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RESEARCH EFFORTS TO DEAL WITH INVASIVE SPECIES IN THE CARICOM REGION

Dionne O Clarke-Harris[1] *and F. Bruce Lauckner*[2]. [1] *Caribbean Agricultural Research and Development Institute PO Box 113, University P.O. Mona Kingston7 Jamaica W. I.,* [2] *Headquarters, Caribbean Agricultural Research and Development Institute, University of the West Indies, St Augustine Campus, Trinidad and Tobago W. I.*

ABSTRACT: The issue of invasive species has long been a challenge to the Caribbean but has been amplified in recent times as the movement of goods and people increases. These species have threatened the region, with potentially devastating effects on agriculture and other economic activities and also biodiversity. The strategy to meet this challenge must be multifaceted, as the issue is complex, involving not only completely differing species/taxonomic groups but also different ecosystems and locations which are influenced by varying human actions. In a report prepared by CAB International, a total of 552 exotic and 446 naturalised and/or native species belonging to 24 groupings (trees and insects, 399 and 135 species respectively, being the largest groups) have been reported in the region. A shortlist of 23 major invasive species threats was presented as those occurring in five or more (up to 16 countries for some species) Caribbean countries. Research is a pivotal component of any developed strategy to tackle any type of invasive. Although the majority of reported invasive species in the region are not agricultural pests, for the purposes of this paper, only species relevant to agriculture were considered. The two case studies selected; Hibiscus mealybug, a notable success story, and whitefly and whitefly-transmitted geminiviruses, an ongoing challenge, highlight the role, value and limitations of agricultural research interventions in the Caribbean context.

Key Words: exotic species, *Bemisia tabaci*, whitefly-transmitted geminiviruses, Hibiscus mealybug, mongoose

RESUME: Le problème d'espèce invasive a longtemps a été un défi aux Antilles mais a été amplifié dans les temps récents comme le mouvement d'augmentations d'articles et gens. Ces espèce a menacé la région, avec dévastant potentiellement des effets sur l'agriculture et les autres activités économiques et aussi la diversité biologique. La stratégie pour rencontrer ce défi doit être à multiples facettes, comme le problème est complexe, impliquant non seulement différant complètement des groupes espèce/taxinomiques mais des écosystèmes et les emplacements aussi différents qui sont influencés en variant des actions humaines. Dans un rapport préparé par le CAB International, un total de 552 exotique et 446 et/ou naturalisé appartenir d'espèce natal à 24 groupements (les arbres et les insectes, 399 et 135 espèce respectivement, être les plus grands groupes) a été rapporté dans la région. Une liste des candidats de 23 menaces d'espèce invasives majeures a été présentée comme ces arriver dans cinq ou plus (augmente à 16 pays pour quelque espèce) les pays des antilles. La recherche est un composant crucial de stratégie développée pour empoigner n'importe quel type d'invasif. Bien que la majorité d'espèce invasive rapportée dans la région est pestes pas d'agricoles, dans le but de ce papier, cette seulement espèce pertinente à l'agriculture a été considérée. Les deux études de cas ont choisi; mealybug d'Hibiscus, une réussite notables et whitefly et whitefly-transmis geminiviruses, un défi continu, soulignent le rôle, la valeur et les limitations d'interventions de recherche agricoles dans le contexte des antilles.

INTRODUCTION

Invasive species are those whose establishment and spread pose a threat to their ecosystems habitat or other species. These species may be alien or indigenous and invasiveness is usually influenced by environmental differences/changes.

Invasions by non native species of varying taxonomic groups are potential threats to the natural ecosystems and biodiversity of the invaded territory. The adverse effects may range from mild to severe while some non native species may be very beneficial. The routes of entry and spread of non natives are also wide ranging being either deliberate e.g. the well known case of the introduction of the small Indian mongoose, *Herpestes auropunctatus*, first in Jamaica in 1872 for the control of rats in sugarcane fields (Cock 1985) or unintentional (the numerous examples of exotic pests entering on imports). This spectrum of possibilities, in tandem with increasing levels of regional and international trade and travel, is the basis of the tremendous challenge posed by the problem of invasive species (Wittenberg and Cock [eds.] 2001, Kairo et al 2003a).

As a first step, each species has to be assessed to determine not only the potential risk to a given ecosystem but consequent economic impacts/costs in order to decide on the type of action warranted i.e. prevention, eradication or management. A proactive approach which effectively minimizes the entry of alien species or allows for early detection of new entrants before successful establishment and spread will considerably minimize the overall cost of elimination or management. This approach must ideally involve cooperation among different sectors as well as collaboration among countries which are major trading partners and/or inter travel destinations.

THE ROLE OF RESEARCH

At every stage of the overall strategy to address invasive species, is a need for research. Baseline information gathering is probably among the most important research components in dealing with invasives. An inventory of native species is the basis for determining species already present and potential threats. Within each country this activity has to be an ongoing process.

Within the Caribbean in recent years, a number of invasive species have threatened the region, with potentially devastating effects on agriculture and other economic activities and also biodiversity. In a project report to the Nature Conservancy, which was prepared by CAB International (Kairo et al 2003a), a total of 552 exotic and 446 naturalised and/or native species belonging to 24 groupings (trees and insects, 399 and 135 species respectively, being the largest groups) have been reported in the region. A shortlist of 23 major invasive species threats was presented as those occurring in five or more (up to 16 countries for some species) Caribbean countries. This list comprised vertebrates (mammals)-10 species, vertebrates (birds)-2, vertebrates (amphibians), trees- 5, aquatic- 1 and insects- 4. The project reported on was a first attempt at collating and synthesizing information on threats posed by invasive species in the insular Caribbean (Kairo et al 2003b).

Research is also critical to the development of appropriate management strategies to deal with identified threats. The five main strategies for dealing with important invasive species are prevention, eradication, containment, control and mitigation and there are basic guidelines for deciding which of these approaches to pursue. Prevention is the most desirable (Wittenberg and Cock [eds.] 2001, Kairo et al 2003 a and b). In the event that prevention measures fail, eradication is the next step if considered feasible. Containment seeks to confine an organism to a designated geographical area and its introduction to other areas is prevented by managing the borders of the designated area. The very familiar option of management can be very costly but is undertaken if the alien species has become established and has gained ground. Available technology is evaluated and suitable options selected to reduce the density and abundance of the pest population below an economic threshold. To determine the success of any programme it is necessary to constantly monitor the system to assess whether targets are met or to detect any unforeseen adverse effects and implement measures to correct for these.

In the Caribbean, there are many examples where the various approaches described above have been used to varying levels of success against invasive species. Although Kairo 2003b expounded that the problem of invasive alien species is broader than the obvious examples and issues associated with species with adverse effects on agriculture and the authors remain mindful of the other insidious examples which exist and must be addressed, for the purpose of this paper, case studies have been selected to highlight the role played by research in two scenarios which have affected/continue to affect the agricultural sector in the CARICOM region. These examples depict the capabilities and limitations within the region for dealing with challenges posed by invasive species and the need for gap analyses and increased regional cooperation to share costs associated with tackling common problems and threats.

Some examples of invasive species that have entered/reemerged and become an established menace to the region's agriculture include the Hibiscus mealybug, *Maconellicoccus hirsutus* (Green); *Thrips palmi* Karny; *Bemisia tabaci* (Gennadius) (B biotype); Citrus leafminer, *Phyllocnistis citrella* Stainton; Citrus blackfly, *Aleurocanthus woglumi* Ashby; imported red fire ant *Solenopsis invicta* Buren; Paracoccus marginatus Williams and Granara de Willink, coconut whitefly, *Aleurodicus pulvinatus,* and the tropical bont tick, *Amblyomma variegatum* (Kairo et al 2003a).

The Hibiscus Mealybug. The Hibiscus (Pink) mealybug (HMB), *M hirsutus*, which originated in Asia was found in Grenada in 1994. The pest was later reported in Trinidad, St Kitts and St Lucia (Parasram 1996). Kairo et al 2003b presented a list of 12 CARICOM territories (a total of 28 Caribbean territories) reportedly having the pest, as at 2003.

The consequent damage caused by the invasion of this pest was unprecedented, and its wide host range virtually made it a threat to the entire agricultural industry of affected countries. The hosts included ornamentals (hibiscus being primary), agricultural crops (e.g. cacao, okra, mango, plums, sorrel, soursop, *Annona muricata*), trees such as samaan, teak and blue mahoe.

Gautam et al (2000) reported that crop losses in Grenada ranged from US$1.77 million-US$ 1.83 million per annum between 1995and 1997. In Trinidad, which was affected later (August 1995) potential losses estimated by the Planning Division of the Ministry of Agriculture were US $125 million with over 200 plant species affected (Parasram 1996 and Gautam et al 2000). The initial approach to combating Hibiscus mealybug consisted of control (chemical and cultural), containment and public awareness campaigns. The countries in the Caribbean which were not yet affected heightened quarantine measures and developed emergency action plans in the event that this pest gained entry. However despite efforts at prevention the pest continued to spread.

The control measures initially recommended, failed to provide long-term results (Gautam 1996 and McComie 1996) therefore, in 1995 the Regional Action Programme was developed which had a biologically-based management focus (Parasram 1996 and Gautam, 1996). Other components were chemical control measures in infested areas and development of information products for public awareness. The Caribbean Agricultural Research and Development Institute (CARDI) identified an expert from the Indian Agricultural Research Institute (IARI), New Delhi, India (Gautam 1996 and Blades *in* Guatam et al 2000). In India and Egypt, Hibiscus mealybug had been controlled using biological control agents, namely, ladybird beetles, *Cryptolaemus montrouzieri* Mulsant, *Scymnus coccivora* Aiyar and parasitic wasps *Anagyrus kamali* Moursi.

and *A. dactylopi* (How.) and some 40 parasitoids and predators including another ladybird, *Nephus regularis* were known to reduce Hibiscus mealybug numbers in the field.

A programme was developed for the introduction, multiplication and release of three lady bird beetles, *C. montrouzieri* , *S. coccivora* and *N. regularis*. These ladybirds were imported into the region in 1996. Supporting research components included study of local natural enemies, monitoring for establishment and subsequent impact on the pest, development of rearing protocols and determination of costs of production (Gautam 1996, Gautam et al 1996a and 1996b).

The parasitoid *A kamali* was also imported into Trinidad, first arriving in February 1996. Studies on this biological control agent and mass rearing were conducted by the International Institute of Biological Control- Caribbean and Latin American Station (IIBC-CLAS) named CAB International (CABI) and the Ministry of Agriculture, Land and Marine Resources Division (MALMR). The studies included evaluation of host plants for laboratory rearing Hibiscus mealybug, field releases and monitoring and evaluation of efficacy (Lopez 1996, Morias 1996, Peterkin et al 1996 and Ram et al 1996). Under a Memorandum of Understanding signed by CARDI and CABI, these parasitoids were reared by CABI and CARDI implemented field activities using these agents in CARDI member countries (Parasram 1996). Although the use of biological control has been a success in all countries in which it has been used against the Hibiscus mealybug, research is still required to ensure that the biologically-based management system can be integrated into all situations especially where other major pests have to be managed concurrently (Kairo 1996).

Despite the resounding success of the biological control initiative in managing the population of Hibiscus mealybug in affected countries, intra regional trade remained constrained as unaffected countries fearful of the entry of the pest on produce and even countries which already had the pest, restricted entry of produce from affected countries in an effort to prevent/contain the problem. CARDI was again mandated to provide the leadership to address this problem. Through adaptive research activities on various post harvest technologies (hot water treatment, fumigation with methyl bromide/magnesium phosphide), post harvest treatment protocols were developed for flowers, fruit and vegetables, the main commodities in intra regional trade (Gautam et al 2000).

Whitefly and Whitefly-transmitted Geminiviruses. There are more than 1200 species of whitefly identified and although feeding damage caused by the insects can be significant it is the ability of some species to vector economically important plant viruses that has resulted in the notoriety of this group of insects. Only three vector species, namely, *Trialeurodes abutilonea* (Haldeman), *T. vaporariorum* (Westwood) and *Bemisia tabaci* (Gennadius) are known to occur in the Caribbean and Central America. Some of the associated diseases recorded in the Caribbean basin include Abutilo mosaic, bean golden mosaic, Euphorbia mosaic, Jacquimontia mosaic, Macroptilium mosaic, Rhyncosia yellow mosaic, Sida mosaic, tobacco leaf curl, tomato yellow mosaic (Brown and Bird 1992) tomato yellow leaf curl, tomato dwarf leaf curl and potato yellow mosaic (CARDI 2003).

B. tabaci is probably the most challenging and has invaded territories throughout the Americas and the Caribbean. In addition to its wide distribution it can colonise a wide range of hosts which compounds the challenge to effectively manage it. *B. tabaci* can colonise as many as 500 species of plants. In Latin America and the Caribbean, *B. tabaci* is a pest of at least 17 crops both as a vector of geminiviruses and/or as a direct pest (Brown 1992). In a priority setting exercise, whitefly and whitefly-transmitted geminiviruses was identified as a priority, common to 13 of 16 member countries of PROCICARIBE Caribbean Integrated Pest Management Network (CIPMNET).

Various aspects of this pest complex and its management have been actively researched by countries throughout the region. In 2002, CARDI was contracted under the EU-CARIFORUM Integrated Pest Management Project to conduct an information gathering exercise which would compile the pockets of information on past and current research activities within the region on whitefly and whitefly-transmitted geminiviruses. This was in response to the identification that information sharing amongst researchers within the region was a shortcoming which forfeits the benefits of collaborative research on common issues. An analysis of the inventory of activities also facilitated gap analysis which could guide the planning of future research to address existing needs.

The areas in which research efforts have been most sustained throughout the region are vector/virus characterization and distribution, inventory of host range, screening for host plant resistance and biological control. In Jamaica there has been some work done on transgenics (tomato). The use of molecular biological techniques to keep abreast of the very dynamic and complex vector/virus relationship has probably been the area where the most significant strides have been made. However, the inventory indicated that much of the required component research has at least been initiated by some country in the Caribbean. The matrix in Appendix 1 indicates the research areas undertaken in 19 (CARICOM countries and other selected countries) in the Caribbean (CARDI 2003).

LIMITATIONS IN THE STRATEGY FOR INVASIVE SPECIES IN THE CARIBBEAN

Kairo et al (2003 b) evaluated the infrastructure used in invasive species management in the Caribbean and listed deficiencies in the following as key limitations

- Early detection systems
- Control and management to coordinate the ongoing efforts with local, regional and international authorities to minimize the adverse effects of existing invasives and restrict their spread.
- Research and monitoring – which require investment in the development of effective and environmentally sound control technologies, human resources (biologists) and other tools needed to ensure long-term success

As demonstrated in the foregoing case studies, there are programmes that contain varying combinations of the above elements however there are gaps which reduce their potential impact.

The model used for addressing the emergent Hibiscus Mealybug, demonstrated the benefits of multi-agency involvement and regional coordination. The regional coordinating mechanism facilitated the implementation of the regional programme while providing support to national efforts in technical and financial areas. The threat to newly invaded countries declined drastically as the region now had a readily available technology and an efficient emergency response mechanism. This regional system has in turn been beneficial to the US Virgin Islands, Puerto Rico, Bahamas, California, Florida, Haiti and the Dominican Republic (Meyerdirk and De Chi 2003).

The scattered pieces of work conducted on whitefly and whitefly-transmitted geminiviruses in the region (CARIFORUM countries) is comprised of much of the required component research. Identified gaps include: the need to evaluate an integrated approach to management of whiteflies and whitefly-transmitted viruses; the continuation of investigations in specialized areas of research for virus and vector characterization and diversity given the dynamic nature of the complex; further evaluation of the potential of biological control agents; and development of protocols for the correct use of suitable selective chemicals which are compatible with biological control agents within an IPM system (CARDI 2003).

In addition, there is a need for the goals and objectives of the various national/regional initiatives to be rationalized to form a fully coordinated Regional Whitefly and Whitefly-transmitted Geminiviruses Management Programme with established centres of excellence, this regional approach has been initiated by the countries of Latin America in a plan of action for effecting a strategy for the management of whitefly and whitefly-transmitted geminiviruses. Collaboration on whitefly diagnosis and information flow through information products and an annual regional workshop were also main areas of focus in the Latin American initiative (CARDI 2003).

Adopting a model of strong regional collaboration in the English-speaking Caribbean and where possible forging links with other initiatives in the Caribbean Basin (and internationally) would help optimize the benefits from the limited human and financial resources available to the region.

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Appendix 1. Analysis of research needs regarding whitefly and whitefly-transmitted geminiviruses in the Caribbean

Country	Area of research							
	Characterisation /distribution of whitefly	**Characterisation /distribution of geminiviruses**	**Host range of whitefly**	**Host range of viruses**	**Host plant resistance**	**Cultural practices**	**Biological control**	**Chemical control**
Antigua and Barbuda	-	+	-	+	-	-	-	-
Bahamas	-	-	-	-	-	-	-	-
Barbados	+	++	+	+	-	+	-	+
Belize	-	+	-	+	+	+	-	+
Cuba	-	+	-	+	-	++	++	-
Dominican Republic	+++	+++	+++	+++	++	+++	++	+
Grenada	-	-	-	-	-	-	+	-
Guadeloupe	++	+	+	+	++	-	+	-
Guyana	-	-	-	+	-	-	-	+
Haiti	-	+	-	+	+	+	+	+
Jamaica	+++	+++	+++	+++	+++	+	+	+

KEY

-	No indication that any work was done in this area	++	Significant level of work done in research area
+	Minimal level of work done in research area	+++	High level of work done in research area

Matrix 1 (*Continued*). Analysis of research needs regarding whitefly and whitefly-transmitted geminiviruses in the Caribbean

Country	**Area of research**							
	Characterisation /distribution of whitefly	**Characterisation /distribution of geminiviruses**	**Host range of whitefly**	**Host range of viruses**	**Host plant resistance**	**Cultural practices**	**Biological control**	**Chemical control**
St Kitts and Nevis	-	+	-	+	+	-	+	-
St Lucia	-	-	-	-	-	-	-	-
Martinique	+	+	+	++	-	+	+	+
Puerto Rico	++	++	++	+	+	-	+	-
St Vincent and the Grenadines	-	-	-	-	-	-	-	-
Suriname	-	-	-	-	-	-	+	-
Trinidad and Tobago	++	++	++	++	-	-	++	-

KEY

-	No indication that any work was done in this area	++	Significant level of work done in research area
+	Minimal level of work done in research area	+++	High level of work done in research area