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OVERVIEW OF RESEARCH ON INVASIVE SPECIES IN THE CARIBBEAN

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ABSTRACT: Invasive species are a serious constraint to agriculture in the Caribbean and global movement of people and goods has increased the incidence of exotic invasives. This problem was recognised by the Caribbean Food Crops Society (CFCS) in 2003, when the society organised a special one-day seminar entitled "Challenges and Opportunities in Protecting the Caribbean, Latin America and the United States from Invasive Species". Since 2003, invasive species have remained at the forefront of CFCS meetings with special invasive species seminars or sessions being scheduled at all but one of the 10 annual meetings from 2003 to 2012. The proceedings for the CFCS meetings for the years 2003-2011 were examined for papers reporting research on invasive species; the programme of abstracts for 2012 was also examined. The total number of presentations at CFCS annual meetings from 2003 to 2012 is 1,111; of these, 231 (20.8%) are on invasive species research. For the period 2003 to 2007 this study lists all the invasive species on which research was reported at CFCS meetings. For the period 2008 to 2012; besides listing the invasives on which research was reported, the countries of study are identified. Also in 2008, 2009, 2010 and 2011 there were several presentations listing invasives of concern or importance. These lists are reproduced here. During the 2003 to 2007 period the three invasives which appear to have captured the most research efforts were Bacterial Wilt, Chilli Thrips and Pink Hibiscus Mealybug. From 2008 to 2012 research efforts on invasive species appear to have stepped up to an even higher level with the following seven receiving the most attention: Black Sigatoka, Chilli Thrips, Citrus Greening, Coffee Berry Borer, Fruit flies, Fusarium Wilt and Red Palm Mite.

Keywords: Caribbean Food Crops Society proceedings, agricultural pests and diseases.

INTRODUCTION

There are a number of important constraints which are proving to be obstacles to the need to improve agricultural production in the Caribbean and thus increase the Region's food sovereignty. The need for greater food sovereignty has become more apparant as global food prices have risen sharply over the last five years, a trend which is expected to continue. The English-speaking CARICOM countries now have an annual food import bill of around US$4 billion. The situation is much the same in many of the French-and Spanish-speaking Caribbean countries that rely largely on imports from Europe and mainland America to meet their food requirements.

Most of the constraints to increasing food production are well known. Climate change, natural disasters, praedial larceny and labour intensive systems are all serious obstacles. Just as serious, if not moreso, are the losses of production due to pests and diseases, many of which are caused by invasive species. With the world now quite literally a global village, movement of people and goods has brought renewed problems and exotic invasives, lacking natural enemies in the local environments, are often extremely disruptive to food plants and animals.
Unlike some of the other constraints to food production, pests and diseases caused by invasives require research efforts by regional agricultural scientists. Recognising this, the Caribbean Food

Crops Society (CFCS) brought the issue of invasive species to the fore in 2003. In that year, at the 39th Annual Meeting of the CFCS in Grenada, the University of Florida organised a one-day seminar entitled "Challenges and Opportunities in Protecting the Caribbean, Latin America and the United States from Invasive Species". At this seminar a number of research papers were presented on efforts to contain pests and diseases caused by invasive species. At most of the Annual Meetings since 2003, the CFCS has had at least one session (usually a full day) devoted to invasive species; this year 2012, the 48th Annual Meeting of CFCS is the 10th meeting (including the Grenada meeting) since the Society brought the issue of Invasive Species to the fore. In this time most of the work in the Caribbean on Invasive Species has been presented in either oral or poster form at the CFCS Annual Meetings.

METHODOLOGY OF THE OVERVIEW

The proceedings of the CFCS Annual Meetings for the years 2003 to 2011 (Caribbean Food Crops Society 2003, 2004, 2005, 2006, 2007, 2008, 2009, 2010, 2011) were all examined for presentations on invasive species. Also examined was the Programme and Abstracts for the 2012 Caribbean Food Crops Society Annual Meeting. These examinations attempted to identify the total number of presentations at these meetings, the number of these presentations which were on invasive species and the number of the invasive species presentations which were research presentations. The definitions of 'presentation', 'invasive species presentation' and 'invasive species research presentation' are not straightforward and the numbers of each identified must necessarily be somewhat subjective and another author doing a similar study may not come up with the exact number found in this study. An attempt to define these three terms follows.

Presentation

This includes both oral and poster methods of delivery. Items in the proceedings (full presentation and abstract only) and items listed for delivery in 2012 were defined as presentations with the exception of panel discussions and welcome and opening remarks at the start of the meetings or at the start of special sessions. The contributions of feature speakers were also not usually defined as a presentation unless the speaker gave a scientific type presentation.

Invasive species presentation

This is a subset of the total number of presentations; those which related to invasive species. However, it was certainly not easy to determine whether a pest or disease is 'invasive'. Even some of the CFCS sessions devoted to invasive species included papers on observation or control of what may not actually be 'invasive'. The following criteria were decided upon:

- Any insect or other animal attacking a crop or farm animal was considered invasive
- Weeds were considered invasive if they were defined as such even if they were not affecting agricultural production
- Animals were considered invasive if they were defined as such even if not affecting agricultural production
- Marine and aquatic invasives if they were defined as such (including marine and aquatic plants)
- Nematodes were usually not considered invasive unless defined as such

- Thrips were usually considered invasive unless specifically identified as native.

Invasive species research presentation

This is a subset of invasive species presentations. It was found to be easier to define what was 'not research' and any presentation which was not identified as 'not research' was considered to be a research presentation. Usually these were considered as 'not research':

- Strategies for management of invasives, including safeguarding measures
- Surveillance, unless research on a surveillance methodology
- Listing or cataloguing of invasives
- Training or technical assistance initiatives
- Diagnostic and identification tasks
- Information systems
- Progress reports on projects/activities
- Pest status reports
- Reports on research efforts
- Risks analysis
- 'How to' guides
- Methods of spread
- Identification of threats.

ANALYSIS

Using the above definitions, Table 1 indicates the number of presentations, invasive species presentations and invasives species research presentations for all CFCS meetings during 2003-2012. Table 1 also indicates whether there was an invasive species symposium or session at the meetings. Under the above definitions there were 1,111 presentations at the CFCS between 2003 and 2012, of which 231 (20.8%) were identified as 'invasive species research presentations'. Attempts were made to identify all the invasives in these 231 presentations. This was sometimes quite a difficult task as some presentations identified the invasive not as the causal agent, but as the symptom or disease (e.g. anthracnose, wilt, rot). The lists of invasives identified were broken into two 5-year periods, 2003 to 2007 and 2008 to 2012. For the first 5-year period (2003 to 2007) the country of research was not identified. For the second 5-year period (2008 to 2012) attempts were made to identify the countries of the research which were reported in the papers.

As it is easier to define a common name from a scientific name rather than vice versa, common names are used in the summary tables that follow. It should be mentioned, however, that language differences caused problems, particularly as the scientific names were not always given.

Table 1 CFCS meetings since 2003: location, number of presentations, number of presentations on invasive species and number of presentations on invasive species research.

Year	Country	Invasive species session	No of presentations	No of presentations on invasives	No of these research
2003	Grenada	Yes	77	33	21
2004	US Virgin Islands	No	72	17	6
2005	Guadeloupe	Yes	126	44	22
2006	Puerto Rico +	Yes	142	60	44
2007	Costa Rica	Yes ++	98	23	18
2008	Florida, USA	Yes	156	58	32
2009	St Kitts	Yes	85	30	19
2010	Dominican Republic	Yes	155	36	26
2011	Barbados	Yes	110	27	22
2012	Cancun, Mexico	Yes ++	90	23	21
Total			1,111	351 (31.6%)	231 (20.8%)

+ Data do not include the presentations at the West Indies Agricultural Economics Conference held jointly with CFCS

++ Invasives species session was not a full day.

Invasives situated at CFCS meetings between 2003 and 2007

Table 2 identifies the invasives which were researched as reported in CFCS presentations from 2003 to 2007. From the initial invasive species symposium in Grenada, 13 researched invasives are listed. At the 2004 meeting in the U.S. Virgin Islands, the CFCS did not schedule a special invasive species session, research studies were on eight invasives; this number rose to 13 in 2005 and to 23 in 2006, a meeting which had a total of 142 presentations, the highest number during the 2003 to 2007 period. In 2007 the number of invasives studied was 13.

Table 2. Lists of invasives identified in invasive species research presentations at CFCS Annual Meetings from 2003 to 2007.

Years	Invasive species	Years	Invasive species
2003	Amblyomma Tick	**2006**	Anthracnose
	Asian Pigeon Pea Pod Fly		Bacterial Leaf Spot
	Bacteria Root Rot		Bacterial Wilt
	Bacteria Wilt		Banana Leaf Borer
	Coffee Berry Borer		Black Sigatoka
	Exotic termites and ants		Chilli Thrips
	Lobate Lac Scale Insect		Citrus Blackfly
	Mole Cricket		Coffee Leaf Miner
	Papaya Mealybug		Cycad Scale
	Pink Hibiscus Mealy Bug		Fruit flies (including W.I. fruit fly)
	Poinsetia Root Rot		Invasive weeds
	Sugarcane Moth Borer		Lethal Yellowing
	Yam Anthracnose		Melon Thrips
			Mites
2004	Bacterial Cranker		Mole Cricket
	Banana Crown Rot Thrips		Nutsedge
	Chilli Thrips		Pigeon Pea Pod Fly
	Coffee Berry Borer		Pink Hibiscus Mealybug
	Melon Thrips		Potato Blight
	Palm Leaf Skeletonisers		Powdery Mildew
	Pink Hibiscus Mealybug		Watergrass
	Rats		White Grub
2005	Ants	**2007**	Black Sigatoka
	Armoured Scale		Bovine Dematophilus
	Bacterial Leaf Spot		Bovine Tuberculosis
	Bacterial Wilt		Chilli Thrips
	Cactus Moth		Classical Swine Fever
	Fruit flies		Coffee Leaf Minor
	Leaf Blight		Cucumber Mosaic Virus
	Mole Cricket		Fruit flies
	Snails and slugs		Itch Grass
	Sweet Potato Grub		Invasive weeds
	Thrips(including Chilli Thrips and Western Flower Thrips)		Potato Y Virus
			Red Palm Mite
	Whitefly		Sweet Potato Weevil

Invasives studied at CFCS meetings between 2008 and 2012

From 2008 onwards many presentations listed what were considered 'important' invasives. Although most of these presentations were not classified as research presentations, these lists are reproduced here as a comparison between what were identified as 'important' invasives and what invasives were being researched.

At the Florida CFCS meeting, Roberts (2008) listed what she considered as 19 important invasives in the Caribbean and Wicher et al. (2008) of CIRAD listed five important invasives to the French Caribbean. These lists are reproduced in Table 3, along with a list of invasives studied in the invasive species research presentations, together with the country of that research; there were 25 invasives researched.

The number of presentations in St. Kitts at the CFCS meeting in 2009 was much less than in 2008 with a consequent reduction in number of invasives researched. The 13 which were named in research presentations are listed in Table 4; this table also lists the important recent invasives according to IICA (Thomas, 2009); important invasives and major threats listed by CARIBVET (Trotman, 2009) and the working groups set up by the Caribbean Plant Health Directors (Fortune, 2009).

Table 3. Important invasives according to Roberts and Wicher et al. and invasive species research presentations at the CFCS Annual Meeting, 2008.

Important invasives according to		**Invasives researched**	
Roberts	**Wicher et al. (French Caribbean)**	**Pest/invasive**	**Country of research**
Avocado Laurel Witt	Black Sigatoka	Avocado Root Rot	Dominican Republic
Banana Streak Virus	Fruit flies	Basil Downey Mildew	Florida, USA
Black Sigatoka	Lethal Yellowing	Black Sigatoka	Puerto Rico
Cattle ticks	Moko	Broad Mite and White Fly on pepper and eggplant	Florida, USA
Chilli Thrips	Sugarcane Yellow Leaf Curl	Chilli Thrips	Florida, USA
Citrus Root Weevil		Citrus Tristeza Virus	Dominican Republic
Coffee Berry Borer		*Cladosporium tenuissimum* (fungus on taro)	Puerto Rico
Cucurbit viruses		Cogongrass	Florida, USA
Elephant Grass		Coffee Berry Borer	Dominican Republic
Giant African Snail		Coffee Leaf Minor	Puerto Rico
Imported Ornamental Clams		Corn Silk Fly	Florida, USA
Mexican Bromeliad Weevil		Downy Mildew (watermelon)	Dominican Republic
Orange Rust of sugar cane		Erythrina Gall Wasp	Florida, USA
Para Grass		Giant African Snail	Barbados
Passionvine Mealybug		Melon Thrips	Florida, USA
Pepper Bacterial Spot		Northern Corn Leaf Blight	Florida, USA
Red Palm Mite		Nutsedge	Florida, USA
Silverleaf Whitefly		Red Palm Mite	Jamaica; Trinidad; USA
Tomato Late Blight		Parasites in goats	Florida, USA
		Phytophthora Blight	Florida, USA
		Phytophthora Root Rot	Florida, USA
		Red Hibiscus Mealy Bug	Jamaica
		Proba distant, plant bug	Florida, USA
		Squash Vein Yellowing	Florida, USA
		Tomato Yellow Leaf Curl Virus	Florida, USA

Table 4. Important invasives according to IICA; important invasives and major threats according to CARIBVET; working groups set up by Caribbean Plant Health Directors and invasive species research presentations as reported at the CFCS Annual Meeting 2009.

IICA	CARIBVET		Caribbean Plant Health Directors
Important recent invasives	**Important invasives**	**Major threats**	**Working Groups**
Black Sigatoka	Avian Influenza	Foot and Mouth Disease	Giant African Snail
Classical Swine Fever	Bovine Tuberculosis	Mad Cow Disease	Palm Pests (including Red Palm Mite)
Giant African Snail	Brucellosis		Tephritid Fruit Flies
Lethal Yellowing	Classical Swine Fever		
Lime Swallow Tail Butterfly	Leptospirosis and Rabies		
Lionfish	Tropical Bont Tick		
Low Pathogenic Avian Influenza	West Nile Virus		
Moko			
Pink Hibiscus Mealybug			
Red Palm Mite			

Invasives researched	
Pest/invasive/disease	Country of research
Ambrosia Beetle	Florida, USA
Chilli Trips	Florida, USA
Citrus Root Weevil	Puerto Rico
Foliar diseases in bitter gourd	Dominican Republic
Fungi on exotic tropical fruits	Puerto Rico
Fungi on mango	Puerto Rico
Passionvine Mealybug	Trinidad
Red Palm Mite	Trinidad
Rice Blast Disease	Guyana
Sweet Potato Weevil	St Kitts
Taro Leaf Blight	Puerto Rico
Trunk Girdling Larva	Belize
Uredosporas on frangipani	Puerto Rico

In 2010 the CFCS Annual Meeting was provided with a list of important animal diseases in Haiti (Gongora, 2010). This list is reproduced in Table 5, together with the 16 invasive problems presented in invasive species research papers at that meeting.

In 2011, Serra et al. (2011) gave a long list of recent invasives and new threats to agriculture; there were also invasive concerns of CARIBVET (Trotman, 2011), the Global Environment Forum (GEF)/CABI Marine Invasive Alien Species project (Budoo, 2011), USDA/APHIS in the Greater Caribbean Safeguarding Initiative (Lemly, 2011) and a list of major virus diseases of banana (Lockhart, 2011). Krauss (2011) identified a number of important, and not desirable, human induced invasives; most of which were connected to pets for humans. Table 6 lists all of these invasives and threats as well as detailing the 17 invasives researched in the CFCS Annual Meeting's invasive species research presentations.

This paper was written before the Proceedings of the 2012 CFCS Annual Meeting were available, but an examination of the programme of abstracts suggested research on 16 invasives were to be

presented. These are listed in Table 7. However, it should be noted that sometimes presentations in the programme of abstracts do not always appear in the final proceedings, usually because the presenter did not attend the meeting. Thus the 2012 list does not necessarily so accurately reflect the presentations as the lists for earlier years.

Table 5. Important animal diseases in Haiti and invasive species research presentations as reported at CFCS Annual Meeting, 2010.

Important animal diseases in Haiti (Gongora)	**Invasives researched**	
	Pest/invasive	**Country of research**
Anthrax	Anthracnose in mango	Dominican Republic
Avian and Swine Influenza	Anthracnose in pigeon pea	Dominican Republic
Classical Swine Fever	Asian Citrus Psyllid	Florida, USA
External and internal parasites	Avocado Laurel Wilt	Florida, USA
Gumboro Disease	Black Sigatoka	Dominican Republic
Newcastle Disease	Citrus Greening	Brazil; Belize; Dominican Republic and Florida, USA
Rabies		
Teschovirus encephalomyelitis	Citrus Leprosis	Jamaica
	Coffee Berry Borer	Puerto Rico
	Coffee Leaf Minor	Dominican Republic
	Frosty Pod Rot (identified as a risk)	St. Lucia
	Fruit fly in citrus	Puerto Rico
	Fusarium Wilt	Dominican Republic
	Giant African Snail	Trinidad
	Orange Rust of Sugar Cane	Florida, USA
	Red Palm Weevil	Florida, USA
	Sweet Potato Weevil	Dominican Republic

Table 6.Lists of invasives and threats and invasive species research presentations as reported at CFCS Annual Meeting, 2011

Invasive concern/threats		Invasive researched	
Invasive	**Listed by**	**Pest/disease/invasive**	**Country of research**
New World Screenworm	CARIBVET (Trotman)	Aquatic weeds	Florida, USA (identified 33 'major' and 32 'minor' invaders)
Lionfish	GEF/CABI (Budoo)		
Aquarium algae	Krauss *		
Cats	Krauss	Black Sigatoka	Guadeloupe; Martinique
Dogs	Krauss	Chilli Thrips	Florida, USA
Rats	Krauss	Citrus Greening	Jamaica
Red Eared Slider	Krauss	Eumusae Leafspot	Guadeloupe; Martinique
Water Thyme	Krauss	Frosty Pod Rot (surveillance)	Trinidad
Banana Bracht Mosaic Virus	Lockhart +	Fruit flies	All Caribbean
Banana Bunchy Top Virus	Lockhart	Fruit rot diseases on pepper	Guyana
Banana Mild Mosaic Virus	Lockhart	Fusarium Wilt (Panama Disease)	Florida, USA
Banana Streak Virus	Lockhart	Lionfish	Bahamas
Cucumber Mosaic Virus	Lockhart	Moko Disease	Jamaica
Anthracnose of pigeon pea	Serra	Palm diseases (Fusarium Wilt)	Florida, USA
Bacterial Panicle Blight	Serra	Lethal Yellowing, Texas Phoenix Palm Decline)	
Bean Common Necrotic Mosaic Virus	Serra	Red Palm Mite	Trinidad
Brown Leaf Spot	Serra	Red Stomach Worm	Guadeloupe
Citrus Greening	Serra	Scales and whiteflies (Croton Scale, Ficus Whitefly, Rugose Spiralling Whitefly)	Florida, USA
Citrus Tristeza Virus	Serra		
Citrus Viroids	Serra		
Fusarium oxysporium (wilt)	Serra	Thrips on yard long beans	Dominican Republic
Gummosis	Serra	Tropical Bont Tick	All Caribbean
Lethal Yellowing	Serra		
Mango Leafhopper	Serra		
Pepper Weevil	Serra		
Pests on ficus	Serra		
Pigeon Pea Pod Fly	Serra		
Passionvine and Coffee Mealybugs	Serra		
Red Palm Mite	Serra		
Stackburn Disease	Serra		
Taro Leaf Blight	Serra		
Anastrepha grandis	USDA/APHIS (Lemly)		
Cotton Seed Bug	USDA/APHIS (Lemly)		
Fruit flies	USDA/APHIS (Lemly)		
Lepidoptera	USDA/APHIS (Lemly)		
Red Palm Weevil	USDA/APHIS (Lemly)		
Tuta absoluta	USDA/APHIS (Lemly)		

* Krauss was reporting on human-introduced invasives

\+ Lockhart was reporting on major virus diseases of banana invasive research

Table 7. List of invasives included in the invasive species research presentations at the 2012 CFCS Annual Meeting according to the programme of abstracts

Pest/invasive researched	Country of research
Black Sigatoka	Tobago
Cauliflower Mosaic Virus	United States Virgin Islands
Citrus Canker	Florida, USA
Citrus Greening	Belize; Florida, USA and Puerto Rico
Coffee Berry Borer	Puerto Rico
Corbisculea flumina (a clam)	Puerto Rico
Invasive anthropods	Puerto Rico
Mexican Bromeliad Weevil	Florida, USA
Mimosa pellita and *Melaleuca quinquenervia*	Puerto Rico
Mulato Grass	Florida, USA
Papaya Mosaic Virus	United States Virgin Islands
Papaya Ring Spot Virus	United States Virgin Islands
Parasites in goats	Florida, USA
Pepper Weevil	Florida, USA
Red Palm Mite	Florida, USA and Trinidad
Thatching Grass *	Puerto Rico

* Thatching Grass was described as a useful invasive

CONCLUSION

The lists presented give some indication of the concerns and threats posed by Invasive Species over the last decade. Although there have not been comparative studies on the economic losses caused by invasives, these almost certainly are a very significant percentage of production costs for agriculture. There are also environmental and social concerns and losses to marine interests.

Perhaps during 2003 to 2007 the following three invasives captured the most research efforts: Bacterial Wilt, Chilli Thrips, Pink Hibiscus Mealybug.

From 2008 to 2012, research efforts probably stepped up to an even higher level with the seven following invasives receiving the most attention: Black Sigatoka, Chilli Thrips, Citrus Greening, Coffee Berry Borer, Fruit flies, Fusarium Wilt, Red Palm Mite.

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