CARIBBEAN FOOD CROPS SOCIETY

49

Forty-ninth Annual Meeting 2013

Port of Spain, Trinidad and Tobago
Vol. XLIX

PROCEEDINGS

OF THE

49TH ANNUAL MEETING

Caribbean Food Crops Society
49TH Annual Meeting
June 30 – July 6, 2013

Hyatt Regency Hotel
Port of Spain, Trinidad and Tobago

"Agribusiness Essential for Food Security: Empowering Youth and Enhancing Quality Products"

Edited
by
Wanda I. Lugo, Héctor L. Santiago, Rohanie Maharaj, and Wilfredo Colón

Published by the Caribbean Food Crops Society

ISSN 95-07-0410

Copies of this publication may be obtained from:

Secretariat CFCS
P.O. Box 40108
San Juan, Puerto Rico, 00940

or from:

CFCS Treasurer
Agricultural Experiment Station
Jardín Botánico Sur
1193 Calle Guayacán
San Juan, Puerto Rico 00936-1118

Proceedings of the Caribbean Food Crops Society. 49:563-574. 2013

CITRUS GREENING OR HUANGLONGBING IN THE CARIBBEAN – FAO's RESPONSE

V. Lopez[1], T. Santivañez[2], L. Myers-Morgan[3], V. Manzanero-Majil[4], and J. Thomas[5].
[1]Food and Agriculture Organization of the United Nations (FAO) Sub-Regional Office for the Caribbean (SLC); [2]FAO Regional Office for Latin America and the Caribbean (RLC); [3]Ministry of Agriculture and Fisheries, Jamaica; [4]Citrus Research and Education Institute (CREI), Citrus Growers Association (CGA), Belize; [5]FAO Representation for Jamaica, Bahamas and Belize

ABSTRACT: Citrus Greening or Huanglongbing (HLB) is a devastating disease of citrus. All varieties are susceptible and there is no known cure for the disease. Trees decline to uneconomic production levels within 1-10 years, depending on tree age. HLB is spreading rapidly in the Americas (Brazil, United States of America, Mexico, Central America, Cuba, Dominican Republic, Jamaica, Belize and most recently, Dominica and Paraguay). The disease is vectored by the Asian Citrus Psyllid, *Diaphorina citri*, which is present in many Caribbean islands and increases the risk of introduction and spread of HLB. Based on a request for support from affected Member States, the Food and Agriculture Organization (FAO) implemented two national projects under its Technical Cooperation Programme (TCP). The first project in Jamaica (October 2010 to March 2013) aimed to build national capacity to effectively respond to the HLB. The second project in Belize (February 2012 to July 2013) complemented ongoing activities to better protect the citrus industry. A third project, at a regional level, covering all the countries of Latin America and the Caribbean and led by the FAO Regional Office for Latin America and the Caribbean (RLC) began implementation in December 2012 with a Meeting of the Committee of Experts. This project was the outcome of a Regional Workshop held in June 2011 in Santiago, Chile, at which FAO was mandated to develop and lead a hemispheric effort for HLB management and networking. Some highlights of the three projects are presented.

Introduction

Citrus Greening or Huanglongbing (HLB) is a devastating disease of citrus (Grafton-Cardwell et al., 2006). Its high socio-economic impact is linked to the fact that all species and varieties of citrus, including those belonging to the closely-related genus *Murraya,* are affected. Furthermore, there is no known cure for HLB, caused by a bacterium that blocks the phloem and prevents the flow of nutrients, resulting in loss of leaves, deformation and early drop of fruits. Trees decline to uneconomic production levels within 1-10 years (depending on tree age) and eventually die. The bacterium, *Candidatus* Liberibacter asiaticus is vectored by *Diaphorina citri*, the Asian citrus psyllid (ACP). In the Western Hemisphere, the ACP and HLB were both first discovered in Brazil, ACP in the 1940s (Costa Lima, 1942) and HLB in 2004 (Texeira *et al.*, 2005). Over the years, both the vector (Halbert and Núñez, 2004) and the disease spread to the major citrus-producing areas of the Americas: Belize, Cuba, Central America, Dominican Republic, Jamaica, Mexico, United States of America (USA) and most

recently (2012), Dominica and Paraguay, and is possibly present in several other countries of the region.

Jamaica and Belize are two countries of the Caribbean where the citrus industry is socially and economically very important and where HLB was discovered in 2009 (IPPC 2010; Manjunath et al., 2010). The estimated value of the industry in Jamaica is about J$4 billion, with 5,460 individuals employed on-farm and 19,500 persons along the value-chain. In Belize, the citrus industry is valued at USD 50 million (the highest of any agri-sector in that country) and supporting the livelihood of 10,000 workers and their families. Both countries had, in recent years, carried out extensive replanting to replace root stocks that were susceptible to Citrus Tristeza Virus (CTV). Many small farmers were still recovering from this costly and time-consuming exercise when their (mostly young) fruit-bearing trees became infected with HLB.

National programmes for HLB management were initiated in both Jamaica and Belize and requests were made to the Food and Agriculture Organization (FAO) for assistance under the Technical Cooperation Programme (TCP) to fill critical gaps. Based on the requests, two national TCP projects were approved: *TCP-JAM-3302 - Assistance to manage Citrus Greening in Jamaica* in October 2010, with implementation between January 2011 and March 2013, and *TCP-BZE-3402 - Assistance to manage Huanglongbing in Belize* in February 2012, with implementation between May 2012 and December 2013.

At a regional consultation held in Chile in June 2011, FAO was given the mandate to provide the necessary coordination for the management of Citrus Greening at the hemispheric level. The project, *TCP-RLA-3401 - Technical Assistance for the Regional Management of Huanglongbing (HLB) in Latin America and the Caribbean* was prepared in response to this mandate and implementation commenced in November 2012.

Results

Activities carried out under the three projects and some of the results are presented below.

Jamaica: TCP-JAM-3302 - Assistance to Manage Citrus Greening in Jamaica

The project was implemented in conjunction with the Ministry of Agriculture and Fisheries (MOAF), in close collaboration with the Jamaica Citrus Protection Agency (JCPA) and the Rural Agricultural Development Authority (RADA). The overall objective was to control the spread of HLB in small farms through coordinated protection, mitigation and resuscitation strategies, resulting in the sustained productivity of orchards. This objective was to be achieved through:

i. development and implementation of an Area-wide Integrated Management Strategy (AIMS), facilitating a cooperative approach to HLB management by geographically-connected farmers;

ii. improved national capability for diagnosis and detection of HLB, through training and upgrade of physical infrastructure;
iii. increased capacity to produce disease-free planting material; and
iv. contribution to the development of a public awareness campaign on HLB.

Development and Implementation of an Area-Wide Integrated Management Strategy

Two expert consultants from Florida (USA) were recruited in April 2011 and conducted activities during three missions (May 2011, February-March 2012 and October 2012). The consultants confirmed HLB's presence throughout the island. The high incidence in the main citrus-producing areas precluded the removal of trees showing disease symptoms. Effective vector control was identified as critical, while horticultural practices, such as foliar nutrient applications, were advised in order to relieve stress and improve growth and yields. It was also recognized that certified nursery stock would eventually need to be made available to assist the replanting of commercial groves.

Management clusters were organized in two key locations in an attempt to facilitate and coordinate vector management and other necessary grove care activities among farmers. The areas were the parish of St. Catherine, which has the largest contiguous citrus plantings, and Clarendon, where the largest grouping of small farmers, representing more than 75 percent of the industry in Jamaica, is based. The JCPA, with support from the R&D Division of the MOAF and RADA, coordinated the formation of the clusters, beginning with the identification of local leadership. A manual on the AIMS Programme was prepared and published, while training of trainers (TOT) workshops were held in an attempt to educate over 100 RADA officers and lead farmers in HLB and psyllid management. Specifically, the topics covered included diagnostics, surveillance, treatment and record-keeping.

A cluster residential programme was designed, requiring soil drenching with nutrients and an insecticide spray, as well as the simultaneous release of the parasitic wasp *T. radiata.* The wasp was expected to provide non-invasive and long-term suppression of psyllid nymphs. This component, however, was only partially implemented due to limited time and resources.

A public awareness programme focusing on commercial production emphasized the need for certified nursery material and concentrated on the potential impact of the disease upon the citrus industry. A flier was designed and distributed in the areas concerned, while a video on the AIMS strategy was published and disseminated widely.

A model plot was established at the Montpelier Research Station to demonstrate long-term psyllid management and improved plant care practices. In addition, a record of current data on citrus acreage and distribution across the island was established. Growers were trained to maintain their logs as a means of assistance for management decisions.

The approach of improving the nutritional status of trees in order to overcome HLB stress resulted in enhanced growth, higher yields and larger fruits during the main production season. In addition, the trees bore smaller but consistent quantities of fruit throughout the year.

Improving Diagnostic and Detection Capability

Under a Letter of Agreement (LOA) signed with the University of the West Indies (UWI), Mona Campus, a total of ten technicians from the MOAF, the JCPA and the private stakeholder Trade Winds Jamaica Limited were trained in August 2011 in molecular diagnostic tools and their use in detecting the causal agent of HLB. The agreement also stipulated the production of a detailed manual on the techniques for detection and diagnosis of HLB covered in the training.

The laboratory facilities at the Post-Entry Quarantine (PEQ) Unit at the Bodles Research Station in St. Catherine were upgraded to allow for a molecular laboratory for screening of the causal agent of HLB. The upgraded facilities and training of officers under the project facilitated the screening of clones of seven citrus varieties.

Increased Capacity to Produce Disease-Free Nursery Material

In February 2012, a consultant from Cuba initiated training in Shoot-Tip Grafting (STG), a technique used internationally to produce clean planting material (Navarro *et al.*, 1975). Further STG training was conducted by another Cuban consultant in June 2012. A total of eleven technicians from the MOAF, the JCPA and Trade Winds participated in and benefitted from this activity.

During the training, seven citrus varieties selected by the industry (Ortanique, Navel Surprise, Local Valencia, Broad Manchester Tangerine, Jamaican Tangelo, Sweet-seeded Grapefruit and West Indian Lime) were successfully shoot-tip grafted, before being re-grafted onto more vigorous rootstock. The finished plant was to be realized within two to three years of the plants being bio-indexed for the seven graft-transmissible diseases. This means that only foundation plants at PEQ are to be used initially to meet industry needs.

In November 2012, two insect-proof model structures – one made for budwood, the other a protected nursery – were designed and erected to demonstrate the production of high quality nursery material. The initial supply of budwood sourced from certified parent trees of various varieties was kept under protected cover at the PEQ Unit since 1997. Plants generated through STG and clean seed source plants, as well as seedlings for use in STG, were also to be stored in this structure. The foundation source trees were tested using the facilities upgraded as part of project activities and found negative for HLB. Budwood collected from the parent trees was used to establish a Quick Multiplication Block (QMB) in the newly-constructed greenhouse at the PEQ Unit.

The demonstration nursery was built as a replica of the budwood facility and located within the property of the West Indies Alumina Company (WINDALCO) in the parish of Manchester. This location was strategically selected for a number of reasons, including its accessibility from either end of the island and the presence in the area of a number of illegal nurseries. In addition, as required by the project, the nursery was managed by a private entity with the resources to provide its own input into project activities.

Twenty participants from across the island, including citrus nursery operators, attended a three-day training workshop in November 2012. An experienced Florida-based nursery operator provided consultancy services under the nursery training component and produced a manual on the methods involved in the production of clean nursery material.

Development of a Public Awareness Campaign

The public education component was central to the project, as it sought to create an awareness of the problem and its management options. This was particularly important, considering that the management of citrus diseases requires collaboration among growers, together with support from the general public and residential owners of citrus plants. Various public relations material was written, edited and designed by the project team in collaboration with various stakeholders. This included a 15-minute educational video, which can be found both on the MOAF Web site and on social media platforms[6]. The video was used extensively at the three TOT workshops and other related activities throughout the country. Material was displayed and distributed at agriculture shows, school functions and farmer training programmes, while a number of articles and interviews appeared in the print and electronic media. Electronic versions of all information products were made available on the MOAF Web site.

Belize: TCP-BZE-3402 - Assistance to Manage Huanglongbing in Belize

The Ministry of Agriculture appointed as national coordinator the Chief Agricultural Officer, who in turn nominated the Director of the Citrus Training and Education Institute (CREI) of the Citrus Growers' Association (CGA) to assist with the technical coordination. The overall objective of the project was to support the development of a citrus industry that was better prepared and coordinated in its response to the disease. This objective was to be achieved through the following key outputs:

i. Establishment of an Area-wide Management Programme, including a review of nursery protocols and training for nursery owners, and support for a biological control programme (parasitoids, indigenous entomopathogens)
ii. Strengthening of HLB diagnostic capacity of the government-appointed laboratory through provision of equipment and materials for providing HLB testing service to farmers and growers
iii. Identification of crop diversification opportunities for former citrus growers and a review of institutional support required for displaced farmers

[6] http://www.youtube.com/watch?v=PeA2mh2GzUw

iv. Recommendations for sustainable funding mechanisms for nursery certification and HLB control programmes
v. Improvement of public awareness and grower education, including posters and brochures for farmers and three training videos

Establishment of an Area-Wide Management Programme for the Psyllid Vector

The three sub-components and activities carried out under each are described below:

Area-Wide Integrated Management System (AIMS)

An experienced consultant from Texas (USA) was recruited to carry out activities in three missions – September 2012, January 2013 and June 2013. The AIMS was developed following the basic principles of area-wide vector control, adapted to meet the needs of local citrus growers. In view of the many challenges facing Belize's citrus producers, an integrated multi-pest control strategy that targeted other key pests and also improved the overall health of citrus trees was considered the best approach. Thus, the program addressed these aspects, together with the production of certified nursery trees. Following extensive grower outreach, the program was launched in October 2012. During the second mission in January 2013, the consultant evaluated progress of the AIMS and put in place specific measures for its improvement. The consultant made recommendations for field monitoring and surveillance to assess HLB impact in the groves, and training for 10 technicians and >300 farmers in ACP control and monitoring.

The third mission reviewed the progress of the amended AIMS. Information was collected on grower participation level and psyllid population levels, grove conditions were evaluated during field visits, and discussed with growers with regard to their personal assessment of the program and its acceptability. An analysis of the field data revealed that psyllid populations declined in most areas where AIMS was implemented. The coordination plan that organized the citrus belt into citrus production management areas (CPMA), with one extension agronomist coordinating each area, worked well to build trust between growers and extension agents, and to meet outreach needs. An overall improvement was noted in most groves, with higher fruit set: this was also acknowledged by many growers, who despite the additional costs involved, expressed willingness to continue with AIMS beyond the end of the project. The key constraints for small growers were the lack of equipment and of financial resources for basic grove care. These results, focusing on the challenges encountered and strategies needed to ensure sustainability at the grower level, were presented to all key stakeholders, including industry leaders.

Nursery Protocols and Training

A citrus nursery production and certification expert from Jamaica was recruited to carry out activities under this sub-component in a two-week Mission (1-15 June 2013). During the first week, the consultant met with key stakeholders and made field visits (groves and nurseries) to determine the impact of HLB, gather information on citri-culture and

identify training needs. The industry's annual demand for certified citrus plants was about 1.6 million, with an annual replacement demand of 700,000. With the discovery of HLB, the number of certified nurseries that were in operation was reduced from 61 to 17. The consultant also analyzed the Belize Citrus Certification Programme (BCCP) and its regulations, reviewing its strengths and weaknesses. Accordingly, the recommendations aimed to strengthen three key areas – the nursery infrastructure and its bio-security, record-keeping and retail nursery regulations. During the second week, the consultant developed and delivered a training course on the production of certified citrus planting material in protected structure to selected industry personnel. The course comprised of a one-day training event wherein detailed presentations on all aspects of the production of certified citrus plants in protected structure were delivered to 33 persons (nursery operators, nursery workers, CGA/CREI technical staff, one member from OIRSA/Taiwan project and a BAHA staff member) including 4 women. The concepts were then re-enforced with real object displays and practical demonstrations.

The consultant produced a Manual *Operating Protocols for Producing Certified, Disease-Free Citrus Plants under Covered Structures in Belize* and a fact-sheet *Mandatory Citrus Certification Programme – Belize*.

Biological Control Programme

The biological control programme under the project targeted parasitoids and indigenous entomopathogens.

As has occurred elsewhere, the parasitoid *Tamarixia radiata* was fortuitously introduced to Belize. The parasitoid was introduced into Reunion (Etienne and Aubert, 1980; Aubert and Quinlici, 1984) for ACP management. Studies on its effectiveness have provided mixed results. The parasitoid was very effective in reducing ACP populations in Reunion and Guadeloupe, but was less so in Florida particularly under cool, dry conditions and in Brazil possibly due to pesticide control regimes (Aubert *et al.*, 1996; Garnier and Bové, 1993; Qureshi et al., 2009; Paiva and Parra, 2012). Laboratory studies suggest that parasitism and host feeding by females account for several hundred ACP nymphs (per female parasitoid) and can result in up to 90% reduction in ACP populations.

In Mexico and southern United States, a number of entomopathogenic fungi have been recorded and studied on ACP, including *Beauvaria bassiana* (and its telemorph, *Cordyceps bassiana*), *Hirsutella citriformis, Isaria fumosorosea, Metarhizium anisopliae* and *M. brunneum* (Gandarilla-Pacheco et al., 2013; Hall et al., 2012; Lezama- Gutiérrez et al., 2012). It is very likely that some or all of these occur in Belize.

Data on the distribution and effectiveness of *T. radiata* and entomopathogenic fungi under Belize conditions is lacking. It is anticipated that augmentative and inundative releases of parasitoids during periods of high ACP activity (e.g. during new flush growth) would be helpful in reducing vector numbers. In addition, biological control is

the only option available to manage ACP populations in abandoned groves and in backyard citrus.

Parasitoids

The mass production and field release of parasitoids was one of the components under the TCP project. This required three separate production areas, for clean plants, psyllid hosts and parasitoids, respectively. Two screenhouses are to be erected under the project for the production of ACP and parasitoids respectively, while an existing screenhouse is being provided by the CGA for the production of clean plants. Training of CREI staff will also be carried out. It is anticipated that mass production and field release of parasitoids will begin before the end of 2013.

Entomopathogens

An expert Insect Pathologist from Florida (USA) was recruited to detect, isolate and identify key ACP pathogens in Belize, evaluate their efficacy under laboratory conditions and support the development of mass production protocols. After a three-week mission, the consultant identified several challenges that needed addressing for successfully implementing such a programme, and this he recommended be done in phases. The first phase would focus on isolating and evaluating the entomopathogens and their occurrence in managed and unmanaged citrus groves. The next phase would involve producing selected isolates on a small scale on rice media and assaying them against healthy psyllids. In the third phase, CREI could either produce or sub-contract the production of promising isolates for field tests. Other recommendations of the consultant included identification and training of staff, procurement of appropriate equipment, production of clean psyllids for testing, and field collection of mycosed psyllids for the isolation and identification of the entomopathogens. A follow-up mission would be planned once all the recommendations had been carried out.

Strengthening HLB Diagnostic Capacity

This component provided for an upgrade of the CGA Laboratory with necessary equipment and materials to improve its capacity to provide detection and diagnostic services to the sector at reduced cost.

Identification of Crop Diversification Opportunities for Former Citrus Growers and a Review of Institutional Support Required for Displaced Farmers

In carrying out activities under this component, an expert consultant and FAO's Marketing Officer analyzed a number of key, relevant areas: production of citrus in Belize, the CGA, the CPBL and processing issues, as well as diversification and (juice) marketing. They reviewed diversification crop possibilities that would be amenable with the existing juicing facilities. It was concluded that the most important thing was to enhance the throughput of the processing factories in order to reduce costs, increase

revenues and improve the competitiveness of the plant. The move from a citrus to a tropical fruit juice industry would be 'market driven' and would have to take place in a coordinated and well-planned manner. The citrus value-chain needed to function more efficiently and improve its current governance structure, and a more detailed review and investment programme was required. Furthermore, it was necessary to enforce adherence of all citrus growers to the national HLB management and control programme (vector control, removal of affected trees, foliar fertilization and replanting of new citrus orchards only with certified seedlings from certified nurseries).

Review of Institutional Support and Recommendations for Sustainable Funding Mechanisms for Nursery Certification and Hlb Control Programmes

This component provided support for identifying sustainable funding mechanisms for citrus certification and HLB control programmes. A consultant from Central America and FAO's Agribusiness and Finance Officer reviewed the current funding mechanism for CGA / CREI as well as those from other countries and programs in the America, based on which ideas and recommendations were provided for achieving long-term sustainability for the citrus industry in Belize.

Improvement of public Awareness and Grower Education

The project made provision for the production and distribution of several awareness-raising materials, including posters for growers (500 copies), CGA Calendars for 2013 (1500 copies), two posters for the general public (200 copies each) and pamphlets for the general public (5000 copies). Three videos are to be produced for continued farmer training (1) HLB management (2) ACP and its management and (3) Production of certified citrus plants

TCP-RLA-3401 - Technical Assistance for the Regional Management of Huanglongbing (HLB) in Latin America and the Caribbean

The goal of this project is to reduce (1) inoculum sources and load, in an efficient and timely manner, (2) infective ACP populations in infested geographical areas and (3) the risk of infestations by external ACP populations migrating from one geographical area to another that is not yet infested.

The goal is to be achieved via four strategic components, resulting in the development of:

i. A dynamic regional information and risk communication system
ii. Protocols / Standard Operation Procedure (SOP) for HLB management
iii. Stronger technical and institutional skills at national, sub-regional, regional levels
iv. Coordination and operating mechanisms

Regional Information and Risk Communication System

The first component deals with the development of an online Regional Information System. A preliminary phase of this tool has already been developed both in English and Spanish, and activities include the collection and analysis of national PPU information; definition of specific epidemic status and risk zones; communication of early detection and risks of HLB /ACP for timely interventions; and the development of national/sub-regional action plans (inclusive of gender) for regional HLB management, which would be based on the national pest status and institutional abilities. Countries of the Caribbean and Latin America that do not yet know the status of ACP/HLB can use the opportunity provided by this component to request assistance for carrying out surveys and developing appropriate national action plans.

Protocols / Standard Operation Procedure (SOP) for HLB management

The proposed Standard Operating Procedure (SOP) for HLB management will be based on an International Standards for Phytosanitary Measure (ISPM), which is applicable to all pests including HLB. The SOP is to be developed by regional experts and plant health agencies to allow harmonized variables at different management stages, and will take into consideration the harmonization of existing protocols for diagnosis, sampling annd actions using national experiences from national SOPs (countries would be appropriately acknowledged).

Capacity Building

At least two e-learning courses are planned: the first 90-hour course would cover epidemiological surveillance and prevention systems, monitoring, HLB/ACP management, biological control and nursery management and the second 20-hour activity will deal with the use of information systems developed under the project. A Regional Training-of-trainers course will also be conducted in HLB management (along the same lines of the first e-learning course but also covering risk communication), followed by national replication of the course by the trainers. It is also proposed that training internships will be provided in HLB laboratory diagnosis.

Coordination and Operating Mechanisms

The project will establish a Permanent HLB Advisory Committee, comprising representatives from each sub-regional plant health organization (CAN, CARICOM/CAHFSA, COSAVE, OIRSA) which would facilitate exchange of information between experts, resolution of the best strategies to manage HLB and identification of regional specialists in specific technical areas. The Advisory Committee would meet annually to exchange knowledge and validate processes. It is also anticipated that the processes would be documented and made available through the Regional Information System.

To date, the Committee of Experts has been formed and has held its first meeting in Chile in December 2012. The website with the information tool is in the process of being launched. The planning for other activities is in progress. The regional project comes to an end in 2014.

Conclusions

Huanglongbing has serious implications for the future of the citrus industry in the Caribbean and Latin America. In the Caribbean, citrus is an important economic and / or backyard crop in all countries and is part of the social and cultural landscape. Management strategies developed under the two national projects (Jamaica and Belize) can serve as models that other countries can emulate in the event that their citrus becomes infected by HLB.

In addition, countries of the region need to take full advantage of the ongoing Regional TCP project that provides the opportunity to determine the in-country status of ACP / HLB and develop national management plans accordingly.

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