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OF THE
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Caribbean Food Crops Society
47th Annual Meeting
July 3–8, 2011

Lloyd Erskine Sandiford Centre
Bridgetown, Barbados

"Assuring Caribbean food and nutrition security in the context of climate change"

United States Department of Agriculture,
T-STAR Sponsored Invasive Species Symposium

Toward a Collective Safeguarding System for the Greater Caribbean Region: Assessing Accomplishments since the first Symposium in Grenada (2003) and Coping with Current Threats to the Region

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"The Nexus of Invasive Species, Climate Change, and Food Security"

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WELCOME AND BACKGROUND

OPENING REMARKS: *Dr. Robert Godrey, Director and Professor, University of the Virgin Islands, speaking on behalf of Dr. Douglas Archer, UF T-STAR Director and Professor, Food and Human Nutrition Department, University of Florida, PO Box 110200, Gainesville, FL 32611 USA. Telephone: 352-392-1784; Email: dlarcher@ufl.edu.*

Welcome and Opening Comments (*USDA T-STAR Invasive Species Symposium*)

I would like to welcome everyone to the 2011 Symposium on Invasive Species sponsored by the USDA T-STAR program, which has a longstanding relationship with CFCS. Dr. Douglas Archer from the University of Florida could not be here this morning, so he sent me the following to read to you.

Greetings to all of you attending the T-STAR Symposium at the 2011 Caribbean Food Crops Society Meeting.

I want to thank Bob Godfrey for reading my greeting to you. Bob is the current Chair of the TSTAR-Caribbean Advisory Group, as well as UVI's Experiment Station Director.

I had planned on being in Barbados, but a family matter interceded. It seems like when it rains it pours when family is involved.

As you know, TSTAR was not funded this year. The current economic situation here in the United States caused extensive budgetary cutbacks to many programs. I regret that TSTAR was negatively affected.

It does not look like a quick resurrection of the program is likely, as the current U.S. Congress is very much against special grants. Unfortunately, a one-size-fits-all mentality does not distinguish between special grants that serve a questionable or limited purpose from those that do extreme good. I put TSTAR in the "does extreme good" category.

We can all take pride in TSTAR's many accomplishments. These grants have formed the basis for countless scientific publications, and as the provider of data that has secured larger, longer-term funding.

In many cases, TSTAR funding has been the first funding to address an emergency situation. I can say that with certainty for Laurel Wilt and its effects on avocados, citrus Blackspot, and Orange Rust of Sugarcane to name a few.

In years past, it has served as the basis for the development of new value added crops and industries in Florida and the Caribbean. It can easily be said that it has improved agriculture throughout the region.

While I am not very optimistic about the return of the program in the immediate future, we will continue to actively seek its return by convincing Congress of the good it has done. We are actively assembling written and video evidence of TSTAR's value to agriculture and to international trade in foods. We will use these materials to convince those with the vote that TSTAR has done and continues to do extreme good.

Again, I regret not welcoming you in person, and I thank Bob for taking on that job. He will introduce our very distinguished guests.

Thanks and best wishes to all of you.

We are sorry that Dr. Archer could not be here. I would now like to introduce our guests on the panel and then each of them will make a few brief comments.

Please note that there has been a slight change in the program. The first speaker is not going to be Arlington Chesney. It will be Bruce Lauckner from CARDI. After he speaks, I will make some comments on behalf of the University of the Virgin Islands. The other opening speakers are Dr. Hector Santiago, Dean and Director at the College of Agricultural Science, Mayaguez campus of the University of Puerto Rico; Dr. Tim Momol, Central District Extension Director, University of Florida; and Mr. Barton Clarke, Chief Agricultural Officer, Ministry of Agriculture and Rural Development in Barbados. So, without further ado, I give you Dr. Bruce Lauckner.

OPENING REMARKS: *Mr. Bruce Lauckner, Head, Strategic Alliances, CARDI, speaking on behalf of Dr. Arlington Chesney, Executive Director, Caribbean Agricultural Research and Development Institute, University Campus, PO Bag 212, St. Augustine, Trinidad, West Indies. Telephone: 868-645-1205; Email: executive@cardi.org.*

Chairman, ladies, and gentlemen, good morning.

I apologize for not being able to attend personally as I did confirm very early and looked forward to being here. In my absence, I have asked Bruce Lauckner to make this presentation on my behalf. It is appropriate that I add my thanks to those who have already thanked the Caribbean Food Crops Society for keeping the issue of invasive species on the "front burner" within this week of activities, with the knowledge that the seeds sown here will bear fruit throughout the year. Thanks are also due to the University of Florida for hosting another of these very important one-day symposia funded under the T-STAR program. I visited Gainesville, Florida earlier this year and am aware of the impact that national and state budgeting is having on the University of Florida's available finances. Therefore, maintaining its support for this event is testimony of the importance that the University of Florida places on this initiative.

I wish to assure everyone that CARDI shares this importance and will continue to support it and its goals and objectives.

The origins of the Caribbean Food Crops Society's association with invasive species go back to 2003 and the first one-day symposium organized by the University of Florida. Several agencies were represented at that meeting, many of whom are here today. I will not risk trying to name all of them, but I will mention two: IICA, my former employer, and CARDI, my current employer.

Those present at the 2003 meeting managed to do what we sometimes fail to do in this Region—that is, to lay a significant foundation to maintain the momentum. We had the full support of the CARICOM Secretariat. The University of Florida managed to maintain the required funding; however, just as important was the agreement of all participating agencies at the first one-day symposium to invest resources (within their individual capacities) in invasive species issues.

For example, CARDI hosted a symposium in Trinidad in 2004 (along with funding from the University of Florida). It was at this symposium where the Caribbean Invasive Species Working Group (CISWG) was created, one year after being conceptualized at the CFCS by a number of agencies with a good mix of gender and discipline.

It was Gilly Evans who first put some concepts on paper that were strongly supported by many, including Everton Ambrose of IICA. Everton then took the writing reins and penned the CRISIS document that sets out the framework and operation of CISWG.

CISWG quickly went from strength to strength, and CARICOM ensured that it was recognised as an "official" body chaired by CARDI. I must emphasize that CISWG is a "body" (rather a loose term). This is because at times some have regarded it as an institution with funds and legal standing. To try to explain CISWG, we have produced a document called "What Is CISWG?" which is available to all of us here today. Please make sure that you read it.

After over half-a-dozen years, CISWG has achieved quite a lot. The Caribbean Regional Diagnostic Network is now very active under the direction of Dr. Tim Momol. USDA/APHIS completed a very comprehensive CISWG Caribbean Pathway Analysis (CPA). CISWG has supported the GEF Invasive Alien Species Project in the Caribbean Region. The Caribbean Plant Health Directors (CPHD) is a very active body, and CISWG played a major role in its formation. In fact, CPHD has managed to shoulder a lot of the work issues identified by CISWG and has benefited tremendously by support from USDA/APHIS. If I may pat CARDI's back here, we have facilitated the project by hosting the Trinidad and Tobago offices of USDA/APHIS, and by assisting with the support staffing to Wayne de Chi, who leads that office. CISWG, CPHD, USDA/APHIS, as well as others have come together to create a Caribbean Invasive Species website and the 2011 meeting of CISWG, to be held in October at the Caribbean Week of Agriculture, will be looking to maximize the effectiveness of this website.

There are those who have criticised CISWG for not doing more and for not attracting more funds. CISWG developed the Caribbean Invasive Species Surveillance and Information Program before discovering that it would cost US$15 million to execute the program. While we are not yet at the stage where funding of that order is available to the Region and there are many other issues that also must be addressed to ensure food sovereignty for the Region, CISWG has taken significant steps in solving the problem.

Once again, many thanks for allowing CARDI to say these words. I am sure this symposium will be very successful. In closing, I wish all of you a very pleasant and productive day.

OPENING REMARKS: *Dr. Robert Godfrey, Director and Professor, Animal Science Department, University of the Virgin Islands, Agricultural Experiment Station, RR 1– Box 10000. Kingshill, St. Croix, Virgin Islands 00850. Telephone: 340-692-4042; Email: rgodfre@uvi.edu.*

I would like to extend a warm welcome to all who are attending the TSTAR Symposium at the 2011 Caribbean Food Crops Society Meeting. We have an excellent set of panelists to present current information on a variety of invasive species that are relevant and important to our island agriculture and economies.

So just what is an invasive species? According to the website for the Center for Invasive Species and Ecosystem Health (http://www.invasive.org), it is "any species, including its seeds, eggs, spores, or other biological material capable of propagating that species, that is not native to that ecosystem; and whose introduction does or is likely to cause economic or environmental harm or harm to human health." This can cover a wide variety of organisms including plants, animals, or pathogens introduced intentionally or accidentally.

Our geographic isolation can be a safeguard against the introduction of many invasive species. We do not have as easy access through land-based corridors like those that exist on larger land masses, such as the continents. Our ports tend to be smaller, with lower volume of traffic through them, compared to ports on the mainland United States, for example.

On the flip side of the coin, our geographic isolation can also be a liability with respect to invasive species. Because we tend to import a higher proportion of our goods, including plants, animals, and their products, the chances of introducing an invasive species tend to be higher. And once species are introduced, they have a greater impact on the local indigenous flora and fauna. Because I am an "animal scientist" I tend to look at invasive species that impact livestock production. Several years ago when foot-and-mouth disease was in the news in the United Kingdom, I realized that it would absolutely devastate the livestock industry on any Caribbean island if it were detected there because the only way to deal with this disease is through depopulation of the susceptible livestock species (cattle, sheep, goats, and pigs).

Methods to control invasive species are varied and tend to be similar to those used in disease outbreaks, which may or may not themselves be invasive species. The prevention of introduction is where a lot of effort has been focused, with varying degrees of success. If this were 100% effective, we probably would not be having this symposium.

Once a species is introduced, attempts are made at isolating and confining it to prevent the spread any further. This involves detection and identification methods that can be very tedious and expensive. It may also entail the destruction of the local host species, either widespread or locally to prevent further spread.

Eradication is the ultimate goal, although it may not be achievable in all cases. This requires very strict and disciplined actions that can be very expensive. It may require removing indigenous species as well to interrupt the life cycle of the invasive species.

Most recently, there has been a lot of discussion and activity relating to the introduction of the Pacific lionfish to the Caribbean. In the U.S. Virgin Islands, there has been a lot of effort directed at dealing with this problem. Our local fisheries are already being stressed by several factors, including climate change, that negatively impacts reef health and over fishing of some species. Now this voracious species with no local natural enemies is adding to the impact on the reef fish population. As an avid scuba diver, I have seen firsthand the rapid rate of increase in the number of lionfish in the region. Two years ago, when I first heard of this species being in the region, I saw only two lionfish all year. Now, I rarely go on a dive, and I dive every weekend, without seeing several lionfish. Efforts to eradicate the lionfish are not able to keep up with the increase in their population. Only time will tell what the long-term impact will be.

Through the efforts of policy makers and researchers in the region, the issue of how to deal with invasive species is being addressed. Those of us on islands realize the high level of impact and importance this issue has to us and our continued vigilance will hopefully minimize the damage that is done.

Thank you for your attention and I hope the information presented in the symposium will be beneficial to you.

OPENING REMARKS: *Dr. Hector Santiago, Dean and Director, College of Agricultural Sciences, University of Puerto Rico, Maygüez, Puerto Rico. Telephone: 787-899-1530; Email: hector.santiago15@upr.edu.*

Good morning everybody! The Caribbean Food Crop Society welcomes you to the Seventh Symposium on Invasive Alien Species that have been held at our society's annual meetings. The first symposium was held in Grenada in 2003, followed by Guadeloupe in 2005, Puerto Rico in 2006, Florida in 2008, St. Kitts in 2009, and the Dominican Republic in 2010. The symposia have been sponsored by the Tropical and Subtropical Agricultural Research Program (T-STAR) of the National Institute of Food and Agriculture (NIFA), formerly CSRES, of the United States Department of Agriculture. T-STAR funding is made available to the Universities of Florida, Puerto Rico, and the US Virgin islands. They are organized every year by scientists from the University of Florida. I would like to acknowledge at this time, Dr. Walter Bowen, Director of International Programs, University of Florida, who is representing Dr. Jack Payne, Senior Vice President for Agriculture and Natural Resources, University of Florida. The key symposium organizers are Dr. "Gilly" Evans, Professor, Tropical Research and Education Center (TREC), University of Florida, and Dr. Carlton Davis, Distinguished Professor Emeritus, University of Florida. I would also like to acknowledge Dr. Christine Waddill, Senior Center Director of TREC. Although she was unable to be here this year, Dr. Waddill has been a key symposium organizer over the past eight years.

The CFCS promotes the inclusion of topics of interest and concern to the Greater Caribbean Basin in the programs of its annual meetings. The spread of invasive species across the Caribbean has been a key constraint to agricultural production in this region. Many cases have been identified. Some of these include the African bone tick, the pink hibiscus mealy bug, the causal agent of the lethal yellowing of palms and the giant tree snail. In Maygüez, Puerto Rico, we are suffering the effects of the coffee berry burrower, Black Sigatoka disease of the Musa's

hair, and red spider mite of palms. Also, there have been reports of the identification of the lethal yellowing of palms. The invasive species symposia serves as a mechanism to share information of the work that is being conducted to identify, manage, and eradicate these organisms. It also provides the opportunity for scientists from the United States and the various islands of the Caribbean to network in this endeavor. As a result of this symposium, a Caribbean Invasive Species Working Group (CISWG) was formed in 2004 that continues to meet to change the policies of the Caribbean states to protect our agriculture, landscape, and natural resources. CARDI has been instrumental in this endeavor, and through its collaboration and leadership, CISWG is striving to meet these objectives.

I wish you success in this symposium and look forward to innovative ways to celebrate the Invasive Species symposia at future CFCS meetings.

Thank you all for your attention.

OPENING REMARKS: *Dr. Tim Momol, Central District Extension Service Director, University of Florida, PO Box 110220, Gainesville, FL 32611 USA. Telephone: 352-392-1781; Email: tmomol@ufl.edu.*

Thank you, Chair, for this opportunity. Colleagues, friends, and distinguished guests.

It is a great pleasure to be here representing the IFAS Extension Dean in this meeting. As we heard, this is the seventh Invasive Species Symposium organized by UF faculty and supported by the USDA T-STAR program. That is a good track record and we appreciate all the faculty who have worked on this for many years. Especially, I would like to recognize Drs. Klassen, Carlton, and Brown. Their efforts were very significant and we appreciate their efforts.

Over the last eight years, the partnership with Caribbean Food Crop Society organizing this meeting has been part of the success, and we express our appreciation to Dr. Santiago and the whole group for that. The accomplishments of the invasive species symposium, I will go over very briefly. T-STAR has been very supportive of researchers presenting their research at these symposia. In addition, extension programs have created more awareness of the invasive species, and changed attitudes of decision makers. When you look at the symposia proceedings, you can definitely find good evidence of those achievements. As a result, some government policies have changed at the US national level and at the state level in Florida regarding invasive species in the Caribbean. I would like to list some of the contributors to these efforts.

University of Florida IFAS, CISWG, and CARDI have played lead roles on many occasions. I thank Bruce Lauckner from CARDI for taking the lead on preparing the CISWG document. That group's accomplishments through the leadership of CARDI are significant.

I also thank USDA/APHIS for helping to establish and support the Caribbean Plant Health Directors Forum (CPHDF). Those efforts are significant. Later on in the presentations, I will discuss the Caribbean Pest Diagnostic Network, which will link some of the activities better

during that presentation. Other international organizations are also listed in the CISWG document. For example CARDI has a new project on invasive species. FAO and IICA always contribute in many different ways on invasive species issues in the Caribbean. And many other organizations which I do not want to miss are listed. Again, a special thanks to Bruce for that document. We thank everyone involved for their participation and contribution. We would also like to thank the UF/IFAS Dean's office for supporting this year's symposium and for organizing the committee. Dr. Gilly Evans and his colleagues have prepared a very interesting and exciting program today. I hope it will be productive for all of you, and we look forward to continued collaboration with our partners in the region.

Thank you.

OPENING REMARKS: *Mr. Barton Clarke, Chief Agricultural Officer, Ministry of Agriculture and Rural Development, Graeme Hall, Christ Church, Barbados. Telephone: 246-428-4150; Email: caomar@caribsurf.com.*

Good morning colleagues. I sincerely trust that you had a good evening and that we are going to have an even better day today.

Invasive Species. Let me just assure you from the beginning that you are not invasive species. I really want you here. What I want to focus on is that Barbados as an example of a small island developing state that has inherently limited capacity and capability, and consequently, in moving forward, we are advocating that some emphasis must be placed on collaboration and cooperation within and among those involved, as well as taking it up to the level, so that we together are in a far better position to manage the invasive species. I said "manage" invasive species because I do not know whether we will ever be in a position to arrest the movement of invasive species, but we need to be better placed to manage them when they do occur. In that sense, we at the national level are in the process of establishing the National Agricultural Health and Food Control Agency as an instrument that seeks to coordinate the efforts of the Ministry of Health, the Ministry of Agriculture, and the Ministry of Commerce, relative to the associated issues, particularly as they relate to what it is we consume at the table. This is a platform that would hopefully see integration into the Caribbean Agricultural Health and Food Control Agency that is being spearheaded by the CARICOM Secretariat, at this time, having had their launch in Suriname last year. That in itself does not exist in a vacuum because, already, we have a meeting of the chief veterinary officers that takes place annually, as well as a meeting of the directors of Plant Protection. So these are two networking mechanisms that will support the regulatory framework. I know it is already working; for example, the veterinary officers were able to do seminar work in Jamaica that resulted in the increase of trade between Jamaica and the other CARICOM nations, with a view to ensuring certain food safety issues were not compromised while, at the same time, mitigating the potential impact of invasive species. Be that as it may, when we speak about collaboration, Barbados has expressed in this forum its gratitude to USDA; the University of Florida; and Ian Gibbs, the entomologist from the Ministry. We have seen much in terms of technology and guidance coming from these institutions which have benefitted our national efforts. In a similar vein, the food and agricultural organizations are always

positioned to respond readily. Currently, there is a program that seeks to address the issues surrounding avian influenza and H1N1, which are still on our doorstep and still need to be addressed.

Invasive species may also offer an opportunity. I note that my good friend, Keith Laurie, here in Barbados has talked about eating the Giant African Snail. Perhaps this is something you may want to offer to join in so that they are not just a threat but also an opportunity. But generally speaking, there are indeed threats. If we bring our story back to climate change, I do recall many years ago when there was a great panic within the Caribbean Region because we woke up one morning and we all found locusts out of Africa all over our beaches. That was a cause for panic. The probability is that these occurrences will become more regular. Therefore we need to move toward early-warning systems and other such mechanisms to help us predict when such invasions might occur, so that we are better prepared in the future. Also, let us not forget, back in the late 1990s, when we had red dye coming out of the mouth of the Orinoco that resulted in a lot of the species that we would normally consume, dying; this is an issue that we need to consider for better management. Hopefully, the regional mechanism of the common fisheries policy and regime will assist all of us in managing these occurrences when they do happen, or at least putting in place mitigating steps to obviate their arrival.

My focus really is to impress on everyone the need for greater collaboration and cooperation to manage these issues.

Thank you very much, ladies and gentlemen.

OPENING ADDRESS: DOUBLE JEOPARDY—CLIMATE CHANGE AND INVASIVE SPECIES

Ray Huffaker, Chair, Food and Resource Economics Department, University of Florida, PO Box 110240, Gainesville, FL 32611 USA. Telephone: 352-392-1826 x204; Email: rhuffaker@ufl.edu.

INTRODUCTION

The negative impacts of climate change on global water resources, agriculture, land resources, biodiversity, and ecosystem services are well known (e.g., temperature increases, increasing carbon dioxide levels, and altered patterns of precipitation). Lesser publicized is how climate change reinforces another key transformational driver: invasive species. The interactive dynamics of both drivers greatly magnify the devastating impacts of each on ecosystem services essential to human life and productive activities. This paper discusses how the academic literature has conceptualized the relationship between climate change and invasive species.

A BROAD CONCEPTUAL FRAMEWORK

The literature links climate change and invasive species with the concept of a bioclimatic envelope. Burgiel and Muir (2010: 6-7) define the bioclimatic envelope as "the particular set of ecological and climatic conditions or parameters necessary for a species' survival…the range of suitable habitats," and conclude that "it is therefore necessary to look at the full suite of variables relevant to a particular species' bioclimatic envelope, as well as its broader symbiotic relationships and trophic webs."

Figure 1 depicts the bioclimatic envelope within this broad context. There are three major interrelated drivers: climate, humans, and ecosystems. In the upper portion of Figure 1, ecosystem provides services essential for human life and productive activities, and feedback from these activities impacts the quality of ecosystem services. Climate provides essential resources sustaining ecosystem productivity, especially water and viable temperatures, and ecosystem provides services mitigating negative climate shifts, including carbon sequestration. In the lower portion of Figure 1, climate determines the scope of human activities; while humans can affect climate through activities increasing global warming.

Figure 1 depicts the ecosystem dynamics regulating interspecies interactions (i.e., symbiotic relationships and trophic webs) with a conventional generalized Lotka-Volterra model. In this example, there are two interacting species, X_t and Y_t, where t represents time. The population of each species (X_{t+1} and Y_{t+1}) is measured as the population in the preceding time period (X_t and Y_t) plus a net proportional growth rate (second term, right-hand side). The net proportional growth rate for each species depends on the current populations of each. An incremental increase in one species that generates a marginal increase (decrease) in the net proportional growth rate of the other represents a symbiotic (competitive or predatory) relationship.

The bioclimatic envelope generalizes the conventional concept of 'carrying capacity' by explicitly accounting for the impacts of climate and human activities on the range of suitable habitats. Consequently, similar to the way in which carrying capacity enters into Lotka-Volterra

models, Figure 1 models the bioclimatic envelopes for *X* and *Y* (BCE_X and BCE_Y) as co-determinants of the net proportional growth rate for each species. As recommended by Burgiel and Muir (2010), Figure 1 offers a broad framework for conceptualizing the impact of climate change on invasive species.

ILLUSTRATION: WESTERN US MOUNTAIN PINE BEETLE

The US Mountain Pine Beetle preys on species of pine trees in the western United States and Canada. Warmer winter temperatures in the region have reduced mortality of the pest, resulting in population outbreaks and significant mortality of pine trees. Dying pines may be replaced by less desirable competitors, contributing to undesirable changes in fire regimes and other ecosystem characteristics (Burgiel and Muir 2010).

Figure 2 analyses this situation within the broad context of Figure 1. There are three interrelated species: pine trees (*X*), pine-tree competitors (*Y*), and pine-tree predators (*Z*). Warmer winters result in a bioclimatic envelope for pine beetles (BCE_Z) that increase the predator's net proportional growth rate. This results in increased predation of pine trees represented by the line connecting the *Z-equation* with the *X-equation*. Since pine beetles benefit from preying on pine trees, there is a 'plus sign' at the end of the line next to the *Z-equation*. Alternatively, since pine-tree mortality increases as a result, there is a 'negative sign' at the end of the line next to the *X-equation*. The next potential ecosystem linkage is that the weakened pine population may be outcompeted by less desirable plant species for vital resources such as sunlight and water. This is represented by the line between populations *X* and *Y*, with the 'negative sign' next to the population suffering competitive losses (*X*).

Identifying these broad interspecies relationships raises a set of complex issues requiring empirical analysis and more extensive ecosystems modeling. For example, what type of predator-prey relationship exists between pine beetles and pine trees? Is it a predator-prey cycle in which the pine beetle population crashes due to the lack of prey? Or, do pine beetles drive pine trees to extinction while switching to another prey? Does predatory pressure on pine trees result in a competitive relationship with other plant varieties that switches from *competitive co-existence* to *competitive exclusion*?

Consider now potential broader impacts among the three drivers (humans, ecosystem, and climate). Reduced pine populations potentially reduce timber profits, ecosystem resilience, and carbon sequestration. Reduced carbon sequestration and increased susceptibility of the region to wildfires could contribute to global warming to the further detriment of humans. As above, determining the extent to which these negative impacts occur would require extensive empirical analysis and ecosystems modeling.

CONCLUDING REMARKS

The framework developed in this paper formalizes the general discussion of climate change and invasive species in the literature, and facilitates the hypothesis formulation of potential interactions. The framework illuminates the substantial interdisciplinary collaboration that will

be required to test these hypotheses, and to apply the resulting knowledge to avert the deleterious impact of climate change in increasing the abundance and spread of invasive species.

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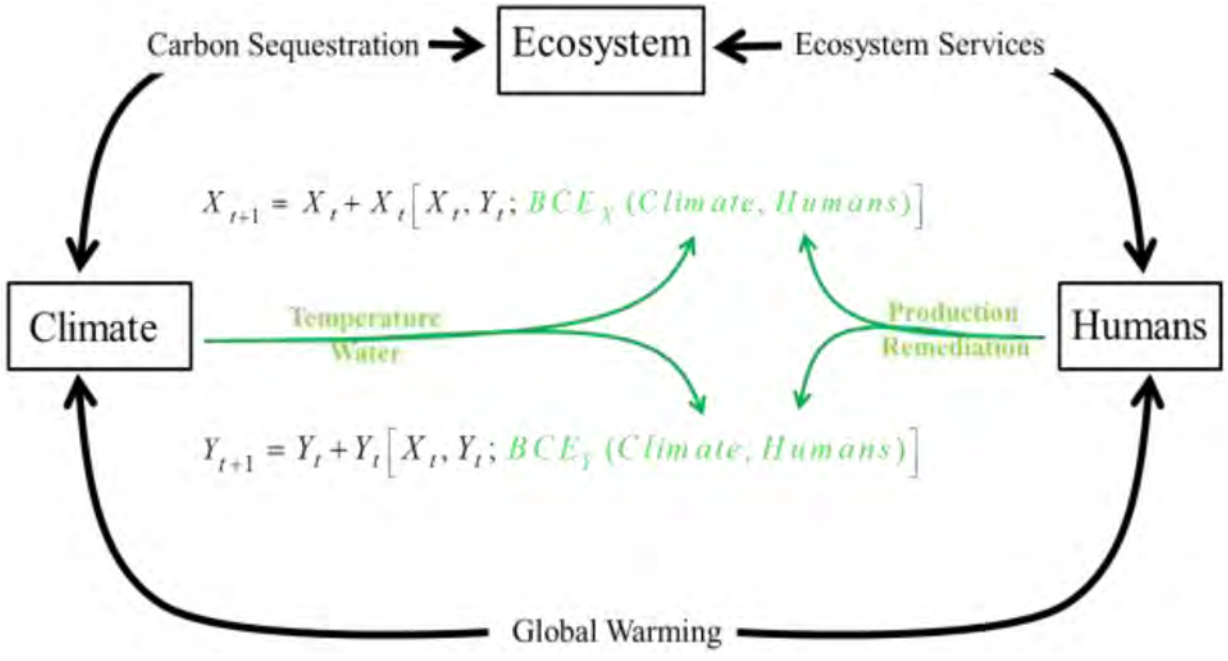


Figure 1. Conceptual framework linking climate change and invasive species

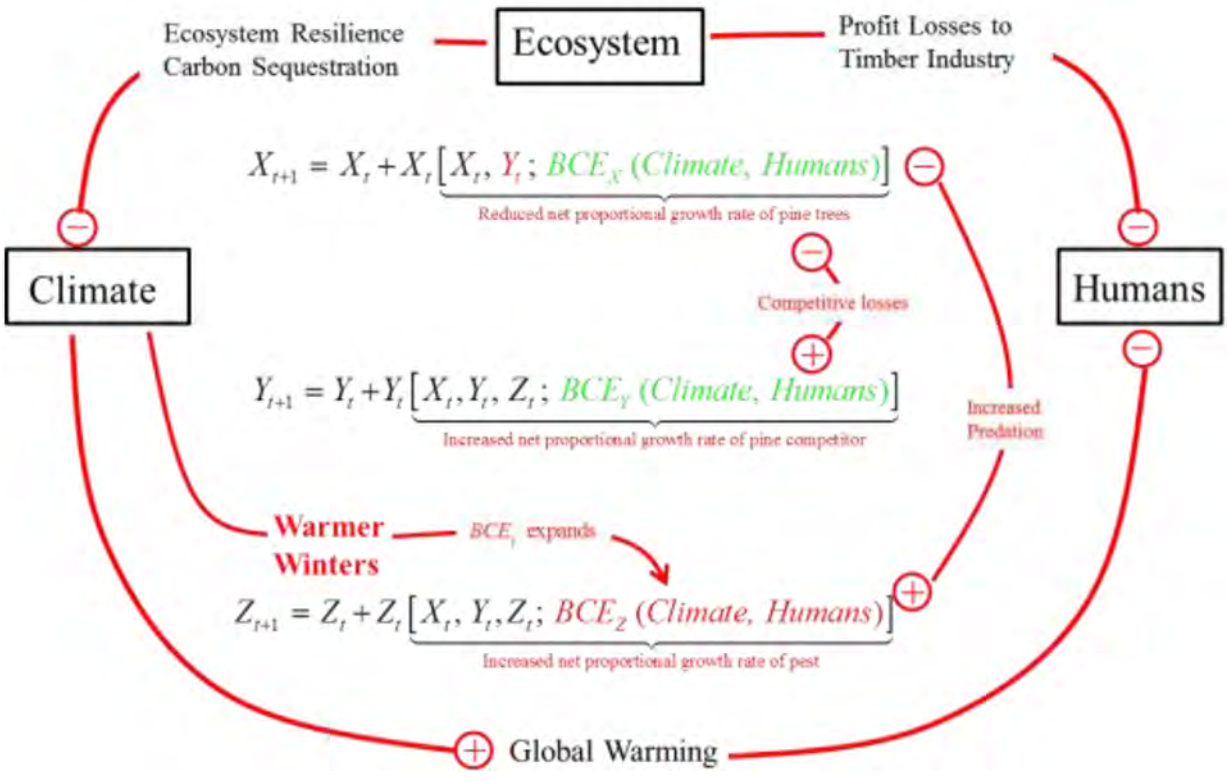


Figure 2. Illustration: Western US Mountain Pine Beetle

VOTE OF THANKS: *Florita Kentish, FAO Sub-Regional Coordinator for the Caribbean, Marien Gardens, PO Box 631-C, Bridgetown, Barbados. Telephone: 246-426-7110; Email: florita.kentish@fao.org.*

Thank you very much, Mr. Chairman, Dr. Robert Godfrey. A very pleasant good morning to one and all; I am very pleased that I could be here with you this morning. My greatest apologies; I know that I lost out not being here yesterday because I have heard from several that yesterday was a very excellent day. The activities were superb, as I have heard from our Chairman this morning in his remarks commenting on the activities and the arrangements being made by the local hosting committee. As I said, I am sorry that I could not have been with you yesterday. Instead, I was flying over the ocean flying for about eight hours really hoping that I was in this place. But I can see already from what has transpired here this morning that this is indeed as for other Food Crop Society meetings, the Caribbean Invasive Species Working Group meetings, very high standard and I want to say that I am very happy on behalf of my organization, the Food and Agricultural Organization of the United Nations (FAO) to be a part of this today. I wish that I could spend the whole day. I'm going to spend at least the morning, but I know that I have colleagues here and some also who will be coming in this afternoon, and if I can find it possible having gone back to the office, I will be back here, because here is where my heart is today. It truly is.

So to you Mr. Chairman, I must thank you for your warm welcome remarks as you opened this very important session his morning hosted largely by USDA T-STAR. We want to thank the T-STAR group from the University of Florida for the work they have done, and how they have stood behind this region in our work in invasive species. Thank you very much. We hope you will take our warm regards also back to Dr. Douglas Archer who would have wished to be with us, but for family reasons he has to be elsewhere and wish him all the best and for his family the best as well from us.

I want to thank you as well Dr. Archer for setting the stage when you spoke about the animal science part, from a point of view of animal science in the area of vulnerability of the region; the vulnerability this region has to invasive species; the serious impact that it is for those of us in the animal kingdom and certainly the plant kingdom as well.

What can I say about my dear friend Bruce Lauckner? You know it was not per chance that you were the one from CARDI this morning, although we do miss having Dr. Arlington Chesney and we always do, but it is no small measure that you were the one this morning to speak on behalf of your organization, CARDI. Although the Caribbean Agricultural Research and Development Institute holds the chair for CISWG, you are indeed the Chair. You have been the one who has been doing most of the work within CARDI, in this organization, CISWG, the hard work bringing the team together each time and keeping the network going. We want to thank you for your words this morning, your joint remarks, those of yours and Arlington Chesney.

Dr. Hector Santiago, once again it was a pleasure to have you here at the opening ceremony of CISWG and you come as one who speaks very much in this for , but also for the entire Caribbean Food Crop Society. We know that your organization, your University has been very

much an integral part of this for the many years it has been on-going and we want to thank you very much as well.

To Dr. Tim Momol from IFAS at the Universityof Florida (Go Gators! I am one too), thank you very much. We are so happy and from your particular area as well. I am so happy that you are able to work along with the team this week, and that we see the very important aspect of extension being an important and integral part of research in the area of invasive species. Thank for sharing with us in the opening ceremony as well.

To Mr. Barton Clarke, the Chief Agricultural Officer of the Ministry of Agriculture and the other parts of that Ministry here in your native Barbados, indeed it is always a pleasure to hear you put things together and as you shared with us the importance of collaboration and coordination for the proper management of invasive species. We want to say that it is important as we progress on in this meeting throughout today that we look at all parts, at the pervasive parts of the whole. And as we look at policy, at research, at management, and at the whole aspect as you have delineated for us so well today. Thank you Mr. Clarke and certainly the rest of your colleagues who are here, I am sure there are many from the Ministry of Agriculture, we want to thank you for all the hard work you have put in in making this particular symposium also a reality.

To our special key speaker, Dr. Ray Huffaker, for the opening address at this symposium on Climate Change and Invasive Species, I listened very attentively and avidly, and you know it's amazing. I agree, perhaps in the short time frame: a bit over-the-head, but you made it extremely clear, as clear as could be. And brought to the table the fact that, with all of the other presentations that we are going to have today, it is important to look it, not as we have always been looking at it, invasive species, but within the lens of what is happening in the area of climate change.

And because of this I want to thank all of the speakers who are to come, who have prepared I'm sure very well, to deliver their particular areas. I want to recognize that even though I look at the end of the sessions today, I don't think there is much in terms of there is somebody who is going to be pulling it all together, the closing remarks and so forth. But I trust that we will go away, having done a bit of networking and recognizing how we can work better together, to really and truly, not only to share what you have done, but what are the next steps and how we can all engage. I know that for instance, the Food and Agricultural Organization, in whatever way, would like to be able to engage in some of the areas and to make the impact in the region so much more poignant.

To the planning committee, I noticed the list of members that were on the planning committee for this particular symposium, Dr. Edward "Gilly" Evans, Dr. Waldemar Klassen, Dr. Carlton Davis, Dr. Douglas Archer, Dr. Dionne Clarke-Harris, Dr. Bruce Lauckner and Mr. Fred Ballen. You can see that at the end of today's session, but I just want to thank them very much on behalf of the organizers for putting on such a very rich level of presentations for this symposium. I, like others here, would like to see that we really and truly come away with not only the documentation of what has happened here, but steps forward, the next steps. What are the things we can do to make the situation so much better in this area? I want to just mention that Dr. Christine Waddill is indeed present with us today. We are glad that she is here, Professor and

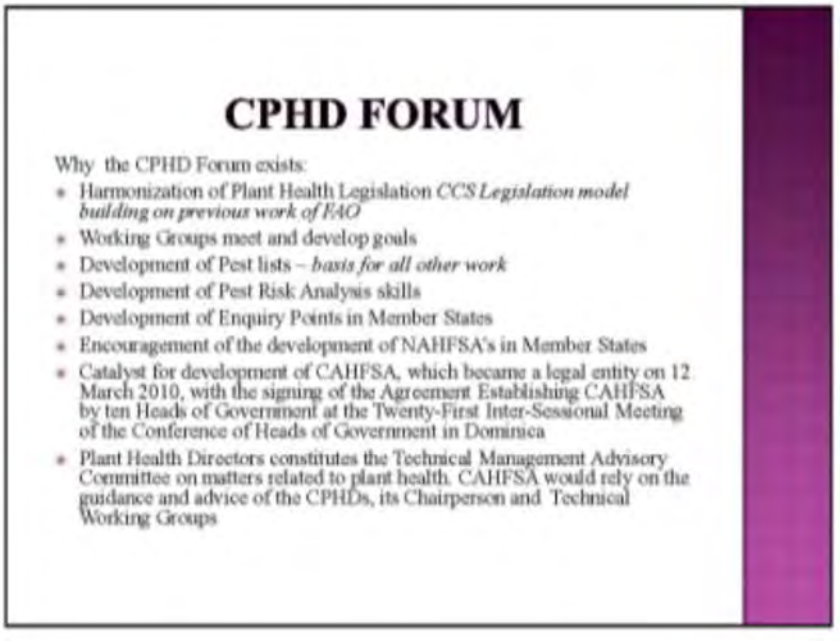
Center Director for Tropical Research and Education Center and she will indeed be giving closing remarks after all of the sessions today. It is indeed a privilege that I had to have been a part of your ceremony this morning, and certainly I just pledge the support of my organization in whichever way within the region and globally that we can be a part of this major area of invasive species.

Thank you very much.

SESSION 1: INVASIVE SPECIES MANAGEMENT: PROGRAMS, POLICIES, AND INSTITUTIONS

CARIBBEAN PLANT HEALTH DIRECTORS (CPHD) FORUM—PAST, PRESENT, AND FUTURE

Ian Gibbs, Entomology Section, Ministry of Agriculture, Graeme Hall, Christ Church, Barbados. Email: iangibbs@yahoo.com.



CPHD FORUM

- Recommendations contained in the reports of the Forum are usually presented to the Meeting of the Council for Trade and Economic Development (COTED) for its consideration and possible adoption as regional policy in the current year
- The issue of sustainability and access to a safe supply of food in the region in the context of food security remains high on the regional agenda
- The mandate of COTED to the CPHDs for the development of agricultural trade protocols in the facilitation of agricultural trade
- CARICOM Ministers of Agriculture had also expressed deep appreciation for the work being done by the CPHDs forum and by the USDA, FAO and IICA as partners in the process

CPHD FORUM

- First Meeting – Georgetown, Guyana, 23-25 April 2008
- Second Meeting - Georgetown, Guyana, 4-5 March 2009
- Third Meeting – Trinidad & Tobago, June 7-8, 2010
- Fourth Meeting - Trinidad & Tobago, May 11-12, 2011

CPHD Forum

At the first meeting of the CPHD, it was agreed that there was a need to establish several technical working groups to address the issues relating to various pests of economic importance to the region

The groups are expected to investigate and advise on all relevant matters related to pests and at times make recommendations for the consideration of the Council for Trade and Economic Development (COTED)

The Working groups so far are:
Giant African snail (now Mollusc Working Group)
Palm Pests
Tephritid Fruit Flies
Emergency Response Preparedness
Safeguarding

Currently, Barbados chairs the Mollusc and Safeguarding WG's

CPHD FORUM

The annual meetings of the Forum address(ed) matters such as:

- WTO SPS measures and International Standards for Phytosanitary Measures (ISPMs)
- Caribbean Agricultural Health and Food Safety Agency (CAHFSA)
- Plant Health Safeguard System
- Offshore Risk Management - Pre-clearance Program
- Pest Diagnostics
- Plant Health Surveillance Pest Response System
- Emergency Response Plans – mitigation of pest introductions

CPHD FORUM

- Caribbean Invasive Species Working Group (CISWG)
- Caribbean Invasive Species Surveillance and Information Programme (CISSIP)
- Recommendations of the Technical Working Groups
- Establishment of Pest Free Areas
- Strengthening Human Resource Capacity
- National Agricultural Health and Food Safety Agencies
- Plant Health Legislation
- Greater Caribbean Safeguarding Initiative
- Coordinating regional and international positions on plant health issues for representation in the international fora

CPHD FORUM

It is important to keep the CPHD Forum alive:

- In the absence of CAHFSA and even NAHFSA's in numerous member states, it is the only avenue available for a regionally united front on plant health issues at the international level
- It is an important source of advice for COTED
- CPHD Forum should be the body which assumes the role of the Regional Plant Protection Organization (mandated under Article 9 of the IPPC)(regional Governments through COTED should inform FAO that CPPC no longer exists)

CPHD FORUM

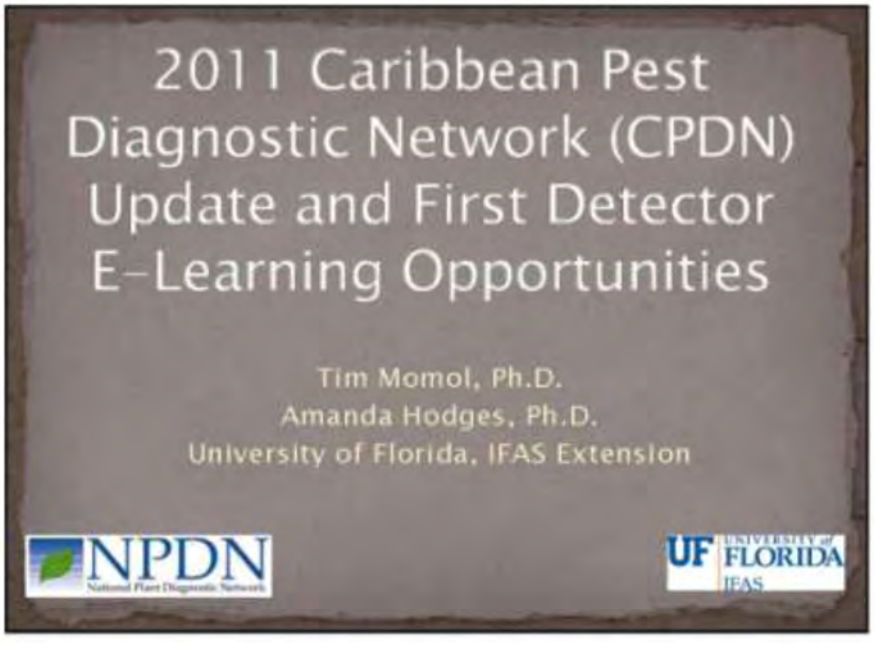
Constraints

- Increase communication among PHD – issues with D-groups e-mail
- Duration of annual meetings – large agendas and only 2 days to accomplish

CPHD FORUM 2011

2011 CARIBBEAN PEST DIAGNOSTIC NETWORK (CPDN) UPDATE AND FIRST DECTECTOR E-LEARNING OPPORTUNITIES

Tim Momol, Central District Extension Service Director, University of Florida, PO Box 110220, Gainesville, FL 32611 USA, and Amanda Hodges, SPDN Associate Director, Entomology and Nematology Department, University of Florida, PO Box 110620, Gainesville, FL 32611 USA. Telephone: 352-273-3957; Email: achodges@ufl.edu.




Barbados, August 2007
Scale Insects & Whiteflies


Barbados, August 2007
Scale Insects & Whiteflies

Barbados, August 2007
Scale Insects & Whiteflies

NPDN First Detector Training

- Train-the-Trainer Program
- County Extension Agents, Crop Consultants, Master Gardeners, Master Naturalists

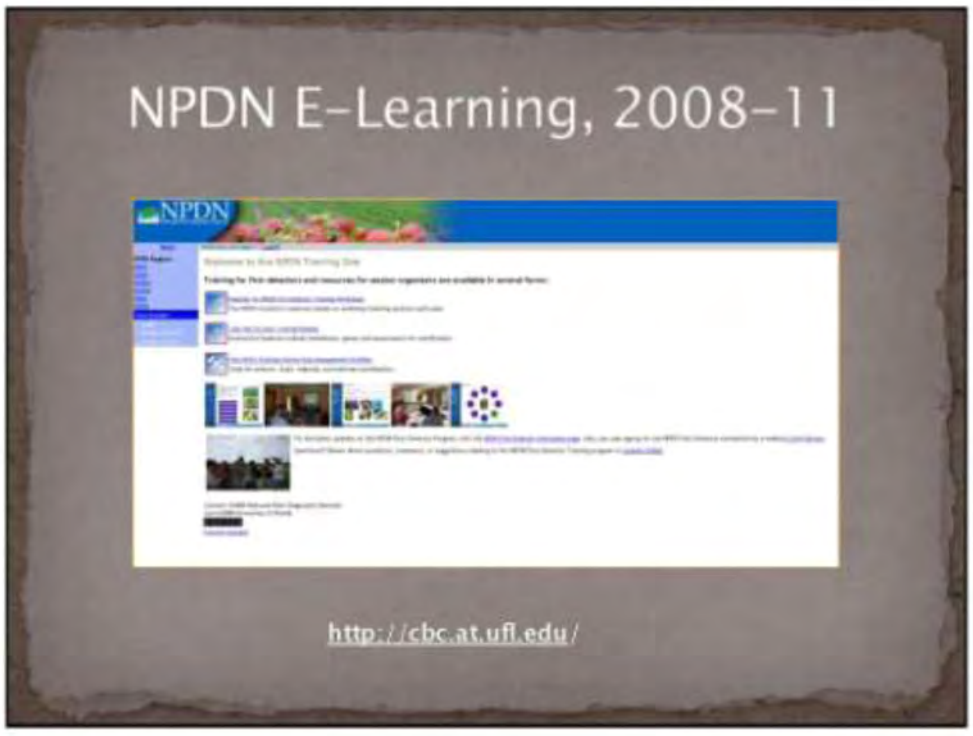
Traditional Training, 2003-11

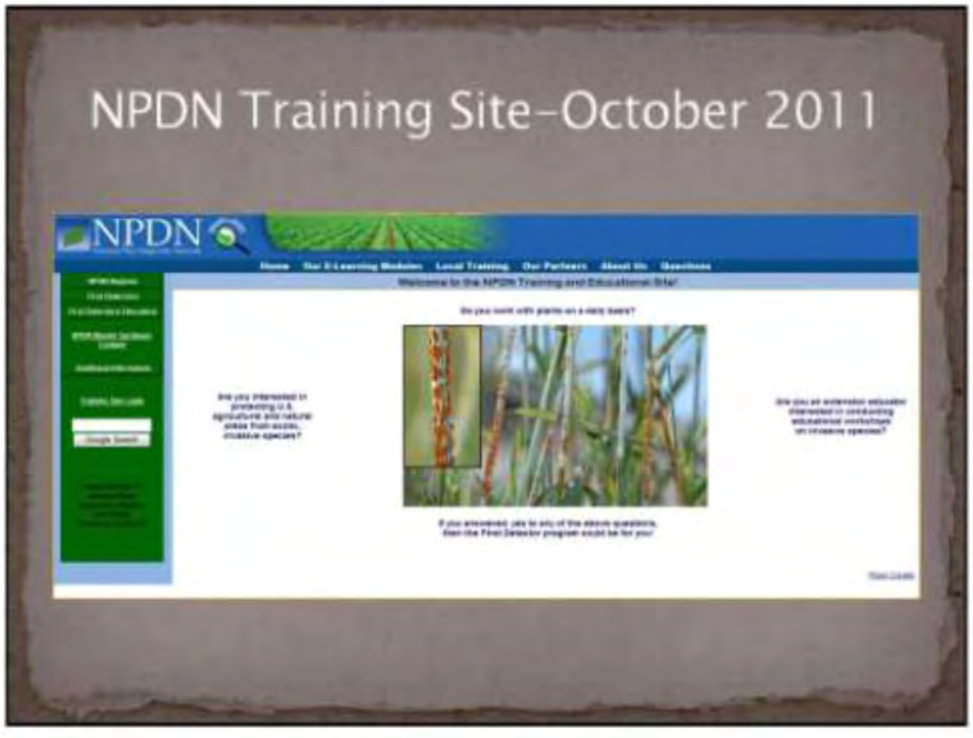
Credits: Frank Hale
University of Tennessee,
West TN REC

- NPDN
  - 821 Sessions
  - 10,736 Registered Participants

NPDN E-Learning

- Online at: http://cbc.at.ufl.edu/
- Crop Biosecurity Course, 2008
- Special Topic Modules
  - Chilli thrips, *Scirtothrips dorsalis*, 2009
  - *Ralstonia solanacearum* Race 3, biovar 2, 2010
  - Emerald Ash Borer, *Agrilus planipennis*, 2010
  - Entomology Diagnostics Modules, December 2011-2012


NPDN E-Learning, 2008-11
NPDN
http://cbc.at.ufl.edu/


NPDN Training Site-October 2011
NPDN

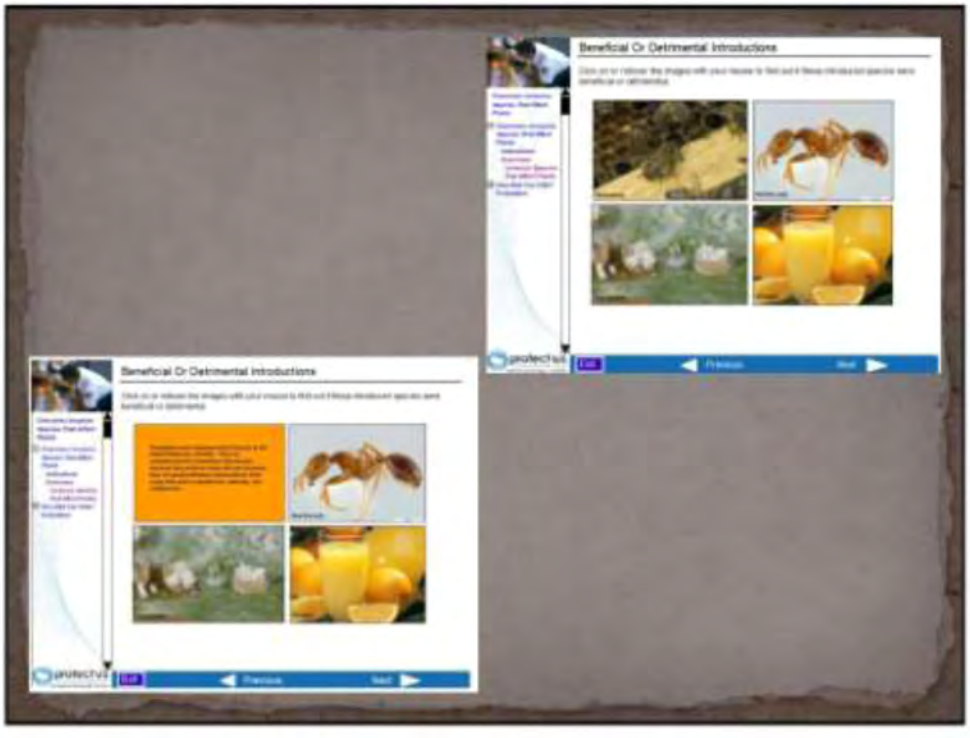

Special Topic Modules
Chilli Thrips
Emerald Ash Borer


NPDN Collaborative Products and Partner Programs


Bugwood Wiki Fact Sheets
First Detector Training for the Master Gardener
NPDN
Insects
http://wiki.bugwood.org/NPDN-MG-Training


LUCID® Keys
SCREENING AID TO PESTS
HOME
KEYS
FACT SHEETS
GLOSSARY
ABOUT
INSECT ANATOMY
Flatid Planthopper
FACT SHEET
About This Tool
Taxa Covered
Palm Resource
http://itp.lucidcentral.org/id/palms/sap/


Multi-Agency Partner Program
Protect U.S., Community Invasive Species Network
Target Audience:
General Public
Small Farmers
K-12
protect u.s.
http://www.protectingusnow.org/

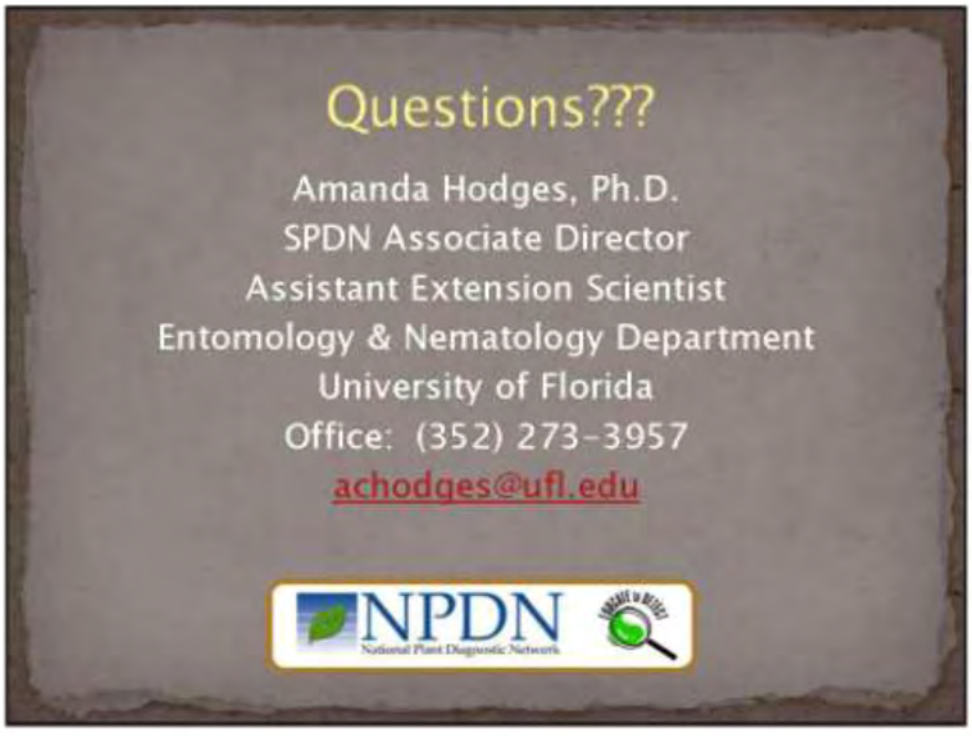

Beneficial Or Detrimental Introductions
Beneficial Or Detrimental Introductions

Sentinel Plant Network

- Target Audience–
  - Botanical Gardens and their clientele
- NPDN and APGA
- Planned Deliverables
  - Scripted Presentations
  - E-learning
  - Workshops

http://publicgardens.org/content/sentinel-plant_network

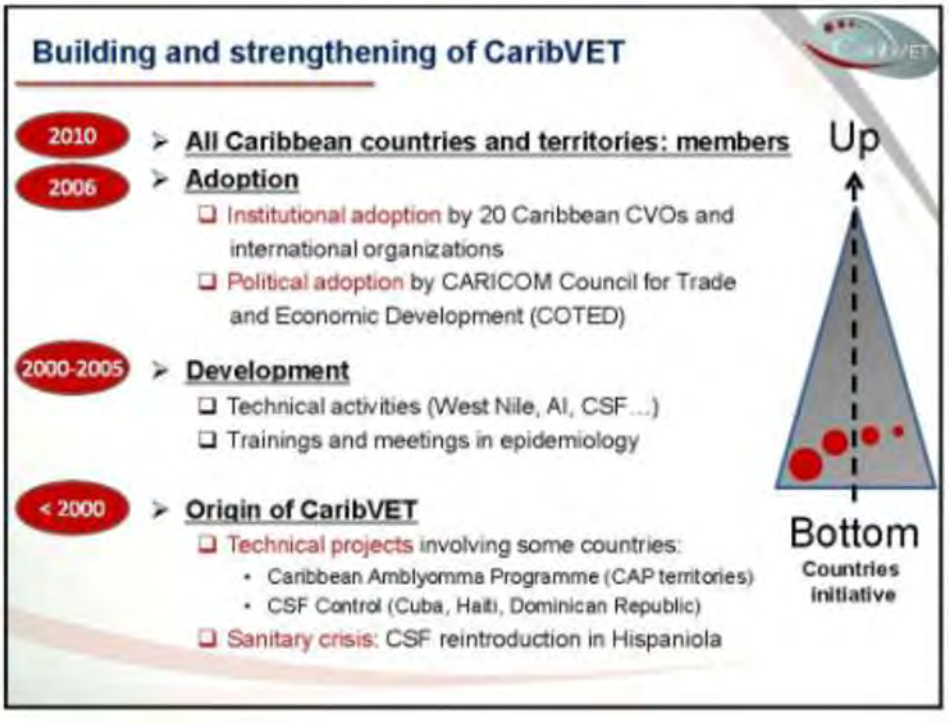
Why Collaborate?

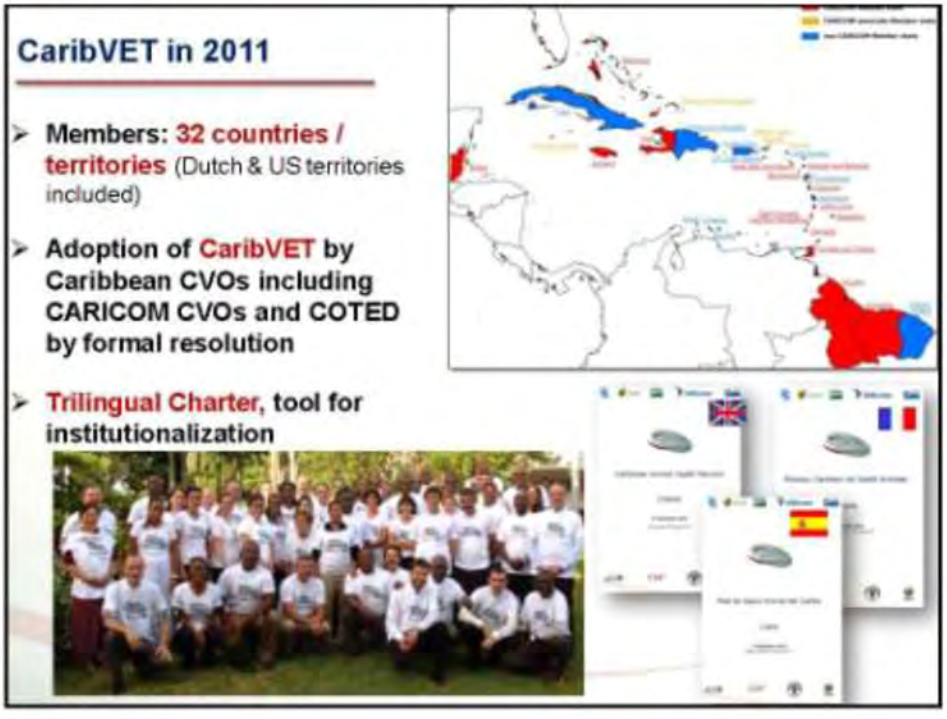

Questions???
Amanda Hodges, Ph.D.
SPDN Associate Director
Assistant Extension Scientist
Entomology & Nematology Department
University of Florida
Office: (352) 273-3957
achodges@ufl.edu
NPDN
National Plant Diagnostic Network

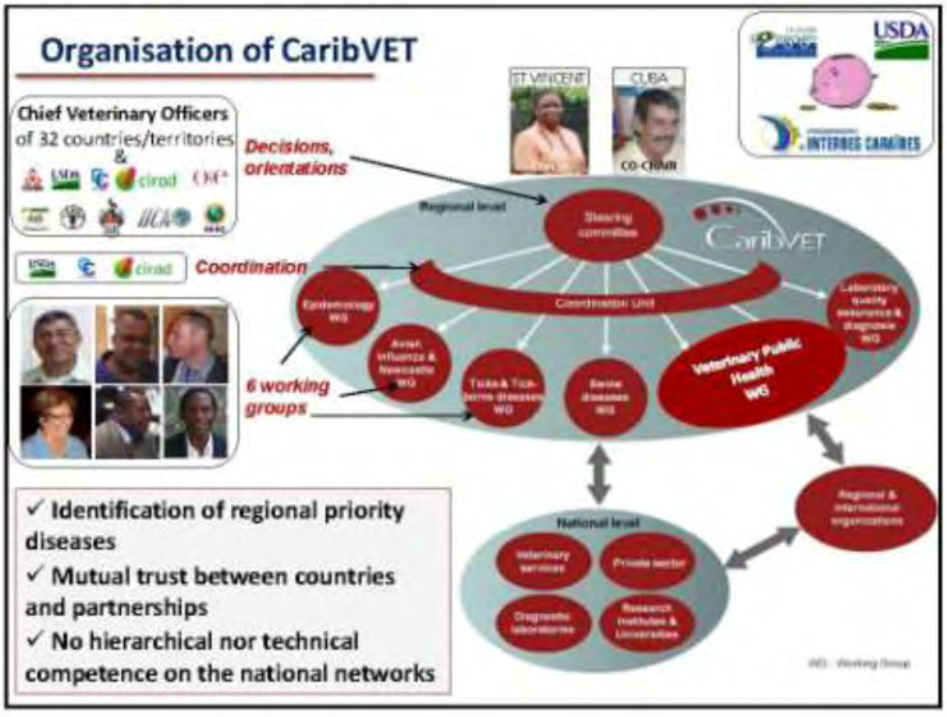
ACHIEVEMENTS OF CARIBVET AND THE WAY FORWARD

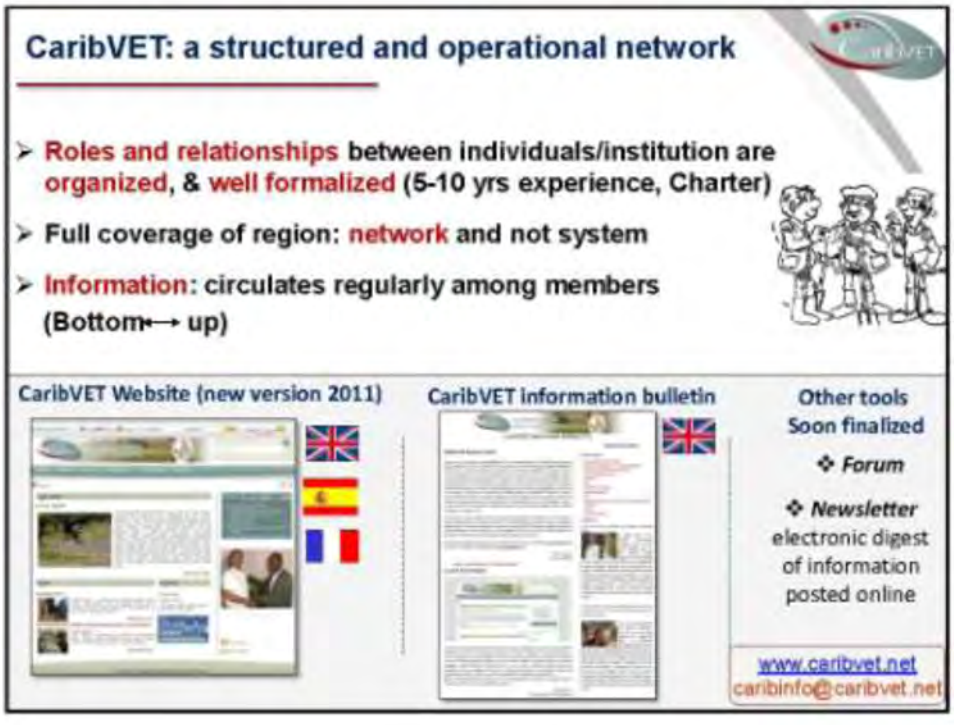
Mark Trotman, Chair, CaribVET Avian Influenza and Newcastle Disease Working Group, Veterinary Services, the Caribbean Animal Health Network, Barbados. E-mail: svo@caribsurf.com.

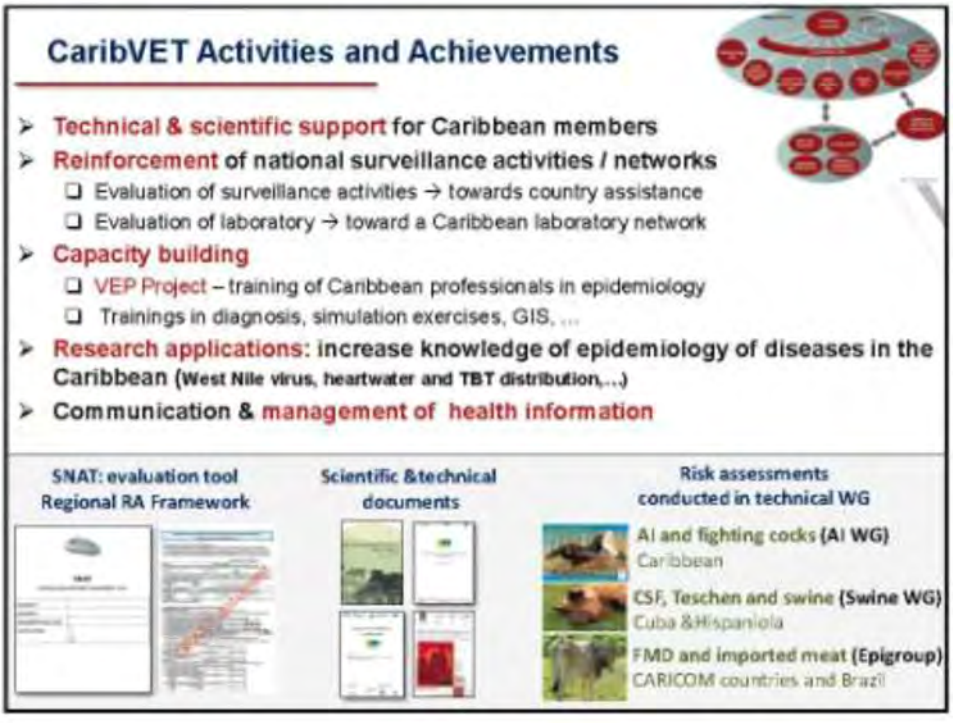

Objectives of CaribVET
Structure, reinforce and harmonize national surveillance networks;
Improve and harmonize the control of animal diseases and implement an early alert system;
Reinforce the technical skills and support the development of tools necessary for surveillance and control including diagnosis capacity;
Improve the knowledge on animal diseases and their distribution in the Caribbean.
Definition of a regional strategy


Building and strengthening of CaribVET
2010
All Caribbean countries and territories: members
2006
Adoption
Institutional adoption by 20 Caribbean CVOs and international organizations
Political adoption by CARICOM Council for Trade and Economic Development (COTED)
2000-2005
Development
Technical activities (West Nile, AI, CSF…)
Trainings and meetings in epidemiology
< 2000
Origin of CaribVET
Technical projects involving some countries:
Caribbean Amblyomma Programme (CAP territories)
CSF Control (Cuba, Haiti, Dominican Republic)
Sanitary crisis: CSF reintroduction in Hispaniola
Up
Bottom
Countries initiative


CaribVET in 2011
Members: 32 countries / territories (Dutch & US territories included)
Adoption of CaribVET by Caribbean CVOs including CARICOM CVOs and COTED by formal resolution
Trilingual Charter, tool for institutionalization


Organisation of CaribVET
Chief Veterinary Officers of 32 countries/territories
&
Decisions, orientations
Coordination
6 working groups
Regional level
Steering committee
CaribVET
Coordination Unit
Veterinary Public Health WG
National level
Veterinary services
Private sector
Diagnostic laboratories
Research institutes & Universities
Regional & international organizations
USDA
INTERVET CARIBES
ST VINCENT
CUBA
CO-CHAIR
✓ Identification of regional priority diseases
✓ Mutual trust between countries and partnerships
✓ No hierarchical nor technical competence on the national networks


CaribVET: a structured and operational network
Roles and relationships between individuals/institution are organized, & well formalized (5-10 yrs experience, Charter)
Full coverage of region: network and not system
Information: circulates regularly among members (Bottom→ up)
CaribVET Website (new version 2011)
CaribVET information bulletin
Other tools Soon finalized
Forum
Newsletter
electronic digest of information posted online
www.caribvet.net
caribinfo@caribvet.net


CaribVET Activities and Achievements
Technical & scientific support for Caribbean members
Reinforcement of national surveillance activities / networks
Evaluation of surveillance activities → towards country assistance
Evaluation of laboratory → toward a Caribbean laboratory network
Capacity building
VEP Project – training of Caribbean professionals in epidemiology
Trainings in diagnosis, simulation exercises, GIS, ...
Research applications: increase knowledge of epidemiology of diseases in the Caribbean (West Nile virus, heartwater and TBT distribution,...)
Communication & management of health information
SNAT: evaluation tool
Regional RA Framework
Scientific &technical documents
Risk assessments conducted in technical WG
AI and fighting cocks (AI WG)
Caribbean
CSF, Teschen and swine (Swine WG)
Cuba &Hispaniola
FMD and imported meat (Epigroup)
CARICOM countries and Brazil

CaribVET, the Way Forward

1/ Role of **connecting** project carriers & countries

2/ Regional **Network sustainability**

3/ Role in **emergency situation**

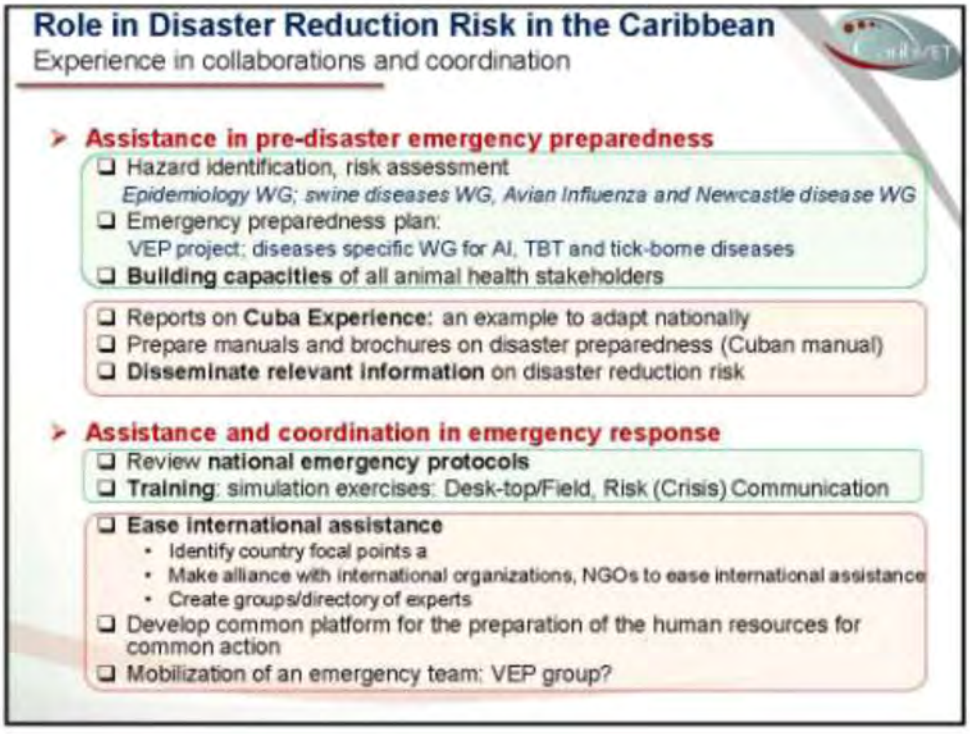
1/ CaribVET: connecting project carriers with Caribbean countries

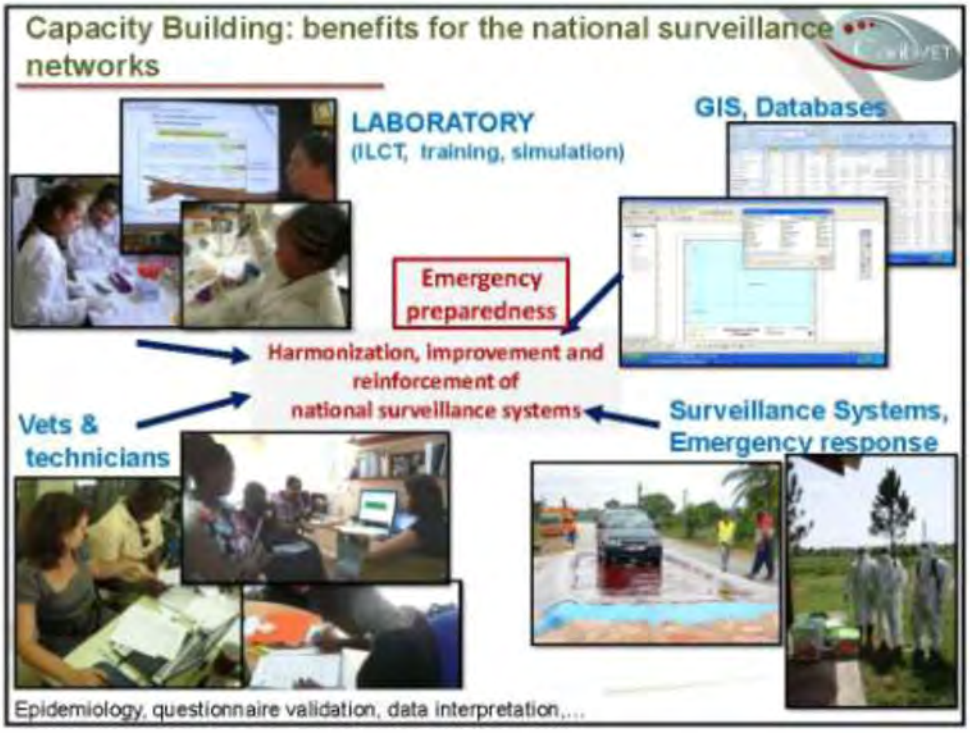
BACKGROUND

- **The New-world Screwworm (*Cochliomyia hominivorax*)**
  - Myiasis in animals and humans; important direct and indirect losses
  - Several Caribbean countries infested
- **The COMEXA**
  - Mexican - American Commission for the eradication of Screwworm
  - Central role in the eradication of NWS from Mexico (1991), and subsequently from Central America

CaribVET Steering Committee meetings: linkage between Comexa and caribbean countries

- 2010: First contact between CaribVET and the Comexa
  - Presentation of the Comexa and screwworm situation in the Americas
- 2011: First ad-hoc meeting: COMEXA + 10 infested and interested countries
  - Presentation of the Caribbean Strategy
    - Objective: implement erradication programs in the Caribbean
    - Prelimary Steps/Projects
  - 2nd Ad-hoc meeting planned in June/July 2011
- Link with the Coordination Unit of CaribVET


Role in Disaster Reduction Risk in the Caribbean
Experience in collaborations and coordination
Assistance in pre-disaster emergency preparedness
Hazard identification, risk assessment
Epidemiology WG; swine diseases WG, Avian Influenza and Newcastle disease WG
Emergency preparedness plan:
VEP project; diseases specific WG for AI, TBT and tick-borne diseases
Building capacities of all animal health stakeholders
Reports on Cuba Experience: an example to adapt nationally
Prepare manuals and brochures on disaster preparedness (Cuban manual)
Disseminate relevant information on disaster reduction risk
Assistance and coordination in emergency response
Review national emergency protocols
Training: simulation exercises: Desk-top/Field, Risk (Crisis) Communication
Ease international assistance
Identify country focal points a
Make alliance with international organizations, NGOs to ease international assistance
Create groups/directory of experts
Develop common platform for the preparation of the human resources for common action
Mobilization of an emergency team: VEP group?


Capacity Building: benefits for the national surveillance networks
LABORATORY
(ILCT, training, simulation)
GIS, Databases
Emergency preparedness
Harmonization, improvement and reinforcement of national surveillance systems
Vets & technicians
Surveillance Systems, Emergency response
Epidemiology, questionnaire validation, data interpretation,...

2/ CaribVET Sustainability

- **Activities funded by projects**
  - Interreg IV Caraibes (2009-2012)
  - USDA-APHIS-IS
  - FSP
- **6th Steering Committee (March 2011) recognized the need for strong advocacy at the national level for the support of participation in the activities of CaribVET**
- **Exploration of other possible sources for assistance**
- **Increase promotion and awareness of the CaribVET network**
  - Develop communication package
  - CaribVET bulletin, press release

3/ CaribVET role in emergency situations

The Caribbean, a region at risk and prone to hazards.
High risk of transboundary animal diseases: endemic and exotic through movements of animals, fomites, people, products of animal origin, …

- **Hazards**
  - **Natural disasters**: storms (wind/rain), earthquakes, hurricanes, fire, smoke
  - **Diseases outbreak**…
- **Threats**
  - Life, **diseases outbreak**, animal loss
  - **Flooding** and insect proliferation
  - **Diagnostic pool, equipment & supplies**
- **Direct & indirect impacts**
  - Need for shelter, ill animals/cadavers
  - Accessibility to farms, **facilities damages**
  - **Staff & supplies shortage**
  - Socio-economical/political **unstability**

CSF reintroduction in Hispaniola (1996)
Haiti Earthquake (2010)
Hurricane Tomas (2010)

Breakdown in health services and infrastructure, increased vulnerability
Distinct role of NEMO and CaribVET


Capacity Building – training of Caribbean veterinarians and paraveterinarians in epidemiology
Trainings
- Concepts in Basic Epidemiology – July 2008 and September 2009
- Live birds market system – August 2008
- Rapid response system – May 2009
Simulation exercises
- Swine diseases outbreak simulation training – April 2010 – DR
- Rift Valley Fever outbreak simulation – May 2010 – US Virgin Islands
- Sampling, conditioning, shipment of AI samples – Dec. 2009, June 2011
- ...
Follow-up of activities
- Continued training in Epidemiology by a software « RANEMA »
- Follow-up of surveillance activities : review of surveillance plans, questionnaires...
- Monthly action report – evaluation of activities – performance indicators
→ Reinforcement of national surveillance systems
→ Support a national & regional emergency response task force
USDA
IICA
cirad


Thank you for your attention
cirad
INRA
CENSA
USDA
OIE
PAHO
Caribbean CVOs + members of the WG
Coordination unit
CaribVET chair, Co-Chair; USDA CARICOM; CIRAD Guadeloupe
Information & CaribVET Bulletin
caribinfo@caribvet.net
&
http://www.caribvet.net

ACHIEVEMENTS OF THE GEF/CABI MARINE IAS PROJECT AND THE WAY FORWARD

Dayne Buddo, Principal Investigator, and Denise Chin, Research Assistant, Discovery Bay Marine Laboratory, University of the West Indies, PO Box 35, Discovery Bay, St. Ann, Jamaica, West Indies. Telephone: 876-973-2241; Email: dayne.buddo@uwimona.edu.

Invasive alien species are the greatest threat to biodiversity after habitat destruction. Invasive Alien Species (IAS) are species originating from another location, usually another country that causes problems for the native species. They threaten an area's biodiversity as they tend to out-compete native species and to dominate the area. There is usually low predation and competition pressure on the IAS by the native species.

Marine IAS are introduced into an area by various ways, such as the hulls of ships, barges, and boats; sea chests; naturally (water currents or water flow); aquaria dispensing; poor disposal practices of live material; and deliberate introductions. However, the main way of introducing Marine IAS to an area is via ballast water. Ballast water is seawater used to fill ballast tanks of large cargo vessels for stability. Ballast water loaded at the source point contains various microscopic and macroscopic flora and fauna that are discharged at the destination port. These introduced species withstand harsh conditions such as low oxygen, low light, and low food in these ballast tanks, demonstrating the tenacity of these invasive species. It is now a trend that ships are becoming larger and faster, increasing the survivability of these species. It is estimated that about 7,000 to 10,000 species daily travel in ballast water around the world. Every nine weeks, a new IAS is established somewhere. The International Maritime Organization (IMO) estimated that 10 billion tonnes of water are moved around the world annually.

The impacts of Marine IAS ecologically are that they displace native marine species and reduce biodiversity. Economically, Marine IAS cause the loss or decline of fisheries, and significant expenditures by private and/or public sector companies for IAS biofouling of power plants seawater intake systems. They can also become human health hazards, for example, envenomation from lionfish and consumption of seafood with high concentrations of *Vibrio cholera* (cholera).

Lionfish (*Pterois volitans* and *Pterois miles*) (Figure 1) is one of the most recent marine IAS and is described as the fastest finfish invasion in history (Morris 2009). Lionfish is a *venomous* fish native to the Indo–Pacific Oceans. This fish was introduced through the aquaria trade. Intentional and unintentional releases of this fish into nearby canals and the Atlantic Ocean have created problems since the 1980s. For example, the lionfish was first sighted in South Florida in the 1980s, and has since made its way, travelling through ballast water and/or current, through the Caribbean, the Gulf of Mexico, and Central America. In Jamaica, the first reported sighting was off the north coast in 2008.

Lionfish consumes large quantities of juvenile reef fishes and shellfish. It reproduces rapidly (every four days, all year) and a single female lionfish can produce 2 million eggs annually. They have few natural predators in the Atlantic Ocean and the Caribbean Sea. The lionfish is predicted to spread throughout the entire Wider Caribbean Region (WCR), including South America.

Figure 1: Lionfish sighted in Jamaican waters.

A coordinated and consistent regional approach is being taken to combat Marine IAS by streamlining management objectives and strategies. The biology and ecology of these IAS was taken into consideration to counteract their spread and impacts. Some of these groups include:

- Regional Ballast Water Task Force
- Regional Lionfish Committee
- Regional Marine IAS Working Group

The **Regional Ballast Water Task Force** was formed in 2009 and is chaired by Jamaica. This group was formed in an effort to advance the IMO's Globallast Program in the WCR. The lead partner countries of this program in the WCR are Jamaica, the Bahamas, and Trinidad and Tobago.

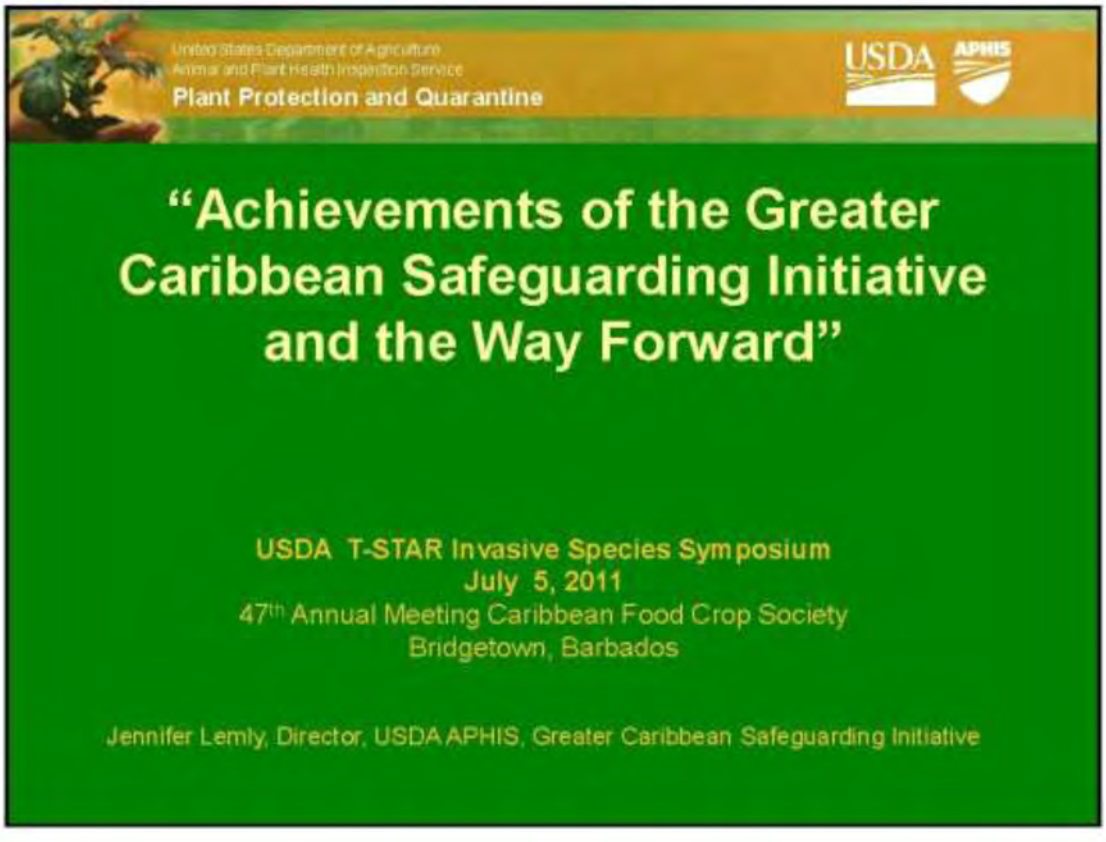
The ad-hoc **Regional Lionfish Committee** was created from a Regional Lionfish Meeting in Cancun in 2010. It is co-chaired by the United States and Mexico. This committee's objective is to streamline the efforts in the region to fight against the lionfish invasion. **A Regional Manual on Best Strategies for Lionfish Control and Research** is one of the major outputs of this committee to guide coastal managers throughout the WCR towards a coordinated approach to deal with this invasion.

Also formed in 2010 was the **Regional Marine IAS Working Group** through the *Mitigating the Threats of Invasive Alien Species in the Insular Caribbean* (MTIASIC) Project. The main objective of this group is to develop a **Regional Marine Invasive Species Strategy** as a component of the Caribbean Invasive Alien Species (CIAS) Strategy. The group is mainly comprised of the partner countries of the MTIASIC Project (i.e., Jamaica, the Bahamas, St. Lucia, Trinidad and Tobago, and the Dominica Republic). The Regional Marine IAS Working Group is chaired by Jamaica.

Regional cooperation is critical in the control and management of marine invasive species in the WCR and is also important to preventing future invasions of species. The management of ballast water releases and the management of marine aquaria releases are two major steps to prevent marine invasions in the future.

ACHIEVEMENTS OF GREATER CARIBBEAN SAFEGUARDING INITIATIVE AND THE WAY FORWARD

Jennifer Lemly, Director, Caribbean Safeguarding Initiative, USDA/APHIS, 4700 River Road, Riverdale, MD 20010 USA. Telephone: 301-734-8295; Email: jennifer.r.lemly@aphis.usda.gov.




United States Department of Agriculture
Animal and Plant Health Inspection Service
Plant Protection and Quarantine
USDA
APHIS
Greater Caribbean Safeguarding Initiative Mission
To strengthen the safeguarding system in the Greater Caribbean Region (GCR) by establishing partnerships with countries in the GCR to prevent, detect, and control existing and emerging plant pest threats.


United States Department of Agriculture
Animal and Plant Health Inspection Service
Plant Protection and Quarantine
USDA
APHIS
Partnerships
• USDA APHIS
– International Services
– Offshore Pest Information Program
– Center for Plant Health Science and Technology
– Emergency and Domestic Programs

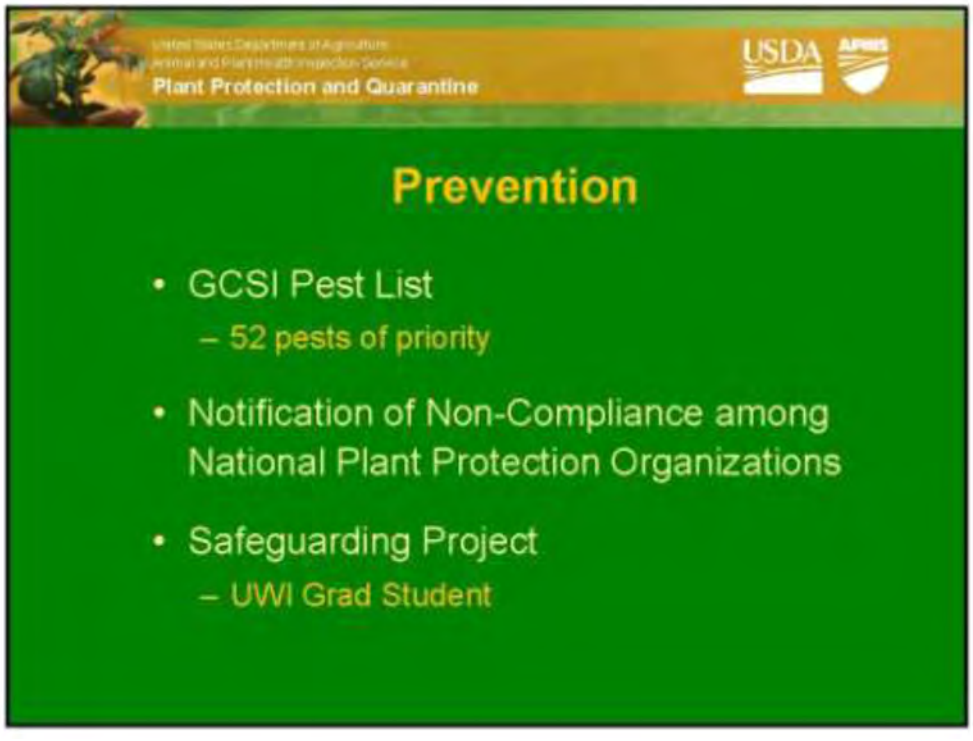

United States Department of Agriculture
Animal and Plant Health Inspection Service
Plant Protection and Quarantine
USDA
APHIS
Partnerships
• Caribbean Plant Health Director Forum
– Technical Working Groups
• Central America
– OIRSA (Regional Plant Protection Organization)

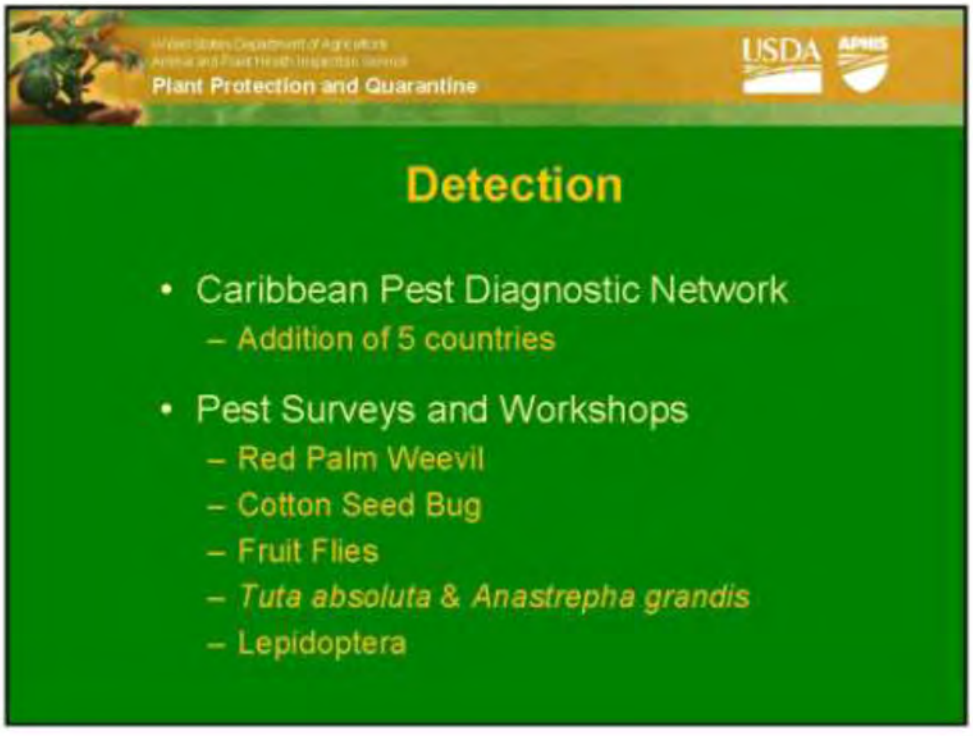

United States Department of Agriculture
Animal and Plant Health Inspection Service
Plant Protection and Quarantine
USDA
APHIS
Partnerships
• International Organizations
– CARICOM: Caribbean Community and Common Market
– CARDI: Caribbean Agricultural Research and Development Institute
– FAO: Food and Agriculture Organization of the United Nations
– IICA: Inter-American Institute for Cooperation on Agriculture


United States Department of Agriculture
Animal and Plant Health Inspection Service
Plant Protection and Quarantine
USDA
APHIS
Partnerships
• International Organizations Cont'
– CABI: CAB International
– IDB: Inter-American Development Bank
– CISWG: Caribbean Invasive Species Working Group
• Universities:
– UF: University of Florida
– FAMU: Florida Agricultural and Mechanical University
– UWI: University of West Indies


United States Department of Agriculture
Animal and Plant Health Inspection Service
Plant Protection and Quarantine
USDA
APHIS
Strengthening
• UWI Regional Plant Quarantine Training
• Increased Communication
– Video conferencing
– Website
• Outreach Initiatives


United States Department of Agriculture
Animal and Plant Health Inspection Service
Plant Protection and Quarantine
USDA
APHIS
Strengthening
• Funding
– Farm Bill Projects
- Strengthen Offshore Safeguarding Efforts in the Greater Caribbean Region
- Real Time Internet Invasive Pest Identification Training
– Allocated Program Funding


United States Department of Agriculture
Animal and Plant Health Inspection Service
Plant Protection and Quarantine
USDA
APHIS
Prevention
• GCSI Pest List
– 52 pests of priority
• Notification of Non-Compliance among National Plant Protection Organizations
• Safeguarding Project
– UWI Grad Student


Plant Protection and Quarantine
USDA
APHIS
Detection
• Caribbean Pest Diagnostic Network
– Addition of 5 countries
• Pest Surveys and Workshops
– Red Palm Weevil
– Cotton Seed Bug
– Fruit Flies
– Tuta absoluta & Anastrepha grandis
– Lepidoptera


Plant Protection and Quarantine
USDA
APHIS
The Way Forward
• Break Work up into Feasible Projects
• Harmonization and Updating of Legislation
• Continued Regional Collaboration
– Communication and information sharing
– Regional projects versus country-by-country
– Minimize duplication

United States Department of Agriculture
Animal and Plant Health Inspection Service
Plant Protection and Quarantine

USDA APHIS

The Way Forward

- Involve the public and industry
  - Actively conduct outreach and engage the private sector

United States Department of Agriculture
Animal and Plant Health Inspection Service
Plant Protection and Quarantine

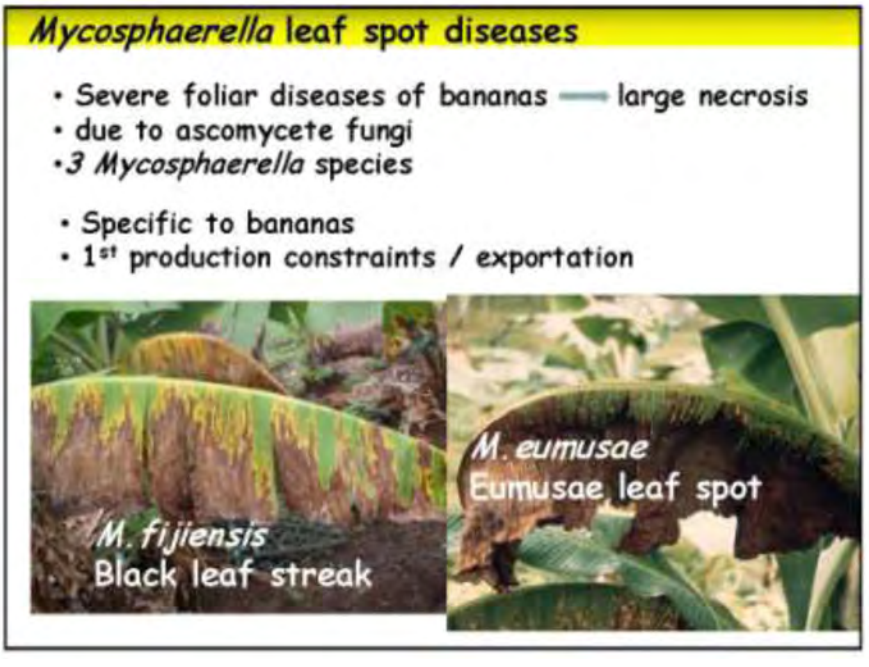
USDA APHIS

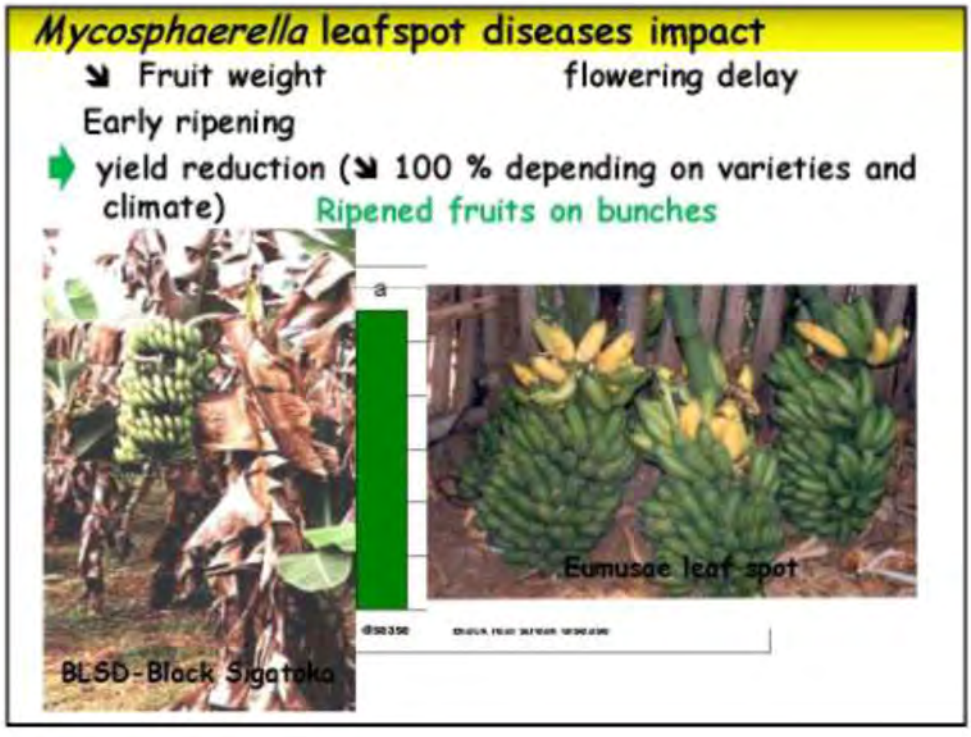
Thank You

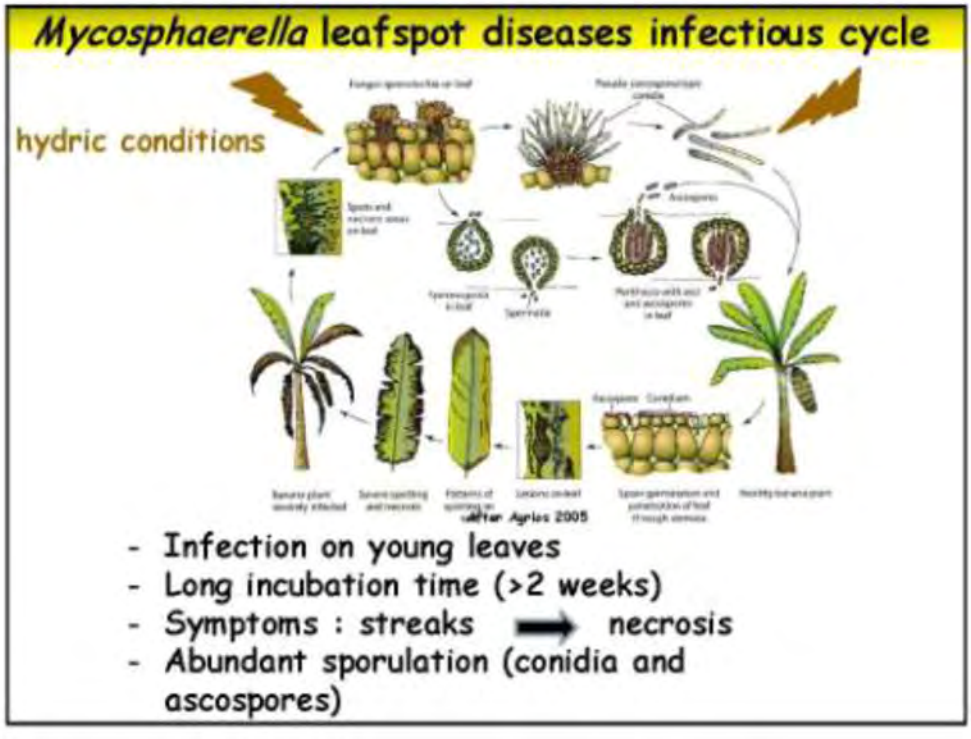
SESSION 2: BANANAS: MAJOR BANAMA DISEASES

BLACK LEAF STREAK AND EUMUSAE LEAFSPOT: TWO DESTRUCTIVE AND INVASIVE LEAFSPOT DISEASES OF BANANA

Catherine Abadie, Marie Zapater, Stephanie Robert, Virginie Ravigne, Francois Bonnot, and Jean Carlier, CIRAD, UMR-BGPI, Campus International de Baillarguet, 34398 Montpellier Cedex 5, France. Telephone: 590-5-90-86-17-66; Email: catherine.abadie@cirad.fr.




Mycosphaerella leafspot diseases impact
Fruit weight
flowering delay
Early ripening
yield reduction (100 % depending on varieties and climate)
Ripened fruits on bunches
a
Eumusae leaf spot
BLSD-Black Sigatoka


Mycosphaerella leafspot diseases infectious cycle
hydric conditions
- Infection on young leaves
- Long incubation time (>2 weeks)
- Symptoms : streaks ➡ necrosis
- Abundant sporulation (conidia and ascospores)

Mycosphaerella sp. dispersal modes

Occurence of 2 dispersal modes

- infected material (suckers, leaf fragments)

➡ non limited in space

- spores

➡ limited in space

Many studies on *M. fijiensis* dispersal at different scales

plot	Abadie *et al*, 2011
region	Halkett *et al.*, 2010
	Rieux *et al.*, 2011
global (world)	Robert *et al.*, 2011

Average dispersal distance : conidia : 3 m
ascospores : 282m

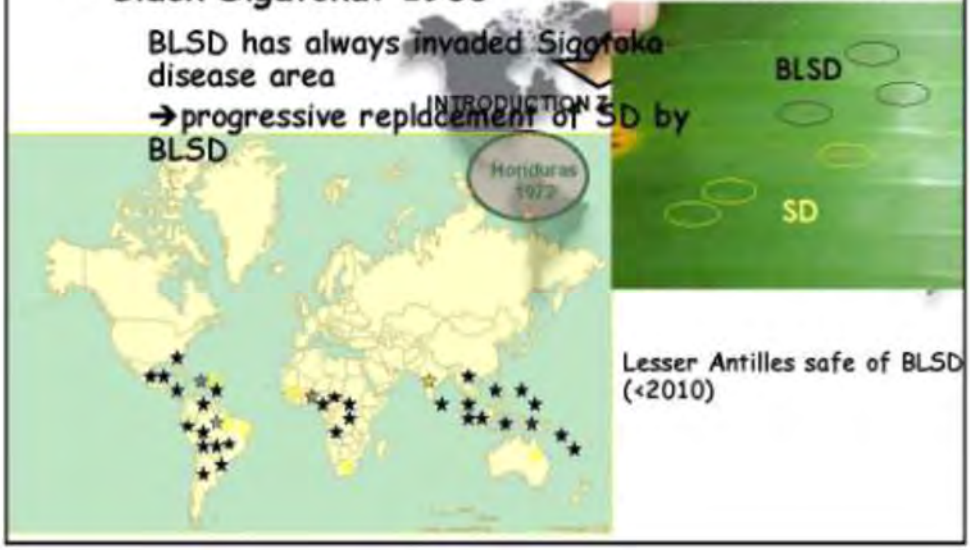
Mycosphaerella sp. origin and distribution

Recent invasive diseases from South-East of Asia

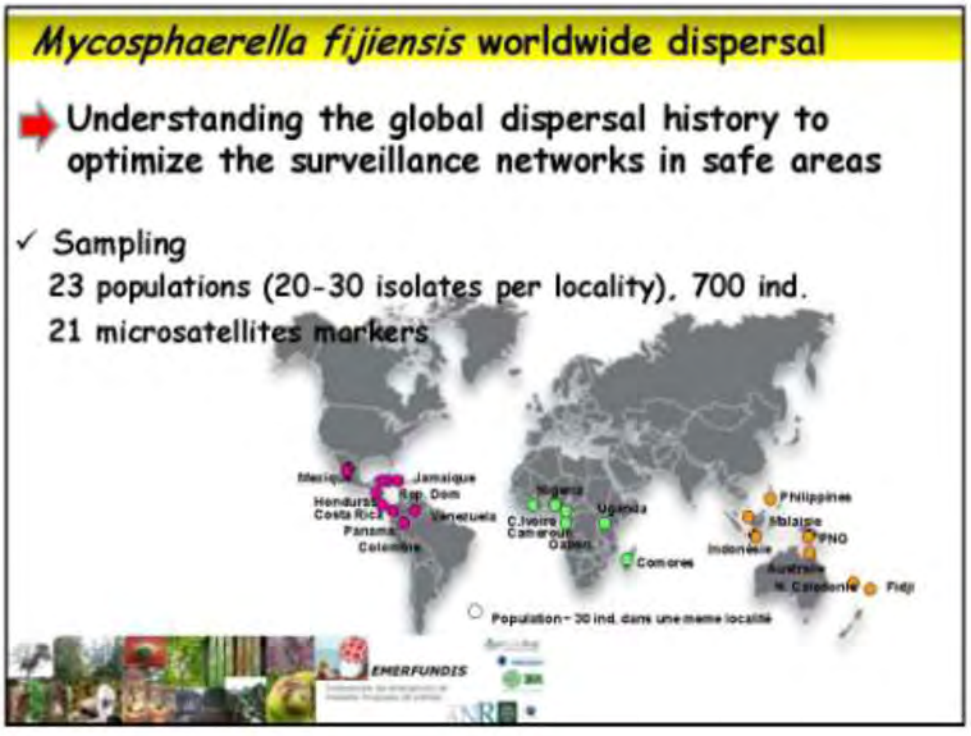
- Black Sigatoka: 1963 *M. fjiensis*/*Pseudocercospora fijiensis*

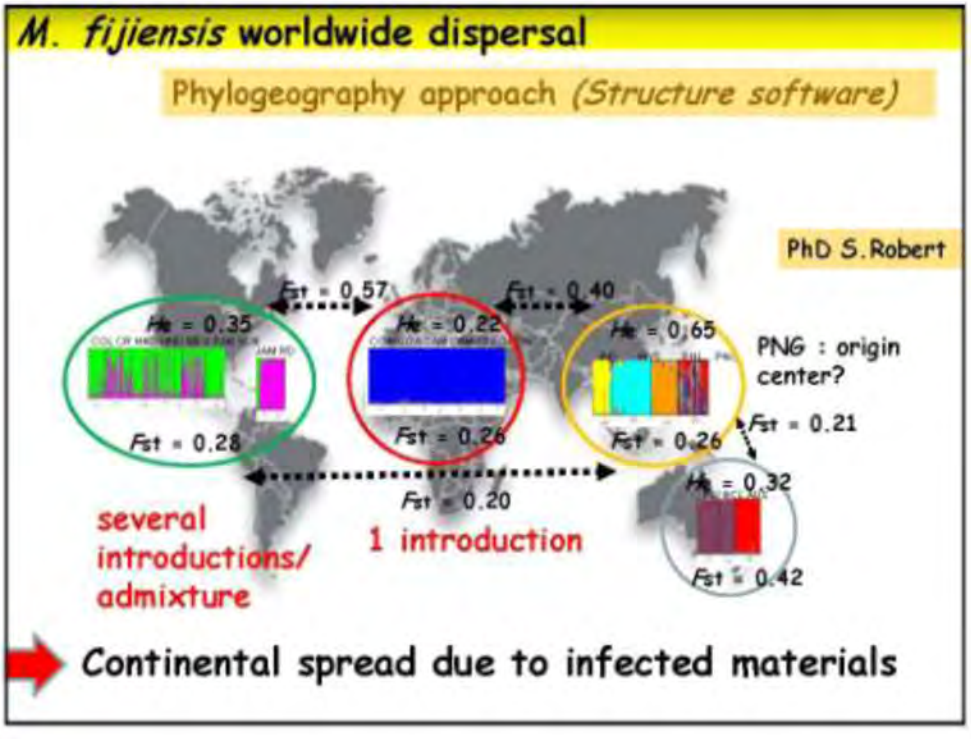
BLSD has always invaded Sigatoka disease area

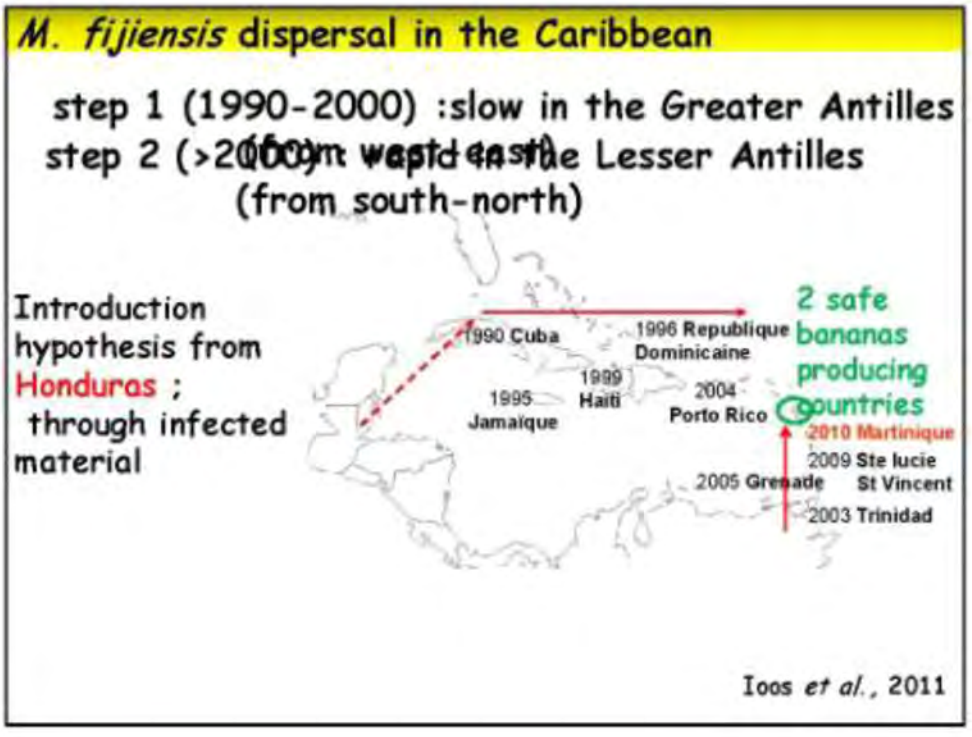
➔progressive replacement of SD by BLSD

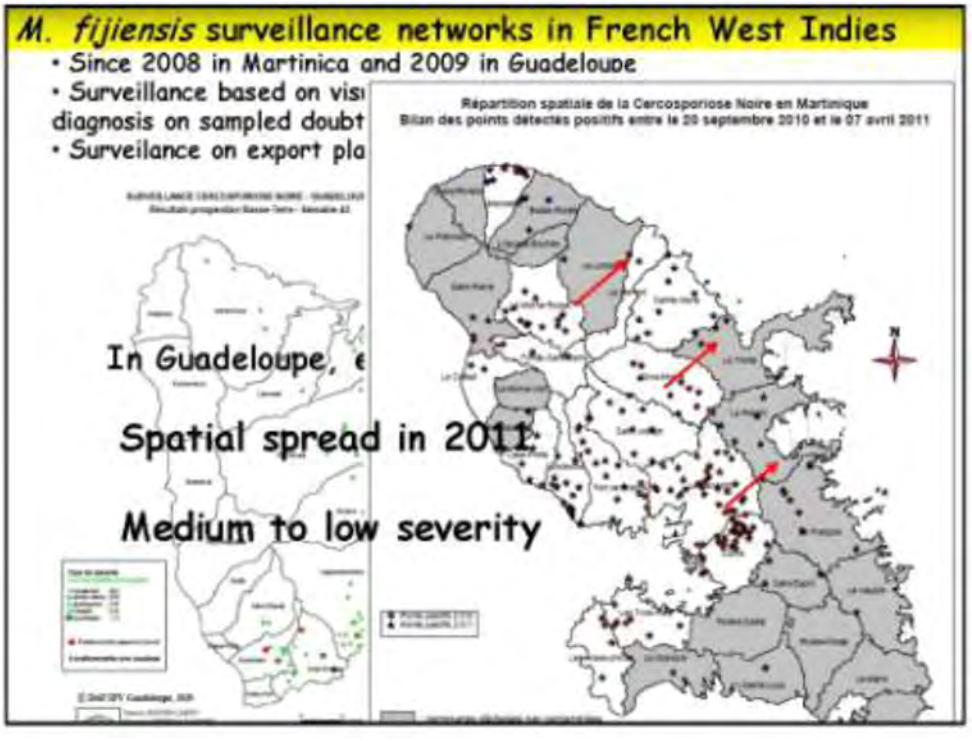


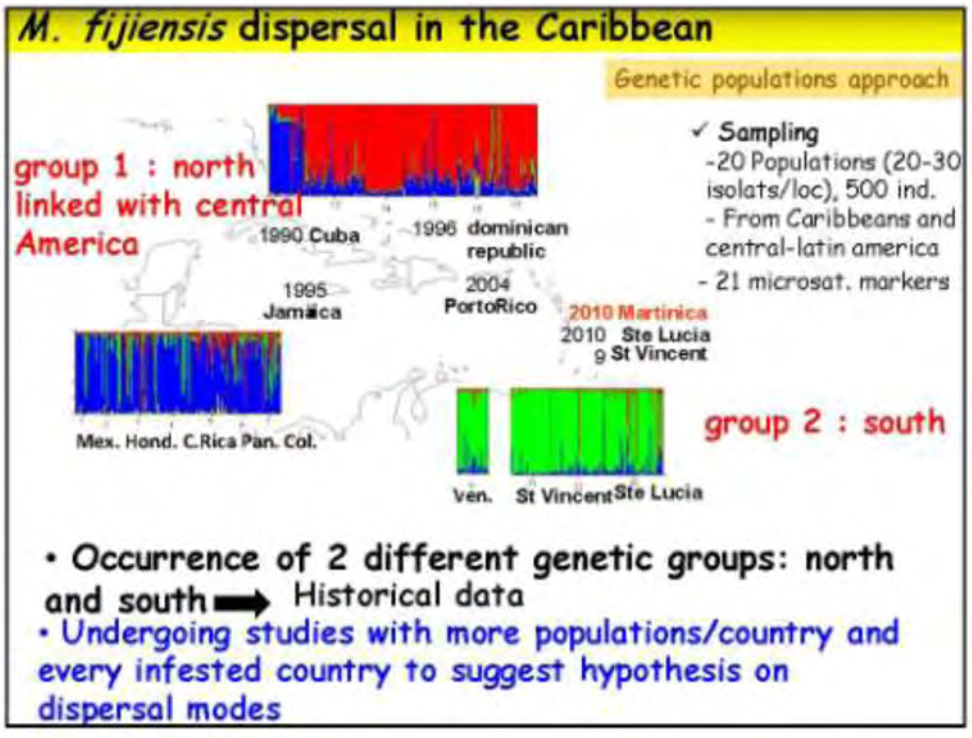
Lesser Antilles safe of BLSD (<2010)

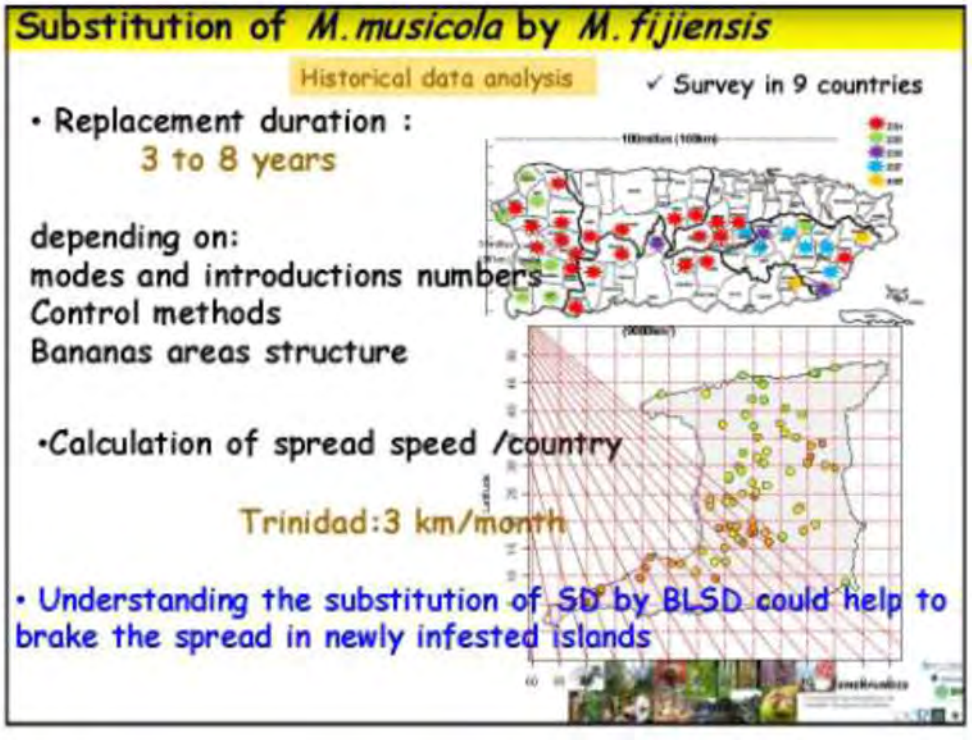

Mycosphaerella fijiensis worldwide dispersal
Understanding the global dispersal history to optimize the surveillance networks in safe areas
✓ Sampling
23 populations (20-30 isolates per locality), 700 ind.
21 microsatellites markers
Jamaique
Rep. Dom
Honduras
Costa Rica
Panama
Colombie
Venezuela
Nigeria
Ouganda
C.Ivoire
Cameroun
Gabon
Comores
Philippines
Malaisie
PNG
Indonésie
Australie
N. Calédonie
Fidji
Population = 30 ind. dans une même localité
EMERFUNDIS


M. fijiensis worldwide dispersal
Phylogeography approach (Structure software)
PhD S.Robert
Fst = 0.57
Fst = 0.40
He = 0.35
He = 0.22
He = 0.65
PNG : origin center?
Fst = 0.21
Fst = 0.28
Fst = 0.26
Fst = 0.26
He = 0.32
Fst = 0.20
several introductions/ admixture
1 introduction
Fst = 0.42
Continental spread due to infected materials


M. fijiensis dispersal in the Caribbean
step 1 (1990-2000) :slow in the Greater Antilles
step 2 (>2000) : rapid in the Lesser Antilles
(from south-north)
Introduction hypothesis from Honduras ; through infected material
1990 Cuba
1996 Republique Dominicaine
1999 Haiti
1995 Jamaïque
2004 Porto Rico
2 safe bananas producing countries
2010 Martinique
2009 Ste lucie
St Vincent
2005 Grenade
2003 Trinidad
Ioos et al., 2011


M. fijiensis surveillance networks in French West Indies
• Since 2008 in Martinica and 2009 in Guadeloupe
• Surveillance based on visi
diagnosis on sampled doubt
• Surveilance on export pla
Répartition spatiale de la Cercosporiose Noire en Martinique
Bilan des points détectés positifs entre le 20 septembre 2010 et le 07 avril 2011
In Guadeloupe, e
Spatial spread in 2011
Medium to low severity


M. fijiensis dispersal in the Caribbean
Genetic populations approach
group 1 : north linked with central America
1990 Cuba
1996 dominican republic
1995 Jamaica
2004 PortoRico
2010 Martinica
2010 Ste Lucia
St Vincent
Mex. Hond. C.Rica Pan. Col.
Ven.
St Vincent
Ste Lucia
group 2 : south
✓ Sampling
-20 Populations (20-30 isolats/loc), 500 ind.
- From Caribbeans and central-latin america
- 21 microsat. markers
• Occurrence of 2 different genetic groups: north and south ➡ Historical data
• Undergoing studies with more populations/country and every infested country to suggest hypothesis on dispersal modes


Substitution of M.musicola by M.fijiensis
Historical data analysis
✓ Survey in 9 countries
• Replacement duration :
3 to 8 years
depending on:
modes and introductions numbers
Control methods
Bananas areas structure
•Calculation of spread speed /country
Trinidad:3 km/month
• Understanding the substitution of SD by BLSD could help to brake the spread in newly infested islands

Mycosphaerella eumusae invasion

Second recent invasive *Mycosphaerella* leafspot disease

- ***Eumusae* leafspot disease (ELSD)**

SYMPTOMS

similar to those of SD but
Primary brown lesion
Oval necrosis (low pressure)

HOST RANGE

various:
Cavendish, Gros-Michel (highly infested)
Plantains
Sucrier
Pisang lilin, Mysore (partially resistant to BLSD)

Mycosphaerella eumusae pathogen

TAXONOMY

perfect stage : *M. eumusae*

imperfect stage : *Pseudocercospora eumusae*

(revised after Septoria) Carlier et al., 2000
Crous and Mourichon, 2002

DIAGNOSIS

- morphology of conidia and conidiophores

conidiophores septate
conidia thiner and shorter than others sp.

Zapater *et al.*, 2008

- molecular markers

quantitative PCR

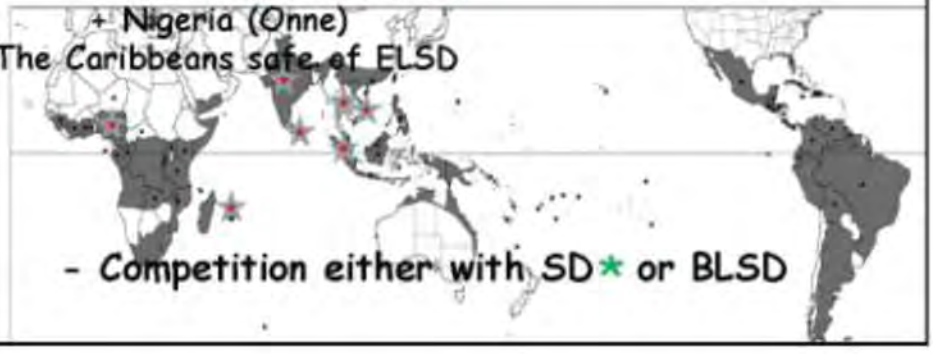
Arzanlou *et al.*, 2007

Mycosphaerella eumusae origin and distribution

ORIGIN
South-East of Asia

DISTRIBUTION
ELSD described in 2000
on samples collected between 1989 and 2000

Geographically located to Southeastern Asia:
India, Sri Lanka, Thailand, Vietnam, South Malaysia
+ Mauritius and Reunion
+ Nigeria (Onne)
The Caribbeans safe of ELSD



- Competition either with SD or BLSD

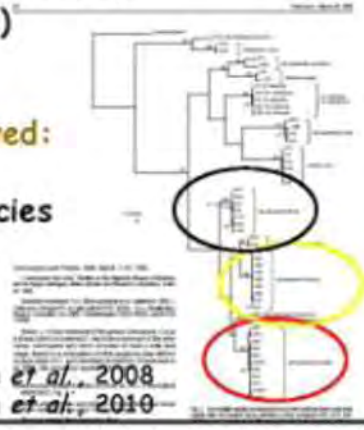
Invasion *Mycosphaerella sp.* leafspots perspectives

- Many information and development of tools occur on *M. fijiensis* (which has been sequenced)
- Further studies on *M. fijiensis* to precise the modes of dispersal in the Caribbeans
- For *M. eumusae*, many topics to study (distribution, control methods..)

Recent phylogenetic studies showed:

Commun ancestor for 3 main species

20 species of *Mycosphaerella* on bananas



Arzanlou *et al.*, 2008
Arzanlou *et al.*, 2010


CIRAD TEAM ON MYCOSPHAERELLA SP.
UMR
BGPI
Population genetics
UPR 26
PhD students
resistance to
fungicides
Control practices
Cropping system
agressiveness
Modeling
Epidemiology, modeling

RE-EMERGENCE OF PANAMA DISEASE (FUSARIUM WILT) AND SPECIAL THREAT POSED BY TROPICAL RACE 4

Randy Ploetz, Professor, Department of Plant Pathology, University of Florida, Tropical Research and Education Center, 18905 SW 280th Street, Homestead, FL 33031 USA. Telephone: 305-246-7000; Email: kelly12@ufl.edu.

ABSTRACT

Panama disease is the most important lethal disease of banana. The causal soilborne fungus, *Fusarium oxysporum* f. sp. *cubense* (Foc), is found in most banana-producing regions and is pathologically and genetically diverse. Races of Foc, which affect different groups of cultivars, have been useful for describing host reactions and new disease outbreaks. Races 1 and 2 are heterogeneous, whereas populations of the pathogen that affect the Cavendish subgroup are more homogeneous; they are separated into subtropical race 4 (SR4), which causes damage only where cold winter temperatures occur, and tropical race 4 (TR4), which causes damage in the absence of predisposing conditions. TR4 is decimating Cavendish monocultures in southern Asia and would affect 85% of the global production of banana were it disseminated more widely. TR4's competence under tropical conditions and the wide range of cultivars that it affects make it a serious threat to export and small-holder production worldwide.

This article summarizes the early history of, and research on, Panama disease, reviews its current status in different producing regions and recent research developments, and concludes with a discussion of TR4 diagnosis, interdiction, and control. Where TR4 has become established, it presents a most difficult management problem. There is an urgent need for innovative and useful research since the available management tactics are not very effective. If TR4 were to become established in the Western Hemisphere, radical changes would be needed in the American Cavendish-based export trades.

INTRODUCTION

Panama disease (fusarium wilt) is the most significant vascular wilt disease of banana (Ploetz 1990; Ploetz and Pegg 2000; Stover 1962). Simmonds (1966) ranked it as one of the six most destructive plant diseases. This notorious reputation stems from damage it caused in the first export trades, which were based on 'Gros Michel' (AAA). Extreme susceptibility to Panama disease, the use of infected suckers to establish new plantings, and the practice of monoculture doomed 'Gros Michel' and led to its eventual replacement by the Cavendish clones (Ploetz 2005; Stover 1962).

Panama disease was first reported in Australia by Bancroft (1876). He speculated that a fungus caused the disease and recognized that suckers that looked healthy could harbor the disease. Smith (1910) was the first to isolate the pathogen, which he called *Fusarium cubense*, and Brandes (1919) was the first to complete Koch's postulates. During the ensuing decades, almost all first reports of the disease in an area were on 'Gros Michel' (Stover 1962). Wollenweber and Reinking (1935) recognized that *F. cubense* was a variant of the common soilborne fungus, *F. oxysporum*. Soon after, their *F. oxysporum* var. *cubense* was renamed *F. oxysporum* f. sp. *cubense* by Snyder and Hansen (1940); it is referred to hereafter as Foc.

As the 'Gros Michel' era ended, Stover (1962): i) contributed new insights on the taxonomy, variation, and physiology of Foc; ii) helped describe Foc's interaction with banana; iii) characterized resistance and susceptibility in banana to this disease; and iv) studied the influence of edaphic factors on the pathogen and introduced flood fallowing as a means for cleansing contaminated soil. In several areas, Stover's results have been superseded by newer work, often with tools that were not available during his career. However, several of his conclusions have been corroborated, including:

1) Resistant genotypes of banana are the best tools for managing this disease (Jones 1994; Ploetz and Pegg 2000)
2) Soil treatments, such as flood fallow, are only temporarily effective (Herbert and Marx 1990)
3) Foc generally appears to have coevolved with its banana host in Southeast Asia (Ploetz 2006a,b; Ploetz and Pegg 1997); Simmond's (1966) hypothesis that strains of Foc could arise (be selected) from the native mycoflora in a new site have not been supported with experimental evidence

The transition by the trades from 'Gros Michel' to the Cavendish cultivars coincided with a dramatic reduction in the amount and types of research that were done on Panama disease (Ploetz 1990). Directly and indirectly, the disease changed the ways in which this multinational business produced and marketed its product. In addition to the massive replanting effort that this entailed, Cavendish fruit required different, far gentler measures for harvesting, handling, and shipping than were used for 'Gros Michel'.

The above focus on export bananas drew attention away from the impact of Panama disease outside the trades (Ploetz 1994). Diverse clones are attacked, many of which are as susceptible as 'Gros Michel' (Ploetz and Pegg 2000). Although these cultivars are still produced in diversified, multicropping situations, their intensive, monoculture production usually collapses (Ploetz 2006b). For example, only temporary production of 'Silk' (AAB) is possible in Brazil, Colombia, Venezuela, and other areas in tropical America. Continued production of this cultivar relies on new, virgin sites, as was required during the 'Gros Michel' era.

Since the Cavendish cultivars had been grown successfully for decades in the same soils that were used to produce 'Gros Michel', it had been presumed that future problems with Panama disease would be restricted to the above cultivars, at least in the Americas (Buddenhagen 1990). The illusion that the Cavendish clones were generally immune to Panama disease in the tropics was shattered in the early 1990s. Serious outbreaks of Panama disease developed in Sumatra and peninsular Malaysia in Cavendish plantations that had been planted for Middle Eastern and Japanese markets (Ploetz 2006b). In these and now several other locations in Southeast Asia, Cavendish has proven to be as susceptible as 'Gros Michel'.

A new variant of Foc, tropical race 4 (TR4), is responsible for the Asian outbreaks (Ploetz 2006a,b; Ploetz 2009). Unlike subtropical outbreaks that affect cold-stressed Cavendish in Australia, the Canary Islands, Cavendish in the absence of predisposing factors. Although it still has a restricted geographic distribution (Figure 1), TR4 continues to spread. Due to its wide host range, TR4 would impact 85% of the world's banana production if it were widely spread (Figure 2) (Molina et al. 2005; Ploetz 2009). TR4 poses a serious threat to the multibillion dollar export trade and the food stability and income of millions of poor farmers.

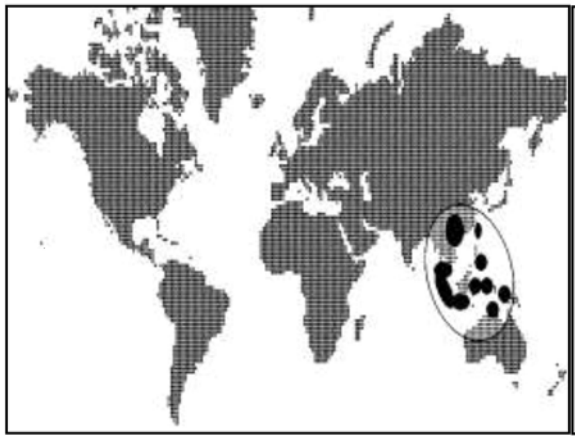


Figure 1. TR4 is found in blackened areas

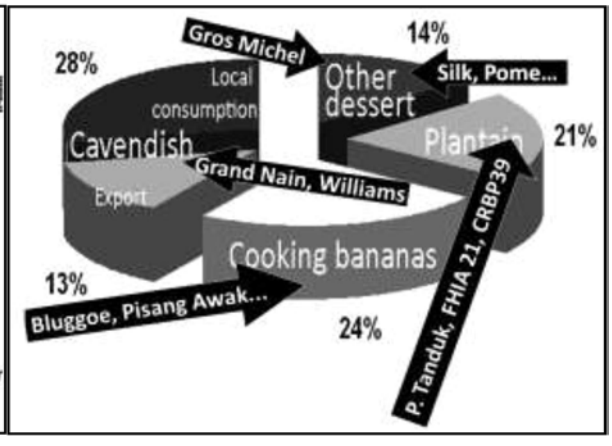


Figure 2. Cultivars that are affected by TR4

Fusarium oxysporum is a species complex of morphologically similar filamentous fungi (O'Donnell et al. 2009). It is comprised of mainly saprophytic strains, and contains plant pathogens that cause vascular wilts, rot, and damping off of hundreds of host species. Agriculturally and economically, it is the most important species in *Fusarium*. Over 150 special forms, formae speciales, of *F. oxysporum* are known, each of which has a unique host range of one or a closely related set of species (O'Donnell et al. 2009).

Foc affects primarily banana and plantain, but other banana relatives are also susceptible (Ploetz 2006b). Diverse characters have been used to study variation in Foc (Boehm et al. 1994; Groenwald et al. 2006; Moore et al. 1993; Stover 1962). Significant progress to understand the population biology of Foc resulted after the development of a straightforward method for determining vegetative compatibility groups (VCGs) in the late 1980s (Ploetz and Correll 1988; Puhalla 1985), and over 20 VCGs of Foc have been reported to date (Ploetz and Pegg 2000).

"Race" has been used to classify strains of Foc since the mid-1900s (Stover 1962). Pathotypes ("races") that affect different groups of banana cultivars are not nearly as well defined as are races of some other plant pathogens (pathosystems in which a gene-for-gene interaction are known are the best examples). Races 1 and 2 of Foc are heterogeneous, and numerous clonal lineages and VCGs have been identified in each (Ploetz and Pegg 2000). Although they are imperfect measures of pathogenic diversity in Foc, race designations are useful when describing host reactions and new disease outbreaks.

Three races of Foc are conventionally recognized on banana: 1, 2, and 4 (race 3 was described for isolates of Foc that affected *Heliconia* spp. (Waite 1963)). Race 1 was responsible for the epidemics on 'Gros Michel', and also affects 'I.C.2' (AAAA), 'Silk' 'Pome' (AAB), 'Pisang Awak' (ABB), and 'Maqueno' (AAB). Race 2 affects cooking bananas, especially those in the Bluggoe subgroup (ABB). And race 4 affects race 1- and race 2-suscepts, cultivars in the Cavendish subgroup and diverse additional cultivars, such as 'Pisang Mas' (AA) (Ploetz and Pegg 2000).

The Cavendish cultivars are affected mainly in the eastern subtropics. For decades, losses have occurred in subtropical Australia, the Canary and Madeira Islands, and South Africa (Ploetz 1990). In these areas, race 4 is comprised of isolates in VCG 0120-01215, and to a lesser extent in Australia, VCGs 0129 and 01211 (Ploetz and Pegg 2000). Cavendish is also affected in Taiwan (Hwang and Ko 2004), and previous reports indicated that this was related to the subtropical outbreaks, even though production areas in Taiwan have relatively warm winters and are technically in the tropics (Kaohsiung, 22°S latitude, is south of the Tropic of Cancer) (Ploetz 2006b). In hindsight, damage in Taiwan may have been due to TR4.

Cold winter temperatures in the subtropics are thought to predispose Cavendish to race 4. For example, photosynthesis of 'Williams', a Cavendish cultivar, was reduced by 75% during the winter in Queensland, Australia (Moore et al. 1993). Damage also occurred on Cavendish in the tropics, but it was uncommon and also associated with predisposing factors (Ploetz 1994). Pockets of damage occurred on Cavendish on Guadeloupe (17°S) after ash from a volcanic eruption lowered soil pH, and in Jamaica (18°S) in low-lying and poorly drained soils above 700 m in elevation.

In summary, prior to the 1990s Cavendish succumbed in exceptional situations but performed well in good soils in the lowland tropics. Since these cultivars had resisted Panama disease for decades in the same soils in which 'Gros Michel' was devastated, it appeared that the 'Gros Michel' populations of Foc were incapable of mutating to virulence on Cavendish (Buddenhagen 1990).

The Special Threat Posed by Tropical Race 4 (TR4). The recent outbreaks of TR4 have been alarming. Isolates of TR4 are in VCG 01213-01216, a unique population that was originally identified in Taiwan in 1990 and is now known to define TR4 (Ploetz, 2006a,b). TR4 has also been reported in Australia (Northern Territory), China (Hainan, Guangdong, and Guangxi), Indonesia (Halmahera, Irian Jaya, Java, Sulawesi, and Sumatra), Malaysia (Peninsular and Sarawak), and the Philippines (Mindanao) (Molina et al. 2005; Molina 2009).

TR4 is distinguished from subtropical race 4 because it is genetically distinct and damages Cavendish in the tropics in the absence of predisposing conditions (Ploetz 2006b). Research is needed to better define the host ranges of the two patho-types. Although they are similar, some clones, such as 'Pisang Lilin' (AA), are affected only by TR4, and the reaction of other clones that are affected in the tropics, such as 'Pisang Berangan' (AAA), is not known in the subtropics since they are not produced there. Alternatively, the tropical response of other clones that are affected by subtropical race 4 in the subtropics is not known [e.g., 'Yangambi Km 5' (AAA), 'FHIA-03' (AABB), and 'FHIA-23' (AAAA)]. Based on the reaction of 'Pisang Tanduk' and

'FHIA-21' (see papers in Molina et al. 2005), it appears that TR4 affects the AAB plantains, and nothing is known about the reaction of the important East African Highland cultivars to TR4. Additional work is needed to clarify the response of these important clones to TR4.

RECENT RESEARCH ADVANCES

Although Snyder and Hansen's name is still used to designate this pathogen, research over the last decade indicates that it is represented by at least three phylogenetically distinct taxa (Fourie et al. 2009; Koenig et al. 1997; O'Donnell et al. 1998; Ploetz 2006; Taylor et al. 1999). The phylogenies of these populations have been investigated with cDNA and DNA sequence work (Fourie et al. 2009; Koenig et al. 1997; O'Donnell et al. 1998; Ploetz 2006; Taylor et al. 1999). These studies did the following: i) identified several clonal lineages within the taxon; ii) delineated relationships within Foc and among the Foc VCGs; iii) demonstrated that some of the clonal lineages of Foc were more closely related to other formae specials of *F. oxysporum* than to other lineages of Foc; iv) suggested that one of the lineages, defined by VCG 01214, may have evolved in Africa, outside the Southeast Asian homeland of banana; and v) indicated that recombination between VCGs 0124/0125 and 01212 probably occurred (it is unclear whether this is historic or ongoing, and whether sexual or parasexual mechanisms have been involved). The significant genetic differences that are evident among the VCG 01214, VCG 0120 and VCG 0124 clades indicate that they are phylospecies, genetically related groups of individuals that are related by descent (O'Donnell et al. 1998).

MANAGING PANAMA DISEASE

Effective disease management relies on avoidance, exclusion, and eradication of the causal agents; protection of, or development of resistance in, the host plant; and treatment of affected plants (Ploetz 2007). Aspects of these principles are discussed as they relate to TR4.

Avoidance. The importance of using disease-free planting materials cannot be overstated, and any measure or legislation that would produce disease/pathogen free materials and disseminate them to growers would be useful (Diekmann and Putter 1996). Banana suckers can harbor bacteria, fungi, nematodes, and viruses, and it is in and on them that many economically important pathogens are moved and established. Thus, tissue-culture plantlets should be used whenever possible. Since Foc is moved effectively in infected suckers, these traditional seedpieces should never be moved internationally.

Exclusion. Excluding pathogens from production areas can be difficult, but is a most cost-effective disease management strategy (Palti 1981). The early detection and accurate identification of pathogens are often important first steps in exclusion, and the certification of pathogen-free status and safe movement of germplasm rely on their success. Recently, an accurate molecular diagnostic method was developed to identify TR4 (Dita et al. 2010). It is being refined/adapted for use with plant and soil samples (Dita, personal communication), and could potentially assist exclusion, eradication and management efforts.

Quarantines can be an important first line of defense against the movement of important pathogens, and most countries have lists of forbidden or restricted pathogens and host plants.

Unfortunately, these rules are not always enforced effectively and there are many examples of destructive agents moving despite quarantines. The spread of TR4 in Asia is an example of the continued movement of an important problem despite general awareness in the region of the extent and seriousness of a problem.

Eradication. If pathogen exclusion has failed, a different set of strategies is needed. These measures are diverse, always more expensive than pathogen exclusion, and are seldom effective. The investment of ca. $1 billion to eradicate citrus canker in Florida is an extreme example of the expense of an unsuccessful effort to eliminate a pathogen (Gottwald et al. 2002).

Pathogen eradication is usually very difficult, and there are no known examples of the successful eradication of a soilborne fungal pathogen in a newly infested area. Eradicating Foc would be especially difficult. Foc survives for decades in infested soil due to its formation of resilient chlamydospores and infection of alternative weed hosts that do not develop symptoms, but perpetuate the pathogen in the absence of a banana host (Waite and Dunlap 1953). Soil disinfestants (e.g., flooding and methyl bromide-chloropicrin fumigation) have been shown previously to be ineffective since Foc can rapidly recolonize treated soils as a facultative saprophyte (Herbert and Marx 1997; Stover 1962).

Protection of healthy plants and treatment of diseased plants. Although diverse chemical, physical, and biological measures have been used against plant diseases, they have had a very limited impact on Panama disease. Fusarium wilts are favored in acidic soils, but serious outbreaks of Panama disease are known in calcareous soils (e.g., pH = 7.5 – 8.2 in South Florida) (Ploetz et al. 1999). There are no effective chemical pesticides that protect banana from Panama disease or allow diseased plants to be effectively treated. For Foc, physical barriers, such as fences, that would be used to restrict inoculum movement, would need to be effectively maintained for a very long time. Although they have received considerable attention, biological control measures for Panama disease that are effective for more than several months have not been developed (Ploetz 2004). Likewise, minimal information has come from "soil health" research. Given the exceedingly complex soil environment and the perennial, polycyclic nature of Panama disease, it is unreasonable to expect soil health strategies to have a very significant impact against this problem.

Resistance. Resistance to disease can be a formidable disease management tool, and genetic resistance obtained via conventional breeding has been responsible for some of the most important advances in production agriculture during the last century (Simmonds and Smartt 1999). Although susceptible genotypes may be useless against foliar diseases that progress rapidly, they can be used for years against slow-developing soilborne diseases before they need to be replaced or replanted. For example, this has been the manner in which TR4 has been managed in Taiwan (Hwang and Ko 2004). Somaclonal variants of 'Giant Cavendish' that have moderate tolerance to TR4 are used for one or two cycles before production is discontinued. Fields are then flooded and/or fallowed to rice before being replanted. These shortened production schemes are more expensive than traditional multi-ratoon schemes and would require radical changes if they were to be adopted in the Americas.

Field evaluation of important cultivars from Latin America and Africa (e.g., plantain and the highland bananas) in countries where TR4 is already present (e.g. Asia) should contribute to increased preparedness in TR4-free countries. Under controlled conditions, germplasm needs to be identified that resists TR4 and which could be used in improvement programs.

TR4 diagnosis, interdiction and control. Given the importance of TR4, the desire to keep the pathogen out of noninfested production areas and the need to detect early outbreaks, recent research has focused on a rapid and reliable diagnostic procedure. Although some reported techniques have not been selective (e.g., Groenwald et al. 2006; Lin et al. 2009), a new PCR diagnostic reliably detects only strains in VCG 01213-01216 (Dita et al. 2010), and is being adapted/refined for use in soil and infected plant material (Dita, personal communication).

Obviously, keeping TR4 out of noninfested areas is a high priority. Action plans, similar to that which has been developed for Tropical America (Ploetz 2008; Pocasangre et al. 2009), should be developed for Africa and areas in Asia that remain free of TR4. Where TR4 is established, it will be necessary to institute new, holistic measures and to accept some losses due to this disease. In addition to using tolerant cultivars, single production cycles (treating the crop as an annual rather than perennial), intercropping, fallowing with nonhost crops, flooding, and the use of silicon or other soil amendments may be useful. Research is needed to identify which measures are most effective.

SUMMARY

Diseases of clonal perrenial crops are among the most difficult management challenges in tropical agriculture (Ploetz 2007). There is an urgent need for innovative and useful research on TR4 since the only available management tactics are not very effective. No effective chemical control measures exist and disease resistance is limited. Biological control efforts have only been moderately successful for annual hosts of fusarium wilts, and there has been no example of the successful use of this approach for a perrenial crop such as banana (Ploetz 2004). Soil health approaches, wherein diverse biotic and abiotic factors are manipulated to directly or indirectly improve plant health, are also in vogue but have offered little real promise for managing this difficult problem. Measures must be taken to exclude TR4 from the Western Hemisphere. Education and a heightened awareness of the nature and seriousness of this threat are needed among quarantine personnel, producers, and those in international commerce.

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VIRUSES THAT THREATEN BANANA AND PLANTAIN PRODUCTION IN THE CARRIBEAN

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ABSTRACT

Virus diseases that have the potential to cause significant damage to banana and plantain production in the Caribbean fall into two categories: those that are not known to be present in the region and those that are present but have not been investigated in detail. The first group includes *Banana bunchy top virus* (BBTV) and *Banana bract mosaic virus* (BBrMV), while *Banana streak virus* (BSV), *Cucumber mosaic virus* (CMV), and *Banana mild mosaic virus* (BanMMV) and similar unidentified viruses comprise the second group. It is of the highest importance to prevent the introduction of BBTV and BBrMV, which can be spread rapidly by their aphid vector *Pentalonia nigronervosa*, which occurs throughout the region. Additional research on the incidence and impact of BSV, BanMMV, and other unidentified viruses would be of value.

INTRODUCTION

Four groups of pathogens attack and can cause significant damage to *Musa* spp. (banana, plantain, and bluggoe) cultivated as food crops. These pathogen groups are fungi (e.g., *Mycosphaerella*, *Fusarium*), bacteria (e.g., *Ralstonia*), nematodes (e.g., *Radopholus*, *Meloidogyne*), and viruses. Viruses differ from the other pathogens in two respects that are of critical importance. The first difference is that viral infections cannot be eliminated by chemical treatment; the second difference is that *in vitro* propagation procedures used routinely to produce pathogen-free propagules for crop establishment or for trans-border germplasm movement are ineffective in eliminating viruses, in contrast to their well-documented efficiency in preventing movement of fungal, bacterial, and nematode pathogens of *Musa*. The practical consequences of these differences between viruses and other pathogens are that first, control of diseases caused by viruses must be based on preventing infection (prophylaxis), rather than on chemical intervention to cure the disease (chemotherapy), and second, sensitive and reliable virus indexing procedures need to be employed in order to eliminate or greatly reduce the possibility of international or even in-country movement of viruses that have the potential to cause significant crop losses.

VIRUSES INFECTING *MUSA* SPP: DISTRIBUTION, EPIDEMIOLOGY AND POTENTIAL THREAT TO FOOD CROP PRODUCTION IN THE CARIBBEAN

Virus diseases that have the potential to cause significant damage to banana and plantain production in the Caribbean fall into two categories: those that are not known to be present in the region and those that are present but have not been investigated in detail. The first group includes *Banana bunchy top virus* (BBTV) and *Banana bract mosaic virus* (BBrMV); the second group includes *Banana streak virus* (BSV), *Cucumber mosaic virus* (CMV), and *Banana mild mosaic virus* (BanMMV).

***Banana Bunchy Top Virus* (BBTV)**

Bunchy top of banana, caused by BBTV, is undoubtedly the most dangerous threat to banana production in the Caribbean since this disease frequently causes total crop loss. This virus occurs in Asia, Australasia, and in isolated pockets in Central Africa and Egypt (Thomas and Iskra-Caruana 2000a). The virions of BBTV are spherical, 20nm in diameter (Thomas and Dietzgen 1991), and the genome consists of six circular single-stranded DNA molecules, each 1000–1100 nucleotides in length (Lockhart and Iskra-Caruana 2000a). The virus is transmitted by vegetative propagation and in a persistent manner by the black banana aphid, *Pentalonia nigronervosa*, the only known vector. Because BBTV infects only *Musa* spp. and is insect-transmitted only by *P. nigronervosa*, which colonizes primarily *Musa* spp., the spread of bunchy top occurs only from infected to healthy banana. Accidental introduction of BBTV into the Caribbean region can rapidly result in catastrophic crop losses, as occurred in Sindh Province in Pakistan in the 1990s (Khalid and Soomro 1993; Khalid, Soomro, and Stover 1993), for the following reasons. First, the aphid vector, *P. nigronervosa*, occurs commonly throughout the region (see Commonwealth Institute of Entomology, Distribution Maps of Pests, Series A, Map No. 242). Second, the vast majority of banana cultivars, (i.e., Musa AAA genotypes), including those most widely cultivated in the region, are highly susceptible to bunchy top (Thomas and Iskra-Caruana 2000a). Third, bunchy top epidemics and consequent crop destruction occur in monoculture agrisystems, in which the pathogen insect vector and very susceptible host plant are in close contact. For these reasons, large-scale plantings of very susceptible bananas common in the Caribbean region, would very likely suffer catastrophic losses following the introduction of this virus. This scenario can be contrasted with the situation in west central Africa (Republic of Congo, Rwanda, and Burundi), where BBTV was introduced, most likely in *Musa* germplasm imported from Asia or Australasia for breeding purposes in the mid-twentieth century. In these areas, bananas are grown in diverse mixed-cropping systems in small-holdings separated by native vegetation that harbor neither BBTV nor the aphid vector, and the disease has not spread to any appreciable extent in the past several decades. Whereas production of bananas (i.e., *Musa* AAA genotypes) would be very seriously impacted by the introduction of BBTV into the Caribbean region, a quite different picture emerges in the case of plantain (*Musa* AAB) and bluggoe (*Musa* ABB) cultivars. These B-genome-containing (i.e., *M. balbisiana*) interspecific hybrids, are generally not affected by bunchy top disease, either because of immunity or a high degree of tolerance to BBTV infection (Thomas and Iskra-Caruana 2000a). In summary, the overall potential impact of BBTV on crop production in the region would depend on the relative proportions of different *Musa* genotypes, and the scale and diversity of the cropping systems used.

Bunchy top symptoms in Cavendish banana

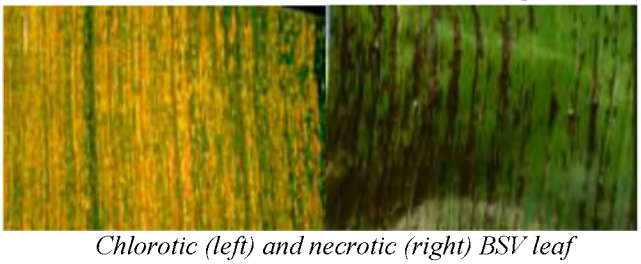
Banana Bract Mosaic Vvirus (BBrMV)

Banana bract mosaic virus (BBrMV), like BBTV, is known to occur naturally only in Asia (Philippines, Vietnam, Western Samoa, India, Sri Lanka) (Thomas and Iskra-Caruana 2000b), and has not been detected in the Caribbean. Unlike BBTV, BBrMV has filamentous virions containing a single-stranded RNA genome typical of virus species in the family *Potyviridae*. Also unlike BBTV, BBrMV is transmitted by at least three aphid species, (*P. nigronervosa*, *Aphis gossypii*, and *Rhopalosiphum maidis*) in a non-persistent manner (Thomas and Iskra-Caruana 2000b) and by vegetative propagation. However, because only *Musa* spp. (banana, plantain, abaca), movement of the virus is, like BBTV, exclusively from infected to healthy plants. Unlike BBTV, which affects only bananas (i.e., *Musa* AAA), no resistance or immunity to BBrMV has been observed in any *Musa* spp. As a result, whereas BBTV would pose a threat only to banana cultivation, BBrMV would spread to banana, plantain, and bluggoe throughout the Caribbean region. Fortunately, plant damage and crop losses resulting from BBrMV infection are far less serious than those caused by BBTV. However, while BBrMV would be incapable of inflicting the total crop loss caused by BBTV, it has the potential of causing significant damage to the full range of *Musa* genotypes cultivated in the region. Reduction in bunch yield of up to 40% has been reported, sucker production and vigor may be reduced, and misshapened or discolored fingers can reduce the marketability of fruits (Thomas and Iskra-Caruana 2000b).

Bract and pseudostem symptoms of bract mosaic in plantain

Banana Streak Virus (BSV)

BSV has been isolated (Lockhart 1986) and is now documented as the most-widely distributed virus in edible *Musa* cultivars, occurring in every production area throughout the world (Lockhart and Jones 2000a). Virions of BSV are bacilliform in shape, non-enveloped, and contain a circular double-stranded DNA genome (Ndowora et al. 1999). In its epidemiology BSV differs from BBTV and BBrMV, which are spread both by vegetative propagation, and more importantly, by efficient aphid vectors (Thomas and Iskra-Caruana 2000a, 200b). The insect vectors of BSV are mealybugs (*Psuedococcidae*) (Lockahrt and Jones 2000a), which do not share the high fecundity and dispersal capacity of the aphid vectors of BBTV and BBrMV, rendering this mode of field spread of limited importance. The spread of BSV occurs primarily by vegetative propagation and by a mechanism unique to the plant virus family *Caulimoviridae*, of which BSV (genus *Badnavirus*) is developed, resulting from the activation of the BSV genomic sequence integrated in the *Musa* genome (Ndowora et al. 1999). These activatable integrated viral



Chlorotic (left) and necrotic (right) BSV leaf symptoms in banana

sequences, referred to as endogenous pararetroviruses, or EPRVs, occur in the *Musa* B genome (i.e. *M. balbisiana*) but not in the *Musa* A genome (i.e., *M. acuminata*) (Ndowora et al. 1999; Thomas and Dietzgen 1991). The result of this strict distribution of activatable EPRVs among *Musa* genotypes means that while BSV infection from EPRVs cannot occur in banana (i.e. *Musa* AAA), all interspecific AxB hybrids (plantain, AAB, and bulggoe, ABB) are prone to this mode of BSV infection. This includes all improved *Musa* tetraploid (AAAB, AABB) or triploid (AAB) hybrids produced by plantain breeding programs around the world (e.g., Honduras, Nigeria, Cameroun, Guadeloupe, and Brazil). Deployment of these improved plantain hybrids to increase food crop production in the Caribbean region will bring with it the risk of BSV disease outbreaks arising from integrated viral sequences present in the B genome component. Such events occur sporadically, and although some predisposing factors (e.g., seasonal temperature fluctuations, tissue culture (Bouhida and Lockhart 1990)) have been identified, further studies are needed in order to permit more realistic assessment of the risk of importing and planting these improved AxB hybrids.

Fruit symptoms caused by BSV infection in Grand Nain (Costa Rica)

BSV symptoms from integrated viral sequences (EPRVs) in improved plantain tetraploid hybrid (AAAB) following tissue culture

Cucumber Mosaic Virus (CMV)

Foliar mosaic symptoms caused by a common strain of CMV in banana (banana mosaic)

Cucumber mosaic virus (CMV), like BSV, occurs worldwide (Lockhart and Jones 2000a). The virus has spherical 30nm particles that contain a segmented single-stranded RNA genome. In its epidemiology CMV differs from other viruses of *Musa* in infecting a very wide range of host plant species, including many cultivated crops (e.g., cucurbits, pepper, tomato) and weeds found commonly in banana and plantain fields (e.g., *Commelina*). The virus is transmitted in a non-persistent manner by a number of aphid species that colonize banana. The result is that unlike BBTV and BBrMV, which are spread by aphid vectors

Initial symptoms of systemic necrosis caused by a heart-rot strain of CMV in 'Williams' banana

only from banana to banana, CMV infection can, and most frequently does originate from a range of other plant hosts of the virus. The threat to food crop production posed by CMV arises from the existence of two distinct strains of the virus (Lockhart and Jones 2000a). Common strains of CMV cause mosaic symptoms that appear in a few leaves and normally cause no significant growth or yield effects. In contrast, heart-rot strains of the virus cause systemic necrosis, resulting in plant death or severe crop damage and yield loss. The threat posed by heart-rot strains of CMV quickly multiplies, because once introduced into an area, the virus is spread rapidly to a wide range of weed or crop species by a number of aphid vectors (Bouhida and Lockhart 1990).

Banana Mild Mosaic Virus (BanMMV)

BanMMV symptoms in Pisang seribu (Musa AAB)

Banana mild mosaic virus, BanMMV, is another virus of banana and plantain that was identified and described relatively recently (Thomas, Lockhart, and Iskra-Caruana 2000). The virus has not been studied extensively, and there are few experimental data on its epidemiology or effect on plant performance or crop yield. It occurs with great frequency in banana, plantain, and bluggoe throughout the Caribbean region (Anonymous 2008). Infection by BanMMV has been associated with distinct leaf symptoms only in a few cultivars, but other observations have suggested additional effects, including reduced plant growth (Anonymous 2008; Thomas, Lockhart, and Iskra-Caruana 2000). Wide distribution and high frequency of BanMMV infection in the region suggest that additional research on the epidemiology and the effect on plant performance and crop yield of this virus would be of value in assessing the level of risk it poses to banana and plantain production, which is currently unknown (Anonymous 2008).

REDUCING THE THREAT TO BANANA AND PLANTAIN PRODUCTION POSED BY VIRUSES

Based on the information and discussion presented above, it can be deduced that reducing any threats to banana and plantain production posed by the viruses mentioned would involve the following concrete steps:

1. Zero tolerance of BBTV and BBrMV presence in any *Musa* germplasm imported for field planting or plant breeding. The highest degree of risk of accidental entry of those viruses may be in Cavendish banana plantlets produced by *in vitro* propagation in commercial operations in countries where BBTV and BBrMV are known to be endemic (e.g., India and the Philippines). All rhizomes used for large-scale tissue culture multiplication should be certified virus-free by PCR testing (Thomas and Iskra-Caruana 2000a). The same certification standard should be applied to *Musa* germplasm introduced for breeding purposes.

2. Reduce spread of BSV by vegetative propagation by selecting virus-free mother plants. This frequently presents problems because BSV symptoms appear only periodically, so that plant selection on the basis of symptoms is highly unreliable. Serological (ELISA) assays are more reliable, but are compromised by the high degree of serological heterogeneity that exists among isolates of BSV (Ndowora and Lockhart 2000). PCR indexing is both sensitive and reliable, but this usefulness is limited to *Musa* AAA or AA genotypes due to the presence of integrated viral sequences and hence false positives in genomic DNA of any *Musa* AxB interspecific hybrid (James et al. 2011). The recent development of a rolling-circle amplification (RCA) protocol that distinguishes between episomal BSV (i.e., circular dsDNA) and integrated (i.e., linear) viral sequences, has made PCR detection of BSV in B genome-containing cultivars highly reliable (James et al. 2011).

3. Raise awareness of the threat posed by the heart-rot strain of CMV, and eliminate any infected plants to reduce the risk of the virus spreading into weed hosts that would serve as reservoirs of virus for transmission by aphids to bananas.

4. Initiate research on epidemiology and effects of BanMMV infection on banana and plantain in single or mixed infection with BSV. This will determine how much attention should be given to this widely-occurring virus.

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RECENT RESEARCH FINDINGS ON MOKO DISEASE AND PROSPECTS FOR MITIGATING ITS IMPACT ON THE BANANA INDUSTRY IN THE CARIBBEAN REGION

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BACKGROUND

Moko disease is a deadly disease of banana and plantains. It is caused by a bacterium, *Ralstonia (Pseudomonas) solanacearum* (Race 2), that evolved from pathogens of wild Heliconia species.

The disease affects all parts of the plant, but the route of infection and the nature of the causal strain determine the type of symptoms. Infection of dessert banana cultivars typically occurs via the roots or rhizome. In these cases, the first signs of the disease are yellowing and wilting of the oldest leaves which eventually become necrotic and collapse. The symptoms spread to the younger leaves which develop pale green or whitish panels before becoming necrotic. The disease may cause the suckers to wilt, possibly without exhibiting the foliar symptoms of yellowing and necrosis. Fruit development is affected, and fingers ripen prematurely and split. Internally, the fruit become discolored and eventually rot. Vascular tissues become discolored and when cut they exude bacterial ooze from which the causal organism can be isolated. In the later stages of infection, the vascular discoloration may be brown or black. In fruit bearing plants, the internal symptoms are most evident in the fruit stem and at the bases of younger leaves. Symptoms of insect-transmitted Moko disease are first seen in the flower buds and peduncles which become blackened and shriveled. The bacterium spreads to the fruit, which may ripen prematurely, and initiates a rot. The infection continues towards the pseudostem, causing blackening of the vascular tissue. Eventually, the bacterium becomes systemic and the whole mat is diseased.

RESEARCH FINDINGS

Moko Disease Prevalence in Jamaica

Moko disease was diagnosed by the Banana Board on bananas in St. James in February 2004, with the CABI International Mycological Institute Identification Services confirming the disease in six locations. This disease is a notifiable disease which means that it is required by law to be reported to government authorities. This collation of information allows the authorities to monitor the disease and provides early warning of possible outbreaks. The department developed a program for the emergency eradication of Moko.

Strains of Moko Disease in Jamaica

The isolates of *Ralstonia* from the Eastern Banana Estate in St. Thomas and the St. Mary Banana Estate in St. Mary (eastern Jamaica) were confirmed by Dr. Alvarez and Professor Buddenhagen as 'SFR' strain while the isolates from the Maroon Town and Heliconia farms in St. James (western Jamaica) were confirmed as 'B' strain.

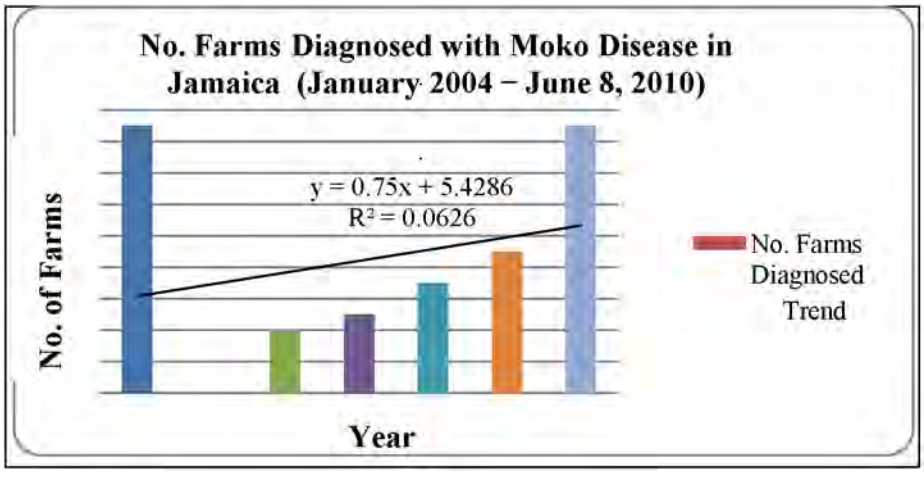
Pathogenicity Test

The pathogenicity test (Koch's postulate) was administered using local isolates. The results of the tests showed the pathogenic nature of the isolates to banana seedlings.

Spread of the Disease

After the eradication attempt at the first outbreak in 2004, the spread of Moko disease of banana and plantains in Jamaica has increased to the original level in just six years (Figure 1). The disease remains in the very same districts of initial outbreak in St. James (the red zone). The average rate of spread up to June 2010 was eight cases per year, or 0.5% of the mats on the infected farms, which is admirably below the target of 10 cases per year. Without the current control measures, the spread of Moko disease would have been exponential, with infection rapidly spreading from farm to farm.

Figure 1. Number of farms diagnosed with Moko disease in Jamaica (January 2004 to June 2010)



Technical, Social, and Legislative Issues

Unavailability of income during the fallow period

After eradication of the infected mats, the field should be left fallow for at least one year to eliminate the bacterium. In the previous eradication attempt, some farmers disregarded the recommendation and replanted the fields with bananas before the fallow period had expired. This practice resulted in plants becoming re-infected with the pathogen. The reason that the farmers gave for replanting before the fallow period had expired was that they needed the income, although they had received lump sum payments in the amount of annualized earnings from Banana Export Company. This may suggest that the payments should have been in installments and supervised.

Compensation

Compensation had advantages and disadvantages. The advantages included assisting farmers to recover from losses, and motivating farmers to declare infected fields and to observe the fallow period. The disadvantages were that the compensation was unsustainable and, in some cases, was utilized for the wrong purposes; encouraged unscrupulous activity; required strict monitoring; and payment had to be verified by proven land tenure, which did not exist in some disease situation.

Non-cooperation by affected farmers to allow their fields to be eradicated

The Moko bacterium cannot be destroyed without killing the host plant, and where the pathogen exists, the only means of effective control is eradication and improved cultural practices. Some farmers refused to allow the eradication exercise on their farms, sold infected planting material to other farmers, and neglected to follow the recommended cultural practices. This contributed to the disease re-emerging and threatening to spread all over the parish and eventually the entire island. This could have resulted in the devastation of the banana industry, with thousands losing their jobs. An economic crisis would have occurred and food security would be threatened.

Refusal to plant suppressive crops

Some of the farmers objected to planting suppressive crops because of the unavailability of a guaranteed market while other farmers refused to have their fields treated for eradication until they could be provided with a compensation package. The proposed package by the farmers included cash compensation per plant, allocation of new land for the period of at least one year and guaranteed market for the suppressive crops grown in the infected fields. If demands were not met, farmers were reluctant to sacrifice their fields. They preferred to get some returns from the bananas and plantains before they die from the Moko disease, although this puts the other farmers and the entire industry at risk.

Failure of law enforcement

The constabulary forces are not convinced that farmers should be prosecuted for non-cooperation according to the Plant Quarantine Order. As a result, some farmers flaunted the law, even when compensated.

Unavailability of clean planting material

The disease is spread via seedlings; therefore tissue culture plantlets are the guaranteed mechanism to prevent spread of the disease when planting. However, the availability of tissue culture plantlets locally was not readily accessible because there were no contractual arrangements in place with The Scientific Research Council (the only local supplier) or any other manufacturer. A lead time of at least six months was required for production of pre-nursery plantlets (before potting). In addition, nurseries for hardening and distribution were not in place.

RECOMMENDATIONS FOR MITIGATION STRATEGIES

1. A comprehensive program is recommended that involves a technical program of the total eradication exercise, followed by a monitoring program in which any new cases are dealt with swiftly. However, unless the social and legal issues are resolved, the technical program will be unsuccessful.
2. The full cooperation and commitment of famers, administrative and legal functionaries, and all stakeholders must be maintained and agreed to in a memorandum of understanding.
3. Farmers must be assisted with planting materials for disease-suppressive crops during the two-year period after all banana fields are destroyed.
4. A compensation package to replace income loss (during the year of fallow) by the affected farmers should be paid in installments and supervised to ensure that farmers comply with all the recommendations so as to prevent practices that encourage resurgence of the disease. The compensation package must include the provision of planting materials for the appropriate suppressive crops accompanied by assistance in land preparation.
5. Clean banana and plantain planting materials should be available to the farmers after the requisite two-year rest from banana and plantain crops in the soil. Planting material should be tissue-cultured plantlets or suckers from certified nurseries.
6. The monitoring and surveillance program must continue throughout the three years subsequent to the eradication procedures.
7. Should funding not be available for a full-scale eradication program, the monitoring, surveillance, and partial treatment of infected crops remains an essential long-term program to curtail spread and empower farmers to protect their banana farming enterprises.
8. The Action Plan to prevent the outbreak in other areas must be implemented and maintained.

SESSION 3: MARINE AND FRESHWATER INVASIVE SPECIES OF IMPORTANCE TO THE CARIBBEAN

THE BAHAMIAN GOVERNMENT APPROACH TO LIONFISH CONTROL

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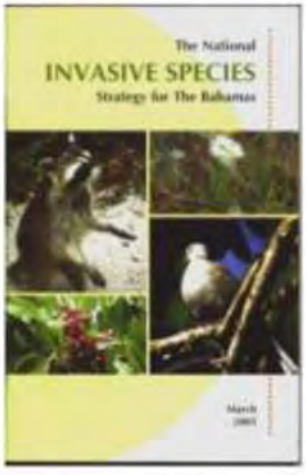
BEST Commission

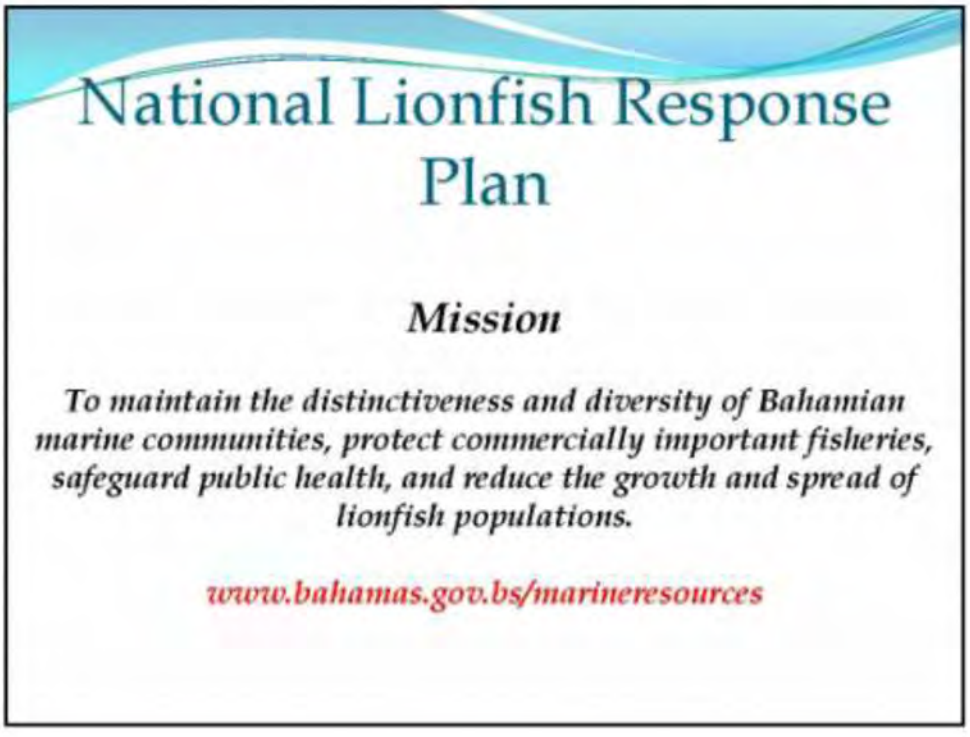
National Invasive Species Strategy (NISS) - 2003

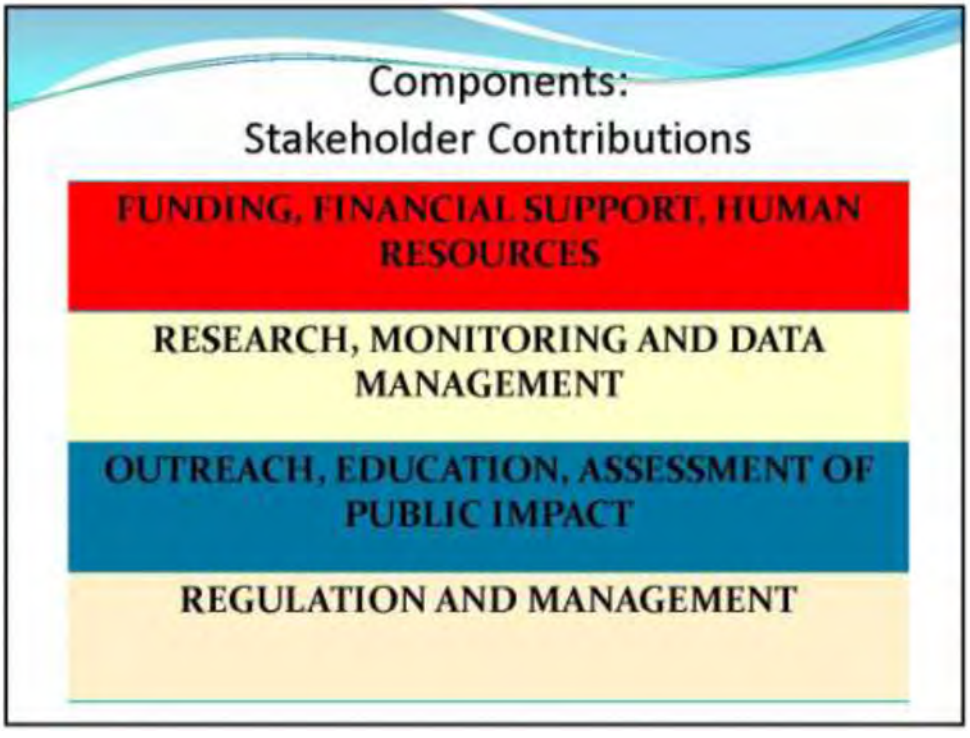
- Article 8(h) of the Convention of Biological Diversity
- Policy
  - Prepare strategic management plans for high priority species
  - Facilitate research on occurrence, distribution and impacts
  - Monitor of IAS populations



Invasion Timeline

- 2004 →
- -2005 → • Major research project on fish diversity • Sightings in North & Central Bahamas
- 2006: Research proposals
- 2007 → • Online sighting survey • 1st Draft of Response Plan • Implementation of activities
- 2008 → • GOB seeks funding for IAS Management • Response Planning workshop formalize plan
- 2009: Launch of projects to assist with lionfish management


National Lionfish Response Plan
Mission
To maintain the distinctiveness and diversity of Bahamian marine communities, protect commercially important fisheries, safeguard public health, and reduce the growth and spread of lionfish populations.
www.bahamas.gov.bs/marineresources


Components:
Stakeholder Contributions
FUNDING, FINANCIAL SUPPORT, HUMAN RESOURCES
RESEARCH, MONITORING AND DATA MANAGEMENT
OUTREACH, EDUCATION, ASSESSMENT OF PUBLIC IMPACT
REGULATION AND MANAGEMENT

STAKEHOLDER GROUPS	
GOVERNMENT AGENCIES	Department of Marine Resources, BEST, Department of Ports, Public Health, Public Hospital Authority, Ministry of Tourism, Ministry of Education
NON-GOVERNMENT AGENCIES	Bahamas National Trust, The Nature Conservancy, BREEF,
COLLEGES AND UNIVERSITIES	College of The Bahamas, Gerace Research Centre
RELATED BUSINESSES	Bahamas Diving Association, Dive and Live Aboard Businesses (Stuart's Cove, Bahama Divers), Dolphin Encounters, Resorts and Hotels
FOREIGN RESEARCHERS AND UNIVERSITY PARTNERS	NOAA-NMFS, REEF, University of Oregon, University of British Columbia, Simon Fraser University, University of Miami
FISHERMEN and FISHING INTERESTS	Fishermen associated with different islands and settlement, Fish sellers

MANAGEMENT STRATEGIES

A) MODIFY OR AMEND existing fisheries regulations for lionfish.

B) ENCOURAGE COMMERCIAL FISHERIES based on lionfish.

C) EXPAND AND IMPROVE PROTECTION OF NATIONAL PARKS AND FISHERIES RESERVES.

D) REQUIRE THE REMOVAL OF DEBRIS and ARTIFICIAL SUBSTRATES around docks, piers and harbours that provide habitat for lionfish.

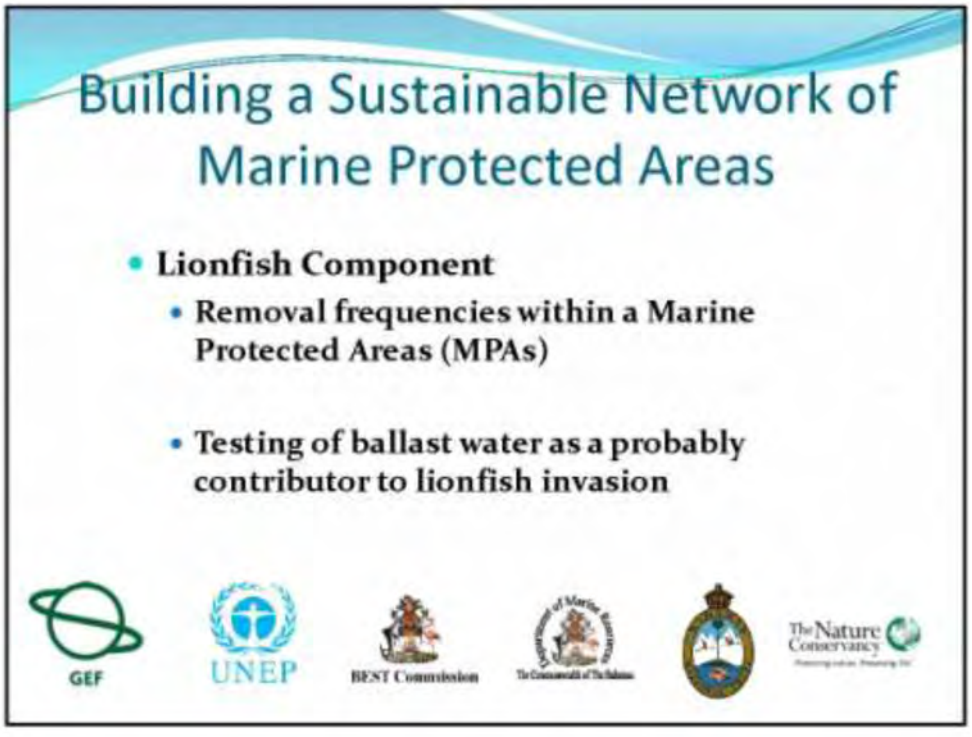
E) IMPROVE COASTAL ZONE MANAGEMENT

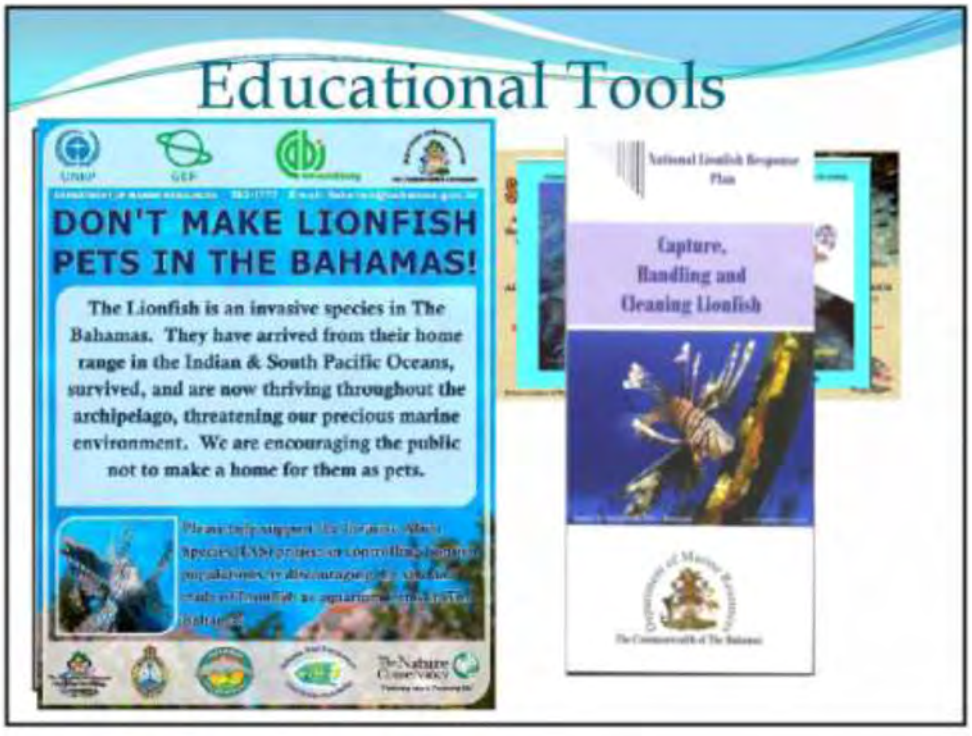
F) BAN LIONFISH AS AQUARIUM PESTS AND PREVENT THE POSSESSION OR TRANSPORT OF LIVE LIONFISH.

G) *PROVIDE A BOUNTY FOR FISH KILLED AND TURNED IN*


NLRP Workshop Results
41 participants, 16
nizations
onents of
gement
ns
handling
ars/nets)
ns on
aning &
fish
specimens
Build capacity to manage lionfish
Pictures courtesy of Stuart Cove's Dive Bahamas


Mitigating the Threats of Invasive Alien Species in the Insular Caribbean (MTIASIC)
Evaluate removal techniques and frequencies
Provide training in safe capture and handling
Conduct lionfish ecological studies to improve management
Enhance and implement policies
Enhance public awareness
Photo of Lionfish Task Team, Lad Akins
GEF
UNEP
www.cabi.org


Building a Sustainable Network of Marine Protected Areas
Lionfish Component
Removal frequencies within a Marine Protected Areas (MPAs)
Testing of ballast water as a probably contributor to lionfish invasion
GEF
UNEP
BEST Commission
The Nature Conservancy


Educational Tools
DON'T MAKE LIONFISH PETS IN THE BAHAMAS!
The Lionfish is an invasive species in The Bahamas. They have arrived from their home range in the Indian & South Pacific Oceans, survived, and are now thriving throughout the archipelago, threatening our precious marine environment. We are encouraging the public not to make a home for them as pets.
Capture, Handling and Cleaning Lionfish

Successful Outreach Initiatives

- Community Meetings major islands
- Lionfish Culinary Demos
  - Annual festivals & Expos
  - Food shows
  - Fish landing sites
  - Tournaments
- Lionfish Tournaments
  - Initiated in 2009 (1,400)
  - Conducted 13 tourneys amongst 4 islands
  - Generate funding for education & outreach

Thank you!!

Research Support

Lionfish Projects

Local Support

TESTING THE FISH INVASIVENESS SCORING KIT (FISK) AS A SCREENING TOOL FOR FLORIDA

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ABSTRACT

Interest in risk analysis for non-native freshwater fishes and other organisms is increasing. Unfortunately, complete risk analysis for a single species is data-intensive, time-consuming, and expensive. A relatively quick and simple screening process may be able to identify species as low or high risk and other species where the risk level is more moderate or uncertain. The Fish Invasiveness Scoring Kit (FISK) was developed in the United Kingdom (UK) as a screening tool to assess potential invasiveness of non-native freshwater fishes. The method is semi-quantitative and provides a scoring framework for biogeographical, historical, biological, and ecological information on a species. Higher scores indicate higher risk. We created a list of non-native freshwater fishes introduced into peninsular Florida, scored two sample species using the online FISK toolkit, and determined risk categories for each species based on original and UK-calibrated FISK. Over 120 fish species were introduced into peninsular Florida, with 33 currently reproducing. Barramundi *Lates calcarifer*, a species not introduced into open waters but used in Florida aquaculture, scored high risk in the FISK. This agreed with a recent risk assessment of the species in Florida. Nevertheless, the score was only a minimal value for high risk in the UK-calibrated FISK. Zebra danio *Danio rerio* scores were at the minimum value for "evaluate further." Previous risk assessment in Florida considered zebra danio to be very low risk. Lack of variation between two scorers for both species suggested that scorers with different levels of experience can come to a similar conclusion using FISK. Future work will evaluate the remaining species, calibrate the scoring thresholds for Florida, and develop a web-based tool of the modified Florida FISK.

INTRODUCTION

Invasive species threaten native species, natural ecosystems, agriculture and other industries, and human health (Lockwood et al. 2007). On the other hand, many non-native species provide important benefits to humans in agriculture and fisheries, and as pets. Management goals vary across different types of agencies, but a balanced management approach is to seek to reduce the negative impacts of invasives while simultaneously allowing for use of non-native species by agriculture, industries, and the public (e.g., Gozlan 2008). Distinguishing high risk from low risk species is an important management goal.

There is considerable interest in the United States and in Florida to evaluate methods and to conduct risk analysis for non-native freshwater fishes and other organisms. For example, one of the priority objectives in the *2008–2012 National Invasive Species Management Plan* (NISC 2008) was the development of screening processes to evaluate invasiveness in non-native aquatic species. Risk analysis has figured prominently in recent congressional initiatives (e.g., H.R. 669, *Non-Native Wildlife Invasion Prevention Act*, and the Senate Committee on Environment and

Public Works' July 7, 2009 hearing on "*Threats to Native Wildlife Species*"). State agencies in Florida reviewed methods through the Risk Assessment Sub-Working Group of the Florida Invasive Species Working Group, with the objective of choosing and adapting methods that work best for Florida. Subsequently, the Florida Fish and Wildlife Conservation Commission evaluated a series of non-native aquatic and terrestrial species, including full risk analyses of grass carp *Ctenopharyngodon idella* (Zajicek et al. 2009b), barramundi *Lates calcarifer* (Hill and Thompson 2008; Hardin 2009), and blue tilapia *Oreochromis aureus* (Hill 2011; Hardin et al. 2011), and of the marine ornamental trade pathway (Zajicek et al. 2009a).

The use of risk assessments and the implementation of risk management (i.e., full risk analysis) for species newly imported and those in trade are effective strategies to reduce the probability that non-native species will establish and have negative impacts (NISC 2008). Risk analysis identifies problematic species and risky activities and provides a framework for managing risks at acceptable levels (Hill 2009). Unfortunately, complete risk analysis for a single species is data-intensive, time-consuming, and expensive (Hill and Zajicek 2007). It can be beyond the resource capability of agencies or industries to evaluate a large number of species. A relatively quick and simple screening process may be able to categorize species at a coarse scale to identify those that have low or high risk and other species where the risk level is more moderate or uncertain. For species with medium or uncertain risk, a thorough evaluation of risk can be conducted as warranted by agency or industry interests. Screening tools also can be used in the initial stages of a full-risk assessment or as a component of a risk assessment scheme (e.g., RAM Committee 1996; Copp et al. 2008).

The Fish Invasiveness Scoring Kit (FISK) was developed in the United Kingdom as a screening tool to access potential invasiveness of non-native freshwater fishes (Copp et al. 2005a,b). The method was adapted from the Australian Weed Risk Assessment (WRA) model (Pheloung et al. 1999). The method is semi-quantitative and provides a scoring framework for biogeographical, historical, biological, and ecological information on a species. Higher scores indicate higher risk, and threshold values are established to categorize species as low, medium, or high risk. FISK was explicitly designed to meet international standards, such as the World Trade Organization Sanitary and Phytosanitary Agreement and the Convention on Biological Diversity, and has been incorporated as a screening mechanism under the framework of the European Non-Native Species in Aquaculture Risk Assessment Scheme (ENSARS) (Copp et al. 2008).

We are in the process of evaluating FISK for use in Florida, including its application to over 120 species of non-native freshwater fishes introduced into peninsular Florida, the calibration and adjustment of scoring thresholds as needed to accurately categorize risk of individual species, and the development of a web-based tool kit to facilitate use and further adaptation of the Florida-specific FISK. In this document, we describe preliminary stages of the overall project.

OBJECTIVES

1) Create a list of non-native freshwater fishes introduced into peninsular Florida
2) Score two sample species using the online FISK toolkit and estimate between-scorer variability
3) Determine risk categories for each species based on original and UK-calibrated FISK

MATERIALS AND METHODS

Development of List of Non-Native Fishes Introduced into Peninsular Florida

We compiled a list of all non-native freshwater fish species introduced into open waters of peninsular Florida, the portion of the state south of the Suwannee River, using the U.S. Geological Survey Nonindigenous Aquatic Species database (http://www.nas.er.usgs.gov/). This region of Florida has differences in climate, habitat, and history of non-native fish introductions from that of northern Florida and the Florida Panhandle region (Fuller et al. 1999; Hill 2002). We used Shafland et al. (2008) and expert opinion to develop a list of species reproducing in peninsular Florida.

Fish Invasiveness Scoring Kit (FISK)

The FISK is an additive spreadsheet type model available on the Internet/World Wide Web at http://www.cefas.defra.gov.uk/our-science/ecosystems-and-biodiversity/non-native-species/decision-support-tools.aspx and is described in Copp et al. (2005a,b). Answers to 49 questions are assigned a value (generally, –1 to 2) or add weighting factors for other questions. The summation of these response values produces an overall score that is correlated to the invasive risk of the assessed fish species. Each question relates to the biology, ecology, history, biogeography, or presence/absence of "undesirable" traits. Responses that are offered for each question are either categorical (yes, no, or don't know) or numerical (1 to 3) and are selected on the basis of expert opinion and scientific literature specific to the species being evaluated. Categories (aquaculture, environmental, nuisance, or combined) are assigned to each question so that the final score identifies the sector most likely to be affected. The total score for a species can range from –11 to 54. The score thresholds for the original FISK pre-screening tool are "low risk" (score < 1), "medium risk" ($1 \leq$ score ≤ 6), and "high risk" (score > 6).

The original FISK model described by Copp et al. (2005a) used the same scoring thresholds as the WRA. Copp et al. (2009) later adjusted the scoring thresholds to calibrate FISK for the United Kingdom. They also incorporated a measure of assessor uncertainty. The UK-calibrated scoring thresholds categorized non-native fish species as "low risk" (score < 1), "medium risk" ($1 \leq$ score ≤ 19), or "high risk" (score > 19). Increasing the score thresholds for high risk proved a better reflection of independent assessments of risk for the species in the United Kingdom.

Scoring Sample Species

Two sample species were chosen to begin scoring using the FISK. We chose two species that (1) we anticipated would score at the relative extremes of the scoring scale, (2) have undergone some level of risk assessment previously in Florida, and (3) have considerable literature or other available data. The first species, the barramundi, a large (up to 200 centimeters in total length), euryhaline fish from Australia, New Guinea, and Southeast Asia, is an important aquaculture and fisheries species. It has not been introduced into open waters in Florida, but was the subject of a full risk analysis conducted by the Florida Fish and Wildlife Conservation Commission due to its use in aquaculture and at a fee-fishing operation in the state (Hill and Thompson 2008; Hardin 2009). The result of the risk assessment was high risk, and additional restrictions were placed on

the possession and culture of barramundi in Florida. The second species, zebra danio *Danio rerio*, is a small-bodied (~50 millimeters in total length) fish from southern Asia that is a well-known aquarium and research fish cultured in Florida. It has been recorded in Florida waters but there is no evidence of reproduction. It was assessed by the Transgenic Aquatic Species Task Force, a scientific advisory committee for the Florida Department of Agriculture and Consumer Services, relative to the potential approval of the culture of transgenic fluorescent zebra danios. The conclusion of the qualitative risk assessment was that zebra danio was of extremely low risk for Florida. Both species were scored by two scorers (JEH and LLL). Both species were placed into risk categories described in the original and UK-calibrated FISK.

RESULTS

At least 122 species of non-native freshwater fishes from 29 families have been introduced into peninsular Florida. The three families with the most introductions are Cichlidae (cichlids | 30 species), Cyprinidae (carps and minnows | 16 species), and Poeciliidae (livebearers | 16 species). A total of 33 non-native species of 10 families have reproducing populations in peninsular Florida. The family Cichlidae (19 species) dominates in numbers of reproducing species, followed by the family Loricariidae (armored suckermouth catfishes | 4 species).

A score of 20 led to an outcome of "reject" for barramundi using both the original and the current (UK-calibrated) scoring thresholds of FISK (Table 1). A strong climate and habitat match between its native range and Florida contributed nearly 50% of the score. Undesirable attributes included large size, predatory diet, and high fecundity. A score of 1 led to an outcome of "evaluate" for zebra danio for both versions of FISK (Table 2). Small size, non-predatory diet, and aspects of the biology resulted in a low score. There was no variability in scores between the two scorers for either species.

Table 1. FISK output for barramundi *Lates calcarifer* for Florida

	Outcome:	Reject
	Score:	20
	Biogeography	9
Score partition:	**Undesirable attributes**	6
	Biology/ecology	5

Table 2. FISK output for zebra danio *Danio rerio* for Florida

	Outcome:	Evaluate
	Score:	1
	Biogeography	1
Score partition:	**Undesirable attributes**	2
	Biology/ecology	-2

CONCLUSIONS

A list of freshwater fishes introduced into peninsular Florida was developed, with literature reviews underway to provide information necessary for scoring each species. While scoring sample species so far suggests that FISK will place species in appropriate positions along the risk scale relative to one another, it also suggests that scoring thresholds may require calibration.

The score for barramundi was well within the category of high risk for the original FISK but had only a minimal score for high risk in the UK-calibrated FISK. We anticipated a higher score based on a previous risk analysis for Florida. During Florida's risk analysis, most assessors considered the risk of escape from the small aquaculture industry and establishment of barramundi to be low, but rated environmental risks high if the species were established (Hardin 2009). In particular, the strong climate and habitat match, large body size, and predatory diet, coupled with high ecological similarity to an important native fisheries species, the common snook *Centropomus undecimalis*, drove the risk estimates. The first three factors contributed considerably to the FISK score. Nevertheless, FISK also strongly weights previous history of invasiveness. Based on barramundi risk, there are no data suggesting negative impacts.

The FISK returned a score that indicated either medium risk or evaluate further for zebra danio, although the score was minimal for the category for both versions of FISK. Members of the Transgenic Aquatic Species Task Force in Florida considered the zebra danio to be very low risk. Indeed, the committee acknowledged the potential for establishment due to a match between the native climate and Florida, yet still estimated the risk of establishment to be very low, and described the species as one of the ecologically least risky species if establishment occurred. Characteristics of the zebra danio that contributed to the FISK score included use in aquaculture and aquarium industries, short generation time, and environmental tolerance.

The lack of variation between the two scorers suggests that scorers of differing experience with risk assessment, non-native fishes, and Florida's environment can arrive at a similar conclusion of risk using the FISK method. One scorer has over 15 years of experience with non-native fishes in Florida and has been involved in several risk assessments of fish or aquatic introduction pathways. The other scorer has about 1 year of experience. The ability of assessors with differing experience to arrive at the same answer is an important attribute of successful risk assessment.

Future research includes completion of the species literature reviews and scoring of species (4 scorers), calibration of scoring thresholds, and modifications to questions or scoring. Upon completion, the web-based Florida FISK will provide a tool for natural resource managers and regulators to screen species newly proposed for culture or importation but not yet introduced into Florida's environment and to integrate into existing risk analysis protocols.

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ACCURACY OF A MODIFIED NEW ZEALAND AQUATIC WEED RISK ASSESSMENT FOR THE UNITED STATES

Alison Higgins, Chair, Caribbean/Florida Fire and Invasives Learning Network, The Nature Convervancy, Florida USA. Email: ahiggins@tnc.org.

Australian Weed Risk Assessment

- 49 questions
  - Domestication / Cultivation
  - Climate / Distribution
  - Weed elsewhere
  - Undesirable traits
  - Plant type → [illegible]
  - Reproduction
  - Dispersal mechanisms
  - Persistence attributes

  History / Biogeography

  Biology / Ecology
- WRA score
  - < 1 → Accept: not invasive
  - > 6 → [illegible]: invasive
  - 1-6 → Evaluate further

Australian Weed Risk Assessment

(Pheloung et al. 1999)

- Across multiple geographies, tests for terrestrial vascular plant species (Gordon et al. 2008):
  - 90% accurate in identifying major invaders
  - 70% accurate in identifying non-invaders
  - 10-15% required further evaluation
- Forms partial basis for USDA APHIS PPQ plant risk assessments
- But: 5 points for aquatic species
  → highly precautionary
- No questions specific to aquatic systems

Species tested

149 non-native aquatic plant species:

- 33 major invaders (documented impacts outside range or naturalized in ≥ 6 countries)
- 32 minor invaders (naturalized in <6 countries)
- 84 non-invaders (in trade but not naturalized in continental U.S.)
- 55 families
- 5 growth forms: attached-floating, erect emergent, free-floating, sprawling emergent, submerged
- All species in U.S. for at least 30 years

AU WRA modified for US

(Gordon & Gantz 2011)

	Reject > 6	*Accept < 1*	*Evaluate 1-6*	Total # Species
Major Invader	100% (33)	0	0	33
Minor Invader	94% (30)	0	6% (2)	32
Non-invader	83% (70)	1% (1)	16% (13)	84
Correctly predicted				33% (34/104)

New Zealand Aquatic Plant Risk Assessment

(Champion & Clayton 2000, 2001)

- Scores for a number of biological, historical, environmental tolerance, impact, and management questions result in a total score for each species
- Used in New Zealand for regulatory and management decisions
- Modified for use in eastern Australia and Micronesia

Modifications to New Zealand approach

- Added specification of the data needed for U.S. and regional (FL, Great Lakes) applications
- Added default scoring rules where appropriate
- Added identification of confidence in the data source
  - Scientific journals
  - Website
  - Inference
  - Default
- Removed need for experimental tests

Aquatic Plant Risk Assessment (AqWRA)

38 questions in 12 categories with scores summed

- Climate/distribution
- Invasiveness elsewhere

} History/Biogeography

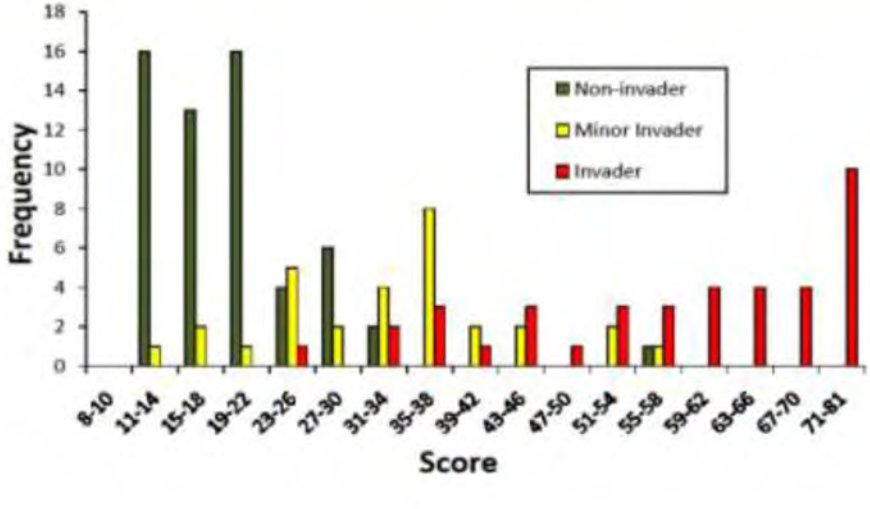
- Habitat breadth
- Potential for spread
- Generation time
- Reproductive capacity
- Competitive ability
- Impacts to water flow
- Impacts to water chemistry
- Impacts to native systems
- Other negative impacts
- Response to management

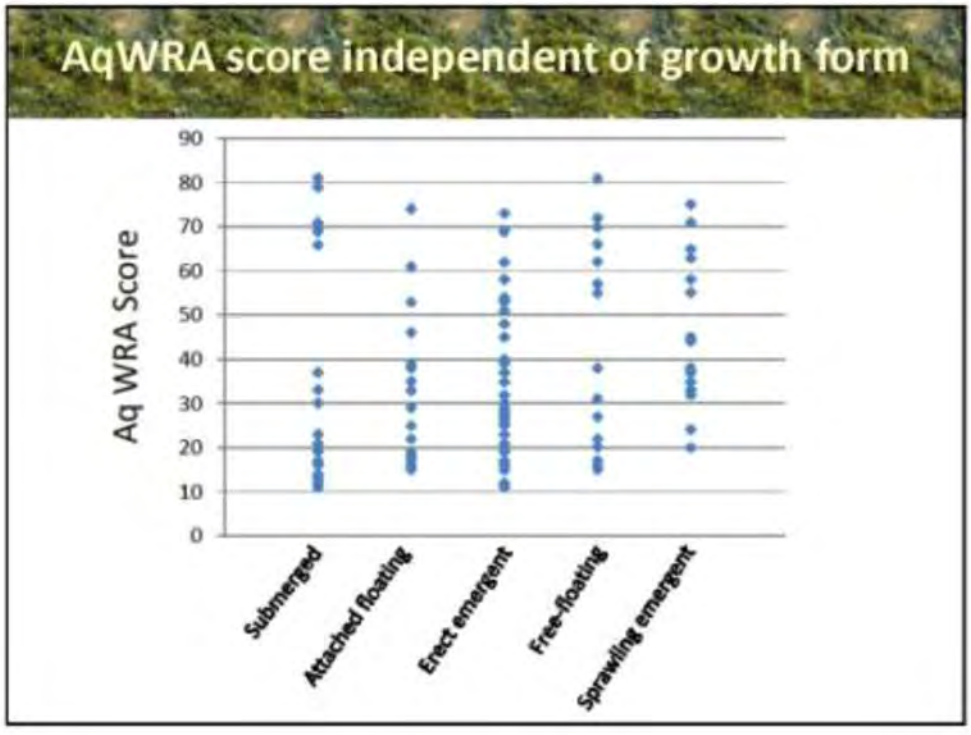
} Biology/Ecology

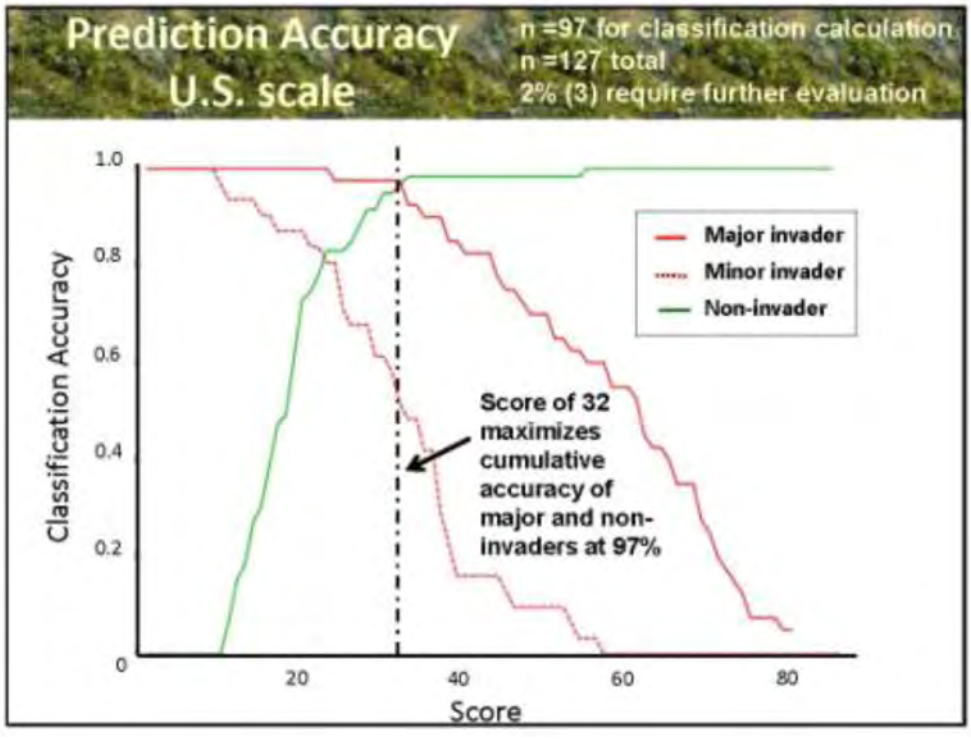
AqWRA score

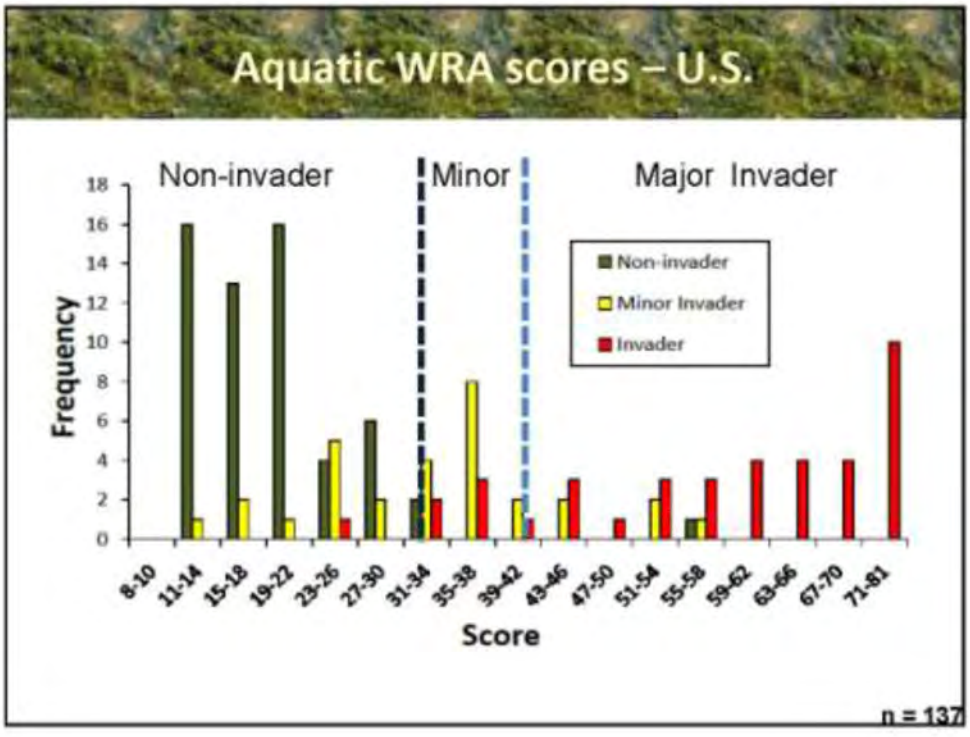
- Range of possible scores 3 to 91
- Empirically determined thresholds for identifying invaders

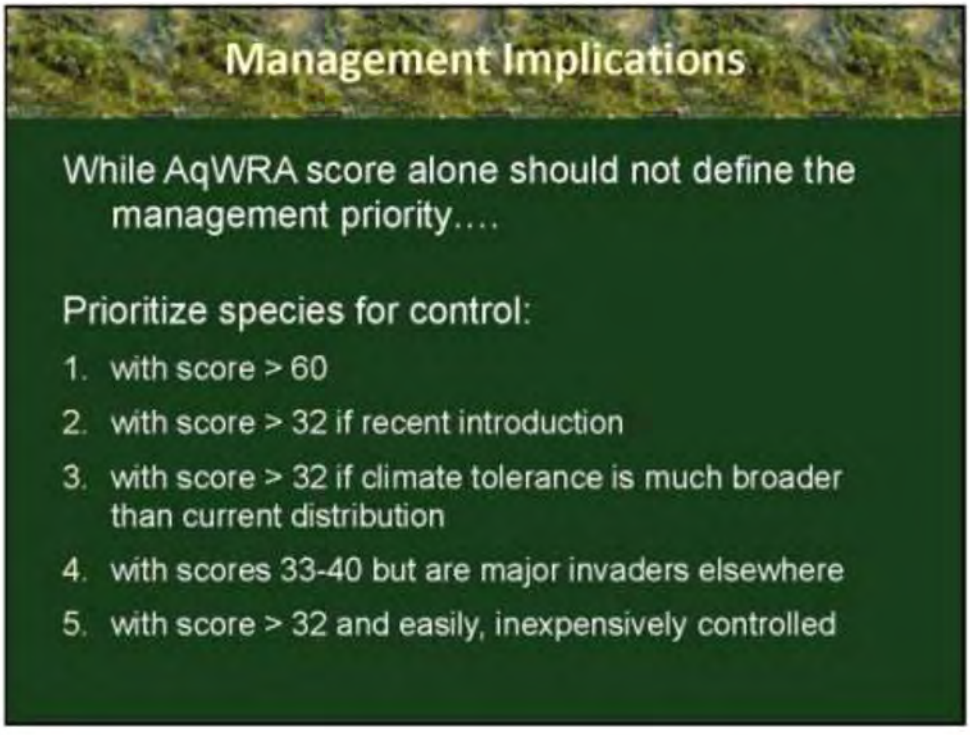
Aquatic WRA scores – U.S.

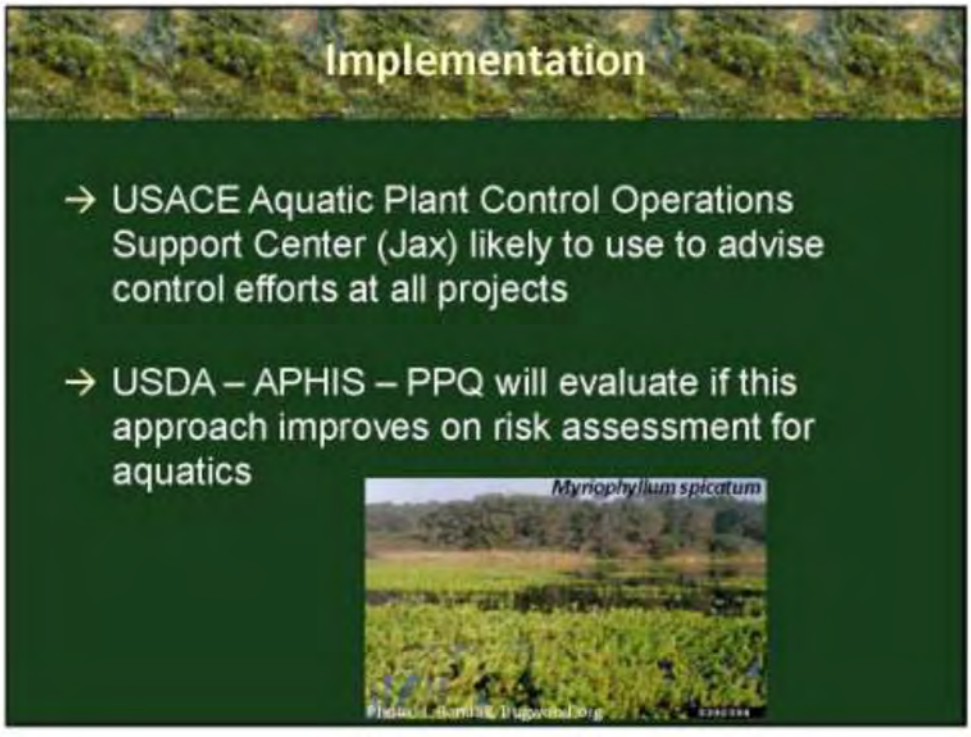



AqWRA score independent of growth form
Aq WRA Score
90
80
70
60
50
40
30
20
10
0
Submerged
Attached floating
Erect emergent
Free-floating
Sprawling emergent


Prediction Accuracy
U.S. scale
n =97 for classification calculation
n =127 total
2% (3) require further evaluation
Classification Accuracy
1.0
0.8
0.6
0.4
0.2
0
20
40
60
80
Score
Major invader
Minor invader
Non-invader
Score of 32 maximizes cumulative accuracy of major and non-invaders at 97%


Aquatic WRA scores – U.S.
Non-invader
Minor
Major Invader
Non-invader
Minor Invader
Invader
Frequency
Score
8-10
11-14
15-18
19-22
23-26
27-30
31-34
35-38
39-42
43-46
47-50
51-54
55-58
59-62
63-66
67-70
71-81
n = 137


Management Implications
While AqWRA score alone should not define the management priority....
Prioritize species for control:
1. with score > 60
2. with score > 32 if recent introduction
3. with score > 32 if climate tolerance is much broader than current distribution
4. with scores 33-40 but are major invaders elsewhere
5. with score > 32 and easily, inexpensively controlled


Implementation
→ USACE Aquatic Plant Control Operations Support Center (Jax) likely to use to advise control efforts at all projects
→ USDA – APHIS – PPQ will evaluate if this approach improves on risk assessment for aquatics
Myriophyllum spicatum

TRADE IN PET, AQARIUM, AND TERRARIUM SPECIES AS A SIGNIFICANT SOURCE OF INVASIVE ALIEN SPECIES IN THE WIDER CARIBBEAN REGION

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ABSTRACT

A wide range of pets, including aquarium and terrarium species, as well as associated organisms, are available via numerous formal, informal, poorly-regulated, or even illegal outlets. Once present in a country, escapes and even deliberate releases are likely to occur. If freed pets become established in the area, they frequently turn invasive. In the Caribbean, internet trade easily eludes proper procedures, and the sheer volume of exotic pets kept, traded, or released in Florida represents a threatening source for invasive alien species (IAS) for the Wider Caribbean Region (WCR). The negative impact can be via predation, competition, habitat alteration, hybridization, vectoring of animal pathogens or parasites (aggravated by shared facilities in trade hubs), zoonoses, and interference with human activity or infrastructure. These mechanisms have led to extinctions of previously rare endemic species in the WCR and continue to threaten others. Examples of IAS originating from the pet trade span across terrestrial, marine, and freshwater species, including plants and live feed for the aquarium trade, as well as bird seeds. Aquatic organisms and increasing outbreaks of zoonoses are particularly problematic. Only a few international standards address risks of invasions associated with the pet trade and only for specific taxa, that is, the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES), the International Plant Protection Convention (IPPC), and the World Organisation for Animal Health (OIE). This gap is now being addressed by an ad hoc Technical Expert Group under the Convention of Biological Diversity (CBD). Existing and incipient preventative tools include pre-importation measures (i.e., importation bans and post-importation measures) that focus on the prevention of release/escape or reproduction of IAS. Their successful deployment invariably involves close collaboration between the government and the private sector, coupled with public involvement and broad-based awareness-raising.

PET TRADE AS AN IAS PATHWAY WITH MULTIPLE SERIOUS IMPACTS

Pets, including aquarium and terrarium species, are animals kept for personal amusement or companionship. Pet-keeping has become popular across the WCR, with particularly the urban young being increasingly interested in exotic and/or unusual pets. A survey by John (2001) indicated interest by Saint Lucias in keeping the native boa (*Boa constrictor*), the red-kneed tortoise (*Geochelone carbonaria*), iguana (native and alien), and local pigeons and doves as pets. Throughout the WCR, Florida (United States) is a prolific source of IAS, including pets and associated taxa, given the sheer volume of species traded through this hub and the number of animals and ornamental plants released there into the wild (Simberloff et al. 1997). Pet feed, such as exotic plant seeds, crickets (Orthoptera), and viable brine shrimp (*Artemia franciscana*), can also exhibit invasive behavior once discarded. Brine shrimp are even marketed online as complete science experimental kits (Figure 1), with some companies offering global shipping.

Figure 1: Brine shrimp (*Artemia franciscana*) kits are marketed online as a unique "grow your own dinosaur babies" experience. Source: http://sciencecastle.com

Growing globalization has been accompanied by the mushrooming of one-stop shopping centers and malls at the expense of specialist retail outlets where expert advice is available. In today's urban areas, a wide range of pet species and accessories, including plants and live feed, are sold in markets, garden centers, and supermarkets. On small Caribbean islands, where total pet trade volume is often below critical mass for specialist commercialization; internet trade; and informal breeding by private individuals for sale, trade, and exchange, are of importance. These pathways are poorly regulated and law enforcement is often impractical. This is complicated by the fact that suppliers often misidentify the species provided (SCBD 2010). In fact, internet trade has brought an almost unlimited variety of exotic life forms within the universal reach by a mouse-click: aquatic rarities, insects, molluscs, exotic mammals, ornamental plants and seeds, together with their parasites, pests, and pathogens. Because many of these organisms are known to be potentially invasive if set free, internet trade represents a marked risk as source of illegally imported alien species.

Once an alien species has been introduced to a new country, there is no such thing as zero risk of escape or release (SCBD 2010). Pets can escape accidentally or be released deliberately because their owners no longer can or want to look after them. *Owners often underestimate the longevity or requirements for space and care*. Misguided sympathy makes matters worse when animals are released into nature reserves in an attempt to provide them with a comfortable habitat. If conditions are conducive and the released species survives, it may affect the native biodiversity at the most vulnerable locations of highest conservation value, where potential damage is greatest. Examples of a range of devastating impacts exist across Caribbean terrestrial, marine, and freshwater ecosystems and encompass:

- Predation Feral cats (Figure 2) and dogs have a severe impact on the indigenous terrestrial fauna of many countries. Even waterfowl and marine turtles fall victims in coastal areas. Feral cats are one of the main biological factors causing the decline and extinction of birds and small reptiles. Of the 625 birds threatened globally because of IAS, cats are responsible for 174 cases (BirdLife International 2008a). Of the 134 bird species that are confirmed to have gone extinct since 1500, 71 cases are attributed to IAS, with nearly half of the (34) to cats (BirdLife International 2008b).

  In the Caribbean Sea, the Indo-Pacific lionfish (*Pterois volitans* and *P. miles*) is a ferocious predator of unsuspecting coral fish. The spectacularly decorative lionfish is an attraction in many private and public aquaria in the New World. Its insatiable appetite for other fish, large size, and venomous spines render it an expensive and challenging pet. Deliberate releases and accidental escapes have been blamed for the Caribbean invasion (Betancur-R. et al. 2011; Schofield 2010).

Figure 2. While domestic cats are poplar pets worldwide, feral cats are one of the main factors causing the decline and extinction of birds and small reptiles
Source: http://en.wikipedia.org/wiki/Feral_cat

In freshwater ecosystems, the red-eared slider (*Trachemys scripta elegans*, Figure 3) preys on small waterfowl, fish, amphibians, and invertebrates. Its robustness is a two-edged sword: this uncomplicated terrapin enjoys great popularity, particularly as a first pet for inexperienced children; at the same time, its remarkable ability to adapt to a range of climates and to invade novel habitats renders it a top IAS. Between 1989 and 1997, over 52 million red-eared sliders were exported from its North American origin to foreign markets. Given its longevity (up to 40 years) as well as invasive and destructive history, imports of *T. scripta elegans* into the European Union have been banned. Numerous Caribbean countries have been impacted (GISD 2010).

Figure 3: Red-eared sliders (Trachemys scripta elegans) make robust pets. An owner who is not prepared to care for them throughout their long lives (≤ 40 years) and releases them into the wild may cause severe ecological impact by this strong, omnivorous competitor.
Source: http://www.wormsandgermsblog.com

Photo: Riccardo Scalera,
http://www.issg.org/database

- Competition with native fauna for food and habitat. The omnivorous red-eared slider feeds on plants and animals alike, thereby competing with native terrapins. Its basking behavior (Figure 1) impacts nesting water birds: if nests get pushed into the water, eggs are killed.

  The tropical macroalgae *Caulerpa taxifolia* is a popular aquarium ornamental. A cold-tolerant aquarium strain, which is believed to have been discarded from a Monaco aquarium, is now highly invasive in Europe, smothering other algal species, sea grasses, and sessile invertebrate communities in the Mediterranean Sea by a combination of competition and toxicity (Lowe et al. 2000).

- Modification of native flora: Herbivorous feral pets can alter floral composition directly through feeding pressure or propagule dissemination, or indirectly either through impacting native herbivores or through rough competition by accessory plants and feed (GISD 2010).

  The lionfish impacts herbivorous fish populations to the extent that the marine floral composition is altered (Lesser and Slattery 2011). In Hawaii, 37% of the major weed species are dispersed by introduced birds. Parrots may fly up to 30 miles in the course of a day, spreading invasive plants high into the rain forest (Fox 2011). These include infamous *Miconia*, *Clidemia* and *Ficus* species. Hanson and Mason (1985) published a list of 435 plant species believed to have been introduced into the United Kingdom as bird feed with viable seeds. Australia learned from that experience, making gamma-radiation of bird seeds compulsory to release imports from quarantine.

- Hybridization can eliminate genetic uniqueness of island endemics, as is the case with green iguanas (*Iguana iguana*), a popular pet of South and Central American origin, which has given rise to fertile offspring with the Lesser Antillean Iguana (*Iguana delicatissima)* in the French West Indies, diluting the gene pool of I. *delicatissima* (Rodrigues in press). The same risk is looming on Saint Lucia, where efforts are underway to eradicate the alien green iguana while its population is still spatially separate from the Saint Lucian iguana (*Iguana* cf. *iguana*), whose taxonomy is still poorly defined (Morton and Krauss 2011).

- Vectoring of animal pathogens or parasites: The fungus *Batrachochytrium dendrobatidis* causes chytridiomycosis in at least 12 amphibian families, leading to death within 10 to 18 days. Chytridiomycosis has brought endemic Caribbean species, for example, the mountain chicken (*Leptodactylus fallax*), to the verge of extinction (Daltry 2009). The pathogen is thought to have been spread principally thought the pet trade, for example, with Africa clawed frogs (*Xenopus* spp.).

  Of the 134 bird species that are confirmed to have gone extinct since 1500, 16 are being attributed to diseases caused by introduced pathogens (BirdLife International 2008b). At least 10 native Hawaiian bird species went extinct due to avian malaria, which was introduced by early settlers with their pet birds that possessed co-evolved resistance to the malaria parasite, *Plasmodium relictum* (Lowe et al. 2000). In the insular Caribbean, tests for two viral diseases, avian influenza and Newcastle disease, are performed on imported wild birds, but only 30% of countries implement quarantine for imported birds (FAO 2011).

- Zoonoses: Several reptiles are known to be carriers of Lyme disease, heartwater, babesiosis, and *Salmonella* bacteria, and have been linked to cross-infection in other domestic or farm animals and to zoonoses, that is, disease transmission from animals to humans (SCBD 2010). In fact, most newly emerging infectious diseases are zoonoses that often have their origin in the international trade of wild animals, particularly those taken directly from the wild.

  In 2003, 40 people in the United States contracted Monkey Pox from African rats imported as pets from the wild via cross-infection of indigenous prairie dogs housed in the same facility. Severe Acute Respiratory Syndrome (SARS) is caused by a coronavirus associated with the trade in small carnivores, especially civets. A 2003 outbreak killed at least 774 people worldwide and cost tens of billions of US dollars (SCBD 2010).

  These examples illustrate how stores and trading hubs create unnatural opportunities for animals from different parts of the world to meet and exchange parasites and pathogens. This was also the case when avian influenza was reported in a Surinamese parrot, sending alarm signals to veterinarians and conservationists throughout the world (Associated Press 2005). In reality, the healthy animal had been taken to the United Kingdom and housed in the same quarantine facility with pet birds from Asia that were carriers of the H1N1 viral strain and passed the deadly infection to the South American bird.

- Interference with human activity and infrastructure: The burrowing habit of the green iguana renders it a nuisance species in urban Florida. Also, at the Puerto Rico airport, they are reported to be posing a collision hazard on the runway (Morton and Krauss 2011).

  Water thyme (*Hydrilla verticillata),* an aquarium ornamental plant native to Asia and Africa, grows vigorously at the water surface, excluding sunlight from other plants and reducing aquatic plant and animal biodiversity in many countries. The dense mats also affect commercial and recreational activities.

INTERNAIONAL REGULATORY FRAMEWORK AND MULTILATERAL ENVIRONMENTAL AGREEMENT

Only a few international standards address risks of invasions associated with the pet trade and only for specific cases:

- Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) regulates the trade of endangered animals and plants. A permit system and genetic barcoding aid in monitoring their movement, the focus is on endangered species, not invasives.

- International Plant Protection Convention (IPPC), with its International Sanitary and Phytosanitary Measures (ISPMs), applies to organisms that are plant pests, including some weedy plants. However, taxa that do not impact plant health are not within the ISPM remit.

- World Organisation for Animal Health (OIE) develops standards to minimize the transfer of zoonotic diseases by restricting the movement of live animals and fish. In 2010, OIE published a review on animals as invasive species that goes far beyond OIE's original veterinary mandate (Pastoret and Moutou 2010).

Although the pathway of introducing alien species as pets (aquarium and terrarium species) remains a gap of national and international regulatory frameworks, some recent initiatives try to close this gap, most notably, the ad hoc Technical Expert Group (AHTEG) of the the Convention of Biological Diversity (CBD), and the Working Group on E-commerce of Specimens of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) that is developing a toolkit to monitor the sale/purchase of CITES-listed species on the internet.

AVAILABLE AND INCIPIENT MANAGEMENT TOOLS

Prevention is the approach of choice, with two principal avenues: (1) prevention of species importation and (2) prevention of release or escape. The latter can further be subdivided into prevention of release and prevention of reproduction (Table 1).

National legislation is required to regulate pre-import steps and reduce the risk of escape/release post-introduction. However, when a country restricts imports of a species, this could be challenged by other countries questioning whether this would be in agreement with the SPS Agreement of the World Trade Organization (WTO). Thus, the decision of whether or not to permit the importation of a species must be science-based. Risk assessments are the main tool to determine the risk of an imported species becoming invasive. In the Americas, the invasive species thematic network (I3N) of the Inter-American Biodiversity Information Network (IABIN) developed a user-friendly Analysis of Invasion Tool and Vector Analysis Pathways Tool covering terrestrial vertebrates, fish, and vascular plants, along with a climate matching module (http://i3n.iabin.net/tools/web_tools.html). A number of countries have developed their own modules, based on national priorities (Simons and De Poorter 2009).

As important as solid legislation is, trade restrictions are unpopular with both public and commercial enterprises. Furthermore, bans do not encourage the improvement of practices and may become counterproductive if they are not efficiently enforced. Thus, current best practices on managing the pet trade as an IAS pathway invariably involve collaboration between the government, the private sector, and experts who conduct science-based and transparent risk assessments. In fact, many initiatives are driven by self-regulation and voluntary measures that also aid the professional image, thereby creating a win-win situation. Policy-makers could support the partnership by incentivizing safer pet trade and ownership practices. Various taxation and polluter-pays models are available to fund interventions, but have not yet been adequately exploited (Perry and Farmer 2011).

Table 1: Preventative measures to manage the pet trade as pathway for invasive alien species

Tool	**Pre-importation**	**Post-importation: Prevention of Release/Escape or Reproduction**
Risk Assessment	I3N IABIN Risk Assessment tool for aquatic and terrestrial animals	
Black lists of prohibited species	Not comprehensive but case-specific (e.g., prohibition of civet imports as a precaution against SARS outbreaks) Monitoring prime online auction sites to remove illegal items	Amnesty to register and keep individuals of recently prohibited species that were procured prior to prohibition, even if not through the official channels
White lists indicate species that may be imported	Import is prohibited until risk assessment shows import is of no concern (e.g., EU white list for aquaculture)	
Customer licensing and record-keeping	Green lists provide information on species that require a license to deter casual pet ownership CITES toolkit offers standard for development of electronic permit system for international wildlife trade	Animal labeling; unique characteristics Amnesty days for existing keepers to register Obligation to microchip pets and maintain license as effective releases prevention Requirement of CITES-listed species to be identified using DNA barcoding
Public awareness and stakeholder involvement, including • Voluntary measures by private sector • Public-Private Partnerships (PPPs)	Influences demand and increases the effectiveness of pre-import risk assessment of live animals May precede formal risk assessment and regulations, especially where capacity is low Self-regulation paralleling regulatory framework Animal inspections, transport measures Proper quarantine, sanitation, and pest control practices	Ecology and potential risk awareness, (e.g., recognition aids by Center for Aquatic and Invasive Plants, University of Florida) Post-import inspections, acclimation, and quarantines (e.g., US National Reptile Improvement Plan Housing, packaging, and handling (e.g., FAO Biosecurity Toolkit) Triploids or Same-Sex Stores Spay & neuter programs Voluntary codes of conduct, Codes of Ethics Care sheets Public education/technical support campaigns (e.g., *Habitattitude* and *BD-free phibs*) Training Hazard Analysis Critical Control Point (HACCP)-based approaches
Re-homing programs		Re-homing of unwanted pets
Pet-sitting programs		Pet-sitting services to assist keepers
Non-viable feed propagules	Gamma radiation of bird seeds compulsory to release quarantined imports in Australia	Canned crickets are now widely available as alternative to live food
Sources: Invasive Plant Council of British Colombia, Canada (2008), Reaser (2011), SCBD (2010, 2011), Simons and De Poorter (2009), and Alison Higgins (personal communication 2011). For further detail**:** National Invasive Species Information Center, National Agricultural Library, USDA (http://www.invasivespeciesinfo.gov/resources/main.shtml); Pet Industry Joint Advisory Council (PIJAC; http://www.pijac.org/); Pet Pathway Toolkit (http://www.petpathwaytoolkit.com/index.html).		

Public-Private-Partnerships (PPPs) work best when coupled with public awareness campaigns and involvement of local communities. The development of voluntary codes of conduct (VCoCs), as well as certification schemes, are instrumental in both self-regulating the industry and raising public awareness (Reaser 2011). In the Caribbean, Anguilla (Connor 2008) and the Bahamas (BEST Commission 2003), in their National Invasive Species Strategies (NISS), have adopted identical VCoCs for the following:

- Zoos and Aquaria
- Farms (agricultural and aquacultural)
- Pet Stores, Breeders, and Dealers
- Pet Owners
- Veterinarians

This is also exemplary in terms of regional harmonization.

Once a species has been imported for the pet trade, a risk of escape/release has been created. The magnitude of this risk, however, can be manipulated. VCoCs have been used to involve the private sector in awareness-raising of their clientele, thereby reducing the risk of pets being released or abandoned. For example, the Ornamental Fish International (OFI) publishes care sheets (OFI has 190 members in 44 countries worldwide and is committed to the OFI Code of Ethics). Similarly, the Ornamental Aquatic Trade Association (OATA) in the United Kingdom prints the statement that "ornamental fish and plants bought for aquariums and ponds must never be released into the wild" on over 2 million fish retail plastic bags annually. Two campaigns by the Pet Industry Advisory Council (PIJAC) in the United States have excellent outreach, also via the internet (*Habitattitude* at http://www.habitattitude.net/ and *BD-free 'Phibs* at http://www.pijac.org/projects/project.asp?p=26). The Marine Aquarium Council (MAC) is an international association of conservation organizations, the aquarium industry, public aquariums, hobbyist groups, and government agencies. MAC promotes responsible and sustainable marine aquarium trade and the certification of best practices. MAC's Handling, Husbandry, and Transport (HHT) International Standard ensures segregation from uncertified organisms, optimal health, and proper documentation during export, import, and retail sales. Organisms sold as MAC-certified must be handled only by MAC Certified professionals, facilities, exporters, and retailers. This is very similar to the Hazard Analysis Critical Control Point (HACCP)-based approaches.

Once a pet species has been freed, early detection and rapid response are essential if eradication is to prevent a full-fletched invasion. Free hotlines and/or bounties encourage reporting of sightings. Recording Invasive Species Counts (RISC) of the Non-Native Species Secretariat (NNSS) in the United Kingdom enables anyone to submit an observation/record, including uploading photos, of an animal or plant listed by the experts as invasive. The Aquatic Plant Information Retrieval System (APIRS) database at the Institute of Food and Agricultural Sciences, University of Florida (UF/IFAS) provides free information on aquatic weeds. After successful eradication, restoration is often attempted. Because eradication of aquatic organisms is nearly always impossible, containment in a certain area or watershed may be an option.

CONCLUSIONS AND FUTURE DIRECTION

Much work remains to be done in bringing the management level of the pet trade, including aquarium and terrarium species, to the standards of most other major IAS pathways. One well-recognized weakness lies in the international legislative framework, which is presently being addressed through a CBD AHTEG. However, numerous tools are already available for prevention, as well as mitigating a negative impact. Many of these are applicable to the WCR, some even spear-headed by the WCR. Their successful deployment invariably involves collaboration between the government and the private sector, coupled with public education and involvement. The joint development of VCoCs, as well as certification schemes, are instrumental in self-regulating the industry and raising public awareness.

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SESSION 4: RESEARCH ADVANCES IN COPING WITH EMERGING INVASIVE SPECIES IN THE GREATER CARIBBEAN

IMPROVED DISEASE DIAGNOSIS: DEVELOPMENT OF A NOVEL MOLECULAR TECHNIQUE FOR THE DETECTION AND IDENTIFICATION OF PLANT PATHOGENS IN HOST TISSUE

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ABSTRACT

The detection and identification of economically important plant pathogens is of paramount importance in Florida and the Caribbean region. Invasive pathogens are particularly grave threats, as exemplified by the recent establishment of citrus canker, soybean rust, citrus greening, texas phoenix palm decline, and laurel wilt diseases in Florida. Accurate and rapid identification of such threats is fundamental to protecting agriculture in Florida, the United States, and Puerto Rico. This research is designed to increase the diagnostic capacity to reduce and possibly eliminate the harmful effects of such invasive species as listed above that have invaded the region or are a future threat to the region, and adversely affect production agriculture and the natural environment. Plant diagnostics play a crucial role in agriculture and ultimately impact society as a whole. Plant diagnosticians face numerous challenging situations, most of which have a major economic impact, such as diagnosing a non-endemic potentially invasive pathogen at a port of entry. In some instances, there may be life-threatening situations like identifying a poisonous plant or mushroom that was eaten by human or animal. Whatever the case may be, possessing the capability to provide clientele with accurate and reliable diagnoses should be a high priority for all diagnostic laboratories. Therefore, we present a novel PCR technique that, when used correctly, can detect and amplify plant pathogenic DNA directly from host tissue that is several orders of magnitude more sensitive than the Standard PCR. The potential use of the High-Fidelity PCR in routine plant diagnostics is readily obtainable, requiring the same equipment and expense used for the Standard PCR. This new technology has the potential to be developed into a diagnostic tool with unprecedented sensitivity and power to protect agriculture.

INTRODUCTION

Eighty percent of the cut flowers and propagative plant materials that enter the United States arrive in Florida as air cargo, and the volume of perishable products imported into the state has doubled every six years. In 2007, the plant inspection station at the Port of Miami (Florida) processed 74% of all plants imported into the United States, making it the busiest port in the nation. These plants represent many different parts of the world, including the tropics (AQAS Database, USDA/APHIS PPQ 2008). Thus, it is not surprising that the "Florida Pathway" is by

far the most important route of entry for high-risk pathogens and pests into the United States; no fewer than 4–5 introductions of significant plant pathogens occur each year in Florida. Puerto Rico is an important port of entry for agricultural commodities in the Caribbean, as well as a major exporter of propagative plant materials and agricultural products from the United States. Although figures are not available, the Commonwealth is also an important point of entry for new pathogens and pests.

The introduction of significant numbers of plant pathogens into Florida and Puerto Rico go unrecognized due to limitations in visual and current molecular protocols to identify regulated species. The plant diagnostic clinic at the University of Puerto Rico receives on average 100 samples from various crops every month, only 5% of those samples are sequenced for species identification. Another 10% of the samples are diagnosed as unknown etiology and remain unidentified. While numerous plant diagnostic samples processed by clinics within the Florida Plant Diagnostic Network are diagnosed as "no pathogens found" (Palmateer, personal communication), some of these samples may in fact be infected by a pathogen, thus emphasizing the need for more sensitive and effective measures for plant diagnostics.

Although a plant may exhibit symptoms that indicate the presence of a bacterial, fungal, or viral pathogen, in many cases no such symptoms exist, even though the pathogen may still be present in a latent state and go undetected by plant inspectors and diagnosticians. Environmental factors such as temperature and moisture are extremely critical in the disease process and more often than not pathogens remain dormant in plant tissue (Swanson et al. 2007). During this phase of dormancy, it can be very difficult to isolate the pathogen using conventional diagnostic methods (i.e., tissue plating on artificial media), which may lead to a misidentification due to the presence of secondary fungi and bacteria or false negatives, either of which could be catastrophic in situations involving select agents. In addition, many pathogens are obligate parasites and cannot be cultured on artificial media, thus requiring molecular diagnostic techniques like the Polymerase Chain Reaction (PCR) for confirmation. However, plant cellular contents (organic and inorganic compounds), including host genomic DNA, can interfere with the efficiency of Standard PCR (Vickers and Graham 1996; Vincelli and Tisserat 2008; Wilson 1997), making the diagnosis of plant disease directly from plant tissue using the PCR extremely difficult and one of the most common limiting factors for obtaining accurate results.

The polymerase chain reaction (PCR) has become widely used since the discovery (Chien, Edgar, and Trela 1976) and subsequent use of heat-stable DNA polymerase for in vitro replication of DNA (Saiki et al. 1988). This alleviated the tedious task of adding fresh DNA polymerase at the beginning of each PCR cycle (Mullis and Faloona 1987), which led to the automation of the procedure through the production of programmable thermocyclers. The PCR is now used routinely to amplify DNA for phylogenetic studies (Chaverri, Samuels, and Hodge 2005; Dettman, Jacobson, and Taylor 2006; Stewart et al. 1999; Crous, Kang, and Braun 2001; Palmateer, McLean, and Morgan-Jones 2003), genomic analysis (Arneson, Hughes, Houlston, and Done. 2008; Nadeau et al. 1992; Lashkari, McCusker, and Davis 1997), and plant disease diagnosis (Yokomi et al. 2008; Trout et al. 1997), and is used to examine genetic diversity within populations of plant pathogens (Zhang, Fernando, and Remphrey 2005; Urena-Padilla et al. 2002; Winton, Hansen, and Stone 2006). However, the Standard PCR is not efficient at producing long sequences, and is generally unable to produce sequences of more than 5 kb

(Barnes 1994). The High-Fidelity PCR (=Long PCR), which incorporates a second heat-stable DNA polymerase with 3'-exonuclease activity, has been shown to produce longer sequences than Standard PCR, with a product size of up to 35-kb (Barnes 1994). The addition of the proofreading enzyme to the reaction containing an n-terminal deletion mutant of *Taq* polymerase was shown by Barnes (1994) to remove mismatched base pairs, allowing strand synthesis to proceed. The use of the proofreading enzyme alone did not amplify the target DNA, which may have occurred because of the degradation of the primers by the 3'-exonuclease activity of the enzyme when used in excessive amounts (Barnes 1994).

In addition to producing longer sequences than the Standard PCR, the High-Fidelity PCR has been shown to efficiently amplify target DNA while in the presence of large amounts of genomic DNA, which can be from a host organism or from the target organism. Vickers and Graham (1996) were able to use a High-Fidelity PCR protocol utilizing a DNA polymerase mixture containing *Taq* polymerase and a heat-stable DNA polymerase with proofreading ability *(Pwo)* to amplify a single copy gene (*Bar*), a marker for the selection of transgenic plants, while in the presence of Barley genomic DNA. The High-Fidelity PCR consistently amplified the target gene, while the Standard PCR only occasionally produced results. The High-Fidelity PCR has also been shown to detect bacterial infections and microbial associations in numerous arthropod species. Jeyaprakash and Hoy (2000) demonstrated that the High-Fidelity PCR was more sensitive than the Standard PCR in detecting *Wolbachia* infections in arthropods. When plasmids containing the *wsp* gene were amplified while in the presence of arthropod DNA, the High-Fidelity PCR consistently amplified 1 fg of plasmid DNA containing the *wsp* gene while the Standard PCR could detect 1 ng of plamid.

Hoy, Jeyaprakash, and Nguyen. (2001) also showed that High-Fidelity PCR was more sensitive than Standard PCR in detecting the citrus greening pathogen '*Candidatus* Liberibacter asiaticus' while in the presence of genomic DNA from citrus psyllids, citrus trees, or citrus psyllid parasitoids. Furthermore, High-Fidelity PCR has been used to detect and characterize a new Microsporidium species from the predatory mite *Metaseiulus occidentalis* (Nesbitt) (Becnel et al. 2002), to identify and distinguish two parasitoids of the brown citrus aphid (Persad, Jeyaprakash, and Hoy 2004), to examine the microbial diversity of *Metaseiulus occidentalis* and its prey, *Tetranychus urticae* (Hoy and Jeyaprakash 2005), and to amplify 16S ribosomal sequences of endotoxin producing bacteria in varying amounts of dust mite DNA (Valerio et al. 2005).

OBJECTIVES

Juana Diaz receives diseased plant samples representing a multitude of pathogens from the Florida Extension Plant Diagnostic Clinic at the Tropical Research and Education Center and from the diagnostic clinic at the University of Puerto Rico. These clinics are a valuable resource for the agricultural community by providing pathogen identification and disease management recommendations where appropriate, and are a viable means for researchers to monitor plant pathogen populations in the surrounding areas. We used this opportunity to investigate the following research objectives, and thus the following procedures relied on both clinics for plant samples analyzed to:

1. Compare the sensitivity of the High-Fidelity and the Standard PCR procedures by inoculating a range of plants with several fungal and bacterial pathogens and amplifying the target organism's DNA directly from plant tissue.
2. Determine whether the High-Fidelity PCR is more sensitive than the Standard PCR in detecting fungi, bacteria, and viruses from naturally infected plant species.

MATERIALS AND METHODS

DNA was extracted using DNA extraction protocol 3 (below) and amplified using the Standard PCR and High-Fidelity PCR protocols (explained below), and the results compared. To quantify the differences between Standard and High-Fidelity PCR, the serially diluted plasmid DNA (1000 ng to 1 fg) was spiked with 10ng of plant genomic DNA. Two negative controls were used: one containing the plant genomic DNA alone and the other without DNA. All reactions wwere replicated three times.

DNA Extraction Protocols

Two protocols were used to extract genomic DNA from plant host tissue.

Protocol 1: Plant DNA: 3.866 grams of leaf tissue were frozen in liquid nitrogen and ground in 8 ml of CTAB buffer (2% cetyltrimethylammonium bromide, 100 mMTris pH 7.5, 20 mM EDTA, 1% polyvinyl pyrrolidone, and 1.4 M NaCl) for 10 minutes before being aliquoted into 8 tubes. The samples were then incubated at 60°C for 16 hours. After two chloroform extractions, the 8 DNA aliquots were combined into 4 aliquots and precipitated in 2-propanol, and then re-suspended in 100 µL sterile water. All samples were pooled to make a 400 µL sample of genomic orchid DNA. Plant DNA was quantified using an Eppendorf BioPhotometer G131 V1.35 (Eppendorf, Hamburg, Germany).

Protocol 2: The leaf spot fungus *Pseudocercospora odontoglossii* was isolated from a *Cattleya* hybrid and identified based on morphological characters (Ellis 1976; Crous and Braun 2003) and host. Single spores were grown on V-8 juice agar for 2 weeks at 25˚C under artificial light at 12L:12D photoperiod. A section of mycelium approximately 2x2 cm was scraped from the surface of the plate with a sterile wooden applicator stick and placed in a 0.5 mL tube. Then the following procedures were performed: 100 µL of Extraction Solution (Extract-n-Amp, Sigma-Aldrich, St. Louis, MO) was added and the sample was ground for 5 minutes with a sterile plastic pestle and heated to 95˚C for 10 minutes; 100 µL of dilution solution (Extract-n-Amp, Sigma) was added to the sample, after which the sample was briefly vortexed; and 30 µL of the extracted DNA was added to 270 µL of sterile water (Harmon, Dunkle, and Latin 2003).

In order to compare the use of the High-Fidelity PCR and the Standard PCR in the diagnosis of plant diseases, several types of commonly cultivated tropical foliage plants were inoculated with bacterial and fungal pathogens using Standard procedures. DNA from these plants was extracted using a third protocol:

Protocol 3: A cork borer (~6 mm in diameter) was used to cut a section of plant material. The plant section was placed in a 0.5 mL tube and the tissue was frozen in liquid nitrogen and ground

with a sterile plastic pestle for 5 minutes. Then the following procedures were performed: 100µL of extraction solution (Extract-n-Amp, Sigma-Aldrich) was added and heated to 95°C for 10 minutes; 100µL of dilution solution (Extract-n-amp, Sigma-Aldrich) were added and the sample was briefly vortexed; and 30µL of the extracted DNA was added to 270 µL of sterile water (Harmon, Dunkle, and Latin 2003). After the DNA extraction, the Standard and High-Fidelity PCR reactions were performed using the following protocols with the appropriate primers.

Total Plant RNA Extraction

Total plant RNA was extracted using a modified RiboPure Kit protocol.

- ***Homogenization:***
  1. Homogenize 0.1 g of tissue samples in Liquid nitrogen using sterile pestle and mortar
  2. Re-suspend in 500 µl of TRI Reagent
  3. Incubate the homogenate for 10 minutes at room temperature
  4. Centrifuge at 13,000 rpm for 15 minutes at 4°C; transfer supernatant to a new tube
- ***RNA Extraction:***
  1. Add 100 µL of BCP to 1 mL of homogenate and mix well
  2. Incubate the homogenate for 10 minutes at room temperature
  3. Centrifuge at 13,000 rpm for 15 minutes at 4°C
  4. Transfer aqueous phase to a new 1.5 mL micro centrifuge tube
- **Final RNA Purification:**
  1. Add 200 µL of 100% ethanol and mix immediately
  2. Pass the sample through a filter cartridge
  3. Wash filter twice with 500 µL of Wash Solution; centrifugate 1 minute at 8,000 rpm
  4. Transfer filter to a new eppendorf tube
  5. Elute RNA with 50 µL Elution Buffer and freeze until concentration reading.

Standard PCR protocol

Standard PCR was be performed using DNA extracted from inoculated plants and plants with suspected diseases in a 25µL reaction volume containing 2.5 µL of 10X PCR Buffer +Mg (Boehringer, Mannheim, Germany), 200 µM dATP, dGTP, dCTP, and dTTP, 400pM of primers ITS4 and ITS5 (White et al. 1990) for fungi, and 16S primers (Weisburg et al. 1991) for bacteria and .2 units of *Taq* DNA polymerase (Bioline, Taunton, MA). Samples were covered with 50µL of sterile mineral oil and amplified using the following temperature profile: (i) 94˚C for 5 minutes and (ii) 35 cycles consisting of denaturing at 94˚C for 30 seconds, annealing at 53˚C for 30 seconds, and extension at 72˚C for 1 minute (the described annealing temperature is for the fungal primers).

High-Fidelity PCR Protocol

High-Fidelity PCR will be performed using DNA extracted from inoculated plants and plants with suspected diseases in a 50 µL reaction volume containing 50 mM TRIS, pH 9.2, 16 mM ammonium sulfate, 1.75 mM$MgCl_2$, 350 µL dATP, dGTP, dCTP, and dTTP, 800 pmol of primers ITS4 and ITS5 (White et al. 1990) for fungi and 16S primers (Weisburg et al. 1991) for

bacteria, 1 unit of Accuzume (Roche Molecular Biochemicals) and 5 units *Taq* DNA polymerase (Bioline) (Barnes 1994). Samples were covered with 100 µL of sterile mineral oil and amplified using 3 linked temperature profiles: (i) 94˚C for 2 minutes; (ii) 10 cycles consisting of denaturing at 94˚C for 10 seconds, annealing at 53˚C for 30 seconds, and extension at 68˚C for 1 minute; and (iii) 25 cycles consisting of 94˚C for 10 seconds, annealing at 53˚C for 30 seconds, and extension at 68˚C for 1 minute plus an additional 20 seconds during each consecutive cycle (Hoy, Jeyaprakash, and Nguyen 2001; Jeyaprakash and Hoy 2000) (the described annealing temperature is for the fungal primers).

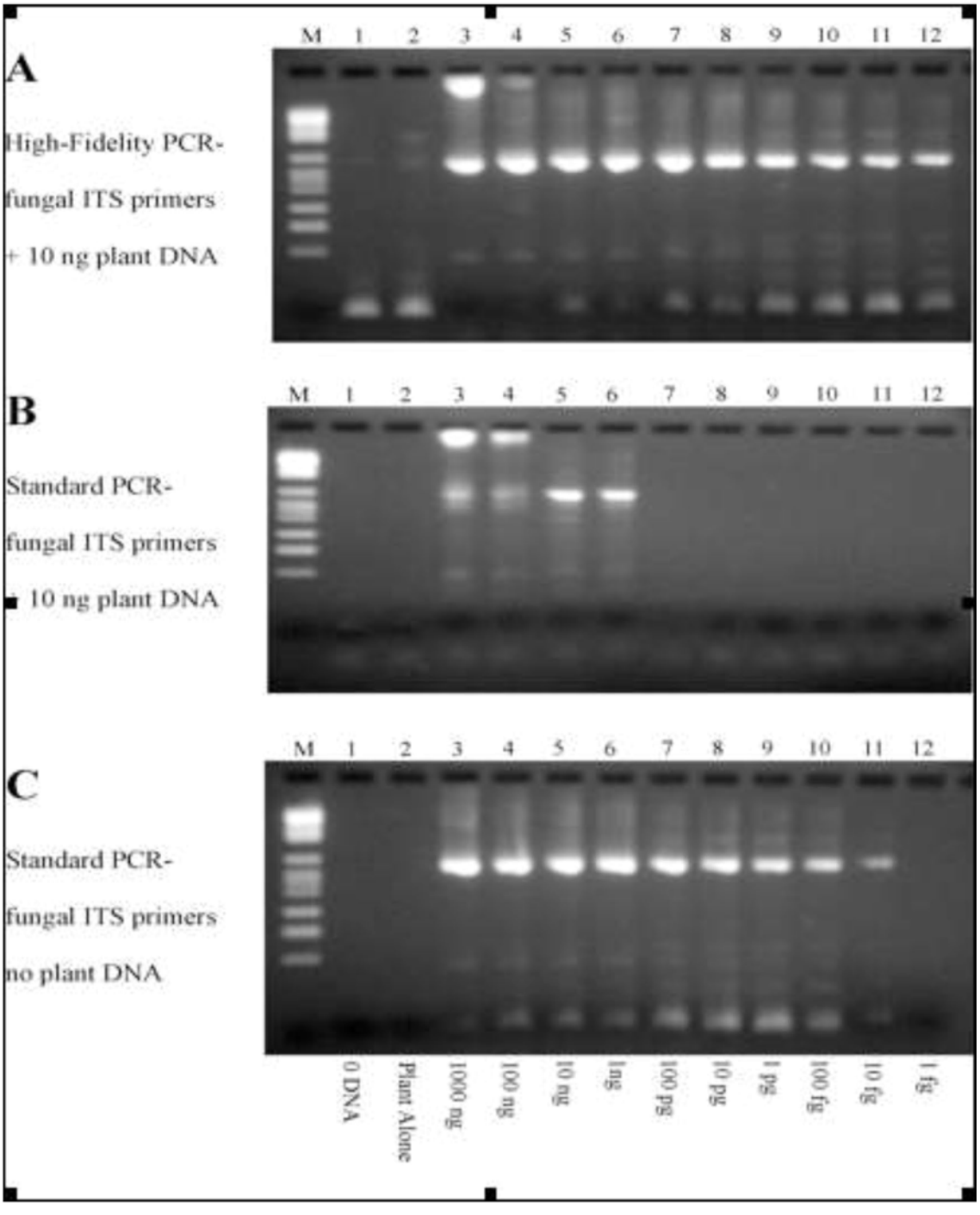
Molecular Cloning for DNA Sequencing

In order to confirm the identity of the obtained PCR product, the target DNA sequences were cloned using the TOPO T/A cloning kit (invitrogen, Carlsbad, CA) and sent for sequencing to the ICBR at the University of Florida (Gainesville). Before ligation into the cloning vector, PCR products were cleaned using the QIAquick PCR purification kit (Qiagen, Valencia, CA) following the manufacturer's recommendations and eluted in 50 µL of sterile glass distilled, glass collected water. A 3' A-overhang was added to the PCR product after purification to facilitate ligation into the cloning vector by mixing the 50µL DNA sample with 5.75 µL 10X High-Fidelity buffer(50 mM TRIS, pH 9.2, 16 mM ammonium sulfate, 1.75 mM $MgCl_2$), 100 mMdATP, and 1 unit *Taq* polymerase (Bioline). The reaction was placed in a thermocycler at 72˚C for 45 minutes. The product was immediately cloned into the TOPO T/A cloning vector following the manufacturer's recommendations (Invitrogen Corporation, Carlsbad, CA), and *Escherichia coli* cells were transformed with the recombinant plasmid. *E. coli* colonies were selected from plates containing X-GAL, IPTG, and ampicillin, and grown overnight in LB broth containing ampicillin at 37˚C. Plasmids were extracted using the Qiagen Plasmid Mini Prep Kit (Qiagen, Valencia, CA) and digested with *Eco*RI restriction enzyme, followed by gel electrophoresis on a 2% agarose TAE gel stained with ethidium bromide to confirm the correct size of the insert.

RESULTS AND DISCUSSION

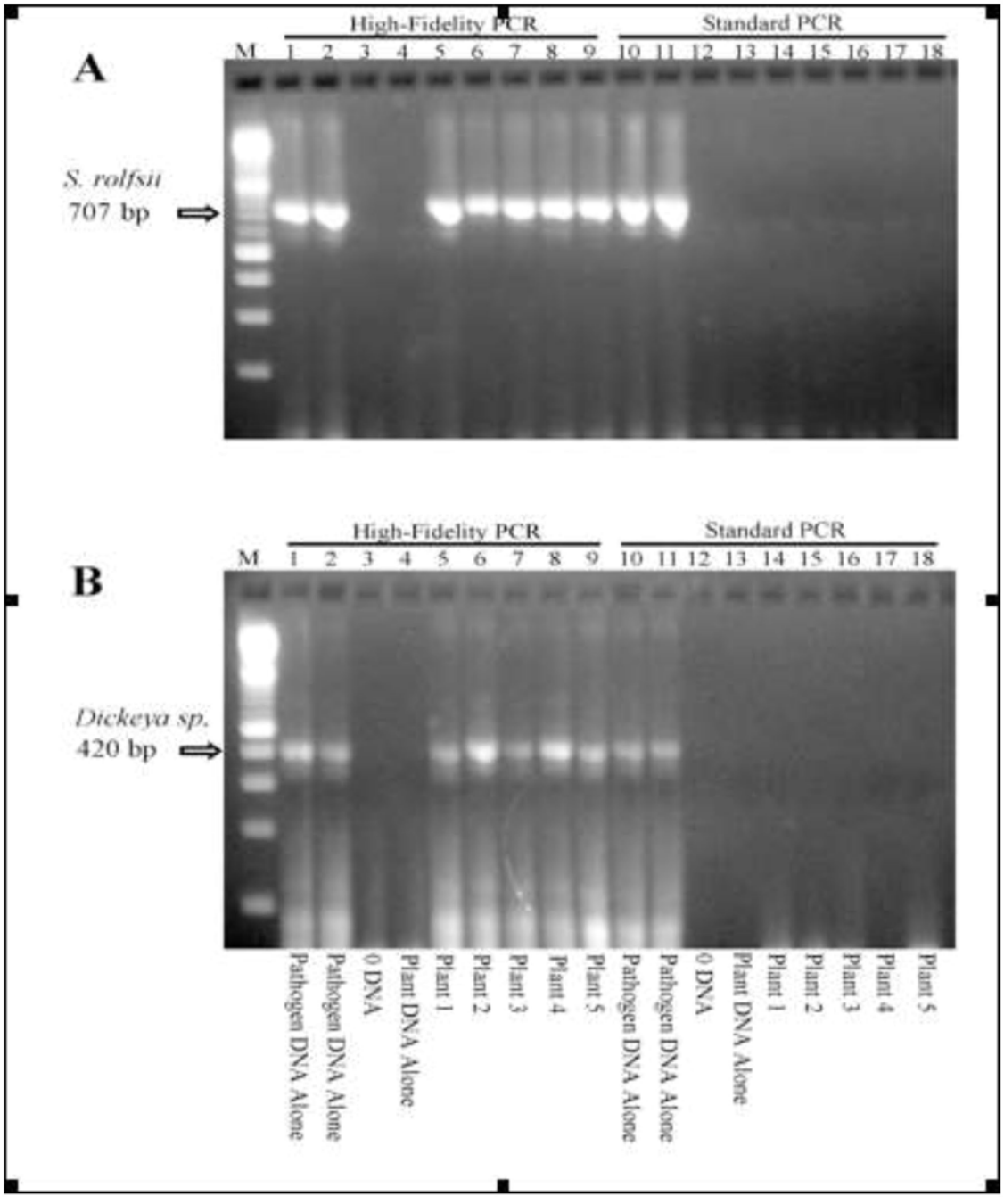
The results of the experiments are shown in Figures 1 through 4.

Figure 1. Comparing High-Fidelity and Standard PCR using plasmid pRC17



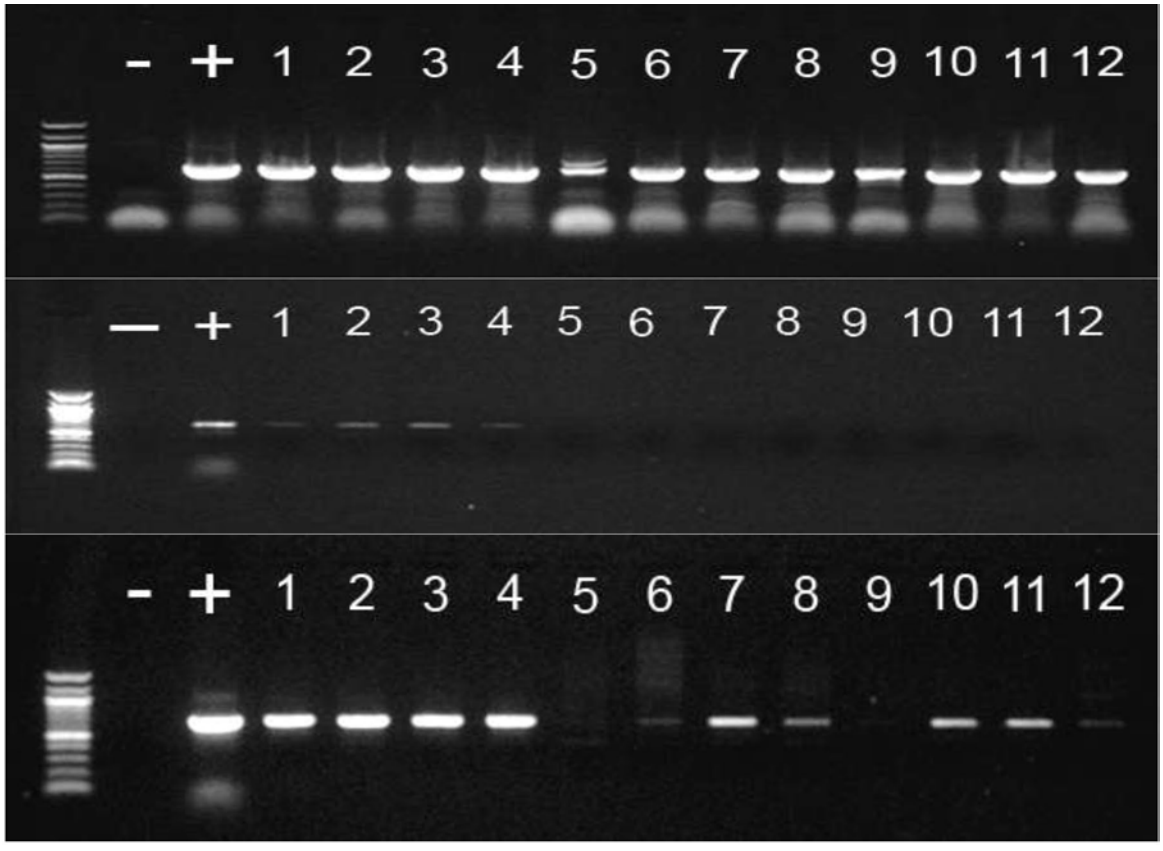
A comparison of High-Fidelity and Standard PCR using plasmid pRC17 containing the 571-bp ITS1, 5.8S, and ITS2 rDNA of *Pseudocercospora odontoglossi* as a template and primers ITS4/ITS5. (**A**) High-Fidelity PCR amplified as few as 207 copies (1 fg) of template in the presence of 10 ng of *Cattleya* DNA, while Standard PCR (**B**) required at least 200 million copies (1 ng) of template for amplification. In the absence of host genomic DNA, the Standard PCR protocol (**C**) amplified as little as 10 fg of template. M=molecular marker IV (Roche).

Figure 2. Comparing High-Fidelity and Standard PCR for two orchid pathogens



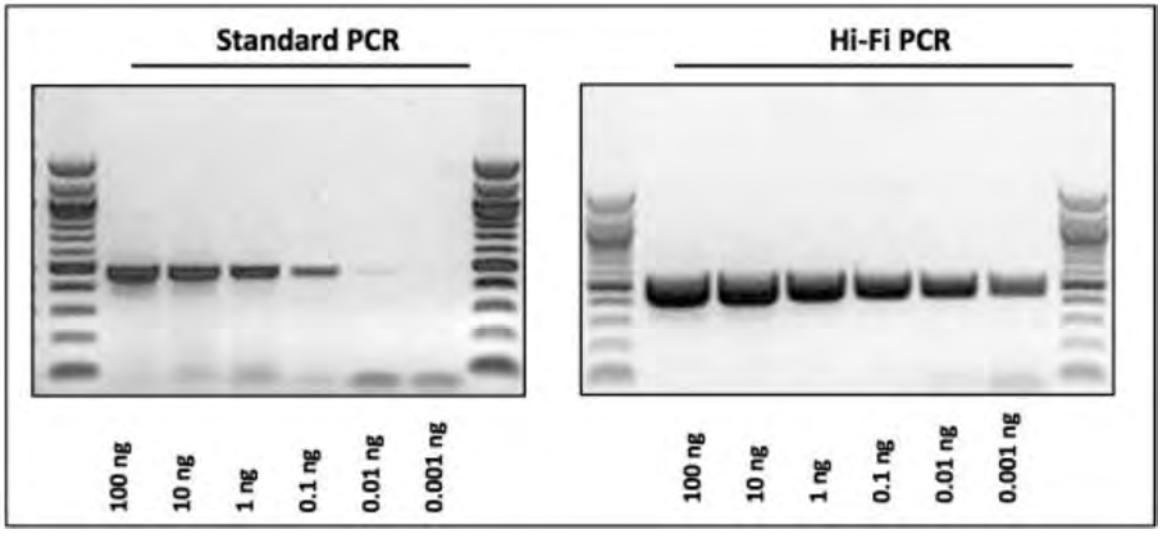
A comparison of High-Fidelity and Standard PCR in the detection of two important orchid pathogens from five inoculated *Phalaenopsis* plants. (**A**) *S. rolfsii* was detected in all five plants using fungal ITS4/ITS5 and High-Fidelity PCR protocol (lanes 5–9), but in none of the plants with Standard PCR (lanes 14–18). (**B**) High-Fidelity PCR detected *Dickeya* sp. in inoculated plants using primers ADE1/ADE2 (lanes 5–9), but not in any plants with Standard PCR (lanes 14–18). M=molecular marker XIV (Roche).

Figure 3. Comparing High-Fidelity and Standard PCR for *P. nicotianae* DNA



Only Hi-Fi PCR using Accuzyme coupled with DNAeasy and Extract-N-Amp extraction positively detected *P. nicotianae* DNA in all samples of all tissues. Accuzyme Hi-Fi PCR also produced positives for the majority of samples using CTAB extraction. LongAmp Hi-Fi PCR detected the pathogen for the majority of samples for all DNA extraction methods except the Shorty protocol. Standard PCR only detected the pathogen for leaf samples using Dneasy extraction. Extraction with Shorty buffer did not produce any positive detection of the pathogen from any sample save a single leaf sample using Accuzyme Hi-Fi PCR.

Figure 4. Comparing High-Fidelity and Standard PCR in RNA extraction



ORSV Primers: (expected band of 474 bp) with Tm 48ºC.
CP-Forward 1: 5' ATGTCTTACACTATTACAGACCCG'3
CP-Reverse 1: 5' GGAAGAGGTCCAAGTAAGTCC '3

Hi-Fi RT-PCR detected 0.001 ng/µl of CymMV and ORSV in a total plant RNA extraction compared to 1ng/ µl of CymMV and 0.1ng/ µl of ORSV, respectively. Thus, Roche Titan One tube kit proved to be more sensitive than conventional RT-PCR amplification. The detection of these viruses was performed on total plant RNA, which implies that when using a viral RNA extraction, these results will likely be enhanced in sensitivity.

These results indicate that High-Fidelity PCR is a more sensitive in detecting pathogen DNA from symptomatic host tissue samples. Our study also indicates that a quick DNA extraction method like the Extract-N-Amp kit produces similar results as a longer method like the DNeasy Kit, even though DNA purity may be lower. The Extract-N-Amp protocol also requires minimal tissue processing.

The advantage of High-Fidelity PCR is that it is similarly easy to run as Standard PCR and does not require special equipment, making it less costly than other molecular detection methods that confer increased detection sensitivity, like real-time PCR. When combined with species-specific primers, this detection method enables diagnosis of specific pathogens directly from plant tissue in a matter of hours, which is especially useful for time sensitive disease problems.

In the future we plan to implement the High-Fidelity detection method for other important pathogens in South Florida, including citrus greening, lethal yellowing of palms, and laurel wilt of avocado.

ACKNOWLEDGMENTS

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INVASIVE SCALES AND WHITEFILES IN THE LANDSCAPE—A SERIOUS THREAT TO THE TOURIST INDUSTRY

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The Landscape A Reservoir of Pests

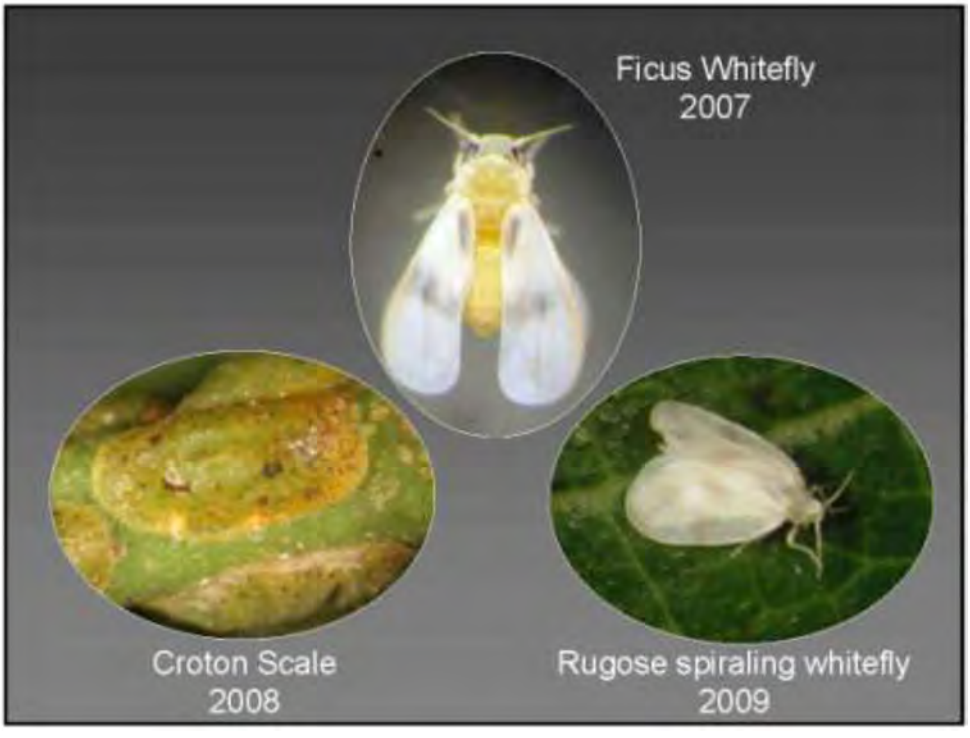
Diversity of host material and habitat make the landscape an ideal place for new pest establishment

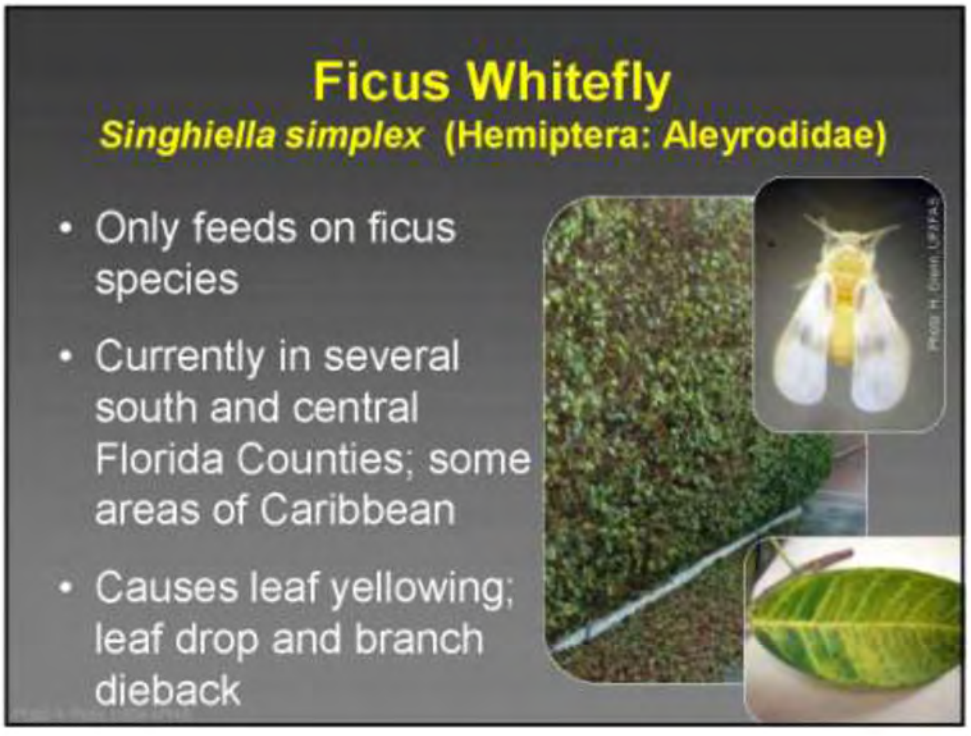
Challenges in Invasive Pests in the Landscape

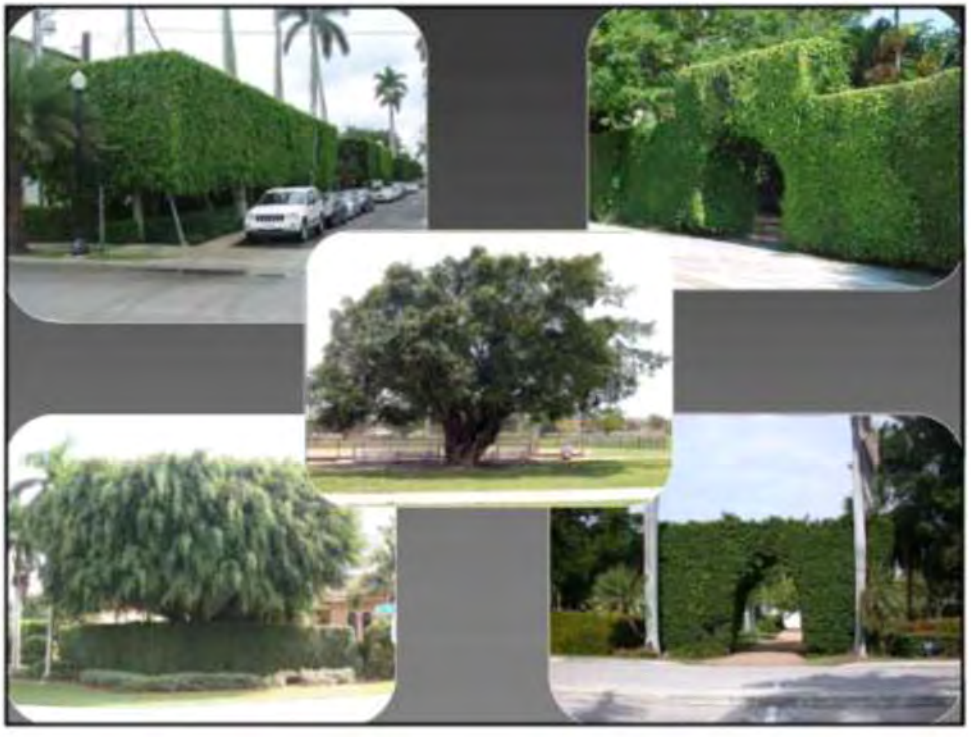
- Detection and identification
- Management strategies for the landscape
- Dealing with everyone from the homeowner to the grounds keeper or landscape manager to the politician
- Attention to high risk pests but little or no reaction to lower risk pests.

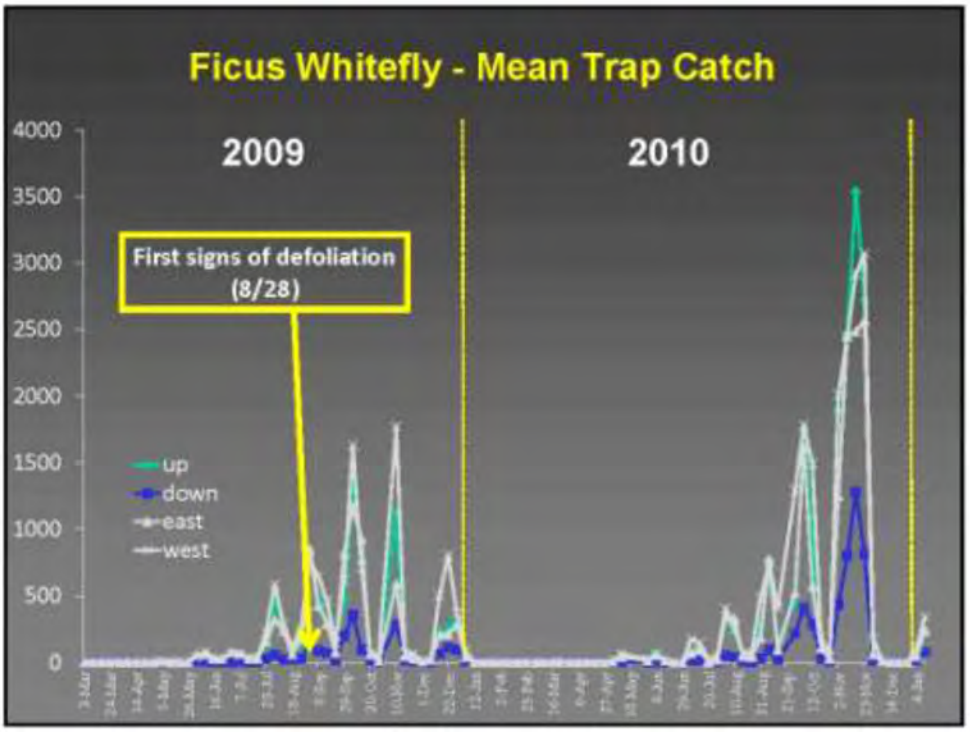
Impact of "Lower Risk" Pests

- Risk of spreading into production areas and moved to new area
- High visual or local impact
- Public, press and politic pressure
- Yet, not considered national risk (lack of funding or resources)
- Could be more problematic in isolated areas
- Reliance on pesticides

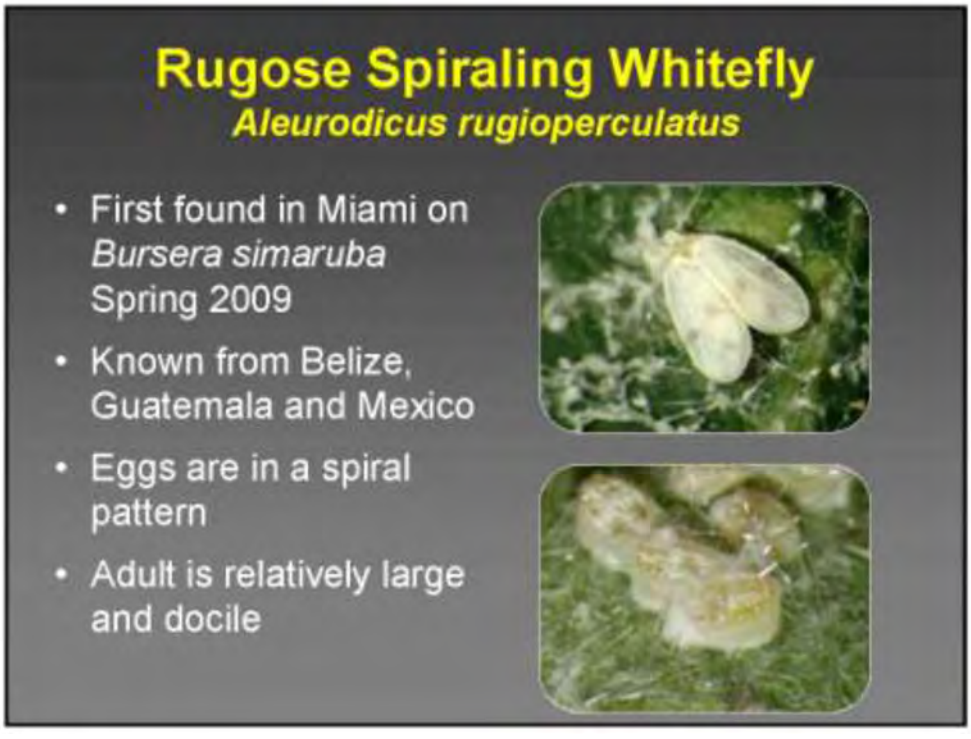



Ficus Whitefly
Singhiella simplex (Hemiptera: Aleyrodidae)
• Only feeds on ficus species
• Currently in several south and central Florida Counties; some areas of Caribbean
• Causes leaf yellowing; leaf drop and branch dieback




Ficus Whitefly - Mean Trap Catch
2009
2010
First signs of defoliation (8/28)
4000
3500
3000
2500
2000
1500
1000
500
0
up
down
east
west

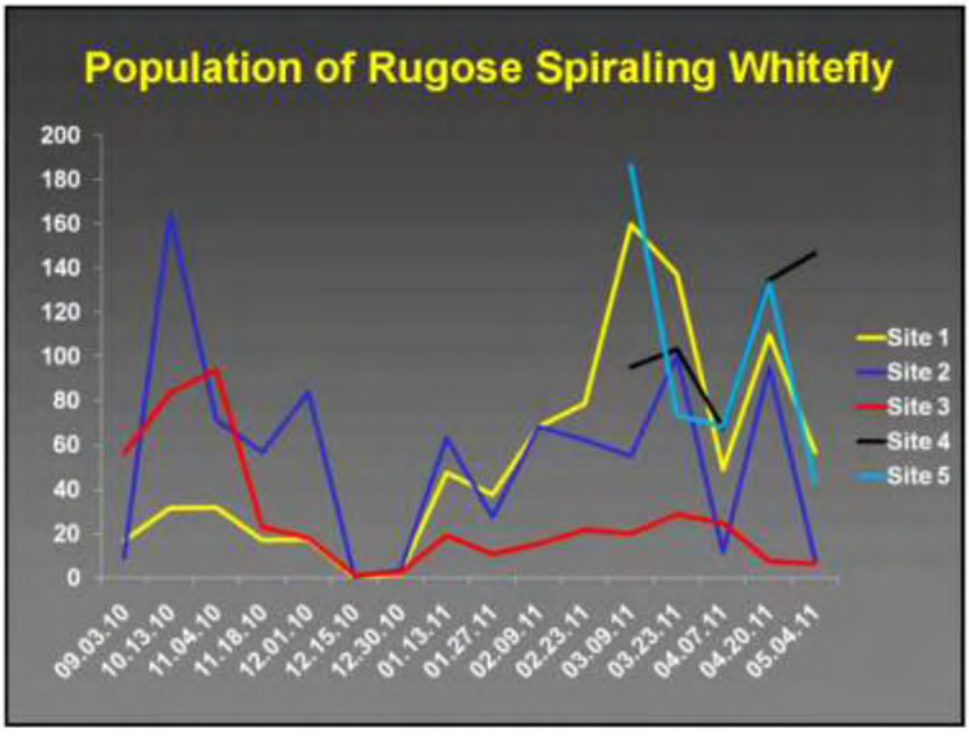

Adult Whitefly
(2-4 days)
Eggs
(10 days)
Ficus Whitefly
Life Cycle
4th instar – puparia
(5.8 days)
*2nd
*3rd
1st instar – crawler
(4.2 days)
2nd-3rd instars – nymphs
2nd instar – 3.7 days; 3rd instar – 3. 3 days

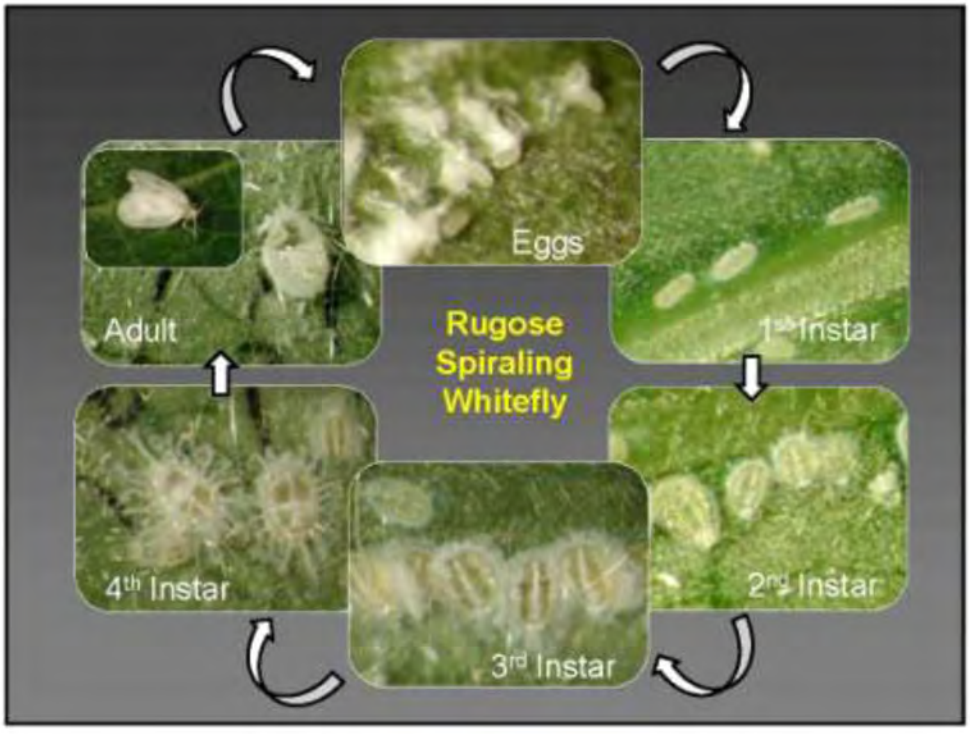

Rugose Spiraling Whitefly
Aleurodicus rugioperculatus
• First found in Miami on Bursera simaruba Spring 2009
• Known from Belize, Guatemala and Mexico
• Eggs are in a spiral pattern
• Adult is relatively large and docile

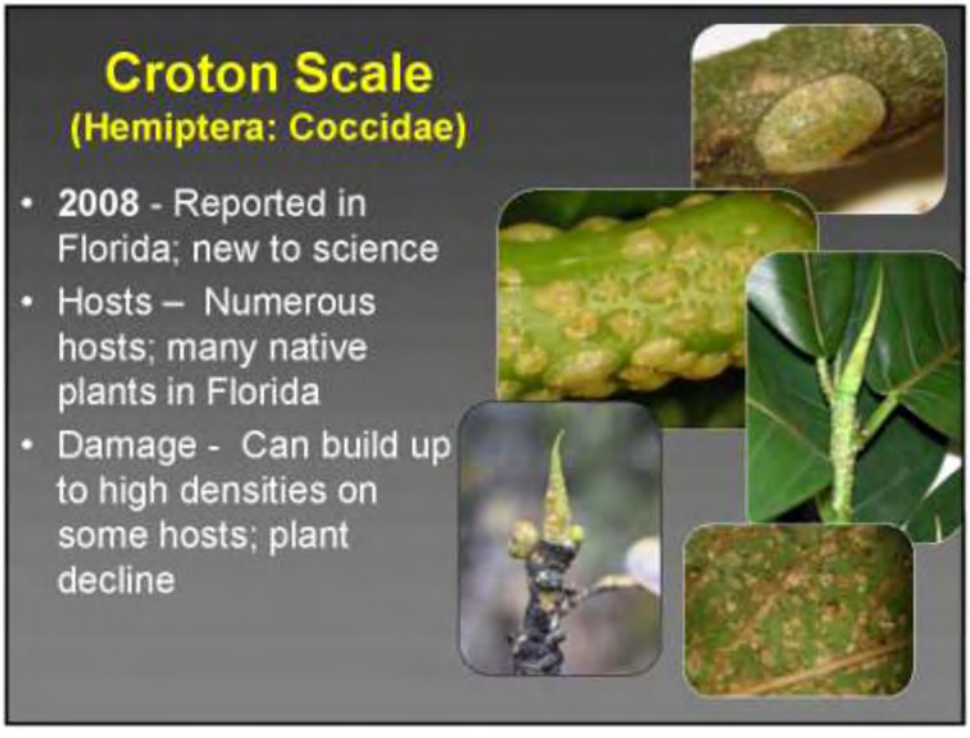
Plants Hosts

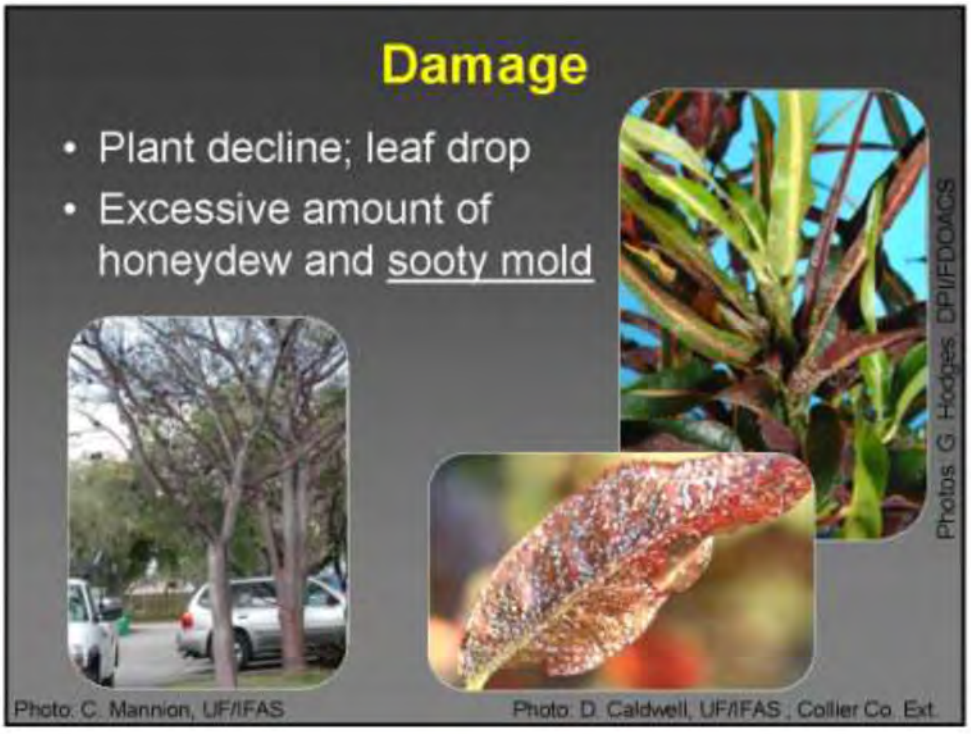
- *Acalypha wilkesiana* (Copperleaf)
- *Annona sp.* (Sugarapple)
- *Araucaria heterophylla* (Norfolk island pine)
- *Bucida buceras* (Black olive)
- *Bursera simaruba* (Gumbo limbo)
- *Calophyllum* species
- *Catharanthus roseus* (Madagascar periwinkle)
- *Chrysobalanus icaco* (Cocoplum)
- *Chrysophyllum oliviforme* (Satinleaf)
- *Cocos nucifera* (Coconut palm)
- *Conocarpus erectus* (Buttonwood)
- *Cordyline fruticosa* (Hawaiian ti)
- *Dictyosperma album* (Hurricane palm)
- *Dypsis lutescens* (Areca palm)
- *Eugenia* spp.
- *Ficus aurea* (Strangler fig)
- *Ficus carica* (Edible fig)
- *Hyophorbe verschaffeltii* (Spindle palm)
- *Mangifera indica* (Mango)
- *Manilkara roxburghiana*
- *Myrica cerifera* (Wax myrtle)
- *Musa* sp. (Banana)
- *Parthenocissus quinquefolia* (Virginia creeper)
- *Persea americana* (Avocado)
- *Phoenix roebelenii* (Pigmy palm)
- *Quercus virginiana* (Live oak)
- *Sabal palmetto* (Sabal palm)
- *Schinus terebinthifolius* (Brazilian pepper)
- *Simarouba glauca*
- *Smilax auriculata*
- *Spondias sp.*
- *Spondias purpurea*
- *Strelitzia nicolai* (White bird of paradise)
- *Strelitzia reginae* (Bird of paradise)
- *Tabebuia* species
- *Terminalia catappa* (Tropical almond)
- *Veitchia* species
- Washingtonia palm
- *Zeuxine strateumatica*

And, the list continues to grow


Population of Rugose Spiraling Whitefly
200
180
160
140
120
100
80
60
40
20
0
09.03.10
10.13.10
11.04.10
11.18.10
12.01.10
12.15.10
12.30.10
01.13.11
01.27.11
02.09.11
02.23.11
03.09.11
03.23.11
04.07.11
04.20.11
05.04.11
Site 1
Site 2
Site 3
Site 4
Site 5


Eggs
Adult
Rugose
Spiraling
Whitefly
1st Instar
4th Instar
2nd Instar
3rd Instar


Croton Scale
(Hemiptera: Coccidae)
• 2008 - Reported in Florida; new to science
• Hosts – Numerous hosts; many native plants in Florida
• Damage - Can build up to high densities on some hosts; plant decline



Development on Croton

	Mean Days (± SD)	
First	12.6 ± 0.6	
	Male	Female
Second	10.4 ± 1.3	11.6 ± 0.89
Third	3.9 ± - 0.8	6.9 ± 0.97
Fourth	2.8 ± 0.8	
Adult (cumulative)	29.7 ± 1.9	31.1 ± 2.1


Pests in the Landscape
• Development and sharing of information and resources for more localized problems
• Promote education and biologically-based management
• Pay attention to pests that are currently "under the radar"

TROPICAL BONT TICK SURVEILLANCE AND CONTROL IN THE CARIBBEAN: HOW RESEARCH OUTPUTS CAN HELP DECISIONS

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INTRODUCTION

Tropical Bont Tick in the Caribbean: Spread and Eradication Efforts

The Tropical Bont Tick (TBT) *Amblyomma variegatum* represents a major constraint for the development of livestock in the Caribbean and in Africa. Indeed, this tick induces blood spoliation and provokes skin infection or abscesses on the site of attachment. It is also responsible for the transmission of *Ehrlichia ruminantium,* a bacteria responsible for heartwater which is a fatal disease of ruminants. In addition, TBT favors the development of the acute form of dermatophilosis, a skin disease caused by the bacteria *Dermatophilosis congolensis*. The tick was first introduced in the Caribbean in the nineteenth century, and now threatens North America. However, heartwater has been diagnosed only in Guadeloupe (including Marie Galante) and Antigua, and *E. ruminantium* has not been identified elsewhere in the Caribbean (Vachiery el al. 2008; Molia et al. 2008).

While the tick was restricted to three Caribbean islands until the 1960s (Guadeloupe, Antigua and Martinique), TBT infested 18 Caribbean islands by the end of the 1980s, from Barbados (southern limit) to Puerto Rico (northern limit) (Barré et al. 1987). This rapid spread coincided with the recent introduction and dissemination of cattle egrets (*Bulbucus ibis*) in the region. Indeed, these birds live in close contact with ruminants and are believed to be partly responsible for the TBT spread by transporting immature stages (Uilenberg 1990; Corn et al. 1993). In the mid-1990s, two eradication programs were launched: the Carribbean Amblyomma Programme (CAP) in the 10 islands of the English Lesser Antilles in 1994 (Pegram, De Castro, and Wilson 1998), and POSEIDOM in the two French islands in 1995 (Barré et al. 1996). There were heterogeneous results concerning TBT eradication. When the programmes stopped (2005–2006), TBT was eliminated from eight islands (St. Lucia, St. Kitts, Montserrat, Anguilla, Dominica,

Barbados, St. Vincent and the Grenadines, and US Virgin Islands), and the level of infestation was slightly to highly reduced in five islands (Guadeloupe, Martinique, Nevis, Antigua, and St. Maarten). Later, ticks were rediscovered in some free islands and eliminated (St. Croix, St. Vincent, and the Grenadines), and three islands considered TBT-free were re-infested (St. Lucia, Dominica, and St. Kitts). The origin of island reinfestation is unknown and we cannot tell whether the new TBT focus in these countries originates from a residual and undetected population or whether it was introduced from infested islands.

Since 2004, it has been recognized that TBT eradication cannot be achieved in the Caribbean because of funding, socio-political, and ecological reasons (Pegram et al. 2002; Pegram et al. 2004; Anonymous 2004). Therefore, new surveillance and control strategies need to be defined, along with the recommendation to move toward a strategy of TBT control in the islands (Anonymous 2004).

From CAP to the Caribbean Animal Health Network

The Carribbean Amblyomma Programme (CAP), as a regional CARICOM programme, mainly implemented by FAO, provided strong technical support to the countries. During CAP, trainings were organized (e.g., tick identification and biology, how to monitor the eradication progress), materials for public information and awareness campaigns as well as acaricides were delivered to the participant countries, and a common database (TickINFO) was developed. The programme also ensured the coordination of surveillance activities and provided technical and scientific advice on surveillance and control strategies. As a result, the veterinary services of the islands involved in the programme collaborated with technical experts and funding agencies as a region to combat animal diseases. This largely contributed to the Caribbean animal health network, CaribVET, which is recognized by the COTED (CARICOM). CaribVET is a collaborative network involving veterinary services and diagnostic laboratories of 32 Caribbean countries and territories, research institutes, and regional/international organizations (Gongora et al. 2008; Dufour and Hendrikx 2011). Given the economic impacts and the risk of TBT spreading throughout the region, the CaribVET Steering Committee recognized TBT and its associated diseases as a regional priority. There are six CaribVET working groups, one of which is dedicated to ticks and tick-borne diseases (T&TBDs). This group provides regional expertise on T&TBDs for harmonized regional diseases surveillance and diagnosis and for control protocols and strategies, and is responsible for the regional communication system/data management.

TBT Research and Expertise in the Caribbean

The biology and ecology of TBT and the research on heartwater in the Caribbean have been thoroughly studied by acarologists, biologists, and epidemiologists coming from Guadeloupe, Antigua, Africa, and the United States. In particular, CIRAD Guadeloupe has conducted research on TBT biology and heartwater for over 30 years in partnership with African laboratories, where both the vector and pathogen originate. The main model study of CIRAD Guadeloupe is the host-pathogen system *Amblyomma variegatum / Ehrlichia ruminantium*, with current research encompassing immunology, genetics, proteomics, and modeling studies.

OBJECTIVES

Most of the time, research is perceived as a complicated science far remote from reality, operational issues, and farmers' concern. This paper illustrates how ticks and tick-borne diseases in the Caribbean are researched by CaribVET to improve surveillance and control strategies implemented in the Caribbean.

METHODS AND RESULTS

The link between research, surveillance and control is an essential component of CaribVET, especially as regards TBT in the Caribbean. Indeed, data from surveillance and control programs, along with good field knowledge, enable the persons in charge of the coordination of these activities to raise specific issues and questions. These gaps in the knowledge of TBT biology, disease epidemiology, or tick response to treatment are opportunities to design relevant applied research, while benefitting surveillance (i.e., implementation of risk-based surveillance) and control (adoption of the best cost-effective strategy).

Role of the CaribVET T&TBD Working Group: Connecting Surveillance and Control with Research Stakeholders

The members of the CaribVET T&TBD working group are Caribbean specialists who are recognized for their competence and/or experience in the theme targeted by the group (CaribVET Charter 2011). Members of the group are veterinary services of islands with TBT-infestation or at-risk of infestation, farmer association representatives, tick experts from the Caribbean, and scientists from research institutes with tick expertise (i.e., CIRAD Guadeloupe and CENSA Cuba).

The group meets annually to discuss the TBT situation in every island, review the latest advances in research and surveillance, share their experiences, and identify the main gaps and constraints that prevent the full operation and success of the field work. At the end of each meeting, the group formulates recommendations for control/surveillance according to each island's infestation level and for the proper applied research to improve TBT surveillance and control. The group leader (CIRAD Guadeloupe) is in charge of coordinating the research and follow-up processes, and reporting the activities of its group to the CaribVET Steering Committee (SC). The working group uses the recommendations as a guideline for implementing future activities. This framework circulates information among the stakeholders and is favorable for the integration of field observations in defining relevant applied research.

Key Role of Laboratories in Research Development and Scientific Communication

Besides being research institutions, CIRAD Guadeloupe and CENSA Cuba are also diagnostic laboratories for T&TBDs and are involved in the national surveillance networks. As such, they are familiar with field constraints and with the objectives of surveillance and control measures implemented by their partners. In particular, because of its TBT expertise, CIRAD Guadeloupe was involved in the Carribbean Amblyomma and POSEIDOM eradication programmes, and developed tight collaborations with the French veterinary services (Guadeloupe and Martinique)

and farmer associations in charge of TBT surveillance and control. This greatly facilitates the communication of laboratories with other national surveillance network stakeholders and members of the T&TBD working group.

Applied Research Needs and the Recommendations of the T&TBD Working Group

The challenges for veterinary services and animal health partners are to reduce infestation levels in the islands where TBT is still present, to quickly identify new foci in the islands where the tick is sporadic and take appropriate control measures, to prevent TBT and heartwater spread to other Caribbean islands, and to reduce the costs of surveillance and control for the islands.

A model of the TBT population dynamics was developed in CIRAD Guadeloupe, based on the bio-ecological and bionomics data collected from the field and from laboratories in Africa and the Caribbean (Porphyre et al. [in preparation]). The model finds direct application in the framework of the T&TBD working group with, for instance, potential TBT distribution range, predicted population dynamics in several islands, and comparison of treatment efficacy.

Other research questions also were raised during T&TBD working group meetings and recommendations were made for countries/territories according to their TBT infestion or at-risk level. Detailed summaries of the meetings of the working groups are available at the CaribVET website (http://www.caribvet.net).

CONCLUSIONS AND PERSPECTIVES

Members of the multidisciplinary CaribVET T&TBD working group collaborate to regularly assess the current TBT situation in the Caribbean, update research advances, and propose practical recommendations for countries according their level of TBT infestation. These recommendations are made by the countries themselves, based on information from researchers and tick experts. This greatly eases the design of cost-effective and sustainable programs to be adopted and adapted at the country level.

In addition, the group recently broadened its scope to include the Common Tick, *Rhipecephalus (Boophilus) microplus*, which is very common in the Caribbean and is responsible for anaplasmosis and babesiosis transmission. This tick may have developed flumethrin resistance where Bayticol® has been intensively used for more than ten years. The CaribVet T&TBD working group is addressing acaricide resistance in the Common Tick and the evolution of anaplasmosis and babesiosis in the Caribbean. CENSA conducts research on anaplasmosis and on alternative control methods of *Boophilus sp*. In addition, work on the identification of best cost-effective strategies to control TBT will aim at preventing resistance in both ticks species.

By promoting continuous links between research and surveillance, CaribVET aims to increase the efficiency of surveillance and control of national diseases and vectors and to improve animal health in the Caribbean.

ACKNOWLEDGMENTS

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NEWLY EMERGING DISEASE THREATS TO PALMS IN FLORIDA

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INTRODUCTION

The subtropical southern one-third of the Florida peninsula (hardiness zone 10) is conducive to the growth of a great diversity of exotic palm species in addition to the 12 species native to the state and the southeastern United States (Meerow 2006). Although the exact tally of species grown in southern Florida is unknown, the living collection of at least 289 genera and 327 species of palms grown within the confines of Fairchild Tropical and Botanic Garden in Coral Gables, Miami-Dade County (http:www.fairchildgarden.org) provides an excellent indicator of the wealth of species available to palm enthusiasts for use as ornamentals in landscape, amenity, or niche plantings.

Plantings of mature palms provide instant, upscale appeal to landscape architectural designs and are in high demand by both residential and commercial developments. However, despite a broad palette of palm species from which to choose, practical considerations, including the porous, alkaline, nutritionally deficient soils of coastal southern Florida, coupled with a backdrop of both native and introduced pests and diseases (Broschat and Meerow 2000; Elliott et al. 2004), have collectively shaped the common usage of palms in landscapes to about 18 favored species. In the central and northern reaches of the state, hardiness zones 9 and 8, respectively, the choice of palms for plantings is restricted to just a few cold-tolerant species. Furthermore, for palms of large stature, choices of cold tolerant palms are limited largely to highly valued *Phoenix* species and hybrids (*P. canariensis; P. dactylifera; P. sylvestris*), Queen palm (*Syagrus romanzoffiana*), Mexican fan palm (*Washingtonia robusta*), and native sabal (cabbage) palm (*Sabal palmetto*), the most widely used species in urban and suburban plantings.

LETHAL YELLOWING OF PALMS: A LINGERING DISEASE WITH DESTRUCTIVE POTENTIAL

Prior to the 1970s, coconut palm (*Cocos nucifera*) was the most popular and abundant species grown throughout southern Florida. Unique among palms in its ability to evoke an exotic tropical appeal to coastal landscapes, this species is often prominently featured in advertisements to promote Florida tourism. In 1971, the first cases of lethal yellowing (LY), a disease of uncertain etiology at that time, was reported on mainland southern Florida (Seymour et al. 1972). Known to sporadically disrupt coconut production in Cuba and Jamaica since the 1800s (Eden-Green 1997), this fast moving, quickly fatal disease killed most of the resident population of Jamaica tall (Atlantic tall ecotype) coconuts, estimated at 700,000 palms in southeastern Florida, within a

five-year period (McCoy et al. 1983). Mortality of 35 other ornamental palm species attributed to LY was also documented during this time (McCoy et al. 1983; Harrison and Oropeza 2008). Catastrophic losses of Atlantic tall coconuts (>7 million palms) to LY in Jamaica during the same era were followed by similar epiphytotics in southeastern Mexico (Oropeza and Zizumbo 1997) and in northern Honduras during the 1990s (Eden-Green 1997). Recurrent widespread mortality of resistant Malayan dwarf and hybrid Maypan coconuts in Jamaica since the late 1990s indicates that as yet undefined changes within the phytoplasma-vector-palm pathosystem have occurred there (Lebrun et al. 2008). To-date, similar unusual increases in disease among susceptible palm species in southern Florida have not been observed.

Originally confined to just four contiguous southeastern counties, bounded by Monroe County in the south and Palm Beach County in the north, long-distance dispersal to and establishment of LY in Lee County on Florida's southwestern coast occurred during the late 1980s. Although further southward advance of the disease into neighboring Collier County, which contains the largest remaining population of about 80,000 Atlantic tall coconut palms in the state has occurred, palm mortality was effectively minimized by the implementation of a rigorous disease management program based upon prompt identification and removal of diseased palms in concert with proactive treatments of adjacent symptomless palms with oxytetracyline hydrochloride (OTC-HCl) until disease abatement, at which time treatments were discontinued (Fedelem 2000). For the last four decades, the persistent threat of LY has demanded the judicious use of susceptible palms, resulting in the widespread popularity of species, such as Queen palm, Royal palm (*Roystonea regia*), Mexican fan palm, Pygmy date palm (*Phoenix roebelenii*), and sabal palm, for landscaping as they do not to succumb to the disease (McCoy et al. 1983; Meerow 2006).

Phytoplasmas are the accepted cause of LY based on their consistent detection in diseased palms by transmission electron microscopy (TEM) Plavsic-Banjac et al. 1972; Thomas 1979), remission of symptoms in response to tetracycline therapy, and absence of any other pathogen. Phytoplasmas are small, unculturable, cell wall-less bacteria, ovoid to filamentous in shape, with minimal (560–1300 kb) A+T-rich genomes (Christensen et al. 2005; Harrison et al. 2010; Kollar and Seemüller 1989). Phytoplasmas have evolved as obligate, intracellular parasites that inhabit the phloem of plants as well as tissues and organs of their various phloem-feeding insect vectors (Garnier et al. 2001; Lee et al. 2000; Weintraub and Beanland 2006). Due to their small size and obligately parasitic habit, confirmation of phytoplasma diseases has traditionally relied upon *in situ* detection of phytoplasmas in host tissues by TEM. Today, more sensitive molecular assays tailored to detect phytoplasma DNA have largely replaced TEM as the method of choice for confirming phytoplasma infection of plants, especially woody perennial hosts such as palms in which they typically occur in low abundance (Harrison et al. 1994).

Sensitive DNA-based diagnostics employing polymerase chain reaction (PCR) assays capable of detecting phytoplasmas in a "universal" group-specific or pathogen-specific manner have been developed (Lee et al. 2000). Assays that amplify 16S rRNA genes when combined with restriction fragment length polymorphism (RFLP) and sequence analysis of resulting rDNA products have also provided a means to precisely identify and classify phytoplasmas for taxonomic purposes (Lee et al. 2000). Twenty-eight 16S rDNA RFLP (16Sr) groups comprising numerous subgroups of strains have been described thus far (Wei et al. 2007). PCR amplification

and RFLP analysis of rDNA have demonstrated that phytoplasmas associated with LY disease of palms in southern Florida exist as a homogenous population of strains (Harrison et al. 2002a). Originally assigned as the sole member of group 16SrIV (coconut lethal yellows group) subgroup A (i.e., 16SrIV-A), at least five additional subgroups of strains have since been identified within the group, including 16SrIV-B, which includes Yucatan coconut lethal decline phytoplasma (YLD) (Lee et al. 2000); 16SrIV-C, which is represented by Tanzanian coconut lethal disease (TLD) phytoplasma (Lee et al. 2000); 16SrIV-D, which contains *Carludovica palmata* yellows (CPY) phytoplasma; 16SrIV-E, which includes phytoplasmas associated with coconut in the Dominican Republic (Martinez et al. 2008); and 16SrIV-F, which is represented by a phytoplasma detected in a *W. robusta* in west-central Florida (Harrison et al. 2008).

TEXAS PHOENIX PALM DECLINE: A NEWLY EMERGING DISEASE OF UNCERTAIN DESTRUCTIVE POTENTIAL

Prior to 2006, no evidence for northerly dispersal of LY beyond the southernmost subtropical tier of Florida had been documented. This well-established zone of confinement mirrors the geographic boundaries within which coconut palm can be successfully grown and encompasses the native range of the neotropical planthopper vector *Haplaxius* (*Myndus*) *crudus* of LY (Howard et al. 1983; 1984), which is not cold hardy. In light of these observations, discovery of approximately 10-year-old, seed-grown *P. sylvestris*, *P. sylvestris* x *P. dactylifera* and *P. sylvestris* x *P. canariensis* hybrids with fruit and foliar discoloration symptoms and ensuing mortality indicative of LY (McCoy et al. 1983) at a palm field nursery in Hillsborough County, west-central Florida, was a new and unexpected development. Foliar and root decay symptoms similar to those observed on *P. sylvestris* and hybrids were also found affecting immature Queen palm (*Syagrus romanzoffiana*) interplanted with symptomatic *P. sylvestris*. Phytoplasmas were subsequently detected by 16SrIV group-specific PCR assay (Harrison et al. 2008) in all declining palms sampled at this site as well as in declining *P. canariensis* and *P. dactylifera* palms located in surrounding communities. RFLP analysis augmented by sequencing of rDNA products from PCR-positive palms identified the associated phytoplasmas as subgroup 16SrIV-D strains not previously documented to occur in Florida. The fact that these strains were indistinguishable from phytoplasmas associated with Texas Phoenix palm decline (TPPD), a lethal disease of *P. canariensis* in Corpus Christi, Texas during 2000 (Harrison et al. 2002) was also noted.

Surveys for diseased palms were conducted during 2007 in Hillsborough, Manatee, and Sarasota Counties by Florida Division of Plant Industry scientists with assistance from the United States Department of Agriculture's Cooperative Agricultural Pest Survey (CAPS) program. Samples from suspect palms from within these three contiguous counties were also provided by University of Florida Cooperative Extension Service personnel, landscape maintenance businesses, and homeowners for molecular diagnostic analysis. The cumulative diagnostic data indicated a decreasing TPPD disease incidence from north to south, implicating Hillsborough, the most northerly county, as the probable epicenter of infestation by subgroup 16SrIV-D phytoplasmas (Harrison et al. 2008). While the majority of sampled palms in the contiguous tri-county area contained subgroup 16SrIV-D phytoplasmas, two *P. canariensis* palms were found to contain subgroup 16SrIV-A phytoplasmas in Sarasota County thus extending the known northward distribution of LY in the state. Also, in Sarasota County, a solitary *W. robusta* was found to harbor a previously undocumented subgroup 16SrIV-F phytoplasma, as did two *P.*

dactylifera, although this novel strain was detected in the latter palms as a mixed infection along with subgroup 16SrIV-A phytoplasmas. While little is known about this new subgroup 16SrIV-F strain, its close rDNA sequence similarity (99.6%) and occurrence as mixed infections with subgroup 16SrIV-A strains in *P. dactylifera* may be of epidemiological and evolutionary significance, as it suggests that both strains are vectored by *H. crudus*.

A program of continued surveillance and sampling of palms has determined that TPPD currently remains most active in the aforementioned tri-county region. However, isolated cases of the disease, mostly affecting *P. sylvestris* palms, have been identified in Flagler, Highlands, Pinellas, Polk, Lake, and Lee Counties. Solitary cases of TPPD disease affecting three new palm hosts, namely, Pygmy date palm (*P. roebelenii*), Senegal date palm (*P. reclinata*), and mule palm (*S. romanzoffiana* x *Butia capitata*), have since been confirmed in Hillsborough County (unpublished data).

In 2008, unusually large numbers of dead and declining *S. palmetto* palms with reddish-brown leaves were first recognized in Manatee and Hillsborough Counties. Common in urban and suburban ornamental landscapes in both counties, the sabal palm is most abundant and widely distributed in rural and coastal forest habitats, and is considered integral to the ecology of most ecosystems statewide. Etiological study of affected palms using molecular diagnostic techniques attributed this newly recognized disease to phytoplasmas (Harrison et al. 2009). As such, *S. palmetto* represents the first native palm species to be impacted by a phytoplasma disease in Florida, and is a cause of great concern regarding the long-term survival of this stalwart species. Phylogenetic analysis of PCR-amplified DNA sequences has attributed the etiological agent of the disease to phytoplasmas seemingly co-identical with subgroup 16SrIV-D phytoplasmas, which was previously associated with declining palm and palm-like hosts in other studies (Cordova et al. 2000; Harrison et al. 2002; Ong and McBride 2009; Vázquez-Euán et al. 2011).

Early-stage foliar symptoms of TPPD on *S. palmetto* are most difficult to diagnose, especially on palms in natural stands, as they are commonly affected by nutritional deficiencies, especially potassium deficiency, inducing discoloration and premature senesecence of up to half of the lower leaves within the palm canopy. Also, *S. palmetto* flowers only once annually, in mid-year, allowing just a short window of opportunity to evaluate palms for evidence of disease-induced inflorescence symptoms. The species is known to die from a variety of other causes such as Ganoderma basal trunk rot, bud rot due to *Phytophthora palmivora*, infestation by (*Rhyncophorus cruentatus*) palm weevils (Meerow 2006; Elliott et al. 2004) and abiotic factors such as saltwater intrusion and drought (Desantis et al. 2007; Williams et al. 1999). Collectively, these factors conspire to complicate visual estimates of disease incidence or distribution.

Currently, sabal palms most affected by TPPD have been observed along a 32-mile corridor from Brandon in western Hillsborough County to Bradenton in northern Manatee County. The incidence of palm mortality has been highest in and around the towns of Parrish, Ruskin, and Palmetto in Hillsborough County. Isolated cases of TPPD-associated sabal decline have been confirmed in five other counties, namely, De Soto, Hardee, Highlands, Polk, and Sarasota. Research currently sponsored by the USDA/TSTAR-C program to provide estimates of the genetic structure of *S. palmetto* and sabal decline phytoplasma populations and to identify insect

vector(s) should provide the means to gauge the long-term impact of the disease on the survival of this palm species in Florida and the southeastern United States.

FUSARIUM WILT OF QUEEN AND MEXICAN FAN PALMS

Since late 2004, a new disease of Queen palm (*S. romanzoffiana*) and Mexican fan palm (*W. robusta*) has spread across the southern half of Florida The disease is caused by a novel fungus *Fusarium oxysporum* f. sp. *palmarum* and largely affects mature palms in landscape settings (Elliott et al. 2010). Early-stage symptoms on both Queen and Mexican fan palms resemble those previously attributed to Fusarium wilt of Canary Island date palm (*P. canariensis*), a disease that is well established in Florida and is caused by *Fusarium oxysporum* f. sp *canariensis* (Simone 2004). Initial symptoms appear on individual leaves of affected palms as chlorosis and one-sided tan to brown necrosis of the leaf blade together with a distinct reddish-brown stripe along the length of the petiole and rachis. Internal tissues beneath the stripe are also discolored. Affected leaves quickly turn necrotic. Foliar symptoms typically appear first on older lowermost leaves and then progress to successively younger leaves until all leaves in the canopy succumb (a process that is 2–3 months in duration). Necrotic leaves quickly dessicate but remain in place and do not droop, break, or collapse. At this terminal phase of disease development, the apical meristem becomes infected and dies, after which the pathogen then invades the stem tissues.

F. oxysporum f. sp. *palmarum* can be consistently isolated in culture from internal tissues of symptomatic petioles and rachides of affected palms. Pathogenicity tests on seedlings using foliar pour on inoculation have confirmed that isolates of the pathogen from either *S. romanzoffiana* or *W. robusta* are pathogenic to both palm species. Confirmation of pathogen involvement and identity is most efficiently determined by molecular characterization using pathogen DNA in a PCR assay incorporating primers that amplify a portion of the translation elongation factor 1-α, a highly informative region for differentiating forma specialies within the *Fusarium oysporum* complex as well as other *Fusarium* spp. The resulting sequences are then best queried for similarity against sequences archived in the FUSARIUM-ID database (http://fusarium.cbio.psu.edu) (Geiser et al. 2004).

The peninsular wide occurrence of the disease attributed to *F. oxysporum* f. sp. *palmarum* in southern Florida suggests either that the pathogen has been present for a considerable time prior to its initial discovery or that it has been rapidly disseminated across the region since 2004 primarily as airborne conidia, rather than by root infection or on contaminated pruning tools as is typical for spread of *Fusarium oxysporum* f. sp *canariensis*. To-date, the disease appears to be uniquely of Florida origin and is incurable at present. Further research on the disease will be needed to determine whether any other palm species are susceptible. The rapidity of observed palm mortality suggests that fungal toxin may be involved in the host-parasite interaction but remains to be demonstrated. From a disease management standpoint, it is unclear whether fungal spores in the soil can lead to root infection of replacement palm plantings, or whether there are fungicides that could be used to protect susceptible palms in areas of active disease.

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IMPACTS OF RECENTLY EMERGED INVASIVE EXOTIC SPECIES AND MAJOR THREATS TO THE DOMINICAN AGRICULTURE

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ABSTRACT

Nearly 20 new registers, interceptions, and phytosanitary problems are presented that correspond to those reported for the Dominican Republic between 2005 and 2011 under the contribution in diagnostics, identification, and/or mitigation by researchers in plant protection of IDIAF. Several of the detected problems are threatening on longer-term specific crops, such as Huanglongbing in the citrus industry, and Red palm mite and Lethal yellowing in the coconut industry. Other species, although causing economic impacts, have been evaluated and practices for their management are being developed and validated, or are already being practiced. The status of some of the species is still unknown. New registers must first be validated and confirmed by the authorities of the Department of Plant Health of the Ministry of Agriculture.

RESUMEN

Alrededor de 20 nuevos registros, detecciones y problemas fitosanitarios para la República Dominicana son presentados, correspondiendo a aquellos reportados entre 2005 y 2011 con la contribución en el diagnóstico, la identificación y/o mitigación por parte de investigadores en protección vegetal del IDIAF. Varios de los problemas detectados están amenazando a largo plazo a cultivos específicos, como la enfermedad Huanglongbing en la industria de cítricos, y como el Ácaro rojo de las palmeras y el Amarillamiento letal en la industria de cocotales. Otras especies o agentes causales, a pesar de causar impactos económicos, han sido evaluadas y las prácticas para su manejo se están desarrollando, validando o ya se practican. El estado de algunas de las especies aún es desconocido. De todos modos, nuevos registros deben ser validados y confirmados por las autoridades del Departamento de Sanidad Vegetal del Ministerio de Agricultura.

INTRODUCTION

The increasing number of travelers and shipment of agricultural commodities from and to the Caribbean, and especially the Dominican Republic (DR), have allowed the introduction and establishment and spread of numerous exotic species, mainly arthropods, and fungal, bacterial,

and viral diseases. Thirty of the most important invasive alien species (IAS) reported in the Dominican Republic between 1975 and 2003 with impacts on Dominican agriculture belonged to the following taxonomic groups: 21 arthropods (16 insects, 4 mites, 1 spider); 1 molluscs; 8 pathogenic diseases (3 fungi, 1 bacteria, 1 MLO, 3 virosis) (Serra et al. 2003b; Serra 2005).

Immediate threats by IAS to the agricultural and ornamental crops in the Dominican Republic include exotic fruit flies (several *Anastrepha* spp., and *Bactrocera*, *Dacus*, and *Ceratitis*), Mango seed weevil (*Sternochetus mangiferae*), *'Q biotype'* of sweetpotato whitefly (*Bemisia tabaci*), Cycad scale (*Aulacaspis yatsumatsui*), Lobate lac scale (*Paratachardina lobata lobata*), Pepper weevil (*Anthonomus eugenii*), Avocado seed moth (*Stenoma catenfer*), African giant snail (*Achatina fulica*), Tropical bont tick (*Amblyomma variegatum*), and Tropical soda apple (*Solanum viarum*) (Serra et al. 2003b, 2005).

INVASIVE SPECIES WITH IMPACT ON DOMINICAN PLANT PRODUCTION

Invasive exotic species belonging to a wide variety of taxons, such as insects, mites, fungi, viruses, and viroids, have been reported to have reached the Dominican Republic. Below are examples of those that have been established, presenting a threat to agricultural crops, including some ornamentals.

Arthropods

Until 2011, only one of the listed threats had been widely reported to have entered the Dominican Republic, the pepper weevil.

Pepper weevil (span. Picudo del ají, *Anthonomus eugenii* Cano): It was previously reported on the neighboring island of Puerto Rico. It attacks the pepper fruits during the flowering period with the larvae feeding inside the fruits, causing the abortion of fruits or spoiling them in association with rotting fungi and bacteria. This curculionid is closely related to the native eggplant weevil (*A. oraapis*, syn. *A. pulicarius*), reported on occasions as a severe pest aborting eggplant flowers (Schmutterer 1990; Baltensperger and Serra 2004). It was first mentioned in 2006 in orchards localized in the eastern regions of the island, causing heavy damages in sweet and hot pepper growing areas, such as Ocoa, Baní and the Cibao region, between 2008 and 2010.

Red palm mite (RPM, *Raoiella indica* Hirst): Since its first detection in the Western Hemisphere in Martinique, French West Indies, the RPM has been disseminated throughout the Caribbean islands, having reached the Dominican Republic in 2005; since then, samplings have been carried out, especially on coconut palms and bananas covering 24 provinces of the Dominican Republic, to register the presence and dissemination throughout the country (Roda et al. 2008; Serra 2007). In the southern/southwestern provinces of Santo Domingo, San Cristóbal, Azua, Barahona, and Pedernales (and beyond the Haitian border), as well as the northern/northeastern María Trinidad Sánchez, Samaná, among others, significant outbreaks were observed in coconut palms (*Cocus nucifera*), ornamentals palms (*Aonidia merrillii*, *Phoenix* spp., *Raphis* sp. and others), and edible and ornamental bananas (*Musa* spp.), and in lower intensities in Strelitziaceae, Heliconiaceae, and Zingiberaceae. At the end of 2006, detections were made for the area between Santo Domingo and Azua. By 2007, RPM had already spread widely over the

southwestern, northern, and northeastern coastal areas, and the central Cibao plain, where the typical yellowing and necrotic symptoms on palm leaves were seen, sometimes in mixed infestations with scales, mealybugs, and whiteflies; and by 2010, significant damages were registered on all the island.

The impact of RPM is severe during dry seasons, and less so during rainy seasons (rain reduces the population dramatically). Coconut producers of the main producing areas of the north and northeastern coast have reported losing between 50 and 70 percent of their yields, and obtaining fruits of low quality. In addition, under very dry conditions at the eastern part of the Samaná peninsula, bananas associated to coconut palms are heavily affected by RPM. The obtained data suggest the dissemination starting from the capital along the southwestern coast or crossing the country from Santo Domingo through the Cibao plain to the northern coast of Puerto Plata province and to the northeastern provinces of María Trinidad Sánchez and Samaná. The quick spread was probably enhanced through the transportation of ornamental palms and other host plants from plant nurseries of the capital area to regions with high construction activity due to tourism infrastructure development. The quick spread was encouraged by winds and storms. In spite of a superior tourism infrastructure on the east coast, a delayed RPM infestation was probably due to the production of palms and other ornamentals in the southeastern provinces. Throughout the study, only relatively low amounts of natural enemies, such as predatory mites *Amblyseius largoensis* (Muma), (Acari: Phytoseiidae), *Stethorus* sp. (Coleoptera: Coccinellidae), and chrysopids, have reached the level of biocontrol similar to findings reported by Peña et al. (2009) for Puerto Rico.

Pests on *Ficus* spp.: Several new pests of the genus *Ficus* that have been registered cause severe leaf drop. The Cuban laurel thrips (*Gynaikothrips ficorum* [Marchal]) was first reported in 1927, a heavy outbreak in 2001 was considered to be linked to this species. Since 2008, severe leaf drop in *Ficus* spp. has spread over the island. This was due to a heavy outbreak of the exotic Ficus whitefly, *Singhiella simplex* (Singh) (Hemiptera: Aleyrodidae), in the absence of effective biocontrol mechanisms with parasitism of <<1%. The species was already widespread in Puerto Rico in 2006. The whitefly parasitoid, *Encarsia protransvena* Viggiani, although still not confirmed, has steadily increased its presence, reaching up to 40 percent in 2011 in *F. retusa* in Santo Domingo, which suggests a stabilization of the population on longer terms.

Mango leafhopper: Since 2009, several researchers have reported the presence of a still unidentified leafhopper, similar to the so-called Flat fish hopper (Flatidae), among the inflorescences of mango trees, especially during the bloom period, when it reaches higher populations. No studies have still been realized to clarify the status as potential pest.

Pigeon pea podfly, (span. 'Moscas asiática del guandul', *Melanagromyza obtusa* (Malloch), Diptera: Agromyzidae): After the establishment of this pest of Asian origin, especially on alternative host plants (e.g., *Rhynchosia* spp., Fabaceae) was recorded (e.g., *Habrobracon* sp., Hymenoptera: Braconidae), the impact of up to >80% yield losses has been reduced (Serra et al. 2003a) due to the adoption of control measures by farmers and the adaptation of native and/or introduced parasitoids (*Melittobia* sp. and *Ormyrus* sp., Hym.: Eulophidae or Ormyridae, respectively). In Puerto Rico, Abreu and Almodovar (2005) reported parasitoids of the genus *Callitula* (Hym.: Pteromalidae) and *Melittobia* sp. (Hym.: Eulophidae) obtained from

Rhynchosia spp. For classical biocontrol purposes, *Ormyrus orientalis* from Australia and India was introduced.

Passionvine and Coffee Mealybugs (*Planococcus minor* (Maskell) and *Planococcus lilacinus* (Cockerell), Hemiptera: Pseudococcidae, respectively): A study is being undertaken in Dominican cocoa and coffee plantations to actualize the inventory of mealybugs, host ranges, and associated arthropods (parasitoids and others) and to confirm/not confirm the presence and status of *Planococcus minor* (Maskell) and *Planococcus lilacinus* (Cockerell) as reported for Hispaniola by Ben-Dov (1994) and Watson and Chandler (2000). There were 75 detections reported entering U.S. ports from the Dominican Republic between 1986 and 2005 (Pérez-Gelabert 2008). The difficulty in finding colonies of the species could be due to the presence of effective natural enemies as shown for *P. minor* in Trinidad and Florida (Francis, Kairo, and Roda 2012; Francis et al. 2012).

Classical biocontrol: Three projects on classical biological control (CBC) of IAS have been successfully accomplished in the Dominican Republic since 2000 with support of USDA/APHIS through the Plant Health Department of the Ministry of Agriculture, experts from diverse institutions and universities, and the scientific follow-up by USDA/APHIS and by IDIAF for Papaya mealybug (*Paracoccus marginatus*: liberating *Acerophagus papayae*, *Anagyrus loecki*, *Anagyrus californicus* Compere, and *Pseudaphycus* sp.), Pink hibiscus mealybug (*Maconellicoccus hirsutus* with encyrtid wasps *Anagyrus kamali* and *Gyranosoidea indica*), Fruit flies (mainly *Anastrepha obliqua* and *A. suspensa*: establishing *Doryctobracon areolatus* (Szépl.), a braconid wasp) (Kauffman et al. 2001; Meyerdirk and DeChi 2003; Serra, Nunez, and Garcia 2004; Serra et al. 2011). A dramatic reduction of mealybug populations has been achieved, with only sporadic outbreaks being, and a positive effect on the targeted fruit flies has been confirmed by some commercial growers of mangos and guava of the San Cristobal and Monseñor Nouel provinces, respectively.

Fungal Diseases

Taro leaf blight disease (span. 'Tizón foliar de la yautía', *Phytophthora colocasiae* Racib.): While it was first reported by Ciferri (1954) in the Dominican Republic in New cocoyam (*Xanthosoma* spp., Araceae), Holliday (1980) confirmed the presence of the pathogen in the Dominican Republic and other Caribbean islands, and Erwin and Ribeiro (1996) confirmed the presence in Taro (*Colocasia esculenta*, Araceae) specifically. In 2004, the pathogen was reported by Méndez, Reyes, and Hernandez (2004) as the causal agent of an epidemic, which destroyed the taro crop in the rather humid northeastern Dominican Republic, making it necessary to establish drip irrigation in arid zones in the northwestern and southern areas of the country. Research with resistant materials (originating at the University of Hawaii) is ongoing at CENTA.

Brown leaf spot or ghost spot (span. 'Mancha marrón de las hojas de yautía' *Cladosporium colocasiae* Sawada): This fungal disease of older leaves, which is present in the U.S. state of Louisiana (Holcomb 1989) has only recently been reported in the Dominican Republic (García and Moya 2012). The disease causes spots that are less visible on the lower leaf surface. As the disease progresses, the petiole turns flaccid from the top to the base, making the leaves drop.

Stackburn disease in rice (span. 'Manchado del grano de arroz', *Alternaria padwickii* (Ganguly) M.B. Ellis): This disease was first reported in the Dominican Republic by Méndez and Reyes (2008). It produces blight in rice plants, with circular brown foliar spots that are brighter in the center and darker on the edges. It is reported to be transmissible by seeds (Ou 1985). The leaf spot syndrome is also caused by other pathogens such as *Bipolaris oryzae*, *Curvularia* sp., *Cercospora oryzae*, *Sarocladium oryzae*, *Nigrospora* sp., *Magnaporte* sp., and the bacteria *Burkholderia glumae* and *Erwinia* sp.

Antracnosis of pigeon pea (*Cajanus cajan*): A pod rot that causes yield losses up to 50 percent in the Mayor production zone (San Juan de La Maguana valley) has been analyzed by Segura, Arias, Godoy-Lutz (2010), and the causal agents Collectotrichum gloeosporioides Penz. and Fusarium equiseti (Corda) Saccardo have been identified by sequencing the ITS region (Godoy-Lutz 2004). No resistant varieties are yet available against this seed-borne disease (Lenné 1992).

Emerging mango diseases: The so-called 'Dieback' and gummosis (span. 'Muerte regresiva', *Lasiodiplodia theobromae* (Pat.)) is a fungus (originating in Asia) that affects several fruit trees such as avocado, macadamia, and citrus spp. In affected plants, twigs die from the tips backwards into the old wood. In the Dominican Republic, researchers use sanitation measures combined with copper sulphate (Pérez no date; Leger 2009). In addition, the so-called 'Witches broom' (span. 'Escoba de Bruja del mango') is present in the Dominican Republic. It is consistent with inflorescense malformation which is caused by the complex of *Fusarium* spp. and the Mango eriophyid mite *Eriophyes mangiferae* (Leger 2009).

Fusarium oxysporum f. sp *lycopersici* race 3: Méndez, Perez, and Camejo (2010) have confirmed the presence of this race in tomato crops (*Lycopersicum esculentum* Mill.) in the Dominican Republic.

Bacteria

Bacterial panicle blight (BPB)**:** (span. 'Añublo bacterial del arroz'): Rice is cultivated as a main food crop in the Dominican Republic (consumption 45–50 kg/capita/year), producing 450,000 metric tons of polished rice on 93,000 hectares. Based on IDIAF research data, the syndrome of 'empty grains of rice' has caused over US$50 million in losses in the Dominican Republic, reducing yields more than 20 percent, especially in the northeastern and north-central regions. The 'empty rice grains syndrome' (ERGS), is believed to be caused by a combination of the panicle rice mite (*Steneotarsonemus spinki* Smiley), the fungal disease, *Sarocladium oryzae* (Sawada), and non-biotic factors. The disease known as BPB (span. "Añublo Bacterial de la Panícula del Arroz) is caused by the bacteria *Burkholderia glumae* interacting with the panicle rice mite (*Steneotarsonemus spinki* Smiley), which initially colonizes the flag leaf to invade the spikelets during the bloom causing the rot, discoloration, and sterility of the grains (Hummel et al. 2009). Although not officially confirmed in the Dominican Republic, in 2008, symptoms resembling those of the bacterial blight in fields of the provinces of Maria Trinidad Sánchez, Monseñor Nouel, and Montecristi, were noticed on the flag leaf sheaths (Halpay, Silverio, and Camejo 2012). Serological tests (ELISA) run by IDIAF researchers of the CENTA to 32 randomly collected panicles and grains gave 17 percent positives. The further extraction of DNA of positive samples and analysis with a specific primer (Qiagen, Gaithersburg, MD) by PCR

confirmed 66 percent positives. This factor (*B. glumae*) is being added to ERGS and is likely to become the most important pathogen associated with the disease complex known as vaneamiento because of its seed-borne transmission capacity (Halpay, Silverio, and Camejo 2012).

Huanglongbing (HLB) or 'citrus greening': *Diaphorina citri* Kuwayama (Hemiptera: Psyllidae), vector of the HLB, has been present in the Dominican Republic since at least 2001 (Serra et al. 2003b). In August 2008, the first detection of HLB symptoms was reported in citrus orchards near Luperón on the northern coast of the Puerto Plata province and confirmed using the PCR technique (Matos, Hilf, and Camejo 2009). Backed by funds from citrus producers, the CENTA laboratory started analyzing samples in 2009. Analyzing 11,568 samples from 27 provinces, 47.5 percent of the samples were positive. HLB has spread from the northern and northwestern provinces to most of the DR areas with citrus trees, and has actually been confirmed for 25 provinces (Matos et al. 2011c). The National Program for Integrated Management of Citrus HLB is coordinating efforts with IDIAF researchers, growers, nurserymen, and the Ministry of Agriculture for the destruction of infected plants and for chemical control of the vector. Some predators and the parasitoid *Tamarixia radiata* (Waterston) (Hymenoptera: Eulophidae) are present, but still no evaluation of their biocontrol has yet been undertaken (Halbert and Nunez 2004).

Phytoplasma, Viruses, and Viroids

Lethal yellowing disease of palms (LY): This phytoplama infects 36 palm species, among those are *Cocos nucifera, Veitchia merrillii,* and *Phoenix dactylifera.* In the Dominican Republic, it was first reported by Carter (1962) in Dajabon in the northeast, having been disseminated very slowly during decades but having reached the region of Cabrera at the western edge of the main coconut growing region in the northeastern and eastern coastal areas. In addition, Martínez et al. (2008) reported for the first time the presence of LY in coconut on the southern coast of Boca Chica. A molecular analysis shows that it is due to the Phytoplasma 16 Sr IV. It has been reported that LY is also approaching the southeastern edge of the main coconut-growing area.

Diverse sucking arthropods potentially associated with coconut groves were listed for the first time in the Dominican Republic by Ferreira, McKamey, and Martinez (2010) as mirid bugs (*Pycnoderes vanduzeei* Reuter, *P. testaceipes* Stål, *Halticus bractatus* Say, *Trigonotylus tenuis* Reuter, *Reuteroscopus hamatus* Kelton, *Taylorilygus apicalis* Fieber) and cicadellid (*Bothriocera undata*). Besides the known cixiid planthopper and LY vector *Haplaxius* (syn. *Myndus*) *crudus* (van Duzee) (Howard, Kramer, and Peralta 1981; Howard, Norris, and Thomas 1983; Howard and Wilson 2001; Ferreira, McKamey, and Guerrero 2012), two other species, *H. jamaicae* (Kramer) of insular Caribbean distribution and the newly described species *H. cabrerensis* has been detected (Ferreira, McKamey, and Martinez 2010). Further studies will be needed to confirm their importance as potential LY vectors.

Virus diseases in vegetables: Several of the viruses present in DR pepper, tomatoes, and cucurbits have presumably not been identified or confirmed on a molecular level yet, so they will need to be targeted in ongoing and proposed projects.

Bean common necrotic mosaic virus (span. Virus del mosaico necrótico común del frijol, BCNMV): It was first detected in the San Juan Valley in 1999/2000 in black and white beans and was probably introduced through seeds of the beans type 'Pinto' or 'Negra' from Africa or the United States, where it is endemic (Godoy-Lutz et al. 2004; Godoy-Lutz, Segura, and Arias 2006). It has been isolated in the Dominican Republic, associated with basic seeds of black-seeded and white-seeded bean varieties distributed for seed production by growers. A study conducted by IDIAF researchers helped to eliminate more than 454 Tm (10,000 qq) of contaminated seeds from stored seed stocks of growers associations. Since seeds of the black-seeded varieties are purchased by non-governmental agencies for distribution among Haitian farmers, there is the probability that the BCMNV present in the DR southwestern region is similar to strains associated with beans in Haiti. In collaboration with Drs. Phil Miklas (USDA) and Flores-Estevez (CINVESTAP/IPN, Mexico), we have determined that the strain present in the Dominican Republic is among the most virulent pathotypes of the BCMNV. By RT/PCR and analysis of the sequence at the amino region at the end terminus of the coat protein gene, the DR strain was assigned to pathogroup VI instead of III, as previously thought, based on ELISA assays inoculation to set of host differentials. The presence of both pathotypes and a recombinant of both should not be ruled out since the latest findings indicate the occurrence of genomic recombination between two distinct virus species within the family *Potyviridae*. Currently, seed testing for potyvirus and the release of new black-seeded varieties such as DPC-40 with both I and bc-3 resistant genes have reduced the spread and severity of the BCMNV in bean production in the Dominican Republic.

Citrus Tristeza Virus (CTV): It has actually spread all over the country The CTV genotype composition in the Dominican Republic is represented by the strains T3, T30, T68, and VT. T30 and VT are widely distributed within the country while T3 is still restricted to only four provinces. T30 and VT were found to be present on all five cultivars sampled. T3 was found in trees of Persian lime (*Citrus latifolia* (Tan.)) and Mexican lime (*Citrus aurantifolia* (Christm. Swingle)) (Matos et al. 2011a).

Citrus Viroids: Matos et al. (2011b), using RT-qPCR to analyze 51 samples from 22 citrus orchards of the main citrus producing areas, reported viroids types II and III for the first time in the Dominican Republic. They confirmed that the cracking of the bark of Persian lime trees is not due to a genetic degeneration, as initially suspected, but to the presence of various types of viroids. No samples were amplified for viroids types IV and V. The results indicate that the presence of viroids type III are widely spread in sampled orchards; nevertheless, the viroids of Exocortis, which were reported in 1996 (Matos et al. 2011a), seem to be rather restricted in terms of distribution compared to viroids types II and III. Only one sample of sweet orange, 'Valencia', of Hato Mayor amplified a viroid type III while the other 19 corresponded to Persian lime, indicating that it is the more sensitive of both cultivars.

CONCLUSIONS

Despite efforts of regulatory authorities in charge of plant quarantine, established international networks, improved infrastructures, and trained staff, IAS belonging to different taxons have entered and become established in the Dominican Republic, causing severe impact on plant production and economic losses to the people involved with the agricultural sector. We will

continue researching IAS detection, diagnosis, and/or mitigation activities in the Dominican Republic, especially under the coordination or participation of IDIAF researchers, through CENTA plant protection laboratories and EEAL and EEML experimental stations. In our study, we emphasized the following complexes or races of species: four arthropods (insects and mites), seven fungi, two bacteria, one phytoplasma, three viruses or virus complexes, and one viroid.

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"Assuring Caribbean Food and Nutrition Security in the Context of Climate Change"

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OPERATION BREADBASKET: A U.S. VIRGIN ISLANDS COMMUNITY OUTREACH AND ASSISTANCE PARTNERSHIP PROGRAM

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ABSTRACT: Operation Breadbasket was a program of the Virgin Islands Farmers Cooperative (VIFC).The primary goal of this program was to reverse the 45-year decline of agricultural production in the U.S. Virgin Islands by reducing the risk of farming through training and community outreach. The technical staff of the University of the Virgin Islands (UVI) Cooperative Extension Service, UVI Agricultural Experiment Station, UVI Small Business Development Center, Virgin Islands Department of Agriculture and the Virgin Islands Bureau of Internal Revenue partnered with the VIFC to conduct risk management training in vegetable crop and small livestock production, farm business development and income tax preparation. The nature of the training was hands-on, onsite; practical applications, instructions and demonstrations for the purpose of having the producer reduce risk, and utilize improved sustainable production methods. Training was conducted on various farms on the island of St. Croix. On each of the farms an assessment was conducted to evaluate and strengthen the producer's knowledge of their farm operations and the utilization of emerging technologies and practices. The program used seven crops (watermelon, tomato, eggplant, okra, cucumber, bell pepper and cantaloupe), small livestock production (sheep, goats and pigs), improved forage management, farm business planning, recordkeeping and tax preparation to provide the participants with the tools needed to successfully manage an efficient farming enterprise. The training was intended to help transition limited resource, socially disadvantaged farmers into productive and profitable farmers through the creation of new farming enterprises and the increased availability of high-quality, locally-grown food. The program provided practical training in farm management, financial management, marketing, production, crop insurance and other risk management tools to educate U.S. Virgin Islands farmers on how to increase their production and income. The program trained producers in various methods of sustainable farming to reduce risks and increase crop, livestock and forage production. The program sought to use the agriculture training as a means to: create a social and economic stimulus while improving the image of farming to attract and develop new farmers. The anticipated outcome is an improvement in our local food system, food security, and overall quality of life in the territory.

Keywords: Farmer training, risk management, limited resource farmers, farming enterprises, community outreach, vegetables, small livestock

Background

The U.S. Virgin Islands were the Danish West Indies prior to their purchase from Denmark by the United States in 1917. Between 1760 and 1960 the Virgin Islands produced most of the food it consumed and St. Croix, the largest and most fertile island, was known as the "Breadbasket of the Caribbean" – (Danish Caribbean) during Danish rule and after the U.S. purchase. Sugar was king, in the islands' agricultural production of a single crop, until 1966 when the last sugar factory on the island of St. Croix was closed. Local farmers were then encouraged to diversify and expand their efforts to provide locally grown food. The diversification attempts included a variety of crops including cotton, citrus and a range of other tree crops. None of these crops endured and cattle, small ruminants, poultry and pig rearing replaced them. The introduction of sorghum as a versatile grain crop for a fledging livestock industry failed, which led to a downturn in poultry and pig production. The grass-fed animals industry survived and dairy farming became a dominant value-added enterprise until the dairy industry closed in 2006.

Today, the economy has changed substantially. A few relatively large tracts of farmland are still utilized for commercial production while home gardens also supply produce to the local markets. However, 95 to 99% of the food consumed in the islands is imported. It is clear that a revitalized, efficient local agriculture industry can provide significant employment opportunities for the residents of the U.S. Virgin Islands (USVI). This Community Outreach and Partnership Assistance Program in farm management, financial management, marketing, production, crop insurance and other existing and emerging risk management tools was conducted to put in place risk management tools for the resurgence of St. Croix's agricultural industry.

Operation Breadbasket

The overall risk of farming in the USVI is a challenging venture: farms are small; land, labor and financial resources are limited; crop insurance is expensive; high cost of agricultural equipment and other inputs; competition from low-priced imported produce; and the increasing age of farmers. Because of these circumstances many producers are unable to sustain a profitable operation.

Agriculture has therefore gained a poor reputation for income generation, dependability and contributing significantly to the local economy. Improving the image of farming is necessary to attract and develop new farmers while at the same time improving our local food system and food security.

Operation Breadbasket was introduced to reduce the risk of farming in the USVI, increase the territory's agricultural production, maintain permanent agricultural employment and create an economic stimulus to improve the quality of life of all in the USVI. This initiative was undertaken through training, community outreach and promoting the resurgence of the agricultural industry. The project educated producers in methods of sustainable farming while providing the training to manage the existing and emerging risks of their farming operation. Operation Breadbasket provided a unique opportunity to transition limited resource, socially disadvantaged farmers into productive and profitable farmers.

Training Activities

The training activities were conducted over a period of one year. The Project Director scheduled and coordinated all events in conjunction with the training team, partners, and consultants to prepare for the project's mobilization of all the tasks. The training was provided primarily for all members of the Virgin Islands Farmers Cooperative but was also available to other farmers and interested persons.

Farm Financial Planning and Management

The training program provided instructions, practical application and demonstration of how to operate a farm enterprise (Fig. 1). This training was intended to raise the awareness of agri-business education.

The University of the Virgin Islands (UVI) Small Business Development Center (SBDC) provided risk management training on how to develop farm businesses plans and operating farmer enterprises. The nature of the UVI SBDC training was practical applications, instructions, and demonstrations of farm management and financial management of a farm enterprise.

The topics covered included:

- Farm Management and Financial Management
- Business of Farming in the VI
- Farm Business Plan development
- Farm Planning
- Developing financial statements
- Recordkeeping training
- Develop recordkeeping templates

This training provided farmers with the tools necessary to begin the development of their farm financial, business plan and the methods of maintaining records of their farm operations.

Income Tax Preparation for Farmers

In an effort to bring farmers in compliance with our local government tax laws, and having farmers licensed annually, the Virgin Islands Internal Revenue Bureau provided training in tax preparation.

The topics covered included:

- Preparation of an individual tax return (1040) with a schedule F
- Internal revenue guide to farming operation
- Farming Tax Exemptions

Vegetable Crops and Small Livestock Production

The UVI-Cooperative Extension Service, UVI-Agricultural Experiment Station and the Virgin Islands Department of Agriculture collaborated to conduct the training classes. The collaborating partners also provided risk management training courses for vegetable crop production (Fig. 2-5) and small livestock (Fig. 6-7) developing a program to reduce producer risk to maintain and enhance the development of the Virgin Islands meat and vegetable crop industry. The trainers provided onsite practical applications, instructions, demonstrations, farm assessment, practices in small livestock and crop management and existing or improved sustainable farming practices in order to reduce the risk of small livestock and crop producers in the Virgin Islands. The hands-on

activities allowed producers to 'learn by experience' and become knowledgeable in emerging farming technologies and practices.

Training was conducted on various farms on the island of St. Croix. On each of the farms an assessment was conducted to evaluate and strengthen the producer's knowledge of their farm operations and the utilization of emerging technologies and practices. The program used seven crops (watermelon, tomato, eggplant, okra, cucumber, bell pepper and cantaloupe), small livestock production (sheep, goats, poultry and pigs), improved forage management, farm business planning, recordkeeping and tax preparation to provide the participants with the tools needed to successfully manage an efficient farming enterprise. The program provided practical training in farm management, financial management, marketing, production, crop insurance and other risk management tools to educate Virgin Islands farmers on how to increase their production and income. The anticipated outcome is an improvement in our local food system, food security, and overall quality of life in the territory.

The crop production training included:

- Farm Layout
- Recordkeeping for Crop Production
- Soil and Water Conservation Practices
- Sustainable/Organic Crop Production and Management
- Nutrient Management
- Crop Rotation
- Integrated Pest Management for Vegetables
- Integrated Pest Management (Pest Scouting)
- Drip Irrigation

The livestock production training included:

- Farm Layout
- The Business of small Livestock Management
- Small Animals for Small Farms
- Small Livestock Identification and Record Keeping
- Pasture Management
- Livestock Nutrition/Health
- Veterinary Services
- Poultry Production and Management
- Sheep Production and Management
- Goat Production and Management
- Swine Production and Management
- Small Livestock Enterprise Budgets (sheep, goats, swine)
- Abattoir Procedures, Rules and Regulations

Conclusion

The training helped limited resource, socially disadvantaged farmers transition into productive and profitable farmers through the creation of new farming enterprises and the increased availability of high-quality, locally-grown food. The program trained producers in various methods of sustainable farming to reduce risks and increase crop, livestock and forage production. The program used the agriculture training as a means to create a social and economic

stimulus while improving the image of farming to attract and develop new farmers. The anticipated outcome is an improvement in the local food system, food security, and overall quality of life in the territory.

Fig. 1. Farm and financial management training.

Fig. 2. Vegetable seedling production training.

Fig. 3. Drip irrigation installation training.

Fig. 4. Transplanting vegetable seedlings training.

Fig. 5. Integrated pest management training.

Fig. 6. Poultry, swine, sheep, and goat production training.

Fig. 7. Veterinary and abattoir services training.

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ENSURING FOOD SECURITY - WHY IT SHOULD BE A NATIONAL PRIORITY, THE BARBADIAN CONTEXT

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ABSTRACT: Barbados can no longer afford to ignore the issue of food security since a high proportion of its food requirement needs is sourced externally. As a Net Food Importing Developing Country (NFIDC), Barbados must give careful consideration to the impact of external developments and their implications particularly in the long run, on food availability. To understand the future of food supply and demand and food security, it is necessary to focus on long-term forces, such as income and population growth, and their effect on the demand for food. This paper reviews the food imports of Barbados over the past eight years both regionally and extra regionally, along with income per capita trends, in order to assess the implications of external developments in the medium to long term on Barbados' food requirement needs and propose strategies in the interim to address the issue.

Keywords: food security, food import, income per capita

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NUTRIENT PROFILING OF FLOUR FROM SELECTED BREADFRUIT (*ARTOCARPUS ALTILIS*) CULTIVARS AND ITS POSSIBLE CONTRIBUTION TO FOOD SECURITY

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ABSTRACT: As a result of a continuously inadequate diet in some regions, there may be an increase in chronic food insecurity. Breadfruit is an underutilized crop with a potentially rich nutrient bank which can contribute to food security in developing regions such as the Caribbean. A major limitation of fresh breadfruit is its short shelf-life of 1 to 3 days. A method of combating this perishability is the conversion of fresh breadfruit to flour. The objective of this study was to determine the nutrient profile of the shelf-stable breadfruit flour from selected cultivars. Eleven breadfruit cultivars (1, 20, LW, LY, SV1, SV3, SV5, J1, J2, J3, J4) from the germplasm collection of the University Field Station, Valsayn, Trinidad, were evaluated for nutrient composition. Fruits were harvested at immature and mature stages of ripeness. The fruit flesh was sliced 5 mm thick, dried at 60° C for 24 hours, milled and sifted through a 0.60 mm sieve. Proximate analyses were done in triplicate and according to the AOAC methods. There were significant differences ($p<0.05$) in dry matter, ash, crude protein, ether extract, iron, copper, manganese and selenium of the breadfruit flours. Cultivar 1 showed the highest levels of crude protein 4.7±0.12 g/100 g while SV1 showed highest ether extract (1.38±0.05 g/100 g). These values are relatively low. However, the carbohydrates and energy of the different flours ranged from 72.76±0.61 to 77.78±1.16 g/100 g and 337.02±9.32 to 346.15±0.49 Kcal/100 g, respectively, illustrating that breadfruit flour can provide more energy than boiled white rice (119 Kcal/100g). Breadfruit flour is also comparable to white wheat-flour and corn-flour (340 and 350 Kcal/ 100 g). The flour from this regionally grown crop could be used as an alternative energy source to the aforementioned imported foods. The effect of maturity was significant for dry matter, protein and energy. As the fruit matured, the values decreased. Knowledge of the nutrients in breadfruit flour is essential to the production of acceptable foods which satisfy the nutritional needs of consumers, thereby contributing to increased use of breadfruit and to sustainable agriculture and food security.

Keywords: breadfruit, flour, nutrient

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THE SEARCH FOR NEW ECONOMIC OPPORTUNITIES FOR HAITI - ASSESSING THE COUNTRY'S POTENTIAL AS A MAJOR PLAYER IN THE GLOBAL MANGO MARKET

Wegbert Chery, Govind Seepersad, and Ardon Iton, University of the West Indies

ABSTRACT: Haiti's agricultural sector contributes 26% of total GDP. Mango is the second largest export crop; an estimated 50% of production remains unutilized and only 10% is exported. This study analyzes Haiti's potential as a global supplier of mango. The study used the Export Competitiveness Coefficient, the Value Chain Analysis as well as the SWOT as assessment instruments for the research. The results of the study indicated that Haiti's Madame Francisque mango is export price competitive for all varieties except Haden in the USA market: Miami, New York and Boston Terminals. Major competitors were Mexico and Puerto Rico. In the value chain analysis, the farmers received the lowest' while the freight companies received the highest percentage of the final wholesale market price. Given the existing fruit tree population, the unutilized production volume is an asset that can be used to make a better contribution to the local economy. Weaknesses include poor infrastructure such as rural road access and packing houses, as well as SPS and postharvest. One of the best opportunities lie in processing/value added; and fruit fly poses the greatest threat.

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MEASURING TOTAL FACTOR PRODUCTIVITY AND TECHNICAL EFFICIENCY IN THE BARBADOS SUGAR INDUSTRY

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ABSTRACT: The Sugar Industry is vital to the economy of Barbados; for its earnings contribute to government budget, balance of trade, foreign exchange. It is also a source of direct and indirect employment to rural and urban Barbados. At present, the Industry's performance is declining significantly due to falling world market price, inefficiencies in production and low productivity. Added to this is the structure of the production system where sugarcane is produced by two entities, independent producers and a government-run corporation, which accounts for diverse production output. The paper attempts to measure total factor productivity (TFP) by using the DEA-based Malmquist Index and technical efficiency (TE) using the stochastic frontier analysis (SFA) in the Barbados sugar industry. The empirical application of the model will use panel data from the last seven years to estimate both the TE and TFP index. The findings will identify the source of the estate's inefficiency in use of inputs and the factors influencing such inefficiencies, as well as the determinants of agricultural productivity. The results of the study it is envisaged should have important implications on policy formulation for improving productivity and efficiency in sugar production to achieve and maintain economic growth.

Keywords: total factor productivity, technical efficiency, stochastic frontier analysis, DEA-based Malmquist index

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EXPANDING YOUR REACH: UTILIZING VOLUNTEERS TO OFFER GARDEN EDUCATION

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ABSTRACT: According to the 2000 US Census, Marion County, Florida, population was 258,916. The 2010 projection is 317,002. This increase in population means an increase in housing and potential increase in fertilizer and pesticide use. In addition to the new Florida Senate bills, Marion County Board of County Commissioners passed its own Fertilizer Ordinance in 2009. Thus, the role of University of Florida/Institute of Food and Agriculture Sciences (UF/IFAS) Marion County Extension in educating residents in best management practices (BMPs) to protect environmental resources becomes even more critical. The Extension Agent is limited in the amount of residents that can be reached. In 1981, Marion County started its Master Gardener (MG) Volunteer program based on the national model. The objectives of the program are to: (i) recruit and train 12 MGs per year; (ii) maintain a Plant Clinic to answer gardening questions; and (iii) conduct educational programs within the community. Residents participating in the program complete an intensive 13-week training course taught by the Horticulture Agent, UF/IFAS Specialists, experienced MGs, and industry professionals. Training takes place once per year. Currently there are 120 certified MGs and 15 MG Trainees. Master Gardeners are required to volunteer 85 hours (75 service, 10 continuing education) to become certified and an additional 85 per year thereafter to maintain active status. One hundred twenty-two MGs donated a total of 17,146 hours in 2010, an equivalent of $312,057 or 8.2 full time employee hours; reached 3,587 residents in the Plant Clinic; conducted 160 educational sessions for 7,192 residents; coordinated a Spring Festival with over 140 booths and attended by over 9,000 residents; and maintain four demonstration gardens and a propagation unit. The implementation of a Master Gardener volunteer program has allowed Marion County to expand its reach to provide research based information to residents on how to increase productivity in backyard vegetable gardens and maintain beautiful lawns and landscapes while protecting the environment.

Keywords: Master Gardener volunteer, protect environment

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OPTIMIZATION MODEL FOR PROFIT MAXIMIZATION OF PUERTO RICAN REGULAR AND SPECIALTY COFFEES IN THE DOMESTIC AND THE EXPORT MARKET

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ABSTRACT: Puerto Rico is a Caribbean island with adequate agronomic, geographic, and weather conditions to produce coffee. The island's coffee production is mainly selling in the domestic market. However, since the end of the 1980's decade the export of high quality coffee has been increasing. Coffee growers and roasters look at the export market (specialty coffees) as an alternative to increase their profits. An optimization model analysis was performed to maximize the profits of Puerto Rican regular and specialty coffees. The analysis considered the regular and the specialty coffees for the domestic market, and only the specialty coffee for the export market. A linear programming problem (LP) was utilized to solve the profit maximization problem. Sensitivity analyses for the price of specialty coffee for the export market and for the price of regular coffee for domestic market were performed. The profit maximization results showed a high allocation of the production in the specialty coffee export markets because of their higher price. However, in reality not all of the island's coffee production will fulfill the quality standard of the specialty coffee market. The sensitivity analysis results showed that the price range increases in the regulated commercial coffee for domestic market and the price for specialty coffee for export market significantly affected the optimal allocation of Puerto Rico production in the different markets.

Keywords: optimization model, linear programming, specialty coffee, Puerto Rico

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CAPACITIES AND SPECIALIZATION OF HUMAN RESOURCES IN THE AGRICULTURAL SECTOR OF SURINAME

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ABSTRACT: Agricultural institutions are becoming increasingly aware of the fact that HRD is crucial in their success and survival. To measure improved performance of farmers, field extension agents and researchers, variables proposed by Ali et al. (2009) and others (Biemans et al., 2004) were incorporated in a questionnaire which was developed to assess agricultural/professional competencies such as subject matter expertise, skills, attitudes, attributes and communication skills of farmers, field extension agents and researchers. Decision on this approach was based on the characteristics of the three populations, the facilities and the infrastructure. Descriptive statistics were used to analyze the data. Results indicated that: (1) agricultural knowledge should be diffused in a proper way; (2) service level upgrade of farmers is needed and extension workers should support farmers in their needs; (3) Extension Agents need a professional training program in which all of the occupation competences are exercised; (4) information sources should be managed better with the use of information and communication technology for farmers; and (5) capacity building for graduate training is needed in several disciplines.

INTRODUCTION

Education, training, extension and research form the basis for the agricultural development. Improvement of the social-economic situation will lead to an increased service of the local market with products from agriculture, stock breeding and the fisheries sector. Furthermore, a better basis arises also for the development of non-traditional plants and the agro-industry.

Agricultural based training offered in the Caribbean continues to perform poor due to limited opportunities for trainers and researchers, limited resources for the maintenance of service laboratories, limited teaching resources and delivery modes, low student enrollment in agricultural careers, and below performance standards of students in scholastic achievements tests (Private Sector Commission of Guyana, 2007). Therefore, in February 2008, the Inter American Development Bank (IADB) and the Caribbean Council of Higher Education in Agriculture (CACHE) signed an agreement formalizing a grant which allowed CACHE to carry out a study on the capacities and specialization of the Human Resources (HR) in agriculture in five participating countries including Suriname (CACHE, 2004). The study in Suriname started in September 2010.

Purpose of the study:

The purpose of this study was to assess the capabilities and specializations of the human resources in the agricultural sector of Suriname.

Objectives of the study:

Specifically the proposed study included the following objectives:

1. An assessment of the current characteristics and competences of farmers
2. An assessment of the current characteristics and competences of field extension agents
3. An assessment of the current characteristics and competences of researchers

MATERIALS AND METHODS

The sample population in this study included: twelve Research staff /Teaching staff /Administrators of Agricultural Institutions, seventy field extension workers from the Extension Service, and sixty farmers.

The questionnaire that was developed consisted of two parts. The first part contained demographic data and questions related to participants' experiences in the agricultural sector. The second part of all three questionnaires contained questions concerning agricultural practices (competencies) needed for sustainable agriculture and improved performance of the individual respondent and the agricultural sector as a whole.

The respondents were asked to rate each competency statement on two similar 1-4 points on the Likert scale. One rating was for the possessed level of competency and the other for the needed level. A validation panel was used to validate the questionnaires. It was tested for reliability and validity.

Data were collected and questionnaires interview schedules were organized and administered for farmers and extension workers by the researchers engaged in the study. The researchers, however, did fill out the questionnaire by themselves. Follow-up procedures included e-mails and telephone calls to the respondents.

Each questionnaire was coded and descriptive statistics such as percentages and frequency counts were applied to measure some of the variables. The data was analyzed (SPSS) and saved in Microsoft Excel.

RESULTS AND DISCUSSION

Farmers characteristics

All respondent farmers were engaged in vegetable production, and more than half (73.3%) earn an income of less than US $500, while the rest (26.7%) earns an income between US$ 500-US$1,500. About 68.0% of the respondents are in agriculture part time, and are working about 3-4 hours a day on their land. The rest (32.0%) of the farmers are full-time and work about 8 hours a day on their farm. The size of 68.4% of the respondents' farmland varies from 1.1 to 6.0 ha. The rest (31.6%) varies between 0.1 to 1 ha. However, the total area under cultivation of most farms (84.4%) varies from 0.1 to 1 ha. Only 13.6% of the farmers had an arable area in excess of 1 ha (1 to 3 ha). All farmers use their personal experience as an agricultural knowledge base and at meetings they prefer to communicate on a one on one basis with other farmers.

Field extension agents characteristics

The age range of 80% of the field extension agents varied between 41 and 50 years. Most Applicant Extension Agents (48.6%) and Junior Extension Agents (7.1%) have attended secondary school, while most Seniors (35.7%) have had higher education (level NATIN, VWO - pre-university education-) whereas the Area Managers (8.6%) are college educated or have attended IOL (Teachers Training Institute) and/or MO-A (Qualified Secondary Teacher).

Data analysis showed that the major tasks of extension agents include extension, training, and research. All extension agents have been engaged in these tasks from less than two years to more than 15 years, and the occupation in which they currently work include extension, horticulture, agronomy, crop protection, animal science, dairy science, food technology, and soil science. Most field extension agents (91.2%) have received training in disease and pest control, water management, integrated pest management, Good Agricultural Practices, marketing of agricultural products, hydroponics, and greenhouse management and have attended 5 to 10 trainings, while on the job. The majority of extension agents (64.3%) have a background in farming and most of them (75%) have more than 15 years of farming experience under their belt. The most important source of agricultural information for extension agents are the Extension Publications, followed by short terms in service training, seminars and conferences and establishing discussions and lectures at work.

Characteristics of researchers

The age of the majority of the researchers (66.6%) ranged between 41 and 50 years. All have university degrees and are employed at the University of Suriname, Center for Agricultural Research in Suriname (CELOS), and the Ministry of Agriculture, Husbandry and Fisheries. Their main tasks include research, training, lab supervision and teaching, in which they have 3 to 15+ years of experience. Currently, the survey respondents are working in research, training and education, extension, agronomy, horticulture, animal science, crop protection, agro-forestry, and soil science. Of the respondents, 57.2% participated in 2 to 3 projects in about the last five years while only two of the respondents participated in more than five projects in the same period of time.

Some projects on which researchers work include cabbage cultivation; storage insect pests in paddy and repellency effect of selected plants; poultry research program focused on reduction of input component in poultry, feed, and cost effective production; jatropha curcas as a biofuel crop; regional survey on cottonseed bug; strengthening of the Amazon initiative consortium for sustainable use of natural resources. CBN-Training in implementation of tailor-made guidelines as a method for evaluation/implementation of agro-forestry results, rapid agricultural baseline assessment in Commewijne and monitoring crops at sites at selected growers in Commewijne, and improving soil methodology at the soil lab of ADEK University. The researchers listed a number of fields/courses which ADEK/FTeW (Faculty of Technological Sciences) does not include in their curricula but are necessary for succeeding in their teaching and research efforts.

The courses/fields which are lacking at ADEK include: controlled-environment agriculture, sustainable farming systems, value added agricultural commodities, agribusiness and trade, biochemistry, biotechnology, organic/sustainable agriculture, agricultural marketing, soil chemistry, virology, field trial statistics, sociology, bio-engineering, soil data interpretation, soil physics, detail simulation in greenhouses, irrigation water management and crop modeling, and

epidemiology (animal diseases). Most researchers (66.6%) are interested in training for more than one month and less than six, and they prefer to go for training to Europe or the USA.

The prioritized areas in which researchers would like to receive training include: Agro-forestry (certificate), Poultry Production (certificate), Biofuel management (certificate), Post Harvest Production and Agro-processing, Protected Agriculture (certificate, MS), Integrated Pest Management (MS), Organic Farming (certificate), Field Trial Statistics (certificate), Gene Banks (MS), Plant-insect interactions (certificate), Plant chemical defenses and use of natural enemies in biological control of insect pest (certificate), agricultural extension topics (certificate).

The majority of the respondents (75%) think that the infrastructure at the department is inadequate. Concerning HRD, faculty members observed that there were no positive changes regarding HRM at the department but some respondents made remarks to the contrary. Most respondents (90%) indicated that the national press is considered the most important source of information about agricultural development in Suriname. The Worldwide web (Internet) and television were also considered an important source of information. Half of respondents in this study said that availability and access to research information has remained about the same in the last five years. Most respondents (66.6%) mentioned that they do share information with other researchers from both national and international organizations.

The majority of respondents (75%) said that they have frequent interaction with the management, and a few stated that their interaction was occasional. They also said that they interacted with the management through meetings. Most respondents considered project funding and government budget allocation to the institute as the most important sources of finance to the department. The researchers (66.6%) rated universities/institutions in the USA and Europe as important sources of technical assistance to the university, national research institutions, and the Ministry of Agriculture.

Required competencies

Farmers rated the levels of competencies they possessed and the required levels of these competences for their job performance. The discrepancy values (DVs) were calculated on the basis of differences between the needed levels of competencies for the job performance of the respondents and the possessed levels. These differences were considered as felt levels of training needs in the identified competencies (Khan et al., 2007). The discrepancy values based on the mean perceptions of the farmers were positive values for all technical competencies in the various agronomic categories. These values suggest that farmers need training in all aspects of vegetable production, fruit and field crops cultivation, crop protection, and in farm machinery.

Field extension agents required competencies

The discrepancy values based on the mean perceptions of field extension agents were positive values for all technical competencies in the following subjects: understanding human behavior, administering properly, conducting program planning effectively, executing program effectively, teaching effectively, communicating properly, exhibiting professionalism, and evaluating effectively.

Researchers required competencies

Based on the positive discrepancy values on the mean perceptions of researchers, the researchers need technical competencies in their ability to use: statistical packages and database operations, GIS, fluent command of one or more languages beside English, facilitate groups to write in-depth research reports, manage creative processes, work under tight deadlines, work well in teams, be self motivated, be flexible in assignments, understand program management, formulate and analyze budgets, understand administrative law, be knowledgeable in design and planning, understand transportation and infrastructure planning, conduct strategic planning, understand demographic analysis, demonstrate knowledge of program evaluation and understand cost and benefit analyses.

Conclusions-farmers:

1. Fragmentation in vegetable production should not be encouraged
2. Earning capacity of farmers should increase to US $ 500 +/month
3. Status of part-time farmers should be changed to full-time farmers
4. Agricultural knowledge should be diffused in a proper way (knowledge management)
5. Networking groups should be established with links with product vertical organizations (fruit, dairy, fish, meat, vegetables, etc.).

Conclusions-field extension agents:

1. Service level upgrade for farmers is needed and field extension workers should support farmers in their needs.
2. Extension agents need a professional training program in which the occupation competencies are exercised.
3. Information sources should be managed better with the use of information and communication technology (internet, media, etc.) so that it becomes better available and payable for farmers.

Conclusions-researchers:

1. Several research staff are lacking skills/knowledge in various subjects/fields in agriculture.
2. Capacity building in graduate training is needed in several disciplines including biotechnology, business and technology, poultry production, IPM, extension animation and communication, poultry production, agro-forestry, protected agriculture, field trial statistics, plant-insect interaction, plant-chemical defenses, biological control of insect-pests by means of plant extracts, natural enemies (parasitoids, predators, and ento-pathogens, livestock production research, and agro-climatology.
3. Development of a training policy within a framework of HRM and development of training programs for faculty members at the University of Suriname (ADEK) in several subjects is necessary.
4. ADEK, Faculty of Technology, Department of Agricultural Production needs to help facilitate training that is linked to Suriname's agricultural sector objectives and should assist with agricultural skills and new innovation technologies.
5. The HRM department at ADEK should promote education of people and improvement of competency, enable better service for department's staffs and faculty members and develop a strong HRM strategy to guarantee a competent and skilled agricultural sector.

6. The aim of the ministry of Agriculture is to improve the image of agriculture and facilitate equal access to training and education opportunities in the agricultural sector through harmonization of training programs and curricula (low/midlevel, high level).
7. A HRD strategy for the Ministry of Agriculture is needed, which means maximizing people development, management, and empowerment through quality skills development.
8. The agricultural sector needs institutional strengthening to achieve the government of Suriname objectives: sustainable agriculture and economic growth and food security.

Recommendations based on the outcome of this study

1. A HRD strategy must be developed to transform the agricultural sector into a more competent and skilled branch of economic activity, better equipped to serve the core strategies of the sector. This transformation could be reached by several plans of action: access and optimal utilization of international training opportunities, build capacity, enrich skills, develop competencies for empowerment, transformation and development of human capacity in the sector. Areas of focus: technicians, students, researchers, policymakers, specialists, administrators.
2. Technical and general competencies which are lacking among farmers, extension field workers and researchers need to be made up for by training, extension instruction and other rural educational services which concentrate on these critical elements. This should be conducted from the perspective of organizational (farm or agri-business) and individual (farmer, entrepreneur or employee) performance improvement, since competence development only makes sense if this perspective is used.
3. A structural revision of the preparation and planning of various courses is needed to support the competence development of farmers through exchange programs, vocational training, undergraduate studies, post-graduate studies, short courses, and conferences and seminars.
4. It is imperative to develop job competency profiles for the personnel involved in extension and research and other groups of personnel of the Ministry of Agriculture.

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TRANSFORMATION OF EXTENSION SERVICES IN JAMAICA TO SUPPORT COUNTRY'S FOOD SAFETY AND FOOD SECURITY

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ABSTRACT: Agricultural extension in Jamaica has evolved significantly since its inception in the late 19th century. Methodologies have moved from the authoritarian *instructor* through variants of top-down approaches, with a few flirtations in participatory methods. The impact of the extension service on production and productivity levels has also undergone notable variations, associated with several factors involving policy direction, global realities of economic landscape and resource challenges. Adoption of global quality standards requires quality-assured services such as training, from institutions such as the Rural Agricultural Development Authority (RADA), Jamaica's leading extension service provider. In keeping with the mandate of the Minister of Agriculture and Fisheries to ensure effective adoption of latest and most modern appropriate technologies to Jamaican agriculture, RADA has embarked on a programme to strengthen its training services using ICT base. Capacity building support had been provided by development projects such as the Food & Agriculture Organization and European Union Food Facility Project to achieve these requirements. Extensive training programme of entire extension personnel is being implemented for capacity building in knowledge base and skills enhancement. Staff had been trained in the use of notebook computers, GIS/GPS technology and data integration into GIS, use and maintenance of weather stations, extension methods, measuring the impact of extension activities on farmer learning. Instead of traditional educational approach to training, where unit of progression is time based and trainer – centered, RADA aims to move towards the competency based training system, where the unit of progression is mastery of specific knowledge and skills and is learner or participant-centered. As a result, extension staff will achieve competencies required in the performance of their jobs, and they will build confidence as they succeed in mastering specific competences. As initial steps in the extension officer re-certification programme, several officers achieved NCTVET Assessors Certified status.

Keywords: Training programme, competency, extension services

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ESTABLISHING A NATIONAL AGRICULTURAL DISASTER RISK MANAGEMENT SYSTEM: THE JAMAICAN EXPERIENCE

Winston Simpson, Rural Agricultural Development Authority

ABSTRACT: Agriculture is a significant source of livelihood for the over 200,000 Jamaican farmers and others similarly dependent on the sector. It is also important for national food security. Most farmers operate small to medium-scale farms on hillsides, using traditional production technologies. Soil erosion and run-off are therefore problematic. The island lies in the Atlantic hurricane belt and experiences a bimodal rainfall pattern which brings droughts and flooding. A tropical latitude predisposes it to sustained high levels of animal and plant pest activity throughout the year, presenting more challenges for farmers and restricting productivity levels. Over the past seven years, the frequency and intensity of tropical cyclone systems affecting the island has increased, further exacerbating the challenge. Droughts have also been notable in some years. Consequent on these have been losses from 2004-2008 in crops and to a lesser extent, fisheries and livestock to the tune of over US$ 93 m. from cyclones alone. Droughts and pests cause much lower levels of loss on a national scale. In an effort to minimize the negative impacts of these adverse events on their clientele, in 2008 the Ministry of Agriculture & Fisheries (MoAF) embarked on an Agricultural Disaster Risk Management programme. This programme introduced a proactive integrated approach involving a wide cross section of sector stakeholder groups looking at risk prevention/mitigation, preparedness, response, and rehabilitation/reconstruction phases of the disaster management cycle. Since 2008 a national multi-sectoral ADRM committee led by RADA was convened by the MoAF to develop and implement the programme. It comprises public and private sector entities and regional institutions. Sub-committees currently guide strategies and activities in three risk areas; two other areas are at different levels of establishment. The national committee is replicated in the 13 parishes through RADA-led committees, which are the functional units of the system. Technical support has been provided by FAO. The system was tested in Tropical Storm Gustav, 2008. The experience highlighted the need for strong collaboration, rapid streamlined data collection systems and recovery mechanisms. Risk insurance has been pursued under the Caribbean Catastrophic Risk Insurance Facility (CCRIF) but poses challenges of accessability to small/medium-scale farmers in particular. This paper presents details of programme development, activities and challenges, and suggests a way forward.

Keywords**:** agriculture, disaster risk management, tropical cyclone, small farmer, Jamaica

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THE SOCIAL CONSTRUCTION OF AGRICULTURE IN JAMAICA: LESSONS FROM POLICY & THE IMPLICATIONS FOR FOOD SECURITY

Winston Simpson, Rural Agricultural Development Authority

ABSTRACT: Agriculture and agricultural education have an image problem. This is unfortunate in a world where agriculture is important to food security and food sovereignty. In the wake of soaring food prices which threaten social unrest, policymakers need to examine how the social construction of target populations has influenced the food and agricultural sector in both the policy agenda and design of policies. The enduring and dominant images of the farmer as rural poor, low-income, manual labourer dependent on agro-ecosystems, which are vulnerable to the vagaries of the weather, for a livelihood, are slowly being changed and replaced with the farmer as an entrepreneur. Traditionally, the social construction of the farmers depicts the group as positive members of society but having weak political power. They are viewed as dependent populations and therefore the benefits to them have reflected this social construction. However, changes brought about by globalization and trade liberalization have forced changes within the industry and there is a departure from the traditionally held construction of farmers to reflect a more positive social construction. There is a clarion call for a comprehensive rethink of policies which determine how resources are allocated toward agriculture in countries that are deemed food insecure. This paper will employ historical and textual analysis to identify the plethora of images and highlight the changes in the social construction of the Jamaican farmer. This qualitative research will examine data from the Ministry of Agriculture budgets, projects and programmes undertaken between 2000 and 2009 in Jamaica. The paper contends that the social construction of agriculture has had significant impact on policymaking and there are important lessons to be learnt that should guide policymakers who are seeking to design policies for the achievement of food security in Jamaica.

Keywords: Farmers, policies

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WILLINGNESS OF CROP FARMERS TO PAY FOR IRRIGATED WATER IN BARBADOS

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ABSTRACT: Access to adequate water resources is a sensitive issue that has engrossed the attention of the entire international community. The allocation of this scarce resource in many countries is generally guided by social issues, ethics, equity, politics, water availability and the need to supply certain key sectors including the agricultural sector. Many countries have sought ensured accessibility to water by adopting pricing policies which allow for the subsidization of this service. Since the 1980's the Government of Barbados, through the Integrated Rural Development Project has introduced measures to encourage the expansion of the agricultural sector and the personal development of farmers. A component of the project, the Irrigation Programme is presently administered by the Barbados Agricultural Development and Marketing Corporation. Under the Irrigation Programme, provision is made for farmers in the southern section of the island to access irrigated water at a heavily subsidized rate. However, this programme conveys a large financial burden to the Government, which compromises the sustainability of the Irrigation Programme in its present form. The following study investigates crop farmers' willingness to pay for irrigation services managed by the Barbados Agricultural Development and Marketing Corporation taking into considering various factors such as income, land size, and age.

Keywords: water, willingness to pay, farmers, irrigation

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EXTENSION ACTIVITIES PROMOTING BALANCED PLANT NUTRITION IN THE CARIBBEAN

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ABSTRACT: Plant nutrition is regarded as one of the main problems limiting crop production in the region. This paper details 20 years of extension activities by Government, private and farmer organizations to promote balanced crop fertilization. Training in a formal classroom setting has not been effective; the limitations identified include poor attendance and limited farmer participation in the discussions. Farmer Field Schools have been more effective especially when the technology was demonstrated on farmers' plots. Factors that have limited the adoption of improved practices include the availability of technical support, the availability of specialized fertilizer materials and attempts to improve fertility on fields with other agronomic problems.

Keywords: Plant nutrition, extension, training, demonstration plots

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THE REHABILITATION AND EXPANSION OF THE COCOA INDUSTRY IN SAINT LUCIA

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ABSTRACT: Cocoa (*Theobroma cacao*) production in Saint Lucia is characterized by low maintenance and low productivity, as well as dependence on very few niche markets. However, the "Fine Flavour" status and quality-conscious growers represent a significant potential for expanding the production of high-value cocoa in a sustainable manner. A project in 2010 had the aim to rehabilitate 200 acres of abandoned and neglected cocoa and establish 100 acres of new cocoa plantings. Assessment of 84 farms revealed that all farms required pest control and fertilization. Pruning was required on 99% of farms, disease control (for black pod and witches' broom) on 98%, shade reduction on 94% of farms. Erosion (82%) and weed control (79%) as well as drainage (61%) were also frequently lacking, but soil health was found to be moderate to very good on all farms, with over 50% scoring "good" and over 5% "very good". Rehabilitation consisted of formation pruning, shade regulation (essentially reduction), pest and disease management, fertilization and capacity-building. The focus was on small-holdings (0.5-10 acres), where the grower was prepared to contribute part of the labour. Expansion focussed on Saint Lucia's East coast. Prioritized cultivars were ICS1, ICS39, ICS95 and ICS98. Permanent shade species were chosen in a participatory manner, resulting in the joint selection of some species recommended as cocoa shade (mango, avocado, wax apple) and others with a less suitable canopy, but other characteristics valuable to the growers, e.g. citrus and West Indian cherry. Challenges encountered were the timely availability of planting material and agrochemicals, farmers' contribution of labour and Hurricane Tomas, which hit on 30 October 2010, and devastated much of the country. Farmers were more inclined to invest time in expansion than in rehabilitation. To ensure the project had a beneficial impact beyond its duration, resources had to be focused on the more motivated farmers, while other producers and extensionists needed to be empowered to make well-informed decisions. In this context, participatory technology transfer as well as strategic planning, with wide stakeholder involvement, was an integral part of all interventions. A road map for follow-up is presented.

INTRODUCTION

Throughout the Caribbean, cocoa (*Theobroma cacao*) is typically produced by smallholders. It is uniquely suited for cultivation in remote areas due to its relatively high value per weight and low perishability. Compared to other cash crops, cocoa is produced in an environmentally friendly fashion: it is commonly grown in diverse agroforestry systems, i.e., under shade, preventing soil erosion and maintaining watershed functions. Cocoa-based agroforestry systems also play an important role as buffer zones in the vicinity of protected areas, by decreasing *de facto* fragmentation. The tree component provides fruits and timber that contribute to farmers' income and thereby decreases dependency on commodity markets. The rehabilitation and expansion of Saint Lucia's cocoa industry thus offers a valuable opportunity to improve livelihoods in a sustainable manner. However, a number of challenges face the cocoa sector in Saint Lucia; strengths, weaknesses, opportunities and threats (SWOT) are summarized in Table 1.

Table 1: SWOT analysis of the Saint Lucian cocoa industry

Strengths	Weaknesses
➢ Producers have culture of quality assurance and record-keeping ➢ Good infrastructure and logistics for commodity export in place ➢ Two propagation centres can supply suitable cocoa germplasm in adequate quantity ➢ Land is available in form of private smallholdings, usually close to grower's home, minimizing the risk of praedial larceny, while allowing close supervision of operations ➢ A significant proportion of land is actively cultivated with temporary or perennial shade already in place	➢ Low and seasonal volume of production regularly drops below critical threshold ➢ Cocoa trees past their economical lifespan are in poor conditions ➢ Poor agronomic practices ➢ Poor post-harvest practices ➢ Low up-take of recommendations as a result of non-participatory (top-down) technology transfer approaches ➢ The upper canopy is frequently made up of trees selected for other products (e.g. citrus) or forest remnants that provide sub-optimal shade for cocoa ➢ Steep slopes and incomplete canopy closure of some fields
Threats	**Opportunities**
➢ Declining soil fertility ➢ Unavailability of high-PK fertilizer ➢ Price fluctuations on international commodity markets are a deterrent to investment into a perennial crop such as cocoa ➢ Risky and far from optimal post-harvest operations lead to heterogeneous and inconsistent quality, potentially affecting the product's reputation ➢ Unsecure land tenure arrangements will limit potential investment by farmers and future expansion	➢ Absence of Frosty Pod Rot of cocoa ➢ World's finest status on US markets ➢ Optimized post-harvest operations could further increase Saint Lucia's cocoa quality and its consistency ➢ European export market potential not yet accessed to any significant extent ➢ Niche markets (especially organic) not yet accessed ➢ Decline of export banana industry encourages diversification into alternative commodity. Shaded cocoa is far better suited for steep slopes ➢ Successful composting and integrated crop management could serve as motivating example for farmers to venture further towards organic production

OBJECTIVES

The principal objective of this one-year project (March 2010 to February 2011) was increasing the profitability of Saint Lucian cocoa-based agroforestry systems in a sustainable manner, with the goal to improve livelihoods. The specific objectives were:

- Increase national cocoa production by expansion of the acreage under cocoa by 100 acres and by rehabilitating 200 acres of semi-abandoned and poorly-managed cocoa with suitable germplasm, accompanied by adequate shade and windbreaks
- Increase farm yield and profitability by introducing, and where applicable optimizing, integrated crop management approaches, including soil fertility management and integrated disease control
- Design and promote diversified - and thus risk-reducing - agroforestry systems with the

opportunity to become less dependent on export bananas

- Prepare a roadmap with prioritized strategic interventions for Saint Lucia's cocoa sector

The project was funded by the European Commission (EC) under the Special Framework for Assistance (SFA2005), managed by the Saint Lucia Banana Industry Trust (BIT) and implemented in coordination with the Ministry of Agriculture, Lands, Fisheries and Forestry (MALFF). Quality Assurance was provided by the Inter-American Institute for Cooperation on Agriculture (IICA).

MATERIALS AND METHODS

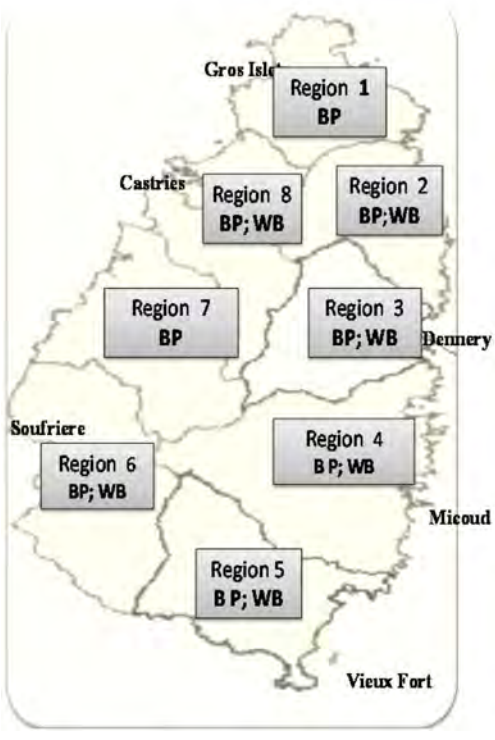

Figure 1: Map of agricultural extension regions in Saint Lucia, with distribution of black pod (BP) and witches' broom (WB).

Selection of farms and training content was conducted with MALFF. For rehabilitation, cocoa fields of 0.5-10 acres were prioritized, focussing on actively managed farms, on which some of the required labour was being made available by the farmer. Eligibility checks soon eliminated nearly half of the original candidates; the up-dated list of 84 farms covered only 124 acres, instead of the 200 acre target. Areas for planting new cocoa (ICS1, ICS39, ICS95) were selected in Regions 2, 3 and 4 (Babonneau, Dennery and Micoud; Fig. 1) and was led by the extension officers for each region. The consultants see substantial merit in converting unprofitable, neglected or abandoned banana fields to cocoa, where this coincides with the farmers' long-term plans, and this influenced the decision-making. The already established banana canopy could provide instant temporary shade and even sub-optimal drainage for banana is generally adequate for cocoa. A total of 106 farms were selected for expansion, covering just over 100 acres, i.e. the project target.During initial farm assessment, the entire field was considered holistically. Input needs (labour, agrochemicals and planting materials) were quantified. Data were analyzed by ANOVA (followed by Tukey test), χ^2 or Kruskal Wallis as appropriate on InfoStat (2004).

Neighbour tree counts per acre were square-root transformed [$x' = (x+3/8)^{0.5}$] to normalize the error distribution (Zar, 1996).

Participatory technology transfer was an integral part of interventions. It aims to build farmers' capacities to make their own crop management decisions, based on a better understanding of the agroecology of their fields, and according to their own unique set of circumstances and priorities (Vos & Krauss, 2004). Because success depended on the support by farmers, institutional partners and other beneficiaries, all detailed planning was carried out with full stakeholder participation. For perennial crops, such as cocoa, the curriculum is based on crop stages.

RESULTS

Cocoa plot sizes ranged from 8.3 acres in Region 6 to 0.93 acres in Region 2 (ANOVA: $P = 0.005$); the national average cocoa plot size was 3.0 acres. The cocoa density in Region 3 (99 trees acre^{-1}), was significantly ($P < 0.001$) lower than in Regions 4 to 6 (252 trees acre^{-1}). Region 2 was intermediate (192 trees acre^{-1}). Cocoa is not a priority crop in Region 3, with traditionally more interest in banana production. The target density for cocoa on flat land is 300 trees acre^{-1} (12'×12' arrangement), but tends to be lower because of slopes and to accommodate neighbour trees. Steep slopes necessitate erosion control on 82% of farms; 61% lacked drainage (Fig. 2), mostly in Region 4 (89%), followed by Region 2 (78%; $P < 0.001$). Composting was practiced on a single, large estate only. All farms required fertilization, particularly potassium, but soil health was found to be moderate to very good on all farms, with over 50% scoring "good" and over 5% "very good".

We observed severe IPM shortcomings: all 84 farms required pest control, 98% disease control (Fig. 2), with no regional differences (χ^2: $P \geq 0.093$). Phytosanitary problems were within the manageable range. The most common pest problems were rats (100% of farms) and termites (35%). Witches' broom (WB) was predominant in Region 3 (Errad), but also present in Regions 2, 4 and 8 (Fig. 1). Black pod (BP) incidence was similar in all areas ($P = 0.634$), but more severe on farms with excessive shade. Other diseases were negligible.

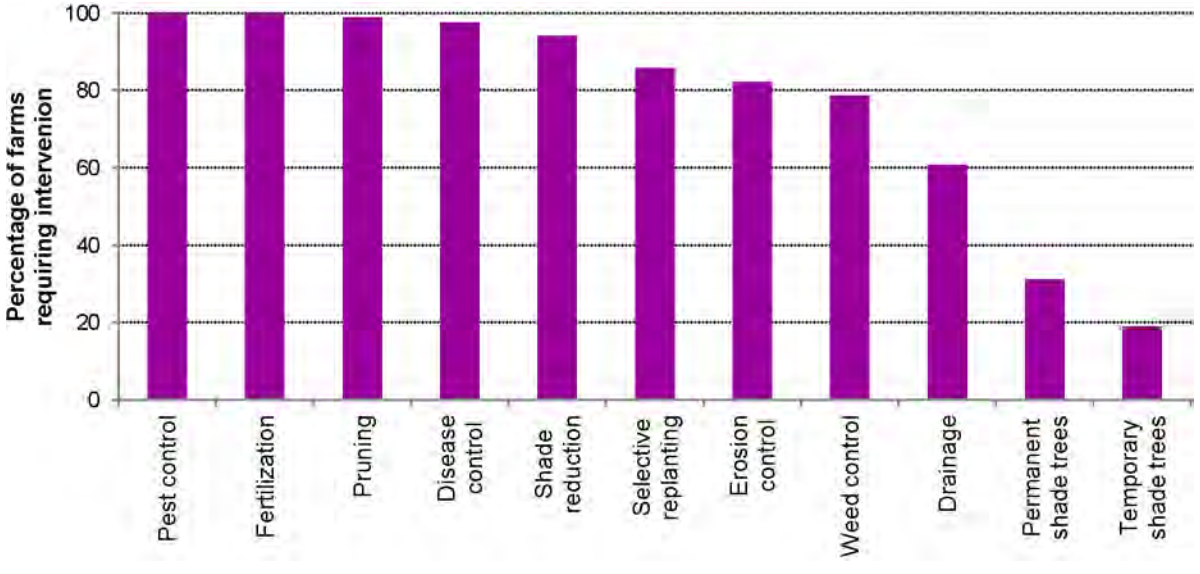

Figure 2: Management needs on farms earmarked for rehabilitation

Most farms had existing temporary (bananas, plantain, tannia) and permanent shade (avocado, mango, breadfruit, immortelle and timber). Canopy management was poor: 99% required cocoa

pruning, 86% selective replanting of cocoa. Shade reduction was needed on 94% of farms across regions ($P \geq 0.066$). The fact that 79% of farms required weed control indicated patchy shade or poor canopy formation: 31% required permanent shade and 19% temporary shade (Fig. 2). While estimates for cocoa planting materials were based on agronomic criteria, i.e. target density, the selection of associated trees was done in a participatory fashion. Farmers' choices were driven by criteria other than optimizing cocoa conditions and related to existing stock: farmers tried to diversify more, particularly with fruit trees (Fig. 3). This parallels the findings of Boa *et al.* (2000) in Ecuador. Citrus species showed most pronounced trends: Key lime was most popular in Region 4 and least in Region 3; Region 2 was intermediate ($P = 0.015$). Valencia oranges grew steeply in popularity from Region2 to Region 4 ($P < 0.001$). Wax apple was more popular in Region 3 than the other regions ($P = 0.010$). Julie mango was most popular in Region 4 and least in Region 3 ($P = 0.013$), while Cabiche mango, avocado, cinnamon, golden apple, guava and West Indian cherry did not differ among regions ($0.077 \geq P \geq 0.085$). These analyses can advise the wider diversification efforts in Saint Lucia.

Cocoa rehabilitation efforts consisted principally of pruning of cocoa trees and shade regulation (essentially reduction). Table 2 shows that a total of 124 acres have been pruned on 84 farms. This area represents 62% of the original target for the project. Several factors beyond the consultant's control limited the rehabilitation efforts:

- Due to the unavailability of most essential inputs (fungicide, herbicide, rat bait, fertilizer, cocoa seedlings) at critical times, only cocoa pruning and shade control could be practiced during the main implementation period. Application of fungicide in early 2011 required re-visiting already pruned farms.
- Over 75% of farmers did not comply with the stipulation that they provide part of the labour and attend rehabilitation session with the trained crew for capacity building purpose. As a result, farm labour accounted for only 5%, which is both unsustainable and undidactic.
- Some farmers failed to show up on the scheduled pruning day or withdrew from the programme, following conflicting advice on pruning needs by advisor external to this programme.

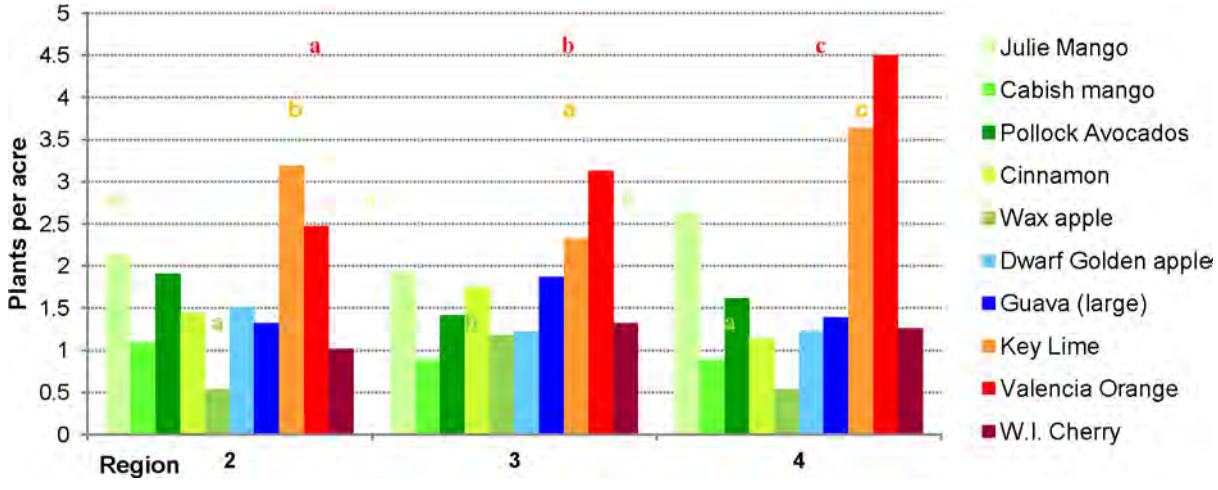

Figure 2: Farmers' preference for permanent neighbour trees of cocoa by region on a per-acre basis. Bars with the same letter do not differ at P = 0.05 (comparison within species only).

Pruning and shade reduction led to a drastic improvement of both mature and young cocoa. On pruned farms, minimal blow-over occurred during Hurricane Tomas, whereas damage was more severe on the neglected farms. However, some farms started to revert towards the previous,

abandoned state; these growers took advantage of project-paid assistance without pulling his/her own weight. Thus, MALFF extension personnel should provide follow-up, to establish a record of conscientious growers who continue actively managing their cocoa.

Table 2: Summary of farms rehabilitated during this project.

Region	Number of Farms	Existing Acreage	Acreage Rehabilitated	Farm labour contribution (%)	Farms (%) contributing labour
Region 2	9	8.3	4.9	5.2	67 [b]
Region 3	14	21.5	16.5	7.1	21 [ab]
Region 4	28	55.5	28.0	7.1	21 [ab]
Region 5	15	24.3	24.3	5.7	20 [ab]
Region 6	16	136.5	47.0	0.0	0 [a]
Region 8	2	3.0	3.0	5.0	100 [b]
Total	**84**	**247.6**	**123.7**	**5.0**	**21.4**

[a, b] Mean followed by the same letter do not differ at $P = 0.05$ (Kruskal-Wallis test).

Cocoa planting was delayed by a severe drought from March to June. Barth nursery was unable to produce sufficient grafted cocoa plants in the remaining time. Thus, availability of cocoa plants presented a challenge to expansion. Many delivered plants were subsequently destroyed by Hurricane Tomas; nursery infrastructure was damaged too. Despite these adversities and delays, a total of 16,400 cocoa plants were delivered and transplanted. This number of plants translates into *ca* 54.7 acres.

Practical farmer field days focussed on pruning. Additionally, the group discussed

- shade reduction, optimizing shade for disease control: WB versus BP; termite control;
- BP and WB control, particularly the use of resistant germplasm for the latter to save labour;
- nutrient deficiencies: recognition, plant biomass distribution: photosynthesis versus soil nutrient cycling; and
- establishment of new cocoa plantings.

A training module for extensionists was also developed and covered:

- "Rehabilitation of and Care for Mature Cocoa Plantings"
- "Establishment of and Care for New Cocoa Plantings"
- "Integrated Pest and Disease Management for Saint Lucian Cocoa". This module also covers rational pesticide use and touches on abiotic disorders, as these frequently go hand in hand with pathogen infections;
- "Frosty Pod Rot (FPR) Threatens Caribbean Cocoa" - this topic is separate from the IPM module, as it is strategic in nature and refers to a pathogen still absent from the insular Caribbean; and
- "Harvest and Post-harvest Management of Saint Lucian Cocoa", focussing on techniques used by organic smallholders in the Dominican Republic (Krauss, 2005), as these methods are particularly suitable to Saint Lucian conditions, but also present the same risks and challenges.

Strategic interventions focussed on stakeholder mapping, FPR prevention, and fine cocoa quality.

CONCLUSIONS AND RECOMMENDATIONS

The majority of planned outputs were fully achieved. Shortfalls were the result of log-frame assumptions, particularly timely availability of farm labour and inputs, not being met. Pledged inputs should be made available until the project targets have been met. The well-received participatory field demonstration should be replicated in other areas by facilitators trained in participatory techniques. For a sustainable impact, farmers need to continue regular pruning. MALFF should up-date its farmer database to rate professionalism and show acreage of crops. In the long term, this information will allow to better target future support on a smaller but more dedicated group of active growers. Farmers' decision-making criteria regarding perennial crops should be considered in diversification efforts. Strategically, MALFF also needs to prevent the introduction on the FPR pathogen, *Moniliophthora roreri,* aim for continuous improvement of fine flavour quality, strengthening of stakeholder linkages, and expansion of high-value niche markets.

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INDICATOR-BASED SUSTAINABILITY ASSESSMENT OF ORGANIC COFFEE AGROFORESTRY SYSTEMS IN TURRIALBA, COSTA RICA

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ABSTRACT: Organic coffee production can be more sustainable than conventional production, but differences within organic management exist. The shade component in organic coffee agroforestry systems can contribute to a more sustainable production system by enhancing social, economic as well as environmental conditions of small-scale organic producers, depending upon shade management. In Turrialba, a sustainability assessment of organic coffee production was realized using the MESMIS methodology to identify critical points, diagnostic criteria and socioeconomic and environmental indicators in order to characterize aspects that can be enhanced. A survey was administered to 22 farms around Turrialba and Grano de Oro in Costa Rica. It was found that rustic shade provides the highest ecological sustainability whereas traditional polyculture provides highest social and economical sustainability. Socioeconomic differences were also observed between organic coffee producers of Turrialba and indigenous Grano de Oro producers. Among the elements that may directly contribute to enhancing sustainability figure the increase of technical assistance for organic coffee production, trainings on fertility management with on-farm resources, and farm diversification with fruit-tree establishment. Further research should focus on studying the interrelations that exist among indicators and determine the minimum variables that are essential to assess the sustainability of productive systems.

Keywords: organic coffee, agroforestry, sustainability

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THE FARMER FIELD SCHOOL APPROACH FOR INTEGRATED PEST MANAGEMENT: THE ST. LUCIA EXPERIENCE

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ABSTRACT: The use of excessive amounts of chemical pesticides and other inputs in the production of short-term, high-value crops in the Caribbean is well-documented. This excess has serious negative implications on human and environmental health, cost of production and trade in agricultural commodities. Over the past decade, a number of regional initiatives have successfully used the Farmer Field School (FFS) approach towards rationalizing the use of chemical inputs in agricultural production. One such initiative was implemented during 2009-10 by the Food and Agriculture Organization of the United Nations (FAO) in partnership with the Ministry of Agriculture, Land, Forestry and Fisheries (MALFF), St. Lucia, under the Project *European Community (EC)-Funded Assistance to Agricultural Diversification in the Windward Islands (GCP/RLA/167/EC – SFA2006).* Using the FFS methodology, the intervention facilitated an Integrated Pest Management (IPM) programme in vegetables. Under Phase 1 (May-August 2009), eighteen Extension Officers, drawn from the eight agricultural regions of St. Lucia, successfully graduated as FFS Facilitators in a Training of Trainers (TOT) programme. The TOT comprised intensive classroom and field training sessions and incorporated a pilot FFS, from which thirteen farmers graduated. Phase II was implemented (February-June 2010) in five agricultural regions, with ninety-eight farmers graduating. It is noteworthy that the cost-benefit ratio using IPM was higher compared to traditional farmer practices in all five regions. Indeed, plans were already in train for Phase III as a collaborative effort between farmers and the MALFF. This joint ownership by the two main stakeholders—farmers and the MALFF—augurs well for the sustainability of the FFS movement in St Lucia. This paper underscores the benefits of the TOT/FFS model, which leads to improved technical capacity of the Extension and Plant Protection services and in turn to the delivery of enhanced services to farmers, resulting in safer and more effective pest and crop management.

Keywords: Farmer Field School, Integrated Pest Management

INTRODUCTION

Integrated Pest Management (IPM) was initially conceived in the 1950's as a programme of combining and integrating pest control measures (biological, chemical, cultural) as a means of reducing the use of highly toxic pesticides in crop production. The concept was later expanded to the integration of all pest control measures used in a compatible manner. One definition is the careful consideration of all available pest control techniques and subsequent integration of appropriate measures that discharge the development of pest populations and keep pesticides and other interventions to levels that are economically justified and reduce or minimize risk to human health and the environment. IPM emphasizes the growth of a healthy crop with the least possible disruption of agro-ecosystems and encourages natural pest control mechanisms (International Code of Conduct on the distribution and use of pesticides, revised version, FAO, 2002).

The participatory IPM approach using the Farmer Field School (FFS) approach was introduced in 1989 in Indonesia in direct response to the high use of pesticides by rice farmers. Given the success of this method in reducing the use of pesticides, the method has been expanded globally. According to van der Berg and Jiggins (2007), "FFS programmes have now been initiated in 78 countries graduating over four million farmers". Farmer participatory approaches seek to empower farmers with the knowledge and confidence to make their own well-informed decisions that are appropriate and relevant to their own individual circumstances (Lopez et al, 2004).

In St. Lucia, a number of pests attack vegetable crops in the field, and pesticide use is the most common, and often preferred, method of control. According to Ramroop (2009), the rate and frequency of application of fertilizers and pesticides by farmers is often higher than the rate recommended by the Ministry of Agriculture, Land, Forestry and Fisheries (MALFF). It was against this background that the MALFF partnered with the Food and Agriculture Organization of the United Nations (FAO) and the European Community (EC) to enhance vegetable production by way of introducing the FFS approach through the Special Framework of Assistance (SFA) 2006. The organizations collaborated to enhance small-farmer crop production by way of a Training of Trainers (TOT)/FFS programme during the period May to August 2009 (Phase 1). Eighteen Extension officers, drawn from eight agricultural regions on the island, participated in the TOT/ FFS and graduated as FFS Facilitators under the programme. The training consisted of intensive classroom and field training and incorporated a pilot FFS, in which thirteen farmers graduated.

In St. Lucia, extension programmes are planned and implemented based on several factors, including specific farmer's requests, perceived farmers problems (by extension service) or government policy. A range of extension methods are employed for information dissemination, but these are mostly "top-down". The introduction and implementation of the FFS approach in 2009 was therefore a hallmark event for the extension service, as this represented a different strategy to traditional approaches.

MATERIALS AND METHODS

The FFS is an open learning environment in which farmers school themselves in IPM techniques for agricultural food production and other related topics. In general, FFS consists of groups of people who get together on a regular, often weekly, basis (season long) to study the "*how and why*" of a particular topic. FFS is about practical, hands-on topics where the field is the teacher and provides most of the training materials like plants, pests, natural enemies and other crop production problems.

One key factor in the success of the FFS has been that there are no lectures and all activities are based on experiential (learning-by-doing) creation and sharing of knowledge. A typical FFS comprises of the following: agro-ecosystem observation, analysis, presentation of results, a special topic and a group dynamic activity. The Agro-Ecosystem Analysis (AESA) is a core activity of the FFS and other activities are designed to support it. The St. Lucia FFS programme was tailored to suit the needs of the farmers. Prior to the start of the FFS, a needs assessment survey was conducted to determine the problems experienced by farmers in successfully growing a particular crop. Based on this survey, a programme of FFS activities was developed and participatory discussions held with the farmers to validate the data collected. This information was then used to develop the cropping calendar for the Farmer practice (FP) plot.

As part of the Field School and based on the AESA, facilitators guided the farmers selecting management methods, combining, cultural, biological and chemical (environmentally friendly products) options, thus leading to the development of an IPM crop management programme.

The AESA process honed the farmers' skills in the areas of observation and decision-making and helped develop their powers of critical thinking. The process began with small group observation of the IPM and FP plots. During the observation process, participants collected field data such as plant height, the types of insects and their populations, and took samples/specimens of insects and plants.

Following the field observations, farmers returned to the meeting place and, using crayons/pencils, drew on a poster paper what they had just observed in the fields. The drawings included: pests and natural enemies observed in the fields (pests on one side, natural enemies on the other); the plant indicating the size and stage of growth, important growth factors such as the colour of the plant and any visible damage and other important features of the environment (the water level in the field, sunlight, weeds, and inputs). All members of the small groups were involved in the creation of the drawing and data analysis. While drawing, farmers discussed and analysed the data they collected and based on their analysis they determined a set of IPM decisions to be carried out in the field. A summary of these management decisions as agreed by the group was also included in the drawing and one member of each small group then presented these findings to the larger group, followed by open questions and discussions. Once consensus was arrived at with regard to the management of the crop, the group reached agreement on the implementation of the recommendations. Drawings from previous weeks were kept on hand as a reference and as material for discussion later in the season. Generally, farmers were very vibrant, innovative and participated in all activities. The trainees and the farmers undertook the implementation of the decisions (spraying, fertilizer application, removal of weeds, etc.) made during the AESAs.

Following the TOT/FFS in 2009, Phase 2 (February to June 2010) was implemented through five FFSs held in various agricultural regions, in which ninety-eight farmers participated and graduated. The participating regions were Regions 1 (Gros Islet), Region 2 (Babonneau), Region 4 (Micoud), Region 5 (Vieux Fort) and Regions 7&8 (Anse La Raye/ Bexon). The crops selected were melons (honey-dew and cantaloupe), cucumber, tomato, melons (cantaloupe) and tomato, respectively. There was a high level of interest for FFS programmes among the MALFF staff, FFS facilitators, farmers, regional heads and other stakeholders.

In both Phase 1 and Phase 2, in the IPM plots the farmers' crop management options included the use of more environmentally-friendly pesticides when compared to the FP plots. The rate of use and frequency of application of pesticides and fertilizer use was generally higher in the FP plots when compared to the IPM plots. This impacted on the higher cost of production (inputs and labour) in the FP plots.

A wide range of IPM management options were incorporated into the FFS/IPM plots. These included plants with beneficial properties, use of natural products and environmentally-friendly pesticides. The establishment of companion plants to repel insect pests or to attract natural enemies was encouraged. The practice of minimal or no use of chemicals for IPM crop management practices was encouraged and enforced since farmers have a general tendency to incorporate chemical pesticides into their crop management practices. It is suggested that the use of natural pesticides, for example, neem, garlic and pepper sprays and other IPM strategies be fully explored by FFS Facilitators and farmers in future IPM programs.

Details of Phase 2 FFS were as follows:

- In Region 1 (Gros Islet), the very cohesive and enthusiastic group of twenty-two farmers opted to incorporate a number of IPM options that included the use of companion/antagonistic plants (cilantro, marigold, corn) and plastic mulch in the rows, resulting in reduced weed growth, reduction of rain splash and subsequently disease incidence. Farmers obtained a premium price for the produce in the IPM plot, compared to that from the FP plot. This was because the IPM fruits were firmer and larger and marketed to the hotels, elite restaurants and other high-end markets.
- In region 2 (Babonneau) a group of twenty farmers developed Farmer Practices and the cropping calendar for the production of cucumbers, wherein farmers used as many as nine different pesticides. In the IPM plots, only three safer and environmentally-friendly pesticides were used during the crop cycle. In addition, farmers opted to incorporate number of IPM options such as use of yellow sticky traps, corn as a barrier crop and cultural control practices for weed control and field sanitation. Weeds were removed before the flowering stage and neighboring areas on the borders were kept weed free.
- In Region 4 (Deruisseaux), twenty-two farmers selected tomato as their crop of choice. IPM interventions included planting on the borders and within the plots plants (marigold, citronella, lemon grass) to attract natural enemies. A trellis system was also used; this allowed for an easy support of the plant and was less labour-intensive than the staking method used in the FP plot.
- In Region 5 (Vieux Fort), the very vibrant group of nineteen dedicated farmers from the Black Bay area selected melons.
- In Region 7&8 (Bexon), fifteen farmers participated, with tomato as the selected crop.

Cost-benefit analysis (CBA) was conducted on the FFS during Phase 2 in an attempt to review and assess the economics of the activities. The process involved weighing the total expected benefits against the total expected costs of one or more actions in order to choose the best or most profitable option. In the CBA for the FFS in the various regions, costs were limited to the expenses incurred for the inputs into the field plots and the benefit was measured by the revenue received from the output or produce. The cost-benefit ratio (ratio of benefit to cost), calculated for the FFS in the five regions, demonstrated the extra benefits that the farmer was likely to get for each unit of cost incurred and therefore gave an indication of the likely size of the return for a given level of investment.

Cost of production exercises during the FFS activities highlighted the importance of proper record keeping. CBA for the FFS (FP vs. IPM) in all regions was determined. The economic benefits of using the IPM far outweighed the economic benefits of using the FP practices in all regions. In Region 1, the CBR was 1:1 in the FP plot, compared to the IPM (3:1) indicating that the economic benefit derived was almost three times compared to the FP plot. The CBR trend continued for Regions 2, 4 and 7&8, where the FP (BCR) was 1: 1, when compared to the IPM (CBR) of 2:1. In region 5, the produce was not separated into the FP and IPM plots and as such the CBR for the entire crop production was determined and this worked out to 3:1.

Beyond the FFS (Phase 2), FFS facilitators, Regional Heads, farmers and other stakeholders have embarked on FFS (Phase 3) activities utilizing resources from the sales of the previous crop and contributions by farmers. Graduating farmers recognized that the benefits of the FFS (in particular the sharing and exchange of knowledge and experience) were great and opted to embark in training other farmers in various areas. Some FFS graduates also formed community

groups and spearheaded business activities, for example production and sale of seedlings and other crops.

Team and group activities during the FFS encouraged experimentation and fostered innovation. Farmers learnt how to build on and use their own knowledge. The FFS involved many farmers and so it is a vehicle for speeding up the adoption of IPM and other techniques.

An evaluation conducted at the end of the FFS in each region is summarized here. Generally farmers indicated that they benefited immensely from the various activities in the programme. There was a general increase in knowledge in crop management and good agricultural practices (GAP). Farmers indicated that they would recommend that all farmers participate in such a programme to have a better understanding of GAP.

CONCLUSIONS

During the workshop on the way forward, the following measures were recommended as imperatives in the process of building long-term resilience and sustainability of FFS:

- promoting FFS as an initiative to empower farmers
- linking policy at all levels, incorporation of practical messages continuously during FFS
- strengthening links among stakeholders, seek ways to reduce cost of farm inputs for farmers
- implementing strategies targeted at different types of farmers (small and large)
- conducting impact assessments to generate information on the FFS.
- involving all stakeholders (farmers, MALFF, NGOs, Extension Services, private sector etc.) in the process.

According to Augier (2009), "as part of a legacy of shifting paradigms in Agricultural Technology Transfer, FFS is here to stay in St. Lucia". It gives the extension personnel more options in terms of technology transfer approaches. The electronic network (St. Lucia FFS Facilitators) continues to provide the medium for the continuous sharing and exchange of information among FFS Facilitators. The benefits of the TOT/FFS model in St. Lucia need to be underscored as it led to improved technical capacity of the Extension and Plant Protection services and in turn to the delivery of enhanced services to farmers, resulting in safer and more effective pest and crop management.

Thus, going forward, farmer participatory approaches should be scaled up so that a larger number of farmers can be reached. It is also necessary to incorporate FFS in policy and in the recurrent budget of the extension services in order to integrate and mainstream it in the national extension system.

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COSTOS DE PREPARACIÓN DEL SUELO Y DE LAS CAMAS CON SUSTRATOS EN LA PRODUCCIÓN DE VEGETALES EN INVERNADEROS

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RESUMEN: Los altos costos de los materiales utilizados en la construcción de camas y su llenado, son problemas que enfrenta el productor cuando decide cultivar vegetales en ambiente controlado. Una alternativa utilizada ha sido la producción en suelo dentro de los invernaderos, tanto de madera, como de metal. El objetivo fue conocer los costos de preparación del suelo y de las camas con sustratos en la producción de vegetales. Se seleccionaron al azar 24 invernaderos en fase de preparación y siembra del cultivo en las localidades de Constanza, Jarabacoa, Villa Trina-Moca y San José de Ocoa. Se tomaron para el análisis tres invernaderos con sustrato y tres de suelo por localidad (24). Los productores fueron entrevistados, se hicieron observaciones y se socializaron las informaciones para corroborar los datos suministrados y recolectados. El costo total promedio de la preparación del sustrato listo para la siembra fue de RD$54.00/$m^2$ mientras la de suelo resultó en RD$14.79/$m^2$. En la preparación de las camas con sustratos y su renovación se tiene un alto costo inicial, la cual se expresa en el valor y el porcentaje del costo total que tienen los materiales y la mano de obra. En el suelo, los costos de mano de obra son mayores y representan la partida con mayor participación en el costo total de la preparación del suelo.

Palabras claves: Costo de preparación de camas, suelo, sustrato, invernaderos, costo de producción

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SOIL FERTILITY EVALUATION OF COFFEE (*COFFEA* SPP.) PRODUCTION SYSTEMS IN BARAHONA PROVINCE, DOMINICAN REPUBLIC

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ABSTRACT: Coffee producers in the Dominican Republic do not use diagnostic techniques such as soil and plant tissue testing, and reported yields are relatively low (<290 kg ha^{-1} parchment coffee). This fact prevents them from identifying the limiting factors (especially nutrients), complicates the work of coffee cultural management practices, and potentially reduces productivity and coffee quality. This research was conducted with the goal of diagnosing the nutrient status and other soil fertility limiting factors, and to refine management options for these agroforestry systems in the Barahona Province. Ninety-six farms within an area of 637 hectares were selected. Soils from each farm were sampled and analyzed for soil fertility parameters. Soils in the area were predominantly clayey. Soil pH varied between 4.61 and 7.69 and soil organic matter ranged between 3.29 and 10.9%. Exchangeable potassium levels were classified as deficient in all areas. The clustering of results identified two main components, which accounted for 76% of the variability of the data and the grouping into five communities by similarity of features. The results show that soil testing of this coffee-growing region can be used as a tool to diagnose the soil fertility status, and guide them in implementing management and fertilization recommendations.

Keywords: Soil fertility, yield coffee, fertility diagnostic

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MINERALIZACIÓN DE NITRÓGENO EN UN SUELO GRANÍTICO ENMENDADO CON MATERIALES ORGÁNICOS

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RESUMEN: La aplicación de enmiendas orgánicas es una alternativa para mejorar las condiciones de salud, calidad y fertilidad de los suelos agrícolas. El objetivo fue cuantificar la mineralización de nitrógeno (N_{min}) en un suelo granítico con aplicación de enmiendas orgánicas *ex situ*. El experimento se realizó en el laboratorio del Centro Regional Quilamapu, INIA, Chile. Se utilizó un diseño en parcelas subdivididas con cuatro repeticiones. Se evaluaron cinco tratamientos: 1) un control (CA); 2) fertilización convencional (FC, en mezcla de urea, superfosfato-triple y cloruro de potasio); 3) bioestabilizado de cerdo (BC); 4) guano de pavo (GP); y 5) guano de broiler (GB). El nitrógeno (N) se aplicó a una concentración de 100 mg N kg^{-1} por tratamiento. Las muestras de suelo se incubaron a 25° C y la humedad fue controlada por pesada. Los contenidos de nitrato + amonio (NO_{-3} + NH_{+4}) se midieron desde cero a ocho semanas. Los datos se analizaron en Infostat mediante un análisis de varianza (ANOVA). Se utilizó la prueba de Tukey al 5% para determinar las diferencias entre tratamientos. La N_{min} promedio fue estadísticamente superior ($p \leq 0.05$) en GP (59±4.9 mg N kg^{-1}) y FC (53±2.3 mg N kg^{-1}) en comparación con la CA, GB y BC. El aporte de N a partir de las enmiendas orgánicas mostró mayor estabilidad a través del tiempo con respecto al fertilizante convencional, por lo que la aplicación de GP y FC constituyen unas fuentes adecuadas de N para este tipo de suelo.

Palabras claves: Fertilización, nitrógeno, enmiendas orgánicas, granítico

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THE EFFECTS OF MOISTURE CONTENT AND ORGANIC MATTER AMENDMENTS ON CO_2 EMISSIONS, CARBON SEQUESTRATION AND SELECTED SOIL QUALITY INDICATORS ON SOME TRINIDAD SOILS

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ABSTRACT: The soils of the Caribbean are a valuable resource, crucial to the provision of many goods and products. Increasing interest in food security and climatic sensitivity will only serve to increase the importance of soils, their study and the goods and services they provide. Agricultural soils have been estimated to be able to sequester 0.8 Pg C yr^{-1} globally, and it is reasonable to expect that with adequate management Caribbean agricultural soils may develop into significant carbon sinks. Management practices that aid in mitigation of climate change may also aid in adapting to the anticipated changes with soil organic matter being particularly critical in this scenario. The main objective of this study was to determine the effects of soil moisture content and organic amendments on CO_2 emissions and changes in selected soil quality characteristics on a range of soils in laboratory-based incubations. Additionally, CO_2 emissions using the traditional alkali-trap and gas chromatography methods were compared with the new Solvita gel system. The soil quality characteristics monitored included soil organic carbon, aggregate stability and water retention capacity. Data is presently being collected and the results of this trial should demonstrate the impact of the factors investigated on carbon sequestration rates and CO_2 emission on some of Trinidad's soils. Subsequently, more informed management decisions relating to carbon dynamics will be possible; also, inferences on the ability of these factors to aid in adaptation to and mitigation of climate change can be made.

Keywords: Carbon dioxide, climate change, soil quality, Caribbean soils

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TECHNIQUES FOR QUANTIFYING N_2O EMISSIONS FROM AGRICULTURAL SOILS

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ABSTRACT: Agricultural soils are a significant source of nitrous oxide (N_2O) originating from the application of nitrogenous fertilizers. Nitrous oxide has been identified as one of the principal greenhouse gases (6%) that enter the atmosphere due to human activities. At present, N_2O contributes at least 5% to the observed total global warming potential, with agriculture being the major sector responsible for the emission of this gas (86%). Since reduction of greenhouse gas emissions is critical in all sectors of society to collectively mitigate global warming and ultimately climate change, it has therefore become imperative to identify and adequately understand some of the methods that can be used to accurately quantify N_2O emissions. This study was developed to investigate three techniques (manual chambers, automated chambers and modeling) for quantifying N_2O emissions from agricultural soils. This would then enable us to recommend management strategies for the agricultural sector for reducing the contribution of N_2O to climate change. A laboratory experiment studied the effects of various N-fertilizer (KNO_3) and moisture treatment combinations on N_2O emissions using a completely randomized design. Hutchinson Chambers that facilitated venting during gas collection was used in this investigation. The chamber-gas- collection system was designed so as to prevent soil disturbance during gas collection. Gas samples were then analysed for N_2O concentration by gas chromatography (GC) using an electron capture detector (ECD). The *ecosys* model was also used to conduct a simulated experiment using input (measured) data from the laboratory study together with additional soil and environmental data associated with the chamber experiment. This experiment tested the performance of the model in quantifying N_2O emissions. Continuous emissions of N_2O were also measured in a field experiment using automated chambers. This paper is expected to shed light on techniques that can be effectively used in Trinidad and the broader Caribbean for quantifying N_2O emissions from agricultural soils. While reducing the emission of this greenhouse gas is crucial to mitigating climate change, the data will also address the issue of efficiency of utilization of nitrogenous fertilizers by crops since a reduction in N_2O emissions could allow more N to remain available for uptake. A full report on the results obtained would be presented at the time of the conference.

Keywords: Nitrous oxide, climate change, ecosys model, Hutchinson chambers, automated chambers

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BIOMASA MICROBIANA DEL SUELO Y ACTIVIDAD DE UREASA EN UNA PRADERA PERMANENTE PASTOREADA DE CHILE

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RESUMEN: En los sistemas de pasturas la productividad de la pradera puede ser influenciada por el manejo, debido a su impacto sobre los microorganismos del suelo y el reciclaje de nutrientes. El objetivo fue evaluar la biomasa microbiana del suelo asociada al nitrógeno (BMN) y carbono (BMC) y la actividad ureasa (AU) en una pradera permanente del sur de Chile en dos sistemas de pastoreo. Antes de iniciar el experimento el suelo tenía una media de 16 mg kg^{-1} Olsen-P, 13% de materia orgánica, 5.2% N y pH de 5.5. El suelo presentaba niveles adecuados de nutrientes para la pradera. Entre la primavera de 2005 y el invierno de 2006 se evaluaron dos sistemas de pastoreo: pastoreo intenso (PI), pastoreo suave (PS) y un control sin pastoreo (C), con tres repeticiones, en un diseño de bloques al azar. El pastoreo incrementó la BMC en un 21,8 y 8,6% para PI y PS, mientras que en el control fue sólo de 1.9%. Los contenidos de BMN también fueron incrementados en un 16 y 19% para PI y PS, respectivamente, en comparación con el control (4 %). La actividad de ureasa aumentó en 13 y 27% para PI y PS, respectivamente en comparación con el control (5%). El pastoreo, produce un flujo más alto de residuos orgánicos y nutrientes en el suelo, que sirve de sustrato para aumentar la reserva de la biomasa microbiana y la actividad de ureasa. Así, en los sistemas de pastoreo se mejora la fertilidad biológica, la disponibilidad de nutrientes y la producción de forraje.

Palabras claves: Pastura, pastoreo, intensidad y frecuencia de pastoreo

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CARACTERIZACIÓN DE MATERIALES ALTERNATIVOS PARA LA ELABORACIÓN DE SUSTRATOS EN INVERNADEROS

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RESUMEN: Los sustratos para producir vegetales en invernaderos requieren diferentes materiales para su elaboración, algunos son de mezclas locales y otros son importados. Sin embargo, los importados son costosos y los locales presentan ciertas limitaciones de disponibilidad en las zonas de producción. El objetivo fue determinar las características físicas, químicas y biológicas de diferentes materiales con potencial para la elaboración de sustratos, provenientes de Cibao Sur y Cibao Nordeste. Se colectaron 28 materiales (tres muestras por material). Se realizaron análisis de varianza, comparación de medias y conglomerados para agrupar los materiales según sus características. El 70% de los materiales tiene un contenido alto de potasio (entre 0.45 y 4.32%) y magnesio (entre 0.64 y 5.83%). El 40% posee un alto contenido de hierro (entre 14,333 y 47,231 ppm) y manganeso (entren 413 y 1143 ppm). Un 40% posee un pH medianamente alcalino y el 60% tiene una conductividad eléctrica alta (entre 2.45 y 16.83 dS/m). El 64% tiene densidad aparente baja (>0.53 g/cm^3), 46% tiene porosidad total adecuada (<82%), el 61% posee una humedad disponible entre 19 y 32%. El porcentaje de saturación de agua fue entre 100 y1800%, excepto la arena (28%) y el limo (42%). El 72% tiene entre 3.73 y 5.18 log UFC de hongos. El 88% posee entre 5.49 y 7.65 log UFC de bacterias. La cantidad de actinomicetos varió con el tipo de material desde 5.01 hasta 7.47 log UFC. Los materiales que presentaron las características adecuadas para la elaboración de sustratos fueron: arena, grava, fibra de coco, carboncillo de arroz, cáscara de arroz y gallinaza compostada.

Palabras claves: Propiedades físicas, químicas y biológicas, sustratos, invernaderos

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EFECTO RESIDUAL DE LA APLICACIÓN DE ABONO ORGÁNICO TIPO BOKASHI EN MAÍZ

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RESUMEN: El éxito de la agricultura sostenible requiere de suelos fértiles y bien conservados, donde se realice un manejo sostenible de los fertilizantes orgánicos usados. El objetivo fue determinar el efecto residual del bokashi. En un ensayo anterior se estudió el efecto de dosis creciente de bokashi (0, 4, 8, 12 y 16 t ha^{-1}) sobre el rendimiento del ají picante. En este ensayo se estudió qué tan substancial fue el efecto residual del bokashi aplicado en el ensayo sobre ají, utilizando plantaciones de maíz (*Zea mays* L.) variedad Comalat. La siembra se realizó en un Vertisol del Campo Experimental Pontón, La Vega (19° 15' LN y 70° 33' LO), altitud de 97 msnm, durante el período enero a junio de 2007. El bokashi fue aplicado dos ciclos de cultivos antes a la siembra de maíz en doble hilera sobre el surco. Se utilizó un diseño de bloques completos al azar con cinco tratamientos y cuatro repeticiones. Las variables evaluadas fueron: rendimiento (t ha^{-1}), altura de la planta (m), grosor del tallo (cm), longitud del fruto (cm), diámetro del fruto (cm). Se realizó un análisis de regresión lineal utilizando el paquete estadístico SAS (Statistical Analisis System). Se encontró un efecto residual significativo del bokashi que fue aplicado al cultivo de ají, el mismo presentó una respuesta lineal entre el rendimiento y las dosis aplicadas en el ensayo anterior (p=0.0001). La aplicación de bokashi podría mejorar la fertilidad natural del suelo y la actividad microbiana, aumentando la disponibilidad de estos nutrientes en cultivos alternos.

Palabras claves: Bokashi, abono orgánico, efecto residual, maíz

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CARBONO BIOMÁSICO EN SUELOS Y SUSTRATOS DE USO FRECUENTE EN INVERNADEROS

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RESUMEN: El manejo de cultivos en invernaderos afecta la actividad biológica en sustratos y suelos, lo que repercute en los procesos de descomposición de los residuos orgánicos y la liberación de nutrientes, como el carbono (C). El objetivo fue evaluar los contenidos de carbono biomásico (CB) en suelos y sustratos en invernaderos. El CB se determinó en muestras provenientes de Villa Trina (VT), Constanza (CO), Jarabacoa (JA) y San José de Ocoa (SJO). Se seleccionaron 115 muestras de sustratos y 38 de suelo de invernaderos (153 estructuras). El CB se determinó mediante fumigación-extracción con cloroformo. Los datos fueron analizados usando el programa estadístico Infostat (2009). Se efectuó el análisis de Prueba T bilateral al 5%. Los sustratos encontrados en los invernaderos con mayor frecuencia fueron: 1) carboncillo de arroz (70%) + grava (30%); 2) fibra de coco (100%); 3) carboncillo de arroz (100%); y 4) fibra de coco (80%) + carboncillo de arroz (20%). El CB en los suelos varío entre 174 y 325 mg C kg^{-1} de suelo seco (ss), mientras que en sustratos fue entre 171y 431 mg C kg^{-1} ss. En CO, el CB promedio fue superior en suelo (263 mg C kg^{-1} ss). En JA, el CB fue mayor en fibra de coco (80%) + carboncillo de arroz (20%), con 431 mg C kg^{-1} ss, que en los demás sustratos. En SJO, el suelo no difirió estadísticamente del carboncillo de arroz (100%) con 259 y 227 mg C kg^{-1} ss, respectivamente. En VT el carboncillo de arroz (100%) fue superior al suelo con 224 versus 174 mg C kg^{-1} ss. Los resultados sugieren un efecto de la aplicación de fertilizantes y/o fuentes de carbono en la actividad de los microorganismos tanto en el suelo como en los sustratos.

Palabras claves: Carbono biomásico, suelos, sustratos, invernadero

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EFECTO DE LA GALLINAZA COMPOSTADA SOBRE EL RENDIMIENTO, CALIDAD Y RENTABILIDAD DE BERENJENA CHINA (*SOLANUM MELONGENA* L.)

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RESUMEN: Los productores de vegetales orientales aplican dosis de abono orgánico que varían entre 4 y 95 t ha^{-1} con rendimientos promedios de 15 t ha^{-1}. Esta situación evidencia la incertidumbre sobre la dosis adecuada, lo que puede ser causa de baja rentabilidad por aplicaciones excesivas y disminución en la producción por aplicaciones bajas. La disponibilidad de información económica sobre el uso de abonos orgánicos en estos cultivos ha sido poco estudiada. El objetivo fue determinar el efecto de la gallinaza compostada sobre el rendimiento de berenjena china. Se utilizó un diseño de bloques completos al azar con cinco tratamientos y cuatro repeticiones. La siembra se realizó en un Vertisol del Campo Experimental Pontón, La Vega (19° 15' LN y 70° 33' LO), con altitud de 97 msnm, durante el período abril a septiembre de 2007. Se aplicaron los niveles 7, 14, 21 y 28 t ha^{-1} de gallinaza compostada (GC) y un testigo absoluto sin aplicación. Los resultados del análisis de regresión indicaron una respuesta cuadrática significativa entre el rendimiento y las dosis aplicadas (p=0.0004). La dosis y el rendimiento óptimos estimados por el modelo fueron: para GC 24 t ha^{-1} y 18 t ha^{-1} de berenjenas en comparación al control (8.2 t ha^{-1}). Las dosis de GC que fueron aplicadas no afectaron la longitud (p=0.1716) ni el diámetro (p=0.2097) del fruto. La aplicación de 21 t ha^{-1} produjo un rendimiento 120% mayor que el testigo. El análisis económico indicó que 21 t ha^{-1} de GC fue la dosis más rentable con una tasa de retorno marginal de198% y un beneficio de RD$ 1.98 por cada RD$ 1.00 invertido en la compra de la gallinaza.

Palabras claves: Abono orgánico, gallinaza compostada, berenjena

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YIELD PERFORMANCE OF TOMATO (*LYCOPERSICON ESCULENTUM*) GROWN IN VARIOUS MEDIA UNDER GREENHOUSE IN DOMINICA

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ABSTRACT: Tomato (*Lycopersicon esculentum*) is the most popular greenhouse crop in Dominica. Production is however characterised by low yields and a growing incidence /severity of bacterial wilt (*Pseudomonas solanacearum*). A trial was conducted to evaluate the suitability of four locally available media to exclude the disease and make production cost effective. The most commonly grown tomato variety, TX54, was selected for the trial. Plants were grown in two litre pots in soil, promix, and two other indigenous media: partially decomposed plant residues from the bay oil extracting process, and a locally produced organic compost. All plants were subjected to the same fertiliser regime and other management practices. Preliminary results indicate that plants grown in the organic compost had more vigorous growth, flowered earlier, had better fruit set and produced heavier fruits.

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ORGANIC MULCHES: WEED CONTROL, MOISTURE RETENTION, SOIL TEMPERATURE, AND CROP YIELD

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ABSTRACT: This paper investigates the use of locally available organic mulch and organic fertilizer for the production of sweet corn in Barbados. It focuses primarily on the impact of locally produced coconut fiber, wood chip, and green waste mulches on sweet corn yield, weed control, moisture retention and soil temperature. The performance of these organic mulches is compared to synthetic mulch and a control (unmulched). The effect of the amendments and cropping density are also assessed. The variety of sweet corn grown was Golden Sweeter 93. Organic pest management practices were utilized throughout the production period. The use of organic mulches did not significantly increase yields in comparison with the control. Cropping densities used in the trial had no significant impact on yield. Weed control among all organic mulches was significant. Coconut fiber and wood chip provided the best weed control among these organic mulches. Organic mulches had 5-10 times less weeds than the control before first weeding. Weeds such as *Commelina elegans*, *Euphorbia heterophylla* L., and *Mimosa* spp. persisted within organic mulch treatments but below economic damage threshold levels. All treatments lead to an increase in moisture retention when compared to the control. Coconut fiber and Wood chip performed the best among the amendments in relation to water retention. Soil Temperature was significantly reduced by all organic treatments, a reduction of 1.3-1.9 °C. The Green Waste treatment resulted in the lowest average soil temperature. The implications and details of these observations in relation to organic crop production, weed management, and soil fertility management are discussed.

Keywords: Organic mulch, sweet corn, weed control, moisture retention, soil temperature

INTRODUCTION

Mulch provides several benefits to agricultural production and these benefits become extremely important in the context of organic agriculture. Organic farming is defined by FAO as an agro-ecological production management system that promotes and enhances biodiversity, biological cycles and soil biological activity without the use of synthetic pesticides, herbicides, or fertilizers. It is based on minimal use of off-farm inputs and management practices that restore, maintain, and enhance agro-ecological harmony. Since synthetic herbicides are excluded from the system and there are no local organic herbicides that are very effective, it becomes of great importance to utilize mulch primarily for the benefit of weed control.

In its recycling efforts, the Sustainable Barbados Recycling Center (SBRC) has been producing several types of organic mulches. These mulches are expected to be used by local farmer mainly as a means of weed control. Organic mulch is a protective covering of organic material with the following internationally documented benefits: weed control, increased water retention, reduction in soil temperature, increased soil biological activity, and increased organic matter content. Depending on the mulch material used, application rate, and environmental factors these benefits are manifested to different degrees. Local research in this area is important since there

are significant economic and environmental benefits that could be derived if these mulches possess the characteristics to facilitate adoption by farmers on a national level.

OBJECTIVES

Major

1) To determine the suitability of locally available mulches for weed control.

Minor

1) To determine the impact of locally available mulches on soil moisture, temperature, and organism activity.
2) To determine the impact of local mulch on the yield of sweet corn.

MATERIALS AND METHODS

This research trial was conducted at the Central Agronomic Research Station, Ministry of Agriculture, Barbados. In the process of field preparation a representative soil sample was taken for chemical analysis. The soil sample was analyzed for soil texture, C.E.C, pH, organic matter, soluble salts and soil nutrients. The physico-chemical characteristics of the experimental site are as follows: Texture = B; Organic Matter = 0.8%; Nitrogen = 5 lbs/acre; P_2O_5 = 24 lbs/acre; K_2O = 353 lbs/acre; pH = 7.5; C.E.C = 79.4 meq/100 cm^3; Soluble Salts = 353 ppm. The nutrient analyses of the fertilizers used are as follows: Chicken manure: 1.1% N, 3.7% P_2O_5, 2% K_2O; Conventional fertilizer: 24% N, 23% P_2O_5, 18% K_2O. Due to the varying concentration of nutrients within each amendment only one macro nutrient could have been held constant across all amendments. As a result, nitrogen was held constant at 150 lbs/acre.

The experiment was set up in a completely randomized design with three factors. The factors were mulch, soil amendment and crop spacing. The crop type selected was sweet corn Golden Sweeter 93. The two types of ameliorant treatments were chicken manure and inorganic fertilizer. The application rate was 150 lb N/acre. There were six mulch treatments: Wood Chip (WC), Coconut Fiber (CF), Green Waste (GW), and Un-mulched Soil/Control (CONT). This resulted in a total of 54 treatments that were replicated three times. The experimental area in total was 16000 sqft and the individual plot size of 600 sqft. Double row spacing was used with intra-row spacing of 10 inches and 12 inches. The inter-row spacing was held constant at 24 inches.

The main treatments in the trial were broadcasted unto the beds and rotivated into the beds immediately after to allow for incorporation. Following incorporation, 12 inch spaced doubled row drip irrigation lines were placed into the field. The experimental area was then manually covered with two inches of the various mulch treatments. This coverage includes both rows and drains. The corn seeds were planted one per hole. Irrigation was regulated using a tensiometer, maintaining an average of 20 bars. Organic methods were used for pest control. The corn was harvested at the milk stage determined by destructive sampling. For determining corn ear weight, four plants were randomly selected and their ears were weighed to calculate the average head weight per plant. Heads were all check for damage by pest or disease. The data collected were subjected to analysis of variance (ANOVA) test. Depending on how the variance was distributed Tukey's honestly significance difference and Tahmane was applied for mean separation at a 0.05 level of significance.

RESULTS

Yield. No interactions or main effect within the experiment had a significant impact on sweet corn yield.

Soil Temperature. Mulch had a significant impact on soil temperature (sig 0.002). As expected the time of the day had a significant impact on soil temperature (sig 0.000). Therefore, soil temperatures in the afternoon were significantly higher than temperatures in the morning. There was no interaction between the mulch treatments and the time of the day. This result demonstrates that if any temperature reductions are achieved, the degree of reduction will be relatively consistent throughout the day.

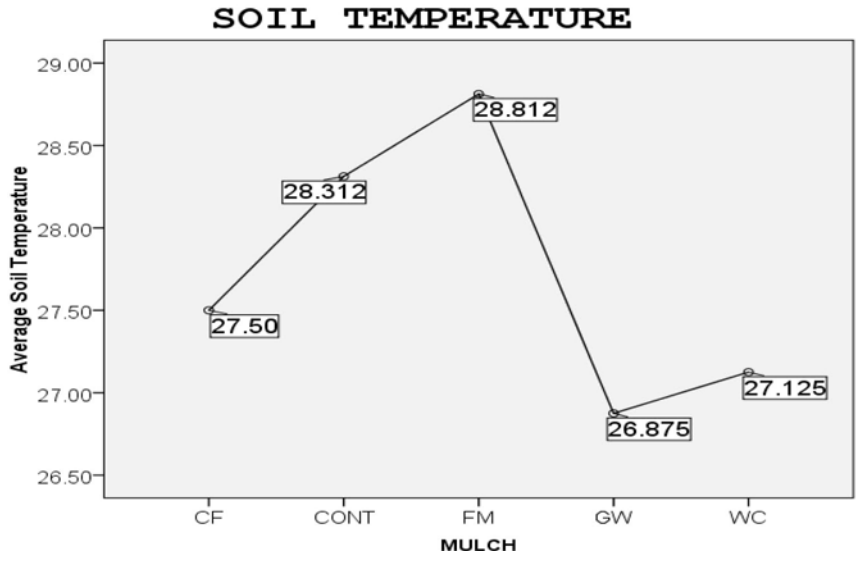

Figure 1. Soil temperature of different mulches.

Green Waste (1.9° C), Wood Chip (1.7° C) and Coconut Fiber (1.3° C) treatments resulted in significantly lower soil temperatures than Ground Cover/Fabric Mulch (see fig 1). This outcome was expected since the ground cover was black and had a tendency to trap heat (Ramakrishna et al., 2006). The mean difference between Green Waste and Fabric Mulch was approximately 2 °C. Only the Green Waste (1.4° C) and Wood Chip (1.18° C) had significantly lower soils temperature when compared to the control. It is possible that smaller particle size and resulting larger surface area of the Green Waste mulch accounted for the difference in temperature.

Weed Score. The main effect Mulch showed significance in relation to weed score (sig 0.000). All mulches lead to significantly lower weed scores when compared to the control (sig 0.000). Similar results were achieved by Kar and Kumar (2007). There was no significant difference between the organic mulches and the Ground Cover/Fabric mulch in terms of weed control.

Within the control, grass weeds dominated. The few weeds present within the organic mulches were mainly broadleaf weeds that could have been already present in the mulch as seeds. The weeds present were: *Commelina elegans* (Water Grass), *Euphorbia heterophylla* L. (Milk Weed), and *Mimosa pudica*. It was evident that the noxious weed *Cyperus rotundus* (Nut Grass) was not suppressed with three inches thick application of these organic mulches.

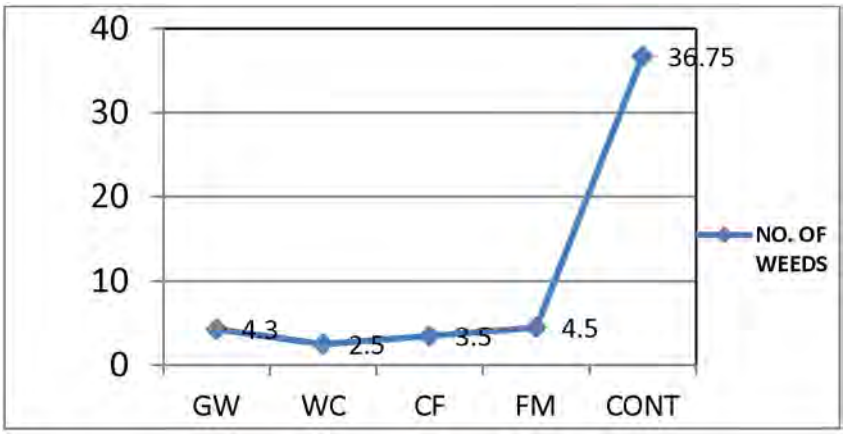

Figure 2. Number of weeds on different mulches.

All mulches led to significant increases in soil moisture content relative to the control. This was expected since mulching could decrease evaporation from the soil by 55% in comparison with non-mulched soil (Xie et al., 2005). Soil moisture content was not significantly different among Ground Cover, Coconut Fiber, and Wood Chip mulch. However, Wood Chip Mulch led to significantly more moisture retention than Green Waste (sig 0.003). The fine particle size of the green waste and its tendency to cling together could have reduced water permeability, increased runoff, thus limiting the amount of moisture entering the soil.

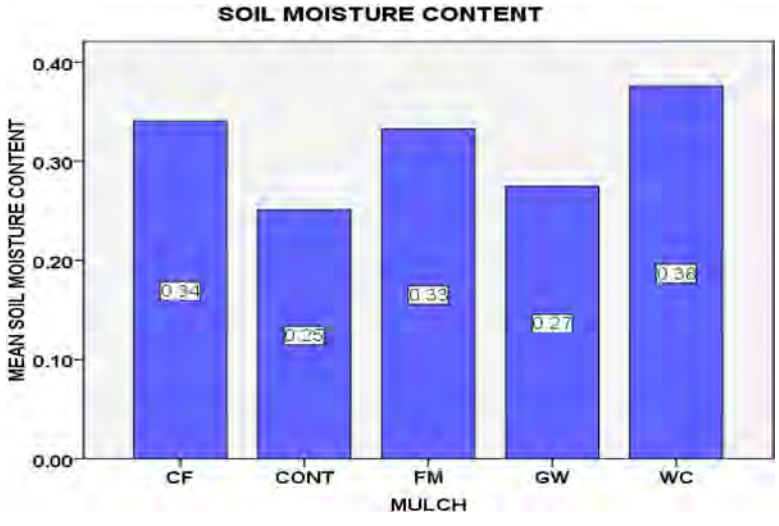

Figure 3. Soil moisture content of different mulches.

The most efficient and cost effective method of application is with a mulch/compost spreader. Application on soil should ideally be three inches thick to achieve appropriate weed control results. Table 1 demonstrates the vast difference in cost between the synthetic ground cover and the organic mulches.

Table 1. Yield, cost of mulch per acre, and cost of mulch applied per acre.

MULCH TYPE	TONS/ACRE	COST OF MULCH/ACRE	COST OF MULCH APPLIED/ACRE
COCONUT FIBER	19	$744	$1144
GREEN WASTE	37	$1488	$1888
WOOD CHIP	37	$1488	$1888
GROUND COVER	NIL	$8750	$8890

CONCLUSIONS

All organic mulches used in this field trial are adequate for use as weed controls. Green Waste and Wood Chip mulches are best suited for the purpose of soil temperature reduction. Wood Cchip and Coconut Fiber mulches provide the greatest benefits in relation to soil moisture retention. Locally produced organic mulch can potentially provide a sustainable alternative to imported synthetic mulch given the agronomic benefits they provide and the low carbon footprint involved in the production of such organic mulches. Further research is required to determine the appropriate mulch thickness required to suppress the persistent noxious weed *Cyperus rotundus*.

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PHYTOREMEDIATION OF MINED SOIL IN THE DOMINICAN REPUBLIC

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ABSTRACT: Mining activities in the Dominican Republic are associated with heavy metal contamination of surrounding areas, increased soil erosion, loss of ecosystem biodiversity, and negative impacts to soil quality (i.e., biological, chemical and physical properties). The objective of this study was to quantify selected soil physical and chemical characteristics of a mined site that was re-planted with *Casuarina equisetifolia* Forst and *Acacia mangium* Willd in order to determine the resilience of these soil properties as related to the cronosequence in the recovery process. The study was conducted in the province Monseñor Nouel, Dominican Republic, near 18° 55' N and 70° 25' W. This region has a mean elevation of 380 masl, and mean annual temperature, precipitation, and relative humidity of 23.7° C, 1.72 mm, and 87%, respectively. The site is predominantly hilly with the most prevalent natural vegetation being *Pinus occidentalis*. Soil quality was different under the *Casuarina* and *Acacia* cronosequences as compared to recently mined soil and that under natural forest. Specifically, soil pH decreased, and soil electrical conductivity, total N, and total C, increased with the *Casuarina* cronosecuence. Our results suggests improvements in soil quality when replanting contaminated mined soils with *Casuarina* and *Acacia* cronosecuences mostly associated with increases in soil organic matter and K and Ca availability.

Keywords: Phytoremediation, soil reclamation, mining soil, soil quality

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RENDIMIENTO DE MATERIA SECA DE ESPECIES LEGUMINOSAS EN DOS LOCALIDADES

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RESUMEN: El uso de especies leguminosas en la producción agropecuaria es una alternativa a considerar para el mantenimiento de la fertilidad del suelo. Estas especies aportan al suelo materia orgánica (MO) y nutrientes, y mejoran sus propiedades; además, mejoran la retención de agua y actividad biológica y reducen el uso de fertilizantes. El objetivo del estudio fue evaluar la producción de biomasa de siete especies leguminosas en dos localidades de República Dominicana. El estudio se realizó en El Limonal (altitud 565 msnm, temperatura media de 22° C, pluviometría anual de 375 mm, suelos ferralíticos con 3.8% de MO y pH 5) y Pontón (altitud 97 msnm; temperatura media, 27° C; pluviometría, 1,423 mm/año; suelo Vertisol con pH ácido, 6.3 y MO, 3%), Provincia La Vega. Se utilizó un diseño experimental de bloques completos al azar con siete especies de leguminosas y tres repeticiones por localidad. Los datos fueron analizados mediante prueba de *t* para datos independientes. En El Limonal, las especies *Crotalaria juncea y Mucuna deeringiana* fueron las de mayor rendimiento con 23,311 (p=0.0001) y 12,039 (p=0.0178) kg ha^{-1} de materia seca (MS), respectivamente. En Pontón, las especies más productivas fueron *Canavalia ensiformis* y *Desmodium ovalifolium* con 36,547 (p=0.0001) y 20,239 (p=0.0005) kg ha^{-1} de MS, respectivamente. *Arachi pintoi y Pueraria phaseolides* produjeron similar cantidad de MS en ambas localidades con rendimientos promedios de 12,200 (p=0.2635) y 18,850 (p=0.0916) kg MS ha^{-1}. Para las especies el sitio influye en el rendimiento.

Palabras claves: República Dominicana, leguminosas, cobertura, contrastante

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VOLUMEN DE LEÑA CONSUMIDO Y EMISIONES DE CO_2 GENERADO EN EL PROCESAMIENTO DE CERDO ASADO EN REPÚBLICA DOMINICANA

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RESUMEN: En República Dominicana se han realizado pocos estudios en relación a las emisiones de carbono (CO_2) provenientes de la quema de leña usada en el procesamiento de cerdo asado (puerco asado). El objetivo fue estimar las emisiones de CO_2 a partir de los volúmenes utilizados en la elaboración de cerdo asado. Se seleccionaron siete puestos de elaboración de cerdo asado en las provincias de La Vega, Moca y Santiago y al Director de la Asociación de productores de Cerdos del Cibao (APORCI). A cada uno se le aplicó una entrevista para determinar el volumen de leña consumido durante el año y el número de cerdos procesados. A base del volumen de leña consumido y estimado, se estimaron las emisiones de CO_2 (metodología IPCC). El consumo estimado de leña fue de 451,440 m^3/año a nivel nacional, el cual genera unas 413,857 toneladas métricas de CO_2. Considerando esta información se pueden inferir dos efectos: 1) las emisiones de CO_2 pueden incrementarse dadas las tendencias de incremento en la demanda de carne de cerdo asado y el número de consumidores; 2) la demanda de leña para el asado de cerdo podría afectar negativamente la cobertura vegetal.

Palabras claves: Leña, fijación de carbono, efecto invernadero

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PRESENCIA DE METALES PESADOS EN SUELOS DEDICADOS A LA PRODUCCIÓN DE VEGETALES EN AMBIENTE CONTROLADO

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RESUMEN: El laboreo intensivo de los suelos y el desarrollo de cultivos agrícolas con uso excesivo de agroquímicos podrían producir un aumento de los contenidos de algunos metales pesados como: cromo (Cr), níquel (Ni), cadmio (Cd) y plomo (Pb) en el suelo. Al aumentar su concentración, estos elementos se convierten en contaminantes del suelo pudiendo afectar la salud humana por ingestión de los vegetales expuestos a los mismos. La determinación de estos contaminantes en condiciones de invernadero no ha sido debidamente evaluada en la República Dominicana. El objetivo fue determinar las concentraciones de Cr, Ni, Cd y Pb en suelos de 40 invernaderos en cinco localidades. Se tomaron ocho sub-muestras para conformar una muestra representativa de cada invernadero. Los datos fueron analizados mediante estadísticas descriptivas. Los mayores contenidos promedios de Cr, Ni, Cd y Pb se encontraron en invernaderos de San José de Ocoa con 63.7, 77.8, 1.8 y 29.4 ppm, respectivamente. Los contenidos de Cr y Ni fueron similares en Villa Trina y Moca con rango promedio de 39.5-39.6 ppm para Cr y 40-53 ppm Ni. El contenido de Cd en las localidades restantes fue <0.002. En general los valores promedios de los contenidos de Cr, Ni, Cd y Pb oscilaron entre 27.0 y 63.7; 30.0 y 77.8; <0.002 y1.8; y <0.002 y 29.4 ppm, respectivamente. En términos generales, los contenidos promedios de estos metales, en ninguna de las localidades excedieron los límites ambientales; sin embargo, en algunos invernaderos hubo excesos, lo que debería llamar la atención por la posible acumulación de estos en el suelo y consecuentemente en los cultivos.

Palabras claves: Metales pesados, invernadero, cromo, níquel, cadmio, plomo

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AGROFORESTRY IN BARBADOS: INTEGRATING MAHOGANY TREES AND BLACK BELLY SHEEP TO FORM A SUSTAINABLE LAND USE SYSTEM

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ABSTRACT: Agroforestry could play an important role in turning marginalized lands in Barbados into economically productive areas, while also promoting long-term sustainability. The design of an effective silvopastoral system for the East coast of Barbados is the subject of this paper. A silvopastoral system requires three main components, which interact to form a holistic system: a tree species, livestock, and forage crops. This system is designed for marginal lands, for example highly erodible lands in the Scotland District, and integrates four components: mahogany trees (*Swietenia mahogani*), Barbados Black Belly Sheep, *Leucaena leucocephala* and Pangola grass (*Digitaria eriantha* subsp *pentzii*). The overall aim of this project is to create a locally adapted land-use system that is both economically and ecologically sustainable. The components of this system interact to be mutually supportive and to reduce competition, thus maximizing plant and animal health, while also maximizing yield. *Swietenia mahogani* is a very rare tree species that is native to the West Indies and produces a very high value wood product. It can grow on soils of varying quality and is well adapted to the climate of Barbados. The Barbados Black Belly Sheep enjoys a growing market both in Barbados and abroad, and is exceptionally well suited to the environmental conditions on the island. The sheep will play a key role in the silvopastoral system, by controlling weeds, cycling nutrients in the system, as well as by providing a consistent income during the trees' long growth period. Pangola grass and *L. leucocephala* will provide ground cover year round to prevent land erosion, as well as providing a well-balanced diet for the sheep. Overall, this system will have many benefits including turning once marginal land productive, helping to preserve an endangered tree species, and improving soil properties, which will lead to decreased erosion in the long term. This project could also have positive effects on the greater Barbadian community, as the mahogany wood could be used in local craft industries, and it provides a healthy, local protein source for human consumption.

Keywords: Agroforestry, black belly sheep, silvopastoral, mahogany, marginal lands

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DIAGNOSTIC AGRI-ENVIRONNEMENTAL DE L'EXPLOITATION AGRICOLE DE L'EPLEFPA DE GUADELOUPE: MÉTHODES, RÉSULTATS ET PERSPECTIVES; VERS DES PRATIQUES PLUS AGROÉCOLOGIQUES

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RÉSUMÉ : Partant du constat que le Monde traverse une crise climatique et écologique de grande ampleur, un processus qualifié de "Grenelle de l'Environnement", a été initié en France dès 2007 (J.O., 2009). Il s'agissait grâce à une large concertation, de définir une feuille de route en faveur de l'écologie, du développement et de l'aménagement durables. Parmi les nombreuses mesures qui ont vu le jour entre 2008 et 2010 suite à ce processus, le plan "Ecophyto 2018" constitue un engagement à réduire de 50% l'usage des pesticides au niveau national dans un délai de dix ans (2008-2018). Ce plan vise notamment à réduire la dépendance des exploitations agricoles aux produits phytopharmaceutiques, tout en maintenant un niveau élevé de production agricole, en quantité et en qualité. Comme lieu idoine pour concrétiser l'engagement du Ministère de l'Agriculture dans cette politique, nombre d'exploitations agricoles des établissements publics locaux d'enseignement et de formation professionnelle agricoles (EPLEFPA) se sont impliquées dans la mise en œuvre du plan. C'est dans cette optique que l'exploitation agricole de l'EPLEFPA de Guadeloupe a procédé à un diagnostic de sa durabilité selon deux méthodes distinctes. Pour chacune, l'objectif est d'effectuer un diagnostic agri-environnemental de l'exploitation. La méthode IDEA (**I**ndicateurs de **D**urabilité des **E**xploitations **A**gricoles) s'appuie sur les trois composantes généralement admises du développement durable : la composante agroécologique, la socio-territoriale, l'économique. A la différence, la méthode DIALECTE (**DIA**gnostic **L**iant **E**nvironnement et **C**ontrat **T**erritoriaux d'**E**xploitation) développée par SOLAGRO depuis 1995, est un outil centré sur l'évaluation simple et globale des impacts - positifs et négatifs – de l'exploitation sur son environnement (http://www.solagro.org/site/255.html). Après usage, ces deux méthodes posent question, car les évaluations qui en ressortent peuvent être très différentes pour des indicateurs de même nature. Toutefois, la méthode IDEA nous a permis de confirmer que l'exploitation agricole de l'EPLEFPA est bien diversifiée. Son évaluation est moyenne sur les plans agroécologique et socio-territorial, et mauvaise sur le plan économique. Enfin, tester ces deux méthodes nous a montré leur inféodation au milieu tempéré, certaines productions et conditions caractéristiques des milieux tropicaux étant difficiles, voire impossibles à prendre en compte de façon correcte dans leur configuration actuelle.

Mots-clés **:** Diagnostic agrienvironnemental, Guadeloupe, exploitation agricole, méthode d'évaluation

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DES VOLAILLES POUR UN CONTROLE ECOLOGIQUE DES ADVENTICES DANS LES VERGERS

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RÉSUMÉ : En zone tropicale humide, les conditions climatiques favorables tout au long de l'année nécessitent un contrôle permanent des adventices. En effet, la concurrence de l'enherbement a un impact fortement négatif sur le rendement et gêne les opérations telles que taille et récolte. Le contrôle des adventices est par conséquent un poste important dans les dépenses d'un producteur de fruits. La pratique du désherbage chimique est à ce jour la plus économique, tant en main d'œuvre qu'en investissement. Mais l'utilisation récurrente d'herbicides dans les exploitations agricoles de la Martinique a conduit à une érosion des sols et à une pollution des eaux. Une solution alternative envisageable est l'association avec des animaux pâturant les adventices, sans porter préjudice à la culture de rente. Une association avec des volailles (poulets et oies) a été testée dans un verger de goyaviers en production. La faisabilité et l'efficacité du désherbage ont été évaluées. Le pâturage par les volailles, principalement les oies, contrôle la biomasse herbacée mais la sélection par les animaux des espèces qu'elles consomment aboutit à une modification significative de la flore. Une analyse économique du système a également été réalisée. Associer un pâturage de volailles à un verger adulte constitue une solution alternative efficace et économiquement viable. La plantation de graminées et de légumineuses pérennes dans le verger pourrait constituer une amélioration de ce système de culture. L'effet à long terme d'une telle association reste à évaluer.

Mots-clés : désherbage, verger, volailles, adventices, agropastoralisme, Martinique, système de culture

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THE EFFICACY OF RYNCHOLURE® IN TRAPPING *RHYNCHOPHORUS PALMARUM* L. THE VECTOR FOR RED RING DISEASE OF COCONUTS IN TRINIDAD

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ABSTRACT: The coconut palm weevil, *Rhynchophorus palmarum* L. (Coleoptera: Curculionidae) is a serious pest of coconuts (*Cocos nucifera* L.) in Trinidad. *Rhynchophorus palmarum* can cause direct as well as indirect damage to coconut trees. Apart from causing death of trees or little leaf syndrome, it is the vector of the nematode *Bursaphelenchus cocophilus* which causes red ring disease. This disease has been devastating the coconut industry for over 100 years and trees between 3-10 years old are highly susceptible. Management of the disease has been through field sanitation and trapping of *R. palmarum*. Trapping of the vector has been demonstrated to reduce the incidence of red ring disease in Malaysia, Brazil and Costa Rica. Traps were used with the aggregation pheromone Rhynchophorol (Rhyncholure®) together with sugarcane or fruit baits and an insecticide. In September 2010 a pre-trial was initiated at four locations in Trinidad to examine the efficacy of using baited traps with Rhyncholure® in reducing populations of *R. palmarum.* Each location was isolated from one another by several kilometres and comprised approximately 1.0 hectare with about 200 coconut trees that were less than 10 years old. At each location one trap made of a discarded 4-litre oil container containing the lure, sugarcane bait and a carbamate insecticide was placed about 1.5 metres high on a leaf petiole close to the trunk of the coconut tree in the middle of the field. The traps were examined weekly for a period of 16 weeks and the number of coconut palm weevils was recorded. The sugarcane bait and insecticide were changed bi-weekly. A total of 651 of these insects was collected over the period with the highest number at Centeno (255) followed by Valencia (186), Carlsen Field (151) and Kelly (59). The results show that the trapping system used was effective in trapping *R. palmarum* and thus reduce their population in the environment. Based on the data gathered, long term trials will now be established to manage *R. palmarum* and in so doing manage the spread of *Bursaphelenchus cocophilus* the causal organism of red ring disease.

Keywords: *Rhynchophorus palmarum*, trapping, Rhynchophorol, *Bursaphelenchus cocophilus*

INTRODUCTION

Coconut (*Cocos nucifera* L.) is an important agricultural crop in Trinidad and Tobago. It is widely used in the fresh state for coconut water or the copra is processed for oil, soaps and perfumes. Coconut milk is also used in culinary delights. The coconut plant adds to the rich biodiversity and has aesthetic value in beautifying a country's landscape.

Apart from socio-economic reasons, pests and diseases are important factors affecting production. The crop has been on the decline for a number of years and consequently has been identified as a priority crop in the Ministry's Action Plan (MFPLMA, 2010). Red ring disease was first reported in Trinidad in 1905 (Hart, 1905) when several thousand trees were destroyed. It is caused by the nematode *Busaphelenclus* (*Rhadinapelenclus*) *cocophilus* (Cobb, 1919; Goodley, 1960) and is one of the most destructive pests of coconut. The nematode is vectored by

the coconut palm weevil *Rhynchophorus palmarum* L. (Coleoptera: Curculionidae) (Griffith, 1968), which can also cause direct damage to the palm by extensive feeding of the larvae to the crown (Griffith, 1987).

In Trinidad it is estimated that red ring disease kills 35 percent of young coconut trees and in Venezuela 35 percent of oil palms died over a ten-year period. In Grenada, 22.3 percent of coconut trees were infected with *B. cocophilus*, 92 percent of which was infested with the coconut palm weevil. There appears to be a synchronized distribution of both *B. cocophilus* and *R. palmarum* from Mexico to South America including the Caribbean (Brammer and Crow, 2001). Red ring disease also affects other tropical palms including date (*Phoenix dactylifera*), Canary Island date (*Phoenix canariensis*) and Cuban royal (*Roystonea regia*); however, it is more associated with coconut and oil palms (Brammer and Crow, 2001). It is also estimated that 72 percent of palm weevils carried *B. cocphilus* (Esser and Meredith, 1987).

Three to 10-year-old coconut palms are highly susceptible and die within two months of infection. External symptoms are manifested in the leaves which wilt, turn yellow from the tip of the leaflets to the base of the rachis, then turn brown. Leaf symptoms usually start on the lower leaves and progress upwards (Griffith, 1987). The major symptoms, however, can be seen from a transverse section of the trunk of the infected tree, which is a band of discoloured tissue within the cortex, giving the characteristic red ring. Symptoms are also seen on the roots and petioles (Griffith, 1987).

Several methods have been used to manage *R. palmarum* and hence red ring disease. The use of chemicals against the palm weevil has not been successful (Hagley, 1963). Cultural methods by removal of diseased trees with aboricides or cutting and burning eliminate the inoculum as well as the host (Griffith, 1987).

In Mexico, the incidence of red ring disease declined from 10.0 percent to 1.0 percent when *R. palmarium* was controlled (University of California, Denver, Department of Nematology, 2002). The effect of trapping *R. palmarum* drastically reduced the incidence of red ring disease in Brazil (Chinchilla, 1991.) (Denise Navia, *personal communication*). Trapping captures adults and there is a decline in future generations of *R. palmarum*. Griffith (1987) recommended a trapping system using guard baskets with fresh tissue from diseased palms sprayed with a 0.1 percent methomyl solution to trap the palm weevil. Other trapping systems have been tried in Trinidad with inconclusive results (Cooper *et al.*, 2000). Servicing these traps was cumbersome since they required diseased tissue as bait.

More recently mass trapping using the synthetic aggregation pheromone Rhynchophorol (Rhyncholure®) together with sugarcane baits have been successful in Costa Rica in reducing population of *R. palmarum* and consequently reducing the incidence of red ring disease (Gibbin-Davis *et al.*, 1995; Oehlsachlager *et al.*, 1995).

The objective of this study was to examine the efficacy of using baited traps with Rhyncholure® in reducing populations of *R. palmarum* in small holdings of 1-2 hectres. The outcome of which will inform on executing longer term trials for management of red ring disease.

MATERIALS AND METHODS

Four small coconut farms comprising of 1.0 hectare each with approximately 200 young trees (less than 10-year old) were selected for the trial. These farms were located approximately 10 kilometres apart at Kelly, Centeno, Valencia and Carlsen Field (Appendix I).

Each trap was made with a 4-litre discarded oil container. Two vents were made on the broad sides of each container to allow for entry of the insect. Four pieces of sugarcane about 15 cm. long were halved longitudinally and placed at the bottom of each container and 5.0 g carbaryl insecticide was applied over the sugar cane bait. The lure was hung from the top of the container by a 15-cm long piece of wire.

At each location, one trap was tied to a coconut tree in the middle of the field, about 1.5 m high, on a petiole close to the trunk. The traps were examined weekly for 16 weeks and the number of coconut palm weevils was recorded. The sugarcane bait and insecticide were changed biweekly.

RESULTS AND DISCUSSION

Over a 16-week period from September 2010 to December 2010 a total of 651 coconut palm weevils (*R. palmarum*) were captured at the four locations. The highest number (255) was captured at Centeno followed by Valencia (186), Carlsen Field (151) and Kelly (59). The highest number captured per trap per week was 61 which were observed on the fourth week at Centeno (Table 1).

Table 1. The number of coconut palm weevils collected from 6th September, 2010 to 20th September, 2010 at four (4) locations in Trinidad

Week	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Total	Mean
Valencia	45	24	16	26	3	0	16	36	12	8	0	0	0	0	0	0	186	11.62
Centeno	39	33	28	61	6	28	5	23	23	6	0	0	3	0	0	0	255	15.94
Kelly	9	11	0	2	10	15	2	2	1	3	4	0	0	0	0	0	59	3.69
Carlsen Field	13	5	5	5	12	26	8	10	4	2	1	12	18	8	12	10	151	9.44
Mean	26.5	18.3	12.3	23.5	7.75	17.3	7.75	17.8	10	4.75	1.25	3	5.25	2	3	2.5	651	*10.17

* s.d. (±) 8.14

The mean number of coconut palm weevil captured was 10.17 (± 8.14) per trap per week. In Malaysia, a mean of 8.65 (± 7.26) weevils per trap per week was captured on oil palms over a 16-week period (Oehlschlager *et al.*, 1992). After the ninth week there was a drastic reduction in weekly captures per trap which could be attributed to reduction in populations of *R. palmarum* and /or depletion of liquid pheromone from the lure. Oehlschlager *et al.*, (1992) reported that the lure releases pheromone for 3 to 4 months after which time it should be changed.

The mean population increased after changing the bait on the third, fifth and seventh week (Figure 1). The decrease during the other weeks may be due to a decrease in plant odors (sugar cane bait) which are needed for attracting the insect, since the pheromone by itself is only capable of attracting palm weevils to a limited distance (Oehlschlager *et al.*, 1993).

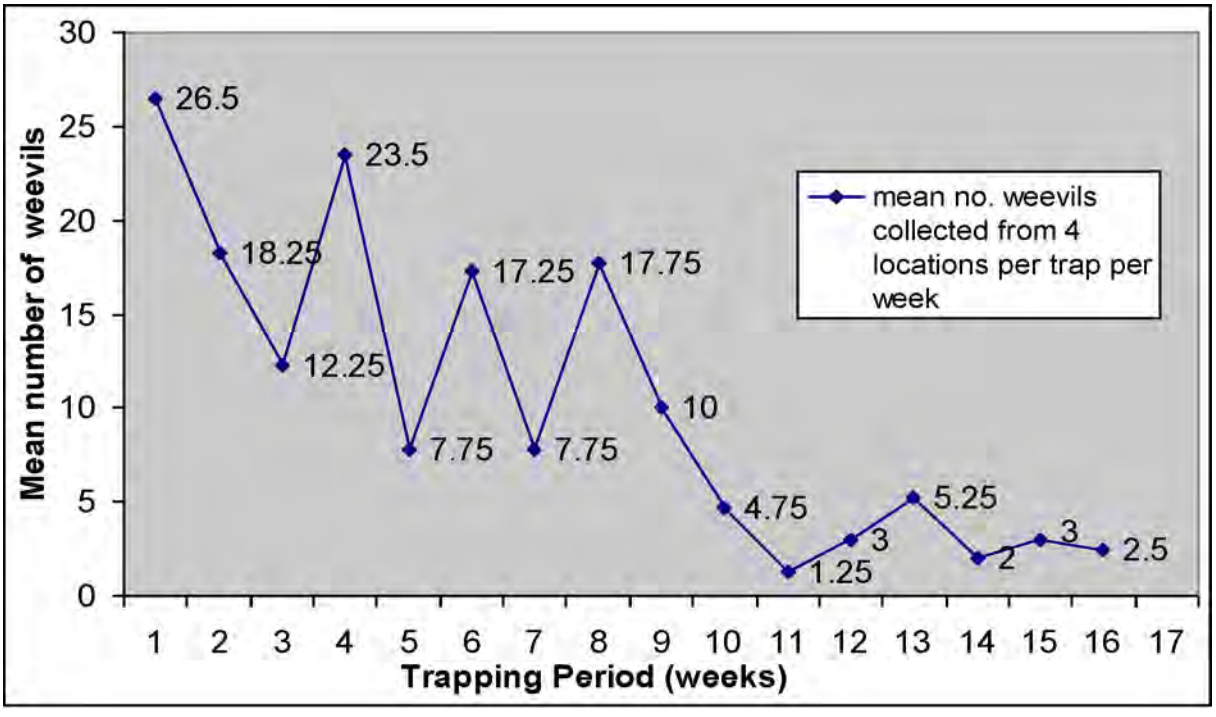

Figure 1. The mean number of coconut palm weevils collected at four (4) locations duration a 16 week period.

The results demonstrate that the trapping system using the lure, sugarcane bait and carbaryl was effective in capturing *R. palmarum* and thus reduce its population in the environment.

Based on the data gathered, traps may become more effective if sugarcane bait is changed weekly instead of biweekly, which is consistent with investigations by Oehlschlager *et al.* (1992). Long term trials can now be established to manage *R. palmarum* and in so doing manage the spread of *Busaphelenclus cocophilus*, the causal organism of red ring disease, since reducing the population of *R. palmarum* is highly recommended as a strategy for lowering the incidence of red ring disease (Griffith, 1987).

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Appendix I. The location of trial sites at Kelly, Centeno, Valencia and Carlsen Field, Trinidad, 2010

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INVENTAIRE DE L'ENTOMOFAUNE AUXILIAIRE DANS DIFFÉRENTES CULTURES AGRICOLES À LA MARTINIQUE

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RÉSUMÉ: Le plan ECOPHYTODOM reprend pour la Martinique l'objectif national de réduire de 50% les pesticides utilisés d'ici 2018 et le recours à des méthodes de luttes alternatives à la lutte chimique. Cependant, le manque de connaissances de la faune locale limite la mise en place de stratégies de lutte biologique. Un inventaire de l'entomofaune auxiliaire a donc été mis en place dans différentes cultures martiniquaises depuis 2010 afin d'obtenir des informations sur les possibilités de ce type de lutte sur l'île. Les prospections ont eu lieu sur des parcelles fruitières (bananes, agrumes, goyaves) et maraîchères (melons, concombres, tomates, choux pommés, laitues). De nombreux insectes capturés semblent prometteurs pour mener une lutte biologique contre les ravageurs des cultures. Les Miridae Anthocoridae, Reduviidae (Heteroptera), les Coccinellidae (Coleoptera), les Syrphidae (Diptera), les Aeolothripidae (Thysanoptera) et les Chrysopidae (Neuroptera), qui sont des organismes entomophages, mais aussi des Hyménoptères parasitoïdes (Braconidae, Aphelinidae, Eulophidae…) pourraient permettre un contrôle de différents ravageurs tels que les pucerons, les cochenilles ou les aleurodes. Cet inventaire a permis de montrer qu'il existe de réelles possibilités de lutte biologique à la Martinique, mais une grande partie des espèces restent mal connues. Des recherches supplémentaires sont alors nécessaires pour affiner les caractéristiques écologiques de chaque espèce: leur régime alimentaire, leur impact réel sur les ravageurs, leurs habitats préférentiels, etc. Ces informations permettraient d'identifier les mesures favorables à cette entomofaune utile et de sélectionner les espèces les plus intéressantes dans un objectif de lutte biologique.

Mots clefs: Martinique, lutte biologique, entomologie, prédateur, parasitoïde, auxiliaire, arboriculture, maraîchage

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ROOT EXUDATE OF *CROTALARIA* SPP. FOR THE CONTROL OF PHYTOPARASITIC NEMATODES IN BANANA CROPPING SYSTEMS

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ABSTRACT: In the promotion framework of alternative low input cropping systems, research on the introduction of cover crops having the ability to reduce the use of pesticides and nitrate fertilizers is widely promoted. This approach is applied for the development of a sustainable banana production in the French West Indies, where practices in intensive monoculture generate critical environmental problems i.e crisis of chlordecone, effect of nematicides and toxic nitrate fertilizers on the food webs (ground, fresh waters and lagoons). One of the main alternatives to the use of these chemicals is the resort in rotation or in mixed cropping systems of nitrogen fixing service plants and/or with nematode regulation properties (*Radopholus* spp., *Pratylenchus* spp., *Meloidogyne* spp.), e.g. allelopathy in banana crops. Among the candidate species, *Crotalaria* spp. has been widely studied (see the review of Wang et al., 2002) because of their aptitude to fix atmospheric nitrogen and their ability to control nematodes in cropping systems. Although the allelopathic properties of root exudates in such processes have been attested by many authors, their mechanisms are not still properly understood today. The aim of this program is the promotion of alternative management for parasitic nematodes, respectful to the environment. This research program seeks to answer agronomic and environmental challenges. Its originality lies in the understanding of the biochemical determinism of crotalaria root exudates in relation to the biotic and abiotic properties of the soil substrate. Practically, experiments in controlled conditions are presented, where we impose i) different biotic conditions –i.e. presence or not of nematodes combined with the presence or not of rhizo-bacteria and mycorhizes-, ii) different abiotic conditions –i.e. natural soil substrate vs. neutral substrate. Results indicate that environmental conditions can affect notably the biochemical compositions of root exudates and the ability of crotalaria to regulate the populations of parasitic nematodes. This background is essential to define management bases for the optimization of allelopathic properties of service crops.

Keyswords: allelopathy, crotalaria, nematodes, root exudates, symbiots

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POPULATION DYNAMICS OF *RAOIELLA INDICA* HIRST (ACARI: TENUIPALPIDAE) AND THE NATURAL ENEMY *AMBLYSEIUS LARGOENSIS* (ACARI: PHYTOSEIIDAE) IN TRINIDAD

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ABSTRACT: The red palm mite, *Raoiella indica* Hirst (Acari**:** Tenuipalpidae) was discovered in March 2006 in Trinidad. Islandwide surveys conducted in 2007 confirmed widespread distribution in both Trinidad and Tobago. The main host was the coconut palm, *Cocos nucifera* L. while other palms, *Musa* spp., *Heliconia* spp. and several species of the family Zingiberaceae were also affected. Natural enemies included lacewings (*Chrysopa* sp.), ladybird beetles (Coccinellidae), predatory thrips (Thysanoptera) and predatory mites in the Phytoseiidae and Cunaxidae families with *Amblyseius largoensis* (Acari: Phytoseiidae) being predominant. The objectives of the study were therefore to assess the impact of *A. largoensis* on population of *R. indica* over time while also looking at the effects of abiotic factors. During 2008 and 2009 population studies were conducted at four locations which were 'hot spots' for *R. indica* in Trinidad. Twenty coconut trees less than ten years old were selected at each site and during each monthly visit two trees were randomly selected for sampling. Six leaflets were taken from the 9th leaf of each tree and carried to the laboratory for processing. Data on leaf area were recorded and counts were made of *R. indica* and *A. largoensis* under the binocular microscope, magnification x 400. The presence of other natural enemies was also recorded and rainfall data was obtained from the Meteorological Office and San Quintin Estate. The data was analyzed using GenStat® (11th Edition) Statistical Software Package. For both years there were significant differences ($p < 0.05$) for *R. indica* between locations. Red palm mite population coincided with that of *A. largoensis* which appears to be a minor pest suppressant. Rainfall had a direct relationship with *R. indica*; population levels of *R. indica* increased during low rainfall and fluctuated to low levels during high rainfall. The findings of this study may therefore inform strategies in a pest management programme.

Keywords: Red palm mite, *Raoiella indica*, *Amblyseius largoensis*, natural enemy, population dynamics

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FAO SUPPORT TO THE MANAGEMENT OF CITRUS GREENING DISEASE IN JAMAICA

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ABSTRACT: The citrus industry is very important to Jamaica's economy in terms of employment, exports and local consumption, with an estimated value of J$4 billion. Local citrus production has declined significantly over the last six years spurred by the effects of the Citrus tristeza virus (CTV), adverse weather conditions, poor management, ageing farmers and declining acreages, raising concerns of the negative impact of the decline on food security and the local economy. Since October 2009, the industry has faced a new threat when the presence of the Citrus Huanglongbing (HLB) or Greening Disease was confirmed. An island-wide survey in February 2010 revealed that HLB was present in all major citrus producing areas with the exception of the parish of Manchester. Further spread of the pathogen (*Liberibacter asiaticus*) is expected given the island wide distribution and abundance of the vector, the citrus psyllid, *Diaphorina citri* (Kuwayama). In addition, *Murraya paniculata* (L) Jack, a known host plant for the psyllid and recently reported a host for the HLB, is also extensively planted in the Jamaican landscape. The Government of Jamaica approached the FAO for technical support, as a result of which the two-year Project TCP/JAM/3302 "*Assistance to manage Citrus Greening in Jamaica*" was approved in October 2010. The Project aims to support the national effort to effectively manage the HLB, particularly in the small farms, through coordinated protection, mitigation and resuscitation strategies, resulting in sustained productivity of orchards. This is underpinned by a multi-pronged approach with five diverse components: Development of (1) an area-wide strategy for HLB management, (2) physical infrastructure, (3) capacity to produce disease-free nursery material, (4) diagnostic and detection capability, and (5) a public education and awareness campaign. Activities under project began in November 2010 and progress to date is presented in this paper. HLB has serious implications for the citrus industry in the Caribbean. The management strategies developed under the FAO Project in Jamaica will provide a model that other countries in the region can follow in the event that their citrus becomes infected by the HLB.

Keywords**:** Citrus Greening, Huanglongbing, Jamaica, FAO Technical Support

INTRODUCTION

The citrus industry is very important to Jamaica's economy in terms of employment, exports and local consumption, with an estimated total value of approximately J$4 billion. Ninety-six percent (96%) of total citrus production is utilized locally for the fresh fruit market or in processing, while 4% of citrus is exported. The citrus industry is also very important to Jamaica's rural economy as it is an integrated industry from on-farm production to distribution of processed products. On-farm employment is estimated at 6,000, out of which are self-employed small farmers. Other aspects of the sector (including on-farm operations, processing, packaging plant, wholesale and retail trades) account for about 19,500 jobs in rural areas. Total land area under citrus production is estimated at 9,000 hectares (ha), with about 5,000 small farmers, 260

medium farmers and 11 large farmers comprising the industry. The varieties grown are sweet-orange, tangelo, tangerine, grapefruit, ortanique and lime.

Local citrus production has declined in recent years, from 140,196 tonnes in 2003 to 122,291 tonnes in 2008, the contributing factors being the Citrus Tristeza Virus (CTV), ageing farmers, poor management practices, declining acreages and adverse weather conditions. In October 2009, the dreaded Citrus huanglongbing (HLB) / greening disease, caused by the pathogen *Liberibacter asiaticus*, was confirmed in commercial groves in the parish of St. Catherine and subsequently throughout the island. This rapid spread was expected given the wide distribution and abundance of the vector, the citrus psyllid, *Diaphorina citri* (Kuwayama), and extensive plantings of *Murraya paniculata* (L) Jack, a known host plant of both the psyllid and the HLB.

This was not the first time that the citrus industry in Jamaica faced a serious pest problem. In the 1990s, CTV became a major threat to the industry with the introduction of the aphid vector. A technical assistance project, supported by the Food and Agriculture Organization of the United Nations (FAO) resulted in the establishment of a mandatory citrus certification programme (Vapnek, 2009). In 2000, the Government of Jamaica, with assistance from the Interamerican Development Bank (IDB), provided loans to farmers under a citrus replanting programme. Still recovering from the impact of CTV, the citrus industry is now faced with the most debilitating of citrus diseases, which could adversely affect the rural communities in which the field and processing facilities are located.

In order to mitigate the impact of the disease on an already-ailing industry, it was considered imperative that actions be taken urgently to implement a cost-effective and appropriate area-wide management (AWM) programme. The Government of Jamaica was challenged by limited technical and human resource capacity with the necessary experience to design and implement an AWM strategy for citrus greening. In light of these constraints, technical assistance was requested from the FAO to develop the AWM strategy.

The two-year Project TCP/JAM/3302 "*Assistance to manage Citrus Greening in Jamaica*" was approved in October 2010. The Project aimed to support the national effort to effectively manage the HLB, particularly in the small farms, through coordinated protection, mitigation and resuscitation strategies, resulting in sustained productivity of orchards. This was underpinned by a multi-pronged approach with five diverse components: Development of (1) an AWM strategy for HLB, (2) physical infrastructure, (3) capacity to produce disease-free nursery material, (4) diagnostic and detection capability and (5) a public education and awareness campaign.

Activities under the project began in November 2010 with the development of a work plan. This paper provides an overview of the project management structure and progress on each of the five components to the end of June 2011, followed by a regional perspective on the HLB problem.

Project Management and Implementation

The Ministry of Agriculture and Fisheries (MoAF), the executing agency, appointed a Project Coordinator (PC) from within the MoAF to coordinate the activities. Support and guidance for the management of the project is provided by a Project Steering Committee (PSC), comprising of the major implementation partners. The PSC is chaired by the Chief Technical Officer, MoAF, with representation from the following agencies: FAO, Division of Planning, Policy & Development (MoAF), Director and Head R&D Division (MoAF), Senior Research Director (MoAF), Plant Quarantine (MoAF), Jamaica Citrus Protection Agency (JCPA), Rural Agricultural Development Authority (RADA), and Jamaica Citrus Growers' Association (CGA). The PSC meets every three months.

The Technical Working Group (TWG), chaired by the PC, undertakes planning and implementation of activities and reports to the PSC. It is comprised of technical staff from the Plant Protection Research Unit (MoAF), the Plant Quarantine Branch (MoAF) and JCPA. The TWG meets 2-4 times a month and liaises with other groups involved in implementation such as CGA and RADA extension.

Consultancies in three areas are being provided by regional / international experts for developing these critical components: Area-wide strategy, Nursery Production and Shoot-tip grafting. A National consultant has also been contracted to provide support to the international / regional consultants.

In addition, FAO entered into a Letter of Agreement with the University of the West Indies (UWI), Mona Campus, to plan and implement a training programme in diagnosis and detection of HLB

The FAO Representation office in Jamaica provides administrative and logistical support to the project, whereas the Plant Production and Protection Officer, based at the FAO Sub-Regional Office in Barbados, provides backstopping as the Lead Technical Officer for the project.

Component 1: Area-wide Strategy for HLB Management

The development of the AWM strategy for HLB was considered to be one of the key components of the project. Two expert Plant Protection consultants were contracted to develop the AWM Strategy based on the following Terms of Reference:

- Review citri-culture, disease and vector distribution in Jamaica
- Assess current management options available and their suitability in the Jamaican context
- Determine implementation mechanisms for the options identified as being feasible
- Undertake stakeholder consultations: formulation & review of strategy / management programme.

The consultants undertook the first of three planned Missions for three weeks during May-June 2011. Based on field visits and consultations with stakeholders of the citrus industry and following a detailed assessment of the situation, the consultants made the following recommendations:

a. The HLB management had to include aspects of sanitation, i.e. propagation and availability of disease-free material for replanting. In tandem with a revision of nursery

regulations, existing nurseries needed to be modified and the prototype facilities for plant propagation (including bud wood) and testing provided for under the project needed to be established as soon as possible. The certification process needed to be visible, transparent and amenable to compliance. Investment by the nursery producers was therefore needed in order to establish adequately-designed screen-houses, preferably outside the production areas. These would produce certified nursery plants that would be used for commercial replanting.

b. It was necessary to ensure effective psyllid control to reduce the spread of the HLB. This strategy would involve using chemical control in commercial and backyard plantings and biological control for inaccessible areas / hedges of *Murraya* in residential areas close to commercial citrus. Simultaneous, improved production practices were necessary, specifically the use of foliar nutrients to relieve tree stress, improve growth/yield and prolong the productive life of the trees.

c. Critical to the success of implementation of the AWM strategy was the establishment of regional management clusters. There was a need for revisiting stakeholder roles and improved collaboration among the various agencies involved in the programme. There was also a suggestion for a restructuring of the Citrus Growers' Association (CGA) to facilitate market redesign. And last but not least, an island-wide awareness programme on the AWM strategy to foster public buy-in.

Component 2: Infrastructure

Support is being provided under the project to develop infrastructure that is necessary to meet the urgent need of providing clean planting material to farmers. In this regard, four activities are being implemented:

- Design and erect structures for bud wood & nursery protection to demonstrate production of quality nursery material
- Establish a screen house for bud wood production
- Establish insect proof demonstration / model nursery
- Train nursery operators in nursery management protocols

Work is ongoing on the design for a demonstration screen house for bud wood production as well as for the insect proof demonstration / model nursery. A consultant has been identified to undertake training in the production and multiplication of bud wood material and will be contracted in due course (pending construction of structures).

Component 3. Production of Disease-Free Materials

The production of disease-free materials for distribution to farmers is another key component of the project. Towards this end, two activities are being undertaken:

- Upgrade of the Plant Protection Laboratory to support the production of pathogen-free bud-wood material for distribution to nursery producers
- Train five Officers from public and private sector institutions [Scientific Research Council, Research & Development Division (MAAF), Trade Winds Ltd] in micro-grafting technique

The process has begun to procure materials and equipment for the upgrade of the Plant Protection Laboratory that will support production of pathogen-free bud-wood material. The training of five Technical Officers in micro-grafting technique is to be undertaken once the laboratory upgrade has been completed. As a result, the hiring of the consultant to undertake training will be contracted in due course.

Component 4. Diagnostic and Detection Capability

Since the diagnosis of HLB by a private laboratory in Jamaica is expensive, the project aims to develop national capacity through the training of six officers in HLB diagnostic and detection capability, with emphasis on molecular techniques. In addition, the project provides for an upgrade of the Plant Protection Laboratory, including installation of the necessary equipment to enable HLB diagnostic support for the citrus industry.

In this regard, the University of the West Indies (Mona Campus) has been contracted to:

- Design an appropriate program and train six officers
- Prepare a Manual on Techniques for HLB Detection & Diagnosis (based on training)
- Provide technical assistance in upgrade of MOAF laboratory to carry out PCR diagnostic work
- Conduct three separate assessments to ensure / verify that persons trained carry out tests accurately

The civil works for upgrade Plant Protection Laboratory (to support HLB diagnosis / detection) is currently underway.

Component 5. Public Awareness and Education Campaign

The TWG is in the process of collating a number of training materials into a Manual. Support from the Information Unit of the MoAF is being sought in the production information pamphlets and posters on symptomology as well as a training video on HLB and its management.

CONCLUSIONS

Despite a number of challenges, mainly the timely implementation of a complex work plan, the project is more or less on schedule. It is anticipated that most of the objectives and outcomes will be realized by the time the project comes to an end.

Regional Perspective

HLB is the most destructive disease of citrus; therefore, it has serious implications for the citrus industry of the Western Hemisphere. The vector *D. citri* is native of Asia and was introduced in Brazil in the 1940s. However HLB was only detected in Brazil in 2004. The psyllid was reported from Florida and Guadeloupe in 1998 and HLB some years later. The psyllid and HLB are now widespread, occurring throughout Central America and in several countries of the Caribbean (Belize, the Bahamas, Cuba, Dominican Republic, Jamaica and Puerto Rico (Halbert and Núñez, 2004; Lopes, 2011).HLB has caused economic losses of the tune of millions of dollars around the world. In Brazil alone an estimated 10 million infected trees have been eliminated. In Mexico, the disease has been detected in 39% of the citrus producing states.

A hemispheric consultation was held at FAO's Regional Centre for Latin America and the Caribbean (RLC) from 20-23 Jun 2011. The objective of the consultation was to review the status of the disease, analyze case studies on its management and most importantly to generate a joint action plan to address this serious threat to citrus. The consultation brought together researchers, plant protection authorities and representatives of the citrus industry from throughout the region. A number of the infested countries —Brazil, Mexico and USA—shared experiences with countries of Central / South America and the Caribbean (Cuba, Dominican Republic, Grenada, Guadeloupe, Jamaica, St. Lucia and Trinidad & Tobago). Among the outcomes of the consultations is a Regional TCP for Central America that is set to begin shortly. The Caribbean countries present at the consultation recommended that surveys should be undertaken in those countries that have yet not reported the psyllid and HLB to determine status so that an early detection / response could be launched accordingly. The consultation also urged collaboration among countries in combating HLB and in particular continued information-sharing and networking. A major outcome of the consultation was that FAO was given the responsibility for developing a hemispheric strategy, and a regional TCP project is to be used for providing the necessary technical support.

Citrus is an important crop in all the countries of the Caribbean that would be negatively impacted if the psyllid and HLB are introduced. At this time, the major citrus producing countries (Jamaica, Belize, and Dominican Republic) are seriously affected by HLB. The status of both the psyllid and HLB in the countries of the Eastern Caribbean, as well as Barbados, Guyana, Suriname and Trinidad and Tobago is not known. It is necessary to determine if the psyllid and HLB is present in these countries so that the necessary measures could be put in place to manage both. It is anticipated that the management strategies developed under TCP/JM/3302 will provide a model that other countries in the region can follow in the event that their citrus becomes infected by the HLB.

ACKNOWLEDGEMENTS

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CURRENT RESEARCH AND EXPECTED PRACTICAL OUTCOMES FOR THE MANAGEMENT OF WHITE YAM (*DIOSCOREA ALATA*) ANTHRACNOSE

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ABSTRACT: Climatic changes are expected to bring a number of challenges to agriculture, among which the necessity to prevent the emergence, or to adapt to epidemic dynamics of pests and diseases. In this context, research needs to switch from disciplinary to interdisciplinary approaches and provide global tools to agriculture for successful, sustainable pest management. At the French National Institute for Agronomic Research based in Guadeloupe, researchers from different fields, from geneticians to social economists, are currently involved in a common program aimed at developing a sustainable, environmentally friendly, high performance agricultural systems based on white yam (*Dioscorea alata*). One of the two most important constraints to white yam production is anthracnose caused by the aerially dispersed fungus *Colletotrichum gloeosporioides*. In the past, measures to control this disease (by the use of host resistance and chemical pesticides) have lost their efficiency because the adaptive capabilities of the pathogen were not taken into account. We present our current research project, in which we try to better understand the interactions between the plant, the climatic variables at canopy level, and the pathogen, and use this knowledge to develop new strategies for crop protection. We studied the genetics of host resistance and developed a map of quantitative resistance traits, in order to help breeding for new resistant cultivars combining agronomical qualities and sustainable resistance. In order to hamper the pathogen's capabilities to take over resistances, we use mathematical modeling and experiments to study how microclimatic conditions at the canopy level can be modified by practices, providing conditions less favorable for dispersal, survival and multiplication of the fungus. Ultimately, we hope to promote a reasoned use of resistant varieties, and include new practices that can be adopted by yam growers in an environmentally and economically performing agricultural system.

Keywords: *Dioscorea alata*, anthracnose, *Colletotrichum gloeosporioides*, climatic conditions

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ECOFRIENDLY MANAGEMENT OF FRUIT ROT DISEASE CHILLI (*CAPSICUM ANNUUM* L.) CAUSED BY *COLLETOTRICHUM CAPSICI*

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ABSTRACT: Leaf extracts from eight plant species at a concentration of 10% were tested against fruit rot disease of chilli caused by *Colletotrichum capsici*. Extract form *Abrus precatorius, Allium cepa* and *Aegle marmelos* were effective in reducing the colony growth of the pathogen in vitro. Confirmation studies of *Collectotrichum capsici* was carried out by following dual culture technique and spore germination studies. The effective treatment was forwarded to pot culture and for field experiment. The pot culture was conducted to test the efficacy of the combined application of antagonists with plant products against the pathogen. The pot culture result revealed that spraying *Pseudomonas fluorescens* on 45th day after planting combined with spraying of extract *Abrus precatorius* (10%) on 75th DAP was effective in reducing dieback and fruit rot disease of chilli. The plant products and biocontrol agents which were effective in pot culture were tested under field conditions, which showed that the spraying of *Abrus precatorius* (10%) 45 DAP followed by *Pseudomonas fluorescens* (0.2%) spraying 75 DAP was effective in reducing fruit rot of chilli.

Keywords: Chilli, *Colletotrichum capsici, Pseudomonas fluorescens*

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MULTIPLEX-PCR IDENTIFICATION AND ANTIBIOTIC RESISTANCE OF *ENTEROCOCCUS* SPP. ISOLATED FROM CONTAMINATED RECREATIONAL WATERS NEAR FARM LANDS IN PUERTO RICO

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ABSTRACT: Enterococci are usually found in the gastrointestinal tract of a variety of organisms. They can also be found in a number of environments, probably through dissemination in animal excrements, cross-contamination and environmental persistence and runoff waters coming from farm lands. Enterococci have also been reported in raw and processed meats, as well as in fermented meats and dairy products. *Enterococcus faecium* and *E. faecalis* are the most common species among the *Enterococcus* genus and are often referred to as environmental and food contaminants. These microorganisms can survive for extended periods of time and grow in 6.5% NaCl and in the presence of 40% bile salts. Also, they can tolerate pH and temperature variations. *Enterococcus* spp. are a common cause of community-acquired and foodborne diseases. Moreover, recent published reports indicate that enterococci isolated from environmental and food samples can exhibit multiple antimicrobial resistance traits. In this work, we were able to identify the enterococci contaminants from recreational waters near farm lands using Multiplex-PCR. The species identified were *E. casseliflavus*, *E. faecalis*, *E. faecium*, *E. avium*, *E. gallinarum*, *E. durans* and *E. solitarius*. Antibiotic resistance studies are currently being performed for all isolates, testing the Minimal Inhibitory Concentration of each isolate using prepared plates for susceptibility testing with wells containing different antimicrobial agents. Results showed that there is a great variability of antibiotic resistance among the isolates. Even though vancomycin and tetracycline resistances are often exhibited by *Enterococcus* spp., this is not the case in our studies so far. Preliminarily, we have also seen different plasmid content in the isolates. This finding may indicate that the variability in antibiotic resistance among the isolates is possibly due to the presence of R-plasmids in some of them. This project is currently been supported by grants USDA-NIFA-2008-38422-19236 and NIH-MBRS-RISE 5R25-GM066250-05A1.

Keywords: *Enterococcus*, antibiotic resistance, Multiplex-PCR

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ORGANOCHLORINE PESTICIDE RESIDUES AND THE INCIDENCE OF BREAST AND PROSTATE CANCER IN BARBADOS

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ABSTRACT: Many organochlorine pesticides and organic pollutants are extremely persistent in the environment and human tissue with many having half-lives ranging from 7 to 25 years. During the decades from 1950s until the 1970s DDT, aldrin, chlordane, dieldrin, and endrin among others, were profusely and indiscriminately used in agriculture, and DDT in public health treatments against vectors of human and animal diseases. While these persistent organic pollutants were restricted and or banned in Barbados before the mid-1990s, stocks of endosulfan were still available in pesticide outlet stores in Barbados in 2002. There is a wealth of epidemiological information on the effects of these and other pesticide chemicals and their influence on breast and other cancer incidence. Suggested mechanisms of action include endocrine disruption, activation of the Aryl Hydrocarbon receptor, and possible subsequent mutation of the *ras* protein in a manner similar to that caused by nitrosamine carcinogenesis. Incidences of both breast and prostrate cancer in Barbados are among the highest in the Caribbean and rank closely behind the United States. In comparison to the United States, the breast cancer mortality rate in Barbados is marginally higher while that of prostate cancer is almost twice as high. Preliminary analysis suggests that the age group with the highest incidences of breast and prostate cancer comprises individuals from the time period when these banned organochlorine pesticides were actively used. This paper investigates the scientific evidence of the most notably carcinogenic organochlorines used in Barbados in relation to breast and prostate cancer incidences.

Keywords**:** Cancer, oncogene, tumour suppressor gene, organochlorine pesticides, persistent organic pollutants

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REVITALIZING SWEET POTATO CULTURES FOLLOWING ONE YEAR ON LOW SUCROSE MEDIUM

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ABSTRACT: Clean virus-free sweet potato plants can be maintained for a year with minimal growth on the same tissue culture medium if it contains low levels of sucrose, from 0.1 to 0.3% sucrose as previously reported. The objective of this study was to evaluate micropropagated sweet potatoes following one year on low sucrose medium when transferred to fresh 3% sucrose medium to revitalize growth. Nodal segments from one year old in vitro cultures on low sucrose were transferred to a standard 3% sucrose MS medium. Data was recorded over time for shoot length, number of leaves and roots. Results indicated no significant difference between developing plant for plant growth once the nodal segments are placed on 3% sucrose medium. Long-term maintenance for a year on low sucrose medium does not influence growth after transfer to fresh medium. Sweet potatoes can be successfully maintained for a year on low sucrose medium to reduce growth and revitalized on fresh medium with 3% sucrose to regain active growth for micropropagation. This research was funded through the VI Dept. of Agriculture Specialty Crops Block Grant and USDA-NIFA.

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CHEMICAL PROFILING VOLATILE FLAVOR CONSTITUENTS OF COCOA

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ABSTRACT: Trinidad and Tobago produces fine/flavour cocoa which possesses unique flavor attributes and fetches premium prices on the world market. This study was undertaken to develop a database of flavour components of selected Trinitario cocoa cultivars. Solid Phase Microextraction (SPME) is a solventless extraction technique, which in combination with gas chromatography has been used extensively for analysis of volatile food flavours. Using this technique, a method was developed to generate volatile flavour profiles for roasted cocoa liquors from beans of Imperial College Selections of Trinitario cacao. These profiles were then compared with the results of sensory analysis of the same samples by a trained panel to establish correlations between chemical and sensory analysis. Correlations have been found between 2,3,5-trimethylpyrazine and the intensity of cocoa flavor; propyl acetate and the intensity of fruity flavor; and linalool and the intensity of floral flavour experienced by a sensory panel. This technique has also proven effective in optimizing cocoa post-harvest processing parameters, including fermentation time for which a period of seven days was identified as optimal for desired flavour development.

Keywords: cocoa, flavor, SPME

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EVALUATION OF COMMONLY USED SINGLE EXTRACTION METHODS FOR THE PREDICTION OF BIOAVAILABILITY OF CADMIUM (CD) IN SOIL TO CACAO (*THEOBROMA CACAO* L.)

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ABSTRACT: Within recent years, increasing emphasis has been placed on the contamination of cocoa beans with heavy metals, particularly Cadmium (Cd). The enforcement of proposed food safety legislation for such contaminants in cocoa can have detrimental effects on cocoa suppliers who may not be able to meet standards set by regulatory authorities. Understanding the processes by which the cacao plant accumulates Cd from soils plays a crucial role in the development of strategies to minimize Cd uptake from soils. The prediction of bioavailable metals has been shown to be a reliable indicator for the estimation of bioaccumulation pathways in plants, soil contamination and metal. Several extraction methods have been used to predict the bioavailability of metals in soils but have not been previously reported for use on cacao. In this study, the extractants Diethylene Triamine Pentaacetic acid (DTPA), Ammonium Bicarbonate- Diethylene Triamine Pentaacetic Acid (AB-DTPA), Ethylene Diamine Tetraacetic acid (EDTA), Calcium Chloride ($CaCl_2$) and Ammonium Nitrate (NH_4NO_3) were used to evaluate the bioavailability of Cd in soil to cacao. Among the five extractants, the extractable Cd generally followed the order: EDTA>DTPA>AB-DTPA>$CaCl_2$>NH_4NO_3. Correlation analysis between the extractable Cd in soil and total Cd content of cacao tissues (nibs, shells, leaves and pods) was done to evaluate the best extractant to represent bioavailable Cd. The Cd extracted by $CaCl_2$ and NH_4NO_3 were significantly correlated with most of the tissues, but their Pearson correlation coefficients were weak. In contrast, extractants AB-DTPA, DTPA and EDTA showed stronger, significant correlations to the Cd concentration in all four tissues. Overall, regression analysis showed that DTPA was most efficient in the prediction of bioavailable Cd in soil for cacao and is being used to develop cost-effective preventive soil treatments to reduce bioavailable Cd to cacao plants.

Keywords: Bioavailability, cadmium, cacao, extractants

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PHENOLIC CONTENT AND ANTIOXIDANT CAPACITY OF COCOA BEANS OF 30 IMPERIAL COLLEGE SELECTION CLONES

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ABSTRACT: Cocoa (*Theobroma cacao* L.) is an economically important crop in Africa, the Far East, the Caribbean and Latin America. Many health benefits, especially in the reduction of heart diseases and hypertension, have been attributed to the consumption of dark chocolates, due to their high antioxidant capacities. It has been reported that cocoa beans and its products contain very high levels of polyphenols and other antioxidants compared to other foods; the reliable measurements of these properties have been prime objectives of our research. One of the most common methods for the determination of total phenolic content in foods is the Folin-Ciocalteu (F-C) method, while several methods can be used for antioxidant capacities, the most common being the Trolox equivalent (TE) antioxidant capacity or TEAC assay. Both of these methods were calibrated and used to evaluate the relationship between the phenolic contents and corresponding antioxidant capacities of fermented and sun-dried cocoa beans of 30 Imperial College Selection clones of the Cocoa Research Unit' genebank in East Trinidad. Total polyphenol contents ranged from 68.64 to 169.11 mg/g, while the extractable water-soluble antioxidant capacities ranged from 15 to 127 mmol TE/g; higher than those reported for cocoa products in published literature. However, the correlations between polyphenol contents and the corresponding anti-oxidant values were weak, possibly because of other non-phenolic compounds with anti-oxidant properties. These findings may be useful in the future production of cacao cultivars with desirable sensory properties and anti-oxidant characters.

Keywords: Cocoa beans, antioxidant capacity, scavenging activity, phenolic content, TEAC assay

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A FOOD SAFETY APPROACH TOWARDS THE MINIMIZATION OF OCHRATOXIN A IN COCOA BEANS IN TRINIDAD AND TOBAGO

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ABSTRACT: Mycotoxins are toxic substances produced on agricultural commodities by many fungi, particularly *Aspergillus, Penicillium* and *Fusarium* and often result in severe losses of the commodity during post-harvest processing and storage. Cocoa is being promoted as a replacement crop for bananas, following the removal of preferential treatment for Caribbean bananas by the European Union, although it is a well-established crop in Trinidad & Tobago. However, strict regulatory levels for Ochratoxin A (OTA) in cocoa beans and cocoa products have been proposed by the EU, necessitating the development of a reliable test method for OTA in cocoa beans by our laboratory. Chemical analyses using this method, coupled with mycological evaluations, were carried out on beans obtained at different points of the cocoa production chain. Several factors have been identified, which affect the presence of OTA in cocoa beans and local chocolates. Our results showed a higher incidence of Ochratoxin contamination in 2007, which was the wettest year, as compared with those in 2006, 2009 and 2010. Possibly toxigenic *Aspergillus tamarii*, *A. niger* and *A. fumigatus* were isolated from fermented and dried cocoa beans sampled during processing and storage. Critical control points were also identified along the processing chain, including harvesting, processing and storage and are currently being used to develop a HACCP-based system for cocoa production in Trinidad and Tobago, and may be similarly applied in the wider Caribbean.

Keywords: Cocoa, mycotoxins, mycoflora, HACCP

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EXTRACTION AND CHROMATOGRAPHIC SEPARATION OF ANTHOCYANIN IN SORREL

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ABSTRACT: Sorrel is important to the culture of the Virgin Islands for its use in making a healthy red holiday beverage. Fourteen sorrel cultivars obtained from the USDA Germplasm Repository and locally in the Caribbean have been evaluated at the University of the Virgin Islands. The calyx of sorrel varies in the intensity of redness between cultivars. The purpose of this research was to determine the concentration of the red anthocyanin pigment in the calyxes from fourteen sorrel cultivars and use paper chromatography to resolve the pigments. Sorrel calyxes were ground 1/1 (w/v) in either ethanol or water. Following centrifugation, the solute was read in a spectrophotometer at 535 nm. Ethanol was found to be better for extracting the anthocyanin pigment. Paper chromatography, utilizing polar and nonpolar solvents, was used to separate the red anthocyanin pigmented compounds. Ethanol was the most efficient solvent for both extracting the red anthocyanin pigment and resolving the compound with paper chromatography. This research was funded through the VI Dept. of Agriculture Specialty Crops Block Grant and USDA-NIFA- Resident Instruction in Insular Areas (Grant #2008-34816-20016).

Keywords: *Hibiscus sabdariffa*, Roselle, flavonoids

INTRODUCTION

Sorrel is grown for its fleshy tart calyxes used primarily during the holiday season to make a healthy drink that is better than cranberry juice (Appell, 2003; George and Morris, 1984). Multiple varieties of sorrel exist with a range of color from white to dark crimson (Fig. 1). Anthocyanin is the primary pigment that is responsible for the red color and it has antioxidant properties (Marco et al., 2005). The purpose of this research was to quantitate the level of anthocyanin from two extraction solvents and use paper chromatography to separate the pigmented compounds.

MATERIALS AND METHODS

Sorrel calyxes from 14 varieties were harvested at maturity and ten average fruits from each variety were selected. The ten fruit were each divided into two groups of five by variety, cleaned to obtain the calyxes, and the mass was recorded. Each set of calyxes was ground w/v with either 70% ethanol or distilled water in a mortar and pestle. The solution was collected in a 50 ml conical tube and centrifuged 15 minutes at 12,000xg. The supernatant was collected and transferred to a 15 ml conical tube and centrifuged 15 min at 12,000xg. Following the second centrifugation, 1 ml of solute was dispensed into 1 cm cuvette and read in a spectrophotometer at 535 nm. The spectrophotometer was zeroed using either 70% ethanol or water prior to running the samples. Samples registering over 3.0 were diluted 3x or 10x until the reading was within the range.

To determine the pigment composition of the sorrel varieties, 20 uL of the solute was placed 2 cm from the base of 2 x 15cm strip of filter paper. The strips were labeled and placed in a 25 mm test tube containing 3ml 70% ethanol, 95% ethanol, acetone or chloroform as the solvent and ran 12 hours in a fume hood. Sample strips were dried and bands counted.

RESULTS AND DISCUSSION

A spectrophotometric scan from 280-800 nm was run on sorrel solute to determine the point of maximum absorption which was determined to be 535 nm. The solvent found to extract the greatest amount of anthocyanin from the sorrel was 70% ethanol, which was better than water. The day neutral and dark sorrel had the highest concentration of anthocyanins (Fig. 2), concentrations that were at least three times greater than those in the other red varieties. The white, pink, bronze and striped sorrel had low concentrations of anthocyanin (Fig. 2).

During the paper chromatography, both acetone and chloroform had a rapid solvent front. Chloroform, being a nonpolar solvent, didn't move any anthocyanin from the starting sample point indicating that anthocyanin is a polar molecule (Fig. 3). In the acetone, a purplish area remained at and slightly above the sample starting point but ended with a lighter and more diffuse final band (Fig. 3). The purplish area indicates that the acetone may have caused a reaction to precipitate some of the anthocyanin compound so they didn't move to the top with the solvent front. When either ethanol or water was used, all the pigmented anthocyanins migrated up from the sample starting point (Fig. 3). Both water and ethanol are highly polar molecules.

A close examination of the final solvent end point showed four distinct bands formed, indicating that the anthocyanin is made up of multiple forms of the red polar pigment (Fig. 4). The four bands of color may indicate the two main anthocyanins which are delphinidin and cyannidin, possibly with lower levels of their glucosides (Dominiquez-Lopez et al., 2008). Future studies are planned to more accurately quantitate and resolve the compounds using a gas chromatograph and/or high pressure liquid chromatography as has been done by Marco et al. (2005).

CONCLUSION

All 14 varieties of sorrel contained some anthocyanin, even if it was a trace amount as found in the white and light forms. The day neutral and dark varieties had the highest levels of anthocyanin. Ethanol was better at extracting the anthocyanin pigments from calyxes than water. Ethanol and water, being stronger polar molecules, were better solvents than acetone or the nonpolar chloroform for use in paper chromatography to separate the anthocyanin pigments.

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Figure 1. Multiple varieties of sorrel indicating variable pigmentation levels.

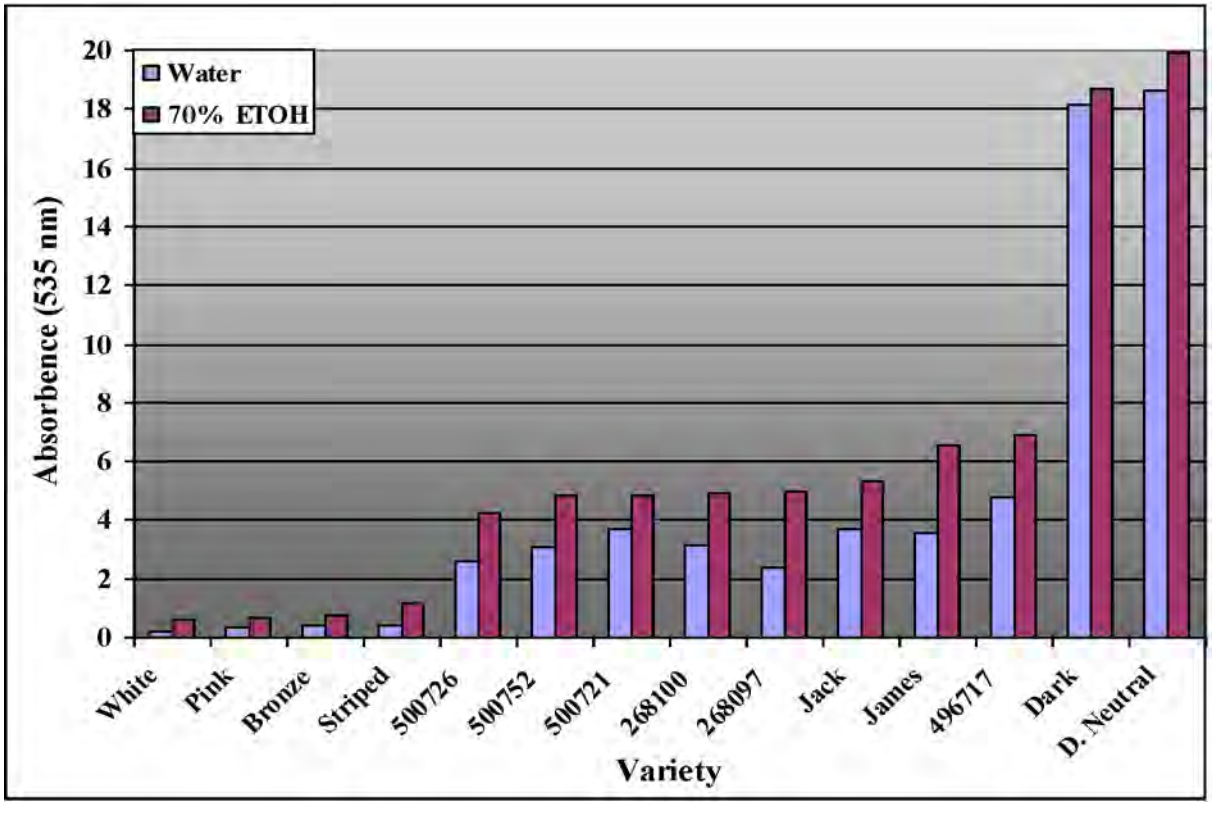
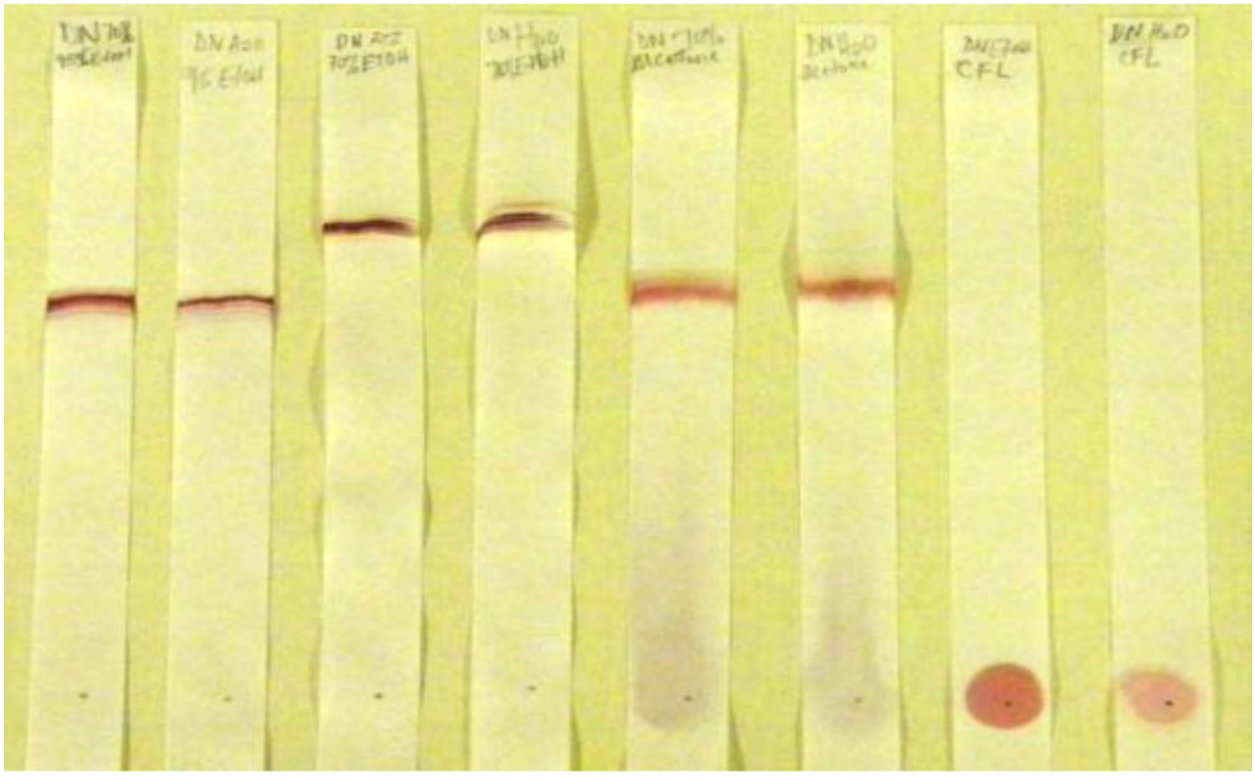


Figure 2. Anthocyanin absorbance level at 535 nm, corrected for dilution, of 14 sorrel varieties extracted with either water or 70% ethanol.



70% ETOH Water 70% ETOH Water 70% ETOH Water 70% ETOH 95% ETOH
95% ETOH 70% ETOH Acetone Chloroform

Figure 3. Extracted pigments resolved on paper chromatography with 95% ethanol, 70% ethanol, acetone or chloroform after 12 hours.

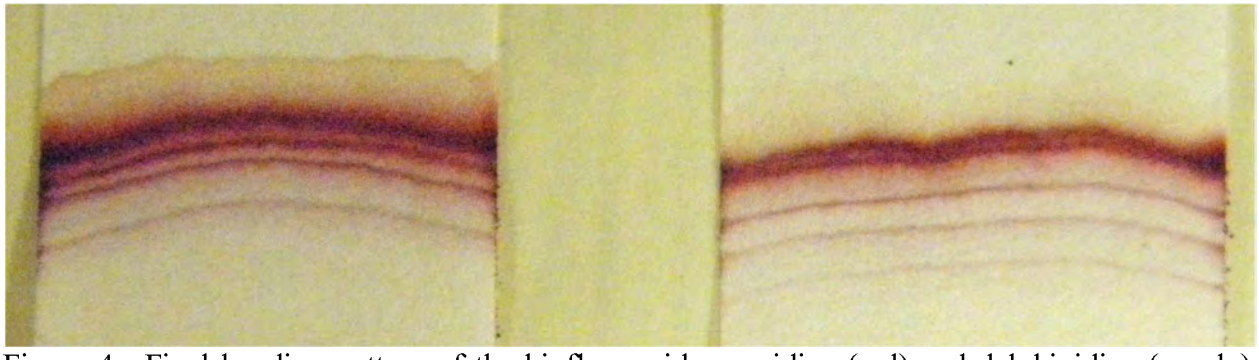


Figure 4. Final banding pattern of the bioflavonoids cyanidins (red) and delphinidins (purple) extracted in 70% ethanol (left) and water (right) resolved in 95% ethanol.

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CAPSAICIN PRODUCTION FOR PHARMACEUTICAL USE: II. FIXED OIL YIELD

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ABSTRACT: Capsaicinoids (8-methyl–*N*–vanillyl-1–6-nonemaide) have significant pharmaceutical and non- lethal force potential. It is used in topical ointments to relieve pain of peripheral neuropathy at low concentrations, as a treatment in apoptosis of prostate cancer cell, and is being tested for the prevention of post surgery pain. Capsaicin is the main capsaicinoids in hot peppers [*capsicum chinense* and *C. annuum*]. Previous research focused on the culinary and food value of hot peppers which are the major source of capsaicin. This study evaluates the crop phenology, agronomic performance, and fixed oil content of eight pepper selection/landraces. The results indicated that the selection 'Carvahlo hot' produced the highest oil yield [9.0ml/100g] compared to 'Bhut Jolokia' [6.0 ml/100 g] and 'Scotch bonnet' [3.5 ml/100 g]. Whilst most of the varieties / landraces cultivated are considered 'hot' based on the Scoville Unit [SU] test e.g. scotch bonnet (300,000SU), seven pots (750,000SU), and Scorpion (>1,000,000SU), the study suggest that 'Carvahlo hot' has the potential for commercial fixed oil production and is evidently hotter than the acclaimed world's hottest pepper 'Bhut Jolokia'.

Keywords: Capsaicinoids, Scoville Unit, *Capsicum chinense, C. annuum*, fixed oil content

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EFFECT OF GIBBERELLIC ACID AND SUBSTRATES ON SEED GERMINATION AND GROWTH PARAMETERS OF CHRISTMAS PALM (*ADONIDIA MERRILLI* BECC.)

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ABSTRACT: Palms are important landscape ornamentals throughout the tropics, and are increasingly used as components of elaborate interiorscapes within malls and office buildings as well as exteriorscapes in home gardens and public gardens. Palms are usually propagated by seeds but germination of seeds for many species is often slow and erratic and germination percentage can be very low. Most of palm seeds germinate best if they were treated with gibberellic acid and maintained in a good porous and nutritious substrate. This treatment also plays an important role in the vegetative growth of the seedlings. Five to six weeks were taken in all treatments and maximum germination percentage was recorded in Sand+Soil+Bagasse substrate.

Keywords: Arecaceae, gibberellic acid, seedlings, substrates, nursery production

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EVALUATION OF THREE PLANT GROWTH BIOREGULATORS ON THE GROWTH AND YIELD OF MONTSERRAT SEA ISLAND COTTON

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ABSTRACT: Sea Island Cotton (*Gossypium barbadense* L.) is the world's premium quality cotton, which possesses the distinct characteristics of an extra long staple, good strength and supreme fineness. The present commercial variety is the Montserrat Sea Island (MSI), which is a subtropical perennial plant with an indeterminate growth habit. In Barbados, the cotton plant develops excessive vegetative growth which places limits on the amount of photosynthetic active radiation (PAR) reaching the lower foliage. Consequently, there is excessive boll shedding, boll rotting and a proliferation of pests, particularly in the lower reproductive area of the plant. In most instances, the cotton plant grows beyond eight feet in height, with the branches interlocking those of contiguous plants. This evidently creates problems for both mechanical and manual harvesting of the seed cotton. The height of the plant and the density of the foliage can be reduced by the use of synthetic growth bioregulators. Mepiquat chloride (Crop smart), mepiquat pentaborate (Pentia) and chlorocholine chloride (Cycocel) are three plant growth bioregulators which control excessive vertical and lateral vegetative growth of the cotton plant. These bioregulators were evaluated in a field trial at the Ministry of Agriculture, laid out as a randomized block design with four replicates, with each plot size being 46.08 m^2. The experimental treatments were mepiquat chloride at a rate of 23.66 ml/22.7 litres of water, mepiquat pentaborate at a rate of 23.66 ml/22.7 litres of water, and chlorocholine chloride at a rate of 25.66 ml/22.7 litres of water. The first treatments were applied when the plants reached an average height of 77.2 centimeters, with two subsequent applications at fourteen days intervals. The application of the bioregulators caused a significant retardation in vertical and lateral plant growth, but the effect of chlorocholine chloride on the vertical and lateral growth of the plant was more significant. The treatments did not affect the number of fruiting branches, but the treatment chlorocholine chloride significantly reduced yield and produced smaller dark green leaves. At the time of harvest, plants treated with chlorocholine chloride produced a high number of unopened bolls. The applications of the treatments mepiquat chloride and chlorocholine chloride did not significantly affect the strength, micronaire, maturity and length of the cotton fibre. However, plant treated with mepiquat pentaborate produced bolls that carry thicker fibres, with the lint having a higher percentage maturity. The results of this study support the perception that the application of the bioregulator mepiquat chloride could reduce the vertical and lateral growth of MSI cotton without compromising the quality and yield of the lint, and allow for the cotton crop to be effectively manually harvested.

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EFFECT OF GROWTH REGULATORS ON ROOTING OF *RONDELETIA ODORATA* JACQ. STEM CUTTINGS

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ABSTRACT: An investigation was conducted to find out the effect of different concentrations of growth regulators (IAA, IBA and NAA) on vegetative growth as well as rooting behaviour of *Rondeletia odorata* Jacq. hardwood cuttings. Adventitious rooting of hardwood stem cuttings was improved by the application of growth hormones. The results had shown that minimum number of days were taken for bud burst or shoot emergence, and maximum sprouting percentage, number of shoots per plant, rooting percentage, maximum number of adventitious roots and longest root were recorded on IBA @ 3000 ppm treatment. Indole-3-butyric acid (IBA) was found to be superior as a growth regulator over Indole-3-acetic acid (IAA) and α-naphthalene acetic acid (NAA). Better response in relation to plant height, number of leaves and maximum survival percentage were also observed on IBA treated cuttings.

Keywords: *Rondeletia*, Rubiaceae, Rooting, IAA, IBA, NAA

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EFFICACY OF ETHYLENE FOR ENHANCING SHADE TOLERANCE IN SPORTS TURFGRASS

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ABSTRACT: Turfgrass management for provision of high quality sporting facilities is becoming increasingly important with recognition of the contribution of sports to tourism, which is a major driver for income security in the Caribbean Region. Bermuda grass [*Cynodon dactylon* (L.) Pers.] cultivars commonly cultivated on sports fields in the Region are adversely affected by shaded conditions likely to occur within enclosed stadia built to attract international sporting events. Poor surface stability and traction, and non-uniform appearance and performance are some of the adverse effects that can occur in turfgrass growing in the shadows of buildings and other structures. In this regard, pot studies were conducted at the University of the West Indies, Cave Hill Campus, Barbados, to investigate the effects of ethephon on the shade tolerance of Bermuda grass, cultivar Princess-77. Ethylene (released from applied ethephon), can potentially be used to enhance shade tolerance due to its frequently observed effects in reducing elongative growth while promoting lateral expansion in various plant species. This is an attractive option since ethephon is relatively cheap and non-toxic and it is already used for other purposes in the horticultural industry throughout the Region. In an initial investigation, turf quality and growth were monitored following the application of ethephon at three concentrations (0, 0.25 and 0.5%) to turfgrass exposed to full light or to 55% shade (provided by shade netting). Ethephon was applied (until leaf drip) to recently clipped (3 cm tall) turfgrass as an aqueous foliar spray, with and without added nutrients, using a handheld sprayer. A follow-up study investigated the effects of repeated application at the 0.25% concentration in shaded and non-shaded turf. Undesirable effects of shading on plant height were significantly reduced by increasing the concentration of ethephon or the frequency of its application. Reduction in the chlorophyll index with ethephon application was partially offset by the inclusion of nutrients in the spray solution. Dry mass of clippings was reduced by ethephon under shaded conditions with significant effects of the 0.25% solution applied at weekly intervals. Results suggest that ethephon use can be considered for counteracting adverse effects of shade on Bermuda grass.

Keywords: green cover, tissue moisture content, image analysis

INTRODUCTION

Bermuda grass, *Cynodon dactylon* (L.) Pers., generally has excellent turfgrass properties and many varieties show tolerance to drought and wear conditions with strong regenerative capacity (Wiecko, 2006). It is widely distributed in tropical regions and is frequently recommended as a warm-season turfgrass for sports fields, lawns and park areas. A major disadvantage of Bermuda grass as a sports turfgrass is that it does not respond well to shaded conditions, and it is ranked low in terms of shade tolerance amongst many of the popular tropical turfgrasses (Wiecko, 2006). Consequently, as the number of enclosed sports stadia increases and/or as stadium capacity increases, shade from surrounding structures can have adverse effects on playing field appearance and performance characteristics. Under shaded conditions, the tight-knit vegetated surface typical of this grass under non-shaded conditions does not form; instead there is increased elongative growth and reduced density of grass shoots with reduced lateral stem initiation (tillering) and growth (Dudeck and Peacock, 1992). Root growth is reduced due to the

fact that resources are diverted more towards upright shoot growth under shaded conditions. A weak (easily uprooted) low density turf with poor surface stability and traction results with consequent adverse effects on field uniformity in terms of appearance and performance characteristics. Shaded areas of sports turf grass often show increased disease problems (Beard, 1997) and require different management regimes in contrast to non-shaded areas, especially with regard to irrigation and fertilization.

Plant growth regulators (PGR's) are often used in the management of turfgrass (Watschke et al., 1992) and may provide cost effective alternatives for reducing the adverse effects of shade on the growth and quality of turfgrass. Trinexapac-ethyl is an anti-gibberellin PGR compound that is often used on golf courses to reduce excess vertical growth and improve turf quality (Tegg and Lane, 2004) and shade tolerance (Baldwin et al., 2009). Ethylene is a cheaper and possibly less toxic PGR that reduces elongative growth and promotes radial expansion and branching (Shatters et al., 1998), which are likely to be beneficial under shade conditions. The ethylene-releasing compound, Ethephon (2-chloroethylphosphonic acid), is commonly available in the Caribbean Region and is often used for promotion of fruit ripening. This compound breaks down to release ethylene gas within the plant's tissues upon application. Ethylene also induces senescence in plants, and can lead to discolorations and consequent poor turf quality (Shatters et al., 1998). Such discolorations can possibly be counteracted by the inclusion of low concentrations of nitrogen fertilizer in ethephon treatment solutions. The current study seeks to determine whether there are possible beneficial effects of Ethephon on the growth and turf quality of Bermuda grass "Princess 77" under shaded conditions. The inclusion of mineral nutrients in the application solution to counteract possible senescence-inducing effects of ethylene was also investigated.

MATERIALS AND METHODS

Two pot studies were conducted under field conditions on the grounds of the Cave Hill Campus of the University of the West Indies, Barbados, during the period November 2008 to March 2009. Seeds of Bermuda grass 'Princess-77' (Pennington Seed Inc., USA) were sown (50 000 seeds m^{-2}) in 2.5L plastic pots containing a 1:1 sand/soil mixture. Plants were watered daily and fertilizer (NPK 24:8:16, Scotts Miracle-Gro Products Inc., USA) was applied weekly. A split-plot experimental design was used for both studies with two main-plot light treatments: Full light, and 55% Shade (applied using shade netting), and four replications. In the first study, the sub-plot treatments consisted of six spray solutions (three Ethephon concentrations: 0, 0.25, 0.5% active ingredient; with and without added nutrients). Nutrients were added to the appropriate solutions using NPK 24:8:16 soluble fertilizer at 6 g/L. In the second study, Ethephon was applied at 0.25% concentration without added nutrients for all treatments and sub-plots consisted of 4 application frequencies: 0, 0.5, 1 and 2 times per week. Ethephon solutions were applied in late afternoon with a hand sprayer until leaf drip, and treatments were applied over a period of 3 to 4 weeks in each study.

Turf was clipped to the rim of each pot at weekly intervals and fresh and dry mass (after drying to constant mass in an over at 80° C) of clippings were determined. Observations were made at weekly intervals just prior to clipping and included turf height, greenness index and percentage green cover. Turf height (mm) was measured using a modification of the Rising Disk method (New Zealand Sports Turf Institute). The equipment consisted of a compact disc (diameter = 12 cm, mass = 15.052 g) with a 30 cm rod (with attached mm height scale at one end) threaded through the central aperture (diameter = 1.5 cm) of the compact disc. The graduated end of the rod was pushed vertically through the turfgrass to the soil surface, and the compact disc was allowed to fall along the rod from a fixed height of approximately 10 cm until it rested on the

surface of the turf being sampled. The height above the soil at which it rested was recorded and one measurement was made per pot. The soil surface was on average about 3 cm below the rim of the pots.

Greenness index was measured using a portable chlorophyll index meter (Field Scout CM-1000, Spectrum Technologies Inc., USA). The instrument was held approximately 30 cm above the turf and six readings were taken at random locations across the surface in each pot. Readings were taken between 10.00 am and 2.00 pm under bright sunlight conditions and average values were recorded. Greenness index is calculated by the instrument based on reflected red and infrared light wavelengths to give a dimensionless number between 0 and 999. Typically, greenness index for dense healthy turf can reach values of about 450. Digital image analysis was used to determine green cover percentage of individual pots. The digital camera was held approximately 30 centimeters above the pot with care not to cast any shadows on the sample area, and images were taken between 10 am and 2 pm. Images were uploaded to a computer and analyzed using image analysis software (Assess 2.0, American Phytopathology Society, USA) where percentage green cover was determined as the percentage of green pixels within the area of interest in each image.

RESULTS AND DISCUSSION

The height of shaded turfgrass decreased linearly as the Ethephon concentration was increased from 0 to 0.5% (Fig. 1) and the regression equation was as follows: $y = 55.8 - 28.6\ x$, $R^2 = 0.99$, where y is turf height and x is Ethephon concentration. No such trend was observed for the turfgrass in full light and shaded turf was marginally taller at 0% (and marginally shorter at 0.5%) Ethephon, compared to non-shaded turf. The dry mass of clippings followed a similar pattern to that of turf height but the decline with increased Ethephon concentration appeared to be much steeper (Fig. 2). The effect of shade in increasing vertical shoot growth and decreasing turf quality has been found for several turf species including Bermuda grass (Tegg and Lane, 2004). In glasshouse studies, 35 mM Ethephon (about 0.5% concentration) was effective in reducing plant height and increasing root production in Bermuda grass (Shatters et al., 1998). Effects of Ethephon on the dry mass of clippings were not significant for turfgrass under full light, and there was a significant decline in the mass of clippings obtained for shaded compared to non-shaded turf treated with 0.5% Ethephon. Adverse shade effects on turf height and clippings dry mass production were not significant following application of the 0.25% Ethephon treatment (Fig. 1 and 2).

Turf height was not significantly affected by the addition of nutrients to the spray solution and there were no significant interactions between nutrient level and other experimental factors with regard to any of the variables measured (data not shown). When data were pooled across Ethephon and light levels, there was a notable increase in the dry mass of clippings and a small but significant increase in greenness index with the inclusion of nutrients in the spray solution (Fig. 3). Although the responses were similar under varying Ethephon and light levels, the addition of nutrients to the Ethephon spray solutions may be beneficial for counteracting some of the senescence-inducing effects of ethylene. Further research is needed to optimize the type and amount of nutrients that should be included in the spray solution. Greenness index was significantly reduced by the 0.25% and 0.5% Ethephon treatments regardless of the light level or whether nutrients were included in the spray solution (Fig. 4). Terminal leaf necrosis and chlorosis of young developing leaves have been observed for Bermuda grass in response to Ethephon application (Shatters et al., 1998). Tissue moisture content of clippings increased with the application of 0.25% Ethephon, with no further increase at 0.5% Ethephon (Fig. 5). This

effect may be consistent with an earlier report of increased leaf/stem fresh mass ratio in Bermuda grass treated with Ethephon (Shatters et al., 1998).

In the second study, height of shaded turf was significantly reduced by increasing the application frequency of 0.25% Ethephon from 0 to 2 times per week (Fig. 6). The effect of shading on turf height was not significant at the Ethephon application frequency of 0.5 times per week (once every two weeks), and a once per week application of Ethephon was sufficient to reduce the height of shaded turf to a value similar to that of untreated non-shaded turf (Fig. 6). Highly significant effects of shading on percentage green cover were observed in the absence of Ethephon applications, and such effects became non-significant when Ethephon was applied at 0.5 or 1.0 time per week (Fig. 7). At 2.0 applications per week, percentage green cover was significantly reduced in non-shaded turfgrass. There does not appear to be any additional benefits of increasing the application frequency beyond 1.0 time per week.

CONCLUSIONS

Ethephon application may be beneficial to counteract some adverse effects of shade on turfgrass. Results suggest that 0.25% Ethephon applied once every 1 to 2 weeks may be effective. Senescence inducing effects of ethylene may be partially reduced by the inclusion of nutrients in the spray solution; further research is needed in this regard.

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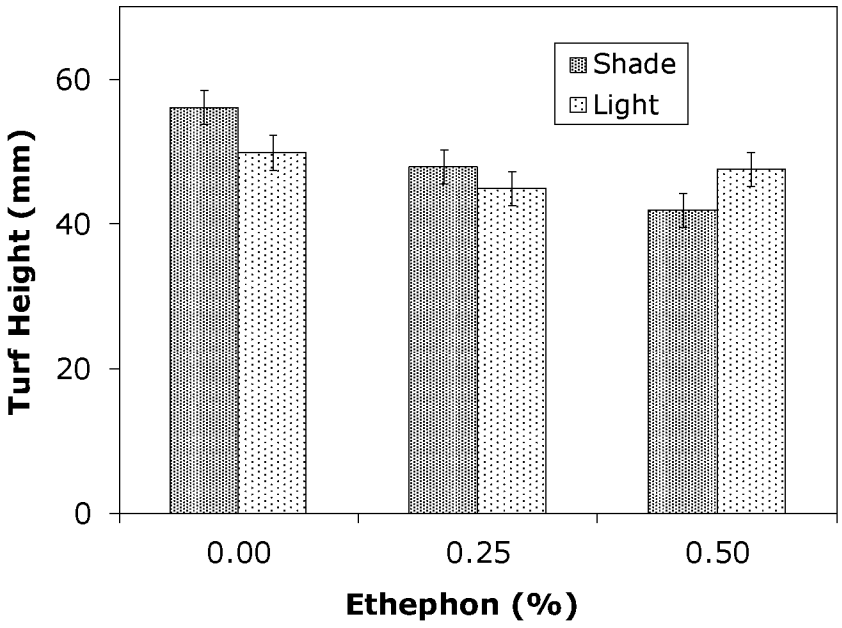

Figure 1. Turf height (mean ±SE) measured just prior to clipping of Bermuda grass subjected to weekly applications of Ethephon solutions under shaded (Shade) and full light (Light) conditions. Data were pooled for treatments with and without added nutrients in the spray solutions.

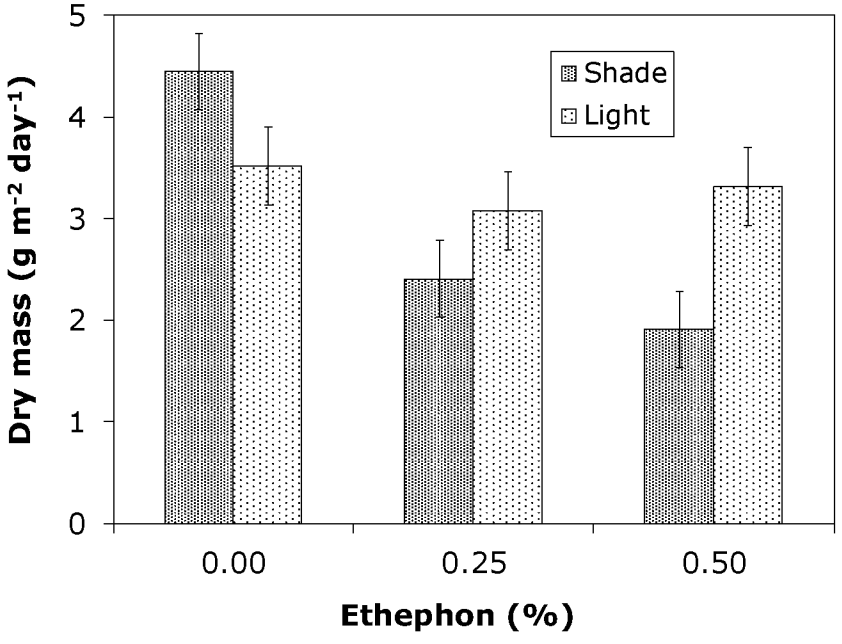

Figure 2. Clippings dry mass production (mean ±SE) for Bermuda grass subjected to weekly applications of Ethephon solutions under shaded (Shade) and full light (Light) conditions. Data were pooled for treatments with and without added nutrients in the spray solutions.

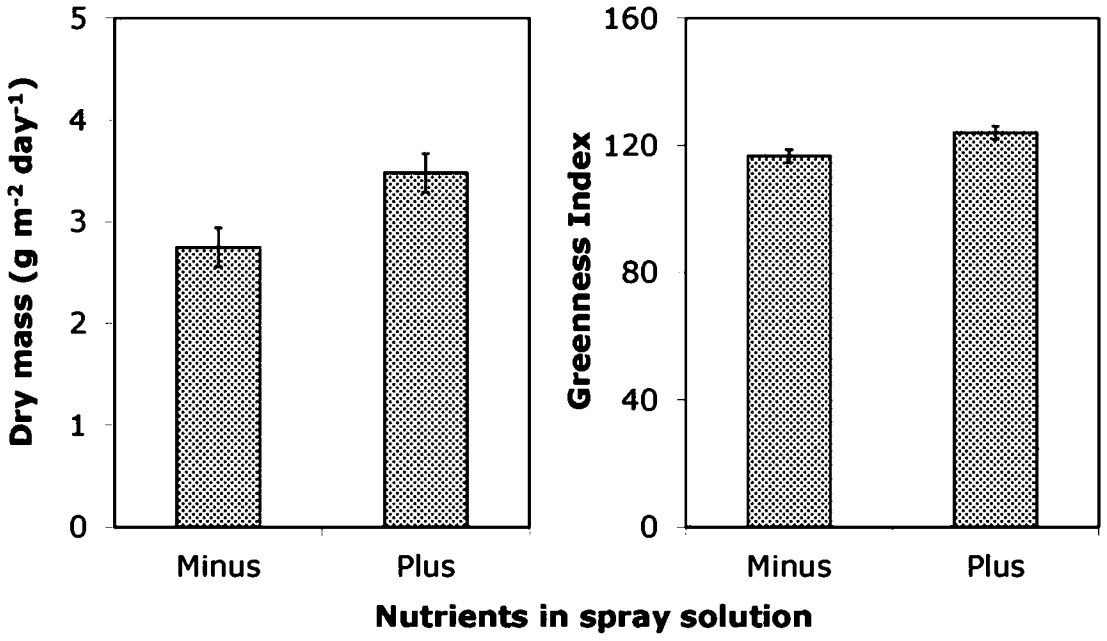

Figure 3. Clippings dry mass production and greenness index (mean ±SE) for Bermuda grass subjected to weekly applications of Ethephon with (Plus) or without (Minus) added nutrients in the spray solutions. Data were pooled for different Ethephon treatments under shaded and full light conditions.

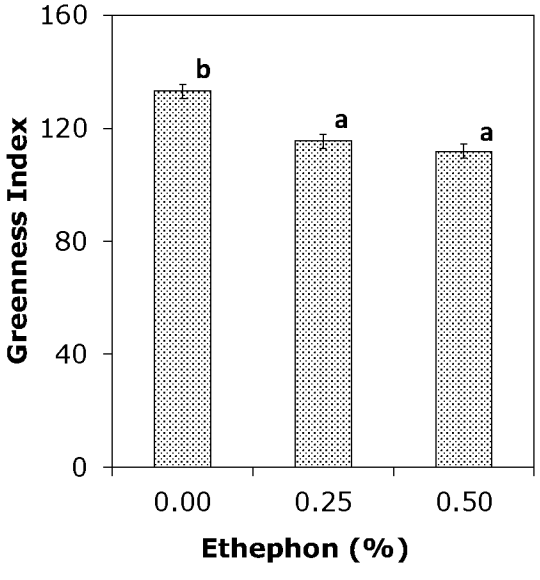

Figure 4. Greenness index (mean ±SE) for Bermuda grass subjected to weekly applications of Ethephon solutions. Data were pooled for treatments with and without added nutrients in the spray solutions under shaded and full light conditions. Means with a common attached letter are not significantly different from each other by the LSD test ($p > 0.05$).

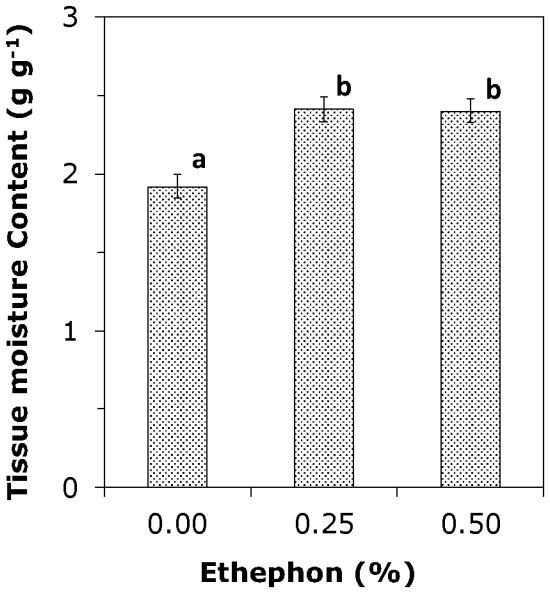

Figure 5. Tissue moisture content of clippings (per unit dry mass, mean ±SE) for Bermuda grass subjected to weekly applications of Ethephon solutions. Data were pooled for treatments with and without added nutrients in the spray solutions under shaded and full light conditions. Means with a common attached letter are not significantly different from each other by the LSD test ($p > 0.05$).

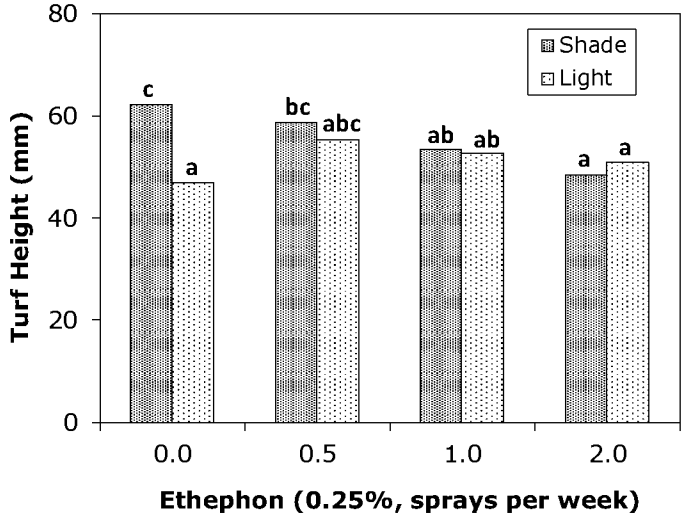

Figure 6. Turf height (mean ±SE) measured just prior to weekly clipping of Bermuda grass subjected to Ethephon (0.25%) applications under shaded (Shade) and full light (Light) conditions. Means with a common attached letter are not significantly different from each other by the LSD test ($p > 0.05$).

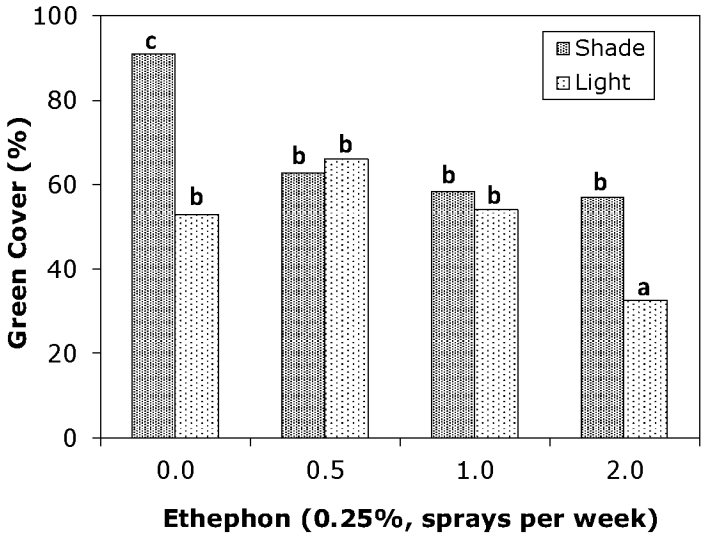

Figure 7. Percentage green cover measured just prior to weekly clipping of Bermuda grass subjected to Ethephon (0.25%) applications under shaded (Shade) and full light (Light) conditions. Means with a common attached letter are not significantly different from each other by the LSD test ($p > 0.05$).

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PLANT SPACING INFLUENCES PRODUCTION ON LATE SEASON PLANTED SORREL (*HIBISCUS SABDARIFFA*)

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ABSTRACT: *Hibiscus sabdariffa*, also known as sorrel in the Virgin Islands, is an annual plant that is grown mainly for its colorful fleshy calyxes during the Christmas Season. Sorrel is used to make a healthy drink that is high in vitamin C and anthocyanins which is claimed to be better than cranberry juice. Sorrel is normally planted at 60 cm during July and August. The objective of this study was to compare sorrel growth and production of a Caribbean day-neutral variety and a Zambian short-day variety planted in September with in-row plant spacing of 20 cm, 40 cm and 60 cm, and 150 cm between rows. Data was collected weekly on plant height, branching and fruit set. The results indicated that the Caribbean day-neutral variety can be grown at 20 to 60 cm with no effect on branching or production. However, the Caribbean day-neutral plants were shorter at 60 cm spacing than either at 20 or 40 cm, while spacing was not an influence on plant height for the Zambian short-day variety at 20 to 60 cm. The Zambian short-day sorrel has greater branching and fruit set as the plant spacing increases from 20 to 60 cm. Planting sorrel in September at 40 cm can increase production per length of row. This research was funded through VI Dept. of Agriculture Specialty Crops Block Grant and USDA-NIFA-Resident Instruction in Insular Areas (Grant # #2008-34816-20016).

Keywords: *Hibiscus sabdariffa*, Roselle, planting density

INTRODUCTION

The sorrel plant (*Hibiscus sabdariffa*), also known as the roselle, is an annual plant in the Malvaceae family with hibiscus, okra and cotton (Duke, 1983). Sorrel contains high levels of vitamin C and anthocyanins and claimed to be better than cranberry juice (Hall, 2005; Appell, 2003). In the Caribbean, sorrel is used to make a healthy drink during the holiday season (Morton, 1987). Sorrel is normally planted in July or August at 60 to 100 cm spacing to obtain large plants when they induce flowers under short days (George and Morris, 1984). Two types of sorrel were planted during the beginning of September to study the influence of late planting under shorter day length. The objective of this study was to compare growth and production of two varieties of sorrel in a late planting with in-row plant spacing of 20 cm, 40 cm and 60 cm.

MATERIALS AND METHODS

Two sorrel varieties were used, Zambia-500752 (ZSD) obtained from the USDA Germplasm Repository, Griffin, Georgia, USA, and a local Caribbean Day Neutral (CDN) variety. Seeds were sown in trays containing eighteen 8 cm^3 cells per tray and filled with ProMix on September 3, 2010. Three trays were planted per variety with two seeds/cell and thinned to one seedling after a week. Three weeks later, the seedlings were transplanted into the field where a drip line, with emitters every 20 cm, was used to supply water. The in row plant spacing was 20, 40 or 60 cm for each variety and 150 cm between rows. Each variety had two sets of five consecutive plants chosen for each between plants, in row spacing for data collection. The plant height,

branch number and fruit set were collected weekly for three months. Data was analyzed using ANOVA, and LSD for the means was done at P=0.05 significance level.

RESULTS AND DISCUSSION

Sorrel seeds germinated within three days and by seven days CDN and ZSD had 100% and 70% germination, respectively. After transplanting to the field, the plants actively grew but yellowing of leaves, interveinal chlorosis, were present especially in the CDN variety due to the high pH caused by the calcareous soil in the field plot. The plant spacing had no effect on plant height for ZSD variety where the height averaged around a meter (Fig. 1). However, the 60 cm plant spacing resulted in significantly shorter plants for the CDN variety. The closer spacing of 20 cm and 40 cm caused the CDN plants to grow taller.

Within seven days of transplanting, the ZSD started branching whereas branching was delayed a week in the CDN variety. Flower buds were observed on the CDN plants within two weeks of transplanting to the field while they were only observed in the ZSD variety after the third week. The in-row between plant spacing had a significant influence on branching with closer spacing resulting in fewer branches (Fig. 2). However, plant spacing had no significant influence on CDN branching (Fig. 2). The number of branches should influence fruiting since flowers develop from the leaf axis along the stem and branches. Therefore, with more branches, there should be more flowers and fruit. Since the CDN plants had similar branching for all plant spacing, we also found no significant difference in the number of calyxes produced (Fig. 3). The 20 cm spacing for Zambian sorrel did produce 150 fruiting calyxes which was significantly less then the 206 and 211 calyxes at 40 or 60 cm, respectively (Fig. 3). The sorrel results were different more because of their variety than because of plant spacing.

CONCLUSION

Sorrel can be planted in September at a closer in-row spacing than traditionally used and still be productive. The Caribbean Day Neutral variety can be grown at 20 to 60 cm with no effect on branching or production. However, the Caribbean Day Neutral plants are shorter at 60 cm spacing than either the 20 or 40 cm in row spacing. However, plant spacing was not an influence on plant height for the Zambian variety at 20 to 60 cm. Zambian sorrel has greater branching and fruit set as the plant spacing increases from 20 to 60 cm. Planting sorrel in September at a closer spacing can increase production per length of row.

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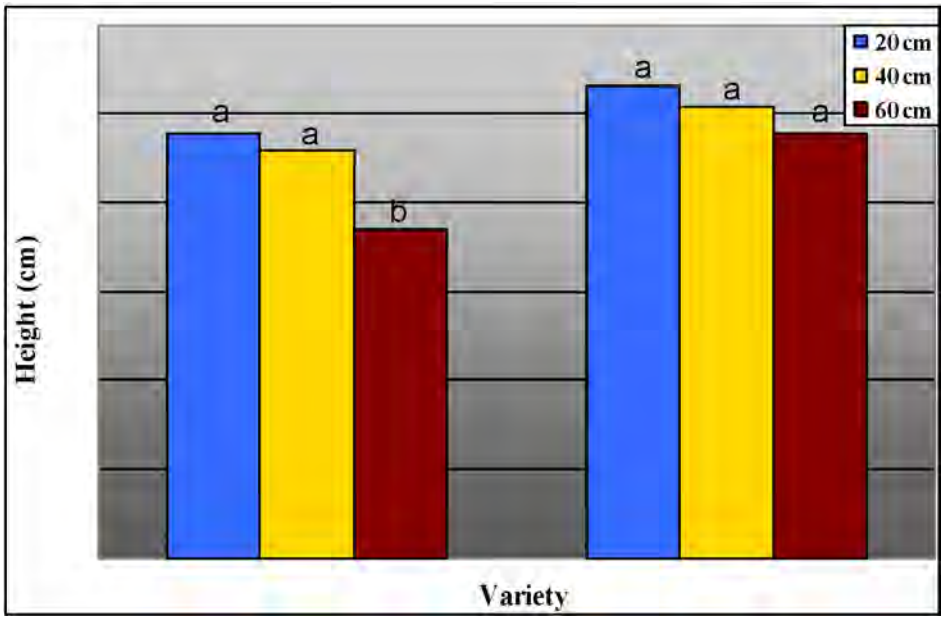

Figure 1. Effect of plant spacing on plant height of two sorrel varieties after 77 days.

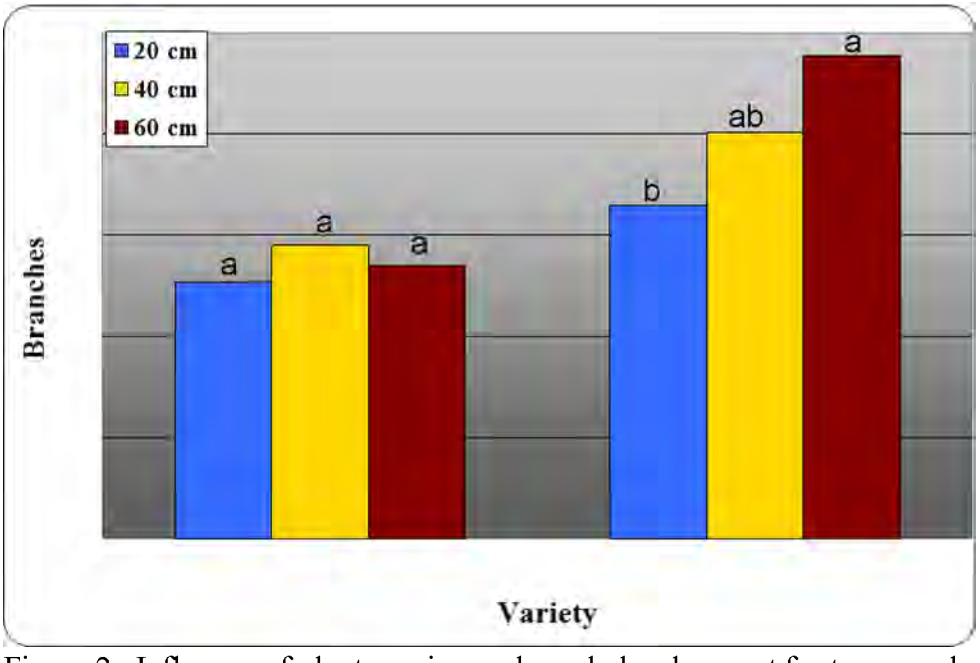

Figure 2. Influence of plant spacing on branch development for two sorrel varieties at 77 days.

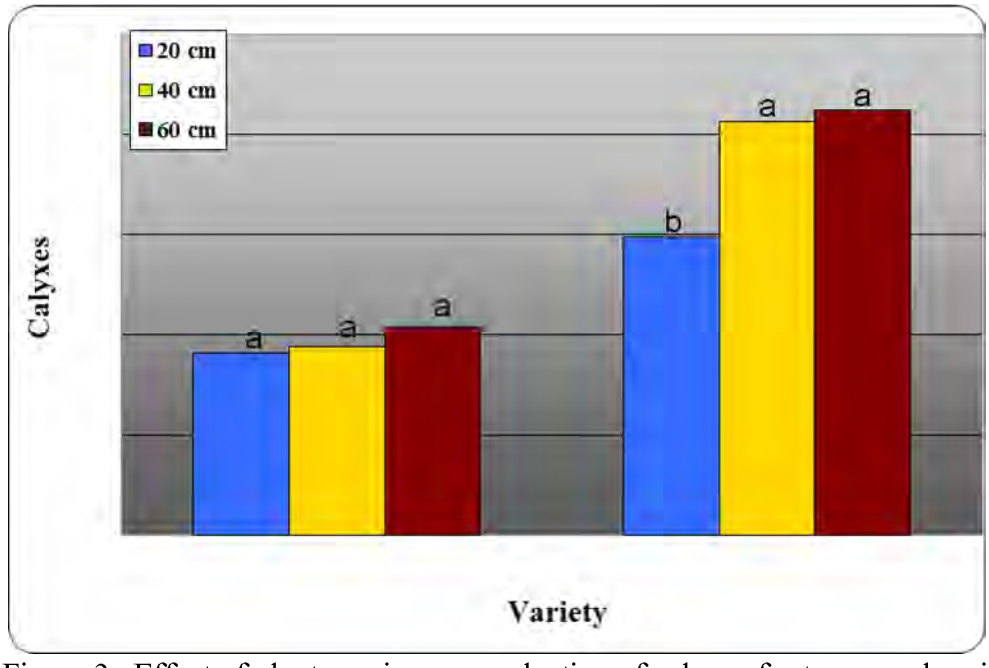

Figure 3. Effect of plant spacing on production of calyxes for two sorrel varieties.

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PROTECTING WATER QUALITY THROUGH GREEN INDUSTRIES BEST MANAGEMENT PRACTICES

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ABSTRACT: The "Green Industries Best Management Practices" (GI-BMP) is a science based educational program for landscape professionals, delivered by the University of Florida's Florida-Friendly Landscaping™ program, Florida Department of Agriculture and Consumer Services and the Florida Department of Environmental Protection. According to a state law that went into effect in 2009, all landscape professionals that apply fertilizer commercially must earn a GI-BMP certification by 2014. The goal of this statewide program is to protect Florida's water resources by teaching landscape maintenance professionals how to apply fertilizer, water and pesticides appropriately. In 2009, a four-star GI-BMP committee was formed with Pasco, Citrus, Hernando and Sumter counties in order to team teach this program in each of these Florida counties. The objective was that 100 landscape professionals would attend GI-BMP area workshops annually from 2009-2011 and 75% of the participants would earn GI-BMP certification by passing the exit exam. The four-star GI-BMP committee has jointly trained 237 landscape professionals from 2009-2011. An average knowledge increase of 15% (n=237) among attendees was realized when comparing pre and post test scores. Eighty-five percent (n=237) became GI-BMP certified by passing the exit exam. According to a post-class survey, 77% (n=113) of 2010 and 2011 participants stated that they would use the recommended fertilizer rates and methods of applications taught in GI-BMP class. Another 85% (n=113) of surveyed participants stated that they would inform their clients of GI-BMP recommendations. Green Industries Best Management Practices teach environmentally safe landscaping principles that help conserve and protect Florida's ground and surface waters.

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THE DEVELOPMENT OF PRODUCTIVITY INDICES FOR SUGARCANE MANAGEMENT IN BARBADOS

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ABSTRACT: Managing sugarcane for higher productivity poses particular challenges in Barbados, given the predominance of shallow soils and absence of irrigation. Average yields over the past 25 years have fluctuated between 46 to 64 tonnes cane per hectare (TCH), which is substantially less than the 72 to 86 TCH achieved in the early 1960s. The existing productivity classification, which is based primarily on annual rainfall and soil depth, is not sufficiently robust to account for the wide variations in yield among farms in the same rainfall zone and soil type. This paper presents an innovative method which incorporates several factors to determine farm-specific productivity potential. Farms that are amalgamations of smaller plantations were dis-aggregated into their respective units. This resulted in a total of 60 farming units being included in the exercise, with an average size of 116 hectares. Information on medium-term, effective monthly rainfall, soil capability and soil characteristics were obtained for each farming unit. This paper describes the Methodological Framework used to develop five distinct productivity groups, and the yield potential derived for each group. The results may be used firstly, to estimate the potential for improved productivity, that is the Productivity Gap; and secondly, the Benefits and Costs of interventions, including Management, to exploit the full potential by reducing the Productivity Gap. We believe this methodology could be applicable to other sugarcane producing regions as well as other cropping systems. It advances the traditional concepts of agro-ecological zoning and is consistent with site specific, precision agriculture which takes into account combinations of production factors in any given locale.

Keywords: Sugarcane productivity, agro-ecological zoning, precision agriculture

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INFLUENCE OF CALCAREOUS SOIL AND PHOTOPERIOD ON CARIBBEAN AND AFRICAN SORREL

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ABSTRACT: Sorrel (*Hibiscus sabdariffa*), commonly known as Roselle, is an annual plant from the Malvaceae family. Sorrel is used to make a healthy drink filled with high contents of vitamin C and anthocyanins, better than cranberry juice. The objective of this study was to evaluate growth of 17 sorrel varieties, from the Caribbean and Africa, for their tolerance to high pH caliche soils and their sensitivity to photoperiod. Seedlings of the sorrel varietieswere established at one foot spacing in calcareous soils during late March. Plant height, flowering and caliche tolerance was recorded over time. For caliche tolerance, plants were ranked from 1 to 5, with (5) being the best and (1) being severely chlorotic and necrotic. Generally, the varieties from Africa had better tolerance to the high pH soil (ranked above 2.5) than the Caribbean varieties. Five varieties appeared to be photoperiodically day neutral by producing flower buds and flowering in May. From these results, a breeding plan will be developed to combine tolerance to calcareous soils with a day neutral photoperiod to enhance year round production. This research was funded through VI Dept. of Agriculture Specialty Crops Block Grant and USDA-NIFA-Resident Instruction in Insular Areas (Grant # #2008-34816-20016).

Keywords: Caliche, day neutral, high pH tolerance, *Hibiscus sabdariffa*, Roselle

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DIAGNÓSTICO SOBRE LA SITUACIÓN DEL CULTIVO DE HABICHUELA (*PHASEOLUS VULGARIS* L.) EN LA CUENCA ALTA DEL RÍO ARTIBONITO

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RESUMEN: La producción de habichuela constituye una de las principales actividades agrícolas de la Cuenca Alta del Rio Artibonito (CAA). Forma parte de la canasta alimenticia y es una importante fuente de ingreso de la zona. La habichuela se produce bajo el sistema de cultivo de tala y quema, en ausencia de prácticas de conservación de suelo y poca asociación de cultivos que han reducido el área boscosa, afectando el flujo del agua y la degradación de los suelos. El objetivo fue generar informaciones básicas para el diseño de una estrategia participativa de producción de habichuela en la CAA. Se seleccionó al azar una muestra probabilística de productores y se aplicó una entrevista. Los datos se analizaron con el software Infostat. El 90% de los productores cultivan habichuela en asocio con cultivos de ciclo corto. Los productores cultivan el suelo aproximadamente seis meses (dos ciclos) y luego migran a otros sitios. El 60% tiene conocimientos sobre prácticas de conservación de suelo, pero solo el 54% las aplica. El 48% de los encuestados manifestó su disposición de cambiar el uso de suelo a sistemas agroforestales. Los productores venden aproximadamente el 95% de la producción y el 5% restante lo consumen y/o usan como material de siembra.

Palabras claves: Diagnóstico, habichuela, Cuenca Alta Artibonito

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MINERALIZACIÓN DE NITRÓGENO EN UN SUELO GRANÍTICO ENMENDADO CON MATERIALES ORGÁNICOS

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RESUMEN: La aplicación de enmiendas orgánicas es una alternativa para contribuir a mejorar las condiciones de salud, calidad y fertilidad de los suelos agrícolas. El objetivo fue cuantificar la mineralización de nitrógeno (N_{min}) en un suelo granítico con aplicación de enmiendas orgánicas *ex situ*. El experimento se realizó en el laboratorio del Centro Regional Quilamapu, INIA, Chile. Se utilizó un diseño de parcelas subdivididas con cuatro repeticiones. Se evaluaron cinco tratamientos: 1) un control (CA); 2) fertilización convencional (FC, en mezcla de urea, superfosfato-triple y cloruro de potasio); 3) bioestabilizado de cerdo (BC); 4) guano de pavo (GP); y 5) guano de broiler (GB). El nitrógeno (N) se aplicó a una concentración de 100 mg N kg^{-1} por tratamiento. Las muestras de suelo se incubaron a 25° C y la humedad fue controlada por pesada. Los contenidos de nitrato + amonio (NO_3 + NH_4) se midieron desde cero a ocho semanas. Los datos se analizaron en Infostat mediante un análisis de varianza (ANOVA). Se utilizó la prueba de Tukey al 5% para determinar las diferencias entre tratamientos. La N_{min} promedio fue estadísticamente superior ($p \leq 0.05$) en GP (59±4.9 mg N kg^{-1}) y FC (53±2.3 mg N kg^{-1}) en comparación con la CA, GB y BC. El aporte de N a partir de las enmiendas orgánicas mostró mayor estabilidad a través del tiempo con respecto al fertilizante convencional, por lo que la aplicación de GP y FC constituyen unas fuentes adecuadas de N para este tipo de suelo.

Palabras claves: Fertilización, nitrógeno, enmiendas orgánicas, granítico

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YIELD, CHEMICAL COMPOSITION AND *IN VITRO* RUMINAL FERMENTATION OF TREE LEAVES AS INFLUENCED BY GROWTH ENVIRONMENT, SPECIES AND HARVESTING FREQUENCY

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ABSTRACT: Protein tree forages can be used to supplement poor quality grass in the diets of sheep and goats in Trinidad and Tobago, but information on the effect of cutting frequency and species on yield, chemical composition and *in vitro* ruminal organic matter digestibility (IVOMD) is limited. The objectives of this study were to evaluate the effect of cutting frequency (6-, 8-, and 12-week intervals) and species on the yield, chemical composition of tree leaves, and to investigate the effect of cutting frequency and species on *in vitro* ruminal organic matter digestibility of tree leaves. Data were collected from the University Field Station (UFS) at Mt Hope, Sugarcane Feeds Centre (SFC), Longdenville and Centeno Livestock Station (CLS), Centeno. Three species, *Gliricidia sepium, Leucaena leucocephala,* and *Trichanthera gigantean*, were compared at UFS. *Gliricidia sepium* and *Trichanthera gigantea* were compared at CLS and the effect of cutting frequency on *L. leucocephala* was evaluated at SFC. At UFS, organic matter (OM) yield was highest ($P<0.05$) for *G. sepium* 12-week (14913 kg/ha) and lowest for *L. leucocephala* 12-week (4402 kg/ha). Similarly, crude protein (CP) yield was highest ($P<0.05$) for *G. sepium* 12-week (4203 kg/ha) and lowest for *L. leucocephala* 12-week (1301 kg/ha). At CLS, crude protein (CP) content was higher ($P<0.05$) for *G. sepium* at intervals 6-(300 g/kg DM), 8-(277 g/kg DM) and 12-week (266 g/kg DM) when compared to *T. gigantea* at 6-(189 g/kg DM), 8-(186 g/kg DM) and 12-week (170 g/kg DM). Acid detergent fibre (ADF) and neutral detergent fibre (NDF) content was higher ($P<0.05$) for *T. gigantea* when compared to *G. sepium.* Acid detergent lignin (ADL) content was highest ($P<0.05$) for *L. leucocephala* (32 g/kg DM) and lowest for *G. sepium* (26 g/kg DM). At SFC, there was a decline ($P<0.05$) in crude protein (CP) content of *L. leucocephala* leaves from cutting interval 6-(264 g/kg DM) to 12-week (247 g/kg DM). *In vitro* organic matter digestibility was highest in *G. sepium* leaves (71%) and lowest in *T. gigantea* leaves (34%).

Keywords: Protein forages, small ruminants, chemical composition, Coppice regrowth, nutritive value, growing conditions

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ANAEROBIC DIGESTION OF DAIRY MANURE FOR ENERGY AND NUTRIENT RECOVERY

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ABSTRACT: Previous studies demonstrated that solid waste generated in confined animal operations in Puerto Rico is equivalent to the organic load generated by six million people. Anaerobic digestion of animal manure is a sound waste treatment technology that mineralizes complex organic molecules into renewable energy and biofertilizer that can be re-used in the farm. The capture and re-use of methane gas significantly reduces the carbon footprint of confined animal operations and net global greenhouse gas production. A project was conduced at the dairy farm of the Lajas Agricultural Experiment Sub-Station to study the anaerobic digestion of farm's dairy waste using three plastic 55-gal anaerobic reactors. Substrate was prepared once a week by diluting fresh dairy cow manure with water to obtain three different desired organic load ratios to represent typical dilution factors found in local dairy farms. Hydraulic retention time was maintained at 30 days due to the high content of total solids in the manure mix and prevailing ambient temperature (28° C) of the substrate that made the process mesothermic. Liquid samples were collected from the feeding tank and effluent outflow. All three digesters were instrumented to record biophysical parameters and the evolution of biogas from the mix using a displaced volume meter. Samples were analyzed for major nutrients, total suspended solids (TSS), total volatile solids (TVS), pH, biological oxygen demand (BOD_5), and chemical oxygen demand (COD). Biogas produced was measured and separated in a GC-MS apparatus. This research focuses on developing design guidelines for the conversion of traditional waste treatment ponds used in the industry into energy reactors that recover carbon in the form of methane gas for power generation. Influent BOD_5 ranged from 17,640 to 29,640 mg/L with a mean concentration of 23,640 mg/L. Influent COD ranged from 39,900 to 44,850 mg/L. Total suspended solids (TSS) ranged from 5090 to 13,670 mg/L and Total Volatile Solids (TVS) ranged from 4330 to 11,080 mg/L. The destruction of BOD, COD and TVS in the entire experiment was at best 26%, 48% and 71%, respectively. Mean daily biogas production ranged from 6.63 to 28.68 L/day.

Keywords: Anaerobic digestion, methane gas, energy reactors, dairy manure

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CHARACTERIZATION OF THE ESTRUS CYCLE OF THE AGOUTI (*DASYPROCTA LEPORINA*): A NEO-TROPICAL RODENT WITH POTENTIAL FOR SEMI-INTENSIVE PRODUCTION, BY VAGINAL COLPOCYTOLOGY

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ABSTRACT: The indigenous fauna of the Caribbean is still to be well studied. These animals are well adapted to the Neo-tropical conditions and hence have the potential for food production using the available feeding resources. The agouti (*Dasyprocta leporina*) is a neo-tropical rodent with great potential for semi intensive livestock production. Captive breeding programs rely heavily on reproductive management practices. The adult reproductive female is the unit of production. A study was undertaken to investigate and characterize the estrus cycle of the female agouti by vaginal colpocytology, in an effort to identify the period of estrus. Five pluriparous, non-pregnant females were flushed with 10% saline once per day for 90 days. The main cell types identified were cornified nucleated, cornified enucleated and leucocytes, which corresponded to the four phases of the estrous cycle. The estrous cycle was found to have a mean length of 31±2 days. It is being suggested that the period of peak sexual receptivity was on the 17th-18th day of the cycle. Work is ongoing with blood analysis of reproductive hormones to confirm this finding from a metabolic standpoint. Further studies will have to be done in order to observe this physically. This information could be used to inform agouti farmers on the best time for breeding for captive management and maximizing the reproductive performance of the agouti under intensive systems of production.

Keywords: agouti, vaginal colpocytology, estrous cycle

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A PRODUCTION MODEL FOR RABBITS (*OCYCTOLAGUS CUNICULUS*) IN THE CARIBBEAN

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ABSTRACT: Rabbit is an important animal protein source towards achieving sustainability and the development of small states. Rabbit production has moved from backyard farming to fully intensive systems and has the potential to replace some of the imported meat products on the market due to the rabbit's prolificacy and ability to consume forages. Because of the shift to intensification farmers are now experiencing problems towards being efficient. In order to reduce some of the limitations experienced, investigations were conducted and an intensive system approach method was developed where each limitation was categorized and placed in order of priority to be dealt with. These limitations were as follows: the availability of space, waste management and the amount of time famers have to spend on a daily basis to perform regular routines for the production unit. With the aim towards achieving sustainability through the production of these small animals, a production model was developed addressing some of the limitations expressed by the farmers. This model facilitates the production of three times more animals / unit area as well as the reduction of the amount of time spent in the unit per weeks by approximately 38 hrs, with the potential to generate energy to be supplied for minor operations i.e. cage flaming conducted in the unit via the use of a bio digester.

Keywords: three tier, bio digester, waste management

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INTEGRATED CONTROL OF GASTROINTESTINAL PARASITISM OF GRAZING SMALL RUMINANTS IN THE HUMID TROPICS

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ABSTRACT: Small ruminants in the humid tropics are strongly affected by gastrointestinal parasitism, with losses exceeding 50% of the production potential. Weather conditions (temperatures around 25° C, range 15 to 35 °C, high humidity) allow rapid development of parasitic nematodes during most of the year (about one week from the egg to the infective larva). The high stocking rate allowed by the forage production (up to 100 goats of 15 to 20 kg per ha), results in a high level of recontamination. Routine administration of anthelmintic drugs has led the selection of parasite populations resistant to most drugs used. The sustainability of small ruminant therefore requires the adoption of integrated control methods designed to reduce the probability of parasite development at every stage of their life cycle. This reduction may be achieved by a combination of: 1) reducing the rate of installation and reproduction of adult worms through the selection of resistant hosts, a food protein supply meeting the animal needs, the use of anthelmintic properties of forage resources; 2) decreasing the level of infestation of pastures through the reduction of the hatching and development rate of free-living stages of parasites, the design of the rotational grazing according to the survival duration of infective larvae, the association of herbivores susceptible to different parasites and; 3) preserving the efficacy of latest available anthelmintics through targeted drenching (i.e. FAMACHA© method) coupled with comprehensive management of pest populations (weaned and adult small ruminants grazing the same paddocks in a "leader-follower" design). These methods should be adapted to each farmer constraints. Their interest will be illustrated by some examples.

Keywords: Gastrointestinal nematodes, sheep, goat, cattle, targeted drenching, grazing design, mixed grazing

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SUPPLY AND AVAILABILITY OF FISHERY WASTE IN TRINIDAD, WITH POTENTIAL FOR USE AS A LIVESTOCK FEED RESOURCE

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ABSTRACT: This study was designed to characterize the fishery waste generated from fishing activities in Trinidad. The fishery waste was separated into two categories; fish waste (FW) and waste fish (WF). Fish waste referred to the viscera, head, tails and skins that would be discarded from a fish upon fabrication. Fish waste data for eight fish landing sites in Trinidad were analyzed for the period 2004-2008. Waste fish refers to the commercial or low value fish caught by the trawl fishery. Waste fish data from all trawling sites across Trinidad was also analyzed for the period 2004-2008. All data was subject to a General Linear Model procedure using Minitab 15 software with year, month, site and fish species as the main effects of the model where applicable. FW data showed no significant yearly variations ($p>0.05$) with an average of 18.6 tonnes per year. It was found that FW varied significantly by the interactive effects of site and species ($p<0.05$), such that the Moruga site generated the largest amount of waste from shark. Shark was the greatest contributor to FW with approximately 50% waste for all landed weight. WF showed a significant increase in 2008 ($p< 0.05$) of 160 tonnes, when compared to previous years. No significant monthly variations in the quantity of WF generated was found ($p>0.05$). It was concluded that the use of WF as a potential livestock feed resource in Trinidad was applicable based on the year round supply observed. FW also presented the opportunity for use but only at selected landing sites where the quantity of waste generated was high. As such, further research is required to assess the nutrient composition of both FW and WF from commercial fish species. The use of these resources as a feed ingredient for livestock can be sustained based on the supply.

Keywords: Fish waste, waste fish, trawl fishery, feed resource