PN-ABN-554



# WHITEFLY RESEARCH

Assignment Number: ST/110

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Chemonics International Consulting Division
2000 M Street, Northwest
Washington, D.C. 20036
(Contract AID No. 596-0165-C-00-1296-00)

UNDER THE AUSPICES OF:

The Non-Traditional Agricultural Export Support Project
(Project No. 596-0108-3-60011)
United States Agency for International Development (USAID)
Regional Office for Central American Programs (ROCAP)
Guatemala City, Guatemala

January, 1993

5a. Avenida 15-45 • Zona 10 • Edificio Centro Empresarial • Torre 1 • 9° Nivel • Guatemala City, Guatemala
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**Trip Report to Costa Rica**
**August 1 - August 8, 1992**

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A trip was made to Costa Rica to attend the regional meeting "Taller Centroamericano y Del Caribe Sobre Moscas Blancas", to present a seminar providing an overview of the whitefly problem in the region, and to serve as an advisor/resource person to the planning committee in developing a five year regional plan to carry out research and devise effective control strategies for *B. tabaci* as a pest and vector of plant viruses.

**Arrival: August 1, 2, 1992.** I arrived in San Jose, Costa Rica on Saturday, August 1, 1992 at approximately 10:40 pm and was met by Mr. Karl Ufer. Stayed overnight at the hotel in San José, and used the morning to organize slides, and to review the literature and reports provided. Also proofread manuscript for submission to proceedings. Dr. Bernal Valverde transported us to Catie in Turrialba (Sunday, August 2, 1992) where we checked into the dorm rooms near the meeting site about 4 pm. Early evening briefings and discussions were held with Dr. Luko Hilje and Dr. Ramon Lastra concerning the schedule and program coordination for the upcoming week. Dinner was with Dr. Ramon and Anna Maria Lastra and Dr. and Mrs. Joseph Saunders.

**Meeting August 3-5, 1992.** Monday, August 3, 1992 I attended the meeting from 8 am-6:30 PM on Monday, August 3, 1992 during which time presentations were given by myself and the researchers in the region. Colleagues were present from the countries of Costa Rica, the Dominican Republic, El Salvador, Guatemala, Honduras, Nicaragua and Panama. There was no representative from Belize, as planned. Mr. Rafael Caballero presented information from Honduras instead of Mr. Alfredo Rueda, Mr. Leopoldo Serono presented instead of Mr. Joaquin Larios, and Mr. Diego Gomez represented Nicaragua instead of the scheduled Dr. Falguni Guharay. The presentations were followed by a discussion session featuring the day's speakers and other colleagues attending the meeting. The evening dinner was spent in Turrialba with Dr. Pamela Anderson and Mr. Diego Gomez.

<u>Tuesday, August 4, 1992</u>. The meeting resumed on the following day with scheduled presentations and subsequent discussions in the morning sessions. Lunch was with Drs. Luko Hilje, Ramon Lastra, Victor Salguero and others, to plan the afternoon agenda for the four breakout groups. I attended the virus-vector/vector biology whitefly taxonomy section as did Ramon Lastra and Pamela Anderson, among others. The first outline for a research/action plan was drafted in the afternoon. Areas upon which research foci were needed were defined and prioritized. A preliminary draft was formulated as a flow sheet by each breakout group. During the subsequent late afternoon session, a representative from each of the four groups presented the idea and priorities defined during the early afternoon breakout session. Dr. Theo Watson,

Department of Entomology, University of Arizona, attended the whitefly control group breakout session and provided expertise in this area. Mr. Karl Ufer attended this session as well. Discussion followed. The meeting was adjourned at 6:30 pm. Dinner was in Turrialba and evening discussions with Mr. Bruno Zachrison (Panama), Diego Gomez, Pamela Anderson (Nicaragua), and Porfirio Alvarez (Dominican Republic).

Wednesday, August 5, 1992. The entire day was spent expanding and refining ideas and feasible approaches for conducting whitefly and virus research in the region. In the morning session, virology and diagnostics, whitefly taxonomy, and ecology were discussed in detail. After lunch, control strategies, resistance and technology transfer issues were addressed. There was much discussion and attention given to details required to develop a feasible and relevant approach to the problem and thus, result in a workable action plan. During the afternoon break, I spoke with Rafael Cabellero concerning his possible future interest in a Ph.D. program in the UA laboratory to expand his present studies on whitefly taxonomy. The meeting adjourned at 6:30 pm.

A second, smaller meeting followed immediately during which the subject of the whitefly biotype survey was discussed. This ad hoc committee was comprised of the individuals who were coordinating the collections in each country. The need for this meeting became evident during discussions which occurred during previous 3 days. As a result, I devised a suggestion for a modified procedure for collecting, short-term storage, and transport to the UA laboratory. This plan is contingent upon approval from Dr. Lloyd Wendel and Dr. Dale Krigsvold whom originally coordinated the exchange. A brief revised protocol has been developed (attached) and will be presented to Dr. Lloyd Wendel for immediate assessment. Upon approval, the new plan and nominal equipment and supplies will be sent from the UA laboratory to Mr. Karl Ufer/Dr. Dale Krigsvold for distribution to the country contacts. It is anticipated that this revision in protocol will expedite the collection and assessment of biotype distribution (specifically the 'B' biotype) in the region. National representatives expressed an interest in accessing the results of the data acquired from samples they collect. I assured them that these data would be made available as rapidly as possible with respect to laboratory analysis (UA) and subsequent communications to all parties involved. This meeting ended at 7:45 pm.

Thursday, August 6. The morning was spent organizing notes, reviewing the previous weeks activities, and preparing most of this report. In the afternoon, I met with students of Dr. Ramon Lastra, toured the tissue culture and other laboratory facilities, and prepared tissue samples (as a demonstration for the students, including a visiting technician from Dr. Victor Salguero's laboratory, for virus analysis in the UA laboratory. The evening was spent having dinner was Porfirio Alvarez (Dominican Republic) and several others present for the tomato meeting held Thursday and Friday at CATIE.

Friday, August 7, 1992. The morning was spent in discussion with Dr. Ramon Lastra regarding present and future collaborations. We exchanged viral clones, cultures, slides, and etc. We also discussed the preparation of a manuscript for publication, a proposal involving collaboration in virology between CATIE, UA, and Rothamsted (Lastra, Brown, Jones), and the potential funding of a graduate program for Ramon's student (Helga) to study geminiviruses in the UA laboratory.

At approximately 1:30 pm, Dr. Ramon and Anna Marie Lastra drove me to San José where I checked into the hotel. Departure at 8 am mandated the overnight stay in San José due to the length of the drive from Turrialba to San José.

Saturday, August 8, 1992. Departure (6 am) for Dallas. Arrived in Portland, Oregon at 11 pm Saturday night. (Attended APS meeting August 8-12).

Thursday, August 13, 1992. Departed Portland (hotel at 5:10 am); flight departure 6:30 am to Dallas. Arrived at noon. Departure Dallas 4 pm. Tucson arrival and home. Preparation of report, review of past week's notes, activities, and etc., during layover in Dallas.

b:costa

# A CRITICAL ASSESSMENT OF BIOTYPES OF THE SWEETPOTATO WHITEFLY IN THE AMERICAS AND ADJACENT LOCALES: FROM 1989 - 1992

Taller Centro Americano y Del Caribe
Sobre Moscas Blancas
August 3-5, 1992, Turrialba, Costa Rica

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## Abstract

Whitefly-transmitted geminiviruses have become of critical importance in tropical, subtropical, and fringe temperate world regions. Geminiviruses drastically reduce yields of vegetable and fiber crops utilized for local consumption and as important revenue generating exports. The host range of the whitefly vector, *Bemisia tabaci* (Genn.) is now estimated to encompass at least 350 plant species, and the insect is present on every world continent within the 30° parallels north and south. Recently, *B. tabaci* also invaded more arid irrigated agricultural regions in the southern-most states of the United States and within two years of the initial crisis-level infestation in 1987, geminivirus-related diseases have become commonplace in nearly every dicot crop species cultivated in the region.

In addition, a new biotype of *B. tabaci* characterized by a wider host range and more aggressive feeding habits has become prevalent in North America (Southern Mexico and US), and throughout the Caribbean Basin (Antigua, Dominican Republic, Puerto Rico). It is feared that this new 'B' biotype which has been introduced and subsequently transported throughout the region on ornamentals and vegetable seedlings will soon move into Central America and Northern Mexico. Indeed, preliminary studies conducted in 1992 indicate the presence of the new biotype in Belize and Guatemala (J. K. Brown, unpublished). *B. tabaci* populations which are indigenous to these areas (thus far spared from invasion by the 'B' biotype) have historically infested cotton, cucurbits and solanaceous crops such as tomatoes, thus WFT geminiviruses has been recognized as important indigenous pathogens. In contrast, the new *B. tabaci* biotype colonizes among others, *Brassica* spp., citrus, cotton, cucurbits, tomatoes, papaya, passionvine (J. Bird, pers. comm.), and pepper, and recently infestations were observed on cassava in Dominican Republic (J. K. Brown, unpublished). In the US (Arizona, California, Florida, and Texas), the 'B' biotype population has apparently displaced the indigenous 'A' type population in less than three years (Brown et al, 1992), and the impact resulting from feeding damage to vegetables and fiber crops and virus epidemics is estimated in the millions of dollars.

In Central America, and other countries in the tropical Americas, vegetable production efforts have been expanded substantially during the past several years to increase monoculture production of melons as an export crop, and to become less reliant on importation of staples such as beans, cucurbits, peppers and tomatoes. This increase in irrigated monoculture has resulted in a substantial rise in the prevalence and distribution of diseases caused by insect-vectored viruses. The ability of the new 'B' biotype of *B. tabaci* to infest a broader range of host plants is believed to be responsible for the dramatic changes recently experienced, and which presently threaten crop production in several world regions.

## Introduction

Whitefly infestations involving *Bemisia tabaci* (Genn.), also known as the cotton, sweet potato, or tobacco whitefly (Cock, 1986; Gill, 1992; Mound and Halsey, 1978), have increased in severity and importance in dry, tropical and irrigated, arid agricultural systems in the Americas and Caribbean Basin since 1981 (Bird and Maramorosch 1975, 1978; Brown 1990; Brown and Bird 1992; Duffus, 1987). Crisis-level infestations (Butler and Henneberry, 1986; Byrne et al 1990), and the associated plant virus diseases (Brown and Bird, 1992) have resulted in devastating losses and decreased productivity in food and fiber crops throughout the region. In Mexico, the Caribbean Basin, Central America (Table 1), and in the US, whitefly-transmitted viruses are now serious constraints to production of food and fiber crops (Brown, 1988; Brown and Hine, 1984; Brown and Nelson, 1987; 1988; 1989a,b; Brown and Poulos, 1990a,b,; Brown et al., 1988, 1989a,b,; 1990; 1991; 1992a,b; Duffus, 1987; Simone et al., 1990).

The sunbelt states of the US, particularly Arizona, California, Florida, and Texas, and in Puerto Rico have recently suffered serious losses in vegetable and cotton crops (Brown and Bird, 1992; Henneberry and Butler, 1992; Schuster et al 1990; Secarra Carmona et al 1990). Adjacent states where cotton and vegetables are produced have also been affected. Horticultural and floricultural crops have been heavily damaged, and *B. tabaci* infestations are a major threat to greenhouse production of ornamentals and cut flowers, and to the vegetable transplant industry. The danger of transporting both whiteflies and the viruses they transmit by way of infested or infected plant materials, respectively, has become a prominent concern for the first time in the US.

The reasons for the change in status of *B. tabaci* from a member of the indigenous insect population (Martin, 1987; Russell, 1957a) to a major pest and important virus vector are not entirely understood. However, changes in local and regional agricultural practices, the expansion of irrigated monoculture of vegetables and other crops, extended growing seasons made possible by horticulturally improved vegetable varieties, the introduction and subsequent resistance of whitefly populations to new chemistries (Byrne and Devonshire, 1991; Dittrich, 1987), and the increase in worldwide transport of plants and plant products have likely contributed to the problem (Brown and Bird, 1992; Byrne et al., 1990).

*B. tabaci* was first described as a pest of tobacco in Greece, only slightly more than one hundred years ago (Cock, 1986). Many additional species of *Bemisia* have been described worldwide (Martin, 1987; Mound and Halsey, 1978). Members of the genus *Bemisia* (and several other whitefly genera as well) are unusual in that, compared to most other whiteflies which are nearly monophagous, or oligophagous and typically infest woody perennials, these insects have an extremely broad host range (Greathead, 1986) comprised primarily of herbaceous, annual plant species. (Byrne and Bellows, 1991; Martin, 1987; Mound and Halsey, 1978).

**Table 1. Summary of Samples Testing Positive for WFT Geminiviruses by DNA-DNA Hybridization (1987-1992)**

| Region/Country | Host Plant |
|---|---|
| A. Central America | |
| 1. Belize | bean<br>pepper<br>tomato<br>weed spp. |
| 2. Costa Rica | tomato<br>weed spp. |
| 3. Guatemala | cotton<br>okra<br>tobacco<br>tomato<br>watermelon<br>weed spp. |
| 4. Nicaragua | bean<br>squash<br>tomato<br>watermelon<br>weed spp. |
| B. Caribbean Basin | |
| 5. Dominican Republic | bean<br>pepper<br>tobacco<br>tomato<br>weed spp. |
| 6. Puerto Rico-USA | bean<br>tomato<br>weed spp. |
| C. Mexico | |
| 1. Sinaloa | pepper<br>tomato |
| 2. Sonora | bean<br>cucurbits<br>pepper<br>tomato |
| 3. Tamaulipas | pepper<br>tomato |

The systematics of whiteflies has been problematic. In particular, the taxonomy of *B. tabaci* has been difficult to reconcile due to the extreme plasticity of key morphological characteristics which are capable of change to accommodate morphological features of the host plant (Bethke et al 1991; Butler et al, 1986; Ghong, 1969; Mohanty and Basu, 1986; Mound, 1963; 1965). As a result, eighteen described *Bemisia* species were synonymized to the binomial, *B. tabaci* (Russell, 1957b), resulting in the recognition of a single, polyphagous whitefly species which inhabits suitable ecosystems on every continent between the 30° parallels, north and south. Recently, these boundaries have been extended to include regions in neotropical and in adjacent temperate zones as well (Brown, 1990; Butler and Henneberry, 1986; Byrne et al., 1990; Costa and Brown, 1990; 1991a).

Although, by survey of documentation on the worldwide distribution of *B. tabaci*, the insect appears to be capable of colonizing at least 500 plant species (Gameel, 1972; Greathead, 1986), the propensity for *B. tabaci* to differentially colonize a specific host or several host species has been documented on many occasions (Bird, 1957; Bird and Maramorosch, 1978; Butler et al., 1986; Burban et al., 1992; Costa and Russell, 1975; Costa and Brown, 1990; 1991a; 1991b). For example, in Puerto Rico, the existence of two biologically distinct races of *B. tabaci* were proposed (Bird, 1957; Bird and Maramorosch, 1978). The "Jatropha" race was associated exclusively with *Jatropha gossypifolia* (L.), and also transmitted a geminivirus (Brown and Bird, unpublished) to and from Jatropha, but could not feed and reproduce on most other plant species tested (Bird, 1957). In contrast, the "Sida" race was characterized by the ability to colonize many other plant species in the region, excluding *J. gossypifolia* (Bird, et al., 1971; 1978). In another report, *B. tabaci* from Brazil did not colonize cassava, *Manihot esculenta* (Crantz), whereas cassava served as a host plant for populations in Africa (Costa and Russell, 1975). In these earlier reports, host-association was the exclusive, recognized criterion for differentiating races or biotypes of *B. tabaci*.

Recently, a new biotype (Gonzalez et al, 1979) characterized by having a broad host range (Table 2) and specifically, a compatible host association with poinsettia, *Euphorbia heterophylla* Pulch. has become of paramount importance in the US, and Caribbean Basin, and Central America (Costa and Brown, 1990; 1991a; Costa et al., 1992; Brown et al., 1991a). In addition to differential host range characteristics, the biotype is distinguishable from the indigenous population traditionally infesting bean, cotton, cucurbits, and other crops in the region by non-specific esterase markers, and by the ability to induce phytotoxic disorders in *Cucurbita* species (Costa and Brown, 1990; 1991a,b; Segarracarmona et al., 1990), honeysuckle (Bedford and Markham, unpublished data), *Brassica* species (Brown et al., 1992c), and tomato (Schuster et al., 1990).

Table 2. Partial list of host species of the 'B' biotype of *Bemisia tabaci*[1]

| Common Name | Genus/Species | Family |
|---|---|---|
| 1. alfalfa | *Medicago sativa* | Leguminosae |
| 2. bean | *Phaseolus vulgaris* | Leguminosae |
| 3. broccoli | *Brassica oleraceae* | Cruciferae |
| 4. buffalo gourd | *Cucurbita foetidissima* | Cucurbitaceae |
| 5. cauliflower | *Brassica oleraceae* | Cruciferae |
| 6. cheesewood | *Malva parviflora* | Malvaceae |
| 7. chrysanthemum | *Chrysanthemum* | Compositae |
| 8. citrus | *Citrus spp.* | Rutaceae |
| 9. cotton | *Gossypium hirsutum*<br>*G. barbadense* | Malvaceae |
| 10. cucumber | *Cucumis sativus* | Cucurbitaceae |
| 11. grape | *Vitus vinifera* | Vitaceae |
| 12. ground cherry | *Physalis spp.* | Solanaceae |
| 13. honeysuckle | *Lonicera japonica* | Caprifoliaceae |
| 14. *Lantana* | *Lantana camara* | Verbenaceae |
| 15. lima bean | *Phaseolus lunatus* | Leguminosae |
| 16. maize | *Zea mays* | Graminae |
| 17. mulberry | *Morus alba* | Moraceae |
| 18. muskmelon | *Cucumis melo* | Cucurbitaceae |
| 19. okra | *Hibiscus esculentus* | Malvaceae |
| 20. peanut | *Arachis hypogaea* | Leguminosae |
| 21. pepper | *Capsicum annuum* | Solanaceae |
| 22. periwinkle | *Vinca rosea* | Apocynaceae |
| 23. poinsettia | *Euphorbia heterphylla* | Euphobiaceae |
| 24. pumpkin | *Cucurbita maxima* | Cucurbitaceae |
| 25. rose | *Rosa spp.* | Rosaceae |
| 26. squash | *Cucurbita pepo* | Cucurbitaceae |
| 27. tomato | *Lycopersicon esculentum* | Solanaceae |
| 28. watermelon | *Citrullus lanatus* | Cucurbitaceae |

[1]Compiled from data contributed, in part, by Dr. M. D. Rethwisch, Department of Entomology, Yuma Agricultural Center, University of Arizona.

Based upon distinct, host and geographically characteristic esterase markers, the new biotype originally derived from poinsettia has been termed the 'B' biotype, while the cotton-derived population historically indigenous to the US and Mexico is termed the 'A' biotype (Brown et al 1991; Costa and Brown, 1990; 1991a,b; Costa et al, 1992). Although the origin of this new biotype is presently unknown, there is strong evidence for the introduction and dispersal of this exotic *B. tabaci* population into the US, and from several foci into the Caribbean Basin, and more recently into Central America (Brown, unpublished).

The results of an ongoing study conducted in the Americas and Caribbean Basin during 1989-1992 in which non-specific esterases were evaluated and used as polymorphic markers of *B. tabaci* populations in the region are reported here. These investigations have allowed for determination of the regional distribution of the two most common North American types, ('A' and 'B') and the first delineation of different esterase markers for populations throughout the new world. In addition, a comparison of host-choice (Sivasupramaniam, Brown and Watson, unpublished), and virus-vector (Idris and Brown, unpublished) capabilities of the North American derived 'A' and 'B' type populations are reported.

## Materials and Methods

Non-specific esterase analysis. Samples of live *B. tabaci* adults were collected from infested plants at study sites and frozen (-20 to -70C). Samples were shipped to the Arizona laboratory on dry or wet ice, and transferred to the freezer (-70C) where they were held until analysis. Individual *B. tabaci* females were homogenized in 12ul 0.1M Tris-borate-EDTA buffer, pH 7.0., containing 10% sucrose (Wool et al., 1989). Whiteflies were analyzed for non-specific esterases (Prabhaker et al, 1987) by native polyacrylamide gel (7.5%) electrophoresis with a 3% stacking gel and a modified Laemmli buffer system as described (Costa and Brown, 1991a,b). Gels were stained for non-specific esterases using the protocol of Wool et al., (1989). Banding patterns were documented and compared among populations.

Host-habituation experiments. Adult *B. tabaci* were reared in colonies on pumpkin, *Cucurbita maxima* (Duchesne) "Big Max" in a greenhouse (22-26C). Whiteflies were allowed to move freely within the confines of the greenhouse, and thus establish new subcolonies as additional pumpkin plants were added. After several generations, test plants (3-4 leaf stage), representing one of eleven different plant species, were introduced into the colony room, and whiteflies were allowed to infest plants for 3 days without restrictions. Adults were removed by aspiration and plants were transferred to a whitefly-free greenhouse where development from egg to adult was completed. Approximately 25 days after initial infestation of test plants, the number of empty pupal cases (indicative of completing the life cycle) was counted and used to estimate relative host habituation as measured by whitefly fecundity. Plant species were ranked in order of those which supported the greatest to the lowest number of offspring.

Transmission Efficiency. The two biotypes, 'A' and 'B', were compared for the ability to transmit two different whitefly-transmitted geminiviruses of tomato. Non-viruliferous adult *B. tabaci* were allowed a 24-hr acquisition-access feed (AAF) on virus-infected tomato plants. Either 1,5, or 10 inoculative whiteflies were transferred to healthy tomato seedlings using an aspirator, and caged on test plants for a 3-day inoculation-access feed (IAF). Whiteflies were killed by fumigation and plants were maintained in an insect-free greenhouse for 4 weeks. Test plants were evaluated for development of characteristic virus symptoms, and transmission efficiencies were calculated. Chino del tomate virus (Brown and Hine, 1984), and the newly described Sinaloa tomato leaf curl virus (Brown, Idris, and Fletcher, in preparation) were the two viruses used in these experiments. In order to reduce variability which could result from different feeding preferences of the two biotypes, a plant (tomato) shared in common as a host by the two viruses was chosen as the virus source plant and as the test plant.

## Results and Discussion

Esterase Marker Types and Distribution of the 'B' biotype. Non-specific esterases have been used as markers to differentiate insect species and biotypes, and in some cases to demonstrate or infer polymorphism (Wool et al 1991). In this study, representative non-specific esterase markers for *B. tabaci* populations throughout North America and the Caribbean Basin were defined by one of several distinct patterns (Fig. 1). In the US, Mexico, and the Caribbean Basin, 'A' and 'B' biotypes were identified, while the representatives from Central American sites in Costa Rica, Nicaragua, and Guatemala had distinct patterns, and which also differed from both 'A' and 'B' pattern types. These latter phenotypes were termed, in order of discovery, the 'C' and 'D' and 'G' esterase pattern types, respectively (Fig. 1; 'G' type not shown). Most populations from urban areas collected after 1991, however, have been characterized as the 'B' type populations based on esterase banding patterns and ability to induce SSL in *Cucurbita* spp.

A 1988-91 survey of the non-specific esterase patterns for *B. tabaci* populations in Arizona, California, Florida, Tennessee, and Texas resulted in a predominance of the 'B' type pattern regardless of the host species sampled (Table 2). In several instances, the 'A' or indigenous population pattern was observed as recently as 1991, and was generally associated with more rural areas (e.g. Sonoita, AZ). Monitoring of 1988-89 populations revealed a mixture of the two esterase marker types, but within a 2-year time period, nearly all *B. tabaci* tested in the US, including Hawaii, were of the 'B' type pattern (Table 2). These data suggest that a rapid shift from the 'A' to 'B' type *B. tabaci* has occurred in the US sunbelt states, Hawaii, and elsewhere since at least 1987-88, the earliest time period for which data are available. This time-frame correlates closely with the recognition of biological, host-related differences between historic or indigenous *B. tabaci*, and those associated with the new poinsettia-derived population in the US. In addition, by 1990-91, the 'B' biotype was found nearly exclusively in Antigua, Dominican

Figure 1. Examples of non-specific.....

Table 2. Non-specific esterase marker differentiation of *B. tabaci* populations in the United States, 1989-1991

| Year | Location | Host Plant | Marker[1] |
|---|---|---|---|
| 1988 | Tucson, AZ | cotton | A |
| | | poinsettia | B |
| | | pumpkin | A |
| | S. Florida | nightshade | B |
| 1989 | Casa Grande, AZ | cotton | A |
| | | tomato | A |
| | | zucchini | B |
| | Tucson, AZ | cotton | A |
| | | poinsettia | B |
| | | pumpkin | A |
| | Florida | nightshade | B |
| | | tomato | B |
| | | Sida sp. | B |
| 1990 | Casa Grande, AZ | cotton | B |
| | | cucumber | B |
| | Yuma, AZ | broccoli | B[2] |
| | El Centro, CA | rappini | B[2] |
| | Florida | tomato | B |
| 1991 | Casa Grande, AZ | buffalo gourd | B |
| | | cotton | B |
| | | pepper | B |
| | Phoenix, AZ | citrus | B |
| | | cotton | B |
| | | muskmelon | B |
| | Sonoita, AZ | cotton | A |
| | Yuma, AZ | alfalfa | B |
| | | cotton | B |
| | | lettuce | B |
| | | muskmelon | B |
| | | nightshade | B |
| | | okra | B |
| | | peanut | B |

Table 2. Non-specific esterase marker differentiation of *B. tabaci* populations in the United States, 1989-1991 (continued)

| Year | Location | Host Plant | Marker[1] |
|---|---|---|---|
| | Hawaii | papaya | B |
| | | *Plumeria* | B |
| | | watermelon | B |
| | Ithaca, NY | poinsettia | B |
| | Jackson, TN | cotton | B |
| | Weslaco, TX | cotton | B |
| | | cucumber | B |
| | | watermelon | B |

[1]All non-specific esterase banding patterns were determined by native gel electrophoresis as described. Pattern 'A' is characteristic of the indigenous cotton population present from at least 1982 until recently in Arizona cotton and vegetable plantings. The 'B' pattern is characteristic of the poinsettia-derived population under investigation in Arizona since 1988.

[2]Marker type based on symptoms of white streaking disorder (WSt) in *Brassica sp.* indicator plants (Brown et al., 1992a).

Table 3. Non-specific esterase marker differentiation of *Bemisia tabaci* populations in Mexico, the Caribbean Basin and Central America, 1990-1992.

| Year | Location | Host Plant | Marker[1] |
|---|---|---|---|
| 1990 | Cancun, Quintana Roo | *Chamoaesyce hirta*, poinsettia | B |
| | Culiacan, Sinaloa | *Parthenium* sp.; tomato | A |
| | Grenada | unknown | B |
| | Guadeloupe | muskmelon | B |
| | San Juan, Puerto Rico | *Jatropha* sp. | N ($\phi$) |
| | | poinsettia, squash | B |
| | Costa Rica | tomato, squash | C |
| | Dominican Republic | squash, tomato | B[3] |
| 1991 | Antigua | squash, tomato | B |
| | Managua, Nicaragua | tomato, squash | D |
| | Sonora, Mexico | cucumber, squash | A |
| 1992 | Belize | pepper | B |
| | Brazil | vegetables | (B) |
| | Sinaloa, Mexico | cucumber | $A_1$ |
| | Sonora, Mexico | cucumber, melon, poinsettia | B |
| | Nicaragua | cotton | B |
| | Panama | vegetables | (B) |

[1]Pattern type 'A' is characteristic of populations in Arizona cotton from at least 1982-1989, and pattern 'B' is characteristic of the 1989 Arizona poinsettia-derived population.

[2]No esterase activity was detectable.

[3]Marker type determined by on site observations of SSL symptoms, a definitive characteristic of the 'B' type populations (Costa and Brown, 1991a,b).

Republic, Grenada, Guadeloupe, Puerto Rico, and in the Yucatan Peninsula (Table 3), all regions proximal to US geographic locales where the 'B' biotype has also been recently documented. These data along with those derived from bioassays in which the ability of *B. tabaci* populations to induce phytotoxic symptoms was evaluated in *Cucurbita*, tomato, or *Brassica* sp. assay hosts (a characteristic thus far exclusively associated with the 'B' biotype) suggest that the 'B' type population is now the predominant biotype in the sunbelt states of the US and in Puerto Rico, as well as in portions of Mexico and the Caribbean Basin adjacent to the US.

In contrast, *B. tabaci* samples collected prior to 1992 from northwest Mexico, and Costa Rica, Guatemala, and Nicaragua in Central American were characterized by the A, C, G, or D esterase pattern types, respectively (Table 3; Fig. 1; G pattern not shown). In one sample obtained from Jatropha in Puerto Rico, however, no esterase activity was detectable (Costa and Brown, 1992), even when 5-10 insects were analyzed (Coats and Brown, unpublished). The ability to detect alpha-glycerophosphate dehydrogenase (GPD) activity (Costa et al., 1992) in esterase-negative (denoted) samples indicated sample quality was not a factor governing the inability to detect non-specific esterase activity.

No phytotoxic disorders (SSL or uneven ripening of tomato) were observed in plants infested by A, C, D, G or N ($\phi$) populations, whereas SSL or symptoms of uneven ripening of tomato were present in all areas in which 'B' type *B. tabaci* were found (J.K. Brown and J. Bird; pers. observ.). The results of this survey indicate that the 'B' type *B. tabaci* is widespread in the US and portions of the Caribbean Basin. As of spring 1992, it has been documented in Belize, and Guatemala, Nicaragua, and in northwest Mexico and, suspect 'B' populations have been reported in Panama, and in Brazil (Brown, unpublished) (Fig. 2).

Because the particular biological characteristics (host range) and phytotoxic disorders associated with the 'B' biotype of *B. tabaci* have not been a reality until quite recently, either a genetic change has occurred in local populations, or, more likely based on these data an exotic insect has been introduced. If the latter is the case, the data presented here may be taken as evidence in favor of the argument that the 'B' type has been introduced into and/or transported throughout the new world on ornamentals and/or vegetable transplants. Although the origin of the new 'B' biotype of *B. tabaci* has not been definitively ascertained, populations with 'B' type esterase patterns have also been identified in *B. tabaci* collected from the Middle East and the Arabian Peninsula as early as 1989 (Brown et al; in preparation).

<u>Host Habitation Experiments</u>. 'A' type host preference was ranked in order from highest to lowest based upon reproduction and survival rates: squash > muskmelon = cotton = pumpkin > watermelon > lettuce = tomato > broccoli > lettuce > poinsettia. In contrast, plants tested in experiments with the 'B' type were ranked: cucumber > muskmelon > broccoli-cotton > okra = poinsettia > watermelon > cauliflower > tomato = lettuce = cassava.

*B. tabaci* populations generally have a very wide host range, albeit there are several examples of narrow host range or apparent specialization (Bird et al., 1978; Costa and Russell, 1975). However, dramatic differences in preference for a host plant based upon relative fecundity data may also be indicative of either recent or transient change in a polyphagous population and suggests that habituation can probably occur rapidly. It is possible that the hosts to which *B. tabaci* populations have been most recently habituated are those upon which developmental rates are relatively most favorable. Indeed, females of the 'A' biotype do not appear to discriminate between host quality of plant species upon which they deposit eggs, in that females have been shown to feed and lay eggs on several hosts, including lettuce, which are not conducive to completion of the life cycle (Costa et al., 1991). Perhaps the potentially great number of eggs produced by *B. tabaci* females (100-300/lifetime) precludes the need for discrimination of hosts which favor the survival of offspring, and the apparently near-random deposition of eggs on a variety of available species, as determined by adult feeding preference (Costa et al, 1991) provides a greater chance for host adaptation and thus survival of this typically polyphagous species. Factors which contribute to mortality of the offspring of North American populations on certain hosts such as lettuce and cassava have not been investigated.

<u>Virus Transmission</u>. In virus transmission studies, both the 'A' and 'B' biotypes were successful vectors of two geminiviruses of tomato, the CdTV (data not shown) and StLCV (Table 4). High transmission efficiencies were positively correlated with an increase in the number of inoculative *B. tabaci* adults. In StLCV experiments, the 'B'type population was the more efficient of the two vectors, with 56% and 83% rates of transmission for 10 adults of the 'A' and 'B' populations, respectively.

Little is known about factors which govern or impact the ability of *B. tabaci* to serve as a vector of geminiviruses. The 'A' type population does not appear to favor tomato for feeding or reproduction, whereas the 'B' biotype can and does utilize tomato, under field and greenhouse conditions, particularly when other food sources are not available (J.K. Brown, unpublished). One possible explanation for the higher rates of transmission observed here by the 'B' biotype is either in the greater inherent acceptance of, or habituation to tomato, and the subsequent potential increase in duration and "quality" of the feeding experience. These observations may in part, explain the recent increase in prevalence of whitefly-transmitted geminiviruses in solanaceous hosts in the US and Caribbean Basin (Brown, 1991; Brown and Bird, 1992). Indeed, in this region, the 'B' type population has predominated only in recent years. Whitefly-host interactions may thus strongly affect virus transmission efficiencies by whitefly vectors, and likewise, may play a role in the evolution of virus host ranges (Brown and Bird, 1992). Some of these characteristics (Table 5) recognized for the 'B' biotype of *B. tabaci* suggest that this insect is quite distinct from *B. tabaci* populations experienced in the recent past in the region.

Figure 2. Distribution of biotypes of.....

The utility of non-specific esterases as general markers for *B. tabaci* populations remains uncertain. The precise functions and biochemistry of non-specific esterases of whiteflies have not been ascertained in detail, with the exception of esterases associated with pesticide-resistant and susceptible phenotypes (Byrne and Devonshire, 1991; Wool and Greenberg, 1990). The lack of information for *B. tabaci* on the DNA level precludes immediate application of genome based techniques to evaluate genetic polymorphism and to directly correlate biological and molecular characteristics. To expedite the evaluation of a near crisis-level situation relative to unprecedented whitefly populations and widespread virus epidemics, non-specific esterase markers were useful for first documenting and subsequently studying the distribution of the 'A' and 'B' biotypes, described herein. The ability to corroborate data from esterase banding pattern studies with that from bioassays for induction of phytotoxic disorders has proven valuable in the context of facilitating the monitoring of 'B' biotype populations, a prerequisite to gaining insights into this new situation.

Table 4. Relative percent transmission efficiencies for Sinaloa tomato leaf curl virus (StLCV) from tomato to the 'A' and 'B' type populations.

| No. Adult Whiteflies | Rate of Virus Transmission | No. Plants Infected/Inoculated | % Transmission | |
|---|---|---|---|---|
| | A | B | A | B |
| 1 | 26/90 | 39/90 | 29 | 34 |
| 5 | 34/90 | 66/90 | 38 | 73 |
| 10 | 50/90 | 75/90 | 56 | 83 |

Table 5. Some characteristics of two populations of *Bemisia tabaci*

| | 'A' Biotype | 'B' Biotype |
|---|---|---|
| Partial Host Range | bean, cotton<br>cucurbits<br>melon, squash<br>watermelon | broccoli, cauliflower, grape<br>citrus, cotton, cucurbits<br>melons, papaya, sweet pepper<br>poinsettia, rappini, lantana<br>rose, squash, tomato<br>ornamentals, watermelon |
| Fecundity | 100 + eggs/female | 200 + eggs/female[1] |
| Virus Vector | + | + |
| Non-specific Esterase Marker | A-type | B-type |
| ds/ss RNA | - | +[2] |
| Direct Feeding Damage | +/- | + + |
| Honeydew-Associated Problems | +/- | + + +[3] |
| Phytotoxic Disorders | - | +[4] |

[1]Bethke et al., 1991.

[2]D. Jimenez, USDA-ARS, Orlando, FL, Pers. Comm.

[3]Byrne and Miller, 1990; Hendricks et al., 1991.

## Acknowledgements

Drs. H. S. Costa, S. Sivasupramaniam, and S. Coats are gratefully acknowledged for contributions to laboratory and/or greenhouse experiments. Appreciation is extended to A. M. Idris and D. Carbonaro Fletcher for assistance in virus transmission studies, and maintenance of whitefly colonies, respectively. Thanks are extended to Drs. A. Cohen, D. Hendrix, T. Henneberry, I. Terry, and T. Watson for helpful discussions during the course of these studies. Thanks also to those who provided whitefly and virus samples for analysis: Drs. P. K. Anderson, F. Bennett, J. Bird, G. Butler, B. Cooper, P. Jones, R. Lastra, P. Rosset, J. Sanderson, and B. Villalon.

## Dedication

To my mother, Elaine Gilchrist Brown and to my friends throughout the Americas.

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# REVIEW OF THE WORKPLAN FOR A REGIONAL WHITEFLY RESEARCH INITIATIVE IN CENTRAL AMERICA, WITH AN EMPHASIS ON COSTA RICA, GUATEMALA, AND NICARAGUA

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Cb:workplan

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## INTRODUCTION AND BACKGROUND

During the past several years, *Bemisia tabaci* Genn., the tobacco (cotton, poinsettia, or sweet potato) whitefly has emerged as an important and devastating new pest and virus vector throughout the Americas. This polyphagous insect is generally capable of infesting a wide range of vegetable, fiber (cotton, kenaf) and ornamental crops, with the newly introduced 'B' biotype having the broadest host range of all biotypes studied to date. Losses attributed to *B. tabaci* result from direct feeding damage and honeydew contamination of food and fiber. The 'B' biotype and others have the capability to induce phytotoxic disorders in certain crop species, possibly as a result of toxin-like components in the ripening of tomato, and white stem (WSt) disorder of cole crops. The most economically important of these are silverleaf of *cucurbita* species, uneven ripening of tomato and white stem disorder of *Brassica* species.

In addition, *B. tabaci* is an effective vector of many plant viruses including geminiviruses, closteroviruses, potyviruses, and several uncharacterized viruses present in the Americas and Caribbean Basin belonging to other viral genera. Diseases caused by geminiviruses are presently of critical concern in bean, *Brassica* spp., cotton, cucumber, melons, pepper, tobacco, tomato, and watermelon, and geminiviruses are the most economically damaging of the whitefly-transmitted (WFT) viruses recognized to date. The closterovirus, lettuce infectious yellows, has a wide host range, and is also a serious virus pathogen in vegetable crops, but thus far has been found only in the US and Northern Mexico. Because the majority of whitefly-transmitted viruses now recognized in the Americas were virtually unknown until 1978-79, very little detailed information is available concerning the genetics of these viruses; this information is now needed for implementation into critically needed resistance programs. With the combined knowledge of virus-vector biology and virus genetics, classical and engineered resistance strategies can be employed to develop resistant or tolerant germplasm. Very little effort has been expended along these lines for LIYV or for most WFT geminiviruses in part because (1) they are only recently recognized as viral pathogens, and, (2) because these viruses typically affect crops grown primarily in the subtropic-tropical areas where resources have not been applied to the study of these pathogens in a magnitude equal to the abundance or importance of the pathogen. With the recent expansion of monoculture production of crops for local consumption and for export in the subtropics/dry tropics, it has become apparent that WFT viral pathogens and the present, nearly disastrous problems must be addressed.

The general lack of definitive information on fundamental characteristics of *B. tabaci* which might be exploited to devise effective control strategies is apparent. Of critical importance is an improved understanding of whitefly genetics, behavior, physiology, and other inherent characteristics which allow *B. tabaci* to acquire and sustain a pest and vector status in cropping systems. Further, the concept of "biotypes" or "races" and the interactions of these subpopulations with their plant hosts is not well understood, and has only recently come under investigation.

The factors underlying recent population explosions of *B. tabaci*, the basis for seasonal population explosions, and the dynamics of the apparently sedentary and dispersing phases of *B. tabaci* are not understood. In addition, in the americas *B. tabaci* populations have been shown to be resistant to several important classes of pesticides thus, there are no effective

chemical control measures to reduce population pressures at this time. Other related areas that must be addressed are management of insecticide resistance in field populations of *B. tabaci*, the mechanism of such resistance(s), and, ultimately dedication to development of biorational and integrated pest management strategies.

A regional planning meeting was held in Turrialba, Costa Rica, August 3-5, 1992 to assess and discuss these newly emerging issues, and to evaluate the impact that *B. tabaci* and the viruses it transmits are having on regional crop production. A special emphasis was placed on bean, melon, and tomato production in Central America and, in particular in Costa Rica, Guatemala and Nicaragua. Delegates from El Salvador, Honduras, Panama and Belize were also in attendance. The primary goals of the meeting were to promote a better working relationship between researchers in the region, to evaluate the research progress to date, to formulate feasible workplans for prioritization of future research issues, and ultimately to implement research outputs on a field level, with the primary concern being a reduction in the impact of the whitefly-virus problems in Central American cropping systems.

Following the formal presentations by attendees and the in-depth discussion sessions designed to review the status of the whitefly as a pest and virus-vector and to evaluate research approaches and progress effected in the region, participants met in subcommittees to develop a work plan for future research and progress and to prioritize needs relative to the problem-solving strategies. The session was chaired by Dr. Luko Hilje of CATIE, Turrialba, CR., and participants who attended this session are listed in Appendix 1.

## EVALUATION OF FIVE-YEAR WORK PLAN

The research categories which were established and addressed are as follows:
(1) Taxonomy, biology, and ecology, (2) Disease diagnostics and epidemiology, (3) Management, and (4) Technology transfer (Appendix 2).

### I. Taxonomy, Biology, and, Ecology, of Whiteflies

#### 1. Taxonomy of Whiteflies in Central Amercia

The workplan delineates a need for a thorough treatment of the taxonomy of whitefly species in the region. Very little information is available concerning the abundance and distribution of these tropical insects with respect to resident species, potential pests and/or virus-vector status. Recently however, a cataloging and taxonomic evaluation of the Aleynodidae in Central America was undertaken by Mr. Rafael Caballero of Honduras. The work has been published as a Masters Degree thesis from the University of Kansas and is an excellent contribution upon which future studies can be based. This study entails a classical approach to whitefly morphology and taxonomy based on characteristics of the exuviae and adults. Mr. Cabellaro has recently returned to Honduras to teach and to possibly continue his studies of the Aleyrodidae. Much additional information is needed throughout the region on this subject matter, and the continuing efforts and resources expended in this research area are critical to developing capabilities for

whitefly identification, the foundation for the basis of successful control strategies. Until recently this area of research has been neglected in many countries worldwide. This in part due to the recent awareness and recognition of the potential pest status of Aleyrodids such as *B. tabaci* and *Trialeurodes vaporariorum* in food and ornamental crops, and to infestations by the ash whitefly in woody perennials, and the citrus whitefly in *Citrus* groves. Past and present agricultural practices have contributed substantially to the new problems associated with these insects. In addition, most Aleynrodids of economic importance occur primarily in subtropical/tropical areas, and the expertise and resources required to investigate this insect family have not been a priority. As a result of the severity and the magnitude of the current whitefly-associated problems, this area of study should be targeted for research as outlined in the work plan.

Recommendations

1. The foundation research on whitefly morphology/taxonomy in the region should be expanded under the leadership of other qualified researchers in the region. In addition, a concerted effort is needed to focus on *B. tabaci* populations and investigations of biological, physiological, and genetic characteristics. In light of the recent advances in the study of strains or biotypes of *B. tabaci* and other insect pest species, studies should include traditional as well as molecular approaches to strain differentiation. Again, understanding the "identity" of the pest is the fundamental requirement for development of effective control strategies. These aspects are especially needed to utilize biorational and integrated pest management approaches, now the basis for the majority of insect control programs on a worldwide basis.

   a. Implementation

      In light of the recent focus and accomplishments of Mr. Caballero, a concerted effort to encourage a continuation of his studies of Aleyrodidae, with an emphasis on *B. tabaci* would be desirable. Several US and European laboratories are addressing related issues and could serve as cooperators/collaborators in a regional project designed to expand the general knowledge base on the subject.

      In the UA laboratory, we are focusing on strains or biotypes of *B. tabaci* in an effort to define the concept of "biotype" as it applies to this polyphagous insect pest and important virus vector. Our current efforts involve investigations of the genetics of *B. tabaci* on a molecular level, and corroboration of these data with biologically relevant characteristics. In addition, our extension of these principals to worldwide populations (in collaboration with Dr. Peter Markham, (John Innes Institute, Norwich, UK) to investigate the biogeographical diversity and evolution of *B.*

*tabaci*, as well as the basis for biological and genetic differences between biotypes of *B. tabaci* will eventually allow us to extend this line of research to questions concerning the evolution of geminiviruses relative to the role that whitefly biotype-virus specificity plays in virus-vector-host plant systems. Mr. Caballero, could play a key role in this collaborative effort by representing the Central American vantage point. This type of international effort will promote valuable communications and interactions between the few scientists worldwide who are committed to addressing these questions. A consensus effort within the region will enhance the potential for development of effective control strategies with a sound scientific basis.

I would also like to suggest as a possibility that Mr. Caballero be encouraged to apply to the Ph.D. program in the Department of Entomology at the University of Arizona to further investigate pertinent taxonomic issues. (Applications for September, 1993 are due in December, 1992). As a faculty member in the Department of Entomology (joint with my appointment in Plant Sciences), I would be pleased to investigate the feasibility of this approach with Dr. Elizabeth Bernays, Head, Department of Entomology, and to assist in preparation of a proposal to obtain the necessary funding.

In such case, a research program involving a multi-disciplinary, comparative approach to the question of systematics, the evolution of *B. tabaci* biotypes, and possibly an investigation of other relevant Aleyrodids from Central America is warranted. To delineate and further define the concept of species and biotype for this family of insects, morphological, genetic and biological characteristics must be defined and corroborated. This is needed to refine our working knowledge of *B. tabaci* pest and virus vector. A program with such a focus could be a reality in light of the variety of expertise present at the UA. Dr. E. Bernays is a specialist in insect-host interaction from a behavioral and chemosensory standpoint, Dr. Mike Wells (Head, Department of Biochemistry) and Don Frolich, a post-doctoral associate (joint between our labs), are investigating the molecular genetics and evolution of *B. tabaci*, and in my laboratory, we are focusing on biological and genetic characteristics of the *B. tabaci* complex with an emphasis on virus-vector interactions. In addition, Dr. René Feyereisen (molecular basis for insecticide resistance) and Dr. Theo Watson (management of resistance in field population), in conjunction with Dr. Susan Coats in my laboratory are investigating the insecticide resistance phenomenon observed for the 'A' and 'B' biotype of *B. tabaci*, and the potential relationship between host adaptation and pesticide resistance.

The addition of Mr. Caballero to our multidisciplinary team effort would be of value to all involved, in that, he would provide a morphology/taxonomic point of view, and have the opportunity to expand his interest and expertise into entomology, evolutionary biology, and molecular biology of *B. tabaci*. These investigations of the subject matter are critical in order to pave the way toward a long term understanding of the *B. tabaci* biotype complexes existing regionally and worldwide, thus advancing food production efforts in the Americas. When these goals were accomplished, Mr. Caballero would return to Honduras with the capabilities and scientific contacts to develop a long term research program on whiteflies in the region. This is an imperative goal with evident short and long term implications. As an aside, Mr. Caballero has expressed an interest in working toward a Ph.D. in Arizona, thus, I have taken the liberty to suggest this strategy as a possibility for accomplishing the important, timely, and far-reaching goals in this area of research.

b. The need for a molecular approach to identify *B. tabaci* populations and corroborate biological aspects is evident. The imperative need to conduct a thorough survey of the *B. tabaci* populations is also of critical importance. We know that in less than 3 years time, the devastating 'B' biotype of *B. tabaci* has invaded North America, the Caribbean Basin, the Eastern Caribbean Islands, Brazil, Belize, and extreme northern and southern portions of Mexico. A sample collected in the Zacapa region of Guatemala in May 1992 was the 'B' biotype. How extensive the infestation is, and the outcome of the potential change in population structure and dynamics in Central America during the next several years is not known. Nevertheless, Drs. Lloyd Wendel and Dale Krigsvold have agreed to coordinate collaborative efforts to identify the *B. tabaci* biotypes in Central America and to monitor the extent of dispersal capabilities of the 'B' biotype. Our laboratory is directly involved in aspects of esterase typing and DNA-level investigations (supported by USDA/APHIS-Dr. Lloyd Wendel), and in collaboration with Dr. Marilyn Houck (Texas Tech, Lubbock, Texas) morphometric-typing of *B. tabaci* populations in the Americas. (in conjunction with Dr. Tom Henneberry/USDA Laboratory, Phoenix, Arizona). In a formal efforts to conduct a survey of the *B. tabaci* populations in Central America have met with some difficulties due to the fragile nature of the insect, and the labile nature of enzymes and DNA in adult insects.

Both a short and long term strategy is needed to reach the desired goals. An alternative method for collection and storage of adult

whiteflies (Appendix II), prior to shipment to the APHIS Laboratory in Mission, Texas and subsequently to Arizona has been proposed and implemented. An affirmative response was received from Dr. Wendel and Dr. Krigsvold to proceed with this approach as soon as possible. The plan involves preparation of small tubes containing either desiccant or 70% etoh which will be forwarded directly to country collaborators (20 per each cooperator) by Dr. Krigsvold in Guatemala. Dr. Krigsvold, with the assistance of Mr. Karl Ufer will insure that supplies reach individual cooperators from the Central American (and adjacent) countries of Belize, Costa Rica, Dominican Republic, Guatemala, Honduras, Nicaragua, and Panama. Adult *B. tabaci* will be collected and transferred to either ethanol or desiccant-containing tubes. Leaves with immature instars will also be collected at the same sites. Shipments will be sent from each country via DHL to USDA/APHIS in Mission, Texas. The Texas laboratory will be responsible for forwarding samples to the Arizona laboratory.

Results of the analysis conducted in the Arizona laboratory will be forwarded to cooperators as it becomes available. It is therefore essential that we receive addresses or fax numbers from cooperators along with samples so these communications can be expedited. This research effort will have long term implications and benefits for future cooperative and collaborative studies within the region and will also provide an organized collection mechanism, and for detailed studies of regional *B. tabaci* and other economically important Aleyrodids.

c. Another aspect to consider involves the need to expediently address the issues and problems resulting from the *B. tabaci* population explosion in the Americas. Ongoing local research efforts and efforts between local and outside collaborators from nearby or adjacent countries should be strongly supported. A multidisciplinary team approach is needed to solve this complex problem. It is imperative that adequate funding be made available to support the necessary research and implementation activities. The funding level must be sufficient for investigators to direct all efforts toward utilizing the specific expertise, and not to political agendas. If scientific approaches are to be implemented and outputs realized, adequate support must be provided and research executed in an organized and expedient fashion. Delay is no longer an option. The effects of virus diseases and associated feeding damage resulting from unprecedented *B. tabaci* infestations must be alleviated as soon as possible in order to avoid local and regional disasters. This action workplan and that formulated in February, 1992 in the US have the potential to serve as the

infrastructural framework for an international problem solving effort.

2a. **Biology and Ecology of Insect-Plant Interaction and Ecology - Fundamental Studies**

There was initially some confusion on how this topic should be handled. Regardless of the validity of the hypotheses, proposed priority issues, and possible approaches, the limited number of scientists in the region mandated that the group focus on specific and timely issues. Critical research areas were as such defined as (1) delineation of life history traits of *B. tabaci* populations, (2) identification of reproductive hosts vs. exclusively feeding hosts (cultivated crops and weeds) relative to population dynamics and primary sources of *B. tabaci* populations, and (3) identification of sources of virus inoculum in the cropping systems and throughout the growing season. There was interest in host plant resistance studies through variety trials, and discussions on potential utility of interference with population dynamics by specific behavior modification strategies. It was recognized that very little was known about *B. tabaci* for most of these aspects and that the group needed to consider these issues in the control strategies section.

Comments

To address the fundamental objectives will require stringently designed experiments, time, and trained personnel. All of these data are needed in order, to develop an infrastructure and set the stage for development of control strategies dependent on management practices, rotation, planting dates, etc. It must also be realized that the new 'B' biotype of *B. tabaci* which is now threatening crop production in some countries in Central America, is biologically and genetically distinct from the previously studied indigenous populations. Thus far, the 'B' biotype has displaced the indigenous *B. tabaci* population in all locations studied thus far within two years following initial introduction.

Recommendations

The investigations delineated in this section should be limited to gaining a fundamental understanding of whitefly-host interactions from a population dynamics standpoint. The basic "picture" needs to be defined before any directed actions can be implemented.

2b. **Biology and Ecology of Insect-Plant Interactions - Application Oriented**

I am separating this section from the previous one to stress the need for philosophically and temporally different approaches. Included in this subcategory are plans to evaluate vegetable cultivars for tolerance to insect reproductive and feeding pressures, to investigate the utility of trap crops and barriers to reduce

populations (directly), and to encourage the development of beneficial insects (predators, parasites) by providing reservoirs of strategically delineated host plant species. When these strategies are tested and proven in different regions and countries, training will be needed to transfer the technology to growers in specific cropping systems.

Recommendations/Comments

These research projects will not result in short-term overnight solutions, but will pave the way for critically needed long-term development of organized strategies to eventually regain an agroecologically balanced system in the context of our present day concept of cropping systems. These are essential components which will contribute to delineation of a gradual, but potentially sustainable management strategy to reduce total population levels. I would not recommend extensive parasitoid and fungal exploration efforts because considerable time is already devoted to this aspect through collaborative international efforts. A more effective means of accomplishing goals related to the use of parasites for biological control (which represents only one strategy for control) would be to effectively coordinate such efforts regionally and with outside cooperators. This will avoid duplication of efforts, conserve resources, and enhance the possibilities for success of viable biological control strategies.

3. **Migration**

The workplan indicates a focus is needed on migration or "dispersal" since both short and long distance movement of *B. tabaci* is possible and likely dependent upon the variables which dictate the need to locate food source(s). The interest in use of barriers to protect crops dictates the need to understand the feasibility of the approach, and thus research on "dispersal" of *B. tabaci* populations. To accomplish this, in part, host plant species must be identified which will attract and sustain feeding needs such that *B. tabaci* is at first attracted to, and then discouraged or deterred from moving or dispersing from that site. Because short and long distance movement have not been studied extensively for *B. tabaci*, little is known about the potential efficacy of this strategy.

Data from experimental studies in various countries and cropping systems may be available to serve as a starting point. Mr. Porfirio Alvarez and coworkers in the Dominican Republic have some experience in this area of research. The short and long distance dispersal patterns from cultivated and weed hosts must be investigated to identify primary and secondary sources of *B. tabaci* and the viruses it transmits. Climatological and meteorological parameters should be corroborated with dispersal studies to develop meaningful data on predictability of patterns as they are delineated. (This is feasible through the installation of portable AZMET weather stations). There is evidence that high humidity/rainy conditions reduce populations, but population cycles and dynamics associated with

export crops have not been studied with reference to *B. tabaci* population dispersal in the region.

4. <u>Natural Enemies</u>

Inventory of natural (indigenous) parasitoids, predators, etc., is needed to identify (Phase I exploratory) and evaluate the impact (Phase II evaluation of efficacy) of naturally occurring insect predators and parasitoids and fungi on *B. tabaci* populations. In most cases studied thus far, biological control agents are extremely useful as a part of integrated pest management and biorational strategies. In addition, long term augmentation coupled with strategies which complement IPM/biocontrol strategies must be systematically investigated. Identification and evaluation of individual and integrated methodologies are needed to solve this complex problem. Again, the need for accurate identification of the specific whitefly species and biotype at the outset is imperative. It is now clear that these data may vary within the region or country. Thus, the entire concept and reality of biotypic differences is not developed to the point that we understand the implications or the capabilities of the biotypes/species to interact and impact the newly introduced or altered agroecosystems.

5. <u>Studies of the Problems, Disease and Disorder</u>

Efforts must be undertaken to identify/survey the identity, prevalence, and distribution of disorders induced by feeding and the virus disease agents transmitted by *B. tabaci*, and other pertinent whitefly genera and species. The impact that these serious diseases and disorders have on crop production must be evaluated, and a framework for the development of tolerant varieties must be devised. Identification of viruses via virus-specific probes (antibody or DNA probes) is mandatory to allow for (1) identification of primary weed and cultivated hosts (1) to quantitatively and qualitatively evaluate virus resistance, and (3) to implement rational resistance strategies for breeding programs. These areas of research overlap with whitefly population dynamics, dispersal, and the disease section of the workplan. In addition, tolerable threshold levels must be delineated for *B. tabaci* (and other whitefly spp.) vectors as well as pests.

## II. (Diagnostico y Epidemiologia de Virus) Diagnostics and Virus Disease Epidemiology

Diagnoses, Characterization, y Epidemiology

Virus disease problems are prevalent and widespread in both traditional and export crops. The whitefly transmitted viruses appear to be increasing in prevalence and distribution as a result of increased levels of the whitefly vector, *B. tabaci*.

The first step to solving these virus disease problems is to conduct a detailed survey to identify the specific virus problems associated with each cropping system. A survey such as this should involve several hundred samples collected at two or three different time intervals throughout the overlapping cropping seasons. Serological identification of most commonly occurring viruses is presently possible using diagnostic kits available through several private companies worldwide. Diagnostics for the whitefly-transmitted viruses are not yet commercially available due to the recent severity and increased complexity of the problem, but several qualified pathologists have the capability to run DNA hybridization assays to determine the presence or absence of geminiviruses. Upon completion of an in-depth survey over a 1-2 year period of time, general information about the detected viral pathogens is available and accessible, and can be useful in implementing short term strategies to reduce the impact of these diseases. More long term approaches requiring characterization of the specific genetic makeup of the pathogens are needed so that resistant varieties acceptable to growing conditions and market demands may be developed.

Short term management strategies which can be implemented immediately include (1) planting of clean (virus-free) seed or transplants, cuttings, canes, etc., (2) rouging and destruction of diseased materials immediately upon recognition of virus disease symptoms, (3) removal of plants and debris immediately after harvest, (4) rigorous weed control, (5) routine disinfecting of cutting and pruning implements, (6) monitoring of aphid, leafhopper and whitefly populations to detect insect flights throughout the season and thus, enable targeting of pesticide applications, and (7) implementation of crop free periods in a region whenever possible.

Ultimately, many of these virus diseases can be combatted only through reduction/elimination of insect vectors (which is usually not possible) and through cultivation of tolerant or resistant varieties. The development of tolerant varieties is a long term, expensive and time consuming effort, but which is presently yielding promising results from activities initiated many years ago for the more well-characterized viruses. For the newly important whitefly-transmitted geminiviruses, efforts are only just beginning, thus tolerant varieties will hopefully become available in the future as these efforts are increased with the recognition of the severity of the problem.

Recommendation

There is a critical need for a focus on research and extension activities relative to these new and timely problems. I would like to suggest a program for consideration which

involves three phases of work and which includes both short and long term goals necessary to solve this new and serious problem in the region. First, a virus survey is needed to identify the viruses present in cropping systems and ascertain the distribution and severity of the diseases. This can be accomplished by regionally located individuals such as Ramon Lastra, those at Universidad Del Valle, and/or others. I am happy to run the geminivirus assays for the time being until we develop a serologically based test (in progress). For the remainder of the viruses, serological kits are available and are presently used at CATIE in Costa Rica and through Agri-labs in Guatemala. One possibility for an offshoot of this approach which would be beneficial in the long run as well, would be to establish a virus diagnostics laboratory in the region so virus identification can be available throughout the immediate and adjacent region. There is no such capability at the present time.

This approach could be presented initially through the offering of a short course in virology next fall (October or November) which includes a hands-on, full day laboratory to instruct the technical workers in the use of serological (ELISA) and DNA hybridization assays. The US based diagnostic company, Agdia, does these hands-on workshops for a nominal fee; I could do a short course if you like similar to that offered in Antigua, but brief. We could consider doing this in conjunction with pertinent individuals in growers groups, Agri-labs, Del Valle, CATIE, etc., etc. What people really need is to understand the potential uses of these assays, how they work, the limitations, and some of the solutions which can become available with such information. We could also develop information sheets with general data regarding vectors, transmission control methods for the most commonly encountered viruses in the region so technical people will have access to "user friendly" control measures. Down the road, a diagnostics laboratory could be put into place in the private sector (such as Agri-labs) or at CATIE, etc., wherever you think would be best. Several people could be trained to run a lab of this kind in 1-2 years. Other pertinent information needed to tie into this groundwork is research on virus vectors, among which include whiteflies, aphids, and beetles. As you know, we are involved in related work on insect vector biotypes, but this is another major facet.

The second stage could be (overlapping with the second phase of the "diagnostics section") to develop a catalog of fingerprints for the plethora of whitefly-transmitted geminiviruses in the region. This is necessary because we have <u>no</u> information on the identity or genetics of this new group of virus pathogens. Because this information is critically needed to conduct epidemiological studies, and serves as the basis for devising control strategies, we must develop an initial understanding of virus genetics and the diversity or similarity of these new viruses to others presently recognized. Information on virus genetics is of critical importance to developing resistant varieties. Therefore a major effort should be put into deciphering who this new enemy is.

We are just beginning to develop and to test the feasibility of methods for such a monumental undertaking. Despite the fact that geminiviruses have been detected, they remain unidentified and uncharacterized. The only solution to the diversity, severity and the widespread nature of the geminiviruses is through transfer of virus resistance into the

cultivars which are horticulturally acceptable to the area and its growing conditions and markets. This cannot be accomplished without a thorough grasp of the pathogens. Due to the timely nature of geminiviruses and their apparent tenaciousness, we must begin immediately to investigate these parameters. An approach such as this could lead directly into the third proposed step in which biotechnological approaches are combined with classical breeding approaches to develop cultivars suited to the area and containing regionally specific virus resistance. Examples of export crops where this is badly needed include squashes, melons, okra, specialty peppers (scotch bonnets, pimientos, etc.) and tomato (where applicable as an export crop).

As you know, coat protein mediated resistance and others such as antisense and defective replicase strategies are presently being used and/or investigated in the pursuit of virus resistance through biotechnology. I believe these approaches offer the best mechanisms for sustainability of export and other crops in the region relative to the whitefly-transmitted and aphid vectored viruses which presently reduce production capabilities. A large project could be proposed to encompass this approach if there is an interest in these ideas and strategies.

## III. (Manejo) Management

### 1. Chemical Control

Evaluation of materials for chemical control of *B. tabaci* is already underway, and needs continued emphasis. Reports were given from several representatives on data from trials conducted to date. There was a need for a more cohesive approach to reduce the load on individual investigators. It was suggested that perhaps a regional group of agronomists (representing each country) should be organized, and in this way share information, test results, etc. A regional bulletin would be useful to relay research and product information as it becomes available.

Recommendations

To reduce work load, fewer compounds should be tested. An emphasis should be placed on valid, standardized testing protocols which are compatible with various crops and sharing information with respect to efficacy, means of application, doses, and solid data on whitefly and virus disease control.

Comments

Dr. Theo Watson, Department of Entomology, University of Arizona is a specialist in chemical control of insects and field management of resistance. He is interested in spending a 6-month sabbatical in Central America with Costa Rica as his headquarters (beginning next summer). He has applied for a Fullbright to support the visit, but as yet, the availability of the funds has not been verified. In the event that he is unable to support this important endeavor on Fullbright funding, perhaps there are alternatives from the standpoint of regional support. There was great enthusiasm among the

agronomists at the meeting to have Dr. Watson spend his sabbatical in the region, and to concentrate on chemical control and resistance management. In the event that Dr. Watson is able to spend six months in Central America, it would be beneficial for all agronomists in the region involved in chemical control studies/technological transfer, etc., to have access to Dr. Watson's expertise during his sabbatical.

2. Cultural Control

This is the best short and long term strategy for population reduction and subsequent virus control. No specific method has been investigated in an experimental regime, but it is accepted that standard sanitation practices, rouging, rotation, use of barriers, etc., definitely reduce *B. tabaci* populations.

Recommendations/Comments

This approach is difficult to incorporate because without one hundred percent cooperation among growers, the positive effects are difficult to demonstrate. With an insect like *B. tabaci*, each crop affects adjacent crops; thus a consensus on strategies for planting and plow-down dates, and implementation of strict sanitation measures must be reached. In combination with chemical control, effective cultural control strategies have the potential to gradually lower the population levels, and subsequently, the amount of virus inoculum in weeds and cultivated species. This is easier to propose than to put into practice. Informing growers of these practices and encouraging compliance should, none-the-less, constitute a priority.

3. Control Measures Based on Behavior Modifications

It was agreed that inadequate information on this topic did not allow for successful application of control measures based on modification of behavior. Very little effort has been directed toward the basic research needed in this area. As information becomes available along these lines, it will be necessary to make adjustments to the stated objectives in the long-term plan.

4. Applied Ecology

There is a paucity of fundamental information on ecological aspects of *B. tabaci*, thus there is little foundation upon which to base application oriented goals. It was decided that land races, wild species, and popularly grown cultivars be evaluated for ability to repel/deter or to withstand whitefly feeding and virus disease pressures. These characteristics, if promising, would be made available for plant breeders to incorporate into locally grown cultivars. This strategy is, by nature, a long term and a necessary alternative for dealing with the problem.

Comment

Coordination, cooperation, and communication between individual researchers in the region will be needed as well as collaboration between virologists and plant breeders to put this strategy into effective practice.

5. Biological Control

Basic and applied aspects of biological control strategies must be taken into consideration. Several countries have agronomists and entomologists in-house with this expertise. An inventory is underway to determine the identity and distribution of biocontrol agents including predators, parasitoids, and fungal pathogens. In addition to determining the constitution of the natural fauna, methods for prioritizing the efficacy of the agent in specific cropping systems and host species relative to chemical and cultural practices are needed. Subsequently, mass-rearing and release will be needed, and ultimately, methodologies for determining optimum timing for release and the means for evaluating efficacies. This is a pure research component at this stage.

Recommendations/Comments

A team approach to these objectives is clearly needed. This is potentially a massive undertaking and should be well-coordinated within the region. In addition, communications with other experts outside of the region should be established so efforts can be consolidated. The same approaches are underway in Mexico and in the United States (California, Florida, Texas) and all involved could benefit from a collaborative/cooperative interaction. It is not necessary to conduct all research and applied aspects in every location, thus specialty areas could be established to allow individuals to focus on a limited number of aspects, and thereby accomplish the objectives with greater precision and efficiency. This approach would provide the best opportunity for successful biological control strategies.

5. Legal Control

It was suggested that policies be established which include awarding of a monetary "reward" for compliance with established planting and plow-down dates. Incentive based mandates must be based on sound cultural practices which in fact are adhered to by growers affecting each other in a country or region. Examples or prototypes of such mandates are presently available in the US and elsewhere and could be useful upon which to base such a control strategy.

## IV. Technology Transfer

Technology transfer was discussed on several levels. The need for coordination between administrators and researchers, researchers and technical workers, and from technical workers to farmers was discussed in detail. Mechanisms for in-country interactions were apparently in place in most situations. The regional coordination efforts were obviously in progress and there was discussion concerning funding for future efforts to strengthen the regional cooperations: (1) annual joint meeting of all national whitefly committees

to exchange data, discuss strategies, update plan, etc., (2) a regional newsletter published on a regular basis to exchange information 2-4 times a year, (3) the need to involve Dominican Republic despite the geographical separateness as a result of the commonality of the problem and existing expertise, and (4) training and workshops by regional and external experts.

Comments

The research and applied infrastructures were formulated and established during this workshop, and overall, the interactions/exchanges were excellent. Certain individuals voiced an interest in establishing priority areas of focus in the country which housed the "expertise" and facilities. Others preferred to cover all the bases in their own country. The two areas of research/application that lend themselves best to a localized approach are Virology, and Whitefly Taxonomy. There is a rationale for the establishment of a regional center(s) to accommodate these needs due to the costly nature of these disciplines, and the limited availability of resources in the way of facilities and trained personnel. These are matters which must be dealt with internally, however, with the primary goal being problem solving on a regional level.

**Appendix II**
**Taller Centroamericano y Del Caribe Sobre Moscas Blancas**
**Participantes en la Sesión Del Miércoles**
**Coordinator: Dr. Luko Hilje (CATIE)**

1. Dr. Ramón Lastra, CATIE (Costa Rica)
2. Dra. Judith Brown, University of Arizona (EE.UU.)
3. Dra. Pamela Anderson, UNA (Nicaragua)
4. Dr. Victor Salguero, Proyecto CATIE-ICTA (Guatemala)
5. M.Sc. Danilo Dardón ICTA (Guatemala)
6. M.Sc. Rafael Caballero, EAP (Honduras)
7. Ing. Pedro Carbajal, SRRNN (Honduras)
8. Ing. Porfiro Alvarez, Programa MIP (Rep. Dominicana)
9. Ing. Leopoldo Serrano, UES (El Salvador)
10. Ing. Diego Gómez, Proyecto CATIE-MAG (Nicaragua)
11. M.Sc. Emilio Martínez, CENAPROVE (Nicaragua)
12. M.Sc. Bruno Zachrisson, IDIAP (Panamá)
13. Dr. Alberto Perdomo, IICA (El Salvador)
14. Dr. Mario Contreras, ROCAP (Costa Rica)
15. Ing. Karl Ufer, PROEXAG (Guatemala)
16. Ing. César Noé Pino, FPX (Honduras)
17. Ing. Juan Marenco, FUSADES (El Salvador)
18. Ing. Evaristo Morales, OIRSA
19. M.Sc. Mario Saborío, MAG (Costa Rica)
20. Un director de Sanidad Vegetal
21. Dr. Theo Watson, University of Arizona (EE.UU.)
22. Dr. Octavio Ramírez, CATIE (Costa Rica)
23. Dr. Tomás Zoebisch, CATIE (Costa Rica)
24. Dr. Bernal Valverde, CATIE (Costa Rica)

APPENDIX I. TALLER DE MOSCA BLANCA

I. Taxonomia, Biologia, y Ecologia

| AREA TEMATICA | ACTIVIDADES | ACCION ESPECIFICA |
|---|---|---|
| I. Taxonomia<br>1. Mosca blanca | 1. Inventario de spp. diagnóstico | En cada país |
| | Capacitación | Instalar capacitación permanente |
| | 2. Determinación de biotipos | Adiestramiento en servicio cursos cortos |
| | | Continuar con colectas regionales |
| | | Instalar capacidad local (equipo y personas) |
| 2. Biologiay Ecologia<br>1. Relacion insecto-planta | Determinación de periodo de mayor susceptibilidad de la población inmigrante en cultivos establecidos. | Cada país por cultivo clave |
| | Mecanismo de resistencia antibiosis | Evalucación de variedades |
| | -Potencial biótico por cultivo (insecto se reproduce) | Cultivos claves |
| | -Período crítico del cultivo | Frijol, melón, etc. |
| | -Interferencia en la selección del cultivo | Preferencia de hospederos<br>Coberturas muertas<br>Coberturas vivas |
| 3. Migración | -Interferencia dentro del cultivo | Cultivos trampas<br>Barreras internas |
| | -Effecto de la hr sobre las poblaciones de mosca | Estudio de laboratorio y campo |
| | -Interferencia con inmigración | Barreras perennes<br>Barreras anuales |

Taller de Mosca Blanca

I. Taxonomía, Biología, y Ecología

| AREA TEMATICA | ACTIVIDADES | ACCION ESPECIFICA |
|---|---|---|
| 4. Ecología-enemigos naturales | Inventario | Regional |
| | Evaluación | Especies claves |
| | Biología | Especies claves |
| | Cria masiva | Especies claves |
| | (efecto de extractos botanicos) | |
| | Introducción de spp foráneas | Establecer contactos con quienes los poseen |
| | Diagnóstico | Capacitación local instalada |
| | Capacitación | Adiestramiento en servicio |
| | | Cursos cortos |
| 5. Ecología-estudio de malezas | Inventario y caracterización *Bemisia y Trialeurodes* (Distribución geográfica de las malezas) | Alimentación<br>Reproducción<br>Reservorio virus<br>Reservorio entomofagos |
| | Aprovechaminento | Incremento enemigos naturales |
| | | USO como cultivo trampo (repelencia) |

Recomendaciones:

1. Los resultados que se puedan considerar confiables deben entrar a la red de informacion. Se sugieren boletines cada 3 meses.

2. Se requiere material para divulgacion a nivel de agricultores.

Taller de Mosca Blanca

II. Diagnostico y Epidemiologia de Virus

| AREA TEMATICA | ACTIVIDADES | ACCION ESPECIFICA |
|---|---|---|
| 1. Diagnóstico | Inclusiones<br>Hibridizacion ADN-ADN<br>Transmisión *Bemisia tabaci*<br>Elisa | Capacitación<br><br>Activar diagnóstico de GV a través de red existente<br><br>Reconocimiento de GV presentes en la región |
| 2. Caracterización | Biología<br>Genética | Transmisión<br>Rango de hospederos<br>Huéspedes alternos<br>Análisis de ADN |
| 3. Epidemiología | Transmision<br>Virus-hospedero | Reservorios de GV<br>Sinergismo viral<br>Parámetros transmisión<br>Período crítico<br>Tolerancia/resistencia<br>Período incubac. Virus<br>Colonización y dispersión |

Taller de Mosca Blanca

III. Manejo

| AREA TEMATICA | ACTIVIDADES | ACCION ESPECIFICA |
|---|---|---|
| 1. Control químico | 1- Evaluación de insecticidas | 1- Eficacia (producto y dosis) |
| | | 2- Selectividad |
| | | 3- Residualidad |
| | | 4- Compatibilidad |
| | | 5- Residuos toxicos |
| | 2- Métodos | 1- Diseño de equipo<br>2- Distribucion de gotas<br>3- Volumen de aplicación<br>4- Densidad de cobertura |
| | 3- Resistencia | 1- Monitoreo de poblaciones resistentes<br>2- Rotación |
| 2. Control cultural | 1- Diversificación del agroecosistema | 1- Barreras vivas |
| | | 2- Manejo malezas<br>3- Cultivo o planta trampa<br>4- Cultivos asociados<br>5- Alta densidad |
| | 2- Manejo de almacigo | |
| | 3- Coberturas de plástico | |
| 3. Etológico control | Trampas | Muestreo control |
| 4. Control legal | Veda | |
| | Rotación<br>Fecha de siembra<br>Manejo de rastrojo | |

Taller de Mosca Blanca

III. Manejo

| AREA TEMATICA | ACTIVIDADES | ACCION ESPECIFICA |
|---|---|---|
| 5. Control biológico | Parasitoides<br>Depredadores<br>Hongos | Estudios básicos<br>Estudios aplicados |

Taller de Mosca Blanca
IV. Transferencia de Tecnología

| AREA TEMATICA | ACTIVIDADES | ACCION ESPECIFICA |
|---|---|---|
| 1. Transferencia de tecnología | Capacitación regional | Talleres anuales |
| | Capacitación nacional | Talleres<br>*Metodología de extensión<br>*En fitoprotección<br><br>Cursos<br><br>Días de campo (PV) |
| | Capacitación zonal | Charlas<br><br>Días de campo (PD) |
| | Asistencia técnica | -Seguimiento a productores en finca<br><br>-Evaluación de la adopción de tecnologia<br><br>Internacional<br>Horizontal |
| | Comunicación-divulgación | Definición y elaboración de materiales<br>-Cuñas radiales<br>-Cuñas TV<br>-Panfletos<br>-Boletines tecnicos<br>-etc. |

Taller de Mosca Blanca
IV. Transferencia de Tecnologia

| AREA TEMATICA | ACTIVIDADES | ACCION ESPECIFICA |
|---|---|---|
| 1. Conclusión: Existen opciones para implementar acciones en el area de transferencia de tecnologías. En cada país existe al momento experiencia y fortaleza para intercambiar información. Se debe mejorar este tipo de intercambio.<br><br>2. Para iniciar un programa masivo de transferencias. Es necesario complementar planes de capacitación.<br><br>3. Delimitar las instituciones a participar en las actividades para este momento, porque algunos países regresan para formar grupos o comisiones.<br><br>4. La mayoría de los países mostraron interés en todos las actividadades pero la priorización por cultivo dependerá de los planes de cada país. | | |