OVERVIEW OF BIOLOGICAL CONTROL OF HOMOPTEROUS PESTS IN THE CARIBBEAN

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ABSTRACT

The potential for biological control of homopterous pests of agricultural crops in the Caribbean region is supported by a rich history of successes and some biological and ecological attributes which favor this approach to pest management. A review of the discovery and importation of parasites and predators of citrus blackfly, *Aleurocanthus woglumi* Ashby into Caribbean Basin countries and subsequent repeated utilization of these natural enemies in newly invaded areas provides evidence that: 1.) Success with a pest in one area is generally transferrable, particularly if cooperation can be established; 2.) More than one natural enemy species can be utilized, and several species can contribute to the ultimate success of the project; 3.) Natural enemies from different regions are sometimes effective under varying conditions in the target areas of introduction; 4.) Successful suppression of a serious pest over a broad area can be obtained with little initial investment via classical biological control; and 5.) No deleterious effects of the successful biological control effort on citrus blackfly were identified, compared to those associated with repeated use of chemical pesticides over a similar area of infestation. Other examples cited provide evidence for the continued emphasis on development and implementation of biological control of the Homoptera.

RESUMEN

El potencial para el control biologico de homopteros plaga en la cuenca del Caribe esta basado en exitos y tambien en la calidad ecologica de esta region, lo cual favorece el enfoque del manejo integrado de plagas. Al revisar los resultados de los hallazgos y la importacion de parasitos y predadores de la mosca negra *Aleurocanthus woglumi* Ashby en los paises del Caribe, y la consiguiente utilizacion de estos parasitos y predadores en regiones recientemente invadidas por la mosca negra, podemos concluir que: 1. El exito en el control biologico de una plaga en una region puede ser transferido a otras regiones, si se establece una cooperacion adecuada. 2. Se puede utilizar mas de una especie de enemigo natural y varias especies pueden a su vez contribuir a el exito del projecto. 3. Los enemigos naturales provenientes de otras regiones son algunas veces efectivos bajo las condiciones de las areas de nueva introduccion. 4. El exito de la supresion de una plaga en una extensa region puede ser alcanzado mediante una poca inversion inicial, empleando el control biologico clasico. 5. Comparado con el uso continuo de pesticidas, no se observaron efectos negativos en este esfuerzo de control biologico de la mosca negra. Se citan otros ejemplos para dar evidencia de que se debe continuar con el desarrollo e implementacion del control biologico del orden Homoptera.

The Caribbean Basin Advisory Group's (CBAG) support of Classical Biological Control is an indication of the current interest in this critical element of Integrated Pest Management. Indeed, biological control is becoming an area of focus for agricultural pest control worldwide. The historical success of biological control in the Caribbean has been advanced through investment of funds, development of facilities, and support of scientific expertise from a number of institutions, including CBAG. The Commonwealth

Agricultural Bureau International Institute of Biological Control, (CAB IIBC, formerly CIBC), Caribbean Agricultural Research and Development Institute (CARDI), Institut National de la Recherche Agronomique (INRA), Escuela Agricola Panamericana El Zamorano (EAP), University of West Indies, various U.S. State Agricultural Experiment Stations, and other educational and research organizations should be credited with facilitating these developments. It behooves the research community to continue its investment in Caribbean projects having a good probability for success. Homoptera are just such an example of a target group for classical biological control projects with a high probability of success. Moreover, they have repeatedly demonstrated the potential to become key pests in diverse agricultural settings worldwide, and have also shown their vulnerability to biological control agents. Thus, the focus on Homoptera in the CBAG workshop and the emphasis in future biological control efforts is undeniably warranted.

DeBach et al. (1970), pointed out that more than 2/3 of all successful examples of classical biological control worldwide have involved homopterous pests, including over 80% of all which were deemed a complete success. In this review and many others, coccids are extremely well represented among biological control attempts, and even more prominent among those which achieved some level of success. More recent estimates of the success of biological control of homopterous pests relative to other target groups have been provided by other symposia authors (Rosen 1992).

Whether the reported rates of success with Homoptera are due primarily to the level of effort expended or to other factors, compelling biological and ecological arguments exist for the continued attention on their biological control. Some of the attributes of the homopteran pests supporting this conclusion include:

1.) Homoptera attack a wide range of economic plant species, representing a broad range of plant families (i.e. coffee, citrus, mango, avocado, papaya, coconut, guava, pineapple, sugarcane, tomato and other vegetables);
2.) Geographic affinities among Caribbean islands and between these islands and adjacent larger land masses (e.g. Republic of Trinidad and Tobago and northern South America) promote common pest and biological control opportunities;
3.) Sessile habits of most Homoptera relative to other insect orders lead to localized, definable populations which but for the small size of the insects are relatively easy to study;
4.) General adaptation of Homoptera to subtropical and tropical climates allows for year-around populations with mixed age structures on perennial and annual host plants. These factors all lead to stable host plant, pest insect, and natural enemy coexistence; and
5.) Homopterous pests are continually spread across geographic areas through infestations on vegetative plant material, and the degree to which this material is moved through commerce and other routes within or into the Caribbean is substantial. This movement both within the Caribbean and worldwide continues the slow spread of these pests, leading to cosmopolitan distribution for many of them. Thus, the opportunity for shared research and, particularly, reciprocity in the exchange of candidate natural enemies for classical biological control is enhanced.

In the Caribbean region, a large number of species occur for which classical biological control has been attempted and for which some level of success has resulted. The review of biological control in Commonwealth Caribbean and Bermuda discussed over 30 species of Homoptera for which some noticeable level of effort has been expended (Cock 1985). Similarly, Clausen's (1978) world review of introduced parasites and predators highlights many biological control projects in the Caribbean and Bermuda, focusing on natural enemies of Homoptera. Targets of classical biological control in the Caribbean and Bermuda which are presented in these reviews or have arisen through recent invasion into the region include:

- Whitefly (Family Aleyrodidae)
  - *Aleurocanthus woglumi* Ashby, citrus blackfly
  - *Aleurodicus cocois* (Curt.), coconut whitefly
  - *Metaleurodicus cardini* (Back)
- Mealybugs (Family Pseudococcidae)
  - *Antonina graminis* (Mask.), Rhodesgrass scale
  - *Dysmicoccus boninsis* (Kuway.), gray sugarcane mealybug
  - *Dysmicoccus brevipes* (Ckll.), pineapple mealybug
  - *Nipaecoccus nippae* (Mask.), coconut mealybug
  - *Phenacoccus gossypii* (Tns. & Ckll.), Mexican mealybug
  - *Planococcus citri* (Risso), citrus mealybug
  - *Pseudococcus longispinus* Targ., longtailed mealybug
  - *Saccharicoccus sacchari* (Ckll.), sugarcane mealybug
- Armored Scales (Family Diaspididae)
  - *Aonidiella aurantii* Mask., California red scale
  - *Aspidiotius destructor* Sign., coconut scale
  - *Carulaspis minima* (Targ.), Bermuda cedar scale
  - *Comstockiella sabalis* (Comst.), palmetto scale
  - *Insulapsis newsteadi* (Sulc.), Bermuda cedar scale
  - *Parlatoria ziziphi* Lucas, black Parlatoria scale
  - *Pseudaulacaspis pentagona* (Targ.), oleander scale
- Unarmored scales (superfamily Coccoidea)
  - *Asterolecanium pustulans* (Ckll.), oleander pit scale
  - *Coccus viridis* (Green), green scale
  - *Icerya purchasi* Mask., cottony cushion scale
  - *Orthezia insignis* Browne, greenhouse orthezia
  - *Orthezia praelonga* (Dgl.)
  - *Parasaisettia nigra* (Nietn.), nigra scale
  - *Protopulvinaria mangiferae* (Green), mango shield scale
  - *Pulvinaria psidii* Mask., green shield scale
  - *Vinsonia stellifera* (Westw.). stellate scale
- Miscellaneous
  - *Aeneolamia* spp., sugarcane froghopper
  - *Saccharosydne saccharivora* (Westw.), West Indian canefly
  - *Sipha flava* (Forbes), yellow sugarcane aphid

It is not the aim of this paper to review all of the biological control efforts on Homoptera in this region, but rather it is to highlight some factors leading to successful biological control and to identify some areas for continued research and implementation over the next 5-10 years.

By way of an excellent example, it is useful to review the case with citrus blackfly, *Aleurocanthus woglumi*, in the Caribbean and neighboring areas. The citrus blackfly is an Old World species native to Asia which is relatively restricted in its host range, utilizing primarily plants in the genus *Citrus* (Family Rutacea). When numbers on citrus increase, populations spill over onto other hosts such as apple, coffee, mango, and fig. Dowell & Steinberg (1990) and Dowell et al. (1981) investigated the relative suitability of various host plants for citrus blackfly development.

The citrus blackfly lays its eggs in a spiral orientation. Immature stages settle and feed on the underside of leaves. The movement of infested plant material provides the primary mechanism by which this pest invades new areas.

A. woglumi was first recorded from Jamaica and the Caribbean in 1913 (Edwards 1932). In Jamaica, it became widely distributed on island citrus, coffee, and other hosts within one year of its detection. It was reported three years later in Cuba (Clausen & Berry 1932). A USDA biological control effort against this pest was begun in Cuba in 1929, with exploration for exotic natural enemies focusing in Malaysia, Java, and Sumatra. These efforts led to the introduction of *Erotmocerus serius* Silv., *Encarsia divergens* (Silv.), and the coccinellids *Catana clauseni* Chapin and *Scymnus smithianus* Clausen & Berry into Cuba. *Encarsia smithi* (Silv.), and *E. merceti* Silv. were collected but did not survive shipment. By 1933, *E. serius* was widespread and considered a success. The parasite was then moved to Haiti and Panama in 1931. *C. clauseni* was only temporarily established.

Jamaica: During this period, efforts to augment the local ant, *Crematogaster brevispinosa* Mayr, were undertaken in Jamaica, as was inoculation of field populations with the entomogenous fungus *Aschersonia aleyrodis* Webber (Edwards 1932). Some success was reported. Introduction of the coccinellid *Delphastis catalinae* Horn was suggested, but apparently was never attempted. In 1931, *Erotmocerus serius* was introduced via Cuba, and by 1936 it was considered a success in Jamaica as well as in Cuba. This parasite also was shipped to Costa Rica from Jamaica in 1933 to combat the blackfly.

Bahamas: Blackfly was present in the Bahamas before 1916, and its suppression by *E. serius* in Cuba led to *E. serius*' introduction into the Bahamas in 1931. Establishment followed but control was not achieved. *Catana clauseni* was introduced in 1936, but no records of its establishment exist. By 1947, however, the blackfly was under control by *E. serius*. A 1972 outbreak on Long Island resulted in the introduction of *Encarsia opulenta* (Silv.) from Barbados in the same year.

Mexico: In Mexico, occurrence of citrus blackfly date to 1935. *E. serius* was imported from the Panama Canal zone in 1938, but failed to establish. Repeated shipments (12) of parasites from the Canal Zone in 1943 and substantial distribution efforts in western Mexico also were unsuccessful. Thus foreign exploration was initiated. Malaysia collections in 1948 led to introductions of *Encarsia smithi* and *E. divergens*, but these were unsuccessful. During 1949-50, foreign exploration obtained *Encarsia clypealis*, *E. opulenta*, *E. merceti*, and *Amitus hesperidum* Silv. in western India and Pakistan. These parasites were shipped to Mexico. A massive program of parasite distribution ensued, since been unequalled, with over 1,600 people employed at the peak of the program. During the period 1951-53, some 1.2 million *E. clypealis*, 2.8 million *E. opulenta*, and 242 million *A. hesperidum* were released across large regions of Mexico infested with blackfly (Smith & Maltby 1964). Because of the success of *A. hesperidum* in Mexico, it was introduced into Ecuador in 1955, where it became established (Clausen 1978).

Blackfly was first recorded in Barbados in 1964. *Erotmocerus serius* was introduced in 1964 from Jamaica, and *Encarsia opulenta* in 1965 from Mexico (Bennett 1965). Both species were established, but *E. opulenta* dominated. Soon thereafter, blackfly populations were so low that it was difficult to field collect parasites (Pschorn-Walcher & Bennett 1967).

Blackfly was reported from the Cayman Islands in 1940's-50's, and two introductions of *Erotmocerus serius* were attempted: one from Jamaica during this period and a second through CIBC in 1966, but it was not detected in subsequent evaluations. However, in 1970, *Encarsia opulenta* was found, indicating that it had been probably introduced with *Erotmocerus serius* in 1966 (Bennett 1970, 1971).

During the 1950's-60's, blackfly was an occasional problem in Jamaica, and, thus, *Encarsia opulenta* was introduced from Mexico in 1964. Once established in Jamaica, *E. opulenta* displaced *Erotmocerus serius* (Van Whervin 1968).

Other areas peripheral to the Caribbean have been invaded by the citrus blackfly. Movement of the pest from Mexico into Texas occurred in the late 1970's, causing serious damage to citrus (Summy et al. 1983). *Amitus hesperidum* and *Encarsia opulenta* were introduced from Mexico and again proved successful in reducing pest populations below damaging levels.

Florida, likewise, was invaded by the blackfly, with the initial introduction being reported on the Keys in 1931. Eradication of this limited infestation was successful by 1937 (Newell & Brown 1939), but the insect again became established in Florida in 1976, this time along the east coast. An enormous Federal-State eradication effort was undertaken for an estimated $15 million but it failed. The introductions of *A. hesperidum* and *E. opulenta* from Texas in 1976 successfully suppressed the pest (Dowell et al. 1981).

The most recent blackfly introduction in the Caribbean region is Puerto Rico in 1988. In 1989, small numbers of *Amitus hesperidum* and *Encarsia opulenta* were introduced from Florida into the San Juan area (H. Browning, unpublished). By late 1990, even though blackfly had spread to several locations on the island, the parasites reduced populations to densities that made field recovery of blackfly or parasites difficult. Efforts are ongoing to spread parasites to new areas of infestation across the Island.

The preceding review of the suppression of citrus blackfly by parasites supports several guidelines regarding biological control of Homoptera in particular and perhaps to biological control in general.

1. Success with a pest in one area generally indicates that control is transferrable to another, particularly if coordination is established. Introduction of a parasite complex has led to commercial control of this serious pest in many areas because of cooperation.
2. More than one natural enemy species was utilized and contributed to the ultimate control.
3. Natural enemies from different regions were effective under varying conditions in the target areas of introduction.
4. Successful suppression of a serious pest over a broad area can be obtained with little initial investment via classical biological control. The cost to most of the successful recipient areas was limited to the expense of shipping the material from a nearby island.
5. No deleterious effects of the successful biological control effort against citrus blackfly were identified, compared to those associated with repeated use of chemical pesticides over a similar area of infestation.

Clausen (1978) and Cock (1985) provide detailed accounts of the biological control of other homopterous pests in the Caribbean region, including those listed earlier. Important additional points are illustrated by this broader review of cases involving the biological control of Homoptera, including:

1. The importance of taxonomy to biological control is inestimable. In addition to natural enemy taxonomy, pest and even host plant taxonomic support can mean the difference between success and failure. This expertise should be enlisted at the outset of a biological control project.
2. Many successful cases of biological control in the Caribbean involving Homoptera have included importation or augmentation with predators, particularly coccinellids. Obrycki (this publication) discusses evaluation techniques for these natural enemies. Evaluation of the predator impact will lead to a better understanding of the role that they play in regulating homopterous populations.
3. The Caribbean region has a rich reserve of natural enemies which is available for export to cooperating scientists in other parts of the world. Reciprocal arrangements could result, and lead to less expensive and more efficient foreign exploration for the natural enemies to combat other Caribbean pests.

4. New pest species continue to invade the Caribbean region, and established pests continue to spread within this area. Many additional examples of partial or complete biological control successes could be achieved through the development and expansion of cooperative interactions.

One of the primary objectives of the CBAG Biological Control Workshop was to identify additional opportunities for biological control in the Caribbean region. Some potential areas for such cooperation in the biological control of Homoptera are:

1. Evaluations of existing natural enemies, focusing on both native and introduced species and the role they play in pest population dynamics. A tremendous need exists to document the outcome of previous natural enemy introductions, because there has been a dearth of information in many introduction projects. These endeavors should: a) identify target niches for additional natural enemy introductions, augmentations, or conservation; b) reduce redundant introductions; and c) assist in the planning of future foreign exploration and importations.
2. Plan for foreign exploration to enhance the biological control of existing pests and to develop strategies for new invaders or for species expanding their distribution within the Caribbean region.
3. Coordinate efforts and scientists to increase reciprocity among and between areas, in order to enhance success rates.
4. Provide taxonomic support to assist in biological control projects. A faunistic study of the natural enemies of Homoptera with a taxonomic component from the outset would be highly productive.

Biological control of Homoptera in the Caribbean region must be considered a priority for future development, and can build on a rich history of success. Native and newly introduced species of Homoptera will continue to plague agriculture in this area, and biological control offers a permanent, inexpensive, and environmentally sound approach for their management.

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APPROACHES TO THE BIOLOGICAL CONTROL OF WHITEFLIES

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Abstract

Biological control has been successful for some whitefly species but not for others. Natural enemies available for control of whiteflies include fungi, predators and parasitoids. Each of these groups has an important place in the ecosystem, but knowledge of their biology and utilization is limited and available mainly for parasitoids. There is no proven method for predicting the success of natural enemies. However, the number of host stages that are not vulnerable to enemy attack, as well as the host refuges, should be reduced in both time and space. This can be accomplished by integrating the use of different natural enemies, plant resistance and selective insecticides. Comparative studies of successful cases of whitefly biocontrol are suggested as a means to increase our knowledge of the necessary attributes of successful natural enemies.