The Systemwide Tropical Whitefly IPM Program

Activity 1. Coordination.

CIAT has the responsibility to coordinate the Systemwide Tropical Whitefly IPM Program (SP-IPM- TWFP), and its various sub-projects in the Americas (described as activities in this section of the annual report), Southeast Asia and subSaharan Africa. These projects are funded by different donors, namely: The United Kingdom Department for International Development (DFID); the United States (USAID) and New Zealand (NZAID) Agencies for International Development; and the Australian Center for International Agricultural Research (ACIAR). The various subprojects that constitute this global effort are currently coordinated by scientists from IITA, CIAT and AVRDC. The International Potato Center (CIP) has participated in the past and currently holds the Chair of the Systemwide IPM Program.

One of the main Coordination activities has been the integration of the various Crop Protection Programme (CPP) projects that target whiteflies as pests and vectors of plant viruses in the Tropics. The whitefly CPP projects that lie outside the coordination of the TWFP, operate in Southeast Asia and East Africa, and target crops, such as cassava, sweet potato and vegetables. The TWFP also targets cassava and vegetables in other areas of the tropics, including their center of origin, and includes the common bean as a major food crop threatened by whiteflies and whitefly-transmitted viruses in the Americas. The TWFP has also been entrusted with the responsibility of supporting the development of new projects on the epidemiological implications of the IPM strategies being promoted by the TWFP.

The TWFP Coordination is also trying to expand its target area, primarily in the Andean region. At present, only Colombia and Ecuador receive technical assistance, but Peru and Bolivia are also suffering the effects of severe whitefly outbreaks in different crops, including potato, tomato and sweet potato. The coordinator of the TWFP responded to a request from DFID and the Bolivian Foundation for the Promotion and Research of Andean Products (PROIMPA), to evaluate the whitefly problem in the mesothermic valleys of the departments of Cochabamba and Santa Cruz. The main whitefly pest in these valleys was identified as *Trialeurodes vaporariorum* and the main crops affected were: common bean, potato and tomato. This whitefly species is not a vector of the main group of viruses transmitted by the whitefly *Bemisia tabaci*, but it has the capacity to kill susceptible plants through its feeding damage and release of substances (honeydew) that promote fungal growth (sooty molds). This type of severe damage was observed in some common bean fields **(Figure 1)** and, to a lesser extent, in potato.

The TWFP is approaching the last stage of Phase III, in which the most promising IPM strategies identified during Phase I, were tested in pilot sites. Hence a meeting of all subproject coordinators from the Americas, Africa and Asia will take place at the end of this month (September) in order to define research/technology dissemination priorities for Phase III. The emphasis of the meeting will be on Farmer Participatory Research; Communication Technology and Knowledge Management.

Figure 1. **Direct (feeding damage) and indirect (sooty mold) damage caused by *Bemisia tabaci* in common bean.**

Figure 2. **Farmer field school organized in El Salvador to disseminate information on IPM practices to control whiteflies and whitefly-transmitted viruses.**

Activity 2. Studies on whitefly (*Aleurotrachelus socialis*) resistance mechanisms in selected cassava genotypes.

As direct feeding pests and virus vectors, whiteflies cause major damage in cassava based agroecosystems in the Americas, Africa and, to a lesser extent Asia. The largest complex of whitefly pests on cassava is in the Neotropics, where 11 species are reported. Eight whitefly species are reported feeding on cassava in Colombia. *Aleurotrachelus socialis* is the major species on cassava in Northern South America (Colombia, Ecuador, Venezuela) while *Aleurotrachelus aepim* predominates in Brazil and *Bemisia tabaci* in Africa and parts of Asia. In whitefly surveys on cassava in Colombia, approximately 92% of the species population is *A. socialis*. For this reason, *A. socialis* receives most of the research effort, especially in the identification of whitefly resistant cassava genotypes and the development of resistant varieties.

The first symptoms of whitefly damage are manifested by curling of the apical leaves and yellowing, necrosis and abscission of lower leaves. This results in plant retardation and considerable reduction in root yield if feeding is prolonged. Damage and yield losses of this type are common with *A. socialis* and *A. aepim.* There is a correlation between duration of whitefly attack and yield loss, which has been recorded as high as 79% in prolonged (11 months) attacks and on susceptible cultivars. Cassava farmers will respond to whitefly attack with frequent applications of toxic chemical pesticides. Pesticide use is costly, often causes environmental contamination, a hazard to human health and may not provide effective control.

Stable host plant resistance (HPR) offers a practical long-term low cost solution for maintaining reduced whitefly populations. Although whitefly resistance in agricultural crops is rare, several good sources of resistance have been identified in cassava and high-yielding, whitefly resistant cassava hybrids are being developed. At CIAT we are systematically evaluating the cassava germplasm bank of more than 6000 accessions. The clone MEcu 72 has consistently expressed the highest level of resistance and is being employed in a breeding scheme to develop whitefly resistant hybrids (see CIAT 2002, IP-3 Annual Report). Additional cultivars expressing moderate to high levels of resistance in field trials include MEcu 64, MPer 335, MPer 415, MPer 317, MPer 216, MPer 221, MPer 265, MPer 266 and MPer 365.

The objective of these present studies is to evaluate several selected genotypes for mechanisms of resistance to *A. socialis* under controlled growth chamber conditions.

Methodology: The genotypes selected for evaluation were MEcu 64, MPer 273 and MPer 334; CMC 40 was the susceptible control and MEcu 72 the resistant control. All genotypes have been field evaluated during numerous trials at CORPOICA, Nataima (Tolima). As previously mentioned MEcu 72 has consistently shown resistance to *A. socialis* and in laboratory controlled resistance mechanisms evaluations, resulted in a 72% mortality, a lower oviposition rate, longer development time and reduced size. CMC 40 supports high *A. socialis* populations and low mortality. In field trials MPer 273, MPer 334 and MEcu 64 genotypes showed low to moderate *A. socialis* populations and few damage symptoms. Four *A. socialis* development parameters were evaluated, mortality/survival, duration of the life cycle, nymphal development size, (Antibiosis), and ovipositional preference (Antixenosis). This was done in two separate experimental designs.

1. Antibiosis Experiments: This was done in two parts; in the first, test plants were infested and evaluated by using *A. socialis* adults harvested directly from the greenhouse maintained colony being reared on the susceptible CMC 40 **(Figure 1A)**. The second evaluations were done by first preconditioning *A. socialis* on the selected test genotypes for two generations. These individual colonies on the five aforementioned genotypes were reared in wooden, nylon mesh lined cages (1m x 1m x 1m) in the greenhouse **(Figure 1B)**. All antibiosis experiments were carried out in the growth chamber (28±1°C, 60-70% RH, 12 hrs. light) by measuring the life cycle development of *A. socialis* as the aforementioned resistant and susceptible genotypes. Cassava plants were grown in plastic pots and were 4 to 5 weeks of age at infestation. Plant infestation was accomplished by introducing 20 whitefly adults into small leaf cages, supported by plastic straws **(Figure 2)**. Each leaf cage has a small lateral opening and with the aid of a pasteur aspirator, *A. socialis* adults are encouraged to enter the leaf cages. Five leaf lobes were infested on each plant (total 180) during a 4-hour period with 3600 adults **(Figure 3A)**. *A. socialis* adults were allowed to oviposit for 24 hours, thereby assuring a uniform population. Leaf cages and adults were then removed and egg infested plants were placed in the growth chamber **(Figure 3B)**. Each leaf lobe was sequentially numbered to assure accurate data collection on each of the tested genotypes.

Figure 1. Antibiosis experiments. (A) Greenhouse colony of *Aleurotrachelus socialis* on CMC 40 (not-preconditioned); (B) *A. socialis* pre-conditioned and reared in nylon-meshed cages on resistant and susceptible genotypes.

Figure 2. Thirty-day cassava plants grown in plastic pots and with attached leaf cages conditioned for *Aleurotrachelus socialis* infestation.

Figure 3. (A) Cassava plants conditioned for *A. socialis* infestation; (B) cassava plants infested with *A. socialis* eggs in the growth chamber (28±1°C, 60-70% RH, 12 hrs light).

To determine the biological cycle of *A. socialis* on resistant and susceptible genotypes, 200 eggs are selected per plant, and an "infestation map" was designed so that daily evaluations of immature development can be recorded for instar changes, growth characteristics and survival/mortality. Daily evaluations were done with the aid of a stereomicroscope on the leaf undersurface. The potted plants, fastened to an iron support rod that allows upward-downward movement for optimal positioning, are inverted for easy observance. A rubber disk inserted at the base of the plant stem at the soil line prevents soil loss or plant movement and injury when the potted plants are invested **(Figure 4)**.

Figure 4. Inverted cassava plants fastened to an iron support rod allowing easy observance of *Aleurotrachelus socialis* development stages with the use of a stereomicroscope.

The differences in duration of biological stages, time of development, morphological measurements of immature stages and adult dry weight were analyzed using the Ryan-Einot-

Gabriel-Welsch Multiple range test (REGW). The rate of survival and relationship between sexes was analyzed with the Chi-Square (X^2) test.

Morphological measurements were done by removing 10 individuals per leaf lobe (40 individuals total per genotype) and taking measurements of the 2nd and 3rd instar nymphs and the pupal stage. A stereomicroscope with a digital dispositive for micro measurement (Wild MMS 225/MMS 2535) **(Figure 5)**.

Figure 5. Digital micrometric measuring devise to determine morphological size of *Aleurotrachelus socialis* immatures.

Dry weight of adult whiteflies was done by placing well-developed pupae in the small leaf cages to prevent adult escape upon hatching. Sexing was done under the stereomicroscope using adult anal morphological characteristics to separate male and females. Captured adults from each of the tested genotypes were placed in plastic vials with cotton stoppers and dried in a Blue-M stove at 37°C for 72 hours. These were weighted on a CAHN C-30 microbalance, sensitive to 1 μg.

2. Antixenosis Experiments. These experiments compared and determined the ovipositional and feeding preferences of *A. socialis* on the five genotypes. One potted plant of each genotype was randomly placed in a 1m x 1m x 1m wooden, nylon meshed lined cage. Each 30-day-old plant contained only three leaves, numbered in descending order from the top, middle and lower portions of the plant. This design allowed measurement of both total and vertical plant preference of oviposition. All plants were of equal height and distributed in a circular fashion to provide each genotype with an equal chance for oviposition **(Figure 6)**. Five hundred *A. socialis* adults of the same age and randomly selected from the whitefly colony being reared on CMC 40, were introduced into the center of each cage. Recorded data was logarithmically transformed (Log H+1) and significant differences were determined using the Ryan-Einot-Gabriel-Welsch multiple F test. The variables were, 1) the number of whiteflies perched on each genotype at 24 and 48 hours after infestation, and 2) the number of eggs oviposited on each genotype after 48 hours. A visual count of perched adults was accomplished by carefully opening each cage without disturbing plants and whitefly adults. Egg counts were made under the stereomicroscope. The evaluation was done 3 times with four repetitions using a randomized block design in the growth room (28±1°C, 60-70% RH and 12 hr. light).

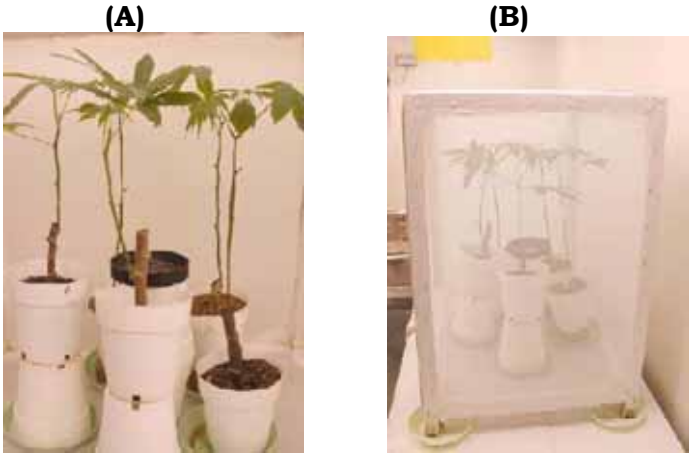

Figure 6. Cassava genotypes (Resistant and Susceptible) placed in nylon meshed cages and infested with 500 *A. socialis* adults for free choice ovipositional preference evaluations in the growth chamber.

Results

1. Antibiosis: No preconditioning.

A. socialis individuals (adult infestation directly from the greenhouse colony = un-preconditioned) feeding on MEcu 64 and MPer 334 had a significantly longer development period than on the other genotypes **(Table 1)** with 36.8 and 36.4 days respectively. MEcu 72 and MPer 273 resulted in a duration of 35.2 and 33.6 days, while CMC 40 the susceptible control had a significantly more rapid development of 32.7 days. The duration of the egg stage ranged from 10.1 (CMC 40) to 11.1 (MEcu 64) and difference between genotypes were significant **(Table 2)**. The greatest differences occurred in the first nymphal instar. Most rapid development occurred on CMC 40 (4.9 days) and longest on MEcu 64 (6.4 days); MPer 334, MEcu 72 and MPer 273 had first instar duration of 6.1, 6.1 and 5.6 days respectively **(Table 2)**. Significant differences between genotypes also occurred in the 2nd and 3rd nymphal instars but they were not as dramatic as in the first instar. The duration of the pupal stage ranged from 9.6 days (CMC 40) to 10.5 days (MPer 334). The relationship between sexes was approximately 1:1 in all of the genotypes evaluated **(Table 1)**.

Table 1. Average development time of *Aleurotrachelus socialis* (non-preconditioned) feeding on five cassava genotypes (resistant and susceptible) in the growth chamber.

Genotypes	n.	Average ± SD	Sex Relation
MEcu 64	63	36.8 ± 2.09 a1	1.0 : 1.0
MPer 334	45	36.4 ± 2.21 a	1.1 : 1.0
MPer 273	94	33.6 ± 1.55 c	0.7 : 1.0
MEcu 72	62	35.2 ± 2.56 b	1.2 : 1.0
CMC 40	152	32.7 ± 1.65 d	1.3 : 1.0
			X^2 : NS^2

1. Ryan-Einot-Gabriel-Welsch Multiple Range test. Columns with the same letter are not significantly different at the 5% level.
2. Independent Test. Female/Male sex relation is 1:1 in all genotypes.

Table 2. Duration of *Aleurotrachelus socialis* developmental stages on whitefly resistant and susceptible genotypes (non-preconditioned) (*n*=200).

Genotypes	Egg	Nymph 1	Nymph 2	Nymph 3	Pupae
MEcu 64	11.1 ± 0.57 a[1]	6.4 ± 1.08 a	4.3 ± 0.71 a	5.1 ± 0.66 a	10.4 ± 0.93 a
MPer 334	10.7 ± 0.47 b	6.1 ± 1.08 b	4.3 ± 0.95 a	5.0 ± 0.94 a	10.5 ± 1.07 a
MPer 273	10.4 ± 0.49 c	5.6 ± 1.01 c	3.7 ± 0.64 b	4.4 ± 0.63 b	10.0 ± 0.84 b
MEcu 72	10.6 ± 0.58 b	6.1 ± 1.05 b	4.4 ± 0.63 a	4.6 ± 0.96 b	9.9 ± 0.87 b
CMC 40	10.1 ± 0.50 d	4.9 ± 0.85 d	3.8 ± 0.59 b	4.4 ± 0.54 b	9.6 ± 0.83 b

1. Ryan-Einot-Gabriel-Welsch Multiple Range (F) test. Columns with the same letter are not significantly different at the 5% level.

2. Antibiosis: With preconditioned *A. socialis.*

Development time for *A. socialis* in this experiment was significantly longer when reared on MEcu 64 (34.5 days) compared to the other genotypes. It was shortest on CMC 40 (31.8 days) and intermediate for the remaining three genotypes **(Table 3)**. Nymphal duration was longest during the first instar; MEcu 64 was longest (6.3 days) and CMC 40 was shortest duration (5.0 days). The remaining three genotypes, MPer 334 (5.6 days), MPer 273 (5.5 days) and MEcu 72 (5.7 days) were significantly different from the susceptible genotype CMC 40 **(Table 4)**. Differences in development duration in the second and third instars were not as dramatic as in the first instar. Duration of the pupal stage ranged from MEcu 64 (10.5 days), the longest, to CMC 40 (9.5 days) the shortest and the remaining genotypes, intermediate **(Table 4)**. Results in this experiment were similar to those in the un-preconditioned experiment, however, the values were lower or of shorter duration, indicating that preconditioning *A. socialis* effects development time.

Table 3. *Aleurotrachelus socialis* development time on cassava genotypes (resistant and susceptible) during preconditioning phase.

Genotypes	N	Average ± SD	Sex Relation
MEcu 64	96	34.5 ± 1.94 a[1]	1.0 : 1.0
MPer 334	124	33.0 ± 1.76 bc	0.9 : 1.0
MPer 273	127	32.8 ± 2.22 c	1.3 : 1.0
MEcu 72	127	33.5 ± 1.82 b	0.8 : 1.0
CMC 40	140	31.8 ± 1.61 d	1.5 : 1.0
			X^2 : NS[2]

1. Ryan-Einot-Gabriel-Welsch Multiple Range test. Columns with the same letter are not significantly different at the 5% level.

Table 4. Duration of *Aleurotrachelus socialis* development stages on whitefly resistant and susceptible genotypes (*n*=200) (preconditioning phase) in the growth room.

Genotypes	Egg	Nymph 1	Nymph 2	Nymph 3	Pupae
MEcu 64	9.7 ± 0.54 b[1]	6.3 ± 1.34 a	4.2 ± 0.86 a	4.2 ± 0.70 a	10.5 ± 1.05 a
MPer 334	9.4 ± 0.54 c	5.6 ± 0.92 b	3.8 ± 0.83 b	4.0 ± 0.52 a	10.4 ± 1.04 a
MPer 273	10.0 ± 0.72 a	5.5 ± 0.99 b	3.8 ± 0.77 b	4.0 ± 0.61 a	9.7 ± 1.21 bc
MEcu 72	9.7 ± 0.62 b	5.7 ± 1.11 b	4.2 ± 1.01 a	4.1 ± 0.58 a	10.0 ± 1.02 b
CMC 40	9.6 ± 0.71 b	5.0 ± 0.87 c	3.8 ± 1.02 b	4.1 ± 0.614 a	9.5 ± 0.95 c

1. Ryan-Einot-Gabriel-Welsch Multiple Range test. Columns with the same letter are not significantly different at the 5% level.

A. socialis survival on resistant genotypes (MEcu 64, MEcu 72, MPer 334 and MPer 273) is significantly lower than on the susceptible check, CMC 40 **(Figures 7 and 8)**. First instar nymphs are the most effected; they have difficulty adhering to the leaf undersurface and initiating feeding on resistant genotypes. This is not a problem on the susceptible genotype CMC 40, where establishment and feeding readily occur **(Figure 7A)**. In the two experiments *A. socialis* survival remained the same (76 and 75% survival) **(Figure 8)**. Without precondition *A. socialis* survival on MPer 344, MEcu 72, MEcu 64 and MPer 273 were 22.5, 31.0, 31.5 and 47.0% respectively. For preconditioned *A. socialis*, the results were similar but the rate of survival was higher for all of the resistant genotypes **(Figure 8)**. For example, in the first experiment MEcu 64 survival was 31.5%, wile in the second it was 48.0%. In both experiments the resistant genotypes had a significantly lower survival rate than the susceptible genotypes (P=0.05). These results indicate that constant rearing of *A. socialis* on resistant genotypes may reduce the effectiveness of the resistant factors. This will play a role in the deployment of resistant cultivars in field plantings.

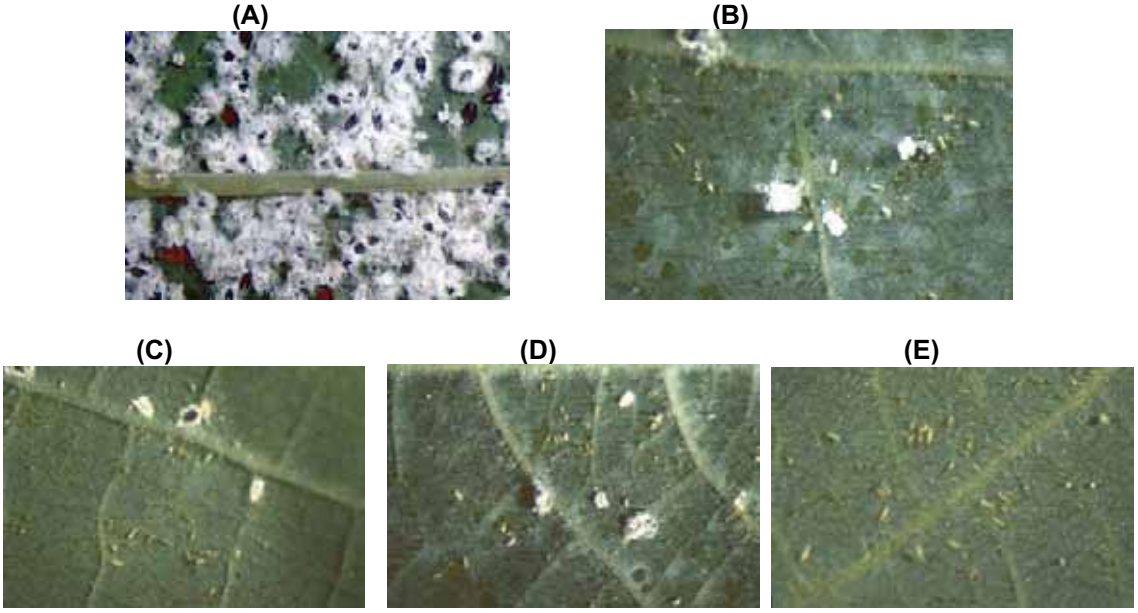

Figure 7. ***Aleurotrachelus socialis*** **nymphal survival on cassava (A) Susceptible control CMC 40; (B) Resistant control, MEcu 72; (C) MPer 273; (D) MPer 334; (E) MEcu 64.**

Morphological measurements of *A. socialis* feeding on resistant and susceptible genotypes show that 2nd and 3rd instar nymphs and pupae were significantly longer on CMC 40 than on the resistant genotypes **(Figure 9)** (P=0.05). The results for width were similar although differences were not always significant. *A. socialis* adult dry weight was significantly lower when feeding on MEcu 64, followed by MPer 334, MPer 273 and MEcu 74 (P=0.05) **(Figure 10)**. All resistant genotypes were significantly lower than the susceptible check, CMC 40, for both the non-preconditioned and preconditioned *A. socialis*.

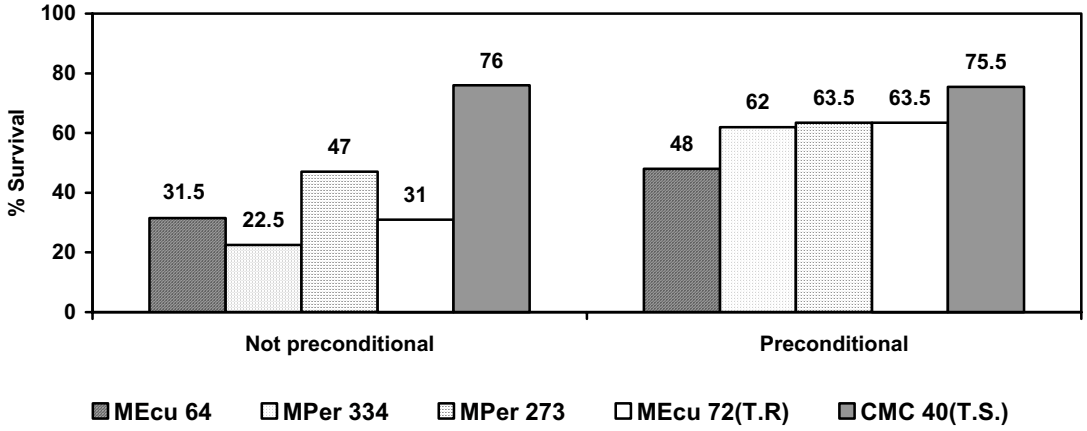

Figure 8. Percent survival of *Aleurotrachelus socialis* feeding on five cassava genotypes (resistant and susceptible) in the growth chamber (28±1°C, 60-70% RH, 12 hrs. light).

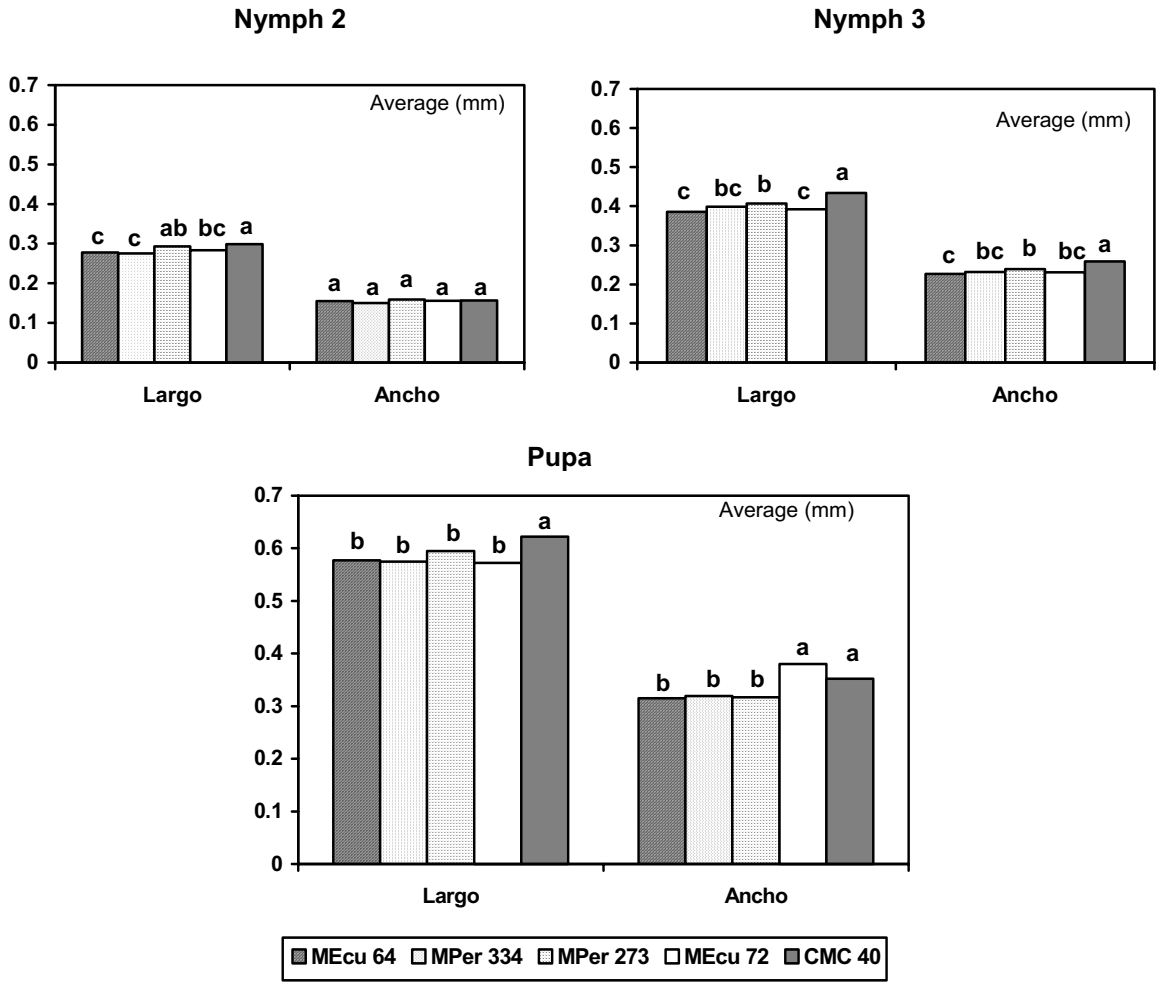

Figure 9. Morphological measurements of *Aleurotrachelus socialis* 2nd and 3rd instar nymphs and pupal stage on five cassava genotypes in the growth chamber.

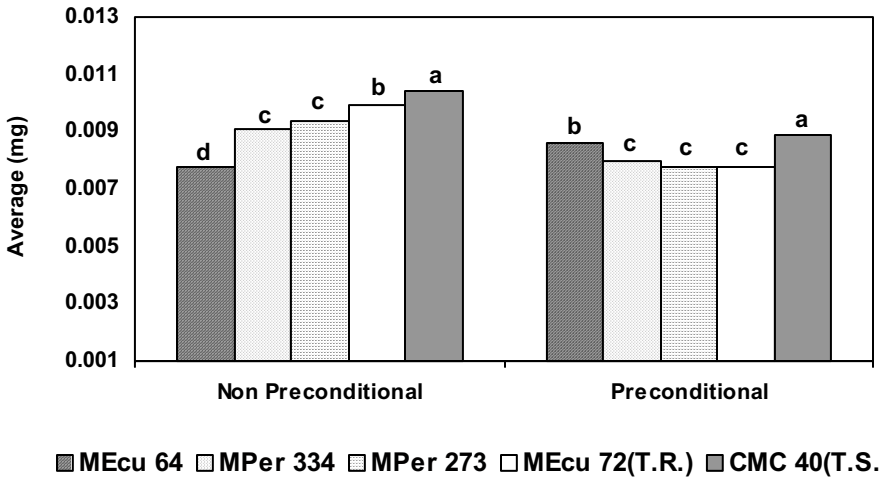

Figure 10. Dry weight of *Aleurotrachelus socialis* adults reared on five cassava genotypes (2 experiments) in the growth chamber.

3. Antixenosis: Free choice feeding preference.
Under a free choice evaluation where *A. socialis* adults were offered five randomly placed genotypes, a significantly higher feeding preference occurred on CMC 40 **(Figure 11)** (P=0.05). There was no significant difference among the remaining resistant genotype, although feeding was lowest on MEcu 64 (the data was logarithmically transformed (X+1)). An interaction was noted between experiment, time (hour) and leaf, where the time of evaluation influenced results on the first leaf, where preference for *A. socialis* feeding was the same at 24 and 48 hours. Leaf one, or the upper most leaf, was the most preferred for feeding **(Figure 12)** in all three experiments, for all genotypes. There was no significant difference in feeding preference on leaves 2 and 3, but in general, feeding activity was higher during the initial 24-hour period **(Figure 12)**.

Oviposition was effected by genotype. Oviposition on MEcu 64 was significantly lower (P=0.05) than on the susceptible check (CMC 40) in all three experiments **(Figure 13)**. In experimental 1, all resistant genotypes were significantly lower than CMC 40; however in experiment 2, only MEcu 64 was significantly lower, and in experiment 3, both MEcu 64 and MEcu 72 were lower **(Figure 13)**. Total oviposition was significantly higher on the upper leaf in all three experiments **(Table 5)**; 75% of the eggs were oviposited on the upper leaf, 15% on the second and 10% on the third leaf.

The combined results for feeding and ovipositional preference and those for mortality and nymphal development indicate that MEcu 64 along with MEcu 72 are the most *A. socialis* resistant genotypes.

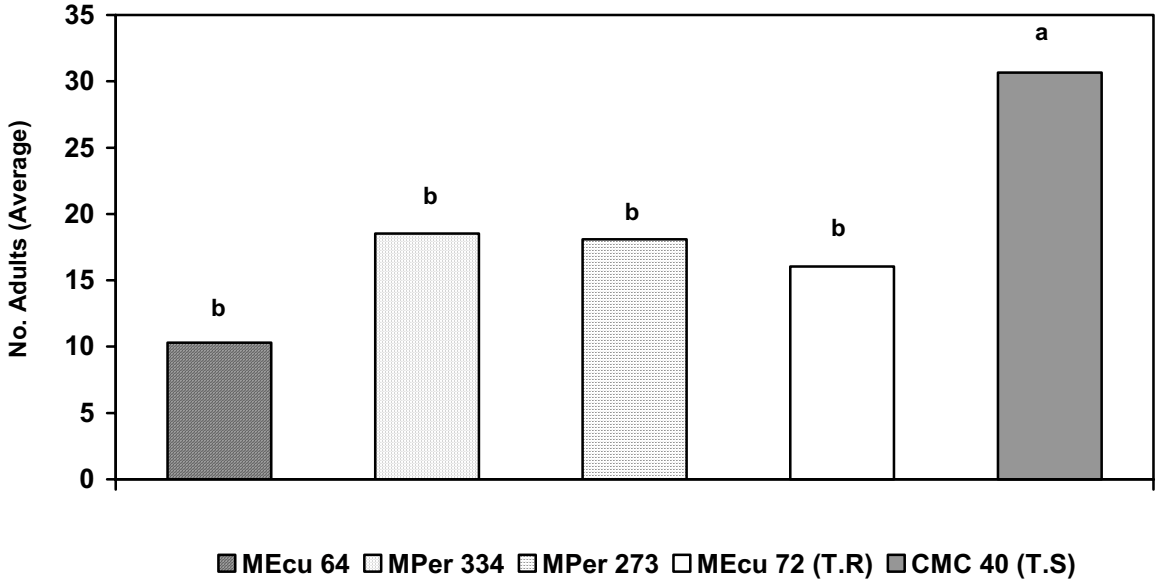

Figure 11. Free choice *Aleurotrachelus socialis* feeding trials on five cassava genotypes (3 leaves per plant and 3 repetitions over a 48hr. period.

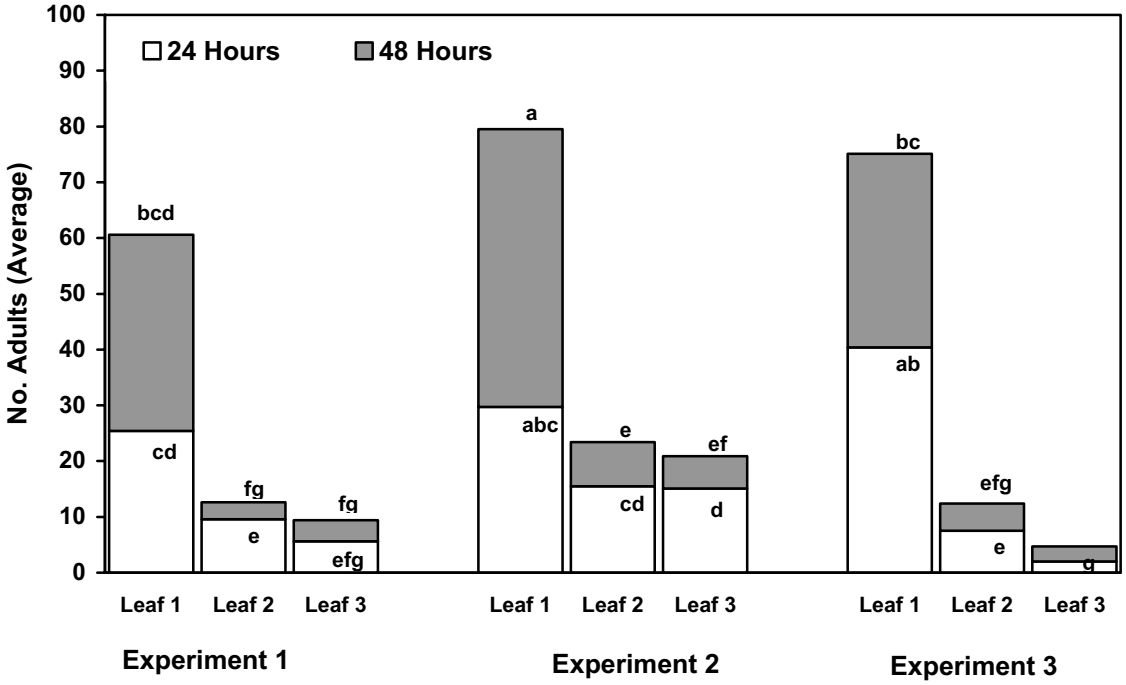

Figure 12. Free choice *Aleurotrachelus socialis* feeding preferred trials on five cassava genotypes on three leaves per plant during a 48-hour period.

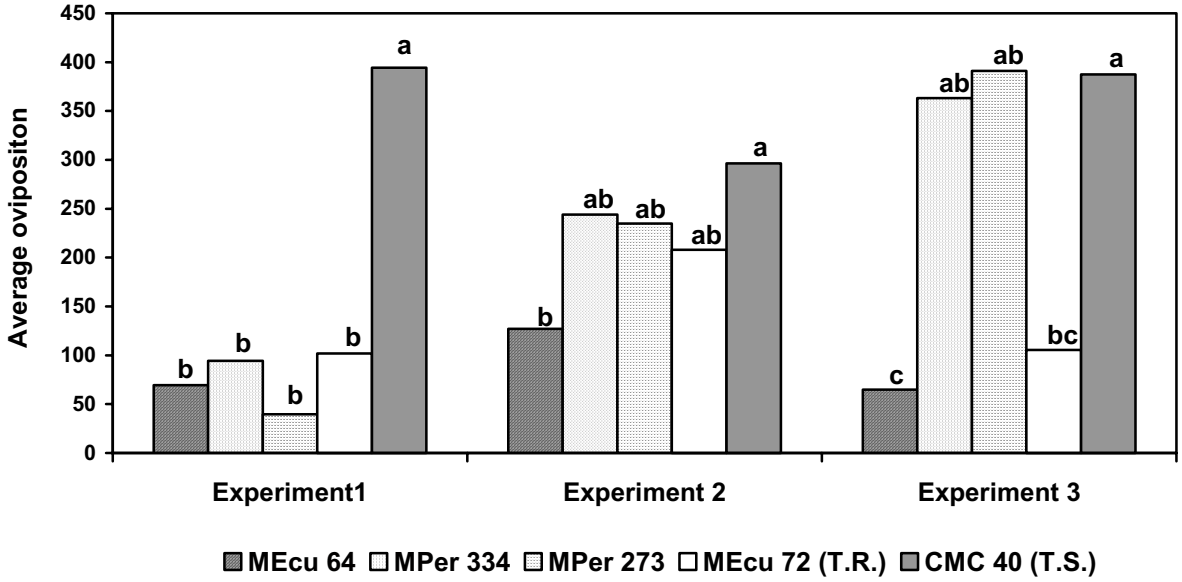

Figure 13. Free choice ovipositional preference of *Aleurotrachelus socialis* on five cassava genotypes (three experiments).

Table 5. *Aleurotrachelus socialis* ovipositional distribution on three cassava leaves of five genotypes in free choice trials.

Leaf Position	Hour	Experimental 1	Experimental 2	Experimental 3
1	48	335.3 a[1]	418.8 a	661.0 a
2	48	50.0 b	135.7 b	93.2 b
3	48	46.6 b	111.7 b	32.9 c

1. Ryan-Einot-Gabriel-Welsch Multiple Range (F) test. Columns with the same letter are not significantly different at the 5% level. Analysis with transformed data. Log (x=1).

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Activity 3. Studies on the biology and development of biotype B of *Bemisia tabaci* on cassava, *Manihot esculenta* and the wild species, *Manihot carthaginensis*.

Whiteflies are major pests of cassava in the Americas, Africa and Asia. Several species are involved; *Aleurotrachelus socialis* predominates in Northern South America (Colombia, Venezuela and Ecuador), while *Aleurothrixus aepim* is the major species in Brazil. *Bemisia tabaci*, a pantropical species prevails in Africa and parts of Asia (i.e. India) where it is the vector of Africa Cassava Mosaic virus (ACMV) and related viruses. Until the early 1990's, *B. tabaci* biotypes found in the neotropics did not feed on cassava, and it has been speculated that the absence of ACMD in the Neotropics may be related to the inability of *B. tabaci* to colonize cassava. Biotype B of *B. tabaci*, has been collected feeding on cassava in the neotropics. However, recent research at CIAT indicates that cassava is not a very successful host (see CIAT Pest and Disease Management Annual Report, 2002, pp. 25-35). *B. tabaci* feeding on beans (*Phaseolus vulgaris*) was successfully transferred to cassava only after completing several generations on other Euphorbiaceae species such as *Euphorbia pulcherrima* (Poinsettia) and *Jatropha gossypiifolia* (Jatropha). However mean longevity, female fecundity, oviposition and adult survival were low when compared to other whitefly species feeding on cassava.

This present study evaluates the potential of *B. tabaci* to adapt to wild *Manihot* species, such as *M. carthaginensis* and compares this to the development of *B. tabaci* on cultivated cassava *Manihot esculenta*, variety MCol 2063.

Methodology: Life table parameters of *B. tabaci* were evaluated in the growth chamber on potted plants of *M. carthaginensis* and the cassava variety MCol 2063. *B. tabaci* longevity, fecundity, development time, survival and demography were calculated. *B. tabaci* populations originated from a colony maintained on *Jatropha gossypiifolia* (Euphorbiaceae), in screened cages (1m x 1m x 1m) for 9 generations (25±5°C, 70±5% RH and 12/12hr. photoperiod). Longevity and fecundity were evaluated by placing 40 pairs (1m x 1f) of recently emerged Biotype B of *B. tabaci* adults in small leaf cages (2.5cm diameter x 2.0cm deep) on test plants. Every 48 hours adults were moved to another leaf area and this was repeated until all (40) females died. When males died, they were replaced until female mortality occurred. Fecundity was estimated by counting eggs oviposited by each female during the 48 hour period; longevity was estimated by the maximal survival of each female.

Development time and survival were studied by placing 50 adults (25 males + 25 females) in the small leaf cages and allowed to feed on the leaf undersurface for 6 hours. Adults were then removed and 200 eggs were selected to evaluate development time from egg to adult and record nymphal survival and sex ratio. Life tables for *B. tabaci* were calculated (Price, 1975) using net reproduction rate (R_o), generation time (T), intrinsic growth rate (r_m) of the population and employing the formula:

$\sum \exp(-r_m x) 1 x m x = 1$

where: x = age

lx = age specific survival

mx = proportion of female progeny from female x

For the calculated values of r_m the corrected age of x + 0.5 were used (Carey, 1993).

Results: The longevity of *B. tabaci* on *M. carthaginensis* and *M. esculenta* (MCol 2063) were similar. It was two days longer on *M. carthaginensis* (12 days) than on *M. esculenta* (10 days) **(Figure 1)**. By the end of 6 days 65% of the females on *M. carthaginensis* and 82.5% of the females on *M. esculenta* had died. The average longevity on the two genotypes differed significantly (Student-Newman-Keuls P<0.05, after K-Wallis P<0.0001).

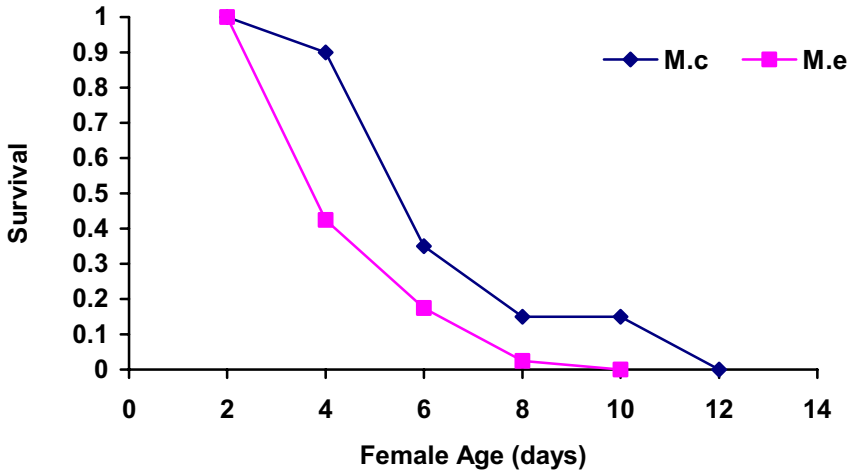

Figure 1. Survival curves of Biotype B of *B. tabaci* feeding on *M. carthaginensis* and *M. esculenta* (MCol 2063).

Oviposition occurred readily on both genotypes but the range was greater on *M. esculenta,* although the difference was not significant (K-Wallis P<0.0001, followed by Student-Newman-Keuls P <0.0.5) **(Figure 2, Table 1)**. The mean ovipositional rate was significantly higher on *M. esculenta* (eggs per female/2 days). All females of *B. tabaci* initiated oviposition within 48 hours of eclosion on both genotypes. On *M. esculenta* 72% of the total oviposition occurred during this 48-hour period while only 35.5% occurred on *M. carthaginensis*. These results indicate a preference of *B. tabaci* to oviposit on *M. esculenta.* Highest oviposition on *M. esculenta* occurred on day 2, while on *M. carthaginensis* it was on days 4 to 6.

B. tabaci development time was significantly lower or faster on *M. carthaginensis* than on *M. esculenta* **(Table 2)**. The development time or life cycle on *M. esculenta* was 11 days (44.4 days) longer than on *M. carthaginensis* (33.3), indicating a more rapid adaptation of the immatures when feeding on *M. carthaginensis*. Taking into consideration that fecundity was higher on *M. esculenta* (8.6 eggs vs. 5.3) **(Table 1)** and combines this with the faster development time on *M. carthaginensis*, it results in the intrinsic growth rate (r_m) to be the same for both genotypes **(Table 2)**. These results indicate that populations of Biotype B of *B. tabaci*, in spite of a higher fecundity on *M. esculenta*, will be of equal growth rates on both genotypes.

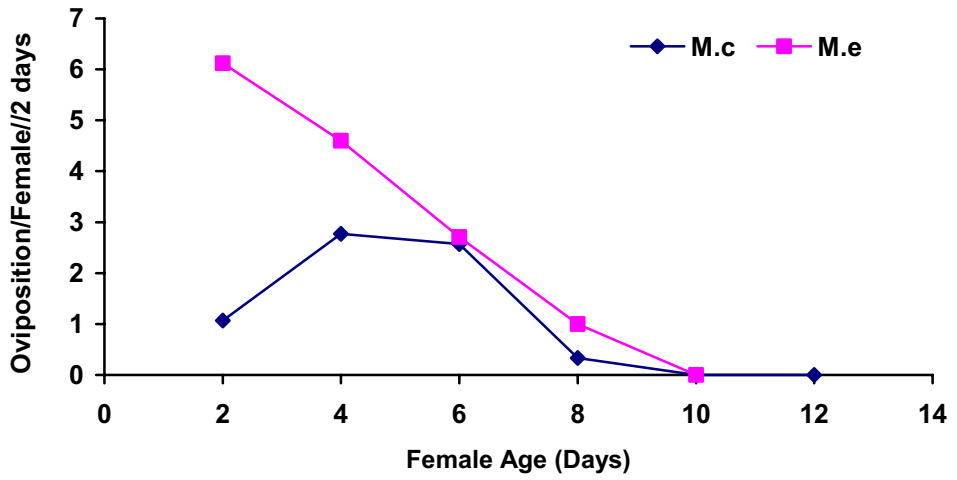

Figure 2. Reproduction curves of Biotype B of *B. tabaci* feeding on *M. carthaginensis* and *M. esculenta* (MCol 2063).

Table 1. Average longevity, fecundity and ovipositional rate (eggs/female/2 days) of Biotype B of *B. tabaci* feeding on *M. carthaginensis* and *M. esculenta* (MCol 2063).

Parameters	*M. carthaginensis*	*M. esculenta*
Average Longevity	5.1 a	3.25 b
Range	2-12	2-10
No insects	30	40
Average Fecundity	5.35 a	8.6 a
Range	1-35	1-41
Average Oviposition Rate	1.05 a	2.64 b
Range	0.25-3.6	0.5-8

Figures followed by different letters across columns indicate significant differences (Kruskal-Wallis) $P<0.001$, followed by Student-Newman-Keuls $P<0.05$).

Survival rates were significantly higher on *M. carthaginensis* **(Table 2)**. Results show that of 200 eggs oviposited on *M. carthaginensis,* 120 or 60% survived to the adult stage, while only 55 eggs (36%) survived to adulthood on *M. esculenta* **(Figure 3)**. Immature survival is a good indication of the eventual ability of a biotype to develop on a genotype. These results indicate that *M esculenta* (MCol 2063) is not an optimal host for Biotype B of *B. tabaci* **(Figure 3)**.

Significant differences in the net reproductive rate were obtained between the two genotypes. It was estimated that at the end of a generation, populations of Biotype B of *B. tabaci* would multiply 8.6 times on *M. esculenta* (MCol 2063), three times greater than on *M. carthaginensis* **(Table 2)**. This can be explained by total reproduction was less on *M. carthaginensis*. One generation of *B. tabaci* on *M. carthaginensis* is 35.6 days vs. 44.8 on *M. esculenta*. These results indicate that *B. tabaci* can complete 10 generations per year on *M. carthaginensis* and eight on *M. esculenta*. Population growth of *B. tabaci* was the same on both genotypes **(Table 2)**. The difference in development time was a more important criterion for the population increase of *B. tabaci* on *M. carthaginensis*, than were the differences in ovipositional rate. Population increases of *B. tabaci* on *M. esculenta* were more influenced by changes in reproduction rate. It

should be noted that the high rate of oviposition of *B. tabaci* on *M. esculenta* can be independent of subsequent development of the immature stages.

Table 2. Demographic parameters of biotype of *B. tabaci* feeding on *M. carthaginensis* and *M. esculenta* (MCol 2063).

Parameter	*M. carthaginensis*	*M. esculenta*
Development time (d)	33.3 a	44.41 b
Rate of survival (%)	60 a	27.5 b
Proportion of females (%)	50.6	50.9
Intrinsic rate of increase (r_m)	0.048	0.048
Net reproductive rate (Ro) ∑lxmx	5.35	8.63
Generation time (T)	35.6	44.76
Days to duplicate population Ln2/ r_m	14.4	14.4

Development time: different letters across columns indicate significant differences (K-Wallis P<0.0001, followed by Student-Newman-Keuls P<0.05). Rate of survival: (χ^2=29.9, 1df, P< 0.0001).

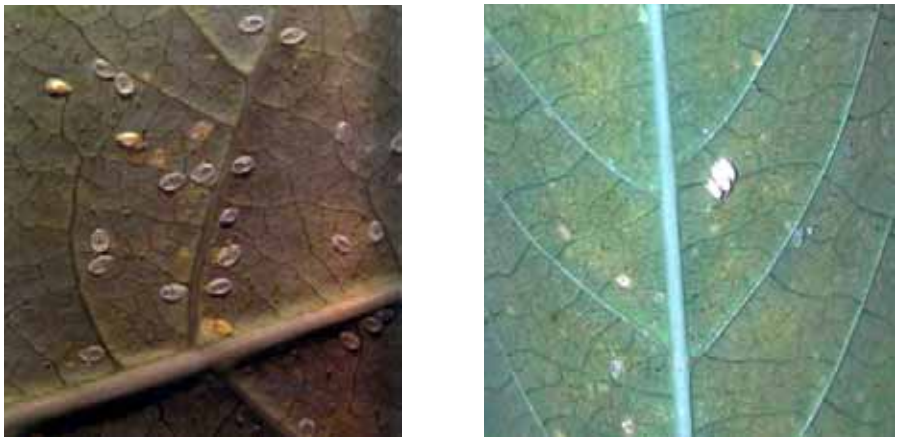

Figure 3. Pupal capsules, pupae and adults of biotype B of *B. tabaci* feeding on *M. carthaginensis* and *M. esculenta* (MCol 2063).

It can be concluded that Biotype B of *B. tabaci* can successfully develop on both *M. esculenta* (MCol 2063) and *M. carthaginensis*. In this case, however, it should be noted that these populations of *B. tabaci* had already adapted to related Ephorbiaceae, Jatropha, prior to being evaluated on the two aforementioned genotypes. Previous research has shown that when the *B. tabaci* populations originate on an unrelated genotype, such as beans (*P. vulgaris)*, they do not readily adapt to *M. esculenta*. These results, however, do provide evidence that biotype B of *B. tabaci* can adapt to Wild *Manihot* species as well as the cultivated species, *M. esculenta* and represents a potential threat to cassava production in the Neotropics.

Contributor: Arturo Carabalí.

Activity 4. Developing integrated pest management components.

Monitoring of the changing situation with whitefly populations in the Andean zone

Introduction

In order to develop appropriate management systems, there is need to monitor the ever-changing situation with species and biotype composition in whitefly-affected areas. This is one of the most important objectives within the DFID-funded project on Sustainable Management of Whiteflies.

Materials and Methods: As in previous years we used RAPD techniques (primer OPA-04) to identify pupae and adults of whiteflies collected throughout the two target areas: the Cauca Valley in Colombia and the Chota Valley in Ecuador. Samples were processed at CIAT. Identification was based on morphological characteristics of pupae and comparison between RAPD patterns in samples brought from the field with those of existing mass rearings of different whiteflies maintained at CIAT.

Results and Discussion: Analysis of 123 samples taken in 23 locations in the Cauca Valley (Colombia) showed that 63% of the whiteflies collected belonged to the B biotype of *Bemisia tabaci*, the most aggressive form of whitefly known to date. This biotype was first recorded in Colombia in 1997. It has very rapidly dispersed to many different areas and is now occupying niches previously reserved to the A biotype or to *T. vaporariorum*. Species composition in the Cauca Valley has changed drastically in the past six years. In 1997, *T. vaporariorum* was by far the most important species, representing 73% of the samples taken while the A biotype represented 15% of samples analyzed. At present, the A biotype can not be found (displaced by the B biotype?), *T. vaporariorum* represents 21% of the samples and the B biotype has become the most important whitefly in the Cauca Valley representing 63% of the samples analyzed **(Figure 1)**. This change has been most dramatic in certain areas like Pradera where *T. vaporariorum* was the key species. Virtually all specimens analyzed in this area belong to the B biotype of *B. tabaci* **(Figure 2)**, which is affecting many different crops.

The now predominant B biotype has caused many serious problems in agricultural areas of the Cauca Valley: uneven ripening of tomatoes, silver leaf disorder on squash, and sooty mold on cotton. In snap bean growing areas, it has become the causal agent of a physiological disorder known as pod chlorosis, which renders the produce useless. Most serious, it has become a very effective vector of a geminivirus that is devastating snap beans in the region **(Figure 3)**.

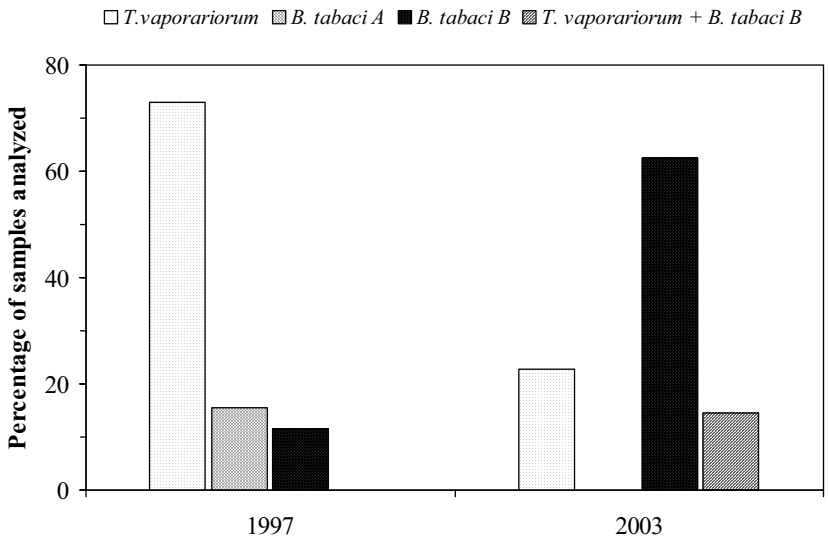

Figure 1. Changes in whitefly species and biotype composition in the Cauca Valley of Colombia (1997-2003).

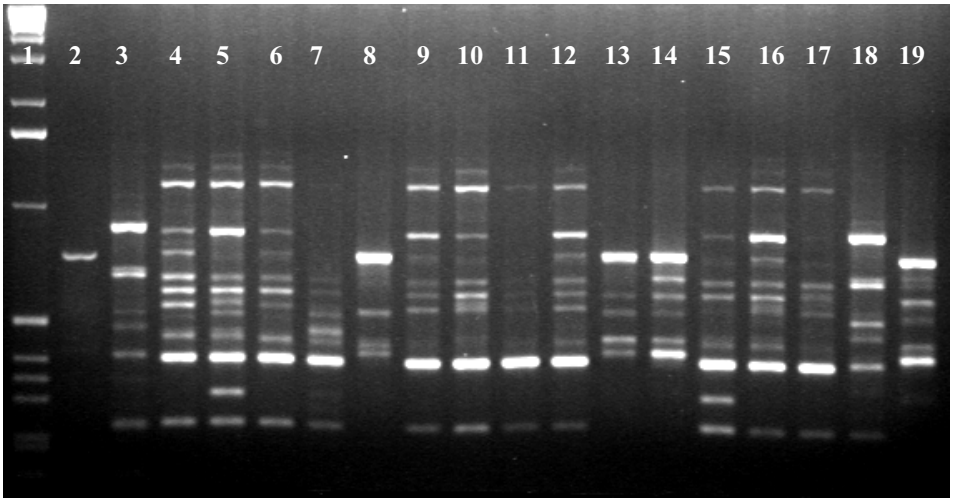

Figure 2. RAPD's for whitefly adults collected in the Cauca Valley (La Tupia, Pradera). Amplificaction using the OPA-04 primer. 1, DNA molecular marker (1 Kb); 2, *Trialeurodes vaporariorum* from reference rearing maintained at CIAT; 3, *Bemisia tabaci* biotype A from reference rearing; 4, *B. tabaci* biotype B from reference rearing; 5 - 7, *B. tabaci* biotype B collected on snap beans; 8, *T. vaporariorum* on snap beans; 9 -12, *B. tabaci* biotype B on squash; 13 - 14, *T. vaporariorum* on tomato; 15 - 16, *B. tabaci* biotype B on tomato; 17, *B. tabaci* biotype B, reference rearing; 18, *B. tabaci* biotype A, reference rearing ; 19, *T. vaporariorum* reference rearing.

Figure 3. "Pod (A) and plant (B) malformation induced by a new whitefly-borne virus in snap beans"

Activity 5. Refining of an action threshold for *Trialeurodes vaporariorum* control.

Introduction

We have successfully developed an action threshold for effective control of *Trialeurodes vaporariorum* on snap beans and dry beans. As shown in previous reports, economic control of the whitefly is achieved when an efficient insecticide is applied when first instar nymphs occur on lower leaves of the plant. To further refine this action threshold and make it user-friendlier, we have added a quantitative estimate of populations.

Materials and Methods: We used the same methodology on snap beans and dry beans. Using a 4 x 4 Latin square design we compared the following treatments: 1, control of first instar nymphs when nymphs occupy less than 30% of the leaf area; 2, control of first instar nymphs when nymphs occupy 30-60% of the leaf area; 3, 1, control of first instar nymphs when nymphs occupy more than 60% of the leaf area; 4, untreated check. Insect populations, damage levels, yields and costs were recorded and analyzed.

Results and Discussion: Highest increases in yield were obtained when chemicals were applied when first instar nymphs appear and occupy less than 30% of the leaf area **(Table 1)**. This means that the action threshold established in previous years can now be enunciated as follows: level 3, when first instar nymphs appear on lower leaves of the plant and occupy less than 30% of the leaf area.

Table 1. Yields responses of snap beans and dry beans to effective chemical control of *Trialeurodes vaporariorum* at varying levels of infestation with first instar nymphs.

Control of First Instar Nymphs	Yields (t/ha)		Yield Increase (%)[a]	
	Snap Beans	Beans	Snap Beans	Beans
When first instars occupy < 30% of leaf area	15.2 a[2]	1.06 a	52.0	14.0
When first instars occupy 30 - 60% of leaf area	11.4 b	1.01 a	14.0	8.6
When first instars occupy > 60% of leaf area	11.2 b	1.02 a	12.0	9.7
Untreated check	10.0 b	0.93 a	----	----
C. V. (%)	11.3	9.6		

[a] With respect to the untreated check

Means within a column followed by the same letter are not significantly different at the 5% level by LSD.

Contributors: J. M. Bueno, I. Rodríguez, C. Cardona.

Activity 6. Development of sampling methods for whitefly populations.

Introduction

The development of appropriate sampling methods for whitefly nymphs and adults is another major objective within the DFID-funded project on Sustainable Management of Whiteflies in the Tropics. Sampling insect populations to estimate infestation levels is essential in any pest management system. Whiteflies pose special sampling problems compared with larger insects given their gregarious habits, small size, and large numbers.

Materials and Methods: we have conducted six field trials aimed at developing sampling methods for nymphs of *T. vaporariorum* on both snap beans and dry beans. Main objectives were: a) To quantify nymphal and adult populations at different crop growth stages; b) To determine the dispersion pattern of populations within the plant; c) To calculate sample sizes; d) To compare different methods of sampling; e) To develop an efficient sequential sampling plan to be used in an integrated management scheme.

Results and Discussion: We will only highlight a few of the results obtained in snap beans. The work on dry beans will be reported in 2004. As shown in **Table 1**, the spatial distribution of nymphal populations on snap beans follows a natural sequence of events: adult colonization, followed by oviposition, followed by establishment of nymphs on the leaves. This is why adults and eggs are more abundant on the upper part of the plant, while third instars and pupae (fourth instars) are more commonly found on the lower part of the plant (stratum 1). We found that all stages are aggregated. For example, nymph populations follow Taylor's Power Law and adjust very well to a negative binomial distribution **(Table 2)**, meaning that populations are clumped. This has important implications for sampling purposes.

Table 1. Number per leaflet of adults and immature stages of *Trialeurodes vaporariorum* on snap beans. Plants were divided into four strata for sampling purposes.

		Days After Planting									
Whitefly stage	**Stratum**	**7**	**14**	**21**	**28**	**35**	**42**	**50**	**57**	**63**	**70**
Adults	1	18.5	11.3	15.3	15.7b[a]	4.9c	2.7c	8.6c	4.1c	1.1d	0.7d
	2				47.7a	13.8b	3.9b	6.5c	3.5c	1.7c	2.5c
	3					35.1a	11.7a	14.9b	7.2b	4.0b	10.3a
	4						6.5b	67.8a	39.8a	6.2a	5.4b
Egss	1	62.2	46.7	76.9	42.3b	33.1b	0.9c	0.0d	0.04d	0.0c	0.09c
	2				154.3a	63.9a	17.7a	4.0c	1.9c	0.2c	4.3b
	3					36.2b	8.8b	31.7b	29.4b	3.6b	2.3b
	4						5.0c	54.0a	56.3a	19.6a	17.8a
Nymphs	1		5.5	9.4	45.0a	39.8a	51.8a	11.8a	3.4c	0.7c	1.8d
	2				0.01b	6.3b	12.8b	14.9a	10.4b	5.8b	10.6c
	3					0.0b	0.0c	0.3b	18.9a	19.7a	11.9b
	4						0.0c	0.04b	4.3c	16.6a	37.6a

Whitefly stage	Stratum	Days After Planting									
		7	14	21	28	35	42	50	57	63	70
Pupae	1					1.9a	16.1a	36.2a	21.5a	5.9a	5.0a
	2					0.0b	0.0b	0.3b	1.6b	3.9b	10.6a
	3					0.0b	0.0b	0.0b	0.0b	0.9c	10.9a
	4						0.0b	0.0b	0.01b	0.0c	7.0a

[a] Each stage analyzed separately. Means within a column followed by the same letter are not significantly different at the 5% level by LSD.

Table 2. Dispersion indexes for nymphs of *Trialeurodes vaporariorum* on snap beans, calculated by means of regression (Taylor's Power Law) and possible fit to a negative binomial distribution. Snap bean plants were divided into four strata for sampling purposes.

		Regression (Taylor's Power Law)				Negative Binomial Distribution			
Strata	DAP[a]	b	r^2	Pr > F	Interpretation	x^2c	df	Pr > F	Interpretation
1	14	1.70	0.95	**	Clumped	13.6	18	ns	Clumped
1	21	1.52	0.77	**	Clumped	13.9	21	ns	Clumped
1	29	1.60	0.88	**	Clumped	35.6	32	ns	Clumped
1	35	1.65	0.99	**	Clumped	44.5	28	ns	Clumped
2	35					14.4	5	ns	Clumped
1	42	1.12	0.69	**	Clumped				
2	42	0.99	0.86	**	Regular	27.7	18	ns	Clumped
1	50	0.93	0.44	NS	Regular	36.3	25	ns	Clumped
2	50	1.59	0.96	**	Clumped	27.1	25	ns	Clumped
3	50					0.9	2	ns	Clumped
1	57	1.57	0.70	**	Clumped	13.5	12	ns	Clumped
2	57	2.08	0.96	**	Clumped	18.1	20	ns	Clumped
3	57	1.62	0.91	**	Clumped	17.4	16	ns	Clumped
4	57	1.79	0.98	**	Clumped	4.4	6	ns	Clumped
1	63	2.06	0.92	**	Clumped	4.0	4	ns	Clumped
2	63	2.20	0.88	**	Clumped	30.3	19	ns	Clumped
3	63	1.71	0.84	**	Clumped	23.7	31	ns	Clumped
4	63	1.14	0.60	*	Clumped	32.2	24	ns	Clumped
1	70	1.66	0.98	**	Clumped	9.8	7	ns	Clumped
2	70	1.82	0.92	**	Clumped	25.4	18	ns	Clumped
3	70	1.77	0.96	**	Clumped	32.4	21	ns	Clumped
4	70	1.01	0.57	*	Clumped	39.0	36	ns	Clumped

[a] DAP = days after planting.
ns = Non significant.
*,** = Significant at 5 and 1%, respectively.

Data obtained from aggregation studies was then used to calculate sample sizes **(Figure 1)** and to develop sequential sampling methods that will be useful in the implementation of integrated management systems for whiteflies on beans and snap beans.

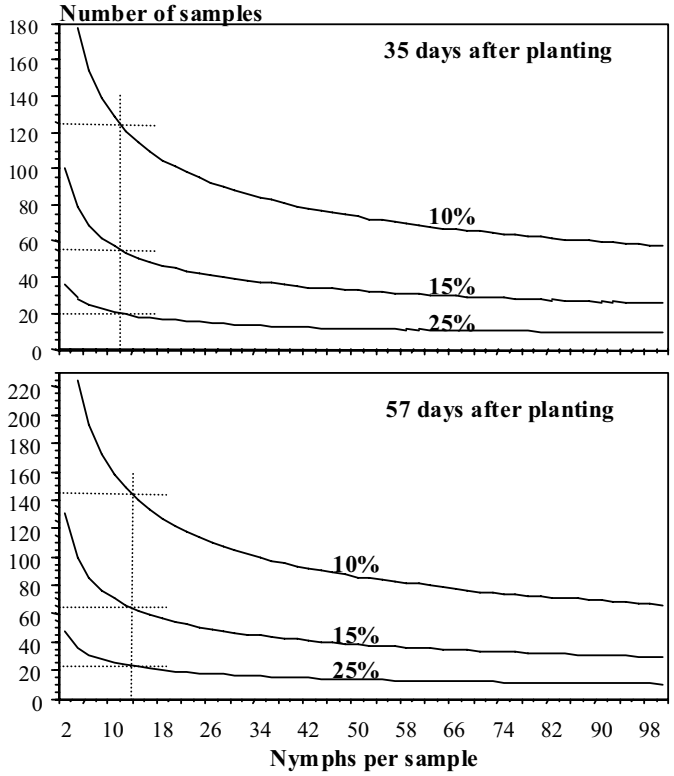

Figure 1. Sample sizes at different precision levels for nymphs of *Trialeurodes vaporariorum* on snap beans.

Contributors: J. M. Bueno, C. Cardona.

Activity 7. Monitoring of insecticide resistance in whitefly populations.

Introduction

Monitoring of insecticide resistance levels in whitefly populations is one of the major objectives of the DFID-funded Project on Sustainable Management of Whiteflies. Given the fact that insecticides will continue to be an essential method of control of whiteflies, periodic monitoring of resistance becomes an important step in the design of appropriate insect pest management strategies.

Materials and Methods: In 2003 we used the baseline data and diagnostic dosages that were established in 2001. Using the diagnostic dosages for both adults and nymphs, we tested populations of whiteflies in the Cauca Valley in Colombia and in the Chota Valley in Ecuador. Adult resistance levels were monitored under field conditions by means of the insecticide-coated glass vial technique. Resistance of first instar nymphs was measured using the foliage dipping technique. Systemic novel insecticides (mostly neonicotinoids) were tested using the petri dish technique (see 2001 Annual Report).

Results and Discussion: Resistance of *T. vaporariorum* adults and nymphs was measured in two critical locations in Colombia and in five locations in Ecuador. In general, the situation has not changed, with populations showing high levels of resistance to organophosphates, some susceptibility to certain pyrethroids, and susceptibility to carbamates like methomyl. With some differences among locations, there is a general trend for conventional insecticides (widely used by farmers) to be less efficient for whitefly control. *T. vaporariorum* nymphs in both Colombia and Ecuador are, in general, still susceptible to insect growth regulators like buprofezin and diaphenthiuron and to novel insecticides like the neonicotinoids imidacloprid and thiamethoxam.

Since the B biotype of *B. tabaci* has suddenly become the key pest in the Cauca Valley, we will highlight results of insecticide resistance monitoring with this species. Adults of this biotype showed high levels of resistance to methamidophos, monocrotophos, carbofuran, and bifenthrin. With some variations, adult populations showed intermediate resistance to carbosulfan and cypermethrin **(Table 1)**. Fortunately, both nymphs and adults of this biotype are still susceptible to neonicotinoids and insect growth regulators **(Table 2)**.

Table 1. Response (percentage corrected mortality) of adults of *Bemisia tabaci* biotype B to conventional insecticides in two consecutive growing seasons. Diagnostic dosages were tested using the insecticide-coated glass vial technique.

Races	Percentage Corrected Mortality[a]			
	2002B	2003B	2002B	2003B
	methamidophos (32 µg/vial)		monocrotophos (300 µg/vial)	
'CIAT'[b]	93.9 a A	94.4 a A	94.8 a A	95.3 a A
Rozo	32.1 b A	18.2 b B	74.7 b A	68.4 b A
Santa Helena	16.8 bc A	17.8 b A	54.4 c A	46.1 c A
La Unión	11.2 c B	22.3 b A	26.1 d A	30.2 d A
	methomyl (2.5 µg/vial)		carbofuran (5 µg/vial)	
'CIAT'	100.0 a A	97.4 a A	96.0 a A	93.9 a A
Rozo	99.4 a A	85.0 ab B	64.8 b A	53.1 b A
Santa Helena	78.1 b A	87.1 b A	24.6 c B	42.1 b A
La Unión	65.1 c A	78.4 b A	21.6 c B	44.0 b A
	carbosulfan (100 µg/vial)		cypermethrin (500µg/vial)	
'CIAT'	94.8 a A	93.4 a A	93.9 a A	93.4 a A
Rozo	88.7 a A	77.5 b B	48.3 c A	39.6 c A
Santa Helena	89.7 a A	70.7 b B	88.7 a A	71.2 b B
La Unión	47.4 b A	53.4 c A	68.5 b A	74.8 b A
	cyalothrin (500 µg/vial)		bifenthrin (5 µg/vial)	
'CIAT'	94.3 a A	91.2 a A	94.3 a A	96.4 a A
Rozo	81.0 b A	60.2 c B	28.8 b A	12.6 d B
Santa Helena	90.6 ab A	78.5 b A	25.2 b A	21.6 c A
La Unión	84.3 b A	84.5 ab A	36.7 b B	49.8 b A

[a] Means within a column followed by the same lowercase letter and means within a row followed by the same uppercase letter are not significantly different at the 5% level by LSD. Each product was analyzed separately.

[b] A susceptible strain of B. tabaci biotype B maintained at CIAT.

Table 2. Response (percentage corrected mortality) of adults and nymphs of the B biotype of *Bemisia tabaci* to novel insecticides in the Cauca Valley region of Colombia. Adults tested in two consecutive seasons. Nymphs tested during the 2003-growing season.

Race	Adults				Nymphs		
	imidacloprid (40 ppm)		thiamethoxam (200 ppm)		buprofezin (16 ppm)	diaphenthiuron (300 ppm)	imidacloprid (300 ppm)
	2002	2003	2002	2003			
Rozo	81.9bB	97.3aA	97.3aA	99.5aA	80.6 b	100.0 a	89.3 b
S. Helena	91.9abA	93.4abA	100.0aA	96.4aB	100.0 a	100.0 a	100.0 a
La Unión	87.4 bA	90.7 bA	97.9aA	91.4bB	100.0 a	98.2 a	100.0 a
'CIAT'	96.3aA	97.9aA	99.5aA	98.9aA	98.4 a	100.0 a	91.1 b

Each product within each semester was analyzed separately. For adults, means within a column followed by a lowercase letter and within a row followed by an uppercase letter are not significantly different at the 5% level by LSD. For nymphs, means within a column followed by the same lowercase letter are not significantly different at the 5% level by LSD.

Contributors: I. Rodríguez, H. Morales, C. Cardona.

Activity 8. Management strategies for whiteflies.

Introduction

Whiteflies have become the object of excessive pesticide use by snap bean and dry bean farmers in the Andean zone. With the body of knowledge acquired in previous years, it is possible to develop whitefly management systems that will at least contribute to reduce pesticide use. We now report on trials conducted to develop ways to reduce pesticide use on snap beans in Colombia and on dry beans in Ecuador

Materials and Methods: Several trials were conducted in the reference sites (Pradera in Colombia, Chota in Ecuador). We compared different approaches for whitefly control based on judicious and less detrimental use of chemicals. Seed treatments and drench applications of novel systemic insecticides were compared with the timing of foliar applications of conventional (less costly) products, in some cases with applications based upon pre-established action thresholds. These treatments were compared with farmers' practices and, in some cases, with untreated checks. In Ecuador, where the project has entered the diffusion stage, large-scale demonstrative plots were used to conduct the trials. Damage levels, insect populations, quality of produce, yields, and benefit/cost ratios were recorded and analyzed.

Results and Discussion: In Colombia (snap beans) alternative management strategies resulted in yields that did not differ from those obtained by farmers with their traditional management approaches **(Table 1)**. Crop appearance, damage (sooty mold) levels, and final produce quality did not differ either. Use of novel systemic insecticides as seed dressing or in drench application resulted in higher benefit cost ratios with a substantial reduction in the amount of applications per crop cycle **(Table 1)**. The use of systemic insecticides in application as drench or seed dressing also had a less detrimental effect on populations of the nymphal parasitoid *Encarsia nigricephalla*, the most important natural enemy of whiteflies in the region **(Figure 1)**.

Table 1. Snap bean yields and benefit/cost ratios obtained with different alternatives for management of the whitefly *Trialeurodes vaporariorum* in the Pradera region of Colombia.

Treatment[a]	No. of applications	Yield (t/ha)[b]	Benefit /cost ratio
Trial 1			
Seed dressing + conventional insecticides 28 and 43 DAP	3	18.4a	3.0
Drench + AT with conventional insecticides	2	17.4a	2.8
AT with conventional insecticides	2	17.5a	3.0
Conventional insecticides at 28 and 43 DAP	2	17.0a	2.9
Farmer's practices	6	13.1b	1.9
Check	0	9.0c	1.7
Trials 2 and 3			
Seed treatment + AT with conventional insecticides	3	13.6a	2.0
Drench + Conventional insecticides at 18 and 42 DAP	2	12.1a	1.7
Farmer's practices	6	12.6a	1.6
Check	0	8.7b	1.4
Trial 4			
Seed treatment + conventional insecticides 34 DAP	3	10.7a	1.7
Seed treatment + AT with conventional insecticides	3	12.7a	2.0
Farmer's practices	7	11.8a	1.6

[a] Seed dressings and drench treatments with neonicotinoids; AT, action threshold; DAP, days after planting

[b] Means within a column followed by the same letter are not significantly different at the 5% level by LSD.

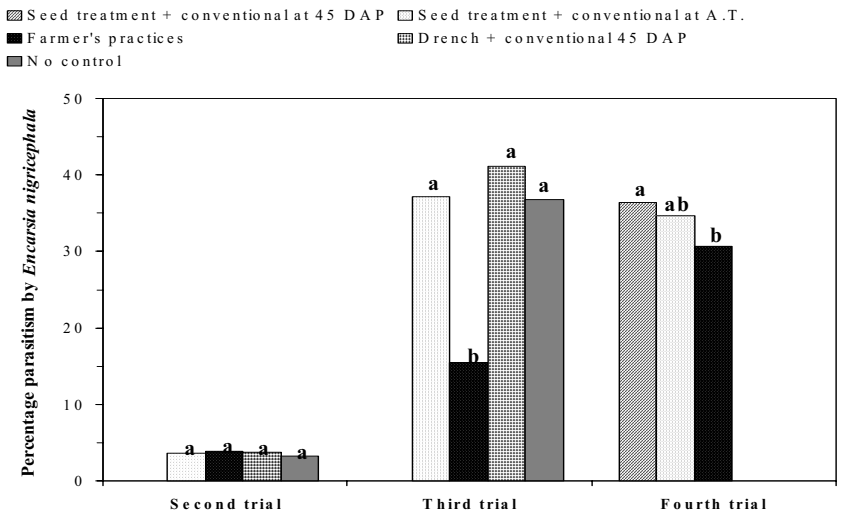

Figure 1. Impact of different whitefly management strategies on parasitism of *Trialeurodes vaporariorum* nymphs by *Encarsia nigricephala*. Bars with the same letter do not differ at the 5% level (LSD).

Trying to find alternatives to insecticides, we tested several entomopathogens. Two commercial formulations of *Verticillium lecanii* and two of *Beauveria bassiana* were completely ineffective against whitefly adults or nymphs.

In the Chota region of Ecuador, two consecutive demonstrative trials showed that integrated management approaches result in high yields of beans of excellent pod quality comparable to those obtained by farmers with traditional (conventional) approaches to whitefly control **(Table 2)**.

Table 2. Whitefly damage levels, quality of produce and dry bean yields obtained in large scale demonstrative trials conducted in the Chota region of Ecuador. Comparison of two management strategies of the greenhouse whitefly, *Trialeurodes vaporariorum.*

Treatment	Damage (sooty mold)[a]		Quality of pods[b]		Yield (kg/ha)
	30 DAP	60 DAP	30 DAP	60 DAP	
Conventional	2.3 a	2.6 a	3.6 a	3.3 a	1327.7 a
MIP	2.0 a	3.3 a	3.6 a	3.3 a	1328.3 a
Coefficient of variation (%).	18.8	36.0	19.2	21.2	17.6

[a] n a 1-5 visual scale (1, no damage; 5, very serious damage.
[b] n a 1-5 visual scale (1, very poor; 5, excellent).
DAP, days after planting.
Means within a column followed by the same letter do not differ at the 5% level of significance by LSD.

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Activity 9. Screening for virus resistance in snap beans.

Introduction

As indicated above, there is a new situation in the Cauca Valley of Colombia where the B biotype of *Bemisia tabaci* has become a vector of a new viral disease on snap beans. There is urgent need to develop virus-resistant snap bean varieties in order to replace 'Blue Lake', the highly preferred but extremely susceptible commercial variety.

Materials and Methods: In collaboration with the Virology Unit and the Bean Breeding section, we screened 120 genotypes (snap beans and dry beans) for resistance to the new virus. We used three replications per genotype. The nursery was established in a hot spot area (La Tupia, Pradera) with high incidence of the disease. Materials were rated 55 days after planting for virus symptoms using a 1 - 9 visual scale (1, no apparent damage; 9, severe damage).

Results and Discussion: Twenty-seven genotypes were rated resistant (damage score 1-4). These included well-known sources of resistance to BGMV and eight promising snap beans breeding materials **(Table 1)**. Others were either intermediate (67 genotypes) or susceptible (21). Reconfirmation of resistance is in progress.

Table 1. Response of snap beans and dry beans genotypes to a new virus disease transmitted by *Bemisia tabaci* in the Cauca Valley of Colombia.

Identification	Pedigree and genealogy	Damage score [a]	Rating
BAT 304		1.0	R
DOR 390		1.0	R
Tío Canela		1.0	R
MD 2324 (gene w12)		1.0	R
A 429 (gene bgm 1)		1.0	R
G 35171		1.0	R
G 35172		1.0	R
DOR 364		1.0	R
DOR 476 (w12 and bgm 1)		1.0	R
Porrillo Sintético		1.0	R
RM-35		1.0	R
DICTA 113 (gene w12)		1.0	R
FEB 212 (gene bgm 1)		1.0	R
EAP 9510-77		1.3	R
ASC 75		2.0	R
ICA Pijao		2.7	R
DOR 482 (w12 and bgm 1)		2.7	R
ASIN 13266-20	G 685 x (ASC 73 x ICTA Hunapú)F1/1P-7P-1P-1P-1P-3P-5P	3.0	R
SB 14565-1	HAV 129 x (G17723 x (G 685 x (ASC 73 x ICTA Hunapú)F1)F1)F5/-4P-1P	3.0	R
ASIN 13266-20	G 685 x (ASC 73 x ICTA Hunapú)F1/1P-7P-1P-1P-1P-3P-5P-1P	3.7	R
RMC-35		3.7	R
SB 14565-4	HAV 129 x (G17723 x (G 685 x (ASC 73 x ICTA Hunapú)F1)F1)F5/-1P-2P	3.7	R

Identification	Pedigree and genealogy	Damage score [a]	Rating
ASIN 13266-20	G 685 x (ASC 73 x ICTA Hunapú)F1/1P-7P-1P-1P-1P-3P-4P	3.7	R
Red Kloud		3.7	R
ASIN 13266-20	G 685 x (ASC 73 x ICTA Hunapú)F1/1P-7P-1P-1P1P-3P-5P-4P	4.0	R
SB 14565-3	HAV 129 x (G17723 x (G 685 x (ASC 73 x ICTA Hunapú)F1)F1)F5/-1P-1P	4.0	R
SB 14565-1	HAV 129 x (G17723 x (G 685 x (ASC 73 x ICTA Hunapú)F1)F1)F5/-4P-5P	4.0	R
Top Crop [b]		9.0	S
'Blue Lake' [c]		8.0	S

[a] On a 1-9 visual scale (1, no damage; 9, severe damage)
[b] Susceptible check
[c] Commercial check.

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Activity 10. Whiteflies as pests and virus vectors in Middle America.

The TWFP has two pilot sites in Middle America, one in El Salvador, Central America (Zapotitan Valley), and a second one in Yucatan, Mexico. The research activities in El Salvador are primarily conducted in collaboration with the national agricultural research program (CENTA); and with the Mexican national program (INIFAP) in Merida, Mexico. The valley of Zapotitan used to be the 'pantry' of the capital city San Salvador, but the emergence of the whitefly problem in this valley put an end to the cultivation of basic food staples, such as beans, and horticultural crops, such as tomato, pepper and various cucurbits. Thus, the objective of the TWFP was to recover the production of these crops in the valley, particularly during the dry months of the year (November-April), when most of the land in the valley is left in fallow even though there is irrigation. The strategy with common bean was to promote the evaluation and release of a new line developed by the Pan American School (Dr. Juan Carlos Rosas) in Honduras. This line (EAP-9510-77) has excellent agronomic characteristics, a high level of geminivirus resistance **(Figure 1)** and, moreover, the commercial color and cooking quality that farmers require. This line has been already registered as a new variety (CENTA-San Andres) and is currently being multiplied for general distribution **(Figure 2)**. The use of this cultivar is expected to reduce pesticide use in more than 70%.

Figure 1. Virus-resistant (background) and golden yellow mosaic-susceptible bean cultivars in El Salvador.

PROMUEVEN VARIEDAD

FRIJOL CENTA San Andrés

"Esta variedad de frijol es buena. Es más tolerante a los virus. El grano y la vaina es gruesa. La vaina carga demasiado... a una mata hasta se le han contado unas 50 vainas o un poquito más. Estamos contentos con esta variedad que nos ha dado el CENTA", testimonió el señor Julio Acevedo, productor de frijol de la zona de Zapotitán.

Un grupo de agricultores escuchan charla sobre el manejo agronómico del cultivo del Frijol CENTA San Andrés, en la parcela del señor José Magaña, Distrito 3, Zapotitán.

El frijol CENTA San Andrés, por sus excelentes características agronómicas se convertirá este año, en el **"caballito de batalla"** de los productores de frijol, ya que la variedad es tolerante a la mosca blanca y ofrece una producción de 33 quintales por manzana.

El frijol CENTA San Andrés, fue introducido al país en 1998, como línea EAP 9510-77, con el apoyo de PROFRIJOL, y está a disposición de los productores desde noviembre del año pasado. La variedad es resistente al virus del mosaico dorado amarillo del frijol, presenta buena tolerancia a altas temperaturas alto potencial de rendimiento, amplia adaptación y excelente calidad comercial de grano.

A través del Convenio entre el CENTA y el Centro Internacional de Agricultura Tropical (CIAT) - Proyecto MIP Mosca Blanca, se inició un Programa que contempla investigación, estudios socioeconómicos y transferencia de tecnología a través de Giras de Observación, a parcelas de productores innovadores, quienes se convierten posteriormente en productores irradiadores de la tecnología.

El convenio considera otros cultivos, como son: el chile dulce, el tomate y el loroco, con el objetivo de que los productores puedan sembrar y cosechar sobre todo en época seca que es la de mayor incidencia de virosis, manifestó el ingeniero José Eduardo Vides, coordinador del Proyecto MIP Mosca Blanca-CIAT.

La semilla de la nueva variedad de frijol CENTA San Andrés, ya está disponible para los productores en la Unidad de Semilla Básica (las 200) en el CENTA, pudiendo comprar desde una bolsa de 50 libras. O pueden obtenerla a través de los productores propietarios de las parcelas visitadas, quienes dejarán la cosecha para semilla.

NotiCENTA

Figure 2. Promotion of the new geminivirus-resistant bean cultivar 'CENTA-San Andres' in El Salvador.

The second most important activity has been the evaluation of physical barriers against insect (virus) vectors, specifically 'micro-tunnels'. These structures are made with simple materials (a synthetic mesh and wire) to protect crops (mainly tomato and peppers) during the first three weeks of vegetative growth, when plants are most susceptible to viruses. The adoption of this simple technology has been outstanding **(Figure 3)** and the economic returns are significant (over $ 8,000 USD/ha in tomato). This technology was first observed in the Yucatan Peninsula, where small-scale farmers adopted it with good results. Unfortunately, the advent of new insecticides effective against whiteflies, and the aggressive marketing strategies of agrochemical companies that have sufficient personnel to reach farmers, resulted in the abandonment of physical barriers in Yucatan. However, the new insecticides are very expensive and do not protect against aphid-borne viruses, which are as abundant as whitefly-transmitted viruses. Farmers have now suffered significant yield losses and, thus, are willing to accept IPM methods, including the use of micro-tunnels and new ferti-irrigation (drip irrigation to apply agrochemicals as well) techniques that facilitate cultural practices for crops grown under cover. The success obtained with these IPM strategies has fostered their adoption by other projects that conduct research in other Central American countries, such as Guatemala, Honduras and Nicaragua.

Figure 3. Micro-tunnels used by small-scale farmers in Central America to control whitefly and aphid-transmitted viruses affecting horticultural crops.

The third activity has been the search for sources of resistance to whitefly-transmitted viruses in horticultural crops, primarily in tomato and pepper. Currently, most of the seed is imported from developed countries, and these varieties do not have resistance against most of the plant viruses found in the Americas. Collaborative research between the Middle American and Southeastern Whitefly subprojects has lead to close collaboration between CIAT and AVRDC to develop tomato varieties possessing resistance to the whitefly-borne viruses present in Central America, Mexico and the Caribbean Region. This year, a total of ten selected tomato lines were evaluated both in Yucatan and the valley of Zapotitan for their reaction to the viruses endemic to these regions. In both localities we were able to select the same tomato genotypes that did not show symptoms of virus infection in the presence of 100% virus-infected controls **(Figure 4)**. These outstanding sources of resistance are now being used as parental materials for crosses with commercial Mexican and Salvadorian tomato genotypes.

The Middle American subproject also includes training and extension activities for national program scientists **(Figure 5)** and farmers **(Figure 5)** under laboratory and field conditions. We expect to enter a third Phase in the TWFP, when the best IPM strategies identified and validated, would be transferred to farmers not only in the Americas, but in other regions of the world.

Figure 4. Geminivirus-resistant tomato lines (foreground) selected in Middle America to control whitefly-borne viruses.

Figure 5. Transfer of IPM technology to agricultural scientists in Central America.

Publications

Book Chapter

Morales, F.J., Palma, E., Paiz, C., Carrillo, E., Esquivel, I., Guillespie, V., Ordoñez, J.L., and Viana, A. 2003. Socioeconomic and agricultural factors associated with mixed cropping systems in small farms of southwestern Guatemala. Cropping Systems:Trends and Advances. The Haworth Press, Inc., N.Y. 650 p.

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In Press

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