotype sensible dans une île de la Caraïbe ne le soit pas dans une autre (Green, 1994).

La propagation du ravageur d'une saison à l'autre peut se faire par le biais du sol, des résidus de récolte dans le sol (Ekefan et al., 2000), ou surtout par le tubercule (Adebanjo and Onesirosan, 1986). Mais le développement des symptômes et des dégâts se fait surtout en saison à fortes pluie et humidité (Cadre et al., 1999; Winch et al., 1993), soit classiquement en août-septembre dans les Antilles, c'est-à-dire à des stades différents du développement des tubercules, selon la précocité des génotypes et la date de plantation.

La mise en évidence de l'impact de l'anthracnose sur la culture, et sur le rendement final, est donc difficile à évaluer, en plein champ, à cause de ces variabilités. Le travail présenté cherche donc à pratiquer in situ des attaques contrôlées d'anthracnose pour évaluer, sur un génotype sensible, la nuisibilité de la maladie selon le stade de développement de la plante auquel a lieu l'attaque.

MATERIEL ET METHODES

Le dispositif expérimental

La variété Plimbite est utilisée pour l'expérience car c'est, dans nos dispositifs expérimentaux à l'INRA de Guadeloupe, un témoin de sensibilité à l'anthracnose facilement disponible ; elle est cultivée à plat, sans tuteurs.

Le dispositif comporte en tout 16 bacs compartimentés, d'une surface de 9 m_ chacun (3m*3m). Chaque bac comprend 3 billons avec 9 plants par billon, soit 27 plants par bac. L'essai comporte 4 séries de 4 bacs alignés.

La plantation est effectuée le 6 juin 2002, avec des morceaux de tubercules de la variété Plimbite récoltés l'année précédente à Duclos; le poids moyen des semenceaux est de 150 g.

Une fertilisation de 800 kg/ha d'engrais complet (15-11-22) est apportée 36 jours après plantation.

Le précédent cultural de la parcelle était du *Vigna sinensis*. Toutes les opérations de labour, billonnage, fertilisation, désherbage, traitements fongicides, arrosage, et récolte, sont effectuées manuellement.

Réalisation des inoculations contrôlées

L'agent pathogène (*Colletotrichum gloeosporioides*) est cultivé sur fragment de papier filtre stérile en laboratoire pendant 30 jours. La « souche » utilisée est en fait un mélange de 5 souches agressives originaires du site expérimental de l'INRA à Duclos.

L'agent pathogène est apporté manuellement au champ, à raison de dix fragments d'inoculum par bac. L'inoculum, placé sur papier filtre, est mis sur des tiges plastiques au-dessus du couvert d'igname. Un apport d'eau par brumisation est effectué dès l'inoculation de façon à favoriser le développement du champignon. Cette brumisation commence le jour de l'inoculation à raison d'une minute toutes les heures de 6 h 00 à 20 h 00, ceci en continu pendant 15 jours.

Trois inoculations sont effectuées au cours de l'expérience, soit une par mois et par série de 4 bacs. La première est faite 76 jours après plantation dans la première série de bacs sur des plants très jeunes et aux tissus « tendres »; la deuxième est faite 106 jours après la plantation dans la deuxième série, et la troisième à 136 jours dans la troisième série de bacs.

Dès la première inoculation, une protection au BENKO+ (chlorothalonil + carbendazine) est effectuée sur toutes les autres parcelles. Elle est répétée tous les 15 jours, afin d'éviter des attaques par une dissémination anémophile des spores de Colletotrichum. Ce traitement fongicide est arrêté, sur les bacs qui vont être inoculés, 15 jours avant cette inoculation.

La quatrième série de bacs n'est pas inoculée et sert donc de témoin ; sur ces parcelles les traitements fongicides ne se terminent qu'à la récolte.

Caractérisation du développement de la plante saine à chaque date d'inoculation et à la récolte

g/plante	76 JAP	106 JAP	136 JAP	Récolte
Poids sec aérien	82.6	76.5	92.8	188.0
Poids frais sout	38.3	95.0	263.7	1016.9
Poids sec sout.	7.9	17.6	54.6	251.5

Caractérisation de l'évolution de l'anthracnose

Tous les 15 jours, une notation des symptômes est effectuée, sur 15 feuilles par parcelle élémentaire, selon l'échelle de symptôme suivante:

0 = feuille saine
1 = quelques petites taches
2 = nombreuses petites taches ou 1-3 grandes taches
3 = 4 grandes taches ou plus
4 = feuille presque ou complètement nécrosée.

Evaluation de la nuisibilité

Elle est effectuée, à la récolte, par l'évaluation du rendement en tubercules de chaque ligne dans chaque bac, ainsi que par l'estimation des composantes de ce rendement : nombre de plantes, nombre de tubercules par plante, poids moyen des tubercules. Cette récolte est effectuée 187 jours, soit 6 mois environ, après plantation.

Traitement statistique des données

Le dispositif est considéré comme un split-plot, avec les différentes dates d'inoculation (date) comme grandes parcelles, et avec 4 parcelles par date de traitement et 3 lignes par parcelle. Les effets « ligne » ne sont jamais significatifs.

RESULTATS

Evolution des attaques d'anthracnose selon la date d'inoculation

La figure 1 ci-dessous montre l'évolution de la moyenne des notes (et de l'écart ± 2 fois l'erreur-type) pour les parcelles successivement inoculées (1 puis 2 puis 3) ou non inoculée et maintenue sans anthracnose (parcelle 4).

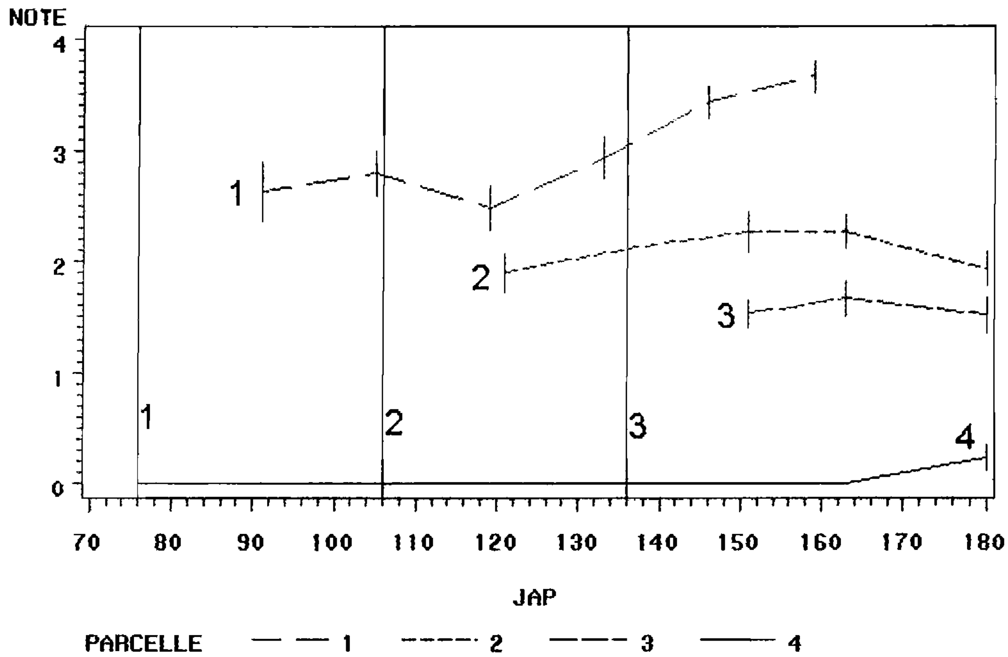


Figure 1. Evolution de la moyenne des notes de symptôme d'anthracnose selon les dates d'inoculation contrôlée. JAP : jour après plantation.

Suite à l'inoculation effectuée 76 jours après plantation, l'intensité de la maladie a été très forte comme en témoignent les notations d'attaque foliaire dont les indices sont proches de 3 dès 90 jours après plantation, et proches du maximum (valeur de 4) à 160 jours après plantation. L'incidence de cette forte intensité de l'anthracnose sur l'appareil aérien de l'igname s'est évidemment traduite par la destruction d'importantes quantités d'organes actifs (tiges et feuilles). Les dégâts sont donc très importants lorsque la plante est constituée majoritairement de tissus très jeunes et en pleine croissance.

Pour l'inoculation effectuée 106 jours après plantation, l'intensité de la maladie est demeurée relativement moyenne avec des indices d'attaque voisins de 2. Les dommages causés au feuillage sont donc bien moindres que dans le cas précédent.

L'intensité des attaques d'anthracnose est restée relativement faible pour la dernière inoculation faite 136 jours après plantation; de ce fait les dégâts sur le feuillage sont réduits.

Les parcelles témoins n'ont pratiquement pas subi d'attaques. Cela montre que les traitements fongicides peuvent encore contrôler la maladie, tout au moins avec les substances actives utilisées à fortes doses et fréquences.

Rendement en tubercules

Bien que les parcelles soient de petite taille il est possible, pour avoir un ordre de grandeur agronomique, de calculer le rendement en tubercules frais, en tonne par hectare.

POIDS FRAIS (tonne/ha)	DATES D'INOCULATION			
	1	2	3	4 (Témoin)
Moyenne	6.4	20.1	27.2	27.9
Test Dunnett / '4'	***	***	NS	

L'humidité pondérale des tubercules n'est pas significativement différente entre traitements ; sa valeur moyenne est de 75.3 %.

Il apparaît que ce rendement varie de façon très importante, d'environ un facteur 4, et qu'il est extrêmement réduit suite à l'inoculation précoce. L'inoculation tardive conduit à un rendement comparable à celui du témoin.

Ce rendement global est en fait la résultante de différentes composantes qu'il est intéressant d'analyser :

rendement par hectare =
nombre de plantes par hectare
x nombre de tubercules par plante
x poids moyen des tubercules

Nombre de plantes par hectare

NOMBRE DE PLANTES	DATES D'INOCULATION			
	1	2	3	4 (Témoin)
Moyenne	20 600	27 800	27 500	27 500
Test Dunnett / '4'	***	NS	NS	

Ces données sont obtenues à la date de récolte finale. La densité de plantes est légèrement inférieure suite à l'inoculation précoce: il y a donc eu mort de certaines plantes. Pour les autres dates d'inoculation la densité de plantes est peu variable et proche de la valeur maximale 30 000.

Nombre de tubercules par plante

NOMBRE (tubercules/plante)	DATES D'INOCULATION			
	1	2	3	4 (Témoin)
Moyenne	1.10	1.25	1.28	1.33
Test Dunnett / '4'	***	NS	NS	

L'effet "date d'inoculation" est significatif sur le nombre de tubercules par plante, mais c'est seulement l'inoculation précoce qui conduit à un nombre de tubercules inférieur: à ce stade les tubercules ne sont donc pas encore (tous) initiés.

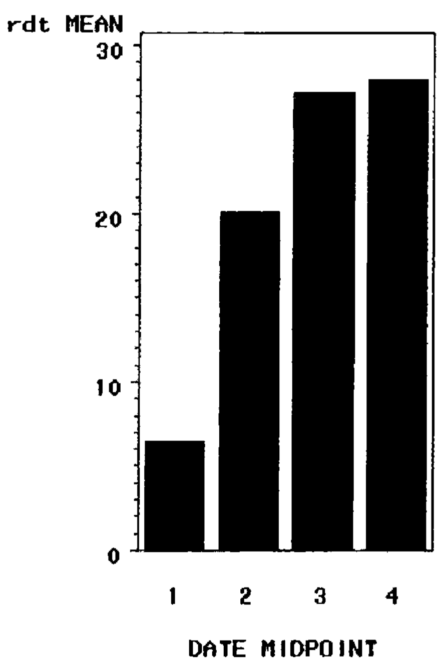
Poids moyen des tubercules

POIDS (kg)	DATES D'INOCULATION			
	1	2	3	4 (Témoin)
Moyenne	0.273	0.576	0.788	0.762
Test Dunnett / '4'	***	***	NS	

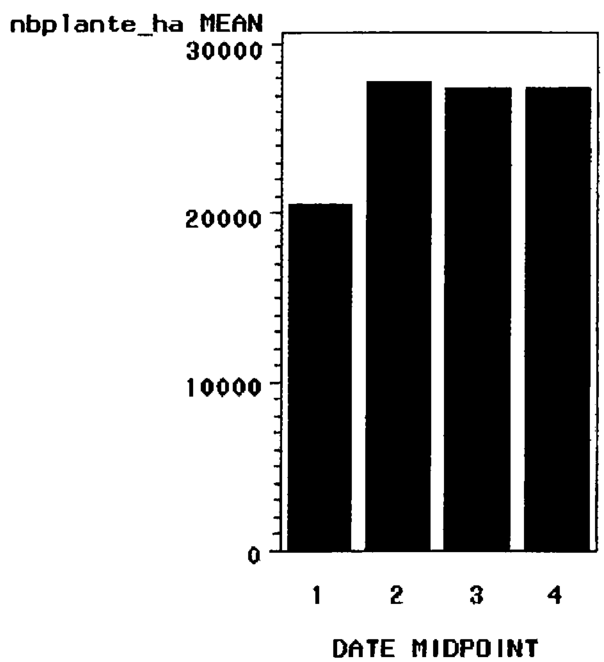
Le poids frais moyen par tubercule est très faible pour l'inoculation précoce, plus du double pour la deuxième date d'inoculation; la dernière date d'inoculation n'a pas d'effet sur le poids moyen des tubercules.

Les grandes différences de rendement créées par les dates successives d'inoculation sont donc essentiellement dues aux différences de poids moyen des tubercules. Seule l'inoculation très précoce réduit aussi le nombre de plantes arrivant à récolte et un peu le nombre de tubercules par plante.

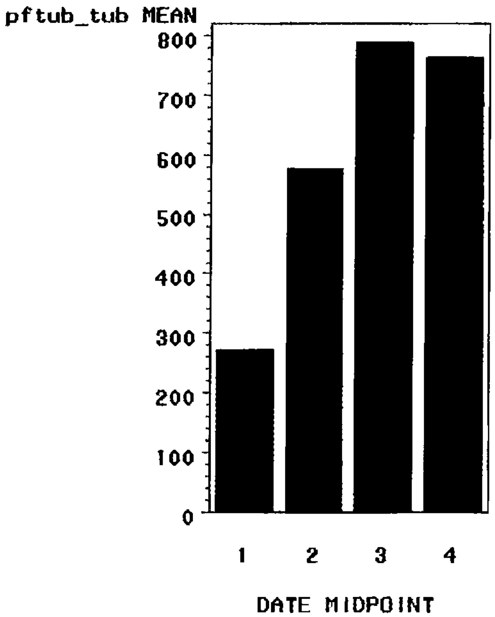
La figure 2 visualise les effets des différentes composantes du rendement sur le rendement final, selon les différentes dates d'inoculation.



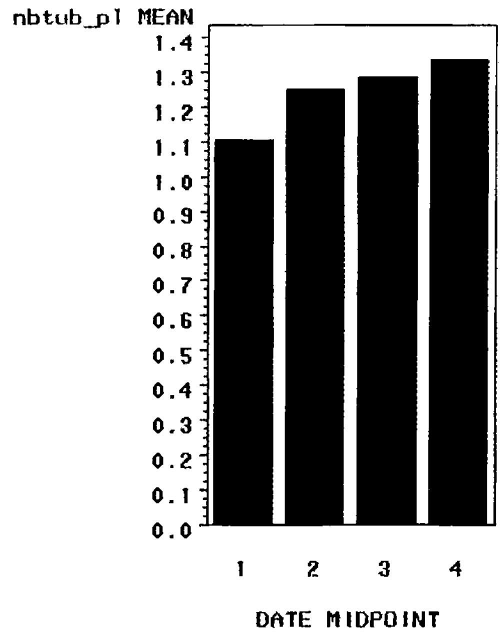
Rendement en tubercules (T ha^{-1})



Densité de plantes à l'hectare



Poids moyen des tubercules (g)



Nombre de tubercules par plante

CONCLUSION

Les attaques précoces d'anthracnose, c'est-à-dire celles qui interviennent, sur le génotype PLIMBITE, moins de 4 mois après plantation, réduisent considérablement la production de tubercules.

Dans les conditions naturelles ces attaques peuvent être fréquentes car les plantations ont traditionnellement lieu, en Guadeloupe, vers le mois de mai, et les conditions de forte pluviométrie, favorables au développement de l'anthracnose, se situent classiquement en août-septembre.

Une nouvelle manière de produire pourrait être d'effectuer des plantations très précoces (de début d'année). Mais ce type de plantation est difficile à réaliser car il nécessite l'utilisation de vitro-plants (les plants issus de tubercule étant trop dormants pour une telle plantation), ainsi qu'une bonne maîtrise de l'irrigation, pour pallier les déficits hydriques courants en période de « carême ». Cela suppose aussi d'utiliser des génotypes dont la tubérisation puisse se faire correctement en jours longs; cette sensibilité photopériodique éventuelle est pour l'instant peu connue.

La recherche de génotypes résistants à l'anthracnose, et la compréhension de la génétique de la résistance à l'anthracnose, et de son maintien, sont donc les moyens les plus sûrs pour assurer une production d'igname satisfaisante aux Antilles.

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A COMMERCIAL NEMATODE FOR MOLE CRICKET CONTROL

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ABSTRACT: This T-STAR project is being conducted in Puerto Rico to determine how to efficiently release, establish, distribute, and evaluate the entomopathogenic nematode, *Steinernema scapterisci*, for *Scapteriscus* spp. mole cricket control. The University of Florida negotiated an agreement with Becker Underwood for commercial production of the nematode that is available as the product, Nematac S. The "mole cricket nematode" has been used effectively to control non-indigenous mole crickets in pastures and turf in Florida since the late 1980s. It parasitizes only *Scapteriscus* spp. in nature and not indigenous mole crickets that are in a different genus, so it is safe to import and release. An effort is being made to quantify the level of mole cricket infection, establishment and rate of dispersal of the nematode, and the level of suppression of mole cricket populations. This project will provide data on efficacy of the product, assist in establishing markets, and eventually help distribute the nematode across the island to maintain invasive mole crickets at low levels.

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A NEW *RALSTONIA SOLANACEARUM* POPULATION AFFECTS ANTHURIUM PLANTATIONS AND CUCURBITACEOUS CROPS IN MARTINIQUE (F.W.I.)

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ABSTRACT: Bacterial wilt of Solanaceaous crops, described in Martinique in the 1960s, was known to be caused mainly by biovar 3 and biovar 1 strains of *Ralstonia solanacearum* (Prior and Steva, 1990). Since 1999, *R. solanacearum* has provoked considerable damage in anthurium fields. These outbreaks are due to new biovar 1 strains, genotypically identical to insect-transmitted "Moko" (bacterial wilt of banana) strains (MLG25, ecotype SFR/A), but not pathogenic (NP) on Banana Cavendish. The number of disease spots has been increasing ever since, spreading to the whole island. The host range of *R. solanacearum* has also widened to *Heliconia caribea*, Cucurbitaceous crops (cantaloupe, cucumber, squash, zucchini), *Canna indica*, and several weeds. Fegan and Prior (2003) distinguished four phylotypes within *R. solanacearum* (I to IV), each subdivided in sequevars. All the isolates collected from 1989 to 2003 were characterized according to this classification. Isolates from Cucurbitaceae, Heliconia, weeds, as well as most of the anthurium isolates were typed in this group of new strains (phylotype II sequevar 4NP), which just appeared in 1998. The isolates from Solanaceae were distributed among new and old strains (phylotypes I and II, biovar 3, and 1, respectively). These results tend to demonstrate the emergence of a new population, with a broad host range and a high dissemination rate, which may overcome the former population. The biological and epidemiological features of these new strains need to be investigated, in order to set up integrated management strategies.

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INCIDENCIA DE INSECTOS PLAGA EN CULTIVO DE RETOÑO EN VARIEDAD DE ARROZ PROSEQUISA 4

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RESUMEN: El cultivo de arroz de retoño ocupa aproximadamente el 85% del área nacional arrocera. Esta realidad favorece la continuidad del ciclo biológico de las plagas, con el riesgo de explosiones poblacionales y pérdidas económicas en las cosechas futuras. Los productores poco conocedores de los insectos que interactúan con el cultivo de arroz, realizan aplicaciones para disminuir las posibilidades de fracaso en la producción. Fue realizado un estudio en Juma, Bonao, República Dominicana, para estudiar la dinámica poblacional de los insectos plaga y benéficos comunes en el sistema de producción de arroz de retoño. Se utilizó una parcela de 2500 m^2 en la cual se cultivó la variedad PROSEQUISA 4, durante la primera cosecha de 2001 y 2002. A final del ciclo los tallos se cortaron a 15 cm de altura. Semanalmente se realizaron monitoreos con 25 pases de jama en diagonal con una red entomológica, dos metros (2) a partir del borde hasta el otro extremo; el muestreo se inició una semana después del brote de los tallos hasta la maduración del cultivo. Las más importantes plagas insectiles identificadas fueron: la sogata (*Tagosodes orizicolus*); el minador (*Hydrellia* sp.); la millonaria (*Collaria* sp.); lorito verde (*Hortensia* sp.) y salta hoja (*Oxyphidium* sp.) éstos tienen mayor incidencia poblacional en la cuarta y quinta semana del ciclo. Los organismos biológicos benéficos más importantes fueron las arañas (*Angiope*, *Tetragnatha*, *Lycosa*), las libélulas (*Agricnemis* sp.), esperancitas (*Conocephalus* sp.), y mariquitas (*Coleomegilla* sp.); su incidencia permitió la regulación de las poblaciones de insectos plaga.

INTRODUCCIÓN

El retoño es la modalidad de cultivo que más se utiliza en la República Dominicana a partir de la introducción de la variedad PROSEQUISA 4 en el 1993. Este método de cultivo fue adoptado por los arroceros debido a que disminuye los costos de producción, comparado con una segunda siembra. No se requiere de preparación de terreno, semillas ni siembra; además, se disminuyen las aplicaciones de fertilizantes y plaguicidas. El retoño de PROSEQUISA 4 puede producir de 80 a 100% de la producción de la flor, dependiendo del manejo y de la época de cultivo.

El retoño hace del cultivo una actividad continua en el año. Esto ofrece un suministro de alimento y albergue para que las plagas realicen su ciclo lo que puede ocasionar explosiones poblacionales detrimentales para la sosteniblidad de la producción. Los arroceros dominicanos dependen, en la mayoría de los casos, de químicos para el control de los insectos. No existe información básica sobre la dinámica poblacional de los insectos plaga, los benéficos y los umbrales económicos para las aplicaciones. La carencia de información hace que el arrocero aplique los insecticidas sin realizar monitoreos previos.

En investigaciones realizadas en América Latina se ha demostrado que, en muchos casos, se evitarían las aplicaciones de plaguicidas si se realizaran los monitoreos previos. Estudios demuestran hasta un 70% de control biológico de *T. oryzicolus* por parasitoides y depredadores.

En Panamá se han registrado hasta 400 larvas de *Spodoptera* sp. por m^2 de arroz, sin efecto negativo en los rendimientos. En otros casos, como *Hydrellia* sp., no se ha podido correlacionar el daño del insecto con la reducción del rendimiento (Pantoja et al., 1997).

El estudio de la dinámica poblacional de cada insecto plaga ofrece la información necesaria para diseñar programas de manejo integrado de plagas. Estos programas se fundamentan en el control racional de las plagas, contribuyendo a hacer más eficiente la producción de arroz en beneficio de los productores, la ecología y la economía nacional.

El objetivo de esta investigación fue determinar el comportamiento poblacional de los insectos plagas y artrópodos benéficos en el cultivo de arroz en retoño.

MATERIALES Y MÉTODOS

Este estudio fue desarrollado en la Estación Experimental Juma, ubicada en la provincia Monseñor Nouel (Bonao), República Dominicana, a 18° 54' latitud Norte y 70° 23' longitud Oeste, y a 178 msnm, temperatura media 26 °C, precipitación media 2200 mm, perteneciente a la zona de vida de bosque muy húmedo subtropical.

En una parcela de 2500 m^2, preparada en húmedo con tractor pequeño, utilizando un diseño no experimental, fue sembrada y retoñada la variedad PROSEQUISA 4, durante el período abril a noviembre de 2001 y 2002. El cultivo principal fue establecido con semillas pre-germinadas sembradas manualmente a 120 kg/ha. La cosecha fue realizada en agosto y los tallos se cortaron a una altura de 15 cm para fines de retoño o rebrote.

Los muestreos de especies plagas y enemigos naturales se realizaron en el cultivo de retoño con una red entomológica pasada 25 veces en la parcela semanalmente durante el período comprendido de agosto a noviembre de ambos años. La primera muestra fue tomada una semana después del corte de los tallos hasta la maduración, iniciando a dos metros del borde del lote y moviéndose en diagonal hasta llegar al extremo opuesto. Las muestras colectadas fueron depositadas en bolsas de polietileno y llevadas al laboratorio, donde se colocaban en horno a 40° C durante una hora para inmovilizar los especímenes y proceder a su identificación y cuantificación, con una lupa estereoscópica y guías ilustradas y consultas a expertos.

El manejo agronómico del cultivo principal se hizo bajo las recomendaciones de la estación experimental. Para el cultivo de retoño la primera fertilización se realizó 10 días después del chapeo con una dosis de 58-30-30 N-P-K kg/ha. La segunda aplicación se realizó 20 días después de la primera a una dosis de 38 kg/ha de N, y la tercera se realizó al inicio de la formación de la panícula a una dosis de 24 kg/ha de N. Las malezas se controlaron de forma manual. No se realizaron aplicaciones de plaguicidas para el manejo de insectos, ácaros y enfermedades. La cosecha se realizó de forma manual. El rendimiento se expresó en kg/ha ajustado al 14% de humedad.

RESULTADOS Y DISCUSIÓN

Los insectos plaga que se identificaron en el retoño pertenecen a los órdenes Homoptera, Hemiptera, Diptera, Orthoptera, Lepidoptera y Coleoptera (Tabla 1). Es una fauna común en los cultivos de arroz bajo riego en países de América Latina y el Caribe (Meneses et al., 2001)

En las condiciones ambientales en que se desarrolló esta investigación los insectos plaga de mayor incidencia identificados en la modalidad de cultivo de retoño fueron *T. orizicolus* (sogata) y *Hydrellia* sp. (minador). La mayor población de *T. orizicolus* se presentó durante la cuarta semana después de iniciado el ciclo de retoño, mientras que la *Hydrellia* presentó su mayor población en la segunda semana, y no se observaron picos poblacionales importantes para la temporada del 2001 (Figura 1).

Durante el 2001, *Hortensia*, *Oxyphidium*, *Conocephalus*, *Collaria*, *Oebalus* y *Panoquina* fueron los insectos de menor importancia en término poblacional, por lo cual pueden considerarse como secundarios en la producción de arroz de retoño.

Para el 2002, *T. orizicolus*, *Hydrellia* sp., *Oxyphidium* sp. y *Conocephalus* sp., representaron los insectos poblacionalmente más importantes, aunque respecto al 2001 los registros poblacionales resultaron inferiores. *T. oryzicolus* mostró sus más altos picos poblacionales en la primera y octava semana de monitoreo, contrario a lo sucedido en el 2001. El primer pico poblacional podría atribuirse al inicio del proceso de colonización sin la intervención de los factores de resistencia ambiental y, el segundo a una disminución de los factores de riesgo de mortalidad en la población, con el subsiguiente incremento de la tasa de multiplicación.

Oxyphidium sp. y *Conocephalus* sp., fueron insectos irrelevantes durante el 2001, de acuerdo a su población; sin embargo, en la temporada del 2002 emergieron como parte del grupo de especies colectadas que dominaron la composición y el tamaño de la población (Figura 2).

Collaria, *Hortensia*, *Oebalus* y *Panoquina* fueron los insectos colectados con menor población en el 2002, registrando *Collaria* sp. la mayor población de éstos.

La mayor población de los insectos *T. orizicolus* ocurrió en la cuarta semana después de iniciado el monitoreo de 2001 (Figura 3), mientras que la población de arañas fue menor. Sin embargo, en el año siguiente la población de arañas exhibió una tendencia a ser mayor sin que ocurriera una explosión poblacional del insecto plaga. Esto se podría explicar dado que en los cultivos de arroz en Colombia, sin aplicación de plaguicidas, el control biológico realizado por parasitoides y depredadores ha registrado una eficacia de hasta 70% (Pantoja et al., 1997). En este mismo estudio sobre *T. orizicolus*, transmisor del virus de la hoja blanca, recomiendan para su control químico descontar tres insectos por cada araña observada en la población durante un muestreo (Pantoja et al., 1997).

La población mayor de sogata se registró en la cuarta semana de evaluación en el 2001 con 130 individuos (Figura 3). Meneses et al. (2001), en estudios realizados sobre umbrales de este insecto en Colombia, recomienda realizar aplicación de insecticida cuando se colectan 200 insectos en 10 pases dobles con una red entomológica.

Los organismos benéficos identificados pertenecían a los órdenes Coleoptera, Orthoptera, Odonata y Araneae (Tabla 1). La mayor incidencia de arañas se presentó de la primera hasta la octava semana después del corte de los tallos, que fue el período de mayor incidencia de insectos plaga (Figura 4).

Es importante señalar que los *Conocephalus* sp. tienen dualidad alimenticia, comportándose como plaga, causando daños en el follaje y la panícula del arroz, o como benéfico, depredando a chinches y huevos de barrenadores, dependiendo de las condiciones que se presenten a medida que se desarrolla el ciclo del cultivo.

Según las cuantificaciones semanales durante el ciclo de retoño, los insectos con mayor riesgo de ocurrencia de altos picos poblacionales fueron *T. orizicolus*, *Hydrellia* sp., y *Oxyphidium* sp. La más alta población de *Tagososdes*, *Hydrellia*, *Oxyphidium* y arañas ocurrió cuando se registró la más baja pluviosidad, durante las primeras seis semanas después de cortar los tallos de arroz para el retoño.

Todas las especies de artrópodo descendieron bruscamente con el aumento de las lluvias a partir de la sexta semana de evaluación. Durante 2002, la pluviometría semanal registrada influyó en las poblaciones de los artrópodos de mayor incidencia, tales como *Tagososdes, Hydrellia, Oxyphidium* y las arañas.

El rendimiento del cultivo de retoño fue de 5,140 kg/ha para el 2001 y 3,067 kg/ha para el siguiente año. La merma en el rendimiento del 2002 pudo deberse al ataque de ratas, y no a la población de insectos plaga, que fueron menor que el año anterior.

CONCLUSIONES

1. Los insectos plaga identificados en el cultivo de retoño fueron: *Tagosodes orizicolus, Hidrellia* sp., *Hortensia similis, Collaria olerisa, Oxyphidium* sp., *Lissorhoptrus* sp., *Panoquina nictelia, Spodoptera frugiperda, Tibraca limbativentris* y *Oebalus* sp.
2. Los insectos plaga más importantes en el cultivo de retoño de PROSEQUISA 4 fueron *T orizicolus* e *Hydrellia* sp., con su mayor incidencia poblacional en las primeras semanas después del corte de los tallos.
3. *T. orizicolus* registró su mayor incidencia poblacional durante la primera y octava semanas después del corte de los tallos, aunque su presencia se observó durante todo el ciclo del retoño.
4. La edad del cultivo se relacionó con la dinámica de los artrópodos que se presentaron durante el ciclo de retoño.
5. El período de mayor incidencia de insectos plaga se presentó entre la primera y octava semanas después del corte de los tallos.
6. La lluvia caída durante el proceso de monitoreo influyó negativamente sobre la dinámica de los insectos plagas y las arañas, cuantificándose su mayor incidencia en los períodos de baja pluviosidad y viceversa.
7. La temperatura y la humedad relativa se mantuvieron relativamente constantes, sin que afectaran el ciclo biológico de los especímenes colectados.
8. Los enemigos naturales registrados en los monitoreos fueron *Coleomegilla* sp, *Hippodamia convergen, Micraspis* sp., *Agriocnemis* sp., *Conocephalus* sp., *Angiope* sp., *Tetragnatha* sp. y *Lycosa* sp.
9. De acuerdo a la especie de insecto plaga, el período de mayor riesgo para la ocurrencia de explosiones poblacionales se produjo en los primeros sesenta días después de iniciado el retoño.

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Tabla 1. Plagas insectiles detectadas en los monitoreos de la parcela.

Nombre científico	Orden	Familia
Tagosodes orizicolus	Homoptera	Delphacidae
Collaria sp.	Hemiptera	Miridae
Hortensia similis	Homoptera	Cy cadellidae
Hydrellia sp.	Diptera	Ephydridae
Oxyphdium sp.	Orthoptera	Tettigonidae
Oebalus sp.	Hemiptera	Pentatomidae
Tibraca sp.	Hemiptera	Pentatomidae
Panoquina sp.	Lepidoptera	Hesperiidae
Spodoptera sp.	Lepidoptera	Noctuidae
Lissorhotrus sp.	Coleoptera	Curculionidae
Conocephalus sp.	Orthoptera	Tettigonidae

Tabla 2. Enemigos naturales identificados en cultivo de retoño, Juma. 2001-2002.

Nombre científico	Orden	Familia
Coleomegilla sp.	Coleoptera:	Crisomelidae,
Hippodamia sp.	Coleoptera:	Coccinellidae
Micraspis sp.	Coleoptera:	Coccinelidae
Agriocnemis sp.	Odonata	Coenagrionidae
Conocephalus sp.	Orthoptera	Tettigoniidae
Angiope sp.	Araneae	Araneidae
Tetragnatha sp.	Araneae	Tetragnathidae
Lycosa sp.	Araneae	Lycosidae

Tabla 3. Período de ocurrencia de altas poblaciones de plagas en retoño.*

Insectos plaga	Período en días después del rebrote
T. orizicolus	21 – 35**
Hydrellia sp.	7 - 35
Oxyphidium sp.	21 – 56

*Valores para 2001 y 2002

**En el 2002 presentó dos picos poblacionales en la primera y octava semanas.

Figura 1. Insectos plaga de mayor incidencia en el cultivo de retoño, Juma, 2001.

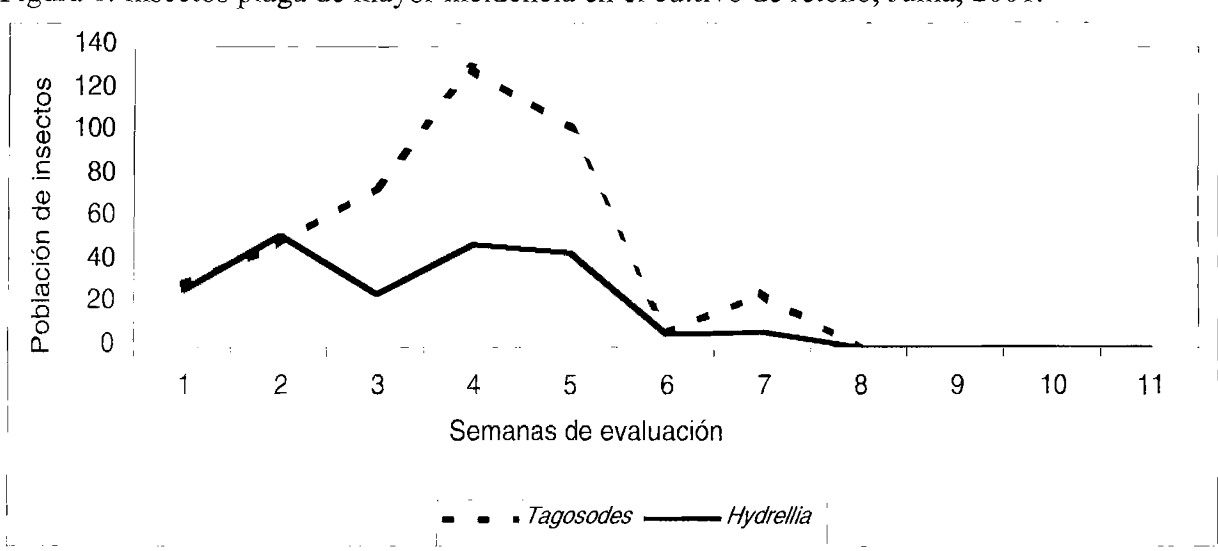


Figura 2. Insectos plaga de mayor incidencia en el cultivo de retoño, Juma, 2002.

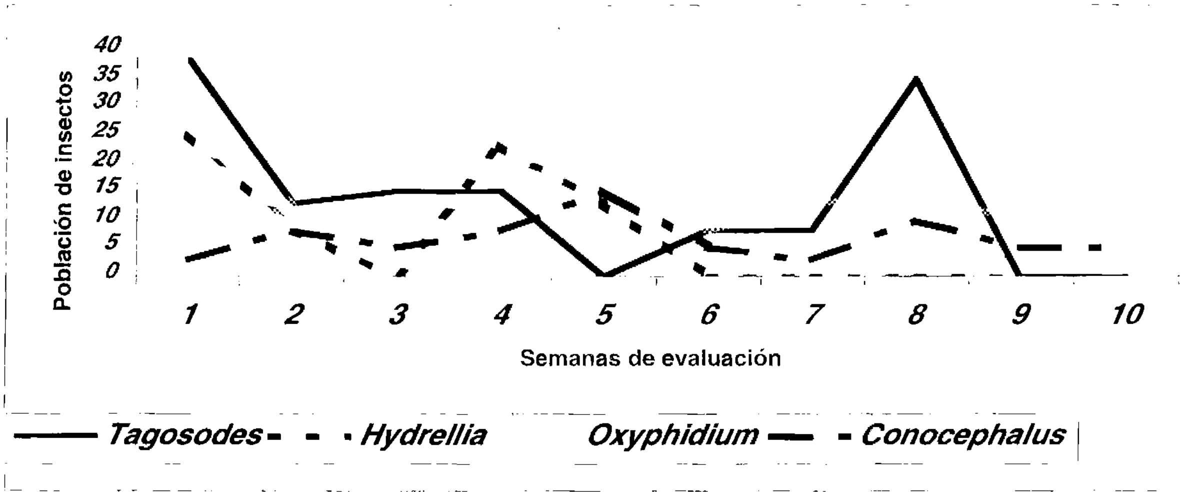


Figura 3. Fluctuación de insectos plaga de mayor incidencia y arañas en retoño en 2001.

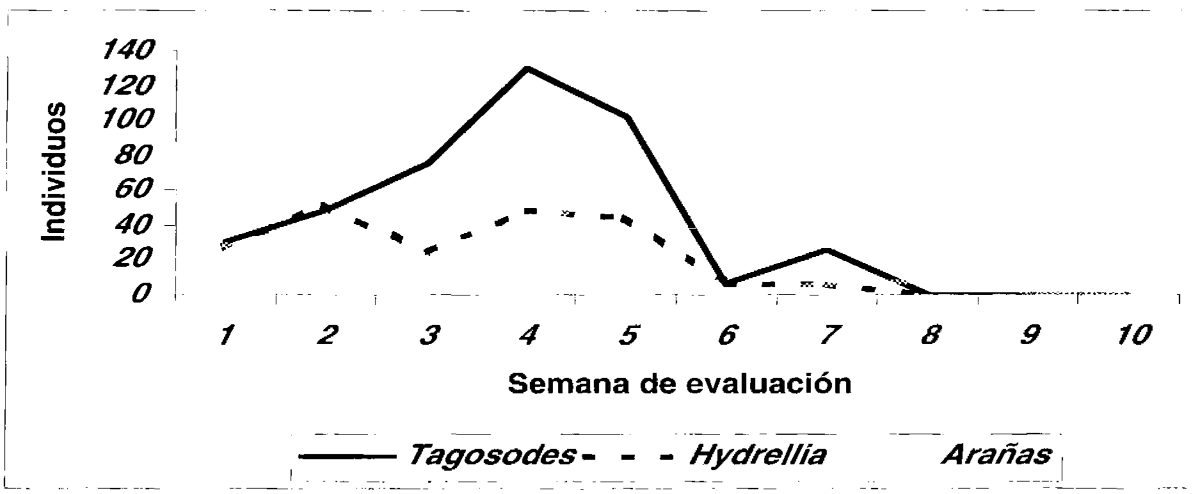
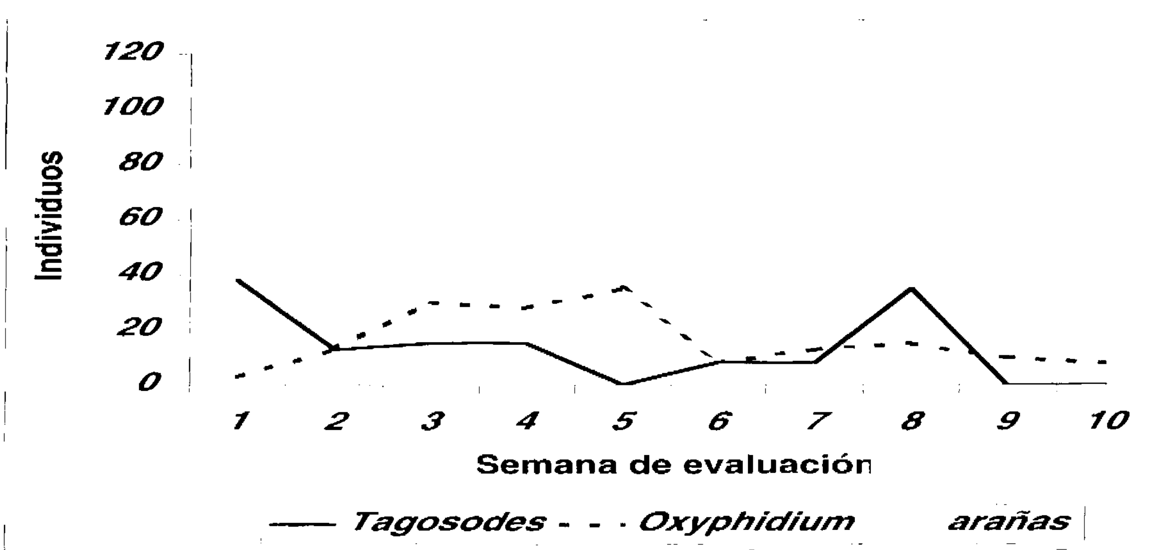


Figura 4. Fluctuaciones de insectos de mayor incidencia y arañas en retoño en 2002.



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MEASURING THE EFFICACY OF THE BIOLOGICAL CONTROL PROGRAM FOR SUGARCANE MOTH BORER *DIATRAEA SACCHARALIS* (F.) IN BARBADOS: JOINT INFESTATION SURVEYS FOR THE PERIOD 1999–2002

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ABSTRACT: This paper reviews the biological control program for the sugarcane mothborer *Diatraea saccharalis* (F.) in Barbados over the period 1999-2002. The data for this period were analyzed, fitting infestation level to variety, crop, rainfall zone, and year, assuming a logistic regression model with a Poisson distribution of all main effects (variety, crop, rainfall zone, and year). The results showed that all first order interactions were highly significant ($p<0.001$) and that the overall joint infestation levels remained below the Economic Threshold Level (ETL) of 5% joints bored. This finding suggests that the pest is continuing to be effectively controlled by its two parasitoids *Cotesia flavipes* and *Lixophaga diatraeae*.

INTRODUCTION

The sugarcane moth borer, *Diatraea saccharalis* (F.) (Lepidoptera: Pyralidae: Crambinae), is the major pest of sugarcane in Barbados. Gibbs (1995) also listed the types of damage this pest causes to sugarcane plants and the resultant losses in cane quality, amount of extracted juice, percentage sucrose, and purity of the juice. Borer injury can also cause the color of the clarified juices and syrups to darken and their turbidity to increase. Secondary infection by fungi such as *Glomerella tucumanensis* (Speg.) Arx and Muller, which causes red rot disease, can occur through the holes bored into the stalks and can lead to the inversion of sucrose to glucose. It is generally considered that bored cane does not keep as well as the sound cane after it is cut for milling.

Losses caused by the moth borer, therefore, may be divided into field loss and factory loss. Each percentage point of joints bored is considered to lead to a 0.5% loss of sugar yield (Cock 1985 citing Metcalfe, 1969).

Moth borer control by pesticide is not a feasible method in Barbados and biological control is considered to be the best and safest control strategy for this pest. Gibbs (1995) reported on the history of the biological control programme for sugarcane moth borer on the island. Prior to 1966, Diatraea saccharalis infestation in Barbados had averaged up to 15.5% joints bored (Alam, 1980).

The Caribbean Agricultural Research and Development Institute (CARDI) started rearing in the laboratory the moth borer's major parasitoid *Cotesia flavipes* (Cam.) (Hymenoptera: Braconidae) in 1994 and releasing it throughout the island, particularly in areas/varieties that had infestation levels greater than the accepted Economic Threshold Level (ETL) of 5% joints bored.

The efficacy of this program is monitored by conducting an annual joint infestation survey at harvest time.

MATERIALS AND METHODS

The annual joint infestation survey was conducted only on sugarcane that would be cut by machine harvesters. Three-stalk samples were taken every 20 stools from the uncut cane next to the open (harvested) side of each field. Sampling was conducted every 10 rows in order to cover a wide area and a total of 100 stalks per field were checked.

The percentage joint infestation was determined as the proportion of joints bored expressed as a percentage of the total joints in the 100 stalks. The field name, sugar cane variety, date of sampling, plantation name, crop (plant cane or ratoon), acreage and rainfall zone were recorded for each sample. Approximately 5% of the total sugarcane acreage is sampled during each annual joint infestation survey.

RESULTS AND DISCUSSION

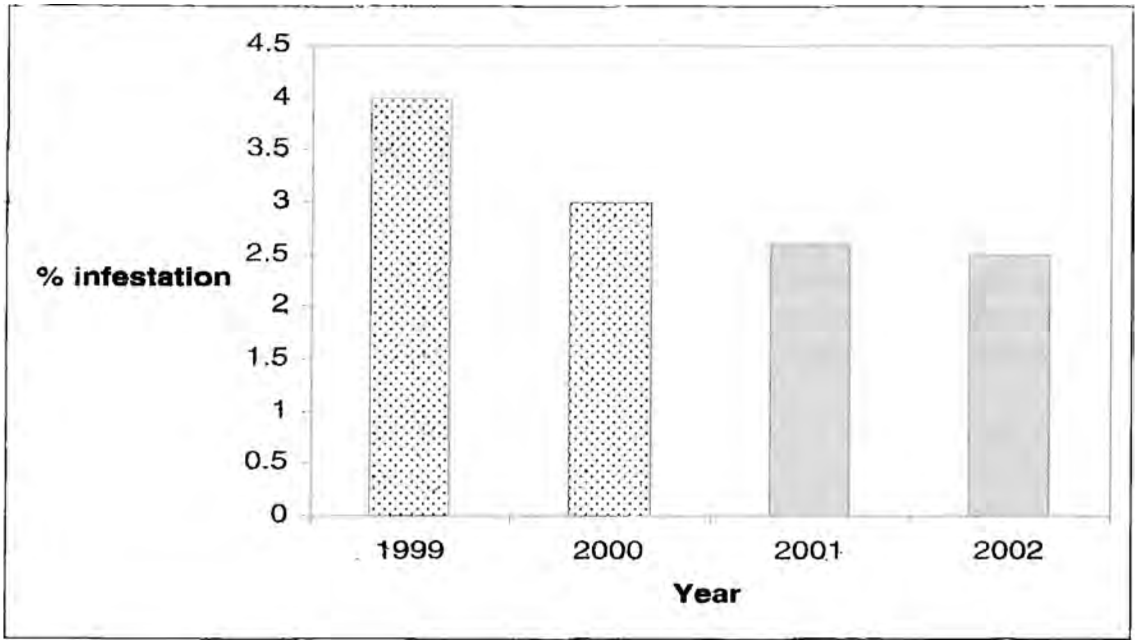
The crop area occupied by the six major sugarcane varieties grown during the period 1999-2002, compiled by the Agronomy Research & Variety Testing Unit (ARVTU) Barbados Agricultural Management Company Ltd. is presented in Table 1.

Table 1. Percentage of the total crop acreage occupied by the six major varieties grown in 1999-2002.

Variety	Percentage of the total crop acreage for the year			
	1999	2000	2001	2002
B62163	9.09	7.37	3.51	1.90
B74541	12.69	10.91	11.22	10.30
B77602	22.02	21.61	24.19	21.28
B80251	7.68	8.73	8.86	7.37
B80689	10.31	9.30	12.04	11.90
B82238	16.20	17.85	20.04	23.06

The average yearly percentage joint infestation by sugarcane mothborer for all varieties over the island during the period 1999 –2002 is shown in Figure 1 (Paulraj, 2002).

Figure 1. Sugarcane moth borer percentage joint infestation for 1999-2002.



An Analysis of Variance (ANOVA) was performed on the data for this period (1999-2002), fitting infestation level to variety, crop, rainfall zone and year, assuming a logistic regression model with a Poisson distribution of all main effects (variety, crop, rainfall zone and year). The results showed that all first order interactions were highly significant ($p<0.001$). The mean percentage joint infestation levels in the various crop stages of the major varieties during the same period are presented in Table 2.

Table 2. Mean percentage joint infestation levels for 1999-2002 in the different crop stages of the six major sugarcane varieties.

Variety	Percentage joint infestation in crop stage				
	Plant cane	1st ratoon	2nd ratoon	3rd ratoon	4th ratoon
B62163	2.32 (5)*	2.77 (7)	1.92 (11)	1.93 (6)	1.22 (7)
B74541	2.99 (12)	1.78 (13)	1.56 (12)	2.27 (8)	1.22 (6)
B77602	3.67 (35)	1.39 (29)	0.88 (16)	1.38 (21)	1.19 (4)
B80251	4.61 (8)	2.61 (3)	1.79 (10)	1.43 (10)	1.71 (3)
B80689	8.14 (20)	3.58 (13)	2.91 (14)	1.79 (8)	4.44 (3)
B82238	4.81 (24)	2.33 (26)	2.86 (25)	2.44 (14)	1.73 (4)

*Values in parentheses are the numbers of observations

The joint infestation levels for the six major varieties for high, intermediate and low rainfall zones during the 1999-2002 period are given in Table 3.

Table 3. Percentage joint infestation of sugarcane moth borer in the major varieties grown in the three rainfall zones for the years 1999-2002.

Variety	Percentage joint infestation in rainfall zones		
	High	Intermediate	Low
B62163	1.95 (31)*	1.65 (5)	3.93 (1)
B74541	2.00 (14)	1.98 (35)	2.74 (5)
B77602	1.96 (41)	1.73 (37)	2.71 (29)
B80251	2.22 (28)	1.93 (3)	4.66 (3)
B80689	4.84 (33)	6.03 (16)	5.28 (10)
B82238	3.11 (46)	3.03 (33)	2.89 (25)

*Values in parentheses are the numbers of observations

Table 4 presents the data collected showing the joint infestation levels in the five crop stages of the six major commercial varieties with respect to rainfall zone.

Table 4. Sugarcane mothborer joint infestation levels in the crop stages of the six commercial varieties, according to rainfall zone.

Crop stages	Percentage joint infestation in rainfall zones		
	High	Intermediate	Low
Plant cane	4.8 (53)*	4.1 (39)	5.5 (23)
1st ratoon	2.26 (40)	1.8 (32)	2.6 (19)
2nd ratoon	1.85 (46)	2.02 (21)	1.5 (21)
3rd ratoon	2.14 (37)	1.98 (21)	2.8 (9)
4th ratoon	1.35 (14)	2.17 (12)	1.8 (1)

*Values in parentheses are the numbers of observations

The six major varieties account for 75.8% of the sugarcane planted in Barbados (Table 1). It is thought that these varieties fairly represent the overall situation with respect to mothborer infestation in the entire sugarcane crop grown each year of the period under review. The levels of joint infestation, determined by each annual survey, can be seen in Figure 1. These levels are consistently below the Economic Threshold Level (ETL) of 5% joints bored and suggest that the biological control program is working successfully.

Moth borer damage is usually higher in plant cane than in subsequent ratoon crops (Table 2). Gibbs (1996) reported on similar findings for the period 1984-1991 and again for 1996. This phenomenon is probably due to a lack of adequate parasitoid numbers in the plant cane, and also plant cane is in the field for a period of eighteen months before it is harvested. Infestation levels decreased with crop ratoon age and were thought to be a result of increasing parasitoid populations and parasitism rates.

In relation to the rainfall zones, percentage infestation of the six varieties was generally higher in the low rainfall zone (Table 3). This was probably due to decreased mortality of moth borer larvae, particularly in the neonatal larval stage before they bore into the stalk. These larvae can be easily washed off the plants by rainfall in the higher rainfall zones and be subjected to predation by ants and predatory beetles on the ground. Data in Table 4 showed again that infestation levels in plant cane are generally higher than in ratoons, irrespective of rainfall zone.

A total of 26,380 *C. flavipes* wasps were reared in the laboratory and released across the island during the reviewed period. These parasitoids were mainly released in areas/varieties identified by the annual infestation survey as having infestation levels greater than the accepted ETL of 5% joints bored. This distribution was an effort to suppress borer infestation and to build up sufficient parasitoid numbers in these 'hot spots'.

Table 5 shows the amounts of sugar and money saved in the years 1999 to 2002 as a result of the biological control program of the two larval parasitoids *Cotesia flavipes* and *Lixophaga diatraeae.*

Table 5. Sugar production and the amount of sugar and money saved through the action of the two larval parasitoids *C. flavipes* and *L. diatraeae* in Barbados during the period 1999-2002.

Year	Acreage	% Joint Infestation	Amount sugar produced (t)	Sugar price received (Bds$/t)	Amount sugar saved (t)*	Amount Bds$ saved**
1999	21,281	3.6	52,317	1,132	3,139	3,553,348
2000	21,541	2.6	58,373	992	3,736	3,706,112
2001	20,834	2.6	49,796	964	3,237	3,120,468
2002	19,648	2.5	44,819	925	2,913	2,694,525
Mean	20,826	2.8	51,326	1003	3,233	3,242,699

*Based on the Joint Infestation level of 15.5% prior to the use of the two parasitoids *C. flavipes* and *L. diatraeae* and the reduction of 0.5% sugar yield for every 1.0% joint infestation.
**Based on the price received for exported raw sugar.

The data in Table 5 assume that the joint infestation level would have remained at the parasitoid pre-introduction average of 15.5% and that this level would have not been adversely affected by the change in varieties grown since that period. Using these assumptions, the average amount of sugar saved per year for the four-year period would be 3,233 t, which represents an average of Bds$ 3.2 million saved per year as a result of the biological control program.

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EFECTIVIDAD DE LA TRAMPA BROCAP® MÁS APLICACIÓN DE PRÁCTICAS CULTURALES EN EL MANEJO DE LA BROCA (*HYPOTHENEMUS HAMPEI* FERR)

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RESUMEN: Durante el periodo abril 2002 a enero 2003, en Gajo del Toro, municipio de Paraíso en la provincia Barahona, se evaluó la efectividad de las combinaciones trampa Brocap más una de tres prácticas culturales recomendadas para el manejo de la broca del café (*Hypothenemus hampei* Ferr). El estudio se realizó en una finca de café orgánico con predominancia de variedad Typica. Se determinó cantidad de brocas capturadas, porcentaje de infestación en la planta, porcentaje de café brocado por kilogramo de café pergamino, costos de aplicación de cada combinación y participación de daños por broca severa en la cantidad de defectos estándares en café oro. La combinación BROCAP® más repela y BROCAP® más pepena resultaron las más efectivas en la reducción del número de frutos perforados y de individuos dentro de los frutos al final de la cosecha. La mayor captura de broca se obtuvo en la combinación BROCAP® más graniteo, seguida por BROCAP® más pepena; mientras en la combinación BROCAP® más repela se capturo la menor cantidad de brocas. El café pergamino brocado por kilogramo fue menor en BROCAP® más repela con 10.11%, seguida de BROCAP® más pepena con 20.44% y BROCAP® más graniteo y el testigo con 40.37% y 40.25% respectivamente. En las tres combinaciones se redujo la participación por daños severos de broca en la cantidad de defectos estándar. BROCAP® más repela fue la combinación de menor costo con 6 jornales por ha, seguida por BROCAP® más pepena con 13 y BROCAP® más graniteo con 16 jornales por ha.

INTRODUCCIÓN

La producción de café orgánico se ha convertido en una opción para colocar el producto final en mercados más seguros y a mejores precios, pero con exigencias de estándares de calidad e inocuidad bastante rigurosa. El manejo de la broca del café es uno de los puntos más importantes y para la producción de este tipo de café, este insecto debe manejarse solo con la aplicación de las prácticas de control manual, físico y/o aplicación de control biológico.

Las prácticas de control manual utilizadas fuera de la cosecha han demostrado ser efectivas para el manejo de la plaga, sin embargo, las informaciones sobre sus costos son escasas. La mayoría de los investigadores están claro en la efectividad de la repela o repase, pero no en términos de los costos de esta práctica (Baker, 1999). Mejía et al. (1998) evaluaron el efecto de la traviesa o recolección de los frutos correspondientes a lo que sería el graniteo, y concluyeron, que la eliminación de los primeros frutos no disminuye los niveles de broca, ni mejora la calidad del café pergamino seco, afectando considerablemente los ingresos del productor.

La trampa BOCAP® desarrollada por el CIRAD de Francia y PROCAFE de El Salvador (Dufour y González, 1999) ha demostrado ser efectiva para la captura de brocas en el periodo intercosecha y ha sido validada por Dufour (2000) en Centroamérica y Pérez et al. (2001) y actualmente se promueve su utilización con la aplicación conjunta de las prácticas manuales de control.

Con el presente trabajo se pretende evaluar la efectividad de las combinaciones trampa BROCAP® más una de las tres prácticas de control manual recomendadas para el manejo de la broca tratando de buscar alternativas para el manejo de esta plaga que sean efectivas y sostenibles económicamente.

MATERIALES Y MÉTODOS

Esta investigación se realizó en una finca donde predomina la variedad de café Typica en Gajo del Toro, distrito municipal de Paraíso, provincia de Barahona durante el periodo abril 2002 hasta enero del 2003.

Se evaluaron cuatro tratamientos con cuatro repeticiones distribuidos en bloques al azar. La parcela experimental tuvo una extensión de 3 tareas. En cada una se determinó el estado fitosanitario antes de la aplicación de los tratamientos.

Los tratamientos evaluados fueron: T1 = utilización de la trampa más aplicación de solo repela; T2 = Trampa más aplicación de Pepena; T3 = Trampa más aplicación de Graniteo; T4 = Testigo absoluto. En cada tratamiento se determinó: el número de brocas capturadas mediante recolección del contenido de las trampas cada 15 días y posterior conteo en el laboratorio; el porcentaje de infestación en 4 ramas de diez cafetos previamente seleccionados; el porcentaje de defectos por daños de broca severa, mediante análisis físico de laboratorio; el porcentaje de café brocado por kg de café pergamino seco, mediante la separación del café brocado; y el costo de aplicación de cada tratamiento.

Los datos fueron transformados por el método de raíz cuadrada más uno y analizados con el paquete estadístico MSTAT.

RESULTADOS Y DISCUSIÓN

Antes de iniciar el experimento

El porcentaje de infestación antes de la evaluación fue elevado en todas las unidades experimentales. En la Tabla 1 se observa que en los frutos dejados en la planta después de la cosecha el número de individuos fue mayor que en los frutos que estaban en el suelo.

Estudios realizados por Guzmán y Reyes (2000), en la República Dominicana, indican que la lluvia, hongos y artrópodos influyen negativamente sobre la broca en los frutos que caen al suelo.

Tabla 1. Niveles de infestación al concluir la cosecha 2001-2002 en plantas y frutos del suelo antes del experimento.

Trat.	TF	FB	%INF	BG-P	BG-S	H-P	H-S	L-P	L-S	P-P	P-S	IN/P	IND/S
T1	51	36	70.6	75	12	0	0	80	19	23	0	178	31
T2	77	61	79.2	30	14	0	0	15	20	50	0	95	34
T3	68	59	86.8	54	23	0	0	56	0	0	35	110	58
T4	78	74	94.9	63	31	0	0	80	19	79	24	222	74

TF= Total de frutos; FB= Frutos brocados; %INF=porcentaje de infestación; BG-P= Número de brocas en frutos dejados en la planta; BG-S= Número de brocas en frutos del suelo; H-P= Número de huevos en frutos dejados en la planta; H-S = Número de huevos en frutos recogidos del suelo; P-P = Número de pupas en frutos recogidos del suelo; P-S = Número de pupas en frutos recogidos del suelo; IN/TR-FP= Total de individuos en frutos dejados en la planta por tratamiento; IN/TA-FP = Total de individuos en frutos recolectados del suelo.

Al finalizar el experimento

En la Tabla 2 se presentan, para cada tratamiento, el porcentaje de infestación, así como el número de brocas adultas e instares inmaduros por cada cien (100) frutos tomados al azar y disecadas al concluir el experimento. En las Figuras 1 y 2 se nota que el efecto de los tratamientos sigue la misma tendencia. Para los niveles de infestación calculada a partir de cuatro ramas de los árboles seleccionados se observa la misma tendencia que en la Tabla 2, como lo explica la Figura 1.

Tabla 2. Nivel de infestación por planta al final de la cosecha 2002-2003 después del experimento.

Tratamientos	TF	FB	%INF	BG	H	L	P	IN/P
T1	100	10	10	8	11	30	2	51
T2	100	13	13	12	6	28	12	58
T3	100	35	35	47	2	18	38	105
T4	100	48	48	77	14	62	11	164

TF= total frutos evaluados; FB= frutos brocados; BG= brocas en el grano; H= huevos; L= larvas; P= pupas; IN/P= individuos por planta.

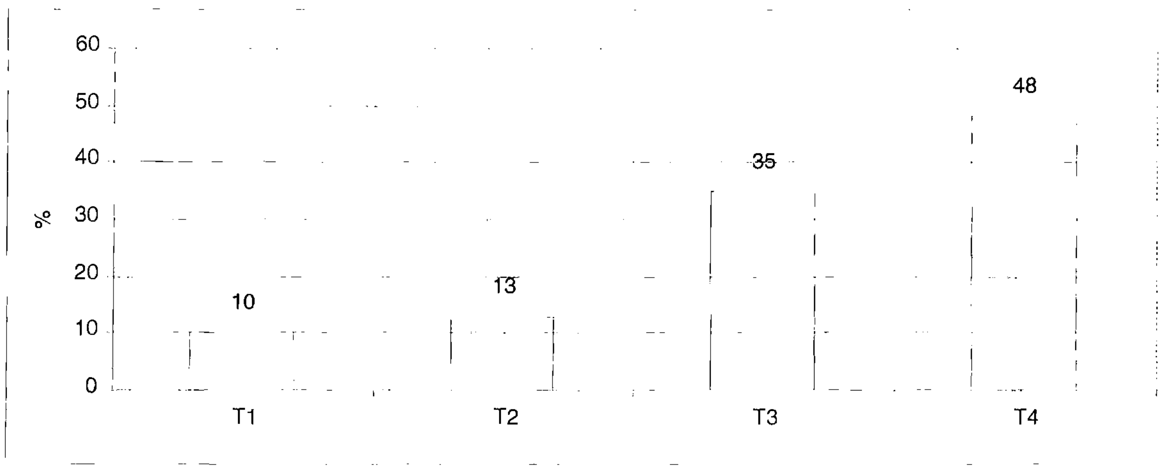

Figura 1. Porcentaje de infestación en cien frutos recolectados y disecados.

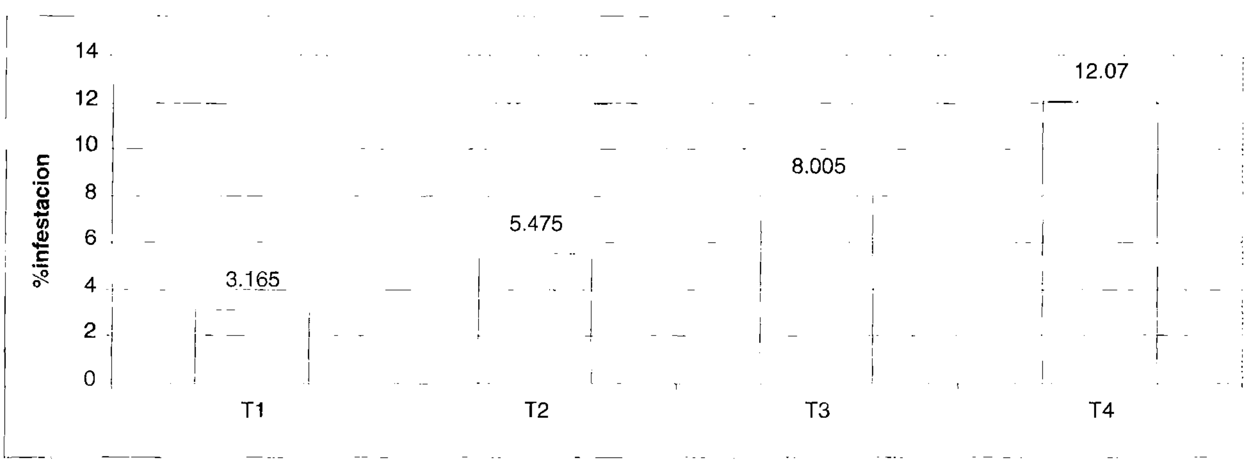

Figura 2. Porcentaje de infestación por muestreo de frutos en árboles.

Brocas capturadas

En las combinaciones de BROCAP® más graniteo y BROCAP® más pepena se capturó la mayor cantidad de brocas (Figura 3). Esto viene a confirmar que los frutos que permanecen en las plantas después de la cosecha son los más importantes para albergar a la broca y los menos expuestos a factores de mortalidad natural de la plaga.

La cantidad de hembras adultas capturadas en el periodo mayo-junio fue influenciada por las lluvias iniciadas a mediados del mes de abril. A partir de los dos meses después de iniciado el trampeo se observó una notable disminución de brocas capturadas, similar a lo observado por Dufour (1999) en El Salvador.

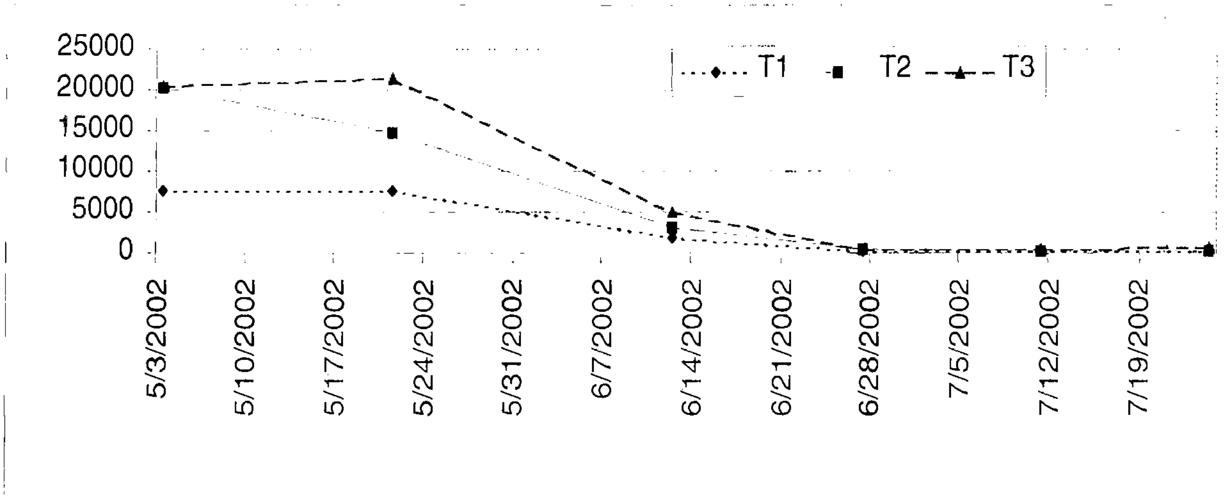

Figura 3. Número de brocas capturadas por la BROCAP®.

De acuerdo con el ANOVA, existen diferencias significativas entre los tratamientos para porcentaje de infestación en la planta (Tabla 3).

Tabla 3. Análisis de varianza para el porcentaje de infestación por broca en la planta.

Fuente de variación	gl	Sc	Cm	Fc	Ft(0.05)	Ft(0.01)
Tratamientos	3	5.3	1.771	32.20	3.86	6.99
Bloques	3	0.21	0.097	1.77		
Error	9	0.49	0.055			
Total	15					

Coeficiente de Varianza = 8.30%

Café pergamino brocado por kilogramo

En la Figura 4 se observa que con BROCAP® más repela la cantidad de café brocado en un kilogramo de café pergamino seco fue de 0.10 kg, seguido por 0.224 kg en BROCAP® más pepena y de 0.404 y 0.402 kg en BROCAP® más graniteo y el testigo, respectivamente.

El ANOVA para el porcentaje de café brocado por kg de café pergamino seco indica que hubo diferencias significativas entre los tratamientos.

Para esta variable las combinaciones BROCAP® más repela y BROCAP® más pepena fueron iguales entre sí, pero superiores a BROCAP® más graniteo y testigo (Tabla 4).

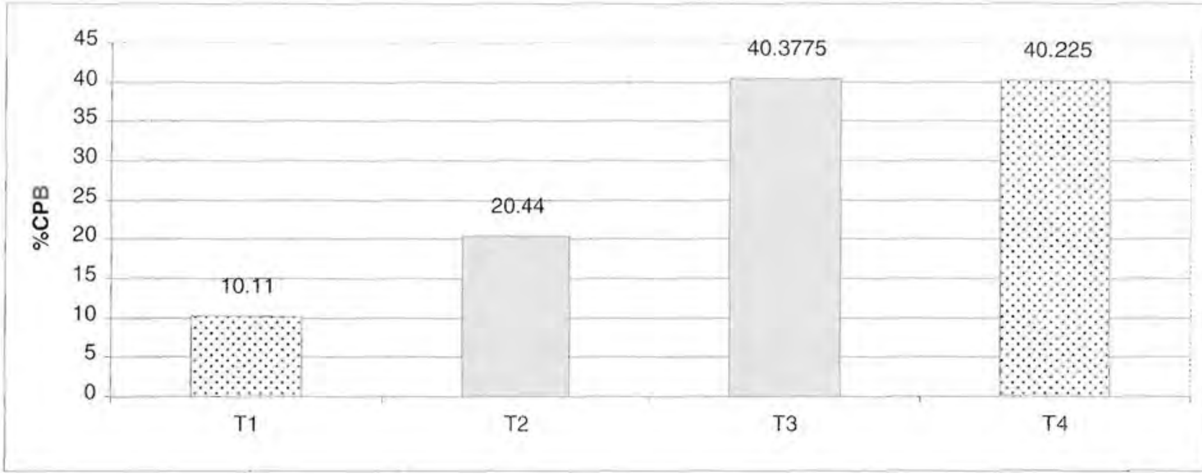

Figura 4. Porcentaje de café brocado por cada kilogramo de café pergamino seco

Tabla 4. Análisis de varianza para el porcentaje de café brocado por cada kilogramo de café pergamino seco.

Fuente de variación	gl	Sc	Cm	Fc	Ft	0.01
Tratamientos	3	26.63	8.877	8.25	3.86*	6.99
Bloques	3	3.56	1.185	1.10		
Error	9	9.68	1.075			
Total	15					

Coeficiente de Varianza = 20.06

Participación de daños por broca severa en defectos standard en café oro

El ANOVA reveló que hubo diferencias significativas entre las tres combinaciones (Tabla 4), pero la separación de medias por la Prueba de Tukey al 0.05 indicó que las combinaciones no son distintas entre ellas pero sí entre éstas y el testigo (Figura 5), por lo que la utilización de la trampa BROCAP® más cualquiera de las prácticas redujo la participación por broca severa en los defectos estándares de café oro.

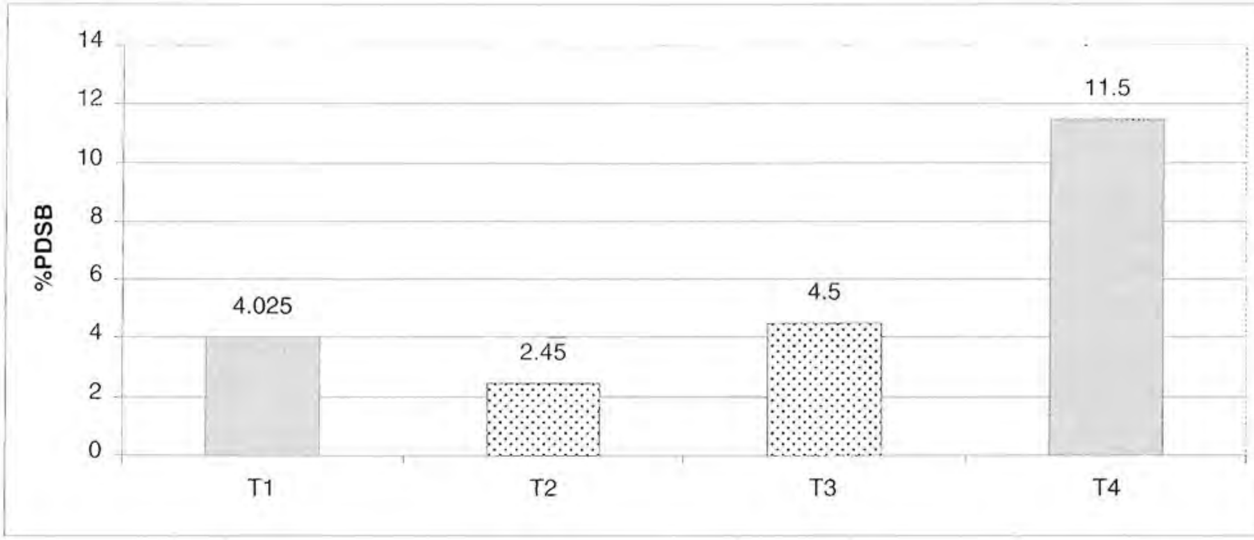

Figura 5. Participación de daños por broca severa en defectos estándares.

Tabla 3. Análisis de varianza para el porcentaje de participación de defectos por broca severa.

Fuente de variación	gl	Sc	Cm	Fc	Ft (0.05)	Ft(0.01)
Tratamientos	3	8.75	2.918	7.10	3.86*	6.99
Bloques	3	0.11	0.036	0.10		
Error	9	3.41	0.379			
Total	15					

Existe diferencia significativa entre los tratamientos. Coeficiente de Varianza = 24.52%.

Tabla 4. Comparación de tratamientos mediante la Prueba de Tukey al 0.05.

Tratamiento	% infestación árbol	%CPB	%PDBS
Trampa+repela	2.023 c	3.380 b	2.202 b
Trampa+pepena	2.642 b	4.510 ab	1.802 b
Trampa+Graniteo	3.000 b	6.322 a	2.287 b
Testigo	3.612 a	6.470 a	3.752 a

Los tratamientos con letras iguales no son significativamente diferentes entre sí.

Para los porcentajes de infestación por planta, así como para el porcentaje de café pergamino brocado, la trampa combinada con repela resultó el mejor tratamiento; sin embargo, es importante destacar que para el porcentaje de participación de defectos físicos por broca severa los tres tratamientos resultaron superiores al testigo.

Evaluación de costos

Tabla 5. Los costos de aplicación del control manual más el uso de la trampa BROCAP® en Gajo del Toro.

Prácticas	No. Jornales/ha	Costo/ jornal ($US)	Costo trampa ($US)*	Costo práctica/ha ($US)	Costo trat. ($US)
T1	6	2.00	4.90	12.00	16.00
T2	13	2.00	4.90	26.00	30.90
T3	16	2.00	4.90	32.00	36.90
T4	0	0	0	0	0

* Se incluye el costo de la trampa el primer año.

De las tres prácticas manuales para control de la broca, la repela fue la que requirió menor cantidad de jornales. En un primer año de utilización de esta combinación, su costo representa un 32.3% del precio de un quintal de café orgánico.

En la validación de la repela, graniteo y pepena, solas y combinadas entre sí, realizada en fincas de productores en Polo, la utilización de la repela como única práctica para control manual de la broca resultó ser la más efectiva y eficiente (Pérez et al., 2001).

Saldarriaga (1994) evaluó la cosecha periódica, la repela y la cosecha periódica más repela y determinó que las prácticas culturales fuera de la cosecha no solo reducen los niveles de infestación de la broca, sino que además generan ingreso.

CONCLUSIONES

Las combinaciones BROCAP® más repela y BROCAP® más pepena fueron igualmente efectivas en la reducción de número de frutos brocados y el número de individuos por planta al final de la cosecha. El periodo efectivo de captura de la trampa BROCAP® para las condiciones de la zona de estudio fue de dos meses.

El porcentaje peso/peso de café brocado por kg de café pergamino seco fue menor cuando se combinaron la recolección de los frutos residuales de la planta más la utilización de la BROCAP®. En la combinación BROCAP® más graniteo se capturó la mayor cantidad de broca pero no disminuyó el porcentaje de infestación ni el número de individuos por planta.

El costo más bajo se obtuvo con la combinación de trampa BROCAP® más repela debido a que se emplea un menor número de jornales.

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EVALUACIÓN DE CULTIVARES DE TOMATE DE MESA (*LYCOPERSICON ESCULENTUM* MILL) TOLERANTES AL COMPLEJO MOSCA BLANCA (*BEMISIA* SPP.) Y GEMINIVIRUS (TYLCV) EN SAN JOSÉ DE OCOA, REPÚBLICA DOMINICANA

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RESUMEN: El complejo moscas blancas (*Bemisia* spp.) - virosis (TYLCV), ha creado susceptibilidad en las variedades tradicionales de tomate, reduciendo la producción hasta en un 60%. Las acciones hasta ahora desarrolladas como la veda y el uso desmedido de insecticidas químicos, provocan desabastecimiento y contaminación en los alimentos y el ambiente. Los cultivares empleados por los productores de tomate presentan una alta susceptibilidad a los ataques del complejo mosca blanca-Geminivirosis. Con el objetivo de evaluar los cultivares introducidos y proveer a los productores de otras alternativas, minimizar el uso de insecticidas, disminuir los costos de producción del cultivo y contribuir así a la sostenibilidad de nuestra producción agrícola, se llevó a cabo un estudio en el Campo Experimental Sabana Larga, del Centro Sur del IDIAF, durante el período Septiembre/01–Abril/02. Se estableció un diseño de bloques completos al azar con 14 tratamientos y 4 repeticiones. En el desarrollo de este estudio no se empleó ningún insecticida para el control de la mosca blanca. Los resultados obtenidos reflejan tres cultivares muy promisorios por su adaptación y tolerancia al TYLCV. Los cultivares que mejor resultado arrojaron fueron: T-3146, T-3163, Caraibo F1 y Pik Ripe 461, con rendimientos de 23.43, 20.85, 19.56 y 17.02 ton/ha, respectivamente. Estos cultivares también fueron los menos afectados por la Geminivirosis.

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CIGAR-END ROT DISEASE OF PLANTAIN (*MUSA ACUMINATA X MUSA BALBISIANA*) IN PUERTO RICO

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ABSTRACT: Diseases are limiting factors in plantain production, affecting not only total production but also fruit quality. Because of a high incidence of cigar-end rot disease in Puerto Rico during the last few years, this disease has acquired greater importance. Its impact can be compared with that of yellow sigatoka, which is considered the most damaging disease affecting plantain on the island. No local research prior to this has been performed to evaluate this disease. Other plantain producing areas report a fungi complex as the causal agent, which includes two or more of the following: *Deightoniella tolurosa*, *Verticillium theobromae* (_ *Stachylidium theobromae*), *Fusarium* sp. or *Trachysphaera fructigena*. This last one, *T. fructigena*, has not been reported in the occidental hemisphere. To identify the fungi associated with this disease in Puerto Rico, we have evaluated plantain fruits with visible symptoms among the clones Maricongo and Enano Común, and the Hilario selection. The symptoms observed in the field include necrosis that begins at the tip of the fruit, with localized darkening, occasional wrinkling of the skin and premature ripening. These symptoms can appear one month after the flowering begins. Under wet or humid conditions, a powdery grayish conidia forms on the shriveled black end of the fruit, giving rise to the burnt tip appearance of the "cigar end," from which the disease gets its name. *Stachylidium* sp., *Fusarium* sp. and *Deightoniella* sp. were identified from fruit samples of the Maricongo and Enano Comun clones, and from the Hilario selection. Other fungi, *Colletotrichum* sp., *Nigrospora* sp., *Botryodiplodia* sp., *Pestalotia* sp. and *Cladosporium* sp., were found with less frequency. It is not clear which fungus or complex acts as primary invader of plantain fruit. Future work will include inoculations with each fungus, and combinations of them, to determine which is/are the primary invader(s).

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A NEW APPLICATION METHOD FOR THE SYSTEMIC FUNGICIDE METALAXYL TO CONTROL POINSETTIA (*EUPHORBIA PULCHERRIMA* WILLD. EX. KLOTZSCH) ROOT ROT CAUSED BY *PYTHIUM ULTIMUM* TROW

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ABSTRACT: The poinsettia cultivar "Freedom Red", highly susceptible to *Pythium ultimum,* was used to explore a better, more effective and environmentally sound application method of the true systemic fungicide metalaxyl. Three different rates of fungicide were used to control root rot. They were applied both as a drench and in paint/fungicide mixes as a coat to the interior of the containers. How much active ingredient was leaching-out of the container was determined for both methods of application. The *P. ultimum* inoculum used in this study was effective in causing disease and death of poinsettia cuttings within three to four weeks after planting in the *Pythium* infested potting mix (LC-1). Treatments with paint alone, paint/fungicide mixes as well as the higher rates of metalaxyl were not phytotoxic to poinsettia plants. Highly significant differences in DSI were found between plants inoculated with *Pythium* alone and control plants grown in containers coated with paint but no fungicide. Both methods of application had similar efficacy in controlling *Pythium*. Results indicate that the paint/fungicide method, although as effective in controlling *Pythium* root rot, is not more environmentally friendly than the traditional drenches. Metalaxyl is a highly polar and water-soluble chemical; as a consequence, it was easily eliminated from the containers.

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DIFFERENTIATION OF *XANTHOMONAS CAMPESTRIS* PV. *PHASEOLI* = *XANTHOMONAS AXONOPODIS* PV. *PHASEOLI* BY RIBOTYPING AND HOST-PATHOGEN INTERACTIONS

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ABSTRACT: *Xanthomonas campestris* pv. *phaseoli* (Xcp) isolated from infected bean leaves from Nicaragua, Costa Rica, and Puerto Rico were compared using ribotyping and pathogenicity on 69 *Phaseolus vulgaris* genotypes. Strains were characterized using the restriction enzymes EcoR1, Pst1, and Pvu11. One ribogroup pattern was observed with EcoR1, two with Pst1, and three patterns with Pvu11. Diversity among strains in ribogroups at the infrasubspecific (pathovar) level was detected with the enzymes Pst1 and Pvu11. Differences in ribogroups indicate the presence of variable regions useful to distinguish within the pathovar level. Twelve bean genotypes were identified with resistance to at least one bacterial strain and were selected for their specific reaction to the strains. Because of the specificity of the reactions, the strains from Nicaragua, Costa Rica, and Puerto Rico are considered pathogenic races of Xcp. These races are not distinguishable by phenotype but they can be recognized by the ribogroup restriction patterns with Pst1 and Pvu11.

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SUPPORT FOR THE DEVELOPMENT OF FARMER PARTICIPATORY APPROACHES FOR IPM IN THE CARIBBEAN: REGIONAL TRAINING OF MASTER TRAINERS IN TRINIDAD

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ABSTRACT: As part of the efforts to support the development of farmer participatory IPM in the region, a Training of Master Trainers course was carried out in 2002. The course was a component of the IPM project funded by the European Union as part of the EC-CARIFORUM Caribbean Agriculture and Fisheries Programme. CAB International, in conjunction with the FAO, implemented the training during August-December 2002. A total of 11 participants from six pilot countries (Dominica, Dominican Republic, Haiti, Jamaica, Suriname, and Haiti) underwent a grueling season-long training. The purpose of the training was to develop a cadre of regional "Master Trainers", who would in turn train Extension staff and farmers in Integrated Crop and Pest Management. The training comprised practical field and laboratory sessions and exercises complemented with interactive lectures and group discussions, all based on the use of Non-Formal Education (NFE) and Participatory methods. As part of the training, participants developed National Action Plans for implementation upon their return home. The Action Plans are currently being implemented in the participating countries spearheaded by the trained Master Trainers.

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DRAMATIC IMPACT OF THE RECENTLY INTRODUCED ASIAN PIGEON PEA POD FLY, *MELANAGROMYZA OBTUSA* (MALLOCH) (DIPTERA: AGROMYZIDAE), IN THE DOMINICAN REPUBLIC

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ABSTRACT: The pigeon pea (*Cajanus cajan* (L.) Millsp.) is the second most important leguminous crop for the Dominicans. Fresh or canned seeds are also exported, i.e., to Puerto Rico and the U.S.A. The crop with very low input requirements is produced in marginal areas and serves as an important source of protein for the peasant farmers. The pigeon pea pod fly (*Melanagromyza obtusa* Malloch) has been a pest in Asian countries for decades and was first reported in the western hemisphere in Puerto Rico and the Dominican Republic in the year 2000 (NPAG 2000; Kauffman 2001; Abud et al., 2002). Alerted by local farmers, between 2002 and 2003 two separate research teams, based at San Juan de la Maguana and San Francisco de Macorís, carried out a survey. The study consisted in the determination of the dispersal of the recently introduced pest, the damage levels and the presence and effectiveness of antagonists of the pest. Pods were collected from plants in more than 20 localities belonging to 5 provinces of the major pigeon pea producing regions in the southwest and south, as well as of more than 20 localities of 8 provinces in the central and north-eastern regions, being present at >95% of the surveyed sites. The infested pods showing small "windows" ranged between 30 to 80% and the damaged seeds between 10 and 80%. From the pods held in paper bags conected to glass tubes, no single parasitoid emerged. The mass release of introduced parasitoids is discussed, trying to reduce the damage by at least 50% and backing biocontrol applying IPM measures.

INTRODUCTION

The pigeon pea pod fly (PPF), *Melanagromyza obtusa* (Malloch) (Diptera: Agromyzidae), originates from Asia, where it has been reported for decades as an important pest of *C. cajan*, in India, Sri Lanka, the Philippines, Thailand, Indonesia, Japan, and Vietnam (Spencer, 1973). The host-plant range includes leguminous genera as *Cajanus*, *Flemingia*, *Rhynchosia*, and others. One interception of *M. obtusa* on soybean has alerted the authorities of the U.S.A., but has to be confirmed as a host as well as okra (*Abelmoschus esculentus*, Malvaceae), *Sesamum indica* L. (Pedaliaceae), and *Vigna* spp. (Leguminosae-Papilionoideae).

The first interceptions in the Western Hemisphere were reported in 2000 from Puerto Rico and the Dominican Republic (NPAG, 2000; Abreu et al., 2000; Abud and Cuevas, 2002) and in 2003 identified in Cuba by Serra (unpubl. data).

BIOLOGY

The life cycle takes between 4 to 5 weeks (Table 1). The PPF female stings into developing pigeon pea pods and lays up to 80 eggs individually. Normally, more than one egg and up to 7 eggs are found in a single pod, 4 being the average (Spencer 1973). After hatching inside the pod the larvae start feeding on the surface of the seeds before boring into the seed. The larvae complete their development, consisting of 3 instars, well protected and practically undetectable until they leave the seed before pupation to feed on the wall of the pod leaving a characteristic oval or round "window" (ϕ 1-2.5 mm) with an epidermal layer. which is perforated by the emerged adult to leave the pod. The adult is a medium sized dark to green metallic fly.

Table 1. Developmental data of the pigeon pea pod fly (Shanover et al., 1999; NPAG, 2000)

Stages	Duration (development eggs>adults: 18-39 days)	
Eggs	3 - 5 days	
Larvae, 3 instars	6-11 d	L1~1.5 d; L2 ~=2 d; L3 2.5 d
Pupae (1.~3 mm)	9-23 d (inside the pod)	
Adults (length~2-2.5mm)	~12 days (longevity)	

MATERIALS AND METHODS

The main objective of this study was to confirm the presence of the PPF, their associated natural enemies and the damage levels in the different regions where *Cajanus cajan* is grown commercially or extensively planted along the roads. The studies were carried out between January 2002 and May 2003 by two teams of the Plant Protection Program of the IDIAF, based at the Estación Experimental Arroyo Loro (EEAL), province San Juan de la Maguana in the southwest, and the Estación Experimental Mata Larga (EEML), San Francisco de Macorís in the northeastern province Duarte.

The team of the EEAL evaluated fields in 19 localities in the southern and southwestern provinces of Elías Piña (3), San Juan de la Maguana (12), Barahona (1), Ocoa (2), and San Cristóbal (2). The team of the EEML evaluated pigeon pea pods sampled in 24 localities belonging to 8 provinces between the southwest and northeast of the country.

Ripe pods were collected at random and put in paper bags (20 cm x 10 cm) and brought to the laboratories, where the aperture was connected with a glass tube (12-15 cm long) held up side down by rubber tie to permit the detection of emerging flies and parasitoids flying towards the light. In the studies carried out by the EEML team, the pupae, emerging flies, percentage attacked pods, and seeds were recorded.

RESULTS

The PPF was found in every locality where samples of pigeon pea pods were taken, with one exception. In the Dominican Republic, a narrow alternative host plant range has been confirmed up to date: *Rhynchosia minima*, *Rhynchosia reticulata*, and *Flemingia macrophylla* (all Leguminosae-Papilionoideae) (Table 2). Only in one pigeon pea sample out of more than 3,000 checked, a parasitizised pupal case was detected, but the parasitoid was not found. Only at 2 dates and in a few of the tiny pods of *Rhynchosia minima* collected in fields of the EEAL, still no confirmed parasitoids (*Euderus*? sp., Hymenoptera: Eulophidae) emerged. No specific predators nor fungal or other diseases of the PPF as biocontrol agents have been found up to date.

Table 2. Host plants of *Melanagromyza obtusa* confirmed in the Dominican Republic.

Host plant	Date	Localities	Collectors	Parasitoids
Cajanus cajan (L.) Millsp.	See Tables 3 and 4			0
Flemingia macrophylla (Willd.) Kuntze ex Merr.	29/9/03	Las Terrenas, Samaná	C.A. Serra	0
Rhynchosia minima (L.) DC.	14/7/02, 3/4/03	EEAL, San Juan de la Maguana	Y. Segura, J. Arias & C.A. Serra	8, 1
Rhynchosia reticulata (Sw.) DC.	15/6/03	Oviedo	M. Reyes (pers. comm.)	not evaluated

The results of the samples achieved by the EEAL team concerning the damage caused by the PPF can be seen in Table 3. The percentages of damaged pods varied between 10 and 65%. The lowest infestation levels were recorded in samples coming from altitudes above 400 m.a.s.l. and in localities with a relatively high use of pesticides (San Cristóbal).

Table 3. Infestation levels of pigeon pea (*Cajanus cajan*) pods by *Melanagromyza obtusa* in 19 localities of the south and southwest region of the Dominican Republic.

Province	Locality	Infested pods (%)
Elías Piña	Guanito, El Llano	62
	El Reboso, El Llano	65
	La Fuente, Hondo Valle	45
San Juan de la Maguana	Buena Vista	30
	Ginova	32
	La Culata	61
	Aromar	65
	Km7, Road San Juan M.-Las Matas	35
	Hato del Padre	60
	Chalona	41
	El Corbano	25
	Las Matas de Farfán	35
	El Cercado, Aguas Frescas	10
	Los Arroyos	24
Barahona	La Sabana Polo	10
San José de Ocoa	Ojo de Agua	25
	Arroyo Hondo	20
San Cristóbal	Palenque	15
	Doña Ana	12

The results obtained by the EEML team are presented in Table 3. The infestation levels of the PPF varied between 3 and 100% of the pods, while between 20 and 85% of the seeds of infested pods were found damaged. The percentage of damaged seeds referred to the total amount of sampled pods ranges between 2 and over 80%. The lowest levels were obtained in mountain valleys as in or near Constanza at higher altitudes (800-1,200 m.a.s.l.) and beginning the harvesting season (Table 4). In some places, the levels at the end of the harvesting season reached levels above 50% of the total seeds.

Figures 1 and 2 show the damaged caused by the PPF on green and dry pods of pigeon pea. Figure 3 shows the pupal cases and emerged adults of the pigeon pea pod fly, recovered from the pods. There was no presence of parasitoids.

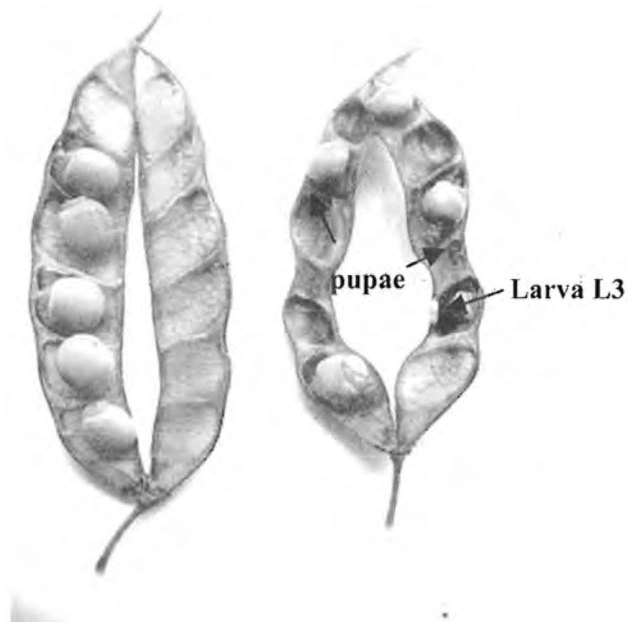

Figure 1. Non-infested (left) and attacked (right) green pods of pigeon pea showing seeds damaged by the pigeon pea pod fly (PPF), *Melanagromyza obtusa* (Malloch) (Diptera: Agromyzidae).

Figure 2. Infested dry pods of pigeon pea showing seeds damaged by the pigeon pea pod fly (PPF) and covered with micelia of fungi after secondary infection.

Table 4. Infestation levels of green pigeon pea pods and damaged seeds by *Melanagromyza obtusa* in 24 localities between the National District, the center and northeast of the Dominican Republic.

Province	Locality	Month	% infested pods	% damaged seeds of	
				infest. pods	total pods
National District	Santo Domingo	Jul.'02	52	72	37
	Santo Domingo	Feb.'02	23	36	8
Monseñor Nouel	Juma, Bonao	Nov.'02	63	47	30
	Juma, Bonao	Dec.'02	65	49	32
Sanchez Ramírez	Angelina, Cotui	Oct.'02	32	64	21
La Vega	Bacumi, Fantino	May'03	53	47	25
	Arroyo Frío	Jul.'02	100	82	82
	Constanza	Jul.'02	9	42	4
	Constanza	Jul.'02	34	52	18
	Constanza	Aug.'02	44	64	28
	Constanza	Oct.'02	47	65	31
	Constanza	Dec.'02	33	38	13
	Constanza	Jan.'03	19	28	5
	La Cienaga	Dec.'02	10	20	2
	El Río	Dec.'02	15	33	5
	El Río	Dec.'02	27	33	9
	Jima	Apr.'02	79	39	30
	Jima	May'02	59	33	20
	Ranchito	Apr.'02	28	23	7
	Ranchito	Apr.'02	53	81	43
	Ranchito	Dec.'02	75	69	51
	Ranchito	Jan.'03	19	32	6
	Ranchito	Feb.'03	70	54	38
Duarte	La Penda, SFM.	Nov.'02	95	64	61
	El Jamo, SFM.	Feb.'02	78	55	43
Salcedo	Salcedo	Nov.'02	59	52	31
	Jayabo	Jan.'03	50	46	23
	Montellano	Jan.'03	63	42	27
María Trinidad	El Factor, Nagua	Jan.'03	87	58	50
Sánchez	El Pozo, Nagua	Mar.'03	64	37	24
	Canela, El Pozo	Apr.'03	81	37	30
Samaná	Juana Vicente	Jul.'02	70	72	50
	Las Terrenas	Apr.'02	100	81	81
	Las Terrenas	Aug.'02	30	85	26
	Las Terrenas	Jan.'03	40	23	9
	Las Terrenas (d)	Feb.'03	43	35	15
	El Naranjito, LT.	Mar.'03	44	43	19
	Los Cacaos	Jul.'02	70	66	46
	Sánchez	Jan.'03	27	25	7

Figure 3. Pupal cases and emerged adults of the pigeon pea pod fly (PPF), recovered from the pods, without presence of parasitoids.

CONCLUSIONS AND RECOMMENDATIONS

The studies carried out in 13 provinces located in the south, southwest, and northeast regions of the Dominican Republic showed that the pigeon pea pod fly is a serious threat to pigeon pea, an economically important crop in the Dominican agriculture, for national markets, export and as a source of protein and income, specially for the poor rural segments of the population. The latter, usually do not use any phytosanitary measures in this crop with low input requirements.

It was also found that the immature stages complete their cycle well protected inside the pods. As alternative host plants were confirmed *Rhynchosia minima*, *Rhynchosia reticulata*, and *Flemingia macrophylla* (all Leguminosae-Papilionoideae). Only from *Rhynchosia minima* pods emerged a few parasitoids of the PPF. Also in Puerto Rico, PPF parasitoids were recovered from *Rhynchosia* spp., but not from pigeon peas (Abreu, pers. comm.).

The absence of effective biocontrol agents in pigeon pea itself, makes necessary the implementation of a classical biological control program based on the most promissing parasitoids screened and selected after a foreign exploration in Asia, where the pest originated. An environmental assessment has been achieved in order to permit the introduction of exotic parasitoids of the PPF to Puerto Rico, after a selection of the most promising species and the exclusion of hyperparasitoids. The existence of effective parasitoids has been reported from different Asian countries (Meyerdirk, 2003, not publ.). An IPM approach should include the search for tolerant cultivars as well as selective insecticides and measures in order to support biocontrol.

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EVALUACIÓN DE OCHO PRÁCTICAS DE CONTROL DE MALEZAS EN EL CULTIVO DEL GUANDUL, *CAJANUS CAJANS* L. MILLSP, EN EL VALLE DE SAN JUAN

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RESUMEN: Durante los años 2001 y 2002 se estudiaron ocho prácticas de manejo de malezas en el cultivo de guandul, *Cajanus cajan* L. Millsp. El estudio se realizó en los campos de la Estación Experimental Arroyo Loro, en San Juan de la Maguana, República Dominicana, con la finalidad de determinar cuál práctica de manejo de malezas resulta más eficiente y cuál reporta los mejores beneficios. Se utilizó un diseño de bloques completos al azar con cuatro repeticiones y ocho tratamientos: T_1 = Desyerbos 20 y 45 DDS + Chapeo 75 DDS; T_2 = Desyerbo 20 DDS + Paso cultivador 45 DDS + Desyerbo 75 DDS; T_3 = Pendimenthatina + Linuron (Pre-emergente) + Desyerbo 45 DDS; T_4 = Pendimenthatina + Linuron (Pre–emergente) + Paso de cultivador 45 DDS + Chapeo 75 DDS; T_5 = Pendimenthatina + Linuron (Pre-emergente) + Desyerbo 45 DDS + Chapeo 75 DDS; T_6 = Desyerbo 20 DDS + Fluazitop butil 45 DDS; T_7 = Desyerbo 20 DDS + Paso de cultivador 45 DDS + Chapeo 75 DDS; T_8 = Pendimenthatina + Linuron (Pre-emergente) + Paso de cultivador 45 DDS + Fluazitop butil 75 DDS. Para el primer año (2001), se encontraron diferencias estadísticas significativas para las variables rendimiento en verde y porcentaje de malezas, resultando los mejores tratamientos T_2 y T_6 con 7,990 y 7,820 kg/ha, respectivamente. En cuanto al porcentaje de malezas, el T_6 fue el tratamiento que presentó los valores más bajos. El mayor beneficio neto (RD$84,014.11/ha) y la mejor tasa de retorno marginal (193%) se obtuvieron con el tratamiento T_2. En el segundo período (año 2002) no se encontraron diferencias estadísticas entre tratamientos para las variables en estudio.

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THE ECONOMIC IMPACT OF INVASIVE SPECIES ON THE ORNAMENTAL COMMODITY IN PUERTO RICO: TOWARDS ESTABLISHING A MULTIDIMENSIONAL FRAMEWORK FOR DATA COLLECTION AND ANALYSIS

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ABSTRACT: The ornamental commodity in Puerto Rico is valued for its economic contribution in the agricultural sector, its contribution to the esthetics of natural scenarios, which impact the tourism sector, and for its environmental role. In the fiscal year 2001, ornamentals generated 4.8% of the total Agricultural Gross Product. In that year the production value at farm level was $34.1 million, the export value $0.5 million and the import value $11.5 million. Of the local production value, 1.5% was exported; 34.3% of the ornamental local market value was imported. The active trade traffic in Puerto Rico is a factor that increases the risk of the introduction of invasive species which affect the agricultural sector. It is necessary to estimate the economic impact of the established invasive species and those with high potential for introduction. The economic analysis must consider the impact on production, on market, and on the environment. The direct and indirect impact on market and non-market areas has to be estimated. The study presented in this paper pretends to gather economic data on the ornamental commodity and biological data on invasive pests and diseases to initiate the development of a comprehensive species risk management framework that incorporates the economic impact of invasive species.

EL IMPACTO ECONÓMICO DE LAS ESPECIES INVASORAS SOBRE LA EMPRESA DE ORNAMENTALES EN PUERTO RICO: HACIA LA DETERMINACIÓN DE LA METODOLOGÍA

RESUMEN: La empresa de ornamentales de Puerto Rico se valoriza por su aportación económica al sector agrícola, su aportación a la estética y a los escenarios naturales que impactan al sector turístico, y por su relevancia ambiental. En el año 2000/2001 esta empresa aportó a nivel de finca el 4.8% del Ingreso Bruto Agrícola. Para ese año el valor de la producción fue de US$34.1 millones, el de exportación US$0.5 millones y el de importación US$11.5 millones. Se exportó 1.5% del valor de la producción local y se importó el 34.3% del valor del mercado local de ornamentales. El activo flujo comercial de Puerto Rico es un factor que incide en la entrada de plagas y enfermedades que afectan al sector agrícola y por consiguiente a la empresa de plantas ornamentales. Es necesario establecer una metodología que estime el impacto económico del control de las plagas establecidas y de las plagas relevantes con potencial de establecerse. El análisis económico debe considerar el impacto en los niveles de producción, de mercado y de ambiente. Este trabajo pretende iniciar la identificación de los factores relevantes para establecer la metodología en la determinación del impacto económico.

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TYPE AND WEIGHT OF PLANTING MATERIAL ON YAM (*DIOSCOREA ALATA*) CV. DIAMANTE YIELD IN SOUTHERN PUERTO RICO

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ABSTRACT: An experiment was conducted in Santa Isabel, southern Puerto Rico, to determine the effect of types and sizes of planting material on yield of yam cv. Diamante. Treatments were whole tubers of two weight ranges, 28 to 112 g and 113 to 200 g; apical tuber sections weighing 28 to 112 g; and non-apical tuber sections of two weight ranges, 28 to 112 g and 113 to 200 g. Yams were planted in a Mollisol (San Antón soil series) with a pH of 8.0 on 4 April 2002 and harvested 27 January 2003. The five treatments were replicated four times in a completely randomized statistical design. Each experimental unit was 344.6 m^2. Total yield of yam tubers ranged from 13.7 mt/ha for the whole tubers (113 to 200 g) to 16.4 mt/ha for the non-apical tuber sections (113 to 200 g). No statistical differences were found among treatments. Low yields may be attributed in part to micronutrient deficiency symptoms, which were observed throughout the experiment during the first four months of crop growth.

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MODIFIED HPLC DETERMINATION OF SUGARS IN SWEET POTATO

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ABSTRACT: The tropical-type of sweet potato is the type commonly grown and consumed throughout the Antilles of the Caribbean Basin. Tropical-type describes varieties that exhibit either white, cream or light yellow-fleshed roots and are intermediate in sweetness. There is interest for the establishment of a quantitative basis for the selection of genotypes by sweetness. However, information on sugar concentrations for the tropical-type sweet potato is limited. Our research group has experienced difficulties in the quantification of glucose and fructose when using a previously developed HPLC technique. This technique was modified for the quantification of glucose, fructose, sucrose, and maltose in tropical-type varieties. Raw, boiled and microwaved roots were dried, then ground. Extractions were done with 80% ethanol. Glucose and fructose determinations were made with a cation exchange resin column (SugarPak I, Waters Corp.) and a mobile phase of CaEDTA and water. Sucrose and maltose were determined by using an amine-bonded silica column (Supelcosil LC-NH2, Sulpelco Corp.). For the latter determinations, the mobile phase was a solution of acetonitrile and water. Determinations were completed with a refractive index detector coupled to the HPLC system. Percentage of recovery of sugars depended on the variety. In raw samples, concentration of sucrose was higher than that of glucose and fructose, whereas maltose was not detected. After boiling or microwaving, maltose concentration increased dramatically and ranged from 11 to 18%.

INTRODUCTION

Tropical-type sweet potato (*Ipomoea batatas*) describes varieties characterized by the intermediate sweetness after cooking that exhibit either white, cream or light yellow-fleshed roots. These characteristics are of preference in the Antilles of the Caribbean Basin. Tropical-type differs from the dessert-type sweet potato, usually grown in the Southern U.S., because of the latter being orange-fleshed and less starchy than the former. Efforts for the improvement of the tropical-type adapted to the Caribbean Basin were reinitiated by the University of Puerto Rico's Agricultural Experiment Station during the mid 1990s. Part of this effort relates to the assessment of the sugar concentrations.

Substantial variation exists for concentration of sugars among sweet potato varieties (Hamann et al., 1980; Kays and Horvat, 1984; Koehler and Kays, 1991). Base line information on sugar concentration for tropical-type varieties was obtained by Hernández-Carrión (2001) by using high performance liquid chromatography (HPLC). This study suggested the need for the quantitative assessment of the concentration of both glucose and fructose for varietal characterization for sweetness among tropical-type varieties. This suggestion was sustained with previous studies such as that of Walter (1992), which indicates that combinations of sucrose, glucose, and fructose can account for up to half of the sweetness in cooked sweet potato.

The objective was to modify procedures such as those described by Picha (1985) and Lewthwaite et al. (1997) to improve the assessment of the concentration of glucose and fructose in the tropical-type. This work is part of a more ample effort for the establishment of quantitative criteria for the selection of new tropical-type varieties based in part on their sweetness.

MATERIALS AND METHODS

Sweet potato roots were obtained from a field planted at the Juana Díaz Experiment Station farm of the University of Puerto Rico. Data for varieties Miguela and Viola were used. Miguela (Badillo-Feliciano, 1976) was the representative for the tropical-type, whereas Viola represented the substaple-type (Martin, 1987). Harvest was 155 days after planting. Roots weighing from 150 to 450 g were selected at random, and after curing were processed either raw, boiled or microwaved. Roots were exposed to boiling water for 30 minutes, microwaved at maximum energy in a 2450 MHz microwave oven for 12 to 15 minutes, or neither boiled nor microwaved.

Once treatments were applied, flesh was removed from the center of the root, dried at 55° C and ground to pass a # 20 mesh for preparing a flour. The flour was placed in crystal jars and frozen at -20° C until the extraction of sugars. Extraction was made by using ethanol at 80%. A chromatograph system equipped with an autosampler and a refractive index detector was used for determinations of the concentration of glucose, fructose, sucrose, and maltose. Sugar separation was accomplished by using two different chromatographic columns. Columns differed in major characteristics and use conditions (Table 1).

Table 1. Principal characteristics and required conditions for the two chromatographical columns used in this study.

	Column[1]	
Characteristics	Amino-bonded	Cation exchange
Outside dimensions	5μm, 250 mm	5μm, 300 mm
Internal diameter (mm)	4.6	6.5
Temperature for analysis (°C)	25	90
Mobile phase	Acetonitrile:Water (85:15)	Water-CaEDTA
Flux of mobile phase (mL/min)	1.5	0.5
Injection: volume/sample (μL)	20	5

[1]Columns used were Supelcosil LC-NH_2 and SugarPakI. Mention of trademarks or commercial goods and their characteristics is to provide specific information and does not constitute endorsement by the University of Puerto Rico.

RESULTS AND DISCUSSION

Sweet potato flour:

Percentage of humidity in the flour varied from 3.2 to 1.9. Freezing the flour was useful as a means for storage, important when a large number of samples are to be processed. Flour was used by neither Picha (1985) nor by Lewthwaite et al. (1997). They prepared a slurry and measured sugars immediately after applying heating treatments.

Retention times for glucose, fructose, sucrose and maltose:

Retention times were calculated by using chemical standards for the sugars. Diluted standards of 1% of each sugar (glucose, fructose, sucrose, and maltose) were used. For sucrose and maltose additional standards of 10, 15, and 20% were included. Mixtures of sugars at various proportions completed the standards. Retention time was calculated as an average of triplicate samples for each of the columns. Retention times for fructose and glucose were close in the amino-bonded column, thus reducing the probabilities for a correct assessment of the concentration of these sugars (Table 2).

Because we were interested in a more quantitative assessment of these two sugars, a cation exchange column was also used. In the cation exchange column, separation of fructose and glucose was clearer, thus improving their concentration assessment (Table 2). Sucrose and maltose, however, coelute in the cation exchange column; thus the amino-bonded column was maintained to assess maltose and sucrose.

Table 2. Average retention time in minutes for glucose, fructose, sucrose and maltose in two chromatographic columns.

	Column	
Sugar	Amino-bonded	Cation exchange
Fructose	4.3	11.6
Glucose	4.7	9.9
Sucrose	5.9	*
Maltose	6.9	*

*Sucrose and maltose coelute in the cation exchange column.

Assessing glucose and fructose concentration using different columns:

As mentioned, assessment of the concentration of glucose and fructose depended on the column (Table 3). These results appeared to be related to the efficiency of the columns in the separation of different sugars.

Table 3. Average glucose and fructose concentration (% dry weight basis) in the same sample when using two chromatographic columns.

		Column	
Root Processing	Sugar	Amino-bonded	Cation exchange
Raw	Glucose	0.36	0.31
	Fructose	0.47	0.70
Microwaved	Glucose	1.71	1.20
	Fructose	1.75	0.96

Percentage of recovery for glucose and fructose in a cation exchange column:

Percentage of recovery was obtained by using the method described by Picha (1985). Twenty grams of flour from each treatment were spiked with 1.0 g glucose, 1.0 g fructose, 2.0 g sucrose and 5.0 g maltose. Percentage of recovery was based on the differences between spiked and unspiked samples. Percentages of recovery for glucose and fructose were relatively high in variety Miguela (Table 4). Percentages of recovery for other varieties and treatment combinations varied, however, between 58 and 86.

Table 4. Percentage of recovery for glucose and fructose under three treatments using a cation exchange column.

	Sugar	
Root Processing	Glucose	Fructose
Raw	99	99
Boiled	95	99
Microwaved	86	94

Assessing sugars concentration in two types of sweet potato:

As expected, sucrose, glucose and fructose were detected in raw samples (Table 5). In raw samples, sucrose concentration was the highest among the sugars. As to individual root processing, glucose and fructose concentrations in Miguela, the representative of the tropical type, were at least twice those of Viola, the substaple type (Table 5). Maltose was not detected in raw samples. After boiling or microwaving, maltose concentration increased dramatically. After cooking, an increase in the concentration of maltose is a general pattern in sweet potato that has been previously detected and reported by various researchers including Shen and Sterling (1981), Picha (1985), and Koehler and Kays (1991).

Table 5. Average concentration of sugar (% dry weight basis) in sweet potato varieties under three flesh processing methods.

		Sugar			
Variety	Root Processing	Glucose*	Fructose*	Sucrose**	Maltose**
Miguela (Tropical)	Raw	1.3	1.6	2.2	undetected
	Boiled	1.6	1.1	2.9	12.6
	Microwaved	2.0	1.4	3.4	13.3
Miguela (Substaple)	Raw	0.5	0.4	4.1	undetected
	Boiled	0.8	0.3	4.6	14.3
	Microwaved	0.8	0.3	4.7	13.1

* A cation exchange column was used to detect glucose and fructose.

** An amino-bonded column was used to detect sucrose and maltose.

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DETERMINING PER CAPITA CONSUMPTION OF SWEET POTATO (*IPOMOEA BATATAS*) FOR ADULTS IN ST. VINCENT & THE GRENADINES

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ABSTRACT: The generalization that the consumption of "Roots and Tubers" (R&T) is on the decline in the Caribbean is widespread. However, little data exist for the empirical testing of this generalization. This study reports the findings from a survey on the consumption of sweet potato in St. Vincent and the Grenadines in January 2003. A 76 percent response rate generated a sample size of 227 that permitted the estimation of the adult annual per capita consumption of 29.03 lb. The hypothesis that urban people consume less R&T than rural people was tested. Of the 227 respondents that permitted the calculation of the annual per capita consumption, 204 permitted the distinction between rural and urban to be made. The annual per capita sweet potato consumption was estimated at 28.22 lb and 34.03 lb for the rural and urban sub-samples, respectively. No statistical support was found in this study for the notion that urban dwellers consumed fewer sweet potatoes than rural consumers.

INTRODUCTION

The importance of the 'Roots & Tubers' (R&T) in the world's food system cannot be overlooked. Individually, cassava, potato, sweet potato, and yam rank among the most important food crops worldwide and, in terms of annual volume of production, cassava, potato, and sweet potato rank among the top 10 food crops produced in developing countries (IFPRI/CIP, 2000). Production and use of R&T tend to be concentrated in countries with lower per capita incomes, where they are a major source of food and nutrition.

The advent of new food production technologies, increasing living standards, and changing lifestyles have had a tremendous impact on the production and consumption of the R&T. Durrant (1987) stated: "Generally, the production and consumption of indigenous root crops have been declining over the last two decades and this trend has been ascribed to a wide variety of factors. Among these factors, the most important would seem to relate to the limited forms in which roots crops may be consumed --given the low levels of processing technology. In addition, there is the relative inconvenience involved in the preparation of these foods when compared with other high-energy staples such as rice and wheat flour".

In the Caribbean region there is a general absence of consumption figures for R&T making it difficult to confirm if whether consumption is indeed decreasing or actually increasing. Efforts have been made to determine consumption figures (Stewart, 2001) based on the following method of calculation:

$$\text{Consumption} = \frac{(\text{production} + \text{imports}) - \text{exports}}{\text{Population size}} = \text{per capita consumption}$$

However, an understanding of the production system and to a lesser extent the marketing system for the R&T in the region will establish how unreliable an estimate from this method could be.

Contemporary consumption theory suggests that as income increases there is a shift from meeting basic quantity requirements in the diet to attributes such as quality. Generally, food consumption at lower income levels is first and foremost motivated to satisfy basic physiological needs for food in the context of traditional food preferences of culture. At higher income levels, as is enjoyed by a fair percentage of Caribbean society today, food consumption is motivated by needs high in the pyramid, such as food safety, status etc., as is illustrated in Figure 1. R&T are an excellent source of calorie intake.

In the last few years there has been an intense debate on the response of nutrition intake to rising incomes. Subramanian (2001) stated: "It was conventionally believed that as income rises households switch to higher valued foods not necessarily with higher calorie content. However, this effect is likely to operate more strongly at higher income levels, so that at low incomes we except calorie consumption to respond positively to income. This view has been challenged suggesting that even among the very poor, as incomes rise households mostly purchase additional taste."

Also suggested by contemporary consumption theory is that consumption patterns of rural and urban folks are different. It is generally believed that rural folks tend to consume larger quantities of R&T than urban dwellers. Support for this view hinges on the fact that urban folks tend to have higher incomes than rural dwellers and, as such, their income elasticity of demand for calories is generally lower than that of rural dwellers.

R&T have been recognized to be of paramount importance for the Caribbean. Of particular interest is sweet potato. It has great potential to contribute to regional food security. The CFNI has identified it as a food source, which can positively reduce the incidences of obesity and the associated diseases such as diabetes and heart diseases. It is also a significant income earner for small farmers in at least 4 CARICOM Countries - Jamaica, St. Vincent & the Grenadines, St Kitts & Nevis, and Barbados. Recently, the product has taken on added dimensions, with a percentage of the production being exported and some being processed into a variety of products such as sweet potato chips, French fries, puddings, etc.

Figure 1. Maslow's Hierarchy of Needs and Food as a Source of Satisfaction.

Self-Actualization: Food to satisfy self fulfilment needs

Esteem: Food to satisfy prestige, superiority and status needs

Belongingness: Food to satisfy love, friendship, and affiliation needs

Safety: Food to satisfy physical and mental health needs

Physiological: Foods to satisfy hunger and thirst needs

For the purpose of this study St Vincent & the Grenadines has been chosen for the first case study. Review of the literature on the production, consumption and utilization of roots and tubers readily reveals the following:

- There is no recent information on the per capita consumption of these crops;
- Cost of production information is not readily available and, where available, in many cases the retail price bears little relation to the cost of production;
- Production is primarily on very small holdings under rain-fed conditions and as such is dependent on the vagaries of the weather;
- Production is not targeted to any specific user/market;
- The application of modern postharvest handling techniques is not widely utilized; consequently, gluts and shortage are often commonplace and the resultant price fluctuations.

The impact of globalization and trade liberalization on small-island states like St. Vincent has been widely documented in the development, economic and agricultural economics literature. It is now generally accepted that these processes offer both opportunities and threats to the small-island states. Of particular interest to many governments and NGOs in the CARICOM region in recent times is the issue of food security and the ability of their agricultural sectors to produce products competitively. Today, many food security policy analysts would agree that unravelling the linkages along the food availability – nutrition pathway is no easy challenge. However, many developmentalists are suggesting that increasing the efficiency and profitability of the R&T industry in developing countries, such as St. Vincent, could have tremendous impact on the economy, health and nutrition, employment generation for the rural poor, etc.

The success of the sweet potato industry in St. Vincent will rely on a carefully choreographed supply chain in a dance of difficult steps. Careful and detailed communication and co-ordination between the numerous farmers/producers, local retailers and exporters and the local processors will be a must before any improvement in the performance of the R&T sector in St. Vincent can be observed. Information on various aspects of the R&T sector upon which decisions can be made would be of paramount importance. This study attempts to provide one piece of the information in the complex sweet potato chain in St. Vincent.

The objectives of this study were:

- To conduct a survey to collect primary data on the per capita consumption of sweet potato;
- To estimate the per capita consumption of fresh sweet potato for adults in St. Vincent;
- To test whether there is any significant difference between the consumption of rural and urban dwellers.

APPROACH AND METHODOLOGY

The distinction between urban and rural is largely based on the predominant activity of the area, and not on distance removed from modernization. For purposes of this study rural is defined as areas where most of the activity and employment was linked to agriculture. Urban on the other hand was defined as those areas where less than thirty percent of the employment was directly related to agriculture. As a result of this definition the primary urban area was classified, as the coastal area between Campden Park and Prospect, whereas towns such as Sandy Bay, Georgetown, Layou and Fancy were considered rural (Figure 2).

The methodology employed in this study was as follows:

1. Review of secondary information on the production, consumption and utilization of sweet potato in St. Vincent in particular, and worldwide with relevance to the CARICOM region;
2. The development and administration of questionnaire to estimate the per capita consumption of sweet potato in St. Vincent;
3. Discussions with key industry players and officials from the Ministries of Agriculture and Trade with regards to sweet potato production, consumption and processing.

The per capita consumption questionnaire was administered to adults on mainland St. Vincent in January 2003. A total of 300 questionnaires were delivered to a random selection of workplaces, such as, banks, public service offices, telecommunication offices, factories and other places that were thought strategic to collect information from a wide cross section of the population. These businesses or organizations were scattered across the island, in both rural and urban areas.

The primary data collected was analyzed by using the statistical package 'SPSS' and consisted mainly of descriptive statistics, such as means and modes and cross tabulations.

Figure 2. Classification of rural (white) and urban (grey) areas in St Vincent.

RESULTS AND DISCUSSION

Of 300 questionnaires distributed, a total of 264 were returned, a response rate of 88%. However, only 227 respondents completed the information permitting the calculation of the per capita consumption for sweet potato. Further, of the 227 questionnaires that were used to calculate the consumption level, only 204 permitted the distinction of urban and rural to be made and these were equally represented, that is, 102 rural and 102 urban respondents.

Table 1 shows the distribution of the sample based on the frequency of consumption of sweet potato categories offered by respondents, the proportion of respondents in each category and the average quantity consumed in pounds. As can be seen in this table the majority of the sample reported eating sweet potato occasionally (defined as four or so times per year). Daily consumption of sweet potato was reported only for approximately 3% of the sample.

Table 1. Distribution of sample based on frequency of sweet potato consumption and the average quantity consumed per category (N=227).

Frequency of consumption	Proportion of respondents ($\mathbf{P}_i$)	Average quantity consumed in pounds (C_i)	Annual conversion factor (R_i)
Daily	0.0308	0.55	365
Once per week	0.2423	0.39	52
Twice per week	0.2026	0.41	104
Three times per week	0.1366	0.39	156
Fortnightly	0.0881	0.33	26
Once per month	0.0529	0.32	12
Occasionally	0.2467	0.30	4

The following formula was then used to calculate the annual per capita consumption for the sample:

$$\text{Annual per capita consumption} = \sum_{i=1}^{7} \mathbf{P}_i\mathbf{R}_i\mathbf{C}_i$$

Annual per capita consumption = 29.03 lb of sweet potato

Tables 2 and 3 show the distribution of the urban and rural sub-samples respectively, and the average consumption quantities in the various categories. The largest percentage of urban consumers of sweet potato is that of occasional consumers, whereas rural consumers are consuming sweet potato once per week. Within a week 63.73 percent of the rural sub-sample recorded consuming sweet potato while for the urban sample the corresponding figure was 61.77 percent. This result tends to suggest support for the notion that the rural dwellers would consume the R&T more frequently than their urban counterparts. However, the underlying proportions are not significantly different ($p = 0.772$).

The rural sub-sample average consumption level was higher than that of the urban sub-sample; however, the numerical difference was only 0.03 lb. The following hypotheses were tested using a Paired T-test:

$$\mathbf{H_o}: \quad \mu_U = \mu_R$$
$$\mathbf{H_a}: \quad \mu_U < \mu_R$$

Where: μ_U = Mean urban consumption
μ_R = Mean rural consumption

With a P-value of 0.615 the alternative hypothesis which stated that the mean urban consumption was less than the mean rural consumption was rejected.

Table 2. Urban sub-sample distribution and the average quantity consumed per category (N=102).

Frequency of consumption	Number of rural respondents	Percentage of sample	Average quantity consumed in pounds
Daily	4	3.92	0.75
Once per week	20	19.61	0.36
Twice per week	21	20.59	0.38
Three times per week	18	17.65	0.37
Fortnightly	13	12.75	0.34
Once per month	2	1.96	0.25
Occasionally	24	23.53	0.28

Table 3. Rural sub-sample distribution and the average quantity consumed per category (N=102).

Frequency of consumption	Number of rural respondents	Percentage of sample	Average quantity consumed in pounds
Daily	3	2.94	0.29
Once per week	28	27.45	0.41
Twice per week	21	20.59	0.46
Three times per week	13	12.75	0.42
Fortnightly	4	3.92	0.31
Once per month	9	8.82	0.35
Occasionally	24	23.53	0.33

CONCLUSION

Based on this study, the annual per capita consumption of sweet potato is estimated to be approximately 29 lb. It must be remembered, however, that the focus of the study was on adults and there is a notion that younger people are eating less R&T than adults. No statistical support was found for the view that rural dwellers on average consume larger quantities of R&T, specifically sweet potato, than urban dwellers.

The changes in consumer food behavior have a number of implications for research; however, testing some of the conventional notions requires some baseline information for meaningful comparisons to be made. Despite the methodological limitations that might be identified with this study, it attempted to provide one bit of the baseline information on sweet potato. As was revealed in this study, the conventional notion that urban dwellers consume less sweet potato than rural dwellers found no statistical support. Investigating the impact of traditional demographic factors in explaining the consumption of sweet potato in the Caribbean offers an exciting area of research with a lot of practical applications to our agribusiness sector.

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POBREZA, CRISIS Y PRÁCTICAS AGRÍCOLAS EN EL CULTIVO DE CAFÉ EN MÉXICO

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RESUMEN: El cultivo de café en México es de gran importancia por el número de productores dedicados a esta actividad, por el volumen de producción que ubica a nuestro país en quinto lugar a nivel mundial, y por el aporte de divisas. En los últimos años, el precio del café ha bajado considerablemente, al grado de hacer incosteable el cultivo. Ante esta crisis a nivel mundial, los productores mexicanos han recibido apoyos estatales para tratar de superar este problema; sin embargo, estos recursos son insuficientes y como consecuencia se ha visto en abandono total y parcial una gran parte de los cafetales, ocasionando la proliferación de plagas y enfermedades, y por ende una reducción en los rendimientos y los ingresos de los productores. Esta situación se ha convertido en un problema extremadamente grave, ya que ha impactado a pequeños productores que dependen de este cultivo por sus propias características de minifundio, niveles tecnológicos y pobreza, entre otras. Como estudio de caso se presentan los resultados de una encuesta aplicada a 200 indígenas totonacos productores de café, en donde se analiza la tecnología usada, los niveles de productividad y las condiciones socioeconómicas de las familias campesinas.

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THE EFFECTS OF AGRONOMIC PRACTICES, SEASONALITY AND AGRO-ECOLOGICAL ZONES ON SUCKERING, SCARRING, AND WEIGHT OF DASHEEN [*COLOCASIA ESCULENTA* (L) SCHOTT VAR. ESCULENTA]

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ABSTRACT: Scarring caused by the removal of suckers attached to the main corm at harvest is a major constraint to dasheen production, marketing and export in Dominica and the other dasheen producing islands of the Caribbean. Scarring makes the corms unpresentable, provides sites for disease infection, and accelerates rotting, which in turn reduces shelf life and marketability. Experiments addressing the above examined the effects of plant depths and spacing on suckering, during the wet and dry seasons, in Grand Bay (average annual rainfall 2400 mm, rainfall pattern – dry season from January to May, moisture regimes Ustic, soil types - smectoids, kandoids latosolics, young soils) and Wet Area (average annual rainfall 5300 mm, rainfall pattern – mild or no dry season, moisture regimes Udic, soil types - kandoids latosolics, alophonic latosolics, young soils). Results showed that the average number of suckers per dasheen corm was more in Wet Area, when compared to that of Grand Bay. Correlation and coefficients of the regression between suckering and scarring in Wet Area, were $r = 0.8647$ ($p<0.001$) in the wet season and $r = 0.4971$ ($p<0.01$) in the dry season. In Grand Bay, $r = 0.7128$ and $r = 0.7351$ in the wet and dry season, respectively, were highly significant ($p<0.001$). These correlations indicate that factors which reduced suckering would also reduce scarring. Suckering and scarring were significantly ($p<0.05$) reduced in both locations, during the dry season in response to decreasing plant spacing. In Wet Area, increasing plant depth was also found to reduce suckering during the wet and dry seasons ($p<0.05$). Fewer suckers were obtained at the deeper plantings when compared to those of the closer spacing. Reduction of suckers on the dasheen corm, as a means of improving corm appearance and prolonging shelf-life, without significantly affecting corm weight negatively, is obtainable in the Wet Area, in the wet and dry seasons, at plantings of 25 to 30 cm deep and a spacing of 55 x 55 cm. In Grand Bay, similar specifications can be obtained only in the wet season at plantings of 65 x 65 cm deep and a spacing of 25 to 30 cm.

INTRODUCTION

The dasheen cultivar called "Comme" or "Common dasheen" forms a single corm, which tends to be oval to round in shape (Prevost, 1977; Robin, 1993). Among the known cultivars it suckers the least and therefore has the fewest scars (Prevost, 1977). This cultivar is the predominant variety grown in Dominica and is recommended for export. In recent years, there has been an increasing demand for dasheen in the Leeward Islands, the United States Virgin Islands, the French West Indies, the expanding ethnic market in the United Kingdom and in Holland. This has resulted in a five-fold increase in dasheen exports over the past ten years.

Although dasheen production and exports are on the increase, exports are still constrained by post-harvest rots due to physical damage to corms during harvest and scarring caused by the removal of suckers during harvest and post-harvest activities (Adams et al., 1985; Cooke et al., 1988; Crucefix, 1990). Whereas physical damage can through care at harvest be prevented, scars cannot. Scars make the corms un-presentable and are sites for disease infection (Adams et al., 1986; Wickham and Elango, 1990) and rotting (Crucefix, 1990).

Post-harvest treatments using Ridomil MZ at the rate of 14 g/23 liter for the extra-regional market and 2.8 g/23 liters for the regional market (Adams et al., 1985; Robin, 2000) have been used as a means for controlling these rots and extending the shelf-life of healthy, undamaged corms.

This technology has sustained the increased exports of dasheen corms to the United Kingdom, Holland and the Caribbean. However, the use of Ridomil MZ as a post-harvest dip has come under serious scrutiny, as global concerns for food safety are addressed. European Union concerns have been manifested by the introduction of zero tolerance to chemical residues on fresh produce. Implementation of this policy will come into effect in 2005 and will affect countries that fail to scientifically prove that chemical residue on fresh produce is within the recognized limits of the various international conventions. Alternative post-harvest technologies are under review and validation; a renewed emphasis on Integrated Crop Management and Good Agricultural Practices which promote safety and health concerns is becoming part of the farm and crop management system of production. Technologies that further reduce suckering, and in turn scarring, are simultaneously being validated, as a means of further reducing avenues for corm infection. This reduction of suckerings coupled with reduced corm damage at harvest, should reduce or remove the need to use chemical post-harvest dips.

Spacing (Cable and Asghar, 1981), depth of planting (Robin, 1990), nitrogen fertilizer (de la Pena, 1990), moisture (Ezumah and Plucknett, 1981; de la Pena, 1983; Pardarles, 1985), and weed competition (Gurnah, 1985) are all known to affect suckering. Observations have shown, that in Dominica, corms of the "Comme" variety have different levels of suckering, depending on location, time of planting and the cultural practices implemented. However, how these agro-ecological zones and cultural practices affect suckering has not been scientifically examined.

A study was therefore conducted to investigate how variations in crop density and planting depth affected suckering of the "Comme" dasheen, when grown in the wet and dry seasons, in two contrasting agro-ecological zones of Dominica.

MATERIALS AND METHODS

Experiments were conducted in two of the major dasheen producing areas: Grand Bay located in zone A2 and Wet Area located in zone D3. Table 1 describes the two locations.

The experiments examined the effects of three planting depths: 20, 25, and 30 cm and three spacing: 55x55 cm (33,025 plants/ha), 65 x 65 cm (23,645 plants/ha) and 75 x7 5 cm (17,760 plants/ha) in a 3x3 factorial arrangement. The nine treatments were laid out as a randomized block with three replicates at each site. Plots were 3.75 x 4.5 m, each plot contained a total of 56, 40, and 30 experimental plants, for the treatments 55 x 55 cm, 65 x 65 cm, and 75 x 75 cm, respectively.

Table 1. Climatic, topographic, and soil data for the two agro-ecological zones in Dominica where the experiments were conducted.

	Location	
Agro-ecological characteristics	Grand Bay	Wet Area
Average annual rainfall	2400 mm	5300 mm
Rainfall pattern	Dry season -Jan. to May	Mild or no dry season
Moisture regimes	Ustic	Udic
Moisture supplying capacity	Low to very low	Moderately high
Temperature	27°C	25°C
Altitude	235 m	500 m
Natural vegetation	Dry scrub	Tropical moist forest
Soil types	Smectoids, Kandoids latosolics, young soils	Kandoids latosolics, Alophonic latosolics, young soils
Soil physical characteristics	Clay loam	Sandy clay loam
Sand	37%	60%
Silt	23%	19%
Clay	40%	25%
Bulk density	1.1 g/cc	0.6 g/cc
Porosity	0.6	0.8
Mean annual soil temperature	Isohyperthermic >25°C	Isothermic 15 - 22°C

Both sites were cleared of vegetation and sprayed with paraquat (25 cc/l) before planting. Suckers of the variety "Comme", with the upper 2 to 4 cm of the corm intact, a basal diameter of 5.0 to 7.0 cm, and a mean weight of 245±15 g, were used as planting material. Suckers were selected from the most vigorous plants, cleaned of all roots, dead tissue and soil; then dipped in a solution of bleach (containing 2% sodium hypo-chlorite) for 15 to 20 minutes. Petioles were cut back to a length of 25 to 30 cm. Planting material came from the same source.

Wet season plantings in Wet Area and Grand Bay were carried out in May. Dry season plantings in Grand Bay and Wet Area were carried out in December and January, respectively.

The experimental plots were kept weed-free during the first 3 months. Paraquat (20 cc/l) was used to control weeds before canopy formation. Subsequent weddings were done manually. At 0.5 and 2 months after planting, 57 g of fertilizer N:P:K (16:8:24:2) + 2MgO was banded around the plants. Within one to two weeks after the second fertilizer application, soil was mounded to a height of 6 to 8 cm around the base of each plant petiole, by moving soil from within a radius of 30 to 35 cm around each plant. Manual harvesting with a fork and cutlass took place 9 to 10 months after planting.

Daily rainfall data were collected throughout the experiment. The number of visible suckers around the main corm of all experimental plants was recorded in each plot one month before harvest. After harvest the number of scars on each corm, from each sample plant, in each plot was also counted. Corm weight was also recorded.

RESULTS AND DISCUSSION

Cumulative monthly rainfall, shown in Tables 2 and 3, was higher in Wet Area both in the wet and dry seasons. Rainfall received by the crop during the critical growth period (0 to 6 months after planting), were 990 mm and 1300 mm higher in Wet Area during the wet and dry seasons, respectively.

Table 2. Comparison of the cumulative monthly rainfall (mm) received by the dasheen plants during the wet season at Grand Bay and Wet Area in Dominica.

Location	Months after planting				
	1.5	3	4.5	6	9
Grand Bay	340	550	980	1230	2000
Wet Area	480	1150	1700	2220	4180

Table 3. Comparison of the cumulative monthly rainfall (mm) received by the dasheen plants during the dry season at Grand Bay and Wet Area in Dominica.

Location	Months after planting						
	3	4	5	6	7	8	9
Grand Bay	450	600	810	1200	1320	1785	2070
Wet Area	1000	1290	1775	2500	3175	3585	N.A.

N.A. – not available

Table 4 shows that, positive and significant correlations were obtained between the number of visible suckers and number of visible scars, an indication that agronomic practices which reduce suckering would also reduce scarring.

Table 4. Correlation coefficients between the number of visible suckers and the number of visible scars on dasheen corms, for Grand Bay and Wet Area locations, during the wet and dry season in Dominica.

Location	Season	r value
Grand Bay	Wet	0.7128***
Grand Bay	Dry	0.7351***
Wet Area	Wet	0.8647***
Wet Area	Dry	0.4971**

** - $P<0.01$ *** - $P<0.001$

Table 5 shows that the closer spacing significantly reduced the number of suckers per plant in both locations, during the dry season ($P<0.05$). During that period moisture supply was a limiting factor, and interplant competition for soil moisture and nutrients increased. A similar finding was repeated by El-Habbasha et al. (1976).

Table 5. Mean number of suckers per dasheen plant, for different spacing during the wet and dry seasons, at the Grand Bay and Wet Area locations in Dominica.

Treatment Spacing (cm)		Number of suckers per plant			
	Location	Grand Bay		Wet Area	
	Season	Wet	Dry	Wet	Dry
55 x 55		3.4	3.5	4.0	4.3
65 x 65		3.6	4.2	4.1	4.5
75 x 75		3.9	5.1	4.4	5.7
S.E.D. (16 d.f.)		0.51	0.58	0.40	0.42
F test		NS	*	NS	*

NS – Not significant, * - P <0.05

Table 6 shows that reduction of suckering at the closer plant spacing during the dry season in Grand Bay, also significantly (P <0.05) reduced average main corm weight per plant (514–612 g), below that of the recommended (900–1300 g) export specifications (Robin, 1993).

Table 6. The effects of plant spacing on average corm weight of the dasheen plant during the wet and dry seasons, in Grand Bay and Wet Area locations in Dominica.

Treatment Spacing (cm)		Main corm weight per plant (g)			
	Location	Grand Bay		Wet Area	
	Season	Wet	Dry	Wet	Dry
55 x 55		930	514	950	858
65 x 65		1004	612	958	886
75 x 75		905	808	1077	993
S.E.D. (16 d.f.)		105	75	106	82
F test		NS	**	NS	NS

NS – Not significant, * *- P <0.01

Since corm weight as an export specification has priority over scarring, it would not be practical to use close spacing to reduce suckering in Grand Bay during the dry season.

In the Wet Area, as shown in Table 7, increasing plant depth significantly reduced the number of suckers per plant both in the wet and dry seasons (P<0.05). Bud dormancy seems to be more prolonged at deeper plantings, but how this occurs in dasheen corms is unknown.

Table 7. Mean number of suckers per dasheen plant, for different plant depths during the wet and dry seasons, at the Grand Bay and Wet Area locations in Dominica.

Treatment Spacing (cm)		Number of suckers per plant			
	Location	Grand Bay		Wet Area	
	Season	Wet	Dry	Wet	Dry
55 x 55		3.4	4.7	4.6	5.5
65 x 65		3.4	4.2	4.9	5.1
75 x 75		3.1	3.9	2.7	3.9
S.E.D. (16 d.f.)		0.46	0.6	0.93	0.42
F test		NS	NS	*	*

NS - Not significant, * - P <0.05

Suckering was significantly influenced in the Wet Area during the dry season by variations in both plant spacing and plant depth.

Table 8 shows that deeper plantings in the Wet Area, during the wet season, increased average main corm weight per plant. Similar observations were made for the wet season plantings in Grand Bay, but the differences were not significant. Corm quality in the Wet Area was further enhanced at the deeper plantings, in the wet and dry season, as a result of a reduction of the number of scars per corm and maintenance of other marketable corm characteristics. Similar findings were obtained in Grand Bay during the wet season.

Table 8. The effects of depth on the average main corm weight of the dasheen plant during the wet and dry seasons, in Grand Bay and Wet Area locations of Dominica.

Treatment Spacing (cm)	Main corm weight per plant (g)			
Location	Grand Bay		Wet Area	
Season	Wet	Dry	Wet	Dry
55 x 55	877	624	874	782
65 x 65	923	634	964	846
75 x 75	1038	677	1146	1110
S.E.D. (16 d.f.)	104	75	106	82
F test	NS	NS	NS	**

NS – Not significant, * *- P <0.01

There was no significant interaction between spacing and plant depth on the number of suckers per plant during the wet and dry seasons.

Overall suckering was higher in Wet Area when compared to Grand Bay, across season and irrespective of the treatments applied. This finding can be attributed to the higher rainfall levels that were observed in Wet Area. Ezumah and Plucknett (1981) indicated that whether suckers matured to contribute significantly to yield depended on water availability.

CONCLUSION

Reduction of suckers on the dasheen corm across seasons, as a means of improving corm appearance and prolonging shelf-life without significantly affecting other corm export weight specifications, is obtainable in the Wet Area of Dominica at plantings of 25 to 30 cm deep and a spacing of 55 x 55 cm. In Grand Bay similar specifications can be obtained only in the wet season at spacing of 65 x 65 cm and planting depths of 25 to 30 cm.

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ANALYSE DES PRATIQUES DES PRODUCTEURS D'ANANAS DE LA MARTINIQUE: UN OUTIL POUR LA MISE EN ŒUVRE DE POLITIQUES DE QUALITE (NORME AGRI-CONFIANCE) ET DE PROTECTION DE L'ENVIRONNEMENT (CONTRATS AGRICULTURE DURABLE)

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RESUME: La filière ananas connaît actuellement, en Martinique, une profonde restructuration caractérisée par la commercialisation de nouveaux produits (crush, jus et cubes aseptiques). Pour réussir le pari de cette transformation, les responsables de la filière ont décidé d'adopter un système d'assurance qualité basé sur les normes ISO 9000 pour la transformation et agri-confiance pour la production. Parallèlement, et pour mieux répondre aux nouvelles exigences environnementales de la société, les producteurs cherchent désormais à réduire l'emploi de produits de synthèse et ceci, avec l'aide de l'Etat français qui a récemment mis en œuvre des «contrats agriculture durable». La définition et la mise en œuvre de toutes ces normes et outils nécessitent de connaître parfaitement les pratiques des agriculteurs. L'analyse de ces dernières, pour chaque type d'opération technique (fertilisation, traitements phytosanitaires, etc.), a permis de mettre en évidence un décalage important entre les recommandations techniques des organismes professionnels et les pratiques des agriculteurs, et cela pour au moins un tiers d'entre-eux. Ces écarts représentent des risques potentiels non négligeables de dégradation de l'environnement et d'obtention de fruits «hors norme». Quant à l'analyse des itinéraires techniques, elle a permis d'identifier cinq types d'agriculteurs selon le niveau de respect des prescriptions techniques. Cette typologie peut constituer un outil essentiel pour la définition de programmes de formations et la mise en oeuvre d'une politique de suivi des produits (traçabilité).

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THE COMMODITY SYSTEMS APPROACH TO SUSTAINABLE AGRICULTURAL DEVELOPMENT IN ST. VINCENT AND THE GRENADINES WITH REFERENCE TO SPECIFIC CROPS–CHALLENGES AND OPPORTUNITIES

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ABSTRACT: This paper explores the practical application of the commodity systems approach to agriculture in St Vincent and the Grenadines with specific reference to hot pepper, dasheen and sweet potato. The analysis of the forward and backward linkages among the researchers, producers and the marketing agency led to targeted interventions that resulted in the selection of suitable varieties, increased production, improved quality, expanded markets and increased revenue for the agricultural sector. These results are expected to form a platform for the implementation of this approach to the development of other competitive agricultural commodities through expanded production, targeted marketing and the introduction of value added products.

INTRODUCTION

The total land area of St. Vincent and the Grenadines (SVG) is estimated at 38,785 ha, and of this amount some 7,202 ha is currently used for agriculture (National Agricultural Census, 2000). The agricultural sector contributed 10.6% of GDP in 2000, and its performance has been directly linked to trends in the banana industry. Changes in the international trade milieu, globalization, trade liberalization and erosion of market preferences and shares have led the Government of SVG to promote agricultural diversification and tourism.

The major components of the Government's agricultural diversification policy framework include export development, food and nutrition security and import substitution (Agricultural Diversification Plan, 1997). In this context, a number of priority commodities were selected on the basis of their measure of competitiveness in extra-regional, regional and/or domestic markets.

The priority crops of importance include: Fruits –mango, citrus, golden apple; Root crops -dasheen, eddoe, sweet potato, yam, tannia, cassava, arrowroot; Vegetables –tomato, cabbage, sweet pepper, hot pepper; Food crops –cowpea pigeon pea, peanut, maize.

In the face of globalization and free trade markets, the potential for production, marketing and utilization of these commodities in SVG can be further developed when the tried and proven Commodity Systems Approach (CSA) is employed. A commodity chain entails tactical interventions at critical nodes of the commodity chain to attain simultaneous development of production, services and marketing.

The methodology produces the following outputs:

- A description of the commodity system, identifying the principal components of the system and major participants and their roles;
- Identification of the priority problems with each component of the commodity system and their causal relationships;
- Identification of possible solutions to the problems and their order of priority;
- An adequate database to identify project ideas and prepare project profiles (La Gra, 1990).

Figure 1 illustrates the different types of participants functioning at diverse points in most commodity systems. The system, which is a consortium of farmers, marketing intermediaries (transporters, exporters, etc.), Ministry of agriculture and research institutions, farmers' organizations and marketing boards, reflects a team approach to problem identification and solving. The dynamic interaction of participants in their respective roles defines the limitations and determines the viability of the process. The commodity system can be sustainable when agro-industry participants and farmers realize profits upon supplying goods and services to their respective markets within the system.

The specific results include one or all of the following:

- Enhanced crop husbandry practices and production levels,
- Enhanced quality of the product,
- Developed and improved access to markets at the local, regional and international levels,
- Improved institutional delivery services to farmers,
- An enabled private sector, especially traders and exporters, to support farmers in producing commodities that have high market demand,
- Improved responsiveness of policy to smallholders' needs,
- Empowerment of farmers,
- Improved farmers associations that are business oriented.

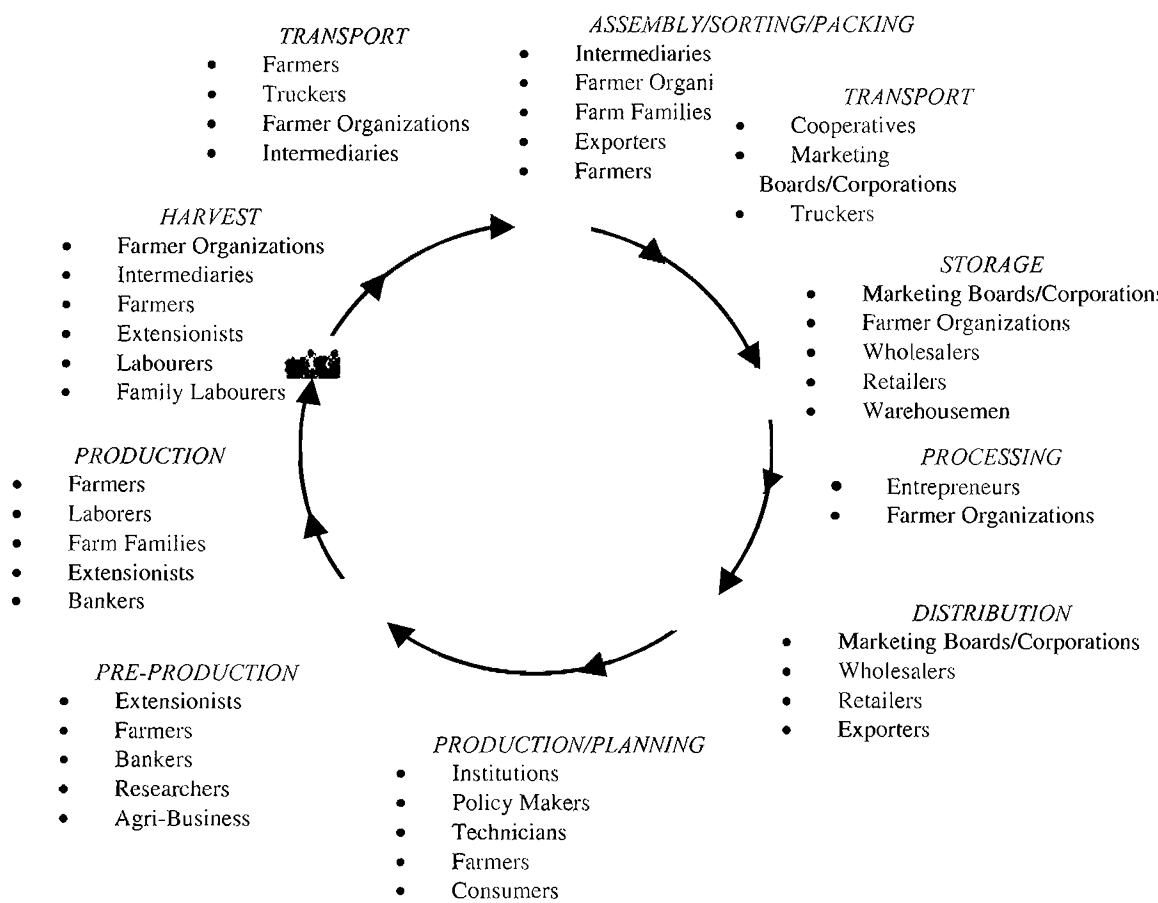
The CSA was successfully utilized in support of the agricultural diversification programme in SVG for the production and export of dasheen. In 1998 a working group on dasheen production and marketing was established to execute the phased establishment of 180 acres of dasheen. The participants of the group included representatives from the Ministry of Agriculture, the Inter-American Institute for Cooperation on Agriculture (IICA), St. Vincent Marketing Corporation (SMC), National Farmers Union, the Caribbean Agricultural Research and Development Institute (CARDI), Development Corporation (DEVCO) and other cooperating institutions. Activities within the work plan and the agencies responsible for its execution are outlined in Table 1.

Through the CSA, there has been a steady increase in the production and marketing of dasheen in SVG. The export volumes moved from 1,479,013 kg in 1998, to 1,621,125 kg in 1999, and a high of 2,137,331 kg in 2000. This approach was applied to hot pepper and has led to major improvements in the performance of the commodity chain.

Table 1. Work plan of the working group on dasheen production and marketing in SVG.

Objective	Activities	Responsible
Schedule phased establishment of 180 acres of Dasheen. Jun.–Dec.1998	Identification of suitable agro-economic zones for dasheen production.	MOA, CARDI, Exporters
	Meeting of farmers at district level in identified areas to encourage dasheen production.	Working Group
	Mobilization of resources (farmers, land, etc.) to establish 180 acres of dasheen at the rate of acres per month.	MOA
	Selection, rapid multiplication and distribution of suitable planting material.	MOA, CARDI, IICA
	Technical Support to farmers and monitoring of production.	MOA, CARDI, Exporters
	Training workshops in dasheen production, harvesting and post harvest handling (farmers and extension officers).	MOA, IICA, CARDI
	Field tours, local and regional (farmers and extension officers).	MOA, IICA, IFAD
	Training workshop in post-harvest handling and packaging (extension officers and exporters).	MOA, CARDI, IFAD
	Project promotion and dissemination of market information.	IFAD, MOA, Exporters
	Harvest and export.	Farmers, Exporters
	Maintenance of database in dasheen production.	MOA

Figure 1. Participants in the commodity system. (Source: La Gra, 1990)



CASE STUDY: HOT PEPPER (*CAPSICUM* SPP.) PRODUCTION AND MARKETING IN ST. VINCENT AND THE GRENADINES

Hot pepper is of special interest to every CARICOM country as it is viewed as an export crop of considerable potential in the international markets of Europe and North America. According to Stewart and Fletcher (2000), the major exporters in the region are Jamaica, Trinidad and Tobago, and St. Lucia, with smaller volumes from Barbados, Dominica and Belize. Regional exports of hot pepper, fresh and processed, from 460 tonnes in 1991 to 3416 tonnes in 1997, with 99% exported to extra-regional markets. Concomitantly, a significant amount of hot pepper products (pepper sauce, ground/crushed pepper, etc.) are imported into the region, primarily from countries in Asia and Latin America. Imports in 1995 were 954 tonnes, 1193 tonnes in 1996 and 763 tonnes in 1997. St. Vincent and the Grenadines contribute a limited volume of hot pepper, fresh and processed, to total CARICOM exports.

The major export markets for fresh hot peppers from the Caribbean exist in the United States, Canada and the United Kingdom. The total imports of US fresh hot peppers have consistently grown over the past 5 years. In 2001, imports totaled over 150,000 MTs valued at $181 million with almost 99% of imports from Mexico. Stewart and Fletcher (2000) reported that Caribbean countries account for 0.3% of the US imports of fresh and chilled peppers, 5% of the UK imports of fresh hot pepper and less than 0.5% of the Canadian fresh hot pepper. Caribbean producers are able to compete on the basis of product differentiation and by focusing on niche markets comprising people of Caribbean origin who generally prefer Caribbean varieties of hot pepper.

The ethnic populations in the UK and US have also driven the demand for hot peppers, and importers believe that their crossover into mainstream consumer market is both real and sustained. Apart from exposure to ethnic dishes (Indian, Caribbean, and Latin America) in their own country, other factors that have led to this development include international travels abroad and exposure to new ingredients via popular gourmet television programs. In addition, a lesser reported trend in the US is the use of hot spices and ingredients to add more flavors to relatively bland foods. CARICOM countries and specifically St. Vincent and the Grenadines can capitalize on the increasing markets for hot pepper, both fresh and processed, and those niche markets comprising peoples of Caribbean origin.

St. Vincent and the Grenadines have produced and exported relatively small quantities of hot pepper during the 1990s. The quantity of annual exports from 1997-2001 is shown in Table 2. During this period, 1998 had the highest quantity and value exported, 189,536 kg and EC$122,526, respectively. This coincided with the execution of the IFAD Project when a task force was formed comprising the MAF, CARDI, IICA, SVMC, and farmers. This was not sustainable after the closure of the Project resulting in decreased yields.

Table 2. St. Vincent and the Grenadines total exports of hot pepper and hot pepper products from 1997 to 2001.

Year	Quantity (kg)	Value (EC$)
1997	43,698	31,313
1998	189,536	122,526
1999	80,016	88,901
2000	49,416	39,644
2001	3,461	2,233
2002	207,905	124,836
2003 – First Quarter	98,531	137,830

Source: Ministry of Agriculture, St. Vincent and the Grenadines

IDENTIFICATION AND DESCRIPTION OF THE PROBLEM

The hot pepper industry in St. Vincent and the Grenadines from 1991 to 2000 was characterized by low production, and demonstrated limited response to the demands of the market. In 1995 an export market was identified for fresh hot pepper from SVG by the FAO Project via the Agricultural Diversification Co-operation Unit of the OECS based in Dominica. The St. Vincent Marketing Corporation was given the responsibility for the export marketing and the Ministry of Agriculture, Lands and Fisheries was given the responsibility to implement the production program.

The problems were identified in the following areas:

1. Planning
    a. Unavailability of credit
2. Production
    a. Lack of proper irrigation systems
    b. Poor quality and inadequate seedling supply
    c. Inadequate supply of production inputs (fertilizers, pesticides, fungicides, etc.)
    d. Low yields
    e. Pest and disease problems (mites)
    f. Inadequate post harvest infrastructure
3. Marketing
    a. Under utilization of markets
    b. Inability to consistently supply produce in the quantities and quality demanded by the market

FORMULATION AND EXECUTION OF THE SOLUTION

A commodity systems approach was adopted in 2001 with the formation of a National Integrated Marketing and Production Strategy Task Force (NIMPS). A fifteen-member hot pepper task force committee was appointed, drawn from the St. Vincent Marketing Corporation, Ministry of Agriculture Lands and Fisheries, Inter-American Institute for Cooperation on Agriculture (IICA), the Caribbean Agricultural Research and Development Institute (CARDI) and other collaborating institutions.

The key members in this commodity chain and their functions are hereunder listed:

1. The Ministry of Agriculture Lands and Fisheries
    a. Research and Development
    b. Extension Division:
        i. monitoring production practices
        ii. identification of pest and disease problems
    c. Communication Division – Dissemination of information to farmers via radio programs, fact sheets and newsletters
2. Mission Taiwan
    a. The production of high quality seedlings
3. CARDI
    a. Provide certified seeds for seedlings production
    b. Conduct research on the agronomy of hot pepper
    c. Demonstrate improved production practices
    d. Selection of suitable varieties for the export markets
4. St. Vincent Marketing Corporation
    a. The Marketing Corporation entered into contractual arrangement with farmers to provide a guaranteed price and markets for hot peppers
    b. This arrangement also ensures that farmers produce varieties that meet with market requirements and production synchronized with periods of high price and demand for hot pepper
    c. The provision of credit for agricultural inputs
5. National Development Foundation (NDF) and Credit Unions
    a. Credit to farmers for startup activities
6. Farmers
    a. Production and marketing of hot peppers

METHODOLOGY

The major elements of this approach included the establishment of a multidisciplinary task force to critically assess the commodity chain with respect to backward and forward linkage and to elucidate the constraints arising therefrom. A series of interventions were arrived at and each agency was given responsibility to execute the constituent activities. Regular meetings were held to monitor and evaluate the composite interventions.

RESULTS

QUANTATIVE INDICATORS OF THE SUCCESS OF THE CSA

Exports began in 1995 with weekly shipments of 4500 lbs. (2045 kg) from November 1995 to April 1996. The variety cultivated from 1995-2001 was the West Indies Red. However, to meet the changing market demands, varieties which are dark green at maturity were also planted in 2002.

At the start of the program in 2001, some 15 farmers were involved in hot pepper production. There was a 10 fold increase in the number of farmers from inception to 2003 and almost a 20 fold increase in the production acreage from 33/4 in 2001 to 65 in 2003 (See Table 3). The export of hot peppers from the St. Vincent Marketing Corporation also showed dramatic increases after the implementation of the Commodity System Methodology in 2001 (Table 4).

Table 3. Number of hot pepper farmers and acreage under cultivation during the implementation of the Commodity System Approach.

Years	Number of Farmers	Production Acreage
2001	15	3.75
2002	65	28
2003	150	65

Table 4. Hot pepper exports from the St. Vincent Marketing Corporation (1994-2003).

Year	Quantity (kg)	Value (EC$)
1994	253	604
1995	369	1,140
1996	861	3,027
1997	2,121	8,315
1998	1,076	46,999
1999	29	137
2000	80	308
2001	508	1,803
2002	32,106	112,424
2003 (January – June 16)	123,339	392,632

INTERVENTIONS ALONG THE COMMODITY CHAIN

Critical nodes along the commodity chain	Changes
Production/Planning	- improved understanding of the roles of participants along the commodity chain - increased access to information on production and marketing - greater availability of credit facilities to farmers for agricultural inputs - empowerment of farmers and increased levels of farmer participation in the hot pepper industry - better planning of production activities to meet the demands of the market
Production	- better quality seedlings - introduced varieties from Trinidad (Faria and Hood), CARDI green, Scotch Bonnet, Orange Habaneros, Yellow Santa Fe, Fresno, Cherry to meet with the changing demands of the market - improved delivery and timeliness of extension services to farmers - improved crop husbandry practices with better agricultural inputs - better quality produce and increased yields
Harvesting and Post harvest	- improved harvesting techniques - improved post harvest handling, sorting and grading
Marketing	- greater responsiveness to the demands of the market for quality and varieties of peppers -Guaranteed price and market for farmers produce - Identification and penetration into new niche markets
Distribution	- improved handling, transport and marketing of produce

CONCLUSION

The success of the Commodity System Approach was evident by overall improvements in production and marketing of hot peppers. This is exemplified by the increased participation of farmers and the proven success of the dasheen and hot pepper industries. Currently the Task Force Approach is being applied to sweet potato production. Given the thrust towards agricultural diversification, this method and its application will continue to hold great promise for the viability of the agricultural sector in SVG. The introduction of value added products could also be the catalyst for the expansion in production and utilization of these crops.

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DEVELOPMENT OF F1 HYBRID PAPAYAS FOR THE VIRGIN ISLANDS

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ABSTRACT: Consumers in the Virgin Islands have a preference for large papaya fruits in the range of 1 kg and above. The large fruited papaya varieties, however, tend to have undesirable characteristics as lower fruit number per plant, lower percentage total soluble solids (sweetness), and lack firmness, thus making them susceptible to damage during harvest and marketing. Through breeding and selection, F1 hybrid papayas have been developed. The inbred lines chosen that developed F1 hybrids with commercial potential were these combinations: '356-3' and 'Cariflora'; 'Cariflora' and 'Solo Sunrise'; 'Cariflora' and 'Tainung 5'; 'Puerto Rico Dwarf', and 'Yuen Nong 1'. Plant characteristics that were evaluated included production of fruit starting within 1 m from the soil surface, stem diameter to tolerate winds, fruit set, as well as tolerance to both papaya ringspot virus and high pH soils. Evaluation of fruit quality included fruit weight, length, width flesh thickness, and sugar content.

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MOUNTAIN BANANAS FROM FRENCH WEST INDIES: FIRST DATA OF PHYSICO-CHEMICAL CHARACTERIZATION

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ABSTRACT: In order to propose a 'mountain' banana on the French market, the physico-chemical caracteristics of bananas, growing at two different altitudes (Low 50 m and High 300 m) in Martinique, French West Indies, were compared. At the same harvest stage, fruits from the high altitude were significantly heavier, bigger and had a higher density and firmness than fruits from the lower altitude. After ripening, the higher altitude fruits were firmer and their peel was harder than those of the fruits from the lower altitude. The fruits from the higher altitude had significantly higher total solids, soluble solids, glucose, and fructose contents than the lower altitude fruits.

BANANE DE MONTAGNE AUX ANTILLES FRANCAISES: PREMIERS ELEMENTS DE CARACTERISATION PHYSICO-CHIMIQUE

RESUME: Afin de proposer sur le marché français une banane dite de montagne, les caractéristiques physico-chimiques de bananes, produites à deux altitudes différentes (B: 50m et H: 300m) en Martinique (France), ont été comparées. A même stade de récolte, les fruits H ont été significativement plus gros, lourds, denses et fermes que les fruits B. Après mûrissage, les fruits H ont été plus fermes et leur peau plus dure que celles des fruits B. Leurs teneurs en matière sèche, en extrait sec soluble, en glucose et en fructose ont été significativement plus élevées que celles des fruits B.

INTRODUCTION

La production bananière est une des principales ressources économiques des Antilles françaises. Pour faire face à la forte concurrence commerciale d'autres régions exportatrices, présentant des coûts de production moins élevés, la banane antillaise doit pérenniser et fidéliser son marché en proposant de nouveaux produits. L'identification d'une « banane de montagne » permettrait de valoriser une partie de la production antillaise en segmentant le marché.

A ce jour, il existe peu de données objectives mettant en évidence des différences de qualité entre la banane d'altitude et de plaine. Chillet et al., (2000) ont montré que des bananes d'altitude étaient moins sensibles à Colletotrichum musae que les bananes de plaine. Récemment, Brat et al., (2003) ont mis en évidence des différences de composition aromatique entre des bananes récoltées à 50 et 450 m d'altitude.

Ces travaux sont encourageants car ils alimentent la réflexion sur l'identification d'une banane de montagne. C'est dans cet objectif qu'une étude a été menée en Martinique sur l'effet de l'altitude sur les caractéristiques physico-chimiques des bananes. Les essais ont été conduits sur deux parcelles situées à 50 et 300 m d'altitude appartenant à un même planteur, ceci afin de s'affranchir des effets des pratiques culturales.

MATERIEL ET METHODE

Matériel végétal

L'étude a été menée chez un producteur de Basse Pointe (Martinique). Les deux parcelles étaient situées à 50 m (B) et 300 m d'altitude (H), sur un sol de type andosol sur cendres et ponces. Pendant la durée de l'étude (décembre 2002 à avril 2003), les températures journalières ont été en moyenne de 24,9°C sur la parcelle B et de 22,9°C sur la parcelle H. La variété étudiée a été la Grande Naine, sous groupe des Cavendish (AAA). Les floraisons ont été marquées entre le stade « fleur pointante inclinée » et le stade « première levée de bractée ». Tous les régimes ont reçu les mêmes soins. Sur chaque parcelle, 20 régimes ont été récoltés à 4 sommes thermiques différentes: 890°j, 960°j, 1015°j et 1090°j, soit 5 régimes par stade de récolte. La somme thermique est égale à la somme des températures journalières, calculée en degré.jour, depuis le stade floraison jusqu'à la récolte en utilisant comme température de base 14°C (Ganry et Meyer, 1975). Les intervalles entre le stade floraison et le stade de coupe (IFC) sont donnés dans le tableau 1. Les fruits ont été lavés puis traités avec une solution fongique.

Tableau 1. Stade des fruits à la récolte selon leur lieu de production

	parcelle B (50 m d'alt.)	parcelle H (300 m d'alt.)
stade de récolte (°jours)	IFC (jours)	
890	79	100
960	86	107
1015	91	114
1090	100	121

Conservation et mûrissage des fruits

Les fruits ont été emballés dans des sacs de polyéthylène perforé pendant 18 jours à 14°C. Ils ont ensuite été mûris à 21°C avec une concentration d'éthylène à 1000 ppm pendant 24 heures, puis conservés à la même température jusqu'au stade de maturité « jaune tigré ».

Analyses

Au stade de récolte : la longueur, le grade, le poids et la densité des fruits ont été mesurés selon Dadzie et Orchard (1997). La dureté de la peau (exprimée en N) et la fermeté des fruits (exprimée en N/s) ont été mesurées à l'aide d'un pénétromètre TA-XT2 selon la méthode décrite par Chillet et de Lapeyre de Bellaire (1996).

Au stade de maturité 'tigré': La fermeté et la dureté des fruits ont été mesurées dans les conditions citées précédemment. La pulpe des fruits a été broyée finement à l'aide d'un broyeur Waring Blendor. Le pH de la purée de banane a été mesuré à l'aide d'un pH-mètre Quick 31314. Pour la mesure de la matière sèche (exprimée en g/100 g de matière fraîche), 2 g de purée ont été séchés dans une étuve à 70°C pendant 24 heures, puis pesés.

La teneur en extrait sec soluble (exprimée en degré Brix) est mesurée par réfractométrie après dilution dans l'eau à 50% de la purée de banane et centrifugation (10000 tours/min pendant 10 min). Le reste du surnageant est congelé à -20°C jusqu'à l'analyse des sucres. Les teneurs en sucres (saccharose, glucose et fructose) (exprimées en g/100mL de jus) ont été analysées par HPLC (Shimadzu SIL-9A). 20µL d'échantillon + un étalon interne (mannitol à 0,4%) ont été injectés sur une colonne CH-620 (Catalog n°25210). Le débit de la phase mobile H_2O a été de 0,5 mL/min.

Les sucres ont été détectés par réfractométrie (Beckman 156 RID). Une analyse sensorielle discriminative de type 'test triangulaire' a été réalisée dans les conditions décrites par Lespinasse et al., (2002) à l'aide d'un panel de 24 juges. L'analyse de la variance a été réalisée selon un dispositif à 2 facteurs croisés : altitude (2 modalités) X stade de récolte (4 modalités) avec 5 répétitions (SAS, 1986).

RESULTATS ET DISCUSSION

Caractéristiques des fruits à la récolte

A la récolte, les fruits H ont été significativement plus lourds, plus gros, plus denses et fermes que les fruits B, à même somme thermique (Tableau 2). Un effet stade de récolte a été observé pour le grade et la densité.

Tableau 2. Caractéristiques des fruits H et B à la récolte

	parcelle B (50 m d'alt.)		parcelle H (300 m d'alt.)		Test F pour les 2 facteurs et leur interaction (1)		
	moy.	ect	moy.	ect	altitude	stade récolte	alt*SR
longueur (cm)	26,4	1,2	26,5	1,1	NS	NS	NS
poids (g)	185	23	205	20	**	NS	NS
grade (mm)	36,0	2,3	37,5	1,7	***	***	*
densité (g/mL)	0,977	0,006	0,988	0,005	***	***	NS
dureté de la peau (N)	57,6	5,9	58,3	5,9	NS	NS	NS
fermeté du fruit (N/s)	154	14	168	10	**	NS	NS

Les valeurs sont les moyennes (et les écarts-type) de 4*5 répétitions
(1) NS : différence non significative ; *, **, *** : différence significative respectivement au seuil de 0.05, 0.01 et 0.001

Les écarts climatiques entre les parcelles H et B pourraient être à l'origine des différences de poids et de densité entre les fruits. Jullien (2000) a montré qu'une diminution de 2°C de la température moyenne journalière entraînait une augmentation de 5% du poids sec de la pulpe à rayonnement constant et à une somme thermique de 900°j. Les différences de fermeté entre les fruits H et B confirment les observations de Chillet et de Lapeyre de Bellaire (1996).

Caractéristiques des fruits mûrs

Au stade tigré, les fruits H ont été significativement plus fermes et ont présenté une peau plus dure que les fruits B (Tableau 3). Les variations de ces caractéristiques physiques sont également liées au stade de récolte. Les teneurs en matière sèche, en extrait sec soluble, en glucose et en fructose ont été significativement plus élevées dans les fruits H que dans les fruits B. Ces variations liées à l'altitude sont supérieures aux variations observées entre des fruits au stade 'jaune à bout vert' et au stade 'tigré' (Chacon et al., 1987). Dans le cas de l'extrait sec soluble, les différences entre les fruits H et B ont augmenté avec l'âge des fruits (Figure 1). A 1090°j, cette différence a été proche de 2°Brix, en faveur des fruits H.

Les données disponibles ne permettent pas d'émettre des hypothèses tangibles quant à l'origine de ces différences. Elles peuvent être liées à des différences de teneurs en substrat (amidon, polysaccharides) ou d'activités enzymatiques (amylase, phosphorylase, acide phosphatase) impliquées dans la maturation des fruits (Kojima et al., 1994; Chang et Hwang, 1990).

Tableau 3. Caractéristiques physico-chimiques des fruits H et B au stade mûr

	parcelle B (50 m d'alt.)		parcelle H (300 m d'alt.)		Test F pour les 2 facteurs et leur interaction [1]		
Fruits mûrs	moy.	ect	moy.	ect	altitude	stade récolte	alt*SR
dureté de la peau (N)	12,1	2,4	18,3	4,9	***	***	NS
Fermeté du fruit (N/s)	22,2	2,7	25,0	3,1	***	***	NS
Ph	4,70	0,18	4,67	0,13	NS	***	NS
Matière sèche (g/100 g mat. fraî.)	24,5	1,2	25,8	1,5	**	NS	NS
extrait sec soluble (°Brix)	21,9	0,7	23,2	0,7	***	NS	NS
teneur saccharose (g/100 mL jus)	12,6	3,6	15,0	3,3	NS	NS	NS
glucose (g/100 mL jus)	3,4	0,2	3,7	0,1	***	NS	NS
fructose (g/100 mL jus)	3,5	0,2	3,8	0,2	**	NS	NS

Les valeurs sont les moyennes (et les écarts-type) de 4*5 répétitions
[1] NS : différence non significative ; *, **, *** : différence significative respectivement au seuil de 0,05, 0,01 et 0,001

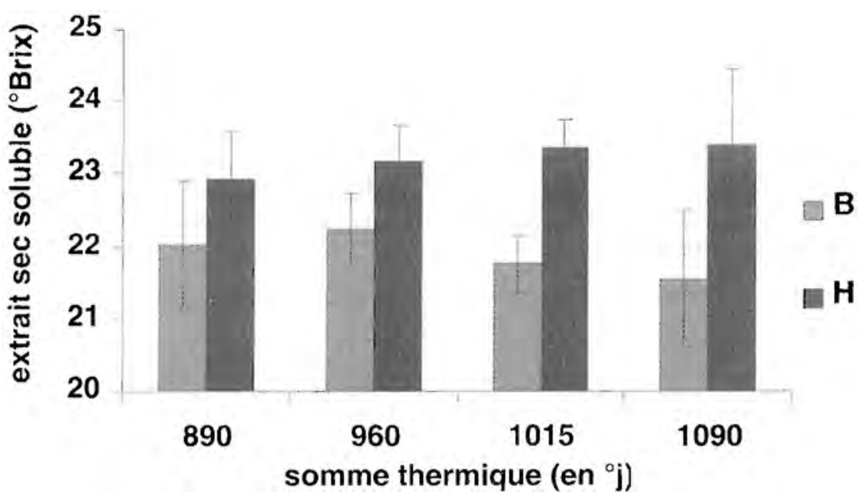

Figure 1 : variation de l'extrait sec soluble en fonction de l'altitude et du stade de récolte (hauteur des barres = ± écart type)

A même somme thermique, aucune différence significative n'a été mise en évidence entre les fruits H et B. Le risque de ne pas observer de différences alors qu'elles existent (risque de 2ème espèce) a été inférieur à 5% (Lespinasse et al., 2002). Contrairement à Brat et al., (2003), les différences physico-chimiques observées n'ont pas permis de distinguer sur le plan organoleptique les fruits H et B.

CONCLUSION

Cette étude a permis de mettre en évidence des différences physico-chimiques entre des fruits récoltés à 50 et 300 m d'altitude. Cet effet altitude doit cependant être confirmé sur un plus grand nombre d'échantillons, en terme de régimes et de parcelles étudiés. La recherche de la compréhension de cet effet altitude devrait permettre de proposer des indicateurs physiques ou biochimiques propres à la montagne. Ces données devront à moyen terme alimenter la réflexion sur la mise en place d'un label « Banane de Montagne » pour les Antilles françaises, dénomination qui est justifiée au niveau national par le décret n°2000-1231.

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EL USO DE 1-METILCICLOPROPENO (1-MCP) Y ATMÓSFERA MODIFICADA (MAP) AFECTA LA FLUORESCENCIA DE LA CLOROFILA Y EL CAMBIO DE COLOR DE LOS PLÁTANOS (*MUSA* SPP. GRUPO AAAB) DURANTE EL ALMACENAMIENTO

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RESUMEN: Los efectos combinados del inhibidor de etileno 1-metilciclopropeno (1-MCP) y el uso de atmósfera modificada (MAP) sobre la fluorescencia de la clorofila y el cambio de color fueron estudiados en plátanos FHIA-21 de diferentes edades durante su almacenamiento a 13.5 °C. La pérdida de clorofila (amarillamiento) de los plátanos almacenados ocurrió más rápido en los racimos de mayor edad, sin embargo, la edad del racimo no tuvo un efecto significativo sobre la pérdida de peso de los mismos ($p>0.05$). El uso de 1-MCP tuvo un efecto altamente significativo sobre la pérdida de clorofila ($p<0.001$). Los plátanos provenientes de racimos de 75 días que recibieron el tratamiento con 1 MCP permanecieron verdes por 63 días, mientras que los que no recibieron el 1-MCP sólo permanecieron verdes por 7 días. El efecto del uso de MAP sobre la pérdida de peso fue altamente significativo ($p<0.0001$). Los plátanos que fueron almacenados en MAP perdieron 0.55% de su peso inicial, mientras que los que no estaban en MAP registraron pérdidas promedio de peso de 4.56% (medido a los 17 días de almacenamiento). El efecto del uso de MAP en reducir la pérdida de clorofila se notó rápidamente (17 días de almacenamiento) en plátanos que no recibieron 1-MCP. Sin embargo, en aquéllos que fueron tratados con 1-MCP, el efecto de MAP no fue tan evidente y hubo que esperar un período más largo (40 días de almacenamiento) para poder observar el efecto. En conclusión, el uso de 1-MCP en combinación con atmósfera modificada puede extender significativamente la vida de anaquel del plátano verde permitiendo a los productores, comercializadores y procesadores organizar y planificar mejor sus actividades comerciales.

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T-STAR FUNDED RESEARCH ON WEED CONTROL IN CROPS OF ECONOMIC IMPORTANCE FOR THE CARIBBEAN BASIN

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ABSTRACT: Weed interference is a major limitation to production of tropical crops by small farmers. Because of lack of interest in herbicide registration for limited-acreage crops, small farmers usually rely on hoe weeding. Sweet potato (*Ipomoea batatas*) and yam (*Dioscorea* spp.) are important root crops in Puerto Rico and throughout the Caribbean. These crops have been identified as poor competitors against weeds. Rhizoma perennial peanut, a legume forage, has shown high nutritive value and yield potential when grown in the Caribbean. However, slow stand establishment provides for rapid weed invasion, a situation also common for yam and sweet potato. In this scenario, farmers need research on applied weed control. The objective of this paper is to summarize results from T-STAR funded research on weed control in crops of economic importance for the Caribbean Basin. In yam, Johnson grass (*Sorghum halepense)* was reduced after a two-year herbicide-crop rotation. The dramatic reduction in *S. halepense* demonstrates the potential of crop-herbicide rotation for the control of specific species. Two promising variety releases of sweet potato, selected from T-STAR research, were evaluated for herbicide tolerance at the time of establishment by using over-the-top applications. The herbicides evaluated were clomazone, ametryn, dimethanamide, and clethodim. Both varieties were tolerant to this management, thus indicating their adaptability to the standard management system. For perennial peanut, the objective of the study was to develop weed control strategies to be used during establishment. Imazethapyr and dimethanamide were evaluated as preemergence herbicides, whereas sethoxydim and 2,4-D-B was evaluated as postmergence herbicides application. Growth of perennial peanut was slow. Weeds were not controlled as expected. This response was probably the result of a combination of slow growth by the crop and rapid weed emergence from the seed bank.

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PASSION FRUIT BY-PRODUCTS AS A POTENTIAL RUMINANT FEED

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ABSTRACT: Passion fruit (*Passiflora* spp.) is consumed extensively in juice blends and cocktails. Native to Brazil, passion fruit is now grown in many countries including the United States. Passion fruit is grown predominantly for its tart juice although it is known to have medicinal purposes. The by-products (rind and seeds) are currently waste products that pose a disposal problem and can be used in animal feeds. Nutritive value of rinds and seeds from Guyana were evaluated for protein, fiber, fat, dry matter, and minerals to ascertain their inclusion as potential ingredients in ruminant diets. Crude protein content of the seeds was higher than that of the rinds; seeds had 11.06% crude protein, which was 149% higher than that in the rind. Fat content of seeds was 20.3%; in the rinds, only 0.40%. Crude fiber content of the seeds was 36.47%; 31.55% for the rind. Seeds also had higher Ca, K, and Mg than the rind. However, phosphorus content was higher in seeds than in rinds whereas Ca/P and Ca/Mg ratios were higher in the rinds than in the seeds. As another measure of feed quality, the Ca/Mg + K ratio was higher in the rind than in the seeds. From this preliminary evaluation of the by-products of the Guyana passion fruit industry, it appears that these materials could serve as potential ingredients in ruminant diets.

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EVALUATING THE RINDS AND SEEDS OF PASSION FRUIT

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ABSTRACT: Passion fruit (*Passiflora* spp.) is found mostly in tropical areas. The two main edible types, the purple (*Passiflora edulis* L.) native to Brazil, and the yellow (*Passiflora edulis f. flauicarpa*), which is said to be of unknown origin. Passion fruit is popularly known for its tart juice that is used in the making of wine and other products. By-products of the industry (rind and seed) have potential as valuable ingredients in ruminant diets. Therefore, seeds and rind from Guyana and Brazil were evaluated for their nutrient contents. Crude protein content of the seeds from both countries was higher than that of the rind. Seeds from Brazil had 28% higher protein content than those from Guyana and 190% higher protein in the rind. Fat content of seeds was similar, with 20.3 and 19.82% for Guyana and Brazil, respectively. Fat content of rind was higher for Guyana with 0.4% compared to 0.21% for Brazil. Crude fiber in seeds and rind was not different for the two countries (36.47 and 35.92% in seeds; 31.55 and 30.46% in rind for Guyana and Brazil, respectively). Copper content was low in seed and rind from both countries. Seeds from Brazil had 233 ppm Fe in the seed, compared to 81 ppm in seed from Guyana, and 178 ppm in rind compared with Guyana's 182 ppm. Zinc content was similar in seed and rind, with seed having the higher value for both countries. With little supplementation, based on these preliminary results, passion fruit by-products can be a nutrient source in ruminant diets.

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MANAGEMENT INTERVENTIONS FOR IMPROVED YIELD IN MANGO CV JULIE

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ABSTRACT: Management protocols to enhance flowering and fruit set of Julie mango were investigated at two locations in Trinidad over two seasons. The protocols tested represented the positive results of previous studies on flowering or yield of Julie mango conducted within the region over the past ten years. Treatments included potassium nitrate for flower induction, and the use of microelements, fungicide and insecticide for improved fruit set and post fruit-set protection. Potassium nitrate application resulted in significant increase of flowering in the second trial only. In the first trial, a combination of all treatments resulted in increased yield, as assessed at 14 weeks. In the second trial increased yield was found to be due to fungicide only. Despite the applications, the yield in the second trial was very poor. This leads to the conclusion that there were limitations other than nutrition, pests or disease that affected final yield.

INTRODUCTION

Julie is the most popular and major export mango in the southern Caribbean. It is a dwarf cultivar that shows readiness-to-flower throughout most of the year. This leads to sporadic flowering that may result in little or no set except for the main crop. The main crop occurs around June and there may be continuous light cropping thereafter. The demand for Julie by exporters has fueled work in making the cultivar more productive.

The approach that has received most attention is the concentration of flowering and improvements in fruit set using growth regulators such as potassium nitrate (KNO_3) and paclobutrazol (Andrews and LeeFook, 1990; James, 1993; Andrews, 1994, Shongwe and Roberts-Nkrumah, 1996; Mossak, 1997). The need for control of pests (Daisley et al., 1994) and the major disease anthracnose (Fortune et al., 1994) has also been reported.

Whitwell (1993) demonstrated the potential losses at fruit set due to pests in Dominica, including the gall midge *Erosomyia mangiferae* Felt, larvae of geometrid moths, thrips *Frankliniella sp.,* and the mirid bugs *Dagbertus* sp. and *Rhinacloa antennalis* (Reuter). Of these the mango gall midge was the most serious followed by the geometrid larvae. Daisley et al. (1994) also reported on gall midge damage and the use of traps for control of fruit fly *Anastrepha obliqua* (Macq.).

The integration of these factors into a single orchard management program has not been tested locally as it has been in Dominca (Robin et al., 1997). To this end, an attempt was made to demonstrate increased yield of Julie through flower induction, enhancement of nutrition, and pest and disease control in two trials at separate locations in Trinidad.

MATERIALS AND METHODS

Two trials were conducted during the period February to May 1998 and June to July 1999, the first at Todds Road Estate and the second at La Gloria estate. Trees were 12 years of age and single tree plots were used.

All spray applications were made with a Stihl™ mistblower. Trees were sprayed to dripping, each tree receiving about 1.5 L of mixture. Trees treated for flower induction were sprayed with an 8% solution of potassium nitrate.

Trial 1: This trial was performed during the dry season of 1998, on the L'Ebranche Soil series. Thirty-nine July mango trees, with relatively few or no panicles, were selected from a single row of fifty trees bordering a trace. On each tree a branch supporting 30-100 terminal shoots was selected to serve as the sample unit. Three treatments were applied to the trees in a completely randomized experimental design with thirteen replicates. The treatments were as follows: Treatment I - control, no intervention; Treatment II, one application of potassium nitrate at day one; Treatment III, one application of potassium nitrate at day 1, followed one week later by an application of microelements, fungicide and insecticide, and applications of fungicide and insecticide after week three and week seven. Microelements were applied as a 0.5% solution of Microzit. Fungicide was applied as a 1.0 % a.i. emulsion of Chlorothalonil as Daconil for the first application, and as Daconex thereafter. Insecticide was applied as a 0.1% emulsion of lambda cyhalothrin as KARATE 2.5 EC™; concentration of active ingredient was 25 ppm.

Three weeks following the initial application of KNO_3, ten panicles were labeled within each sample unit. In two units ten panicles were unavailable within the plot, so the nearest adjacent panicles were labeled to make up the required number.

The number of terminal shoots in each plot was recorded at the start of the trial. The number of panicles per plot was determined 21 days after the KNO_3 application. The number of fruit per labeled panicle, fruit per plot, and fruit per tree was recorded at fourteen weeks. At this time, fruits were of two distinct sizes. Fruit, which had set during the initial four weeks of the trial, were roughly 8-12 cm long whereas a subsequent period of fruit set resulted in fruit 2-4 cm in length. Canopy diameter was measured in two directions at fourteen weeks after treatment. Panicle counts of treatments II and III combined were compared to the control using a t-test (Statgraphics 6). Fruit per shoot, fruit per panicle, and fruit per tree of the three treatments were analyzed by ANOVA (Minitab, 1991). Data for the latter (fruit per tree) were standardized by the surface area of the canopy assuming a hemispherical shape.

Trial 2. This trail was conducted on a 5-ha block of Julie on Tarouba clay soil at the La Gloria estate in south Trinidad. For this trial uniform management of the trees began one year prior to the study and included pruning branches close to the ground. The pruning served to minimize variability within blocks. A factorial experimental design was adopted in order to determine which of the treatments, in which combinations, were responsible for the increased fruit set. This trial was laid out as a factorial (3 factors, 2 levels) in a randomized block design with 11 blocks.

Treatments were as follows:

1. Microelement x 1
2. Insecticide x 2
3. Fungicide x 3
4. Microelement x 1, Insecticide x 2
5. Microelement x 1, Fungicide x 3
6. Insecticide x 2, Fungicide x 3,
7. Microelement x 1, Insecticide x 2, Fungicide x 3
8. No applications.

The insecticide used was alpha cypermethrin as Pestac 5EC™ at a rate of 50 ppm, and the fungicide was Daconex™ as in Trial 1 at a rate of 13.3 g/L. Microelement rate was 2.1 g/L using Microcomplex Foglaire™. All trees were fertilized with NPK (26:0:26) at a rate of 500 g/tree on 23rd July and 500 g/tree 19th November 1998. Potassium nitrate was applied on three occasions - 2nd and 10th March, the second because of rainfall during the first application. The final application was on 28th April 1999 after removal of young fruit. Fungicide treatments began on 19th February 1999 and were repeated at monthly intervals. Insecticide was applied on 24th March 1999 and repeated after three weeks.

Flower count was done as a percentage of canopy covered on 26th February 99 and 24th March 99. This data was expressed as high (>60%), medium (30-60%) and low (0-29%). Total fruit set per tree was recorded 7 weeks after potassium nitrate treatment by harvesting off all fruit and doing a count. Results were analyzed by ANOVA (Minitab, 1991).

RESULTS

Flower induction

The effect of KNO_3 on flower induction was not demonstrated (Table 1).

Table 1. Effect of KNO_3 application on flower induction.

Treatment	Mean percentage of shoots with panicles (SEM)
KNO3	38.0 (5.0 %)
Control	22.9 (7.4 %)

Computed t statistic = 1.61, $\alpha = 0.05$ P 0.116

Fruit set

Trees treated with KNO_3 followed by microelements, fungicide and pesticide showed increased fruit set (Table 2).

Table 2. Effect of management practices on fruit set per shoot, per panicle and per tree (Todds Road, 1998).

Treatment	Mean fruit set			
	per 100 shoots * P = .036	per 10 panicles P = 0.1	per m^2 canopy Large fruit P= 0.08	Small fruit P = 0.008
Control	1.37 (0.24) {0.87}	0.62 (0.57)	3.35 (1.84)	3.66 (0.76)
KNO_3 only	1.57 (0.24) {1.47}	1.30 (0.51)	4.49 (1.84)	1.23 (0.76)
Full works	2.26 (0.24) {4.11}	2.30 (0.51)	9.06 (1.84)	0.13 (0.76)

* Data transformed $y = \sqrt{(x + 1)}$, {Back-Transformed Mean} (SEM)

Flowering

Most trees were observed to be flowering on 26th February 1999 after undergoing uniform vegetative flushing in August 1998. Flowering response to the March applications of potassium nitrate was observed to be very good on 1st April 1999, three weeks after the second application. More than 95% of trees flowered heavily whereas non-trial trees had only 45% of trees flowering heavily ($P<0.001$). Flowering of trees after the last application of potassium nitrate was neither heavy nor uniform, and the trial was subsequently discontinued.

Fruit set

Fruit set was poor resulting in a mean of just 12 fruits per tree (SEM= 0.75). Yield data as count gave a skewed curve and were therefore transformed (√) before analysis. Analysis of Variance showed significant effect due to fungicide treatment ($P<0.002$).

Table 3. Means table of fruit set, Trial 2 La Gloria Estate.

Factor	Mean Yield/tree (Transformed)	SEM	Back Transformed mean
Fungicide	3.355	0.300	11.3
No Fungicide	1.983	0.300	3.9
Insecticide	2.526	0.304	6.4
No Insecticide	2.813	0.296	7.9
Microelements	2.448	0.300	6.0
No Microelements	2.891	0.300	8.4

Table 4. ANOVA table, transformed fruit set data for Trial 2.

Source of Variation	Degrees of freedom	Seq SS	Adj MS	F	P
Block	10	102.817	10.303	2.68	0.008
Fungicide	1	41.224	40.253	10.47	0.002
Insecticide	1	1.920	1.761	0.46	0.501
Microelement	1	4.143	4.202	1.09	0.300
Fungicide*Insecticide	1	13.148	12.542	3.26	0.075
Fungicide*microelement	1	0.285	0.213	0.06	0.815
Insecticide*microelement	1	8.706	8.706	2.26	0.137
Fungicide*Insecticide *microelement	1	6.903	6.903	1.80	0.185
Error	68	261.465	3.845		
Total	85	440.630			

DISCUSSION

Trial 1 was successful in demonstrating an increase in fruit set with full management, but was unsuccessful at demonstrating whether the increase was due to panicle initiation or protection of panicles plus nutrition. Both these factors may be operating but against a background of high variability. This variability may be inherent, in which case a larger sample size may be necessary, or may be due to differences in location or prior management. It was observed that one stretch of trees, from tree 16 to tree 30, produced very few fruits. It is possible that these trees had experienced competition for light from either adjacent trees or vine cover.

The results of Trial 2 indicate that at the La Gloria site only fungicide treatment was instrumental in increasing yield despite the low set that occurred overall. The reason for poor set is unknown but is thought to be unrelated to pollinator activity since houseflies were seen in the field and two non-Julie trees there fruited well. Few female flowers were evident from a cursory examination of Julie inflorescences in April 1999. It is proposed that the sex ratio of Julie be monitored over time together with the flowering pattern of possible pollinizer cultivars in a follow up exercise. Van Hau (1997) reported that potassium nitrate did not affect sex ratio of seedling mango inflorescences, however, Shongwe and Roberts-N'Krumah (1996) reported increased maleness in panicles of Julie but no data were provided. Trial 2 also confirmed the action of potassium nitrate in increasing flowering in Julie.

Examination of insects on a few panicles at the time of insecticide application showed that some pests were present including geometrid larvae, thrips, mirid bugs, and gall midges. Whitwell (1993) demonstrated the potential losses due to these pests in Dominica, especially the gall midge. The populations that he referred to, however, were higher than those observed in these trials. In addition, the concentration of flowering due to the potassium nitrate should have resulted in relatively low pest densities. Although it is possible that these insects could have resulted in the loss of developing fruit, we are confident that if pests were an important limiting factor in this trial, this would have been picked up in the analysis for insecticide treatment.

Despite the ample flowering and the opportunities presented in the trial to control pests and disease and to satisfy nutritional requirements, fruit set was uniformly very poor. Whereas this finding may be generally indicative of an off-year production, the poor set was not due to physiological fruit drop as there was very little fruit set in the first place. Also discounted was the possibility that blossom blight prevented fruit set. This did not appear to be the case, nor was there a shortage of pollinators in the field.

This leads to the conclusion that the problem is one of poor initial set probably due to low percentage of bisexual flowers, unavailability of pollenizer pollen or abnormal flower development. Abnormal flower development may be reflected as poor stigmatic receptivity, low viability of pollen, or poor ovule or style development. The clarification of these issues is the next logical step in elucidating and solving the problem of the sometime poor yield despite adequate induced flowering in Julie mango.

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ANATOMICAL INVESTIGATION OF ABSCISSION ZONE SITES IN *CAJANUS CAJAN* (PIGEON PEA)

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ABSTRACT: Premature abscission of flowers and young pods has been identified as a limitation to pod yield in pigeon pea. The various vegetative and reproductive abscission sites are identified and investigated, both in naturally occurring and ethylene induced abscission. Explants containing the abscission sites were fixed, wax embedded, sectioned, and stained. Observations using the light microscope revealed that the typical abscission zone consisting of a few layers of small brick shape cells found in most species does not occur in pigeon pea. In pigeon pea the layer of separation consists of a row of densely cytoplasmic cells. In the case of leaf sites, protection is afforded by the suberization of the exposed cells. At the reproductive sites, there is some periderm formation in some cases. The anatomy of the vegetative and reproductive sites is compared.

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EVALUACIÓN DE SIETE CULTIVARES DE TOMATE INDUSTRIAL (*LYCOPERSICON ESCULENTUM* MILL) EN AZUA, REPÚBLICA DOMINICANA

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RESUMEN: Se realizó un estudio de campo en la Estación Experimental, Azua, del Centro Sur, del IDIAF, entre noviembre del 2000 y abril del 2001. El objetivo del estudio fue comparar el rendimiento, calidad y tolerancia aparente al virus *Tomato Yellow Leaf Curl Virus* (TYLCV) de 7 cultivares de tomate industrial (*Lycopersicon esculentum* Mill). Los cultivares Gem Pride, 1149, Nema 512, Hypack 159, Peto 98, Hypeel 261 y Zenith fueron manejados en el campo siguiendo la práctica de la zona. El estudio se condujo con un diseño de bloques completos al azar con cuatro repeticiones. Se midió el rendimiento de frutos, peso/fruto, brix y porcentaje de infección aparente con el TYLCV. Los resultados obtenidos fueron sometidos a análisis de varianza y separación de medias (DMS al 5%). Gem Pride fue el único cultivar que no presentó síntomas del TYLCV, mientras que los demás presentaron incidencia entre el 93 y el 100% a los 55 días después del trasplante. Los mejores rendimientos de frutos correspondieron a Gem pride, 1149 y Nema 512, con valores de 55.69, 49.49, y 46.70 t/ha, respectivamente, en tanto que los valores de brix pueden considerarse como de regular a bueno, estando en el rango de 3.4 y 4.2 para todos los cultivares.

INTRODUCCIÓN

El tomate industrial (*Lycopersicon esculentum* Mill), es el principal cultivo hortícola en la República Dominicana y uno de los cultivos más importantes de la zona sur del país. A nivel nacional se siembran unas 10,000 ha/año, principalmente en las regiones sur y noroeste. Anualmente se hacen evaluaciones de cultivares (variedades e híbridos) de tomate en las regiones productoras, en busca de materiales con buena adaptación a nuestro medio, alta tolerancia al complejo mosca blanca (*Bemisia* spp.)-virosis, altos rendimientos y buenas características para la industria del procesamiento. Estas evaluaciones tienen énfasis especial sobre el complejo moscas blancas (*Bemisia* spp.)-virosis, que de ser una plaga secundaria se ha convertido en la principal plaga agrícola mundial (Brown 1994).

El uso de variedades tolerantes y/o resistentes a la virosis, con alto rendimiento, calidad para la industria del procesamiento y a bajo costo sería uno de los mecanismos ideales para mejorar la rentabilidad del cultivo. El objetivo de este estudio es proveer a los productores informaciones comparativas de 7 cultivares de tomate industrial, con énfasis en el rendimiento y la tolerancia al complejo moscas blancas (*Bemisia* spp.)- virosis, en la Estación Experimental, Azua, del Centro Sur del IDIAF de la República Dominicana.

MATERIALES Y MÉTODOS

En la temporada de noviembre de 2000 a marzo de 2001 se realizó un experimento de campo en la Estación Experimental, Azua de Centro Sur del IDIAF, ubicada en la coordenadas 18°23′ de latitud Norte, 70°50′ de longitud Oeste y a una altitud de 25 msnm.

El clima corresponde al de bosque seco sub-tropical, con una temperatura media anual de 27°C, precipitación promedio anual de 650 mm, humedad relativa del aire 73.3%, velocidad del viento 8 km/hr y una evapotranspiración potencial de 1,730 mm anual. Los suelos pertenecen al orden de los Entisoles con una textura franco arenosa, pH entre 8.0 y 8.5 y bajo contenido de materia orgánica.

El método de siembra fue el de semillero y luego trasplante. Las plántulas procedentes de semillero a campo abierto (cantero) fueron trasplantadas a los 31 días de la siembra.

Los cultivares evaluados fueron: Gem Pride, 1149, Nema 512, Hypack 159, Peto 98, Hypeel 261 y Zenith distribuidos en un diseño de bloques al azar con 4 repeticiones.

Las unidades experimentales fueron dos camellones de 4 m largo y 1.80 m de ancho (14.4 m^2) a hileras dobles separadas a 40 cm entre hileras 25 cm entre plantas y 180 cm entre parejas de hileras dobles. El área útil fue de 7.20 m^2, o sea, dos camellones de 180 cm de ancho cada uno por 2 m de largo (32 plantas por cultivar por repetición).

Todos los cultivares tuvieron el mismo manejo de campo siguiendo el utilizado en las principales zonas de producción. Se regó por gravedad en camellones, aplicando un riego durante la siembra, otro a los 5 días después del trasplante (riegos técnicos) y seis durante el ciclo del cultivo con una frecuencia de 12 días. Se realizó una fertilización con 727.27 kg/ha de la formula 15–15–15, en dos aplicaciones, a los 4 y 24 días después del trasplante (ddt) y una tercera fertilización con 509.09 kg/ha de sulfato de amonio a los 34 ddt. Control de malezas químico fue con fluazifob–butil + metribuzina a una dosis de 500 ml + 5 onzas, respectivamente, en tanque de 200 litros de agua, aplicado a los 15 ddt. Se realizaron tres desyerbos manuales con el uso de azadas, el primero a los 24 ddt conjuntamente con el segundo aporque y fertilización y los dos restantes a los 34 y 75 ddt, respectivamente. Se aplicaron los fungicidas mancozeb y metalaxil + clorotalonilo a partir de los 40 ddt con los primeros síntomas del tizón tardío (*Phythophthora infestans*). En total se hicieron 3 aplicaciones cada 15 días, a la dosis recomendada por el fabricante. Se hicieron aplicaciones de los insecticidas sumithion, metomil y javelin en dosis comerciales a los 5, 40, 56 y 71 ddt, para controlar minadores de las hojas (*Liriomiza* spp.) y gusanos del fruto (*Trichoplusia* spp. y *Heliothis* spp.).

No se hicieron aplicaciones de insecticidas que pudieran tener efectos sobre las moscas blancas, con el objetivo de evaluar la incidencia del virus (TYLCV) en los cultivares a nivel de campo.

Las variables evaluadas fueron incidencia de virosis (TYLCV) en porcentaje de plantas con síntomas del virus, rendimiento (t/ha), grado brix (%SS), y peso por fruto (g). El virus se determinó por sintomatología típica a los 25, 40 y 55 ddt. Se evaluó el rendimiento en dos cosechas comerciales a los 91 y 108 ddt. Los resultados fueron sometidos a análisis de varianza y separación de medias por diferencia mínima significativa al nivel de 5% de error.

RESULTADOS Y DISCUSIÓN

Los resultados obtenidos indican que hubo diferencias estadísticas significativas ($p < 0.05$) entre los cultivares evaluados y para todas las variables medidas en el ensayo. Los cultivares más productivos fueron Gem Pride, 1149 y Nema 512, con rendimiento intermedio Hypack 159 y Peto 98, en tanto que el menor rendimiento se obtuvo con Zenith (Tabla 1). Los mayores pesos promedios de 10 frutos fueron obtenidos por Nema 512, Hypack 159 y Gem Pride (119.5-128.0), en tanto que el grado brix puede considerarse entre regular y bueno estando en el rango de 3.4 a 4.2 (%SS) para todas las entradas en estudio.

La incidencia de moscas blancas (*Bemisia* spp.) y geminivirus (TYLCV), entre los cultivares evaluados fue relativamente alta. La cantidad promedio de mosca blancas (*Bemisia* spp.) por planta fue de 5 durante el ensayo. La incidencia de TYLCV a los 55 ddt fue de cero para Gem Pride hasta 100% para Hypeel 261. Al momento de las evaluaciones de virosis, el cultivar Gem Pride no presentó síntomas aparentes de la enfermedad; sin embargo, los demás cultivares tenían los mejores porcentajes de plantas con síntomas de virosis (Tabla 2).

Tabla 1. Rendimiento, peso/fruto y grado brix, en siete cultivares de tomate industrial en Azua.

Cultivar	Procedencia	Rendimiento (t/ha)	Peso/Fruto (g)	Brix (%SS)
Gem Pride	Petoseed	55.69 a	114.3 a	3.6 a
1149	Linda	49.48 a	85.8 b	3.8 a
Nema 512	Petoseed	46.70 a	128.0 a	3.4 b
Hypack 159	Petoseed	44.97 b	119.5 a	3.5 b
Peto 98	Petoseed	42.01 b	73.8 c	3.7 a
Hypeel 261	Petoseed	38.80 bc	90.2 b	3.8 a
Zenith	Bejo	29.25 c	77.6 b	4.2 a
LSD		9.57	13.98	0.68

* Valores con la misma letra no difieren estadísticamente entre sí (DMS al 5%)

Tabla 2. Incidencia de virosis en cultivares de tomate industrial durante los primeros 55 días después del trasplante (ddt) en Azua.

Cultivar	% de plántulas con síntomas de virus.		
	25 ddt	40 ddt	55 ddt
Gem Pride	0 a	0 a	0 a
Hypack 159	4 b	48 b	93 b c
Zenith	1 a	44 b	96 c
Nema 512	4 b	58 b c	98 c
Hypeel 261	4 b	64 b c	100 c
1149	7 b	79 c	96 c
Peto 98	20 c	91 c	97 c
LSD	4.55	11.51	3.60

* Valores con la misma letra no difieren estadísticamente entre sí (DMS al 5%).

No hubo correlación entre incidencia de virosis y el rendimiento. Estudios previos han demostrado que esta correlación en la mayoría de los casos no es significativa (Payan et al., 2000; Alcántara, 1998). Por ejemplo, 1149 presentó la misma incidencia de virus (TYLCV) que Zenith a los 55 ddt (96%), pero el 1149 reportó rendimientos superiores que el Zenith, 49.48 versus 29.25 t/ha, respectivamente. Estas diferencias pudieran atribuirse parcialmente a que los cultivares tienen diferentes potenciales de productividad y adaptación a las diferentes zonas de producción.

Según los resultados de este ensayo y bajo las condiciones del estudio, en términos de productividad las mejores opciones son el Gem Pride, 1149, y Nema 512. El Gem Pride fue el único cultivar que no presentó síntomas de geminivirosis (TYLCV) durante el estudio.

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EVALUACIÓN DEL CULTIVAR DE CEBOLLA (*ALLIUM CEPA* L.) "ORIENT F1" EN CUATRO PERIODOS DE SIEMBRA EN BANÍ, REPÚBLICA DOMINICANA

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RESUMEN: Un experimento fue conducido durante el periodo de noviembre 2001 hasta junio 2002 en el Campo Experimental Escondido, Baní, del IDIAF, ubicado a 18°16' latitud norte, 70°20' longitud oeste, altitud 60 msm, temperatura media 27.5° C y una precipitación de 965 mm. El objetivo fue evaluar cuál es el periodo óptimo y la influencia en la producción y calidad de los bulbos de cebolla. La unidad experimental estaba constituida por 20 m_, el área útil de 4.20 m_. Las variables evaluadas fueron rendimiento (total, comercial y no comercial), número de frutos (total, comercial y no comercial), diámetro medio y pesos medios de los bulbos. Las variables evaluadas fueron sometidas a análisis de varianza y separación de medias al 5%. Hubo diferencia estadística significativa en el periodo de siembra del 11 de junio 2002, el cual produjo un rendimiento total de 39.76 t/ha y comercial de 37.00 t/ha, siendo superior a los rendimientos del periodo de siembra del 18 de mayo 2002 el cual produjo un rendimiento total de 38.01 t/ha y comercial de 36.08 t/ha. El periodo del 5 de mayo produjo un rendimiento total de 32.15 t/ha y comercial de 28.14 t/ha. En cuanto al número de bulbos totales y bulbos comerciales, la siembra en el periodo del 11 de junio 2002 produjo el mayor número de bulbos totales con 934,000/ha y comerciales, 777,000/ha. La siembra en el periodo del 11 de mayo produjo un total de 810,000/ha bulbos, de los cuales 736,000/ha eran comerciales.

INTRODUCCIÓN

El cultivo de cebolla (*Allium cepa* L.) ocupa el segundo lugar en importancia económica entre las especies hortícolas. La cebolla se usa en su estado fresco, para condimentar las comidas y también se le atribuyen algunas propiedades medicinales. En la República Dominicana se siembra alrededor de 3,500 ha, involucrándose alrededor de 4,000 a 6,000 productores (SEA-2002)

Según Montes y Holle (1990) el problema fundamental del cultivo consiste en la adaptación de cultivares para las distintas épocas, lo que origina dificultad para suministrar a los productores semillas que se adapten a las diferentes zonas. Según Reís (1982), los factores climáticos que más inciden en la formación y desarrollo de los bulbos son el fotoperíodo y la temperatura. La cebolla es muy exigente en hora-luz y los efectos de la temperatura están ligados a la altitud. Según Sarita (1991), dependiendo de las horas luz los cultivares se clasifican en cultivares de días cortos, aquéllos que necesitan entre 10 y 12 horas luz para la formación del bulbo; cultivares de días intermedios, que necesitan entre 12 y 13 horas luz; cultivares de días largos, los cuales necesitan más de 14 horas luz.

El objetivo del experimento fue evaluar cuál es el periodo apropiado y su influencia en la producción, productividad y calidad de los bulbos de cebolla (*Allium cepa* L.).

MATERIALES Y MÉTODOS

Para la realización de este experimento se utilizo el cultivar Orient F1 de color rojo y días intermedios. Sc utilizó un diseño de bloques completamente al azar con 4 repeticiones. Las parcelas experimentales estaban conformadas por un área de 20 m_, y un área útil de 4.20 m_. La siembra fue directa y los periodos de siembra fueron el 5 mayo 2002, el 18 mayo 2002, el 11 junio 2002 y el 29 junio 2002. Las cosechas se realizaron el 20 septiembre 2002, el 5 octubre 2002, y el 25 octubre 2002, con una media de cosecha de 120 días.

Las variables evaluadas fueron el número de bulbos totales (000/ha), número de bulbos comerciales y no comerciales; rendimiento (t/ha), total, comercial y no comercial; diámetro ecuatorial (cm); peso medio de los bulbos (g); número de plantas cosechadas (000/ha); e incidencia de plagas y enfermedades.

Al experimento se le aplicó un manejo similar al realizado por los productores de cebolla de la zona. Para el control de malezas, se realizaron 3 desyerbo manuales y dos aplicaciones de los herbicidas Fluazifop Butil, 1 a 1.4 l/ha, y Oxyfluarcifen, 0.5 l/ha. Se realizaron 14 riegos y la fertilización se realizó sobre la base de 400 kg/ha de fertilizante dividido de las siguiente manera: 100 kg/ha de la fórmula 15-15-15 a los 8 días después del trasplante (ddt), 100 kg/ha a los 40 ddt y 2000 kg/ha de sulfato de amonio (21% de nitrógeno) a los 60 ddt. El control de plagas y enfermedades fue posible después de monitoreos y de que se realizaran diez aplicaciones de insecticidas y funguicidas.

RESULTADOS Y DISCUSIÓN

La Tabla 1 muestra los rendimientos totales, comerciales y no comerciales. Estos resultados fueron sometidos a análisis de varianza y separación de medias al 5%. Para rendimiento total el análisis detectó diferencias estadísticas significativas entre los diferentes periodos de siembra. En las siembras del 18 mayo 2002 y 11 junio 2002 se produjeron los mayores rendimientos totales de 39.76 y 38.00 t/ha, respectivamente.

En el caso de los rendimientos comerciales, expresados en (t/ha) con diámetro comercial superior (>5.5 cm) hubo diferencia estadística significativa. La siembra del 18 mayo 2002 con 11.35 t/ha y la siembra del 5 mayo 2002 con 9.93 t/ha, fueron superiores a la siembra del 11 junio 2002, con 6.23 t/ha. La siembra del 29 junio 2002 no produjo rendimientos con ese diámetro.

No hubo diferencias estadísticas significativas en los rendimientos de bulbos comerciales con diámetro de 3-4 cm y calculados en t/ha. Sí hubo diferencias en los rendimientos de bulbos comerciales con diámetro de 4-5 cm. El análisis detectó diferencias estadísticas significativas entre la siembra del 11 junio 2002 (21.18 t/ha) y la siembra de 18 mayo 2002 (16.49 t/ha). Los rendimientos más bajos se produjeron en las siembras del 5 mayo 2002 y el 29 junio 2002 con 9.95 y 4.33 t/ha, respectivamente.

Hubo diferencias estadísticas signficativas en los rendimientos de los bulbos no comerciales (diámetro <3.0 cm, cebollas dobles, podridas y puerrotes). Los mejores resultados se lograron con la siembras del 18 mayo 2002 y el 11 junio 2002 con 1.92 t/ha y 2.76 t/ha, respectivamente.

Tabla 1. Medias para el rendimiento total, comercial y no comercial en cuatro periodos de siembra de cebolla (*Allium cepa* L.), 2002.

Periodos de siembras	Rend. Total (t/ha)	Rend. Comercial según θ (t/ha)			Rend. No-comercial (t/ha)
		> 5 cm	3-4 cm	4-5 cm	Diámetro < 3 cm
5 mayo	32.15 ab**	9.93 ab	8.26 b	9.95 bc	4.01 a
18 mayo	38.01 a	11.35 a	8.24 b	16.49 bc	1.91 bc
11 junio	39.76 a	6.23 bc	9.59 b	21.18 a	2.76 bc
29 junio	24.71 c	0.00 c	15.36 a	5.52 c	3.83 ab
Medias	33.66	6.18	10.36	13.29	3.13
DMS= 5%	3.160*	2.254 *	3.051 *	3.128 *	1.165 *

(*) Significativos al 5%, (**) Los resultados seguidos de las mismas letras no difieren significativamente.

La Tabla 2 muestra el número de bulbos totales, comerciales y no comerciales. Estos resultados fueron sometidos a análisis de varianza y separación de medias al 5%. Hubo diferencias estadísticas significativas en el número de bulbos totales entre los diferentes periodos de siembra evaluados.

También hubo diferencias estadísticas significativas en el número de bulbos comerciales con un diámetro >5 cm, calculados en (000/ha). La siembra del 18 mayo produjo la mayor cantidad de bulbos con 127,000/ha, seguido por la siembra del 5 mayo (113 000/ha) y superior a la siembra del 11 junio (3,000/ha), mientras la siembra del 29 junio no produjo bulbos comerciales.

Hubo diferencias estadísticas significativas para el número de bulbos comerciales, con diámetro entre 4 y 5 cm. También hubo diferencias estadísticas significativas para él número de bulbos no comerciales, con diámetro inferior a 3 cm, cebollas dobles, podridas y puerrote en 000/ha.

Tabla 2. Medias para el número de bulbos total, comercial y no comercial, 2002.

Periodos de siembras	Núm. de bulbo total	Núm. de bulbos comerciales 000/ha			Núm. de bulbos no comerciales 000/ha
5 mayo	752	113 ab***	214 c	211 bc	214 bc
18 mayo	810	127 a	230 bc	379 ab	74 c
11 junio	934	33 b	321 ab	423 a	157 bc
29 junio	759	0.00 b	373 a	50 c	336 bc
Medias	814.50	68.25	284.50	265.75	195.25
DMS = 5%	N.S.	23.11 *	90.04 N.S.	62.37 *	69.98 *

(N.S.) no significativo, (*) Significativo al 5%, (***) Los resultados seguidos de las mismas letras no difieren siginificativamente.

Hubo diferencias estadísticas significativas para las variables: plantas cosechadas (000/ha) y diámetro ecuatorial (cm). También para el peso medio de los bulbos y el número de plantas sin doblar (Tabla 3).

Tabla 3. Media de las variables diámetro ecuatorial, número de plantas sin doblar y plantas cosechadas y peso medio de los bulbos, 2002.

Periodos de siembras	Diámetro (cm)	Núm. de plantas sin doblar 000/ha	Núm. de plantas cosechadas 000/ha	Peso medio de los bulbos (g)
5 Mayo	4.82	53 c	752 c	64.200 a
18 Mayo	4.55	135 b	810 b	58.477 b
11 Junio	4.83	144 b	934 a	58.602 b
29 Junio	4.33	205 a	759 c	39.037 c
Medias	4.63	134.25	814.50	55.163
DMS = 5%	N.S.	21.44*	48.48 *	7.607 *

(N.S.) no significativo, (*) Significativo al 5%, (***) Los resultados seguidos de las mismas letras no difieren siginificativamente.

Estos estudios preliminares indican que el periodo de siembra más apropiado para el cultivar de cebolla Orient F1 es el comprendido entre el 18 de mayo y el 15 de junio, en la época de primavera en la zona de Baní.

Se debe continuar con las validaciones de los cultivares en diferentes zonas productoras y épocas para lograr aumentar la producción y productividad en el cultivo de cebolla. También se recomienda continuar la siembra del cultivar Orient F1 en la época de primavera.

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EVALUACIÓN DE VARIEDADES INTRODUCIDAS DE MUSÚ Y AJÍ PICANTE EN LA VEGA, REPÚBLICA DOMINICANA

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RESUMEN: El cultivo de vegetales orientales se inició en la República Dominicana en 1976, por productores asiáticos. Estas especies se expandieron rápidamente por contar con un mercado seguro. Los agricultores utilizaron semillas seleccionadas por ellos mismos, sin tomar en cuenta la degeneración por segregación genética que pudiese afectar la productividad y calidad de los frutos. El objetivo de esta investigación fue evaluar variedades introducidas de musú y ají picante. Se realizaron dos ensayos en La Vega, en el periodo febrero-agosto de 2002. Se utilizó un diseño de bloques completos al azar con 4 repeticiones. Para musú, las variedades evaluadas fueron Cylinder 2, San-C y Local. Para el ají, se evaluaron Hot Beauty, Super Flavor, Home Flavor y Local Largo. Las variables medidas fueron rendimiento, forma y tamaño del fruto. El musú Cylinder 2 obtuvo mayores rendimientos (25.8 t/ha) que San-C (16.9 t/ha) y Local (14.8 t/ha). Los frutos de Cylinder 2 son cilíndricos y pequeños (18 cm de largo y 6 cm de diámetro). El San-C y Local tienen forma alargada. El San-C es mayor (43 cm de largo y 4 cm de diámetro) que el local (38 cm de largo por 3.8 cm de diámetro). Para el ají, los mayores rendimientos se obtuvieron con Hot Beauty (17.6 t/ha), Local largo (17.1 t/ha) y Super Flavor (13.9 t/ha). Home Flavor mostró rendimientos estadísticamente inferiores a las otras variedades (9.5 t/ha). Los frutos de todas las variedades de ají tienen forma recta. Home Flavor y Super Flavor fueron más largos (13 cm) que Hot Beauty y Local (11 cm).

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CALLUS INDUCTION AND SHOOT PRODUCTION IN *CAPSICUM CHINENSE* (POD TYPE SCOTCH BONNET)

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ABSTRACT: Various explants excised from greenhouse-grown and in vitro-germinated seedlings of *Capsicum chinense* were inoculated onto MS medium supplemented with different concentrations of 2,4- dichlorophenoxyacetic acid (2,4-D) and benzyladenine (BA) or BA and indolacetic acid (IAA) treatments, to allow callus induction and shoot formation, respectively. All cultures were incubated at 28° C with a 16-hour photoperiod (3000 lux). All 2,4-D / BA treatments induced callus on stem, hypocotyls, and leaf explants. The 0.8 mg/L 2,4-D and 1.5 mg/L BA, 2.0 mg/L 2,4-D and 3.0 mg/L BA and 3.2 mg/l 2,4-D and 1.5 mg/L BA treatments gave the best results. The calli produced were of compact, friable or mixed types. Shoot tip and nodal explants produced shoots on all BA/IAA treatments and the control; bud burst ranged from 40% to 100%. IAA 1 mg/L and BA 8 mg/L gave 100% budburst and IAA 1 mg/L and BA 1mg/l gave the greatest shoot height. No shoots were produced directly on leaf, hypocotyls, or seed leaf explants. The response of explants derived from greenhouse and that of those of in vitro origin were compared.

INTRODUCTION

There have been extensive studies conducted on callus induction and shoot production from explants of *Capsicum annuum*. The purpose of such study has an important role to play in establishing a regeneration protocol by determining the specific optimal conditions for plant regeneration.

This present investigation of *Capsicum chinense,* a member of the *Capsicum annuum* species complex, is modeled in part after successful attempts at callus induction of *Capsicum annuum* L. using leaf tissue (Kintios et al., 1996) and shoot production using nodal and shoot tip explants (Christopher et al., 1994).

The aim of this investigation is to determine the specific effects of manipulating explant source, explant type, and growth regulator concentration on callus induction and shoot production of *Capsicum chinense,* and to compare these effects as a means toward future development of a regeneration protocol.

MATERIALS AND METHODS

The *Capsicum chinense* pod type Scotch Bonnet was used in the study. Donor plants were obtained from two sources. The first source was greenhouse grown seedlings treated with Torque™, Commando™, and Neemco™ in the first, second, and third weeks, respectively, prior to use. The second source of plants was seedlings germinated from seeds treated with 20% sodium hypochlorite supplemented with two drops of Tween 20 for 20 minutes.

The various media were prepared by using the standard Murashige and Skoog basal medium supplemented with growth regulators, 3% sucrose, and 0.8% agar, adjusted to pH 5.8 and autoclaved at 121° C for 20 minutes. The callus induction media were supplemented with 0.8 mg/L 2,4-D and 1.5 mg/L BA; 0.8 mg/L 2,4-D and 3.0 mg/L BA; 0.8 mg/L 2,4-D and 4.5 mg/L BA; 2.0 mg/L 2,4-D and 3.0 mg/L BA; 2.0 mg/L 2,4-D and 4.5 mg/L BA; 3.2 mg/L 2,4-D and 1.5 mg/L BA); 0.0 mg/L 2,4-D and 0.0 mg/L BA, designated MS callus induction media 1, 2, 3, 4, 5, 6, and 7.

The shoot induction media were supplemented with 1.0 mg/L IAA and 1.0 mg/L BA; 1.0 mg/L IAA and 2.0 mg/L BA; 1.0 mg/L IAA and 4.0 mg/L BA; 1.0 mg/L IAA and 8.0 mg/L BA; 1.0 mg/L IAA and 12.0 mg/L BA; 0.0 mg/L IAA and 4.0 mg/L BA; 0.0 mg/L IAA and 0.0 mg/L BA; designated MS shoot production media 1, 2, 3, 4, 5, 6, and 7.

Leaf discs, stem, and shoot tip explants were excised from the greenhouse seedlings and sterilized with 10% sodium hypochlorite supplemented with Tween 20 for 10 minutes and then rinsed in three changes of sterilized distilled water prior to use. Leaf, hypocoltyl, cotyledon, nodal, and shoot tips were also excised from the in vitro germinated seedlings

The greenhouse derived leaf and stem tissues as well as in-vitro derived leaf and hypocotyls tissues were placed on the callus induction media at ten replicates per medium. Greenhouse derived nodes and shoot tips as well as in vitro-derived leaf, cotyledon, hypocotyls and nodes, and shoot tips were placed on the shoot production media at ten replicates per medium. The explants were then placed under conditions of 26.56 V/m^2 light intensity and 16-hour photoperiods for four weeks.

Results were analyzed in terms of percentage contamination, percentage callus induction and callus texture, and percentage bud burst and shoot height.

RESULTS

Greenhouse derived explants that were subjected to the sterilization procedure succumbed to both bacterial and fungal contamination at 1.5%, 1.4%, and 11.4% for leaf discs, stem, and nodal and shoot tip explants respectively. Also, 14.7% of the leaf tip explants were further lost because of the high concentration of a sodium hypochlorite. There were no further such losses among the other explant types.

Calli were induced on each of the greenhouse derived explants in all the media except the control after four weeks. Table 1 indicates the results of the callus induction treatments for greenhouse derived leaf explants.

Table 1. Greenhouse leaf discs and the percentages and types of calli induced in the seven media after four weeks.

Medium			Callus type %		
2,4-D:BA mg/L (approx. ratio)			Compact	Mixed	Friable
1	0.8:1.5	(0.5)	55.5	33.3	11.1
2	0.8:3.0	(0.3)	60.0	40.0	0
3	0.8:4.5	(0.2)	80.0	20.0	0
4	2.0:3.0	(0.7)	50.0	37.5	12.5
5	2.0:4.5	(0.4)	40.0	60.0	0
6	3.2:1.5	(2.0)	22.2	33.3	44.4
7	0:0		0	0	0

Most of the calli induced on the leaf discs were compact. The greatest percentage friable calli was achieved on Medium 6 (3.2 mg/L 2,4-D and 1.5 mg/L BA). Medium 1 induced calli first and achieved the largest calli within the duration of the experiment.

Table 2 shows that a greater percentage of friable calli were induced on stem tissue at 90% for Medium 1 (0.8 mg/L −1 2, 4-D and 1.5 mg/L BA) and Medium 4 (2.0 mg/L 2,4-D and 3.0 mg/L BA); and at 100% for Medium 6 (3.2 mg/L 2,4-D and 1.5 mg/L BA).

Table 2. Showing Greenhouse stems and the percentages and types of calli induced in the seven media after four weeks.

Medium			Callus type %		
2,4-D:BA mg/L (approx. ratio)			Compact	Mixed	Friable
1	0.8:1.5	(0.5)	0	10	90
2	0.8:3.0	(0.3)	100	0	0
3	0.8:4.5	(0.2)	90	10	0
4	2.0:3.0	(0.7)	0	10	90
5	2.0:4.5	(0.4)	0	40	60
6	3.2:1.5	(2.0)	0	0	100
7	0:0		0	0	0

Medium 1 again induced calli first but Medium 6 produced the largest calli within the duration of the experiment. Also, 100% friable calli were induced on each of the in vitro-derived explants in all the media except the control.

Like the greenhouse derived explants, Medium 1 induced calli first whereas Medium 6 produced the largest calli for both explant types within the duration of the experiment. Tables 3 and 4 show results for callus induction using in vitro-derived explants.

Table 3. In vitro leaves and the percentages and types of calli induced in the seven media after four weeks.

Medium			Callus type %		
2,4-D:BA mg/L (approx. ratio)			Compact	Mixed	Friable
1	0.8:1.5	(0.5)	0	0	100
4	2.0:3.0	(0.7)	0	0	100
6	3.2:1.5	(2.0)	0	0	100
7	0:0		0	0	0

Table 4. In vitro hypocotyls and the percentages and types of calli induced in the seven media after four weeks.

Medium			Callus type %		
2,4-D:BA mg/L (approx. ratio)			Compact	Mixed	Friable
1	0.8:1.5	(0.5)	0	0	100
4	2.0:3.0	(0.7)	0	0	100
6	3.2:1.5	(2.0)	0	0	100
7	0:0		0	0	0

From the results of the experiment it was evident that the greatest shoot height was achieved from nodal and shoot tip explants derived from in vitro-grown seedlings at 10.9 ±1.99 mm in Medium 2 (1 mg/L IAA and 2 mg/L BA). This was significantly greater than the 4.0 ± 1.00 mm-shoot height achieved in Medium 1 (1mg/L IAA and 1 mg/L BA). These results are indicated in Table 5 below.

Table 5. Percentages bud burst and mean shoot height/mm after 22 days for greenhouse and in vitro-grown nodes and shoot tips for the seven media.

Medium		In vitro nodes & shoot tips		Greenhouse nodes & shoot tips	
	growth regulators [iaa]/[ba]mgl-1	percentage bud burst	mean shoot height/mm and standard error	percentage bud burst	mean shoot height/mm and standard error
1	1:1	80	4.0 ± 1.00	100	6.4 ± 1.41
2	1:2	80	3.4 ± 0.77*	100	10.9 ±1.99
3	1:4	80	2.3 ± 0.92	90	4.3 ±1.02
4	1:8	90	2.8 ± 0.94*	70	1.0 ± 0.63
5	1:12	50	0.7 ± 0.66	100	6.6 ± 2.17*
6	0:4	50	3.7 ± 2.22	100	2.5 ± 0.65
7	0:0	40	0.6 ± 0.38	80	3.0 ± 1.05

*explant(s) exhibited proliferation.

Two media of the shoot production treatment containing greenhouse-derived explants exhibited proliferation in Medium 4 (1mg/L IAA and 8 mg/L BA) in four explants and in Medium 2 (1mg/L IAA and 2 mg/L BA) in one explant. Medium 5 (1mg/L IAA and 12 mg/L BA) of the shoot production treatment containing in vitro-derived explants also showed proliferation.

DISCUSSION

The sterilization protocol proved effective for the stem tissue since the contamination percentages were low. However, even though the contamination percentages were also low for the leaf tissue, the concentration of, and exposure to, the sodium hypochlorite seemed to have been too damaging to the leaf tissue. There was a significant loss of tissue to the sterilization procedure because leaf tissue is much thinner and more delicate than the stem tissue. Conversely a significant percentage of the nodal and shoot tip explants succumbed to contamination because the crevices within the nodes and tips harboured fungi and bacteria which could not be penetrated by the sodium hypochlorite solution.

Calli were induced in each of the callus-inducing media except the control, which contained no growth regulators, all of which suggests that growth regulators are required for callus induction. From the results of the callus induction experiment it appears that the degree of callusing is proportional to the ratio 2,4-D to BA concentration. 2,4-D is an auxin, which, in addition to its role as a root inducer, also induces callus development. For the greenhouse-derived explants, Medium 6 (3.2 mg/L 2,4-D and 1.5 mg/L BA) produced the greatest percentage friable calli in every case and contained the highest concentration 2,4-D as well as the highest 2,4-D: BA ratio at 2.0. Friable calli are useful in tissue culture since the callus is easily divided, for transfer to other medium or any similar manipulation. Compact calli are less readily divided and mixed calli share similar properties with both friable and compact calli. It appears that the higher the 2,4-D ratio the greater the percentage of friable calli.

In addition, in each case calli were induced first in Medium 1 (0.8 mg/L 2,4-D and 1.5 mg/L BA) which contained the lowest concentration of either growth regulator, all of which suggests that low exogenous growth regulator concentrations, but not a complete absence of growth regulators, is required to initiate callus induction.

Also 100% friable calli were induced with either in vitro explant type since the younger tissue responded more effectively to the exogenous growth regulators than the greenhouse-derived explants in forming calli.

The results of the shoot production treatment showed that there was a greater overall percentage of bud burst achieved with the nodal and shoot tip explants. Higher percentages of bud burst were achieved at lower concentrations of BA for both explant types except the in vitro explants in Medium 5 (1 mg/L IAA and 12 mg/L BA). Both explant types seem to have responded well to growth regulator concentrations at the lower end of the BA range. It seems that the higher concentrations of BA inhibited bud burst, as well as the increase in shoot height for both explant sources. The explants responded to the control media, all of which suggests that they are producing endogenous growth regulators and require only a minimal additional amount of BA to achieve bud burst or an increase in shoot height once bud burst has taken place.

The greatest shoot height was achieved using in vitro-derived nodes and shoot tips in medium containing 1mg/L IAA and 1 mg/L BA. This represents a lower BA concentration than that in which the greatest shoot height was achieved for the greenhouse-derived explants. Two media of the shoot production treatment containing greenhouse derived explants exhibited proliferation in Medium 4 (1mg/L IAA and 8 mg/L BA) in four explants; in Medium 2 (1mg/L IAA and 2 mg/L BA) in one explant. Medium 5 (1mg/L IAA and 12 mg/L BA) of the shoot production treatment containing in vitro-derived explants also showed proliferation in two explants. Proliferation seems to take place at higher BA concentrations for each explant source.

Again in vitro-derived explants seemed to be more tolerant of higher BA concentrations than greenhouse-derived explants. Proliferation of shoots is useful in tissue culture since multiple shoots in this case are produced from one explant. This is especially useful if the explant contains the desired traits.

Only one of the hypocotyl explants produced a shoot since this explant type does not contain pre-formed meristems. Pre-formed meristems are groups of localized actively dividing cells that give rise to root and shoot systems. A high percentage of shoots was not expected from this explant type.

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GROWTH AND YIELD RESPONSE OF PUERTO RICAN SWEET PEPPER TO LEVELS OF DRIP IRRIGATION IN THE VIRGIN ISLANDS

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ABSTRACT: Puerto Rican sweet pepper also known as 'Ají dulce' (*Capsicum chinense* Jacquin) is a popular crop in the Virgin Islands. It is mainly used for culinary seasoning by most Puerto Rican residents. In spite of its popularity, no crop management studies have been done to improve yield and production. This study was conducted to determine the response of Puerto Rican sweet pepper to levels of drip irrigation. Peppers were planted on 1 May 2002 into rows 91 cm apart. Within-row spacing was 61 cm. Treatments consisted of three drip irrigation regimes (levels) based on soil moisture tension of -20 kPa, -40 kPa, and -60 kPa. The trial was laid out by using a randomized complete block design with three replications. Peppers were harvested on six dates from 23 July to 27 August 2002. Data collected included total number of fruits, number of marketable fruits, marketable fruit weight, and total irrigation water use. Results indicated no significant ($P>0.05$) differences in measured parameters; however, there was a trend for yield to increase with increasing irrigation rate. Plant height and marketable yield increased with increasing application of irrigation water from -60 kPa to -20 kPa. Regression analysis indicated a significant ($P<0.0274$) linear response to irrigation rates. Highest marketable yield was obtained from irrigation regime where soil moisture was maintained at -20 kPa. Although not statistically significant, decreasing soil moisture tension from -60 kPa to -20 kPa resulted in 30% increase in marketable fruit yield. Total water use was highest (1763 m^3 ha^{-1}) at irrigation regime of -20 kPa and lowest (547 m^3 ha^{-1}) at -60 kPa. Although yield was highest at the -20 kPa regime, water use and cost were not efficient, thus resulting in lower economic returns to irrigation water compared to returns with irrigation regimes of -40 kPa and -60 kPa.

INTRODUCTION

Among the Puerto Rican community in St. Croix, U.S. Virgin Islands, a particular sweet pepper cultivar known as 'Ají dulce' is popular and is mainly utilized for culinary seasoning. Ají dulce is not a hot pepper and its mild taste gives characteristic flavor to most Puerto Rican recipes. Ají dulce is also known as Puerto Rican chile pepper and described as a tiny, wrinkled, flying-saucer-shaped sweet chile that looks and smells like the incendiary Habanero or Scotch Bonnet hot pepper, but lacks the strong pungent flavor.

In the Virgin Islands, Puerto Rican sweet pepper along with West Indian hot peppers are a specialty cash crop. These specialty peppers are commonly grown by small-scale farmers for local markets, but there is also an opportunity for export market (Crossman et al., 1999; Marsh, 1988; 1991). Small-scale growers with limited farm resources can improve their income by growing Puerto Rican sweet pepper. Yield can be increased by growing improved cultivars combined with good management practices such as fertilization and drip irrigation. Little research information is available on Puerto Rican sweet pepper in the Caribbean. Most of the literature deals with hot peppers, where studies on cultivar evaluation, plant spacing and drip irrigation have been reported (Adams et al., 2001; Anon, 1988; Cooper et al., 1993; Marsh and Rhoden, 1990; McGlashan, 1988; O'Keefe and Palada, 2002). No studies have been reported on the effect of drip irrigation on hot pepper in the Caribbean. But in Colombia, South America, Sanchez et al. (2003) reported no significant effect of irrigation levels on plant height, rooting depth and biomass of Ají dulce. However, they reported that yield increased with increasing irrigation rates.

Like other sweet pepper cultivars, Puerto Rican sweet pepper is sensitive to the effect of moisture stress. Cooper and Gordon (1992) reported reduced yields and decreased fruit size when hot peppers were subjected to severe moisture stress. Moisture stress resulted in severe fruit drop and decreased total yield (Ganpat, 1973). Studies in the Virgin Islands indicated that hot peppers did not respond to drip irrigation rates, but the interaction between irrigation and cultivar was significant (Palada et al., 2001). Drip irrigation is an efficient method of applying water and nutrients for the production of high value horticultural crops such as Puerto Rican sweet peppers. For example, Byer et al. (1992) reported that in Barbados, marketable yields in excess of 33,600 kg/ha can be achieved with the use of drip irrigation.

This study was conducted with the following objectives: 1) determine growth and yield of Puerto Rican sweet pepper with drip irrigation regimes, and 2) measure water use and determine optimum drip irrigation requirement of Puerto Rican sweet pepper.

MATERIALS AND METHODS

The study was conducted at the Agricultural Experiment Station, University of the Virgin Islands, St. Croix, USVI (lat. 17°42'N, long. 64°48'W). The soil is a Fredensborg loamy, fine carbonatic, isohyperthermic, shallow Typic Calciustolls. Mean annual precipitation is 1015 mm and rainfall distribution is not uniform through the year. The field experiment was conducted from May 1 to August 27, 2002. Thirty-day-old seedlings of local Puerto Rican sweet pepper cultivar were transplanted in three rows per plot with row spacing of 91 cm apart and in-row spacing of 61 cm. Treatments consisted of drip irrigation regimes (scheduling) based on soil moisture tensions of -20 kPa, -40 kPa, and -60 kPa as determined by soil tensiometer (Irrometer, Riverside, CA).

The drip irrigation system consisted of main and submain lines made of 15-mm black polyethylene hose. The laterals were made of 15-mm T-tape (Hardie irrigation, Sanford, FL) with laser-drilled orifices (emitters) 61 cm apart. Soil tensiometers were installed at 15-cm depth near the base of a plant to monitor soil moisture levels. The tensiometer was placed in the middle row for each treatment. Flow meters were installed for each irrigation regime to measure irrigation water use. The experimental design was a randomized block with three replications.

Prior to planting, basal application of composted (dehydrated) cow manure (2-1-2) was incorporated during the final field preparation (rototilling) at the rate of 10 tons/ha. Subsequent fertilizer was applied via fertigation with soluble fertilizer (20-20-20) at total rate of 100-100-100 NPK in kg/ha. This was applied in six equal fertigations on May 8, 23, June 7, 20, August 8 and 26. Insect pests were managed with organic sprays such as Bioneem, Botanicguard, Dipel, Mpede and Pyrellin.

The crop was harvested six times during the production season from July 23 to August 27, 2002. Yield samples were harvested from five plants of the middle rows. Plant height was measured during the first harvest. Data on number of fruits, fruit size, and fruit yield (total and marketable) were collected for each harvest. Irrigation water applied per treatment was recorded weekly and total water use was calculated at the end of the trial by subtracting the initial flow meter reading from the final reading taken at the last harvest.

Growth and yield data were analyzed for statistical significance by using the General Linear Model (GLM) by SAS. Differences in treatment means were compared by using the Duncan's Multiple Range Test at 5% significance level. To determine the response of Puerto Rican sweet pepper to irrigation level, a regression analysis was performed using irrigation regime as independent variable and plant height and yield as dependent variables.

RESULTS AND DISCUSSION

Plant Height

Data on Table 1 show that although plant height increased with increasing irrigation water application (-60 kPa to -20 kPa), the response was not significant. Differences in plant height between irrigation regimes were small (Table 1). No moisture stress was exhibited by plants under the -60 kPa, but plants were shorter than plants grown under -20 and -40 kPa irrigation regime. This result is consistent with those obtained by Palada et al. (2001) who reported that drip irrigation level did not influence plant height of hot pepper cultivars.

Number of Fruits, Fruit Size and Yield

The number of fruits was significantly influenced by irrigation regime (Table 1). A highly significant linear response ($P<0.01$) was observed with increasing irrigation water application. Number of fruits increased from $70.7/m^{-2}$ at -60 kPa to $98.2/m^{-2}$ at -20 kPa. This result is not consistent with those reported on hot peppers, where drip irrigation level had no significant effect on the total number of fruits (Palada et al., 2001). In this report, differences were influenced by cultivars rather than irrigation regimes.

Although the effect of irrigation was significant on the number of fruits, fruit size was not influenced by irrigation regime (Table 1). However, data showed that smaller fruits (3.55 g) were produced from irrigation regime of -60 kPa than those from -40 and -20 kPa treatments, with average fruit size of 3.82 g and 3.75 g, respectively. Palada et al. (2001) reported that fruit weight (size) was not influenced by drip irrigation, but differed significantly among cultivars of hot pepper.

There was a significant linear response ($P<0.05$) for marketable fruit yield to irrigation regime (Table 1). Marketable fruit yield increased with increasing irrigation water application. Yield increased from 2527 kg ha^{-1} at soil moisture tension maintained at -60 kPa to 3706 kg ha^{-1} at -20 kPa (Table 1). Increasing irrigation regime from -60 kPa to -20 kPa resulted in 32% yield increase for Puerto Rican sweet pepper. The significant yield increase due to increased level of drip irrigation obtained in this study is not consistent with that reported on hot peppers (Palada et al., 2001). However, their results indicated an interaction between cultivar and irrigation regime.

Table 1. Response of Puerto Rican sweet pepper to irrigation regimes, UVI-AES, 2002.

Irrigation Regime (kPa)	Plant height (cm)	Fruit No. (m^{-2})	Fruit size (g)	Marketable Yield (kg ha^{-1})
-20	71.6	98.2	3.75	3706
-40	70.3	86.8	3.82	3296
-60	67.6	70.7	3.55	2527
Linear	NS	**	NS	*
Quadratic	NS	NS	NS	NS

*Significant at $P<0.05$, **Significant at $P<0.01$, NS=not significant

Irrigation Water Use, Efficiency and Economic Returns to Irrigation Water

Data on the estimated irrigation water use and efficiency are shown in Table 2. The highest total irrigation water use was recorded in plots under -20 kPa irrigation regime, and the lowest irrigation water use was obtained from plots under -60 kPa. The higher irrigation water use at -20 kPa regime resulted in higher water cost ($7457/ha) compared to $2314/ha for the -60 kPa regime (Table 2). This finding resulted in lower water use and cost efficiency for irrigation regime with higher water application (-20 kPa and -40 kPa) than that of -60 kPa. Consequently, this was reflected in lower economic returns to irrigation water for the irrigation regimes of -20 kPa and -40 kPa. Although ratio of returns to irrigation water was lower in higher irrigation regimes, other economic parameters should be considered in determining economic returns and profitability. The 32% increase in yield under the -20 kPa regime may result in higher overall returns if all other costs are considered in the budget analysis. However, the data presented here would indicate that Puerto Rican sweet pepper can be produced under limited or reduced irrigation water application. Minimum drip irrigation level resulted in higher returns to irrigation water.

Table 2. Estimated gross returns, water use, cost efficiencies and returns to irrigation water of Puerto Rican sweet pepper grown under three drip irrigation regimes, UVI-AES, 2002.

Irrigation Regime (kPa)	Gross returns[1] ($/ha)	Water use (m^{-3}/ha)	Water cost[2] ($/ha)	WUE[3] (l/kg)	WCE[4] ($/kg)	Returns to irrig. water[5] ($/$)
-20	24,459	1763	7457	475	2.01	3.28
-40	21,754	867	3667	263	1.11	5.93
-60	16,678	547	2314	216	0.92	7.21

[1]Puerto Rican sweet pepper local market price at US$6.60/kg.
[2]Irrigation water cost at US$4.23/$m^{-3}$
[3]WUE=water use efficiency expressed in kg sweet pepper produced per cubic meter of water used.
[4]WCE=water cost efficiency expressed as cost of water to produce a kilogram of sweet pepper ($/kg).
[5]Returns to irrigation water= dollar return per dollar cost of irrigation water ($/$).

SUMMARY AND CONCLUSIONS

This study has shown that irrigation regime influenced the yield of Puerto Rican sweet pepper in terms of number of fruits produced and marketable yield. Marketable yield increased with increasing application of irrigation water. Irrigation regime did not influence growth in terms of plant height. Neither was fruit size affected by irrigation regime, but smaller fruits were produced under reduced irrigation application. This study also indicates that Puerto Rican sweet pepper can be produced with minimum irrigation water; however, maximum yield response is possible at maximum irrigation water application.

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CULTIVAR EVALUATION FOR WATERMELON IN THE U.S. VIRGIN ISLANDS

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ABSTRACT: An on-farm cultivar evaluation trial for watermelon (*Citrullus lanatus*) was conducted to compare differences in crop development, marketable yield, and tolerance to pests and diseases. Two large size cultivars ('Crimson Sweet' and 'Desert King'), and three ice box cultivars ('Jade Star', 'Sugar Baby', and 'Yellow Doll') were direct seeded on 23 August 2002 into rows 1.22 m apart and spaced 0.91 m within rows. The trial was established in a randomized complete block design with three replications. Cultivars were harvested on six dates from 30 October to 25 November 2002. Data collected at each harvest included total number of fruits, fresh weight, number of marketable fruits and percentage soluble solids (brix). All cultivars had excellent germination ranging from 90 to 100%. Vine length to first flower ranged from 102 cm for 'Yellow Doll' to 213 cm for 'Crimson Sweet'. All plots were infected with powdery mildew; no cultivar showed tolerance. Statistical analysis showed significant differences ($P<0.05$) in total number and marketable fruits per plant, but not in fruit weight. Cultivars with greatest number of marketable fruits were 'Yellow Doll' (27.6) and 'Sugar Baby' (27.3). 'Desert King' produced the lowest number of fruits (5.6). Cultivars with highest average fruit weight were 'Crimson Sweet' (4.6 kg) and 'Desert King' (4.2 kg). 'Yellow Doll' produced the smallest average fruit size (1.4 kg). Among cultivars, differences in percentage soluble solids (brix) were significant ($P<0.05$). Generally, ice box cultivars were sweeter than the larger size cultivars. Brix reading was highest for 'Jade Star' (11.12) followed by 'Yellow Doll' (10.48). In terms of marketable number of fruits, it appears that ice box cultivars of watermelon are more productive than larger size cultivars. On the basis of this study, cultivars 'Yellow Doll' and 'Sugar Baby' should be grown in the Virgin Islands.

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APROPIACIÓN SOCIAL DEL TERRITORIO: EL RETO EN LA RESERVA DE LA BIÓSFERA DE "LA SEPULTURA", CHIAPAS, MÉXICO

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RESUMEN: La Reserva de la Biósfera "La Sepultura" en el estado de Chiapas, con una superficie de 167,309 hectáreas, fue decretada el 5 de junio de 1995. Actualmente esta reserva cuenta con una dirección, un Programa de Manejo y un Consejo Asesor. La habita un total de 23,145 personas, distribuidas entre 127 localidades, de las cuales 47 son comunidades rurales (ejidos) y 80 son rancherías. Los suelos existentes en la reserva son principalmente de vocación forestal, pero su uso se ha cambiado, históricamente, principalmente por las actividades económicas agrícolas y ganaderas. La actividad que más ha impactado los recursos naturales del área son los cambios de uso del suelo y el aprovechamiento forestal selectivo carente de un manejo sustentable de los mismos. Sin duda, el reto mayor para los programas operativos lo constituye la concepción que se tiene por parte de las autoridades sobre el papel que juegan los habitantes dentro de la reserva; son un estorbo para la conservación o son sujetos portadores de futuro. En este artículo discutimos los alcances de las posturas. Cómo pasar de habitantes a actores sociales para que se pueda romper el cerco en el cual se encuentran conformado por una red de instituciones y de empresas y saltar a un estilo de desarrollo diferente. Primero romper los cercos ideológicos, económicos, institucionales, organizativos, y políticos en que se encuentran.

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CHLORED INSECTICIDES (CHLORDECONE, HCH) CAUSING ENVIRONMENTAL POLLUTION AND FOOD PRODUCT CONTAMINATION IN FRENCH WEST INDIES

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ABSTRACT: For several years, banana crop protection against weevils (*Cosmopolites sordidus*) and nematodes (*Radopholus similis*) has led to massive use of organochloride insecticides (chlordecone and HCHB) in French West Indies (Martinique and Guadeloupe). These chemical products have been prohibited since 1993, but they always cause a wide pollution of agricultural grounds, mainly because of their high chemical stability. That ground pollution gives rise to pollution of the rivers and of drinkable water resources, contamination of some crops (root –vegetables such as dasheen, sweet potato, yam), contamination of animals living in the sea and in rivers (fish, shellfish), and contamination of mammalian tissues. This situation warns about health risk for people. An action plan has been created by state official services, with a close collaboration between scientific research organizations and agricultural services. The plan has two parts: First is risk assessment with a cartography of contaminated grounds; an inventory of food vegetables likely to be contaminated; studies concerning the way hazardous compounds are distributed inside tubers; effects that can be expected after cooking, on people exposed because of their food habits, and assessment of residue quantity in common foods. Second is risk management, with collection and destruction of old and abandoned chemical compound stock on farms (bound to lead to point source pollution); farmers' obligation to submit ground analyses before planting, giving regular and clear informations to people; and a strengthened plan of control to prevent availability of contaminated food products.

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THE BRAND REGIONAL NATURAL RESERVE OF MARTINIQUE: PROMISE OF QUALITY AND DIFFERENCE

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ABSTRACT: The 40 Regional Natural Reserves of France have had the role, since their creation in 1966, to protect and develop the inheritance of their classified territory while contributing to its economic, social, and cultural development. Since 1996, they have offered the possibility to the businesses of their territory to use the trademark "Regional Natural Reserves of ...". A charter Quality established by type of product and an agreement signed with the company, fix control and conditions of use of this trademark. Like other products in Metropolitan France, honeys of Martinique have profited since the end of 2001, from the trademark "Regional Natural Reserve", which offers to the consumer a guarantee of origin, of authenticity, of know-how, and of naturalness. Developing products carried out in strict respect for scheduled conditions, this brand presumes a traceability. After the first year since launching, the trade mark promise of quality for the consumer appears to be an economic development tool allowing a better product evaluation. New work is in progress to develop the use of the trade mark with other agricultural produce and artisanal or tourist items.

LA MARQUE PARC NATUREL REGIONAL DE LA MARTINIQUE PROMESSE DE QUALITE ET DE DIFFERENCE

RESUMEN: Les 40 Parcs Naturels Régionaux de France ont pour mission, depuis leur création en 1966, de protéger et valoriser le patrimoine de leur territoire classé en contribuant à son développement économique, social et culturel. Depuis 1996, ils offrent la possibilité aux entreprises de leur territoire d'utiliser leur marque. Une charte Qualité établie par type de produit et une convention signée avec l'entreprise fixent les conditions d'utilisation et de contrôle de cette marque. Comme d'autres produits en France métropolitaine, des miels de Martinique bénéficient depuis fin 2001, de la marque Parc Naturel Régional qui offre une garantie d'origine, d'authenticité, de savoir-faire et de naturel au consommateur. Promotionnant des produits réalisés dans le strict respect d'un cahier des charges, elle suppose la mise en place d'une traçabilité. Après une première année de lancement, la marque, promesse de qualité pour le consommateur, se révèle comme un outil de développement économique permettant une meilleure valorisation des produits. De nouveaux travaux sont en cours pour développer l'usage de la marque à d'autres produits agricoles, artisanaux ou touristiques.

INTRODUCTION

Cet exposé a pour objet de présenter la démarche engagée par le Parc Naturel Régional de la Martinique (PNRM) en matière de valorisation de produits et services de son territoire offrant qualité et authenticité au consommateur, au travers d'un outil propre au réseau des Parcs Naturels Régionaux de France, « la Marque Parc ».

Il s'appuiera pour cela sur la présentation du Parc ainsi que de sa marque puis sur celle de la démarche menée par le PNRM concernant le marquage du miel.

I. Le Parc Naturel Régional de la Martinique

Un Parc Naturel Régional est un territoire classé par l'Etat à la demande des élus locaux, en raison de la qualité et de la fragilité de ses paysages, de ses milieux naturels et de son patrimoine culturel.

Apparus à la fin des années 60, les Parcs Naturels Régionaux de France, territoires d'expérience, affichent depuis plus de 30 ans, une politique de développement durable, associant développement social et humain à la protection de l'environnement. Aujourd'hui au nombre de 40, ils représentent plus d'un dixième du territoire national, où vivent près de 2,5 millions d'habitants.

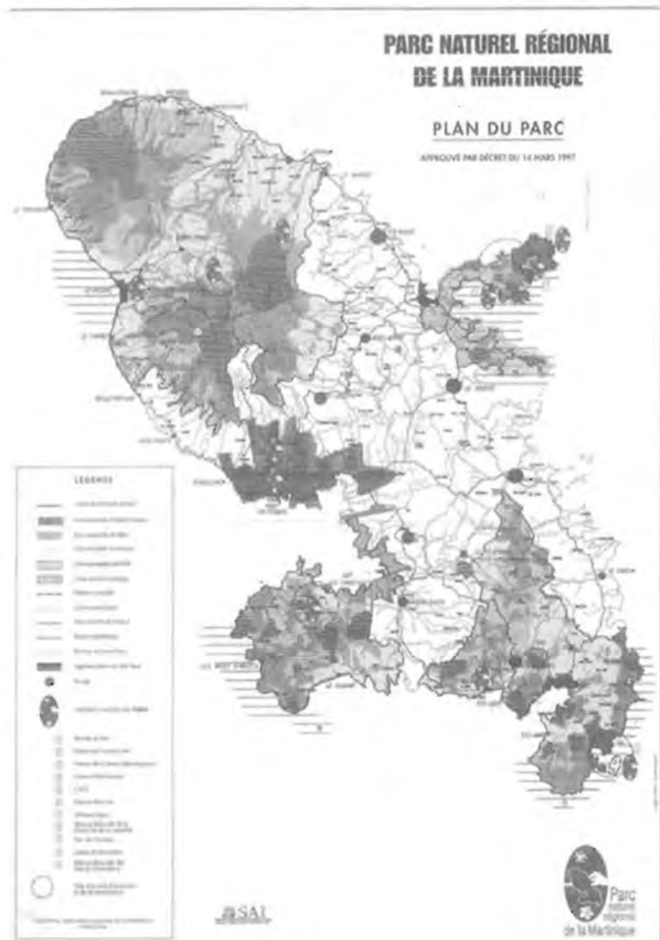
Pour réaliser leurs objectifs, ils s'appuient sur une structure administrée par les élus locaux et un contrat valable 10 ans, la Charte du Parc. Leurs missions fondamentales sont :

- de protéger leur patrimoine, par une gestion adaptée des milieux naturels et des paysages,
- de contribuer à l'aménagement du territoire,
- de contribuer au développement économique, social et culturel et à la qualité de vie,
- d'assurer l'accueil, l'éducation et l'information du public,
- de réaliser des actions expérimentales ou exemplaires dans ces domaines.

Le Parc Naturel Régional de la Martinique s'appuie sur **un territoire de 62 725 ha.** Découpé en quatre secteurs géographiques, il couvre en superficie environ la moitié de l'île et concerne 32 communes de la Martinique.

Parmi ses missions fondamentales, le PNRM, comme tous les autres Parcs Naturels Régionaux de France, oeuvre pour le développement économique et social de son territoire. Ainsi, il soutient la valorisation économique des ressources naturelles et culturelles et contribue à leur promotion notamment grâce à l'usage de sa marque.

Parc naturel régional de la Martinique



II. La Marque collective « Parc Naturel Régional de la Martinique »

La dénomination « Parc Naturel Régional » et son emblème figuratif constituent une marque collective, propriété du ministère de l'Environnement. Chacun des 40 Parcs est gestionnaire de sa marque et peut depuis 1996 l'attribuer à des produits et des services de son territoire en échange de la signature d'une Charte Qualité et d'une convention d'utilisation.

Trois déclinaisons d'usage ont été crées pour permettre l'identification de trois familles de produits :

- « **Produit du Parc Naturel Régional de ...** » pour les produits agricoles et artisanaux,
- « **Accueil du Parc Naturel Régional de ...** » pour les prestations touristiques,
- « **Savoir-faire du Parc Naturel Régional de ...** » pour les prestations artisanales.

Produit du Parc naturel régional de la Martinique ®

Accueil du Parc naturel régional de la Martinique ®

Savoir-faire du Parc naturel régional de la Martinique ®

La distinction par la marque est une reconnaissance de qualité. La Charte Qualité, spécifique au type de produit ou service marqué, rédigée localement en concertation avec les acteurs de la filière, décline un certain nombre de critères sélectifs, contrôlés après l'attribution, qui traduisent les quatre valeurs Parc garanties au consommateur :

- une origine « Parc », (provenance du produit et de ses matières premières)
- une authenticité (lien identitaire entre le produit et le territoire)
- une fabrication artisanale (non standardisée, privilégiant la dimension humaine)
- un caractère naturel (une production en respect de l'environnement)

Démarche partenariale, l'attribution de la marque s'appuie sur une volonté mutuelle et affirmée des producteurs et du Parc à s'investir dans la promotion, la commercialisation et le contrôle des produits marqués. En valorisant le potentiel d'image et de sympathie accordée aux Parcs Naturels Régionaux, cette marque apporte une plus-value aux entreprises tout en offrant une **promesse de qualité et de différence** au consommateur.

Les entreprises bénéficiaires, accompagnées et conseillées dans leur développement, profitent ainsi de l'ancrage territorial de la marque (identifiant la Martinique) mais aussi de sa dimension nationale (par référence au label « Parc Naturel Régional »). A ce jour, plus de 300 entreprises et environ 85 produits ou prestations en bénéficient dans l'ensemble des 40 Parcs Naturels Régionaux. Environ la moitié d'entre eux sont des produits ou prestations proposés par des agriculteurs comme le Miel, le raisin de table, la viande bovine, le lapin, les fromages, ... ou encore les accueils à la ferme.

III. Le miel « Produit du Parc Naturel régional de la Martinique »

En Martinique, le miel est le premier produit bénéficiant de la marque « Produit du Parc Naturel Régional de la Martinique ». Amorcée en 1999, cette démarche a été engagée pour répondre aux objectifs de quelques apiculteurs et du PNRM de promouvoir et valoriser les ressources du territoire tout créant de la plus-value.

Si environ 120 apiculteurs se déclarent chaque année en Martinique , les professionnels (plus de 60 ruches) ne sont qu'une quarantaine et seulement une douzaine d'entre eux font de l'apiculture une activité principale. L'encadrement technique de la filière est déficitaire et l'apiculture ne fait l'objet d'aucun programme de recherche ou d'enseignement ni programme de suivi. La filière, très divisée est par ailleurs inorganisée et maîtrise mal les facteurs de production dont beaucoup sont importés à des coûts élevés.

Souffrant depuis une dizaine d'années d'atteintes à la production (introduction du Varroa jacobsoni) et d'un manque d'encadrement technique, un petit groupe d'apiculteurs solidaires s'est constitué pour défendre les caractéristiques particulières du miel martiniquais et faire reconnaître la qualité de leur savoir-faire et de leurs produits.

Le Parc Naturel Régional a choisi quand à lui de s'engager dans une réflexion sur l'apiculture poursuivant un double objectif : celui de promouvoir un produit du terroir martiniquais dont l'image est attachée au patrimoine naturel et celui de mieux connaître cette ressource florale afin d'en favoriser la protection.

Le projet de marquage du miel « Produit du Parc Naturel Régional de la Martinique » a été initié sur la base de ces objectifs. Sous l'animation du Parc Naturel Régional de la Martinique, experts et professionnels ont alors activement participé au groupe de réflexion qui a travaillé pendant un an à la rédaction de la Charte Qualité validée à l'échelon local par le Comité du Syndicat Mixte du Parc et à l'échelle nationale par le Bureau de la fédération des Parcs.

Cette Charte Qualité du Miel marqué « Produit du parc Naturel régional de la Martinique » décline en 10 articles les conditions d'attribution de la marque Parc. L'article 2 fondamental, traduit les **quatre valeurs Parc qui garantissent un miel** :

- d'origine exclusive du territoire du parc,
- dont la production est conduite en respect de la qualité du territoire,
- dont les techniques de fabrication préservent au mieux toutes ses qualités naturelles et de fraîcheur et dont les conditions de commercialisation privilégient un rapport convivial et transparent avec le consommateur,
- dont l'authenticité s'appuie notamment sur une valorisation de la typicité des flores mellifères.

Par ailleurs, l'usage de la marque est scrupuleusement codifiée par une charte graphique valable pour l'ensemble du réseau des Parcs Naturels Régionaux. Ainsi, tout support (promotionnel , commercial ou signalétique) y faisant référence doit faire l'objet d'un accord préalable des instances du Parc. Dans le cas du miel, pour offrir une image cohérente au consommateur, les étiquettes ainsi que les enseignes signalant la marque sont fournies par le Parc Naturel Régional de la Martinique.

Produit du Parc naturel régional de la Martinique ®

Expression de la flore de notre territoire et d'un savoir-faire artisanal, respectueux de l'environnement, ce miel bénéficie de la marque Parc Naturel Régional de la Martinique.
Elle vous garantit un produit d'origine conforme à la charte que se sont imposés les apiculteurs pour vous offrir un miel authentique et de qualité.
Pour en savoir plus : PNRM - Domaine de Tivoli B.P. 437 - 97200 Fort de France

Le respect des engagements pris par les bénéficiaires de la marque fait l'objet d'un contrôle avant et après l'attribution au travers des procédures d'agrément et de contrôle mises en place sous la responsabilité du Président du Parc Naturel Régional de la Martinique. Elles sont analysées par un Comité technique de suivi et de contrôle qui a eu pour mission d'une part de participer à l'élaboration de la charte Qualité et d'autre part de vérifier le respect des conditions d'attribution de la marque pour les premiers demandeurs ayant obtenu la marque fin 2001.

Ainsi, lui ont été soumis sur la base d'un bilan de visites d'aptitude effectuées à la production (ruchers, miellerie, stockage) et à la commercialisation accompagné de résultats d'analyses de miels, une grille de notation lui permettant d'évaluer la vérification des « Plus Parc » et proposer les dossiers d'attribution.

Concernant le contrôle, ce même comité est chargé d'analyser les rapports de visites effectuées au cours des 3 années pour lesquelles est signée la convention d'attribution, ainsi que les résultats d'analyses de miels effectués sur chaque lot marqué.

Enfin, afin d'assurer **la traçabilité** de chaque lot ayant reçu la marque, chaque apiculteur se doit de porter une indication de lot (identifiable par la DLUO[1]) et d'effectuer les enregistrements correspondants à la gestion de ce lot (date de récolte, nombre de ruches, cadres et volume récolté, date d'extraction, date de conditionnement, quantité conditionnée, ...) qu'il transmet chaque trimestre en renvoyant au Président du Parc Naturel Régional de la Martinique, l'imprimé de « Relevé trimestriel d'opération et de suivi des miels marqués ».

En cas d'anomalies constatées au cours du contrôle, le Comité technique de suivi et de contrôle pourra proposer des avertissements ou des sanctions pouvant aller jusqu'au retrait temporaire ou définitif de la marque.

IV. Conclusions et perspectives

Quatre apiculteurs se sont engagés fin 2001 dans l'usage de la marque Parc qu'ils peuvent apposer sur le miel qu'ils produisent dans le territoire du Parc dans les conditions exigées.

Au bilan, un volume total d'environ 400 l de miel a été vendu marqué en 2002. Il correspond à dix récoltes effectuées entre le 4 mars et le 28 mai dans le territoire du Parc. Cette production, relativement faible par rapport au volume envisagé en 2001, a été très vite écoulée sur le marché.

Ainsi, les 6 premiers lots marqués début mars, soit un volume de près de 300 l de miel ont été vendu en quasi totalité en l'espace d'un mois en vente directe sur le marché ou sur des foires agricoles.

Les difficultés de début de saison (pas de floraison du Gliciridia sepium suite à la pullulation de la chenille de l'Azeta repugnalis) ont ensuite largement restreint la production. Les apiculteurs n'ont pu réaliser par la suite que de très petites récoltes conduisant à un marquage de très faible quantité (à peine 15 l). Un seul producteur ayant marqué fin avril deux lots, soit une centaine de litre, a pu donc proposer du miel marqué sur le reste de l'année.

En terme d'impact, malgré une présence sur le marché relativement courte, il apparaît que la marque :

- par son effet promotionnel, joue le rôle d'un produit d'appel interpellant une clientèle nouvelle,
- contribue à une image de qualité attirant une clientèle en recherche de garantie,
- souligne l'origine et l'authenticité d'un produit stimulant de nouvelles formes d'achat notamment affectives,
- légitime une différence de prix acceptée par la clientèle.

Sur cette première année de lancement, la marque se révèle donc bien comme un outil de développement économique qui pourrait être un levier supplémentaire accompagnant le développement de la production locale et permettant aux producteurs une meilleure valorisation de leur produit. Elle répond par ailleurs aux demandes encore non satisfaites du marché pour des produits locaux bénéficiant de signes distinctifs de reconnaissance leur assurant qualité et sécurité.

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[1]DLUO : Date Limite d'Utilisation Optimale fixée à 2 ans après la date de récolte

Assurant le suivi de cette première démarche, nous programmons par ailleurs d'améliorer la connaissance de notre flore mellifère et du potentiel de ressources que pourrait représenter certains espaces. Nous souhaitons aussi développer nos techniques d'évaluation des risques potentiels d'atteintes tant quantitative que qualitative à la ressource florale ou à la production de miel. Enfin, nous souhaitons renforcer nos interventions pour sensibiliser la population au respect de la flore mellifère.

Pour conclure, nous envisageons d'étendre la gamme de produits et services marqués vers d'autres filières alimentaires, mais aussi vers l'artisanat et le tourisme. Afin d'interpeller les professionnels motivés et prêts à s'engager dans ce processus, qui par la nécessité de constituer une Charte Qualité spécifique, consensuelle et validée localement et nationalement, nécessite plusieurs mois de travail, nous nous sommes engagés cette année dans une étude prospective multisectorielle sur l'ensemble du territoire du Parc.

Nul doute que cette action révèle et mette en valeur des productions de qualité réalisées sur notre territoire offrant garanties et promesse de différence au consommateur.

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FOOD WASTE EFFLUENT AS A NITROGEN SOURCE FOR TWO GRASS SPECIES

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ABSTRACT: Digested food waste effluent (WE) may support crop yields and enhance soil quality. Field studies were conducted during 2000 and 2001 at Florida A&M University (FAMU) research farm at Quincy, Florida, to evaluate the dry matter yield of Sorghum sudangrass (*Sorghum bicolor* (L.) Moench) and ryegrass (*Lolium multiflorum* Lam.) and soil nitrate status to applied WE. The experimental design was a Randomized Complete Block (RCB) with 4 replications. The crops grown during the summer and fall were treated with WE at nitrogen rates of 0, 112, 224, and 336 kg ha^{-1}. WE was manually applied in split applications of 50% at planting and 50% at 28 days after panting (DAP). Soil and above ground plant samples were collected bi-weekly to determine dry matter (DM) accumulation, crop N content, and soil nitrate status. DM yield was significantly higher ($P< 0.05$) for WE treatments of 224 and 336 kg ha^{-1} of N compared to that with the 0 and 112 kg ha^{-1} N rates. At the higher N rates, Sorghum sundangrass had DM yields up to 39,000 kg ha^{-1} whereas ryegrass DM was up to 5,248 kg ha^{-1}. The study indicates that WE can be used as a nutrient source for crops.

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COMPORTAMIENTO DEL HIERRO EN MEZCLAS DE RESIDUOS SÓLIDOS URBANOS MEJORADOS CON SULFATO DE HIERRO MONOHIDRATADO. UN ESTUDIO MEDIANTE ESPECTROSCOPÍA MÖSSBAUER

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RESUMEN: En numerosas ocasiones la aplicación de fertilizantes minerales y el retorno de los residuos de las propias cosechas no son suficientes para mantener un nivel adecuado de materia orgánica en los suelos, que es uno de los factores que más influyen en la estructura correcta de los mismos. Por otra parte, en los países desarrollados no es fácil encontrar cantidades suficientes de materia orgánica a precios razonables, por lo que a veces se acude al uso de residuos sólidos urbanos (RSU) en la mejora de los suelos (Aggelides and Londra, 2000; He et al., 1992; Wong et al., 1999). En otros casos los RSU son mezclados con otros productos procedentes de la industria, conformando así un nuevo producto más eficaz y útil en las aplicaciones agrícolas. En este trabajo se estudia el comportamiento del hierro en muestras de RSU cuando se le añaden cantidades controladas del sulfato de hierro monohidratado mediante los métodos de espectroscopía Mössbauer. Se determinan los contenidos de Fe^{3+} y Fe^{2+} en los compuestos de hierro mediante los espectros Mössbauer registrados a temperatura de nitrógeno líquido. Se observa un crecimiento de la quelatación del hierro con el aumento de la cantidad de SFM añadida al RSU.

ABSTRACT: On numerous occasions the application of mineral fertilizers and the return of crop residues are not enough to maintain an appropriate level of organic matter in the soil. This is one of the factors of great influence in the correct structure of the soils. On the other hand, in the developed countries it is not easy to find enough quantities from organic matter within a reasonable price. That is why Municipal Solid Wastes (MSW) are used to improve soils (Aggelides and Londra, 2000; He et al., 1992; Wong et al., 1999). In other cases, the MSW are blended with other industrial products, conforming a new more effective and useful product in the agricultural applications. In this work, the iron behaviour in samples of MSW is studied when controlled quantities of the Ferrous Sulphate Monohydrated (FSM) are added by means of the Mössbauer spectroscopy methods. The Fe^{3+} and Fe^{2+} contents in iron compounds are determined by means of the Mössbauer spectra registered at liquid nitrogen temperature. A growth of the iron chelatation is observed with the increase of the quantity of FSM added to the MSW.

INTRODUCCIÓN

El compost producido en las plantas de tratamiento de residuos sólidos urbanos de las ciudades puede ser una fuente continua e importante de materia orgánica (MO), que puede usarse como mejorante orgánico de aquellos suelos que presenten una deficiencia en este sentido. A veces estos residuos incorporan cantidades apreciables de materiales tales como chatarra, vidrios, plásticos, aluminio, etc., (Madrid et al., 2001) haciendo que su composición no sea la deseada en cada caso, para la corrección del suelo.

El uso de RSU está abundantemente documentado en la literatura científica, pero a veces el control de la composición de estos materiales no es lo rigurosamente deseable, pudiéndose dar riesgos medioambientales presentes o futuros.

La calidad de estos residuos sólidos se ha medido en la literatura científica por el valor analítico de dos grupos de parámetros. Por una parte los parámetros puramente agronómicos tales como N, P, K, C/N, etc., y por otra parte por el nivel de metales pesados o elementos traza que han contenido, para medir el riesgo medioambiental que su aplicación pudiera producir. Desde este punto de vista se ha incluido el Fe de forma sistemática calculado en las analíticas como hierro total.

Existe una divergencia notable en los valores del contenido de Fe que dan diversos autores, o que puede encontrarse en las aplicaciones comerciales. Así, Soumaré et al. (2002) cita valores de 10900±160 (p.p.m.) para un compost analizado en Bélgica; Madrid et al.(2001) cita valores medios de 0.97% sobre materia seca. Agrimartin (1995) da valores del 2%, etc. Esta diversidad es perfectamente comprensible por la propia diversidad de fuentes de la que el RSU procede, pero en todos los casos han obviado la consideración importante de especiar y diferenciar los valores del contenido de Fe^{3+} o Fe^{2+} que suponen los valores citados, por lo que esa información, bien científica o comercial, tiene escaso interés, puesto que el Fe^{3+} es insoluble y difícilmente absorbible por la planta (Orihuela et al, 1999).

El valor del parámetro Fe-total en un compuesto orgánico tiene escaso valor, especialmente cuando ese compost se usa en suelos calizos para intentar mejorar, además, la clorosis férrica de algunos cultivos mediante fertilización orgánica.

Los métodos tradicionales de análisis químico no permiten diferenciar los contenidos de Fe^{3+} y Fe^{2+}. La Espectroscopía Mössbauer (Furet et al., 2002) deviene como una técnica instrumental analítica efectiva para la valoración de los compuestos de Fe^{3+} y Fe^{2+} a partir de la determinación de las áreas de las componentes del espectro Mössbauer de cada sustancia o muestra a investigar.

El objetivo del presente trabajo es cuantificar la mejora que se produce en un RSU, en su contenido en hierro, cuando se le añaden cantidades controladas de sulfato de hierro monohidratado (SFM).

MATERIALES Y MÉTODOS

Se estudió el comportamiento del SFM en la mezcla con RSU. Las mezclas se prepararon de la siguiente forma: Se llevó el RSU a un estado de compostaje homogéneo antes de su mezcla con SFM. Se partió de una cantidad de 5 kg de RSU. Se hicieron cuatro replicaciones para cada tratamiento que se considera. Los tratamientos son los que se consigna en la Tabla 1 con las fechas de las tomas de muestras.

Tabla 1. Características de los diferentes tratamientos.

Muestra	SFM añadido (g/kg)	Características
MRS-1	0	Muestra testigo de RSU
MRSS-2	50	Tomada al inicio(09-09-02)
MRSS-3	200	Tomada al inicio(09-09-02)
MRSS-4	400	Tomada al inicio(09-09-02)
MRSS-5	50	Tomada al final(21-10-02)
MRSS-6	200	Tomada al final(21-10-02)
MRSS-7	400	Tomada al final(21-10-02)

Las muestras se secan en estufa a 60° C hasta peso constate y se muelen para su posterior análisis por Espectroscopía Mössbauer. Las mediciones fueron realizadas en un espectrómetro de aceleración constante en régimen de transmisión del Laboratorio de Física del Estado Sólido de la Universidad de Maine de Francia. Se estudia el comportamiento del Fe^{3+} y Fe^{2+} durante el proceso de mezcla (fase inicial) y durante un período de tiempo (42 días) después de mezclado el RSU con el SFM (fase final).

RESULTADOS Y DISCUSIÓN

Se obtuvieron todos los espectros Mössbauer de las muestras estudiadas y en la Tabla 2 se presentan los parámetros de cada espectro, así como los valores de las áreas de los subespectros que dan una medida de la concentración de cada compuesto de Fe^{3+} y Fe^{2+}, que es la información de mayor interés para este trabajo. Como ejemplo se muestran en las Figuras 1 y 2 los espectros Mössbauer a 77 K de la muestra testigo MRS-1 (Figura 1) y de una muestra de mezcla del RSU con SFM, MRSS-2 (Figura 2). Se observa una componente magnética resuelta en dos subespectros con parámetros característicos de compuestos de Fe^{3+} y Fe^{2+}. La parte central de los espectros muestra dos componentes paramagnéticas con parámetros característicos de compuestos de Fe^{3+} y Fe^{2+}.

Tabla 2. Parámetros Mössbauer de las muestras de residuos sólidos urbanos mezclados con sulfato de hierro monohidratado a temperatura 77 K.

MRSS-2				MRSS-3			
Is(mm/s)	Qs(mm/s)	A(%)	Componente	Is(mm/s)	Qs(mm/s)	A(%)	Componente
0.37	0.62	30	Fe^{3+}	0.40	0.62	29	Fe^{3+}
0.36	1.16	35	Fe^{3+}	0.44	1.29	26	Fe^{3+}
1.38	3.03	30	Fe^{2+}	1.40	3.03	45	Fe^{2+}
1.38	3.55	5	Fe^{2+}				
MRSS-4				**MRSS-5**			
0.39	0.53	16	Fe^{3+}	0.46	0.64	38	Fe^{3+}
1.37	3.08	82	Fe^{2+}	0.46	1.19	29	Fe^{3+}
1.38	1.97	2	Fe^{2+}	1.40	2.64	12	Fe^{2+}
				1.38	3.40	21	Fe^{2+}
MRSS-6				**MRSS-7**			
0.50	0.64	28	Fe^{3+}	0.48	0.47	14	Fe^{3+}
0.50	1.16	10	Fe^{3+}	1.38	3.07	49	Fe^{2+}
1.38	3.12	51	Fe^{2+}	1.38	3.52	37	Fe^{2+}
1.39	3.68	11	Fe^{2+}				

Is: corrimiento isomérico (referido al Fe); Qs: desdoblamiento cuadropolar; A: área del espectro

Tabla 3. Valores de contenido (%) en las diferentes muestras.

Muestra	gSFM/kg RSU	Fe^{2+}	Fe^{3+}
MRS-1	0	15	43
MRSS-2	50	35	65
MRSS-3	200	45	55
MRSS-4	400	84	16
MRS-1	0	15	43
MRSS-5	50	33	67
MRSS-6	200	62	38
MRSS-7	400	86	14

Para la muestra MRS-1 el contenido de Fe^{2+} es aproximadamente la tercera parte del Fe^{3+} (15% frente a 43%) (Tabla 3). A medida que se aplican cantidades mayores de SFM ocurre que, tanto en la fase inicial como en la fase final, aumenta el Fe^{2+} que queda retenido por la muestra orgánica, terminando en valores próximos al 85% (Figura 3). Con respecto al Fe^{3+} el proceso se ha invertido, puesto que comienza con valores altos y termina con valores próximos al 15% (Figura 4).

La efectividad del proceso de reducción del hierro se consigue a partir de dosis superiores de 50 g de SFM / kg de RSU (Figuras 5 y 6). Estas aplicaciones llevan de inmediato a una reducción del Fe^{3+} en la masa orgánica que pasa a Fe^{2+}.

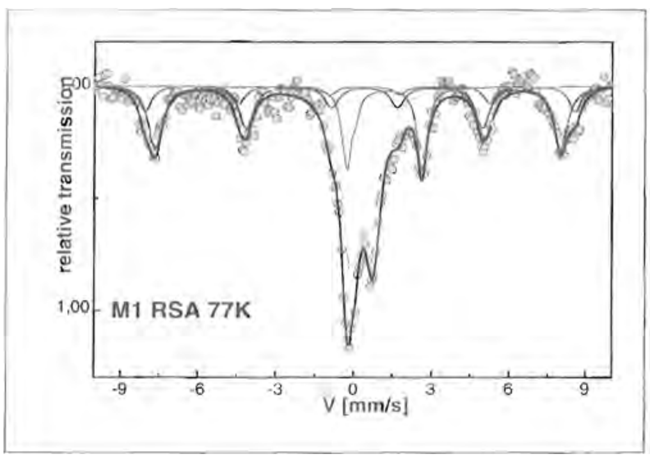

Figura 1. Espectro Mösbauer a 77 K de MRS-1

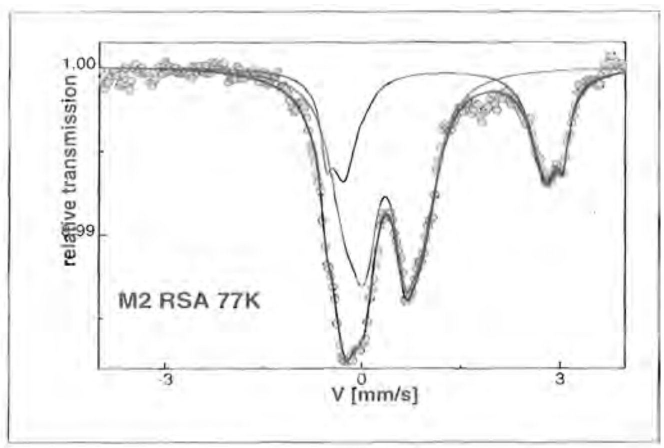

Figura 2. Espectro Mösbauer a 77 K de MRSS-2

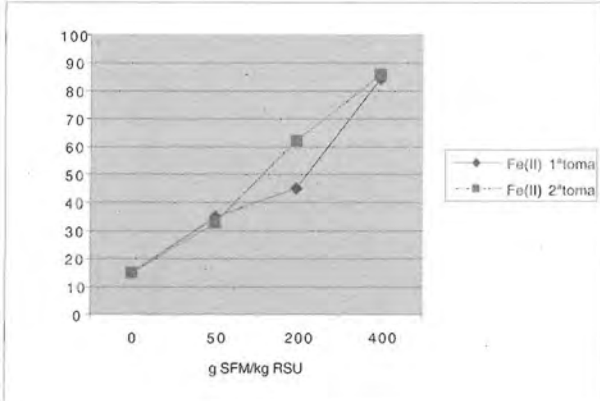

Figura 3. Valores de Fe^{2+}. Fase inicial "versus" final

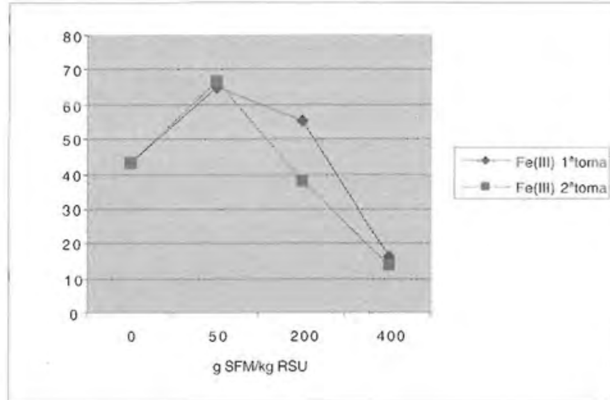

Figura 4. Valores de $Fe3^{+}$. Fase inicial "versus" final

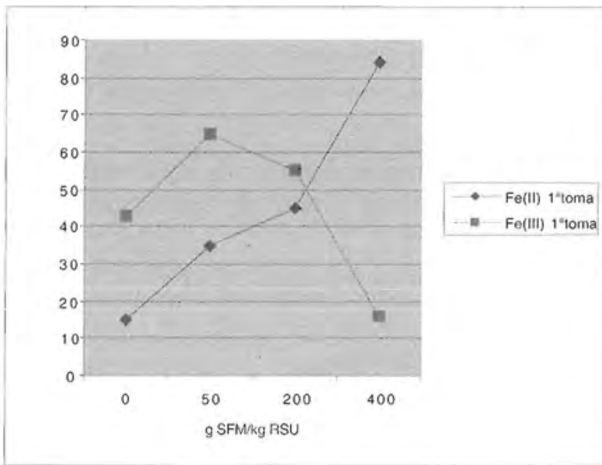

Figura 5. Valores de Fe^{2+}"versus" Fe^{3+}. Fase inicial

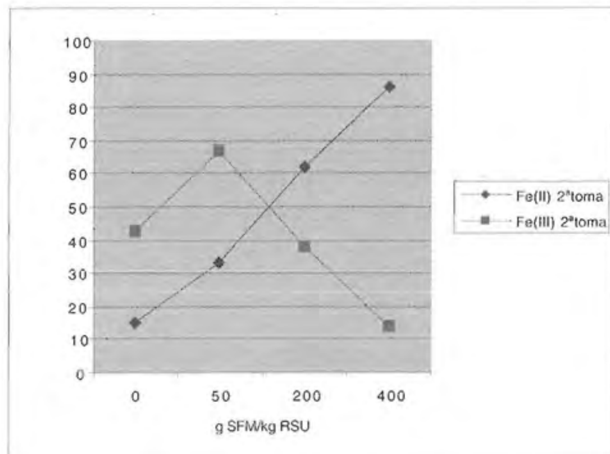

Figura 6. Valores de Fe^{2+}"versus" Fe^{3+}. Fase final

CONCLUSIONES

Los métodos de la espectroscopía Mösbauer permiten una valoración y diferenciación del Fe^{2+} y Fe^{3+}, proporcionando una información importante en el proceso de reducción del hierro en la materia orgánica usada como mejorante del suelo.

La aplicación de sulfato ferroso monohidratado al residuo sólido urbano induce un proceso de reducción del hierro de considerable intensidad, que se pone de manifiesto de forma inmediata, en los primeros días después de su aplicación. Por ello, las recomendaciones a efectos agrícolas de esta mezcla serían de su uso prácticamente inmediato, puesto que sería innecesario esperar procesos de maduración superior a este tiempo.

Como conclusión final puede decirse que de la mezcla de sulfato ferroso monohidratado y del residuo sólido urbano, se genera un producto más idóneo para la corrección de clorosis férrica que, el producto inicial del que se parte.

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DRINKING WATER DISINFECTION USING ULTRAVIOLET LIGHT: AN ALTERNATIVE TO CHLORINATION

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ABSTRACT: Ultraviolet (UV) light to disinfect drinking water was evaluated under laboratory conditions. Suspensions of estimated bacterial count of 1 x 10^5 to 1 x 10^8 colony forming units (CFU) per milliliter of *Escherichia coli*, *Salmonella typhi*, *Shigella flexneri*, and *Streptococcus faecalis* were exposed to UV light at 254 nm in 5-cm depth of water for 20, 10, and 5 s. Bacterial suspensions with turbidities ranging from 0 to 160 Nephelometric Turbidity Units (NTUs) were exposed to UV light for 20, 10, and 5 s at 5-cm depth of water. Bacterial growth populations were estimated by serial dilution, plate count, and membrane filter methods. Bacterial kill was measured as a function of germicidal UV light dose and turbidity. UV light irradiation for 5 s reduced bacterial count from 1.8 x 10^7, 1.2 x 10^7, 2.2 x 10^7 CFU mL^{-1}, and colonies too numerous to count of *E. coli*, *S. flexneri*, *S. typhi*, and *S. faecalis*, respectively, to non detectable levels. A 100% bacterial kill was observed at 5, 10, and 20 s of UV light exposure in water containing an average of 25, 55, and 60 NTUs, respectively. Increased turbidity had a negative effect of reducing the UV light dose reaching targeted organisms, thus reducing bacterial DNA damage and subsequent disinfecting effectiveness. There was no evidence of photoreactivation after exposure of irradiated bacteria to visible light for 24 hours.

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SEDIMENT MODELING AND TRANSPORT IN A TROPICAL WATERSHED

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ABSTRACT: The objective of this work is to model the sediment export potential of a tropical watershed located in the upper central region of Puerto Rico with a watershed modeling system such as the Hydrological Simulation Program – Fortran (HSPF) contained in the Watershed Modeling System WMS v6.1. Land use and other coverages have been developed using a suite of programs, air photography, satellite imagery, and ground truthing. Total suspended sediment samples were taken by using a combination of ISCO-3700 auto-sampler controlled with an ISCO-4200 flow meter that monitors runoff hydrographs from large precipitation events. Base flow was monitored by 15-day grab samples. Watershed outlet coincides with a USGS gage station that monitors flow and sediments. Samples were taken after every runoff event above a pre-established threshold. Samples were analyzed in the laboratory for total suspended sediments by EPA Method 160.2. This work will provide an important tool to develop TMDL for sediments in the watershed and to develop management plans to reduce sedimentation of important water reservoir located downstream.

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TOWARDS A REGIONAL CO-OPERATION PROJECT IN AGRONOMIC RESEARCH FOR A SUSTAINABLE AGRICULTURAL DEVELOPMENT OF THE CARIBBEAN ISLANDS

VERS UN PROGRAMME DE COOPERATION REGIONALE EN RECHERCHE AGRONOMIQUE POUR UN DEVELOPPEMENT AGRICOLE DURABLE : SURETE SANITAIRE ET QUALITE DES PRODUCTIONS ET DES PRODUITS ANIMAUX ET VEGETAUX. CONSTITUTION D'UN RESEAU ASSOCIATIF DE CHERCHEURS CARIBEENS

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ABSTRACT: The associative network of Caribbean researchers concerns the research organizations of the Caribbean insular countries and the French West Indies departments, for which the agricultural sector remains a priority in terms of economic and social development. Agricultures in these countries is confronted with many present or forthcoming plant health problems, all of which justifies the setting of a special program about health and food safety systems and quality of livestock and vegetable production and products in connection with the PROCICARIBE and CARDI programs. This program will be set for the following projects: Bananas and plantains: Impact of the introduction of new hybrid varieties of bananas and plantains on the dynamic balance of the populations of some pathogenic agents and pests, nematodes, fungi, and viruses; Sugar Cane: Support of a sustainable sugar and rum production and preservation of the agricultural landscape in the Caribbean by optimizing the processes of variety selection; Citrus: Promotion of a sustainable citrus fruit cultivation and plant health observatory; Tomato and pepper: Improvement of the market-gardening productions: creation of disease and pests resistant tomato and peppers adapted to the Caribbean environment; Coconut: Towards a global research program on integrated control of the coconut lethal yellowing disease in the Caribbean; Sheltered cultivation in the humid tropics: Training of Caribbean technicians in sheltered vegetable cultivation to improve the durability of these systems of production; Small ruminants: Development of sustainable high quality meat production systems. The expected results are (i) the widening of the cooperation in the sub-region of the Caribbean in pathologic and genetic aspects in some priority crops and selected breeding lines, and (ii) training of a regional research team to manage the continuity of the works in the region. In addition, other results will be (i) development and transfer of new advanced pathologic and genetic methods, (ii) production of knowledge on diseases and genetic resistance and, (iii) creation of new varieties and breeding lines.

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1. Origine du projet, antécédents et problématique

Le réseau associatif de chercheurs caribéens concerne les pays insulaires de la Caraïbe et les Antilles françaises pour lesquels le secteur agricole demeure prioritaire en terme de développement économique et social. Les agricultures de ces pays sont confrontées à de nombreuses maladies dans le secteur animal et à d'importants problèmes phytosanitaires présents ou en émergence, qui justifient la mise en place d'un programme spécifique sur les aspects sécurité sanitaire et qualité des productions et des produits animaux et végétaux.

Origine du projet

Le projet de création d'un réseau associatif de recherche agronomique caribéen résulte de la volonté et des besoins exprimés par les représentants de l'Etat, du Conseil Régional de Guadeloupe et des organismes de recherche des pays de la Caraïbe et des DFA au cours du séminaire[2] «Sécurité sanitaire, sûreté alimentaire et qualité des productions et des produits animaux et végétaux dans la Caraïbe» qui s'est tenu en novembre 2001 en Guadeloupe. Ces besoins de coopération ont été confirmés au cours des missions effectuées par le chargé de coopération régionale du Cirad et par le Président de l'INRA du Centre de Recherche Agronomique Antilles Guyane CRAAG, dans divers états de la Caraïbe pour analyser la faisabilité et vérifier l'intérêt des partenaires locaux de la recherche caribéenne à participer au montage et à l'animation d'un tel projet. Ce thème et cette problématique de développement ont aussi été reconnus comme prioritaires par différentes instances régionales et nationales pour la construction d'un développement agricole durable dans la Caraïbe (CARICOM, FAO, CFCS et CPPC).

Antécédents

Au cours du séminaire de novembre 2001, les besoins de diagnostic ont été soulignés ainsi que la nécessité de mettre en place des systèmes de contrôles fiables, grâce à des réseaux d'épidémiosurveillance animale et végétale sur des bases scientifiques et techniques en relation avec la réglementation des états.

Il a aussi été reconnu la nécessité de mettre à la disposition, de la communauté scientifique régionale, des décideurs politiques et des représentants de la société civile, l'état d'avancement, les progrès de la recherche et les innovations qui découlent de ce travail de mise en réseau. Ce travail de synthèse et d'information doit se traduire par un effort de communication grâce à l'animation en réseaux, aux échanges d'expériences et à la mise à disposition de l'information sous toutes ces formes en privilégiant l'@-information.

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[2] Séminaire « Sécurité sanitaire, sûreté alimentaire et qualité des productions et des produits et des produits animaux et végétaux dans la Caraïbe », du 26 au 29 novembre 2001, Gosier, Guadeloupe (CD-ROM)

Mise en adéquation offre-demande

La consolidation de la coopération régionale française et européenne en recherche agronomique dans la Caraïbe nécessite aussi la mise en place d'une politique commune de programmation de la recherche de la part des organismes de recherche oeuvrant dans les départements français d'Amérique (DFA) de manière à constituer une offre de recherche en adéquation avec la demande et l'offre des partenaires caribéens.

2. Définition et objectifs

Le réseau associatif de recherche agronomique regrouperait un certain nombre de chercheurs des pays de la Caraïbe et des DFA qui participeraient à la structuration d'un pôle de réflexion et d'animation de recherche et d'innovation sur le thème « sécurité sanitaire et alimentaire » et dont les objectifs seraient les suivants :

Objectifs principaux

Objectifs géostratégiques et écononomiques

Participer à la construction de l'espace européen de la recherche au sein des régions ultrapériphériques et favoriser l'intégration de cet Euro-Région dans son espace caraïbe;
Encourager et participer à la mise en place d'une démarche de coopération régionale inter-états et inter-institutions sur les questions de sécurité sanitaire et qualité des productions et des produits animaux et végétaux;
Favoriser la libéralisation et le développement des échanges commerciaux au sein de la Caraïbe et entre la caraïbe et les régions avoisinantes;

Objectifs environnementaux

Permettre aux frontières vivantes de l'Europe des Amériques de jouer un rôle moteur dans le développement durable de la région Caraïbe;
Limiter les impacts environnementaux des pratiques agricoles, par des démarches de protection intégrée

Objectifs organisationnels

Mettre en place un réseau associatif de chercheurs caribéens en recherche agronomique sur les aspects sécurité sanitaire et qualité des productions et des produits animaux et végétaux;
Croiser les compétences entre les différents instituts, dans une démarche pluridisciplinaire
Renforcer et de dynamiser les systèmes de recherches nationaux, universitaires et privés des pays insulaires de la caraïbe et plus spécifiquement des pays de la ZSP caraïbe;
Favoriser les échanges entre les différentes équipes de recherches nationales et la formation et l'encadrement de chercheurs;
Faciliter la constitution d'équipe pluridisciplinaire et opérant transversalement autour du thème « sécurité et qualité »;

Assurer le transfert d'innovation au moyen des nouvelles technologies de l'information (NTIC), de séminaires, d'ateliers, de missions d'expertises et de publications;

Objectifs de politiques scientifiques et techniques

Former des chercheurs, transférer les nouvelles technologies, diffuser l'information, le savoir faire, les méthodes de travail appliquées en relation avec le diagnostic, la défense des cultures et l'amélioration génétique animale et végétale;
Favoriser une intégration plus soutenue des pays les moins avancés de la Caraïbe dans la dynamique actuelle de coopération régionale en recherche agricole (Institut Inter Américain de Coopération Agricole IICA, Caribbean Agricultural Research and Development Institute CARDI et University of West Indies UWI);

Améliorer les connaissances scientifiques et de contribuer à la mise à disposition d'une base scientifique destinée à l'élaboration des politiques et réglementations qui seront nécessaires dans le cadre des futurs accords économiques et régionaux (APER) qui rentreront en vigueur à partir de 2008.

Objectifs spécifiques

Epidémiosurveillance

Mieux appréhender dans les états insulaires de la Caraïbe la situation phytosanitaire des agrumes, de la banane, de la canne à sucre, du cocotier, de la tomate et du piment, et proposer des plans d'actions et des programmes de recherche concertés et adaptés à cette situation;
Mettre en réseau des laboratoires de diagnostic phytosanitaire, animer, former, informer et adapter les dispositifs nationaux de diagnostic et de contrôle des principaux ravageurs et maladies des cultures susnommées;
Développer les techniques d'ingénierie génétique et les outils d'aide à la sélection, à la cartographie du génome et au diagnostic des principales maladies (présentes et en émergence) et de leurs vecteurs associés dans la zone;

Amélioration génétique

Obtenir des variétés de banane, canne à sucre, cocotier, tomate et piment résistantes aux maladies et adaptées aux conditions pédo-climatiques variées de la Caraïbe insulaire;
Sélectionner des géniteurs et obtenir des lignées de petits ruminants adaptés aux conditions caribéennes et à la production de viande de qualité;

Echanges d'expériences et transfert de technologie

Echanger de l'information sur la ou les démarche qualité produit entreprise(s) sur chacune des filières par les états ou les organisations professionnelles;
Echanger des expériences sur les politiques de bonnes pratiques agricoles mises en place au niveaux des états et des filières;

S'impliquer dans la mise en place en réseau et au niveau de chacun des états de la Caraïbe insulaire, des bases de données informatiques relatives aux questions de sécurité sanitaire et de qualité des productions et des produits alimentaires:
- liste des institutions et personnes en charge du contrôle phytosanitaire;
- liste des principaux ravageurs et maladies;
- liste des produits phytosanitaires utilisés par production;
- matériels et méthodes d'analyse, de diagnostic et de contrôle utilisés;
- liste de méthodes et technologies de production plus sûres et respectueuses de l'environnement;

3. Le programme et le contenu du réseau associatif

L'activité scientifique des réseaux est articulée autour de sept sous-réseaux correspondant aux principales filières agricoles de la zone caribéenne soumises à des risques sanitaires importants et nécessitant une mise en commun des connaissances, des dispositifs, des laboratoires et une programmation des travaux des équipes de recherche.

Les filières concernées sont les deux filières traditionnelles et vitales pour les économies de la Caraïbe insulaire, la banane et canne à sucre, et cinq filières de diversification.

Les projets retenus dans une première phase sont les suivants:

3.1. Impact de l'introduction de nouvelles variétés hybrides de bananiers et plantains sur l' équilibre dynamique des populations de certains de leurs agents pathogènes et ravageurs: nématodes, champignons et virus.
3.2. Réseau amélioration variétale de la canne à sucre vis à vis des principales maladies pour une production durable dans les pays de la Caraïbe.
3.3. Promotion d'une agrumiculture durable et observatoire phytosanitaire.
3.4. Amélioration des productions maraîchères: création de tomate et de piments résistants aux parasites et adaptés aux conditions tropicales de la Caraïbe.
3.5. Le jaunissement mortel du cocotier dans la Caraïbe: caractérisation de la diversité et de la variabilité des phytoplasmes associés à cette maladie.
3.6. Formation de techniciens caribéens à la production protégée de légumes pour améliorer la durabilité de ces systèmes de production.
3.7. Etudes de systèmes de production durable de viande de qualité de petits ruminants: mise en place d'une démarche qualité pour la filière viande dans la Caraïbe.

Il convient de rappeler l'existence du réseau épidémiosurveillance animale caribéen, mené en partenariat avec l'IICA, l'OEI, la FAO et les services vétérinaires de 17 pays de la Caraïbe et des Guyanes, qui est déjà parfaitement fonctionnel au niveau caribéen et possède sa propre dynamique. Il est convenu de ne pas l'intégrer dans un premier temps dans le réseau associatif objet de cette communication.

CONCLUSION

Le réseau associatif de chercheurs caribéens en recherche agronomique devrait permettre le développement, l'amélioration, l'harmonisation et la validation de nouvelles méthodes et de techniques plus performantes de diagnostic de pathogènes existants ou émergents tels que les virus, les bactéries, les phytoplasmes, les champignons et autres agents pathogènes impliqués dans la sécurité sanitaire et la qualité des produits.

La réalisation de ce programme de recherche permettra l'échange et l'amélioration de matériel végétal pour aboutir à moyen terme à la diffusion de matériel sélectionné et adapté aux conditions pédo-climatiques caribéennes.

La mise en place d'observatoires phytosanitaires dans les divers pays de la caraïbes permettra d'assurer une veille efficace quant aux maladies émergentes, à leurs vecteurs et aux parasites de cultures concernées. Les données de ces observatoires seront consignées dans une base de données intégrée dans un site web. «Réseau des observatoires phytosanitaires caribéens» (coopération IICA-CARDI-PROCICARIBE-PV et FDDCECs).

L'information concernant les résultats de la recherche sera restituée sous forme de publications, de fiches techniques et sous des formes diverses au cours des ateliers techniques.

Les actions entreprises dans le cadre de ce réseau associatif concerneront la recherche, la vulgarisation, la formation et les informations et participeront aux échanges d'expériences nécessaires au développement de la coopération régionale caribéenne au bénéfice des agricultures et des agriculteurs caribéens dans le cadre d'un développement durable et respectueux de l'environnement.

Enfin on peut espérer que la mise en adéquation en matière de recherche agronomique de l'offre et de la demande des états insulaires de la Caraïbe pourra participer à la structuration d'un système régional de recherche agricole (IICA, CARDI, universités et systèmes nationaux de recherches agricoles), qui permettra d'asseoir une partie des bases de la future politique agricole commune de la communauté caribéenne en construction (CARICOM) et de l'AEC.

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SOIL-BASED CARBON SEQUESTRATION IN A PUERTO RICO WATERSHED

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ABSTRACT: The amount of organic carbon sequestered in the soils of the Río Grande de Arecibo watershed in west-central Puerto Rico was estimated by using soil survey information at a scale of 1:20,000; laboratory characterization data; and GIS technology (ARCView v3.2a). Calculated to a depth of 1 m or to a lithic or paralithic contact if shallower, the soils of the 42,690-ha (42.69 km^2) watershed contain a total of about 4.8 x 10^6 Mg (4.8 million tons) of carbon. Average carbon content per 1 m^2 is 10.9 kg, ranging from 3.0 kg in the shallow and sandy Dystrudepts to 22.7 kg in the deep and clayey Hapludox. The variability is attributed to significant differences in the geology-controlled soil parent materials, terrain characteristics, and soil diversity. Eroded soils occupy 16,500 ha or 39% of the watershed. If these soils could be restored to their original state, an additional 379,000 Mg of carbon would be sequestered. Although this is an increase of only about 8% above the current carbon stock in the watershed, it nevertheless contributes to the sequestration of atmospheric carbon and thus to mitigating global warming. It would also enhance the agricultural productivity of the soils as organic matter controls soil fertility and soil quality. However, given the adverse landscape conditions, characterized by strong dissection and slopes of more than 40% in 85% of the watershed, realizing this potential will require substantial efforts and input. Proactive measures of soil conservation would have been both more effective and efficient than reactive land management practices to rehabilitate the damaged ecosystems.

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A GENERALIZED SOIL MAP OF THE CARIBBEAN REGION

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ABSTRACT: Many countries in the Caribbean region have soil maps that are usually old or use legends and terminologies unique to the location. The Francophone countries have good soil information, but soil maps follow the French tradition of mapping that is not appreciated by the American school. Puerto Rico uses the standards and quality control procedures of USDA Natural Resources Conservation Service, whereas Cuba has its own procedure with soils classified according to the FAO legend. Lack of a common base is a hindrance for sharing of soil information and may become an important obstacle for technology transfer within and from outside the region. The poster presents a first attempt to generalize the soil information for all the countries. The map scale is 1:2.5 million and is inadequate for country-specific applications and only assists in obtaining an idea of the broad patterns and kinds of soils. With the exception of Gelisols, all Orders of Soil Taxonomy may be encountered. Some soils like Histosols have a too limited occurrence to be depicted at this scale but are present in Trinidad, Puerto Rico, Cuba, and on the mainland of Central and South America. The ages of the soils range from very recent, such as those derived from recent volcanic eruptions, to the highly weathered Oxisols of Cuba and Puerto Rico. Using Puerto Rico as an example, maps at different scales are illustrated showing the need for each country to have farm level soil information.

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EFFECT OF LIMING AND FERTIGATION FREQUENCIES ON NITROGEN RETENTION ON COTO CLAY

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ABSTRACT: Nitrate leaching through the soil profile can result in a significant loss of fertilizer N, and may be a source of nitrate concentration in groundwater. Highly weathered soils may exhibit substantial anion exchange capacity (AEC), which retards the movement of anions such as NO_3^- through the profile. However, AEC decreases as soil pH increases with agronomic practices such as liming. A study was conducted to determine the effect of lime application and frequency of N fertigation on NH_4^+ and NO_3^- concentrations on Coto clay. A field experiment was established at the UPR Experiment Station at Isabela, PR, using peppers as the test crop. Two lime treatments (lime or no lime) and two fertigation frequencies (weekly or bi-weekly applications) were evaluated. Soil samples were collected every two weeks at four depths and analyzed for NH_4^+ and NO_3^- by steam distillation. During the first year, probably due to spatial variability and buffering capacity of the Coto clay, the limed plots did not reach the expected pH level. Consequently, no significant differences were observed between lime treatments. No significant differences between fertigation treatments were observed either. During the second year, lime application was doubled, and pH in the limed plots increased from an average of 4.6 to approximately 6.4. Nitrogen analyses of soil and plant material from the second year is currently under way. Results are also presented from laboratory studies conducted to evaluate NO_3^- adsorption characteristics of Coto clay. Adsorption isotherms were conducted under three pH levels and nine NO_3^- solution concentrations.

INTRODUCTION

Increased NO_3^- concentrations in groundwater due to leaching from intensive crop production systems have become an environmental and economic concern (Andraski et al., 2000). High concentrations of NO_3^- in surface and groundwater can cause eutrophication of our water reserves. Also, concentrations of NO_3-N above 45 mg L^{-1} may cause serious health problems like methemoglobinemia, or "blue baby syndrome" (Spalding and Exner, 1993).

Nitrate losses from agricultural fields can be minimized by following agronomic practices to reduce erosion, leaching, and to promote a more efficient crop uptake. The capacity of the soil to adsorb or retain nitrate may contribute to reducing its movement through the soil profile (Bellini et al., 1996; Qafoku et al., 2000). Highly weathered soils may exhibit a net positive charge at low pH (anion exchange capacity), which retards the movement of anions such as NO_3^- through the profile. However, these soils are usually limed to reduce toxic levels of exchangeable Al^{3+} and improve their fertility. Liming will improve crop performance but may decrease the soil capacity to retain nitrate, thus promoting its movement to lower depths, out of the root zone.

Eick et al. (1999) evaluated the surface charge properties and nitrate adsorption capacity of four Louisiana subsoils by determining Point of Zero Net Charge and measuring nitrate adsorption isotherms, and found that net positive charge retarded NO_3^- movement significantly. Another parameter that influences anion retardation is ionic strength (Ishiguro et al., 1992; Bellini et al., 1996), with higher solution concentrations resulting in a lower retardation coefficient (Katou et al., 1996; Qafoku et al., 2000).

Studies have also shown that there are other factors that can reduce or even eliminate nitrate retention, such as the presence of phosphate (Melamed et al., 1994), sulfate or fluoride (Eick et al., 1999). A study is needed to better understand the relationship of soil chemical and physico-chemical characteristics to nitrate movement in the acid soils of Puerto Rico.

The objectives of this investigation were to determine the effect of lime application and frequency of N fertigation on NH_4^+ and NO_3^- concentrations on Coto clay and to study NO_3^- adsorption at different pH levels and nitrate concentrations.

MATERIALS AND METHODS

Field Study

A field experiment was established during March 2002, at the UPR Experiment Station at Isabela, PR, using peppers as the test crop. Two lime treatments (lime or no lime) and two fertigation frequencies [weekly (F1) or bi-weekly (F2) applications] were evaluated. The limed plots received a broadcast lime application of 7.41 tons/ha. The lime was incorporated into the soil prior to planting.

A total nitrogen rate of 225 kg/ha was applied by fertigation, using KNO_3 and urea as the fertilizer sources. The F1 treatment (weekly) received a total of 12 fertigations, and the F2 treatment received 6 fertigations in a 3-month period. Soil samples were collected from each plot every two weeks at 20-cm increments, down to 80 cm. The samples were analyzed for NH_4^+ and NO_3^- concentrations by steam distillation, after extraction with 2 M KCl and two hours' shaking time (Mulvaney, 1996).

A second field experiment was established during February 2003. Conditions were the same as those of the first year, except the amount of lime applied to the limed plots was doubled (14.82 tons/ha). This addition was to achieve a pH level closer to the recommended 6.5.

Soil Characterization

The soil at the experimental site is a Coto clay, classified as a very-fine, kaolinitic, isohyperthermic Typic Eutrustox. Samples were collected from two depths (0-20 cm and 20-40 cm) for characterization and for the adsorption study.

The samples were air dried, mechanically ground, and passed through a 2-mm sieve. Selected chemical, physical, and mineralogical properties are presented in Table 1. Soil pH readings were taken in a 1:2 soil/water ratio by using an Orion model EA 940 pH meter. Organic matter was determined with the Walkey-Black method (Nelson and Sommers, 1996). Particle size distribution was determined after fractionating the samples for mineralogical analyses. The mineralogy of the clay fraction was determined by x-ray diffraction after pretreatment using standard procedures (Kunze and Dixon, 1986). Free iron oxide content was determined by using the citrate-bicarbonate-dithionite method (Jackson et al., 1986).

Potentiometric titrations

The methodology of Marcano-Martínez and McBride (1989) and van Reij and Peech (1972) was used to determine the PZSE for the samples. For each depth 4 g air-dried soil was added to 40 ml of electrolyte solution (0.1, 0.01, and 0.001 N KCl); pH was adjusted (before reaching the final 40 ml volume) with measured amounts of HCl or KOH to achieve a range from 3 to 7. The tubes were capped and shaken twice daily for one hour over a 3-day period.

After this time the samples were centrifuged and supernatant pH was measured. The amounts of H^+ and OH^- adsorbed by the samples were determined by subtracting the amount of acid or base necessary to bring 40 ml of electrolyte solution (without soil) to the same pH.

Table 1. Selected chemical, physical, and mineralogical properties of Coto clay.

Depth (cm)	pH[a]	OM	Sand	Silt	Clay	Fe_2O_3	Mineralogy[b]
		----------------------------			% -------------------------		
0-20	4.2	2.76	35.10	19.35	45.55	14.50	k, go, gi, i, chl
20-40	3.9	1.54	28.72	1.85	69.43	14.41	k, q, go, i, chl

[a]1:2 soil/water ratio.
[b]k=kaolinite, go=goethite, gi=gibbsite, i=illite, q=quartz, and chl=chlorite

Batch study

To study the effect of pH on nitrate retention, three lime treatments (0, 2, and 4 g $CaCO_3$ kg^{-1}) were applied by first mixing with air-dried soil, then wetted to approximately field capacity with deionized water and incubated for 3 weeks. The samples were then re-dried and re-sieved, and final pH was measured. In the 0- to 20-cm depth, pH levels changed from 4.2 to 5.2 and 6.1, in the respective lime treatments. In the 20- to 40-cm depth, pH changed from 3.9 to 4.5 and 5.6, respectively.

For each depth and each lime treatment ten grams of soil were placed in 50 ml centrifuge tubes. Samples were washed twice with 20 ml 0.1 M KCl by shaking for two hours to determine the presence of retained NO_3^-. Immediately after washing, 20 ml of $Ca(NO_3)_2$ solution, at one of nine concentrations (zero, 1, 2, 4, 6, 8, 10, 15, and 20 $mmol_c$ L^{-1} NO_3^- - N), was added to each tube. The tubes were placed on a shaker at room temperature (25° C). After equilibrating for 2 h, the suspension was centrifuged and the equilibrium concentration of NO_3^- was determined by steam distillation.

RESULTS AND DISCUSSION

Field Study

During the first year of the field experiment (2002) great spatial variability resulted in pH levels ranging from approximately 4.1 to 5.4 in the untreated plots, and from 4.4 to 6.1 in the limed plots. No significant variation in NO_3^- nor NH_4^+ concentrations was observed between the lime and no lime treatments at depths over 20 cm. Nor was any significant difference observed between the fertigation treatments. Nitrate and ammonium concentrations did not vary significantly at depths over 20 cm (Table 2). A higher concentration of both parameters was observed at the depth of 0-20 cm.

Average nitrate concentrations at the 60- to 80-cm depth, when multiplied by bulk density (1.33 gm cm^{-3}) and average volumetric moisture content for the season (0.3 cm^3 cm^{-3}) showed solution concentrations of 46.9 mg L^{-1} and 46.1 mg L^{-1} for the lime and no lime treatments, respectively. These values are close to, but higher than, 45 mg L^{-1}, the EPA safe drinking water standard for NO_3-N (Code of Federal Regulations, 1987). Considering this vertical interval to be below the root zone, potential nitrate leaching and, consequently, groundwater contamination, should be a concern under conditions similar to those of this study.

In the second-year pH level analyses, no significant spatial variation was observed. Plots with no lime showed pH levels averaging 4.6, whereas limed plots reached an average pH of 6.5, as expected. NO_3^- and NH_4^+ analyses for this season, as well as those for nitrogen uptake by plants, are currently under way.

Table 2. Average soil NO_3^- and NH_4^+ concentrations (mg kg^{-1}) for the field study.

	Lime		No Lime	
Soil depth (cm)	NO_3^-	NH_4^+	NO_3^-	NH_4^+
0 - 20	27.2	8.5	21.2	11.9
20 - 40	14.3	5.8	12.3	7.2
40 - 60	14.2	5.4	11.3	6.1
60 - 80	10.6	5.1	10.4	7.9

Potentiometric titrations

The PZSE is the pH at which the net charge is independent of electrolyte concentration. Titration curves for different ionic strengths intersect at this common point. Figure 1 shows that there was not one exact point of intersection for the three curves in the 0- to 20-cm depth. The 0.1 N curve intersects the 0.01 N curve at a pH of approximately 3.55, and the 0.001 N curve at approximately 3.46. Both of these values are below the native pH (4.2) at this depth.

For the 20- to 40-cm depth, Figure 2 shows that the 0.1 N and the 0.01 N curves intersect at a pH of approximately 3.88. The 0.1 N curve intersects the 0.001 N curve at a value close to 3.52. The 0.01 N and the 0.001 N curves intersect at approximately 3.45. These values are also below the native pH (3.9) at this depth.

The mineralogy results (Table 1) for our soil agree with those reported by Jones et al. (1982) for the same soil. Although large quantities of high point of zero charge Fe oxides were found, the presence of organic matter, kaolinite and other low point of zero charge minerals reduced the PZSE in the samples. The greater difference between these values in the 0- to 20-cm depth may reflect the effect of higher organic matter content (Marcano-Martínez and McBride, 1989). These results are consistent with Appel et al. (2003), who reported PZSE values of 3.4-3.5 on an Oxisol from Puerto Rico.

Batch study

Observed values show that there was no NO_3^- adsorption by the Coto clay at the studied depths. Generally, greater amounts of nitrate concentrations were found in the equilibrium solution than in the original solution (Table 3). These results are opposite to those reported by other studies performed on similar soils (Ishiguro et al., 1992; Bellini et al., 1996; Katou et al., 1996; Eick et al., 1999), and suggest either (i) desorption of residual nitrate despite washing with 0.1 N KCl or (ii) microbial or enzyme activity (Kowalenko and Yu, 1996).

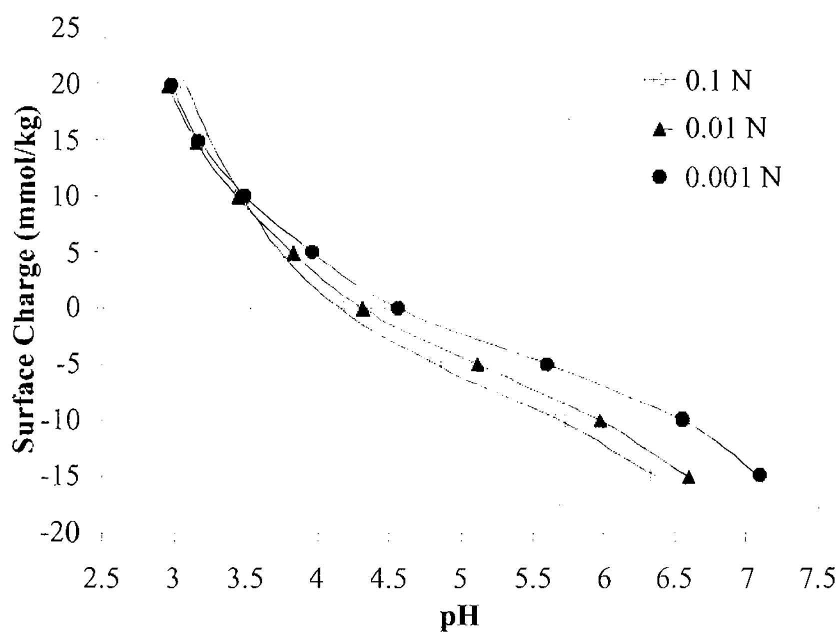

Figure 1. Potentiometric titration curves for the 0- to 20-cm depth.

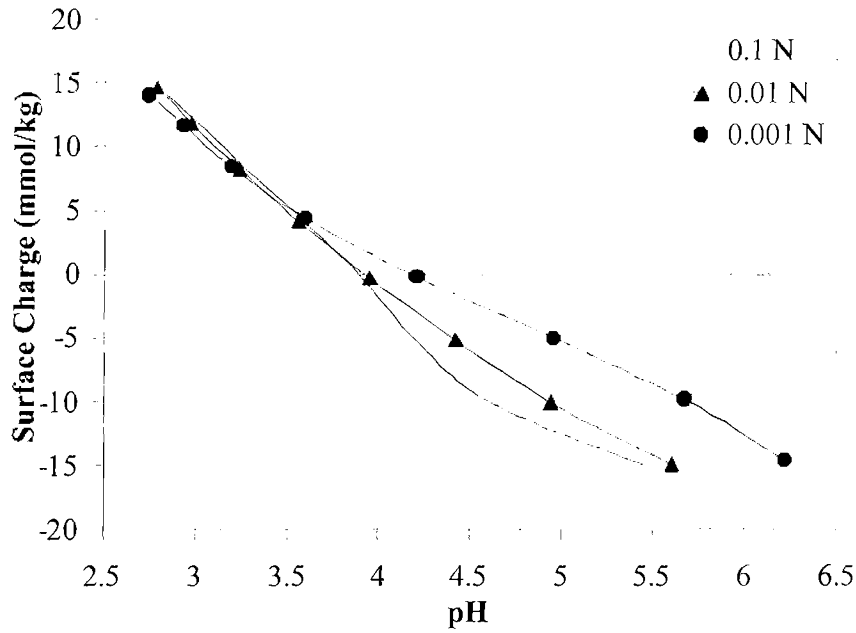

Figure 2. Potentiometric titration curves for the 20- to 40-cm depth.

Table 3. Comparison of original vs. equilibrium solution concentration of NO_3-N (mg/L).

NO_3^- sol. (mg/L N)	Depth (cm)	Lime (g/kg)	pH	eq. NO_3^- (mg/L N)	NO_3^- sol. (mg/L N)	Depth (cm)	Lime (g/kg)	pH	eq. NO_3^- (mg/L N)
0	0 - 20	0	4.2	0.00	8	0 - 20	0	4.2	10.65
		2	5.2	0.69			2	5.2	12.21
		4	6.1	0.11			4	6.1	11.67
	20 - 40	0	3.9	0.00		20 - 40	0	3.9	10.65
		2	4.5	0.22			2	4.5	11.20
		4	5.6	0.22			4	5.6	10.80
1	0 - 20	0	4.2	1.23	10	0 - 20	0	4.2	14.78
		2	5.2	0.91			2	5.2	16.16
		4	6.1	2.43			4	6.1	15.47
	20 - 40	0	3.9	1.30		20 - 40	0	3.9	12.97
		2	4.5	2.03			2	4.5	13.37
		4	5.6	1.92			4	5.6	13.41
2	0 - 20	0	4.2	2.46	15	0 - 20	0	4.2	21.74
		2	5.2	3.55			2	5.2	21.41
		4	6.1	3.30			4	6.1	21.59
	20 - 40	0	3.9	2.43		20 - 40	0	3.9	18.77
		2	4.5	2.86			2	4.5	18.88
		4	5.6	2.75			4	5.6	19.89
4	0 - 20	0	4.2	4.71	20	0 - 20	0	4.2	29.45
		2	5.2	5.94			2	5.2	30.29
		4	6.1	6.12			4	6.1	30.51
	20 - 40	0	3.9	4.35		20 - 40	0	3.9	26.70
		2	4.5	5.18			2	4.5	26.45
		4	5.6	5.14			4	5.6	27.61
6	0 - 20	0	4.2	8.41					
		2	5.2	9.78					
		4	6.1	9.42					
	20 - 40	0	3.9	7.61					
		2	4.5	8.26					
		4	5.6	8.22					

CONCLUSIONS

Low PZSEs suggest negative charge development and, therefore, repulsion of anions. A study to determine anion exchange capacity for the Coto clay at the studied depths is necessary to corroborate this conclusion. Results obtained from the field and nitrate retention studies coincide, however, and indicate little or no nitrate retention capacity for this soil, even at low pH levels. Potential nitrate leaching should be considered when establishing a management plan for the Coto clay.

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EVALUATION OF PERCOLATION AND NITROGEN LEACHING FROM A SWEET PEPPER CROP GROWN ON AN OXISOL SOIL IN NORTHWEST PUERTO RICO

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ABSTRACT: A study was conducted to evaluate the influence of agricultural lime ($CaCO_3$) on the movement and uptake of inorganic nitrogen for a sweet pepper crop (*Capsicum annuum*) grown on an Oxisol soil (Coto clay) in northwest Puerto Rico. The Coto clay soil, which contains the 1:1 kaolinite mineral, has a low pH (4 to 4.5). The 1:1 type clays are known to possess a net positive charge at low pH, resulting in the adsorption of negatively charged ions such as nitrate. From an environmental standpoint this characteristic of the 1:1 clay is favorable, since nitrate leaching, a major cause of groundwater pollution in many areas, is reduced relative to soils with net negative charge. However, agricultural plants, such as sweet peppers, favor a higher soil pH (approximately 6.5), which can be obtained by the application of agricultural lime. This application, however, may have the negative effect of increasing the potential for nitrate leaching, as the net charge in the soil particles becomes positive with increasing pH. This paper describes the results of a nitrogen leaching analysis for two sweet pepper crop seasons. The analysis was based on multiplying the daily percolation flux through the soil profile by the measured concentration of nitrogen below the root zone. Irrigations were scheduled using the pan evaporation method for estimating crop water requirements. No significant difference in nitrogen leaching was observed for the lime and no-lime treatments. This finding was attributed to the low nitrate retention capacity of this soil, even a low pH. The average percentages of nitrogen leached during the 1st and 2nd season, relative to the amounts applied, were 26% and 15%, respectively. Leaching events were associated with large rainstorms, suggesting that leaching of N would have occurred regardless of the irrigation scheduling method used.

INTRODUCTION

Sweet pepper crops were planted at the UPR Experiment Station at Isabela in northwest PR (Figure 1) March 2002 and January 2003. Harmsen et al. (2002) provided a detailed description of the experimental layout of the field site. The soil at the Isabela Experiment Station belongs to the Coto series. It is a very fine kaolinitic, isohyperthermic Typic Eutrustox. These are very deep, well drained, moderately permeable soils formed in sediments weathered from limestone. The available water capacity is moderate, and the reaction is strongly acidic throughout the whole profile. Consistence is slightly sticky and slightly plastic in the Oxic horizons. A strong, stable granular structure provides these soils with a very rapid drainage, despite their high clay content (Keng et al., 1981). Average values of hydraulic properties published for the Coto clay soil near the study area are as follows: air dry bulk density 1.39 g/cm^3; porosity 48%; field capacity 30%; wilting point 23%; available water holding capacity (AWHC) 9% (Soil Conservation Service, 1967). The AWHC of this soil is low for clay. Typical values for clay are 15 to 20% (Keller and Bliesner, 1990). A small value of AWHC means that there is a greater potential for leaching since the soil moisture content associated with the field capacity is more easily exceeded.

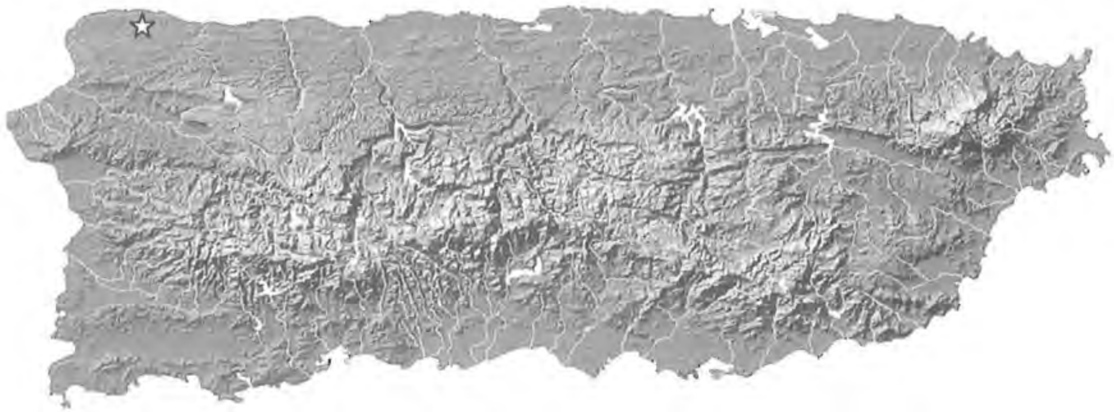

Figure 1. Location of field site at Isabela, PR (☆).

The experimental site of 0.1 ha was divided into four blocks, each block divided into four plots, one for each treatment, for a total of sixteen plots. The plots measured 67 m^2. The treatments included two lime levels (lime and no lime) and two fertigation frequencies (F1 weekly, and F2 bi-weekly). Each plot had four beds covered with plastic (silver side exposed) with two rows of sweet pepper plants per bed. The transplanted sweet peppers were grown in rows 91 cm apart, plants 30 cm apart along rows, with beds 1.83 meter on center. This gave a plant population of approximately 37,000 plants per hectare. There was an initial granular application of triple super-phosphate of 224 kg/ha and 80 kg/ha of 10-10-10 fertilizer. Peppers were planted from 11 March through 13 March 2002 and from 27 January through 31 January 2003. KNO_3 and urea were injected through the drip irrigation system throughout the season at different frequencies (F1 weekly or F2 bi-weekly). The total nitrogen applied during the season was 225 kg/ha. After transplanting, soil samples were taken bi-weekly at 20-cm increments, down to an 80-cm depth from each plot to be analyzed for moisture content and nitrogen concentration. Each date when soil samples were collected, whole plants were harvested for growth data. Periodic pesticide applications were made to control weeds and insects affecting crop growth.

Water Balance

A water balance approach was used in this study to estimate percolation past the root zone. The water balance is shown in the following equation:

$$PERC = R \cdot RO + IRR - ET_c + \_S \qquad (1)$$

where PERC is percolation below the root zone, R is rainfall, IRR is irrigation, RO is surface runoff, ET_c is crop evapotranspiration, and $\_S = S_1 - S_2$, where S_1 and S_2 are the water stored in the soil profile at times 1 and 2, respectively. The units of each term in equation 1 are in mm of water per day.

Rainfall (R) was obtained from a tipping bucket-type rain gauge located on the Experiment Station property. The rain gauge was located within a weather station complex located approximately 0.4 km from the study area. The weather station consisted of a 10-meter (high wind resistant) tower with lighting protection, data logger and radio communication system, and sensors to measure the following parameters: wind direction and speed, temperature, relative humidity, barometric pressure, cumulative rainfall, and solar radiation (Zapata et al., 2001).

Irrigation (IRR) was applied through a drip irrigation system. The inline-type emitters produced a flow of 1.9 liters per hour per emitter at a design pressure of 10 pounds per square inch (psi). Emitters were spaced every 30 cm. Irrigations (IRR) were scheduled on the basis of estimated evapotranspiration rate as determined from the following equation:

$$IRR = ET_{pan} = (K_c\ K_p\ E_{pan}) \qquad (2)$$

where ET_{pan} is the pan evaporation-derived evapotranspiration, K_c is the evapotranspiration crop coefficient for sweet peppers (FAO Paper No. 56, Allen et al., 1998), which varied daily; K_p is the average annual value of the pan coefficient equal to 0.78 for Isabela, PR (Goyal and González, 1989). A cumulative water meter was used to control the gallons of irrigation water applied.

The evapotranspiration term in equation 1 was estimated from the following equation:

$$ET_c = K_c\ ET_o \qquad (3)$$

where K_c is the crop coefficient (dimensionless) and ET_o (mm/day) is the reference evapotranspiration obtained using the Penman-Monteith equation, given below (Allen et al., 1998):

$$ET_O = \frac{0.408\ \Delta\ (R_n - G) + \gamma \left(\frac{900}{T + 273} \right) u_2\ (e_s - e_a)}{\Delta + \gamma\ (1 + 0.34\ u_2)} \qquad (4)$$

where Δ is the slope of the vapor pressure curve (kPa $^oC^{-1}$); R_n is net radiation (MJ m^{-2} d^{-1}); G is the soil heat flux density (MJ m^{-2} d^{-1}); γ is the psychrometric constant (kPa^{-1}); T is mean daily air temperature at 2-m height (^oC); u_2 is wind speed at 2-m height; e_s is the saturated vapor pressure (kPa^{-1}); and e_a is the actual vapor pressure (kPa^{-1}). Equation 4 applies specifically to a hypothetical reference crop with an assumed crop height of 0.12 m, a fixed surface resistance of 70 sec m^{-1} and an albedo of 0.23.

Data required by equation 4 were obtained from the weather station located near the study area. Wind speeds obtained from the 10 m high tower were adjusted to the 2 m wind speed, required by the Penman-Monteith method, by means of an exponential relationship. Initial values of the crop coefficient were obtained from the literature for sweet pepper for the initial, mature and end crop stages (FAO Paper No. 56). Adjustments of K_c were made during the calibration of equation 1 as described later in this section. ET_o was estimated on a daily basis using a spreadsheet program.

The values of S in equations 1 and 2 were obtained from the following general formula: S = $\_{v}$*Z, where $\_{v}$ is the vertically averaged volumetric soil moisture content over the depth Z, obtained by multiplying the moisture content, mass-basis ($\_{m}$), by the soil bulk density and dividing by the density of water. The soil bulk densities were obtained from undisturbed soil cores.

Between sampling dates when measured values of $\_{v}$ were not available, daily values were estimated by using equation 1 along with information about the moisture holding capacity of the soil. In this method, if the water added to the profile by rainfall or irrigation exceeds the soil moisture holding capacity (or field capacity), then the excess water was assumed to be equal to PERC and the moisture content was set equal to the field capacity on that day. This approach has previously been used for irrigation scheduling (Shayya and Bralts, 1994), waste landfill leachate estimation (Fenn et al., 1975) and estimation of aquifer recharge rates (Thornthwaite and Mather, 1955; Papadopulos & Associates, Inc., and MathSoft, Inc. 1994). In this study, the effective field capacity of the soil was determined in situ by saturating the soil and obtaining the soil moisture content within 48 hours.

Calibration of the water balance equation was accomplished by adjusting the ratio of runoff to rainfall (RO/R) within reasonable limits, until the measured and estimated soil moisture content were in reasonable agreement. 1 – RO/R represents the fraction of rainfall that infiltrates into the soil bed. This contribution of water can occur in several ways for the plastic covered bed-type system used in this study. Rainfall may enter directly through the holes in the plastic made for the plants. Rainfall that runs off of the plastic into the furrow or that falls directly into the furrow may also be absorbed into the beds. Under flood conditions, which occurred on several occasions during the two crop seasons, water could have entered the beds under a positive water pressure. For non-flooding rainfall events, soil water may move from the furrows into the beds by means of unsaturated flow, which is controlled by the pore water pressure gradient between the furrow and the bed.

Nitrogen Leaching

Nitrogen leaching (nitrate and ammonium) was estimated by multiplying the daily value of PERC by the concentration of nitrogen within the 60-to 80-cm depth of soil. This vertical interval was considered to be below the root zone, since plant roots were not observed within this interval any time throughout the two seasons. The following equation was used to estimate nitrate and ammonium leaching, respectively:

$$L_{NO3} = 0.01\ \_{b}\ NO_3\ PERC\ /\ \_{vol} \quad (5a)$$

$$L_{NH4} = 0.01\ \_{b}\ NH_4\ PERC\ /\ \_{vol} \quad (5b)$$

where L_{NO3} and L_{NH4} are the kg of nitrate and ammonium leached below the root zone per hectare; NO_3 and NH_4 are the nitrate and ammonium soil concentration in mg/kg in the 60-to 80-cm depth interval; PERC is the percolation rate in mm; and $\_{b}$ and $\_{vol}$ are the bulk density (gm/cm^3) and volumetric moisture content (cm^3/cm^3) in the 60-to 80-cm depth interval. Equations 5a and 5b were used on a daily basis. Each measured value of soil concentration used in equation 5a and 5b was based on the average of four replications. Values of NO_3 and NH_4 between sampling dates were linearly interpolated.

RESULTS AND DISCUSSION

The Coto clay soil was analyzed for various physical and hydraulic properties (Table 1). The soil has a relatively high sand content and high hydraulic conductivity in the 0- to 20-cm interval, which accounts for its high water intake capacity. We observed on several occasions the rapid infiltration of water after large rainfall events. In fact, the value of hydraulic conductivity for the 0- to 20-cm interval is similar to that of sand, which averages 900 cm/day (Freeze and Cherry, 1979). Bulk density, porosity, hydraulic conductivity, moisture content at 0.33 and 15 bars pressure, and AWHC were obtained from undisturbed cores in the laboratory.

Measured soil pH soil was between 4 and 5. Laboratory incubation tests were performed to determine the proper amount of lime needed to be applied to the soil to increase the pH to around 6.5 in the limed treatments; this amount was 7.4 tons lime/ha. The first year the pH did not respond as expected in the limed plots; therefore, this may have contributed to there being no significant difference observed in the estimated nitrate losses by leaching between the lime and no-lime treatments. The second year the amount of lime applied to the limed treatments was doubled (14.8 tons lime/ha) and pH levels rose as expected.

Figure 2 shows a comparison of the evapotranspiration derived from pan and Penman-Monteith methods during Year 2. ET_{pan} was observed to have higher variability than ET_c. For reference, Figure 2 also shows the ET_c based on long-term average climate data for Isabela, PR. The seasonal ET for the methods of pan, Penman-Monteith and Penman-Monteith based on long-term data were 447 mm, 402 mm, and 511 mm, respectively.

Table 1. Physical and hydraulic properties of Coto clay in the 0-20, 20-40, 40-60, and 60-80 cm depth intervals.

Depth (cm)	% Sand[1]	% Silt[1]	% Clay[1]	Soil Classification	Bulk Density	Porosity
0-20	35.10	19.35	45.55	silty clay	1.36	0.49
20-40	28.72	1.85	69.43	clay	1.36	0.49
40-60	22.50	5.00	72.50	clay	1.31	0.51
60-80	20.00	5.80	74.20	clay	1.29	0.51

Depth (cm)	Hydraulic Conductivity (cm/day)	In-Situ Field Capacity Year 1 Site	In-Situ Field Capacity Year 2 Site	Moisture Content at 0.33 bar Pressure	Moisture Content at 15 bar Pressure	Available Water Holding Capacity (AWHC)
0-20	1210.06	0.33	0.44	0.44	0.39	0.05
20-40	316.99	0.33	0.37	0.37	0.27	0.10
40-60	70.10	0.37	0.36	0.36	0.31	0.05
60-80	12.19	0.37	0.38	0.38	0.3	0.08

[1]Soil texture data for the 40 to 60-cm and 60 to 80-cm depths were obtained from Soil Conservation Service (1967). All other data were measured during the project.

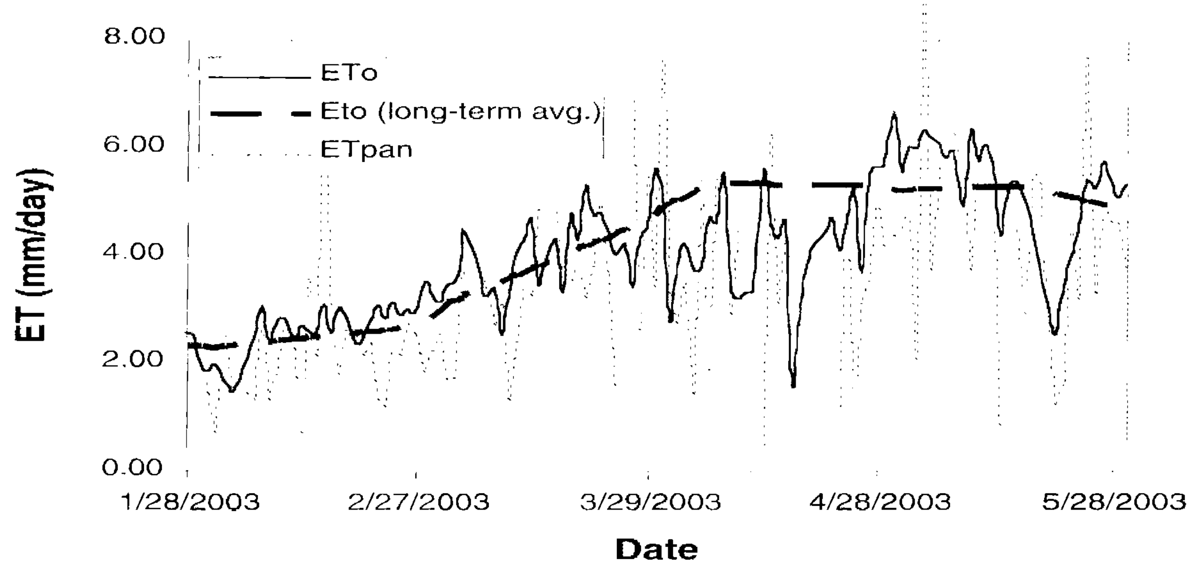

Figure 2. Daily values of evapotranspiration for a sweet pepper crop between 27 January to 12 June 2003, at Isabela, PR. Evapotranspiration was derived from the pan evaporation and Penman-Monteith methods.

The water balance equation (Eqn. 5) was calibrated for the site conditions. Figure 3 shows the simulated and measured average soil moisture content for Year 1 and Year 2. The measured moisture contents shown in Figure 3 represent the vertically averaged moisture content over all sixteen plots. The minimum and maximum measured soil moisture content is also shown in Figure 3. Vertically averaged values of the in situ-measured field capacity equal to 0.39 and 0.35 were used in the Year 1 and Year 2 analyses, respectively (averages from Table 1). It was necessary to use a value of RO/R = 0.25 reasonable agreement between the estimated and measured soil moisture content. During Year 1, the beginning of the season was quite wet. On 6 April 2002, a 176-mm rainfall occurred, which caused severe flooding of the study area. During Year 2, a rainy period occurred from 5 April to 18 April with flooding observed in the field plots. The largest rainfall of the season occurred on April 10, 2003 equal to 97 mm.

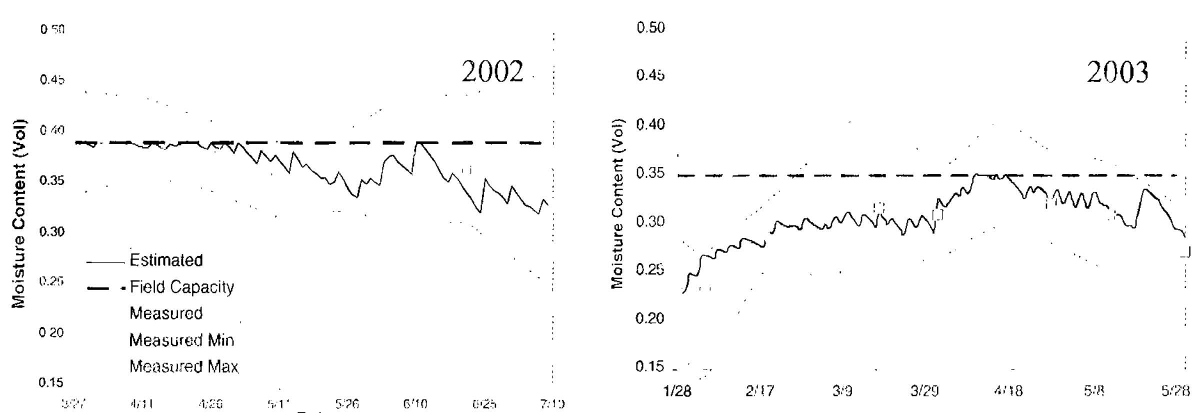

Figure 3. Estimated and measured volumetric soil moisture content between 27 March and 9 July 2002, and 27 January and 12 June 2003.

According to the procedure described above, percolation occurred on those days when the estimated moisture content exceeded the field capacity moisture content (0.39 for Year 1 and 0.35 during Year 2). On those days, the water in excess of the field capacity was assigned to PERC and the moisture content set equal to the field capacity. This can be seen in Figure 3 for those days in which the moisture content curve touched the dashed horizontal line associated with the field capacity moisture content. Figure 4 shows the estimated percolation during Year 1 and Year 2. During the 6 April 2002 rainfall event of 175 mm, 43 mm was converted to percolation. During the 10 April 2003 rainfall event of 97 mm, 31 mm was converted to percolation. Recall that only 25 percent of the rainfall was allowed to infiltrate, which was equal to 44 mm on 6 April 2002, and 24 mm on 10 April 2003. In the latter case 18 mm of irrigation was also applied, which together (24 mm + 18 mm) equaled 42 mm. In this case 31 mm was lost to percolation and 11 mm was stored in the root zone. Table 2 shows the Year 1 and Year 2 seasonal components of the water balance.

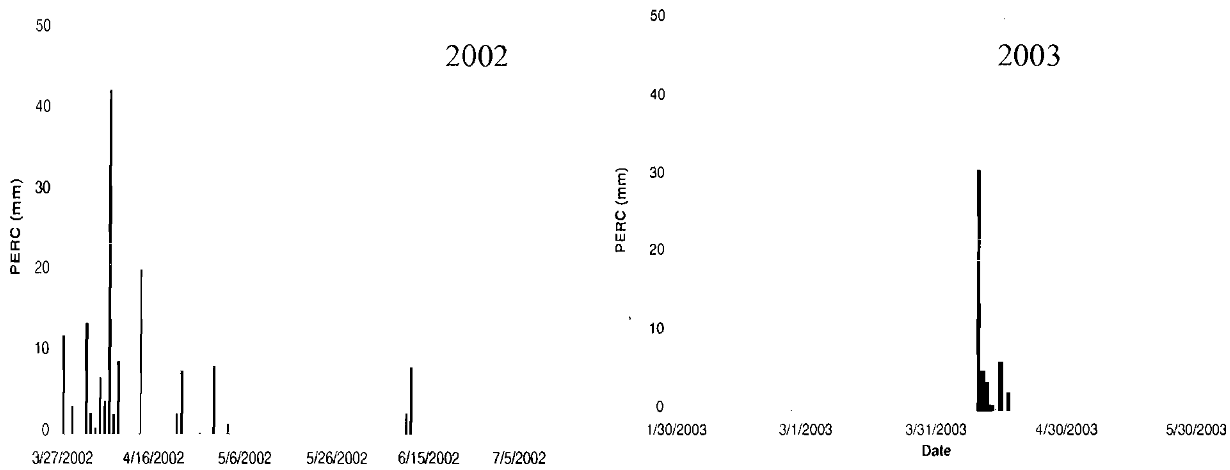

Figure 4. Estimated percolation past the root zone during the Year 1 and Year 2 seasons.

Table 2. Components of the seasonal water balance for Years 1 and 2.

	Year 1 (2002)	Year 2 (2003)
R-RO	175	136
IRR	350	411
ETc	416	441
_S	50	-52
PERC	159	54

Table 3 compares the Year 1 and Year 2 results of the nitrogen leaching analysis. The leached nitrate and ammonium estimates were obtained from equations 5a and 5b, respectively. Figure 5 shows the nitrate concentrations in the 60- to 80-cm depth interval during the Year 1 season. During Year 1 the range of estimated nitrogen leached was between 36 and 67 kg/ha. During Year 2, the range of estimated nitrogen leached was between 27 and 36 kg/ha. Interestingly, the amount of nitrate lost (average of all treatments) on 6 April 2002, and 10 April 2003, was 19.6 kg/ha and 20.1 kg/ha, respectively. For years 1 and 2 this represented 34% and 60% of the total N lost by leaching during the two seasons, respectively. Figure 6 shows the estimated percentage of nitrogen (i.e., nitrate plus ammonium) leached relative to N applied (225 kg/ha) during the Year 1 and Year 2 seasons for the four experimental treatments.

Table 3. Nitrate, ammonium and nitrate plus ammonium (Total) leached during Year 1 and 2 for the four experimental treatments.

		2002				2003			
	Units	LF1	LF2	NLF1	NLF2	LF1	LF2	NLF1	NLF2
NO3	kg/ha	36	50	47	42	34	32	34	24
NH4	kg/ha	10	13	21	11	2	3	2	3
Total	kg/ha	46	63	67	54	36	35	36	27
Total	%	21	28	30	24	16	16	16	12

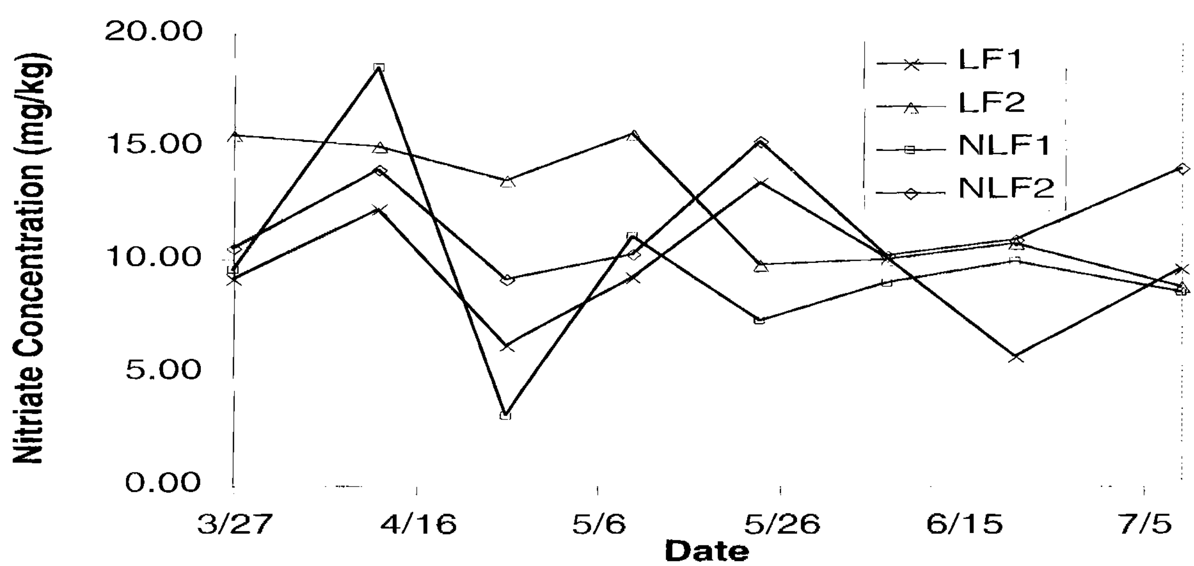

Figure 5. Year 1, Soil nitrate concentrations in the 60- to 80-cm depth interval. Values between the sampling dates were obtained by linear interpolation.

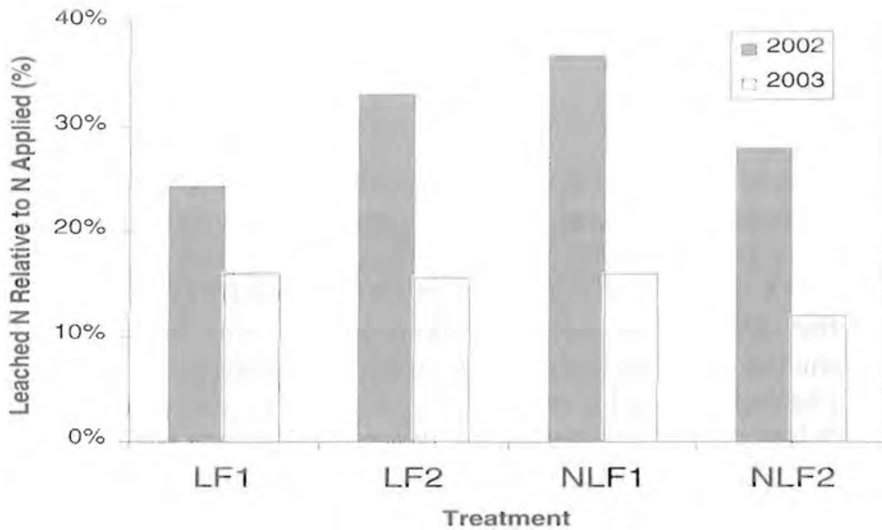

Figure 5. Estimated nitrogen leached during the Year 2 season. LF1 is the Lime-Fertigation 1 treatment, LF2 is the Lime-Fertigation 2 treatment, NLF1 is the No-Lime-Fertigation 1 treatment, NFL2 is the No-Lime-Fertigation 2 treatment.

The smallest amount of nitrogen leaching occurred in the LF1 treatment in 2002 and the NLF2 treatment during the second year. There is no clear difference between either the lime or fertigation treatments. Ammonium leaching was typically much lower than nitrate leaching (Table 3) except in the case of treatment NLF1 in 2002, in which 21 kg/ha ammonium was leached as compared to 47 kg/ha nitrate. The fact that no clear difference was observed between nitrogen leaching for the two lime treatments is consistent with laboratory studies currently being conducted on the Coto clay soil at the University of Puerto Rico Mayagüez Campus, which indicates that the pH at which this soil will possess a net positive charge (< 4) is below the native pH measured in the field (around 4.3).

METHOD LIMITATIONS

There are several sources of uncertainty in the estimates of nitrogen leaching, which include:

- Between sampling dates, soil nitrogen concentrations were derived by linear interpolation. Nitrogen concentrations were measured every two weeks. In some cases, the average nitrate concentration was observed to change as much as 15 mg/kg in the 60- to 80-cm depth interval. The estimated nitrogen leaching would be in error if these concentrations did not change linearly between sampling dates.
- The method of estimating percolation in this study does not account for the leaching that can potentially occur by unsaturated flow. All leaching was assumed to occur when the moisture content of the soil exceeded the soil field capacity. However, significant downward gradients can exist which would result in unsaturated flow. Although not presented in this paper, continuous soil pressure data obtained from vertically spaced tensiometers indicated downward hydraulic gradients throughout most of the season.

SUMMARY AND CONCLUSIONS

This paper described the results of a nitrogen leaching analysis for two sweet pepper crop seasons. The study was conducted on an Oxisol soil in NW Puerto Rico. The analysis was based on multiplying the daily percolation flux through the soil profile by the measured concentration of nitrogen below the root zone. Irrigations were scheduled using the pan evaporation method for estimating crop water requirements. Estimated percolation in 2002 was three times greater than that which occurred in 2003, whereas the nitrogen leached during 2002 was only slightly greater than two times the nitrogen leached during 2003.

No clear difference in nitrogen leaching was observed for the lime and no-lime treatments. This result is consistent with on-going studies of the Coto clay, which indicate that this soil has little to no capacity to retain nitrate. The average percent of nitrogen (nitrate plus ammonium) leached during the 1st and 2nd season, relative to the amounts applied, were 26% and 15%, respectively. Leaching events were associated with large rainstorms, suggesting that leaching of N would have occurred regardless of the irrigation scheduling method used. During the first and second seasons, respectively, 34% and 60% of the total N lost by leaching occurred during a single day (6 April in 2002, and 10 April 2003) when flooding was observed in the study areas.

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EVALUATING THE PRODUCTION OF TWO LETTUCE VARIETIES UNDER GREENHOUSE AND FIELD CONDITIONS

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ABSTRACT: A vegetable survey in the vegetable growing areas of Kwatta and Wijambo revealed that in general the lettuce growers do not possess sustainable farming techniques. This situation exists despite the fact that statistics from the Ministry of Agriculture and Animal Husbandry and interviews with the management of supermarkets, vegetable buyers, and farmers have revealed that the consumption of lettuce has increased over the last five years. At the same time WTO regulations (phytosanitairy regulations) require farmers to employ sustainable cultivation technology which would lead to more safe, efficient, and higher quantity and quality of agricultural products. Relevant to these regulations, a preliminary study was conducted to compare two lettuce varieties (Trinity Star and Black Seeded Simpson) under greenhouse and field conditions. Variables that were measured included plant height, number of green leaves, leaf area, and fresh weight. Additionally, a crop analysis and a taste test were also conducted as part of the study. Results of the study indicated that the production of both lettuce varieties was much higher in the greenhouse than under field conditions. However, the taste test revealed that the quality of lettuce produced under field circumstances was much better than that of the lettuce produced in the greenhouse. The crop analysis revealed that the nutrient range was optimal for the lettuce variety Trinity Star in the greenhouse.

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NÍQUEL EN HOJAS Y FRUTOS DE FRESA. ESTUDIO SOBRE UN SUELO MEJORADO CON S.F.M. (SULFATO DE HIERRO MONOHIDRATADO)

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RESUMEN: El estudio de determinados metales pesados en los frutos comestibles de las plantas, en las verduras de consumo directo o en los forrajes que consumen los animales tiene un interés obvio por su trascendencia en la salud humana. Además, determinados niveles de algunos de estos metales pueden modificar el metabolismo de las plantas produciendo alteraciones notables en su crecimiento y desarrollo que puede llegar incluso a la muerte de la misma. Uno de los metales que genera un notable interés es el Ni, no solo por las repercusiones que su absorción tiene en el proceso del control metabólico de la ureasa, sino por la existencia de plantas hiperacumuladoras que pueden tener un fin importante en los trabajos de fitorremediación. El estudio de las alteraciones metabólicas en cada caso, dependerá de las especies, niveles del elemento en los suelos en los que se cultiva, coeficiente de transferencia del metal hacia la planta, tolerancia de la misma, etc. El objetivo de este trabajo es valorar los niveles de Ni en suelos que puedan ser transferidos a las hojas y frutos de fresa en un cultivo en macetas. Se observó que los suelos con un pH inicialmente elevado se mejoraron con la adición de un sulfato de hierro monohidratado (S.F.M.), que evita la aparición de las clorosis férricas que aparecen en estos cultivos cuando se plantan en condiciones de basicidad.

ABSTRACT: The study of certain heavy metals in plant fruits, in vegetables of direct consumption or in forages has an obvious interest for its damage to human health. Also, certain levels of some of these metals can modify plant metabolism, thus producing remarkable alterations in growth and development, even death of the plant. One of these metals is Ni, not only because of its absorption in the metabolic control process of the urease but also because of the existence of hyperacumulator plants important in remedial phytology. The study of metabolic alterations in each case will depend on the species, levels of the element in the soils, coefficient of transfer of the metal toward the plant, and plant tolerance. The aim of this work was to evaluate the Ni content in soils, in leaves and in strawberry fruits cultivated in pots. An improvement of the high pH soils with the addition of a Ferrous Sulphate Monohidrated (FSM) was observed. This FSM prevented ferric chlorosis, which had appeared under high pH conditions.

INTRODUCCIÓN

El níquel es un metal ampliamente distribuido en la naturaleza y su importancia biológica es importante desde el reconocimiento de su papel en el metabolismo de bacterias, animales y plantas. La toxicidad del Ni en los seres humanos y animales hace mucho tiempo que es de sobra conocida. El Ni daña los vasos que riegan el corazón, y el sistema nervioso central y reduce las defensas inmunológicas de los organismos animales. También puede causar eczemas, inflamaciones alérgicas y carcinomas de las membranas mucosas.

El Ni se encuentra en la naturaleza por aportación de una doble vía: natural y antropogénica. Las erupciones volcánicas o las microgotas de los rompeolas marinos son fuentes naturales de Ni. La industria del acero, la incineración de las basuras, la aplicación de algunos agroquímicos, determinadas extracciones y procesos en la minería, etc. son procesos antropogénicos a considerar (Bennett et al., 1982).

El contenido de Ni en los suelos varía ampliamente dependiendo de la composición mineral del mismo. En los suelos agrícolas suele variar entre 5-500 mg/kg con un nivel medio de 50 mg/kg (Bennett et al., 1982). Los suelos serpentiníticos o muy ricos en materia orgánica, sobre todo en regiones áridas o semiáridas, son los más ricos en Ni.

La toxicidad en las plantas fue primero documentada en aquellas plantas que crecían en suelos serpentiníticos (Anderson et al., 1973). Las plantas toman níquel en cantidades considerables causándoles efectos tóxicos tales como clorosis, débil crecimiento, disminución de la cosecha y desórdenes en su metabolismo. Así, niveles superiores a 100 mg/kg de Ni en suelo, en los que se plantó perejil (*Petroselinum crispum*, var. *neapolitanum*), presentaron síntomas de clorosis con una disminución notable de sus niveles de clorofila en hojas, con disminución asimismo del N, del Mn y de la 1,3,8-p mentatriene, que es el compuesto que le da el aroma característico a esta planta (Mordy and Atta-Aly, 1999). Así mismo, la toxicidad de Ni en las planta se manifiesta con una senescencia prematura, inhibición en el desarrollo de granos, inviabilidad de los mismos, etc.

El Ni es un elemento muy móvil en el interior de la planta, por lo que existe peligro de una excesiva acumulación en determinados órganos de la misma, y su consecuente devaluación para el consumo (patatas, verduras, forrajes, etc.). Se ha demostrado que altos niveles de Ni en la célula pueden producir cambios estructurales en la mitocondria (Simon et al., 2000) o en cloroplastos (Molas et al., 2002).

Los primeros pasos para entender el papel biológico del níquel en las plantas y otros organismos vivos (Mishra and Kar, 1974; Eskew et al., 1978, 1984; Brown et al., 1987) abrieron el camino para una mejor comprensión de la conducta del sistema suelo-planta en el movimiento de este metal.

La concentración de Ni en las plantas oscila en un rango de 0.05-5mg/kg (Urem et al., 1993), y aunque no se ha probado que sea un micronutriente esencial para las plantas superiores, hay una amplia documentación relativa a los efectos beneficiosos de este metal en el crecimiento de las mismas (Mizar and Kar, 1974; Eskew et al., 1978, 1984; Brown et al., 1987). Pasado un cierto nivel el elemento se vuelve tóxico (100 mg/kg).

Otros autores señalan otros niveles de toxicidad, así Anderson et al. (1973) y Jaffré et al. (1976) señalan que la toxicidad para las plantas se alcanza a partir de niveles próximos a 50 mg/kg. Autores como Poulik et al. (1997) señalaron que las plantas de cebada morían con niveles de Ni por encima de 168 mg/kg. No obstante hay un número de especies adaptadas a altos niveles de absorción de Ni (hiperacumuladoras) en suelos serpentiníticos que contienen más del 3% de su peso en Ni en sus vástagos. Bollard et al. (1983) y Reeves et al. (1999) han realizado una amplia revisión de las especies adaptadas a altos niveles de níquel en estos suelos.

Eskew et al. (1984) observaron que el Ni se requería como factor metabólico en el funcionamiento correcto de la enzima ureasa (previene el efecto tóxico de la urea en el tejido de la hoja, por ejemplo) y concluyeron que es esencial para el metabolismo nitrogenado de la soja (*Glycine max* L.). El Ni no interviene en el metabolismo directo de la enzima pero es esencial en el proceso de funcionamiento de la misma (Marschner et al., 1986). La ausencia de Ni, cuando las plantas se abonan con nitrogenados, provocaría la formación de urea, que es perjudicial para los tejidos, independientemente de la forma de aplicación. Esta acumulación de urea se manifiesta por manchas necróticas en los parénquimas foliares. La necesidad de la presencia de Ni en la correcta actividad de la enzima ureasa (que actúa en el metabolismo correcto de los compuestos nitrogenados en el interior de la planta), fue también puesta de manifiesto por Gerendás y Salttelmacher (1999) en estudios sobre el calabacín (*Barssica napus* L. Var *annua*, cv. Calypo)

Así mismo se han observado que ciertos niveles tóxicos producen disminución de la fotosíntesis y de la transpiración, detención del crecimiento y hasta la muerte de la planta, o de algunos de sus órganos. Por ejemplo, deteriora el crecimiento de los sistemas radiculares afectando a todo el metabolismo de la planta.

La absorción de Ni depende fundamentalmente de la especie, de la estructura del suelo y del pH, que al disminuir aumenta la biodisponibilidad y las cantidades absorbidas por las plantas (Adriano et al., 1986; Urem et al., 1993). El Ni se complejaría con los ácidos orgánicos de estas especies, los cuales pueden contribuir como mecanismo de tolerancia, aunque no sea el único. Por otra parte, la absorción de Ni por determinadas plantas (*Streptanthus polygaloides*, un hiperacumulador) puede hacer a la planta resistente al ataque de polífagos herbívoros (*Spodoptera exigua*) (Boyd and Moar et al., 1999).

MATERIALES Y MÉTODOS

a) Métodos físicos

Esta experiencia se realizó en un invernadero de la Escuela Politécnica Superior La Rábida, Huelva (España). Se eligió una planta de gran importancia económica en la provincia como es la fresa, en concreto la variedad Camarosa. Estas se plantaron en macetas de unos 10 litros de volumen a mediados del mes de noviembre.

Se realizaron una serie de tratamientos, utilizándose para ello seis productos orgánicos de diferentes casas comerciales (Aborgabi, Atilatrans, Fertikali, Infertosa, Lezcano y Tradired), sulfato ferroso monohidratado (SFM) y abono 15-15-15.

Cada tratamiento consta de cinco repeticiones, de esas cinco repeticiones se tomó una muestra representativa de hojas, suelos y frutos para su análisis, en las siguientes fechas: 1ª toma de suelos principios del mes de octubre, antes de la aplicación de los distintos tratamientos; 2ª toma de suelos principios del mes de junio del año siguiente; 1ª toma de hojas y frutos a mediados del mes de marzo; 2ª toma de hojas y frutos a mediados del mes de julio.

b) Métodos químicos

b.1) Determinación de Metales Pesados en Suelos

Una vez obtenidas las muestras éstas se llevan al laboratorio donde en primer lugar se llevan a peso constante mediante su secado en estufa a unos 60° C durante 2-3 días. Posteriormente, se trituran en un molino preparado para el efecto. El siguiente paso es la digestión de las muestras de suelo, para ello se pesa una cantidad de 5 g de suelo seco y molido en tubo de agitación, se le añade 30 ml de una disolución de acetato amónico, se agita durante 30 minutos y se deja reposar 24 horas.

Se extraen 20 ml del sobrenadante y se lleva a una placa calefactora a unos 110º C hasta sequedad, se le añade 2 ml de una disolución de HNO_3 al 50% y se vuelve a dejar en sequedad, se vuelve a añadir 2 ml de otra disolución de H_2O_2 al 30%, se deja en sequedad añadiéndose, posteriormente, 5 ml de una disolución de HCl al 50%. Pasados unos 15 minutos se retira de la placa calefactora y se recoge con agua destilada hasta un volumen de 100 ml.

b.2) Determinación de Metales Pesados en Hojas y Frutos

La obtención de muestras secas y molidas se lleva a cabo de igual forma que en los suelos. Estas muestras se calcinan en estufa mufla a 550º C durante 2-3 horas. Las muestras calcinadas son las que se digieren. Para ello, se pesa aproximadamente 0,1 g de muestra, se le añade 5 ml de una disolución 2,8 M de HCl y se lleva a la placa calefactora durante 24 horas a 90º C. Pasado este tiempo se retira de la placa y se deja enfriar a temperatura ambiente, una vez fríos se añade 1 ml de H_2O_2, se vuelve a colocar en la placa durante otras 24 horas, transcurridas las cuales se retira de la placa y se recoge el líquido hasta un volumen de 100 ml con agua destilada.

La determinación de los distintos metales pesados en suelos, hojas y frutos se llevó a cabo por el Laboratorio de Investigación + Desarrollo de la Universidad de Huelva, mediante determinación en ICP óptico.

c) Clave de Tratamientos

- T1: Suelo sin ningún tratamiento de abonado.
- T2: Suelo mejorado con el equivalente a 750 kg/ha del abono 15-15-15 un mes antes de plantación.
- T3: Suelo con el tratamiento T2 más 1% de materia orgánica sin S.F.M.
- T4: Suelo con el tratamiento T2 más 2% de materia orgánica sin S.F.M.
- T5: Suelo con el tratamiento T2 más 3% de materia orgánica sin S.F.M.
- T6: Suelo con el tratamiento T2 más 1,5% de materia orgánica con Nivel Bajo (Nivel 1) de S.F.M.
- T7: Suelo con el tratamiento T2 más 1,5% de materia orgánica con Nivel Medio (Nivel 2) de S.F.M.
- T8: Suelo con el tratamiento T2 más 1,5% de materia orgánica con Nivel Alto (Nivel 3) de S.F.M.
- T9: Suelo con el tratamiento T2 más el equivalente a 250 kg/ha de S.F.M.
- T10: Suelo con el tratamiento T2 más el equivalente a 500 kg/ha de S.F.M.
- T11: Suelo con el tratamiento T2 más el equivalente a 1.000 kg/ha de S.F.M.

RESULTADOS Y DISCUSIÓN

En la Tabla I se presentan los resultados de las mediciones del contenido de Ni determinado en los frutos, hojas y suelos de las plantaciones de fresas estudiadas.

El Ni varía en los suelos a lo largo del tiempo de la experiencia, pasando de un nivel de 120,48 p.p.b. a 163,34 p.p.b. y esa variación es significativa (0.011) (Gráfico 1), sin importar el tipo de tratamiento que se ha realizado, aunque hay una notable diferencia entre los diferentes productos en su efecto sobre la disolución del Ni (0.001).

Los diferentes niveles de materia orgánica probados en la experiencia no muestran diferencias significativas. La presencia de S.F.M. es la que ha inducido la disolución del Ni en el suelo (0.048) (Gráfico 2). El abonado con fertilizante 15-15-15 no actúa significativamente.

Se observa que el nivel de Ni en hojas de fresa no varía con la edad de la planta. Las plantas que reciben abonado orgánico tienen menos Ni que aquéllas que no se abonan y esa diferencia es significativa (0.019). Pero, además, a mayores cantidades de materia orgánica, mayor es el efecto de quelatación y menor es el nivel de Ni en hojas (0.002) (Gráfico 3).

La presencia de S.F.M. en los suelos también actúa sobre el nivel de Ni en las hojas (Gráficos 4 y 5). La presencia de abono mineral (15-15-15) también es un factor a tener en cuenta en el nivel de Ni en las hojas, puesto que a mayor nivel de abonado menor nivel en hojas (0.000) (Gráfico 6).

El nivel de Ni en los frutos de fresa en la primera toma (565, 34 p.p.b.) es mayor que en la segunda (167,65 p.p.b.) y esa diferencia es significativa (0.001) (Gráfico 7). La materia orgánica realiza el mismo efecto que en las hojas, es decir a medida que aumenta el nivel de materia orgánica en los suelos se quelata más Ni, hay menos transferencia a las hojas y éstas transferirán menos Ni al fruto (Gráfico 8), pero esa diferencia no siempre es significativa. Esto puede ser debido al hecho de que la planta tenga un mecanismo de transferencia de Ni de las hojas hacia los frutos independiente del nivel de las mismas.

CONCLUSIONES

Las aplicaciones de sulfato de hierro monohidratado en suelo hacen que el Ni se vuelva más soluble a lo largo del tiempo. Los diferentes productos que se utilizan para mejorar el nivel de materia orgánica del suelo también influyen en el nivel de disolución de este metal.

El abonado orgánico de los suelos disminuye el nivel de Ni en las hojas de fresa debido a que la materia orgánica quelata el metal en el suelo y las plantas tiene menos cantidad de este metal para absorber. Un correcto abonado mineral (15-15-15) produce un mejor desarrollo foliar y porcentualmente disminuye el nivel de Ni en hojas.

Al comienzo de la recolección el nivel de Ni en fruta es mayor que al final, debido a que la cantidad de fruto recolectado es mayor en la 2ª toma y el porcentaje de Ni transferido desde las hojas a los frutos se disminuye, no solo por el efecto "reparto" (misma cantidad de Ni para mayor cantidad de fruta cosechada), sino también por el menor nivel que ya tenían las hojas, puesto que la planta tiene mayor desarrollo foliar con la edad. Se observa que la presencia de S.F.M. no influye en el nivel de Ni en la fruta.

Tabla 1. Datos de los contenidos de Ni en frutos, hojas y suelos de las plantaciones de fresas.

Referencia	Ni 1ªt frutos (ppb)	Ni 2ªt frutos (ppb)	Ni 1ªt hojas (ppm)	Ni 2ªt hojas (ppm)	Ni 1ªt suelos (ppb)	Ni 2ªt suelos (ppb)
T3-ABO	4459	162	1,91	0,67	236	168
T4-ABO	793	163	0,75	0,61	292	221
T5-ABO	746	211	0,49	0,54	305	272
T6-ABO	896	187	0,43	0,61	211	192
T7-ABO	767	122	0,47	0,51	198	173
T8-ABO	544	145	0,47	0,57	211	176
T3 ATI	921	305	0,59	1,88	82	116
T4 ATI	325	500	0,61	0,80	69	76
T5 ATI	334	135	0,49	0,60	69	64
T6 ATI	1987	172	0,42	0,55	138	196
T7 ATI	479	122	0,33	0,28	164	166
T8 ATI	247	136	0,64	0,68	180	190
T3 FER	262	141	0,46	0,51	99	106
T4 FER	263	114	0,32	0,47	79	104
T5 FER	217	108	0,33	0,42	77	110
T6 FER	258	128	0,31	0,46	105	226
T7 FER	341	151	0,33	0,40	105	480
T8 FER	292	89	0,32	0,33	104	158
T3 INF	730	189	0,61	1,22	73	98
T4 INF	549	171	0,86	0,95	72	71
T5 INF	332	188	0,68	0,21	68	84
T6 INF	337	190	0,48	0,13	87	111
T7 INF	268	69	0,51	0,61	81	152
T8 INF	229	99	0,63	0,52	97	240
T3-LEZ	254	100	0,57	0,39	112	94
T4-LEZ	208	124	0,58	0,46	102	354
T5-LEZ	125	110	0,42	0,43	227	299
T6-LEZ	158	113	0,68	0,37	87	184
T7-LEZ	112	94	0,49	0,73	93	193
T8- LEZ	403	82	0,50	0,37	82	194
T3-TRA	586	357	0,53	0,49	78	103
T4-TRA	250	124	0,49	0,55	77	84
T5-TRA	235	119	0,50	0,18	94	91
T6-TRA	476	104	0,40	0,37	92	86
T7-TRA	177	96	0,42	0,52	132	293
T8-TRA	221	90	0,50	0,41	108	106
T1	0	217	0,91	2,68	79	99
T2	1305	180	0,68	0,46	79	169
T9	786	181	0,63	0,83	97	146
T10	346	376	0,37	0,45	95	127
T11	961	410	0,54	0,74	104	125

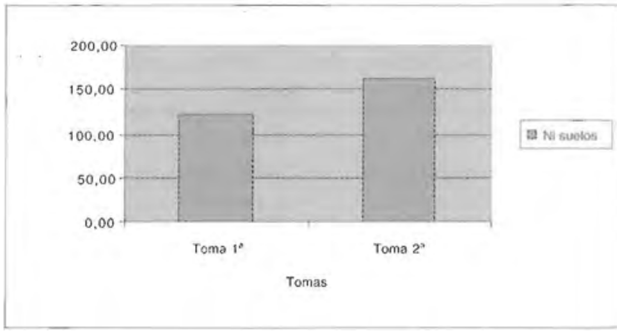

Gráfico 1: Comparación Níquel (p.p.b.) en suelos según Tomas.

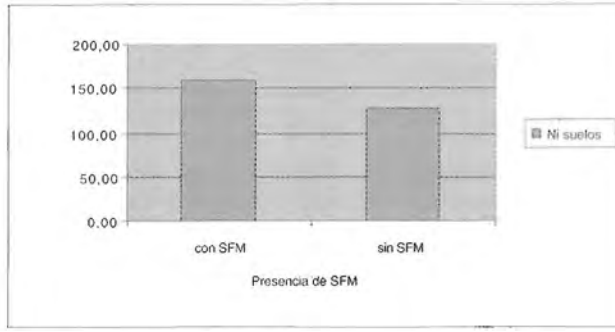

Gráfico 2: Comparación Níquel (p.p.b.) en suelos según presencia de SFM.

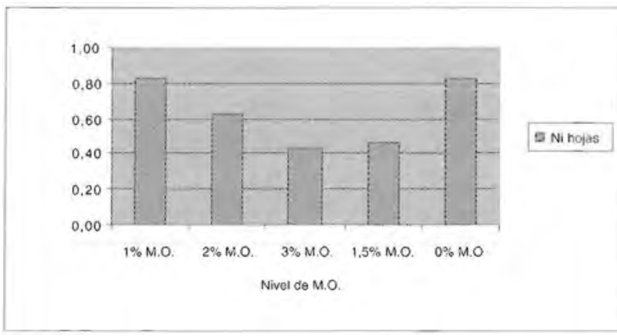

Gráfico 3: Comparación Níquel (p.p.m.) en hojas según nivel de M.O.

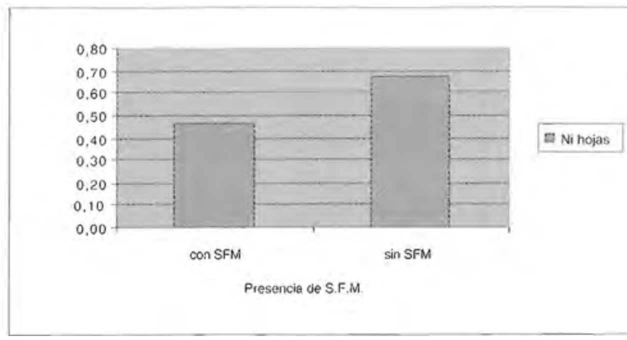

Gráfico 4: Comparación Níquel (p.p.m.) en hojas según presencia de SFM.

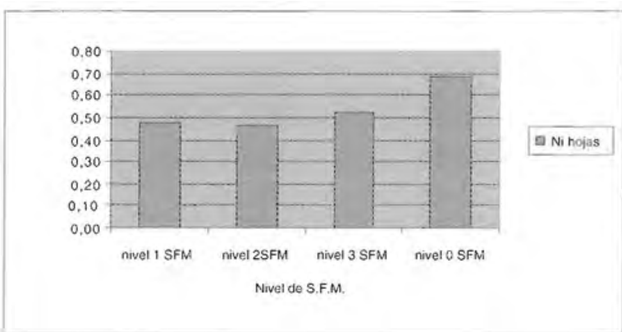

Gráfico 5: Comparación Níquel (p.p.m.) en hojas según nivel SFM.

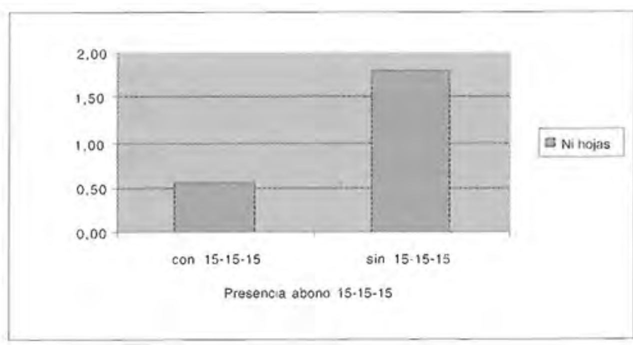

Gráfico 6: Comparación Níquel (p.p.m.) en hojas según presencia de abono 15-15-15.

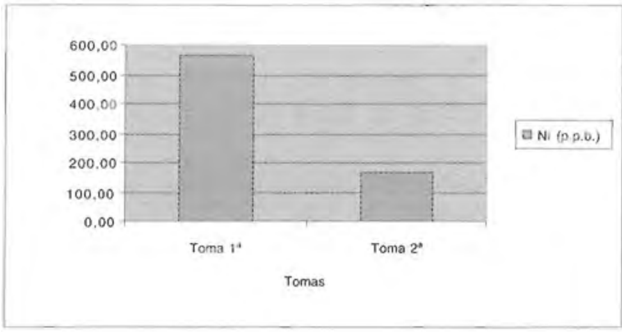

Gráfico 7: Comparación Ni (p.p.b.) en frutos según Tomas.

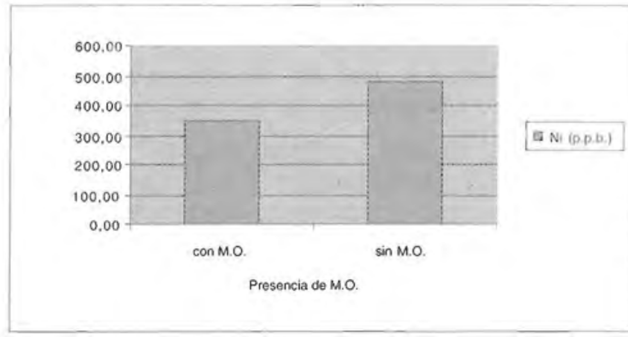

Gráfico 8: Comparación Ni (p.p.b.) en frutos según presencia de M.O.

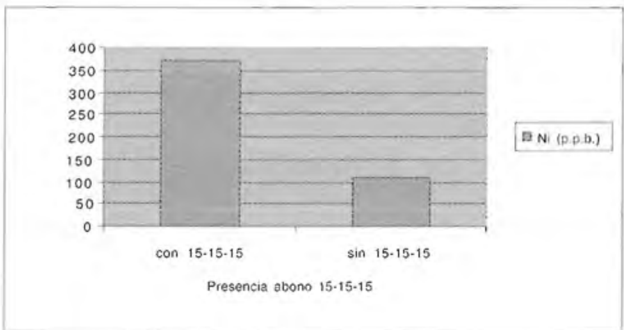

Gráfico 9: Comparación Ni (p.p.b.) en frutos según presencia de abono 15-15-15.

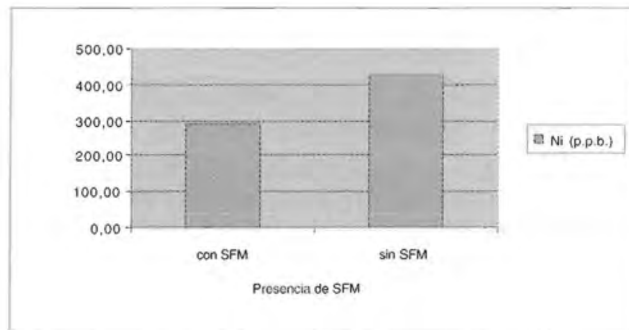

Gráfico 10: Comparación Ni (p.p.b.) en frutos según presencia de SFM.

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EVALUACIÓN DE TRES FRECUENCIAS DE RIEGO Y PREPARACIONES DE SUELO EN TOMATE INDUSTRIAL (*LYCOPERSICON ESCULENTUM* MILL), AZUA, REPÚBLICA DOMINICANA

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RESUMEN: Se realizó un estudio de campo en la Estación Experimental Azua, del Centro Sur, del Instituto Dominicano de Investigaciones Agropecuarias y Forestales (IDIAF), entre diciembre de 2001 y junio de 2002. Dicha estación está ubicada a una altitud de 25 msnm con una precipitación media anual de 650 mm/año. El presente estudio se efectuó con el fin de conocer cómo la preparación de suelo puede ayudar a alargar la frecuencia de riego y ahorrar agua. Se evaluaron tres frecuencias de riego y tres preparaciones de suelo. Se determinó que cuando se preparó el suelo con vertedera, sin importar la frecuencia de riegos (10, 12 y 15 días), y cuando el suelo se preparó con cincel y se regó a los 10 días se obtuvieron los mejores rendimientos promedios (60.43-50.11 t/ ha), reflejándose un incremento con relación a las demás preparaciones de suelo hasta de un 42%. El menor volumen promedio de agua por riego se logró con la frecuencia de 15 días, con una reducción de 8.89% (1,395.37 m^3/ha) con relación a la frecuencia de 10 días. El análisis marginal de costos que varían reporta los mayores beneficios netos por cada peso invertido cuando el suelo se preparó con vertedera y se regó cada 10 días; seguido de cuando el suelo se preparó con vertedera y se regó cada 15 días.

INTRODUCCIÓN

El cultivo del tomate industrial (*Lycopersicon esculentum*) es de gran importancia para la economía de la República Dominicana y el valle de Azua ya que comprende uno de los principales cultivos industrializados de gran escala y el primero dentro de las hortalizas. La creciente demanda interna y el mejoramiento del mercado de los derivados del tomate industrial a nivel mundial y la demanda de mano de obra, evidencian ser de gran importancia para la economía de Azua, que representa el 45% del área que se siembra bajo riego.

Del área cultivada anualmente en Azua, el 78% de los productores son parcelaros de reforma agraria, la cual cultivan en promedio unas 20 tareas; el otro 22% le corresponde a pequeños productores privados.

Este cultivo requiere suelo con una alta capacidad de almacenamiento de agua por las características de sus raíces y por la susceptibilidad a la sequía, lo que lo hace ser un cultivo exigente en agua con intervalos muy cortos. Dadas las grandes extensiones del cultivo, la poca disponibilidad de agua y la importancia que representa la producción del tomate industrial en la economía nacional, se hace necesario buscar alternativas de riego que contribuyan a mejorar el uso del agua.

En este cultivo se utilizan cada año, de acuerdo al área sembrada en Azua, unos 70 millones de metros cúbicos de agua. Este alto consumo se debe a la baja eficiencia en el uso del agua de riego, así como a la profundidad del arado, que influye de manera directa en la cantidad de agua almacenada en el suelo. Tradicionalmente la profundidad del arado con rastra es de 15 cm, lo cual permite una muy baja lámina de agua en el suelo. Dado a que el consumo de agua se incrementa en función del desarrollo del cultivo, se hacen cada vez más cortos los intervalos entre riegos.

MATERIALES Y MÉTODOS

El estudio se inicio en noviembre del 2001, en la estación experimental Azua, de centro sur del IDIAF, ubicada a 25 msnm, con una pluviometría de 650 mm/año, la temperatura media es de 27.5°C, los suelos son Entisoles con una textura franco arenosa. El clima está clasificado de acuerdo a la zona de vida de Holdridge como bosque seco subtropical.

En un área de 3.6 tareas, se realizaron tres métodos de preparación de suelo con diferentes implementos (rastra, cincel y vertedera) según el alcance de cada equipo, luego se le dieron sus pases normales.

La siembra de la planta se efectuó siguiendo un diseño de parcela dividida, con 9 tratamientos y 3 repeticiones, los factores estudiados fueron (preparación de suelo y frecuencia de riego). La unidad experimental consistió en parcela de 4 camellones sembrados a doble hileras de 10 m de largo y 7.20 m de ancho, con un área de 72 m_. El área útil estuvo formada por los dos camellones centrales, con 3.75 m de largo por 3.6 m de ancho, con 60 plantas por tratamiento y por repetición para un área de 13.5 m^2.

Los siguientes tratamientos fueron: 3 frecuencias de riego establecidas a los 10, 12 y 15 días; 3 preparaciones de suelo con cincel, rastra y vertedera.

P1f1 preparación con cincel y frecuencia de 10 días
P1f2 preparación con cincel y frecuencia de 12 días
P1f3 preparación con cincel y frecuencia de 15 días
P2f1 preparación con rastra y frecuencia de 10 días
P2f2 preparación con rastra y frecuencia de 12 días
P2f3 preparación con rastra y frecuencia de 15 días
P3f1 preparación con vertedera y frecuencia de 10 días
P3f2 preparación con vertedera y frecuencia de 12 días
P3f3 preparación con vertedera y frecuencia de 15 días

La lámina de agua aplicada a cada método de preparación de suelo fue medida utilizando un aforador sin cuello de 20 X 90 cm a la entrada del ensayo para determinar el caudal de entrada y posteriormente el volumen de agua aplicado, para esto se utilizaron nivel de mano, cinta métrica y sifones.

Se dio un manejo el cultivo de la forma que se practica en Azua, excepto a lo que concierne a riego y preparación de suelo; se realizaron tres aplicaciones de fertilizantes a razón de 750.75 kg/ha de la formula 15–15–15, en dos aplicaciones, a los 10 y 28 días después del trasplante (ddt) y una tercera fertilización con 500.09 kg/ha de sulfato de amonio a los 45 ddt. Se controlaron las malezas de forma química y manual, la primera con el uso de fluacifob butil + metribuzina a una dosis de 500 cc+ 5 onzas por 200 litros de agua, y la segunda con el uso de azadas aplicando tres desyerbos durante el periodo de cultivo. Las plagas como moscas blancas, gusanos del fruto y minadores se controlaron previo monitoreo y se hicieron aplicaciones preventivas contra hongos del follaje.

El trasplante del tomate fue manual. Antes de la aplicación de las frecuencias de riegos se realizaron tres riegos hasta el establecimiento de la plántula. Se realizó un muestreo antes de cada riego, y otro muestreo dos días después del riego, esto a diferentes profundidades en función de la etapa de desarrollo del cultivo.

Los datos recolectados en el estudio fueron procesados y analizados utilizando el 'software' de estadística "MSTACT" mediante la configuración de hojas electrónicas para el análisis estadístico y económico. Los tratamientos fueron sometidos a análisis de varianza y separación de medias por Duncan al valor del 5%.

RESULTADOS Y DISCUSIÓN

En cuanto al volumen promedio de agua aplicado por riego, la mejor frecuencia fue la de 15 días, con una reducción de 8.89% (1,395.37 m_/ha) con relación a la frecuencia de 10 días. En cambio la diferencia entre los intervalos de 10 y 12 días fue de 1,083.33 m_/ha, equivalente a un porcentaje de reducción de 7.41% en comparación con la de 10 días. El menor tiempo de riego se registró en la frecuencia de 12 días con un tiempo promedio de 5.75 horas; sin embargo, el menor número de riegos coincide con la frecuencia de 15 días con 5 riegos, seguido por la frecuencia de 12 días con 6 riegos, alcanzándose el mayor número de riegos, con un total de 7, en la frecuencia de 10 días.

La menor lámina promedio aplicada por riego se registró en la frecuencia de 10 días, con un promedio por riego de 224 mm, el mayor valor se registró en la frecuencia de 15 días con un valor de 285 mm (Tabla 1).

Tabla 1. Volúmenes, caudales y láminas promedio aplicadas por frecuencia de riego en tomate industrial.

Frecuencias en días	Caudal (l/seg.)	Tiempo Riego (Hora)	Núm. de Riego	Volumen (m_)	Área	Lamina (mm)	Volumen (m_ / ha)
10	21.39	6.59	7	508.04	324	224	15,691.35
12	23.27	5.75	6	473.30	324	243	14,608.02
15	20.08	6.30	5	463.19	324	285	14,295.98

En la Tabla 2 se presenta el comportamiento de la humedad antes y después de cada riego por frecuencia de riego para los métodos de preparación de suelo (cincel, rastra y vertedera). La menor humedad antes del riego se registró en la frecuencia de 15 días, cuando el suelo fue preparado con cincel, con un valor de 8.94%; y la mayor en la frecuencia de 15 días con valor de 12.31% para la preparación de suelo con vertedera. Un comportamiento parecido se registró en las frecuencias de 12 y 15 días en los valores de humedad para después del riego en la preparación de suelo con vertedera, variando desde 14.48 y 17.49%.

Los déficit promedios con que se estuvo regando en cada método de preparación de suelo fueron de un 42% en vertedera, seguido por el cincel con un 34%. El menor déficit se obtuvo cuando se empleó el método de preparación con rastra, 20%.

Tabla 2. Comportamiento de la humedad antes y después de cada riego por método de preparación de suelo en tomate industrial.

Preparación de suelo	Humedad antes del riego			Humedad después del riego			(DHS)
	F= 10 días	F= 12 días	F= 15 días	F= 10 días	F= 12 días	F= 15 días	
Cincel	11.78	11.02	8.94	15.70	15.71	15.90	34%
Rastra	10.41	11.15	7.02	15.28	15.63	14.85	20%
Vertedera	10.48	9.37	12.31	15.41	14.48	17.49	42%

DHS = Déficit de Humedad en el Suelo.

En la Tabla 3 se pueden apreciar los efectos de las diferentes frecuencias de riego y preparación de suelo sobre el rendimiento. Hubo diferencias estadísticas significativa ($P<0.05$) para la variable rendimiento cuando el cultivo se sometió a diferentes frecuencias de riego y preparación de suelo.

Cuando el suelo se preparó con arado de vertedera y se regó a los 10, 12 y 15 días no afectó el rendimiento fresco de frutos del tomate industrial, o sea, que dio lo mismo regar con cualquiera de las frecuencias utilizadas en el estudio. De igual manera se comportó la frecuencia de 10 días y cuando el suelo se preparó con cincel; los menores rendimientos se obtuvieron cuando se regó a los 12 y 15 días en suelo preparado con cincel y a los 10, 12 y 15 días cuando el suelo se preparó con rastra con una reducción de la producción hasta de 42% en algunos casos.

Tabla 3. Rendimiento total (t/ ha) en los 3 métodos de preparación de suelo y 3 frecuencias de riego en tomate industrial.

Número Entrada	Tratamientos	Rendimiento (t/ ha)	Reducción del rendimiento
7= P3f1	Preparación con vertedera y F= 10 días	60.43 a	
8= P3f2	Preparación con vertedera y F= 12días	55.96 a	NS*
9= P3f3	Preparación con vertedera y F= 15 días	52.69 ab	NS*
1= P1f1	Preparación con cincel y F= 10 días	50.11 ab	NS*
5= P2f2	Preparación con rastra y F= 12 días	44.13 bc	S*
6= P2f3	Preparación con rastra y F= 15 días	42.72 bc	S*
3= P1f3	Preparación con cincel y F= 15 días	42.50 bc	S*
4= P2f1	Preparación con rastra y F =10 días	41.39 bc	S*
2= P1f2	Preparación con cincel y F= 12 días	35.31 c	S** (42%)

*Valores seguidos por la mima letra no difieren estadísticamente (DMS 5%)

S** Con relación a la preparación con Vertedera y frecuencia de 10 días.

ANÁLISIS MARGINAL

Según el análisis marginal sobre los costos que varían que reporta los mayores beneficios netos está el tratamiento de preparación con vertedera y F = 10 días, con un total de costos que varían de RD$ 5,693.00, unos beneficios netos de RD $ 63,197.20 y una tasa de retorno marginal de 446% (Tabla 4). Seguido del tratamiento preparación con vertedera y F = 15 días, con un total de costos que varían de RD $ 4,913.00, unos beneficios netos de RD $ 59,713.60.

Tabla 4. Análisis marginal sobre costos que varían.

Tratamientos	Total de costos que varían RD $	Beneficios Netos RD $	TRM %
Preparación con Rastra y F=10 días	3,445.00	43,739.60	-
Preparación con Rastra y F=12 días	4,020.00	46,288.20	-
Preparación con Vertedera y F=15 días	4,913.00	59,713.60	-
Preparación con Vertedera y F=10 días	5,693.00	63,197.20	446.0

TMR = Tasa de Retorno Marginal

CONCLUSIÓN

Los mejores rendimientos se alcanzaron cuando el suelo se preparó con arado de vertedera sin importar la frecuencia (10, 12 y 15 días) con que se regó el cultivo; seguido por la profundidad del cincel y cuando el cultivo se regó a los 10 días.

El menor volumen de agua (14,295.98 m^3) utilizado se logró con la frecuencia de 15 días y el mayor (15,691.35 m^3) cuando el cultivo se regó con frecuencias de 10 días.

Según el análisis marginal, el tratamiento que reporta los mayores beneficios netos por cada peso invertido es el de preparación con vertedera y frecuencia de 10 días, seguido del tratamiento cuando el suelo se preparó con vertedera y se regó a los 15 días.