# Effect of Intercropping Common Bean with Poor Hosts and Nonhosts on Numbers of Immature Whiteflies (Homoptera: Aleyrodidae) in the Salamá Valley, Guatemala

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**ABSTRACT** Intercropping with poor and nonhosts was tested as means to reduce densities of whitefly eggs and nymphs on common bean (*Phaseolus vulgaris* L.) in central Guatemala during dry and rainy seasons. Row and mixed intercrop field designs were used, with pesticides evaluated on a subplot level in the row-intercrop test. Tomato (*Lycopersicon esculentum* Mill.) was also evaluated in the mixed-intercrop test. Intercropping failed to reduce whitefly densities, although interpretation of data was difficult because of high variability among samples and reduced crop quality in some intercrop and pesticide treatments. Imidacloprid effectively reduced whitefly densities, but imidacloprid combined with intercropping offered no advantage over imidacloprid in monoculture. Laundry detergent and vegetable oil were tested as less-toxic inexpensive alternatives to pesticides under monocropped and intercropped conditions during the dry season, but failed to provide protection against whiteflies or other sucking insects. *Trialeurodes vaporariorum* Westwood was the predominant whitefly species in the area. *Bemisia tabaci* (Gennadius) on bean comprised ≈10% of the total whitefly population at the end of the dry season, 46% in the middle of the rainy season, when overall populations were lowest, and 1.15% toward the end of the rainy season. *Encarsia pergandiella* Howard was the predominant whitefly parasitoid throughout the study, and the only parasitoid reared from whitefly nymphs on bean in the dry season. Members of the *Encarsia meritoria* species complex and *Amitus fuscipennis* MacGown & Nebeker were recovered from tomato during the rainy season. Parasitoid diversity increased in the rainy season on tomato intercropped with roselle (*Hibiscus sabdariffa* L.) and corn (*Zea mays* L.) compared with tomato grown in monoculture. Intercropping with poor and nonhosts did not reduce whitefly densities on bean in an economically significant manner under high, intermediate, or low whitefly populations levels in either the dry or rainy season.

**KEY WORDS** *Bemisia tabaci*, *Trialeurodes vaporariorum*, intercropping, polyculture, vector management

Many traditional small farmer cropping systems in the tropics are characterized by some degree of intercropping (Andrews and Kassam 1976, Kass 1978, Perrin and Phillips 1978), which has been associated with suppression of herbivore damage under certain circumstances (Risch et al. 1983, Andow 1991). One of the mechanisms by which intercropping may reduce crop damage is by disrupting the ability of certain herbivores to find and exploit host plants (Vandermeer 1989). Trenbath (1975, 1976, 1977) suggested that the build-up of passively dispersed herbivores might be reduced on crops that were mixed with nonhosts because a portion of the herbivore population might become 'lost' to nonhost surfaces (the "flypaper effect").

*Trialeurodes vaporariorum* Westwood, the greenhouse whitefly, and *Bemisia tabaci* Gennadius are serious pests of horticultural crops throughout Central America (Hilje 1993). *T. vaporariorum* tends to be more common above elevations of 500 m, and *B. tabaci* below 500 m (Caballero 1994). Both species attack most major crop groups (Russell 1963, 1977; Mound and Halsey 1978; Naresh and Nene 1980). *T. vaporariorum* and *B. tabaci* cause mechanical damage to crops by extracting water, carbohydrates, and amino acids from the phloem (Hendrix et al. 1996). *T. vaporariorum* vectors closteroviruses (Duffus 1996), and *B. tabaci* vectors both closteroviruses and geminiviruses to a broad range of crops (Brown 1994). The oviposition rate and longevity of each species vary on different host plants (van Boxtel et al. 1978, van de Meredonk and van Lenteren 1978, Naresh and Nene 1980, Coudriet et al. 1985, Costa et al. 1991, Simmons 1994, Aslam and Gebara 1995).

Damage from both *T. vaporariorum* and *B. tabaci* limits production of common bean (*Phaseolus vulgaris* L.) throughout Central America, where bean is a food staple (Scheiber 1983, Dardón 1992, Hilje and Arboleada 1992, Hilje 1998). Epidemics of bean golden mosaic geminivirus have increased in Central America since the arrival of the B-biotype of *B. tabaci* in the late

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1980s (Brown and Bird 1992, Rodriguez 1994). *B. tabaci* has developed resistance to most classes of pesticides (Dittrich et al. 1990, Denholm et al. 1996). The systemic insecticide imidacloprid (Bayer) is currently effective against whiteflies (Norman et al. 1993). However, imidacloprid is costly and is not registered for many low-value crops. Low resource farmers in the tropics require safe, effective, and inexpensive methods for managing whiteflies on common bean and other crops.

Aspects of the behavior of *T. vaporariorum* and *B. tabaci* suggest that they may be susceptible to management via a mechanism such as the fly-paper effect. Neither *T. vaporariorum* nor *B. tabaci* responds to host-specific visual or olfactory cues (Mound 1962; Vaishampayan et al. 1975a, 1975b; van Lenteren and Noldus 1990). When predisposed to colonize, they apparently respond to the yellow–green range of light spectra reflected by most vegetation (Vaishampayan et al. 1975a; Coombe 1981, 1982; Byrne et al. 1996). Feeding behavior studies and examinations of precibarial and cibarial chemosensilla of *B. tabaci* (Hunter et al. 1996) and *T. vaporariorum* (van Lenteren and Noldus 1990, Lei et al. 1998) suggest that the two species may have to probe a plant to determine its suitability as a host. Bernays (1999) reported that *B. tabaci* moved more often and oviposited less on certain caged plants when these plants were combined with other plant species than when they were grown alone.

These observations suggest that adults of *B. tabaci* and *T. vaporariorum* might expend significant time and energy assessing unacceptable hosts when these are mixed with a suitable host, and therefore invest less energy in colonizing and feeding on the more acceptable crop. Efforts to reduce whitefly densities and transmission of whitefly viruses by intercropping or establishing barriers with poor or nonhost crops have been successful in some instances (Sharma and Varma 1984, Rataul et al. 1989, Morales et al. 1993, Ahohuendo and Sarkar 1994) and ambiguous in others (Fargette and Fauquet 1988). Gold et al. (1990) reduced densities of *Aleurotrachelis socialis* Bondar and *Trialeurodes variabilis* (Quaintance) on cassava by intercropping with maize and cowpea, but suggested that the inferior quality of the intercropped cassava may have rendered it less attractive to whiteflies. Reduced plant quality due to intercrop competition often affects the results of intercropping experiments (Kareiva 1983).

We examined whether intercropping common bean with poor and nonhosts of whitefly would affect densities of whitefly eggs and nymphs on bean foliage when compared with bean grown in monoculture. We hypothesized that the presence of unacceptable crops and poor hosts might force the whitefly adults to invest more time and energy probing and moving among unacceptable hosts, and so reduce the overall time and energy invested in ovipositing and feeding on bean, the preferred crop. In addition, we speculated that this expenditure of energy might increase mortality among the whitefly population, reducing the numbers of adults that reached intercropped plants compared with crops grown in monoculture. In the first experiment, monocropped and intercropped bean plots were subdivided into plots containing pesticide treatments to determine if intercropping combined with pesticide provided an advantage over intercropping alone.

Our work was carried out in central Guatemala, at the eastern end of the Salamá Valley. A system of gravity-fed irrigation canals was installed in this portion of the valley in the 1970s, allowing year-round cultivation of horticultural crops, primarily tomato (*Lycopersicon esculentum* Mill.). This in turn has contributed to the unmitigated build-up of whitefly populations in recent years. An additional objective of our work therefore was to confirm the identification of the predominant whitefly species in the valley, and to gather data on the relative proportion of different whitefly species in the dry and rainy seasons.

## Materials and Methods

The research was carried out at the Instituto de Ciencia y Tecnología Agrícolas (ICTA) field station in San Jerónimo (15° 03′ 40″ N, 90° 15′ 00″ W), Baja Verapaz, Guatemala, at 1,000 m above sea level. The area is classified as subtropical dry forest under the Holdridge system (Holdridge 1967, de la Cruz 1982). The dry season is from November to April. Soils on the station belong to the Salamá series and are characterized as loose and friable, with a low cation exchange capacity and a substratum of volcanic ash (Sharer and Sedat 1987, Krug 1993).

A tractor was used to cultivate the experimental area and form rows at the beginning of the dry season (19 March) and rainy season (13 August) experiments. Application of fertilizer, weeding, and all other aspects of plot management were carried out manually. Crops were fertilized according to local recommendations (ICTA 1993, Superb 1997). Fungicides and pesticides were applied with a 16-liter Matabi "Super 16" backpack sprayer (Goizper S. Coop., Guipuzcoa, Spain). Water from a furrow irrigation system was made available to the station every 6 d for 3 d during the dry season and upon request during the rainy season.

Two experiments were carried out between March and December 1998 to evaluate the effect of row and mixed intercropping arrangements on the densities of immature whiteflies on bean. The row intercrop experiment was referred to as the 'diversity' study, and the mixed intercrop experiment was called the 'mosaic' study.

**Diversity Study.** The diversity study was initiated in March toward the end of the dry season, when whitefly populations are highest. Bean was intercropped in alternating rows with corn, cabbage (*Brassica oleracea* L.), cilantro (*Coriandrum sativum* L.), roselle (*Hibiscus sabdariffa* L.), and velvetbean [*Mucuna deeringiana* (Bort.) Small]. These crops are either poor hosts or nonhosts for the whitefly species predominant in the area, and were chosen from crops grown regionally to represent a diverse range of plant architecture

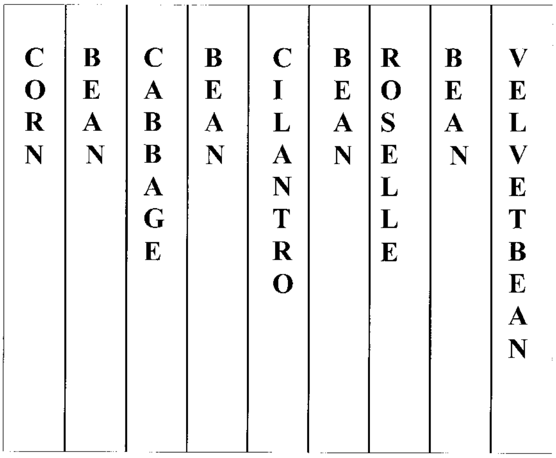


**Fig. 1.** Whole plot design for intercrop treatment in diversity experiment: bean is planted in alternating rows with velvetbean, roselle, cilantro, cabbage, and field corn.

and plant chemistry. All have dietary and market value, except for velvetbean, which is primarily used as a forage and green manure. This study included subplots with pesticide treatments. Bean was double-cropped in this study.

The bean variety used was 'ICTA-Santa Gertudis,' a cultivar developed and promoted by ICTA as resistant to bean golden mosaic. The field corn hybrid used was 'ICTA HB-83' (ICTA 1993). 'Costanza' cabbage (Petoseed, Saticoy, CA) was used. Cultivar information was not available for cilantro, velvetbean, and roselle, which were grown from locally acquired seed.

We used a split-plot design, with two whole plot treatments (monocrop, intercrop) and three subplot pesticide treatments (imidacloprid, detergent/oil, control). Each treatment was replicated four times. Whole plots contained nine rows, 17 m in length. Monocrop plots consisted of eight rows of bean. Intercrop plots consisted of nine rows of a bean/intercrop mix. The five intercrop species were planted in alternating rows with bean in the following order: velvetbean, roselle, cilantro, cabbage, corn (Fig. 1).

Spacing between plants in rows was 20 cm for bean, corn, cilantro, and velvetbean and 40 cm for cabbage. Space between rows was 1.0 m. Corn, cabbage, cilantro, and roselle were planted 25 March. Velvetbean was planted 26 March. Bean was planted 5 and 6 April. Each whole plot was divided into three sections of 5.67 m in length. These sections were demarcated with nylon cord supported by stakes. Each section was randomly assigned to the imidacloprid treatment, the detergent and oil treatment, or the control.

Imidacloprid (Confidor 70 WG; Bayer AG) was prepared at a rate of 0.73 g/liter of water. Approximately 0.01 liters (10 cc) of this mixture (7.3 mg imidacloprid) was applied to the base of each bean plant receiving the imidacloprid treatment. Imidacloprid was applied to bean at emergence, 1 wk after emergence, and 3 wk after emergence. Imidacloprid is not registered for bean, and was included for comparison only. Olmeca vegetable oil (Olmeca S.A., Guatemala) and Unox laundry detergent (Quimicas Lasser S.A., El Salvador) were applied at a rate of 1%, or 0.016 liters (16 cc)/16-liter spray tank (Calderón et al. 1993). An elbowed nozzle attachment was used to apply the mixture to the lower surface of leaves. Detergent or oil was applied in rotation every 5 d.

Bean plants were sampled on six occasions: 17 April (1 wk after emergence), 25 April, 3 May, 12 May, 19 May, and 17 June. The sample unit on 17 April, 25 April, 3 May, and 19 May (samples 1–3 and 5) was a 3.35-$cm^2$ disc removed with a cork borer from upper and lower stratum leaves (McAuslane et al. 1995). The disc was removed from the underside of the central leaflet to the right of the mid-vein. Five plants per plot were sampled on these dates. The average of the two discs was used in treatment analysis. On 12 May and 17 June (samples 4 and 6), one whole plant per subplot replicate was sampled.

A leaf area meter was not available at the research site, therefore other plant size parameters were measured to compare plant size among treatments. Five plant heights per plot were measured on sample dates 3, 5, and 6. Five plants per plot were weighed on sample dates 4, 5, and 6. On 12 May, five whole bean plants per plot were enclosed quickly in plastic bags and refrigerated. These plants were sampled to estimate the number of generalist predators on the bean plants as well as whitefly immatures.

Plants were examined under a dissecting microscope and the numbers of whitefly eggs, nymphs, parasitized nymphs, and fourth-instar nymphs were recorded. The red eyes of the nymph become conspicuous in the final stage of fourth-instar *B. tabaci* nymphs. This stage was used to estimate the proportion of *B. tabaci* relative to *T. vaporariorum* in the nymph population. Earlier instars of *B. tabaci* and *T. vaporariorum* can be distinguished, but this is prohibitively time-consuming when high numbers of nymphs are being counted. In each study and for all crops, only the undersides of leaves were examined for whitefly immatures (Ekbom and Rumei 1990).

Fourth-instar whitefly nymphs were mounted in the laboratory of Margarita Palmieri at the Universidad del Valle in Guatemala City and sent to Avas Hamon of the Division of Plant Industry, Gainesville, FL, USA, for identification. Andrew Jensen of the United States Department of Agriculture in Beltsville, MD, USA, identified nymphs on dried plant material. Leaves or whole plants with nymphs showing symptoms of parasitism were placed in unwaxed cylindrical 0.95-liter cardboard cartons (Fonda Group, Union, NJ, USA) for parasitoid emergence. Several weeks later, dead parasitoids were placed on cotton in gel capsules and sent to Greg Evans of the Division of Plant Industry for identification.

Tissue from bean plants exhibiting symptoms of bean golden mosaic was analyzed using ELISA (Agdia, Elkhart, IN) in the laboratory of Margarita Palmieri. The total number of plants per row and the number of plants with bean golden mosaic symptoms was counted for all even-numbered rows in each bean study.

Three of the intercrop species were examined to determine their suitability as whitefly hosts. Five velvetbean plants were examined for whitefly immatures on 3 May and 9 May. The outline of the leaves was traced onto paper, and this area was measured using a LI-COR portable leaf area meter (model LI-3000A, LI-COR, Lincoln, NE) in the United States. Whole plant examinations were made of 12 cabbage plants on 6 June and 10 roselle plants on 8 June.

Imidacloprid-treated bean was harvested 29 June. Detergent/oil-treated bean and untreated bean was harvested 6 July. On 10 July, a second bean crop was planted in the former imidacloprid subplots. A randomized complete block design with four replications was used to compare whitefly immatures on bean grown under two treatments: monocropped or intercropped with the five intercrop plant species, which were by then fully mature or senescing.

Spacing between bean plants was 20 cm for this second bean crop. Bean plants were sampled weekly for 6 wk from 19 July through 23 August. Eight whole bean plants per plot were sampled during week 1, four plants per plot on week 2, and two plants per plot for the remaining weeks. The number of trifoliate leaves per plant was recorded each week. The second bean crop was harvested 20 September.

**Mosaic Study.** This study was carried out toward the end of the rainy season. A mixed intercropping design was used, with field corn, roselle, tomato, and bean planted in a mosaic pattern. The purpose of this experiment was to create a cryptic environment for bean and tomato by mixing them with field corn and roselle plants to conceal them from whitefly adults. Field corn is a nonhost and roselle is a poor host for the whitefly species in the area, and each grows to be considerably larger than bean or tomato. The mosaic pattern was tested to determine if under extreme conditions whitefly host-finding could be disrupted by intercropping with unacceptable hosts. The same crop cultivars were used as in the diversity study. Tomato seedlings (cultivar 'Elios') were bought from Piloncito Verde, Chimaltenango.

Numbers of immature whiteflies were compared on bean grown in monoculture, and on bean intercropped with corn and roselle. Numbers of immature whiteflies were compared on tomato grown under the same two treatments. Each treatment was replicated four times and arranged in a randomized complete block design. Monocrop plots contained four rows of tomato adjacent to four rows of bean. Intercrop plots consisted of eight rows of mixed crops. The order of crop species within the row for the intercrop treatment was corn, roselle, bean, corn, roselle, and tomato (Fig. 2). The first crop in consecutive rows was staggered so that each bean or tomato plant was surrounded by corn, roselle, and the other main crop, but was not immediately adjacent to a conspecific.

Rows were 8 m in length and between-row spacing was 1.0 m. Spacing between plants was 40 cm for all intercrop plants and the monocrop tomato, and 20 cm

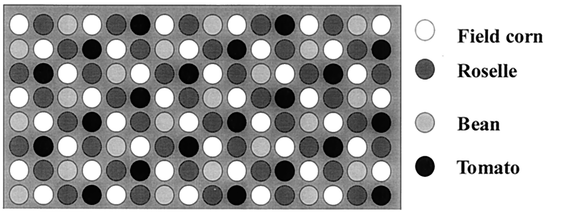


Fig. 2. Plot design for intercrop treatment in mosaic experiment. Field corn and roselle are planted in pairs alternating with bean and tomato.

for monocrop bean. Corn and roselle were planted 18 August. Bean was planted 8 October. Tomato seedlings were transplanted 20 October.

Whole plant counts were obtained from bean on 18 October, 22 October, 27 October, 1 November, 5 November, and 17 November. Six plants per plot were sampled on the first date, four plants per plot were sampled on 22 October through 1 November, and two plants per plot were sampled on 5 November and 17 November. Plant height was measured on each sample date. Number of branches was recorded on sample dates 3–6, and plants were weighed on the last three sample dates. Number of plants per row and number of plants with bean golden mosaic symptoms were counted 2 December.

Whole plant counts were recorded from tomato on 21 October, 29 October, 5 November, and 12 November. On 22 November and 6 December, the plants were too large for whole plant counts. We decided therefore to examine only the lower third of the plant on these last two dates to focus on comparing levels of parasitism in monocropped and intercropped tomato. During the first 2 wk, four plants per plot were sampled. During week 3, two plants per plot were sampled. On the remaining three sample dates, three plants per plot were sampled. Plant heights were measured on the first five sample dates. Number of branches per plant was recorded between 29 October and 22 November, and fresh plant weights were taken from 5 November through 22 November. On 2 December the number of tomato plants per row was recorded. On 7 October one whole roselle plant per block was examined for whitefly immatures.

**Statistical Analysis.** Because of high variability in whitefly numbers, counts were transformed using log $(x + 1)$ before analysis. Untransformed counts are presented in tables and text. Numbers of whitefly immatures, natural enemies, plant size characteristics, and virus incidence were compared using analysis of variance for split plot or randomized complete block, followed by Tukey's mean separation procedure when appropriate (SAS Institute 1996).

## Results

The predominant whitefly species in the Salamá Valley was determined to be *T. vaporariorum.* Whitefly populations were highest at the end of the dry season (March–May), dropped with the first cool, wet

**Table 1. Height and weight ($\bar{x} \pm$ SD) of bean plants under two cropping systems and three pesticide regimes (diversity study, first bean crop)**

| Date | Pesticide | Height, cm | | | Weight, g | | |
|---|---|---|---|---|---|---|---|
| | | Monocrop | Intercrop | Mean ± SD | Monocrop | Intercrop | Mean ± SD |
| 3 May | Imidacloprid | 8.19 ± 2.76 | 8.70 ± 2.75 | 8.44 ± 2.73a | — | — | — |
| | Detergent/oil | 5.85 ± 1.33 | 5.72 ± 1.29 | 5.79 ± 1.24b | — | — | — |
| | Control | 5.98 ± 1.18 | 5.99 ± 1.72 | 5.99 ± 1.46b | — | — | — |
| 12 May | Imidacloprid | 26.61 ± 9.05 | 28.55 ± 6.86 | 27.60 ± 7.95a | 71.50 ± 62.34 | 105.80 ± 58.94 | 88.65 ± 59.08a |
| | Detergent/oil | 13.39 ± 3.36 | 11.85 ± 2.95 | 12.60 ± 3.21b | 31.45 ± 9.15 | 27.93 ± 12.07 | 29.69 ± 10.09b |
| | Control | 10.88 ± 3.51 | 11.45 ± 4.10 | 11.15 ± 3.76b | 38.63 ± 27.32 | 23.38 ± 3.40 | 31.00 ± 19.78b |
| 19 May | Imidacloprid | — | — | — | 158.50 ± 120.77 | 152.50 ± 72.98 | 155.50 ± 92.43a |
| | Detergent/oil | — | — | — | 25.95 ± 14.68 | 36.75 ± 17.79 | 31.35 ± 16.16b |
| | Control | — | — | — | 26.25 ± 7.68 | 29.25 ± 10.69 | 27.75 ± 8.76b |
| 17 June | Imidacloprid | 46.75 ± 15.78 | 55.00 ± 4.40 | 50.88 ± 11.59a | 160.25 ± 92.25 | 167.75 ± 113.85 | 164.00 ± 96.01a |
| | Detergent/oil | 20.88 ± 6.61 | 28.25 ± 6.44 | 24.56 ± 7.22b | 26.13 ± 20.22 | 37.50 ± 22.47 | 31.81 ± 20.70b |
| | Control | 25.50 ± 4.43 | 21.00 ± 5.23 | 23.25 ± 5.09b | 24.88 ± 20.58 | 15.75 ± 6.24 | 20.31 ± 14.90b |

Data are means of five replications. Means in columns for a given week followed by the same letter are not significantly different ($P < 0.05$) according to Tukey's studentized range test. No letters present indicate no differences for that week. No differences ($P > 0.1$) between means in monocrop versus intercrop treatments on any sampling date.

months of the rainy season (June–August), and rose again to intermediate levels by the end of the rainy season (October–November). Relatively few fourth-instar *B. tabaci* nymphs were observed throughout the 10-mo study. Observations of fourth-instar *B. tabaci* and geminivirus symptoms on bean and tomato were highest at the end of the dry season and rare at the end of the rainy season. In the middle of the rainy season, when overall whitefly populations were at their lowest, almost 50% of observed fourth-instar nymphs were *Bemisia.* The strain or strains of *B. tabaci* present in the Salamá Valley were not determined.

**Diversity Study.** Differences in levels of whitefly immatures, predators, plant density, percent bean golden mosaic geminivirus, and yield were not significant between monocropped and intercropped treatments on any sampling date ($P > 0.1$) except for 12 May, when whole plant egg counts were higher on intercropped bean (850.7 ± 1,725.8 eggs per plant) than monocropped bean (98.17 ± 309.93 eggs per plant) ($F = 5.55$; df = 1, 3; $P < 0.1$). Other statistical differences in the diversity study occurred among subplot pesticide treatments only.

Three weeks after germination, bean plants treated with imidacloprid were clearly larger and more robust than those in the detergent/oil treatment and control (Table 1). Plants in the detergent/oil treatment showed symptoms of phytotoxicity. In addition, plants in the detergent/oil and control treatments were stunted, with shortened stems and petioles. A chlorotic burn appeared along the leaf border and tip, typical of leafhopper damage. Whole plant examinations on 12 May revealed high densities of thrips (Thysanoptera) and leafhoppers (Homoptera: Cicadellidae) on plants in the detergent/oil treatment and the control. Size differences between the imidacloprid-treated bean and the other two treatments increased during subsequent weeks (Table 1).

Although there was a significant interaction between main effects and subplot effects on week 1 ($F = 2.58$; df = 2, 3; $P < 0.1$), egg densities tended to be lower on imidacloprid-treated bean plants than plants in the detergent/oil treatment and control during the first 2 wk of sampling (Table 2) (17 April: monocrop - $F = 3.15$; df = 2, 6; $P < 0.05$; intercrop - $F = 9.20$; df = 2, 6; $P < 0.01$; 25 April: $F = 20.47$; df = 2, 12; $P < 0.01$). On the second and third weeks of sampling, nymph densities were lower on imidacloprid-treated bean than the other treatments (Table 2) (25 April: $F = 7.74$; df = 2, 12; $P < 0.01$; 3 May: $F = 29.83$; df = 2, 12; $P < 0.01$).

By 3 May, the trend in oviposition had reversed as large, healthy plants treated with imidacloprid were able to support higher numbers of eggs and stunted, unprotected plants in the other treatments apparently became less suitable for oviposition (Tables 1 and 2) ($F = 9.38$; df = 2, 12; $P < 0.01$). On 12 May there was an interaction between main and subplot effects ($F = 3.27$; df = 2, 12; $P < 0.1$). Egg counts were higher among intercropped treatments on bean plants treated with imidacloprid than on the other two treatments on this date ($F = 20.55$; df = 2, 6; $P < 0.01$). Nymph counts similarly tended to be higher on imidacloprid-treated plants than other treatments on 12 May (monocrop - $F = 5.01$; df = 2, 6; $P < 0.1$; intercrop - $F = 43.58$; df = 2, 6; $P < 0.01$) and 19 May ($F = 3.61$; df = 2, 12; $P < 0.05$).

Fourth-instar *B. tabaci* nymphs were observed for the first time on 12 May, when whole plant examinations were carried out due to unequal plant size across treatments. Numbers of fourth-instar *B. tabaci* were lower in the imidacloprid treatment (0.13 ± 0.35 per plant) and in the detergent/oil treatment (0.38 ± 0.52) than the control (7.62 ± 12.22) ($F = 3.34$; df = 2, 12; $P < 0.07$). The ratio of fourth-instar *Bemisia* to *Trialeurodes* from all treatments on 12 May was 65:573 (10.2% *Bemisia*). Incidence of *Bemisia* on subsequent sampling dates was not high enough for meaningful comparison.

On the third week of sampling, numbers of fourth-instar *T. vaporariorum* were lower on imidacloprid-treated bean plants (0.03 ± 0.13 nymphs per cm$^2$) than on plants treated with detergent and oil (0.99 ± 1.55) and the control group (0.78 ± 1.89) ($F = 10.68$; df =

**Table 2. Whitefly eggs and nymphs ($\bar{x} \pm$ SD/cm$^2$) on bean leaves under two cropping systems and three pesticide regimes (diversity study, first bean crop)**

| Date | Pesticide | Egg | | | Nymph | | |
|---|---|---|---|---|---|---|---|
| | | Monocrop | Intercrop | Mean ± SD | Monocrop | Intercrop | Mean ± SD |
| 17 April | Imidacloprid | 46.38 ± 44.68a | 43.18 ± 35.08a | 44.78 ± 39.68 | — | — | — |
| | Detergent/oil | 68.90 ± 43.74b | 74.93 ± 53.57b | 71.91 ± 48.37 | — | — | — |
| | Control | 56.30 ± 50.31ab | 108.3 ± 90.84b | 82.30 ± 77.11 | — | — | — |
| 15 April | Imidacloprid | 17.70 ± 15.86 | 17.10 ± 15.40 | 17.40 ± 15.45a | 5.53 ± 5.00 | 13.23 ± 17.24 | 9.43 ± 13.13a |
| | Detergent/oil | 31.33 ± 24.62 | 28.93 ± 18.62 | 29.96 ± 21.09b | 42.83 ± 42.26 | 59.15 ± 61.52 | 52.16 ± 54.01b |
| | Control | 62.43 ± 49.36 | 62.90 ± 43.88 | 62.70 ± 45.60c | 27.60 ± 30.70 | 29.35 ± 27.28 | 28.60 ± 28.37b |
| 3 May | Imidacloprid | 11.80 ± 14.27 | 16.70 ± 18.95 | 14.25 ± 16.74a | 8.08 ± 11.40 | 7.05 ± 9.28 | 7.57 ± 10.28a |
| | Detergent/oil | 3.41 ± 5.20 | 4.27 ± 4.76 | 3.84 ± 4.94b | 20.32 ± 21.42 | 25.15 ± 18.92 | 22.73 ± 20.10b |
| | Control | 6.57 ± 8.92 | 10.55 ± 24.57 | 8.56 ± 18.36ab | 28.15 ± 21.85 | 37.58 ± 38.60 | 32.87 ± 31.33b |
| 12 May[a] | Imidacloprid | 279.50 ± 535.02 | 2,533.75 ± 2,292.44a | 1,406.63 ± 1,956.23 | 621.00 ± 613.60a* | 1,547.25 ± 1,293.9a | 1,084.13 ± 1,060.19a |
| | Detergent/oil | 8.75 ± 13.00 | 15.00 ± 17.63b | 11.88 ± 14.72 | 30.25 ± 31.49b* | 47.50 ± 62.00b | 38.88 ± 46.44b |
| | Control | 6.25 ± 5.68 | 3.25 ± 2.87b | 4.75 ± 4.46 | 205.75 ± 136.3ab* | 64.25 ± 90.17b | 135.00 ± 131.03b |
| 19 May | Imidacloprid | 19.21 ± 32.05 | 23.41 ± 45.87 | 21.31 ± 38.98a | 3.00 ± 2.65 | 11.72 ± 29.46 | 7.36 ± 21.04a |
| | Detergent/oil | 3.91 ± 10.76 | 11.19 ± 31.36 | 7.55 ± 23.36b | 1.31 ± 1.25 | 3.35 ± 7.72 | 2.42 ± 5.56b |
| | Control | 0.31 ± 0.44 | 14.75 ± 44.22 | 7.53 ± 31.63b | 1.69 ± 2.17 | 2.78 ± 5.82 | 2.23 ± 4.36b |
| 17 June[a] | Imidacloprid | 0 | 0.25 ± 0.50 | 0.13 ± 0.35 | 30.25 ± 38.02 | 17.25 ± 15.13 | 23.75 ± 27.68 |
| | Detergent/oil | 0 | 0.25 ± 0.50 | 0.13 ± 0.35 | 2.50 ± 3.11 | 14.00 ± 16.73 | 8.25 ± 12.73 |
| | Control | 0 | 0 | 0 | 13.25 ± 23.19 | 3.00 ± 2.45 | 8.13 ± 16.22 |

Data are means of five replications. Means in columns for a given week followed by the same letter are not significantly different ($P < 0.05$) according to Tukey's studentized range test. No letters present indicate no differences for that week. *, $P < 0.1$.

[a] Means from weeks 4 and 6 represent counts from one entire plant per replicate.

2, 12; $P < 0.01$). There were no treatment differences ($P < 0.05$) in the number of fourth-instar *T. vaporariorum* on week 4 (28.86 ± 48.58 nymphs per plant). Numbers of fourth-instar *T. vaporariorum* were higher on imidacloprid-treated bean plants (5.43 ± 7.84 nymphs per cm$^2$) than on plants in the detergent/oil treatment (0.05 ± 0.27) or the control (0.51 ± 1.23) ($F = 26.89$; df = 2, 12; $P < 0.01$) on 19 May and 17 June (imidacloprid: 17.37 ± 16.99 nymphs per plant; detergent/oil: 1.38 ± 1.77; control: 0) ($F = 18.32$; df = 2, 12; $P < 0.01$).

In the 12 May sample, the number of parasitized nymphs was higher in the imidacloprid treatment (15.00 ± 18.47 nymphs per plant) and control (16.00 ± 18.26) than in the detergent/oil treatment (4.25 ± 7.16). Parasitism was higher in the imidacloprid treatment than the other two treatments on 19 May (imidacloprid: 2.98 ± 4.19 parasitized nymphs per cm$^2$, detergent/oil: 0.13 ± 0.34 parasitized nymphs per cm$^2$, control: 0.78 ± 1.26 parasitized nymphs per cm$^2$) ($F = 11.21$; df = 2, 12; $P < 0.01$) and 17 June (imidacloprid: 29.50 ± 21.23 parasitized nymphs per plant, detergent/oil: 6.00 ± 6.30 parasitized nymphs per plant, control: 4.75 ± 6.86 parasitized nymphs per plant). Parasitism was presumably highest on imidacloprid-treated plants because these plants were larger and supported more hosts than untreated plants.

Parasitoids reared from bean in the diversity experiment were almost entirely *Encarsia pergandiella* Howard (Hymenoptera: Aphelinidae), although a few individuals from the *Encarsia meritoria* species complex were reared from the second bean crop early in August. Sex ratios for *E. pergandiella* ranged from ≈15% males in mid-May, when host and parasitoid populations were high, to 33% males in July and August, when overall populations were low, to ≈26% males in November and December, when both populations were high again.

Generalist predators collected from whole plant bean samples on 12 May included *Geocoris* sp. (Hemiptera: Lygaeidae), Coccinellidae (Coleoptera), predatory Thysanoptera, Neuroptera, syrphid larvae (Diptera), and spiders. Only *Geocoris* sp. was present in sufficient quantities for statistical comparison. Levels of *Geocoris* sp. were higher on imidacloprid-treated bean (0.60 ± 0.87 per plant) than on bean in the detergent/oil treatment (0.05 ± 0.22) or the control (0.25 ± 0.16) ($F = 15.14$; df = 2, 12; $P < 0.01$). This is not surprising given that imidacloprid-treated bean plants were significantly larger and supported higher numbers of whitefly nymphs than plants in the other two subplot treatments (Tables 1 and 2).

There were more plants per row in the imidacloprid treatment (26.50 ± 4.88 plants per row) than in the control (22.28 ± 6.75 plants per row) ($F = 4.25$; df = 2, 12; $P < 0.05$). Plant density in the detergent/oil treatment was intermediate (24.00 ± 7.76 plants per row). The percentage of plants with bean golden mosaic symptoms was different among all subplot treatments (imidacloprid: 7.27 ± 7.03%; detergent/oil: 14.86 ± 10.53%; control: 21.99 ± 15.86%) ($F = 11.21$; df = 2, 12; $P < 0.01$). Eight bean plants out of ten

**Table 3. Whitefly immatures per plant and number of trifoliate leaves per plant on bean grown among senescing intercrops versus monocrop (diversity study, second bean crop)**

| Date | | Egg | Nymph | Trifoliate leaves |
|---|---|---|---|---|
| 19 July | Monocrop | 1.25 ± 1.76 | — | — |
| | Intercrop | 2.00 ± 2.38 | — | — |
| 26 July | Monocrop | 3.44 ± 3.29 | 0.94 ± 2.11 | — |
| | Intercrop | 2.75 ± 2.11 | 1.25 ± 1.34 | — |
| 3 Aug. | Monocrop | 16.25 ± 8.14a* | 8.50 ± 6.50 | — |
| | Intercrop | 8.25 ± 6.32b | 6.13 ± 3.64 | — |
| 10 Aug. | Monocrop | 17.38 ± 6.99a | 22.25 ± 13.02 | 7.88 ± 2.53 |
| | Intercrop | 6.00 ± 4.38b | 21.13 ± 10.56 | 7.00 ± 2.51 |
| 17 Aug. | Monocrop | 6.63 ± 6.02 | 37.50 ± 26.27 | 11.25 ± 3.94a |
| | Intercrop | 6.25 ± 6.11 | 34.75 ± 29.48 | 8.50 ± 2.20b |
| 23 Aug. | Monocrop | 4.50 ± 5.83 | 78.50 ± 66.33 | 23.50 ± 7.01a |
| | Intercrop | 7.75 ± 4.86 | 41.00 ± 24.87 | 13.50 ± 3.02b |

Means in the same column for a given week followed by a different letter are significantly different ($P < 0.05$, *, $P < 0.1$) according to analysis of variance. The absence of letters indicates no treatment differences ($P > 0.1$)

showing symptoms of bean golden mosaic tested positive for the presence of geminivirus. The bean yield per row was higher in the imidacloprid treatment (0.29 ± 0.09 kg) than in the detergent/oil treatment (0.05 ± 0.03 kg) and the control (0.02 ± 0.03 kg), neither of which produced marketable yield ($F = 38.48$; df = 2, 12; $P < 0.01$).

**Intercrop Species as Whitefly Hosts.** Very few whitefly eggs or nymphs were found on cabbage, roselle, and velvetbean. Cabbage plants were large (254.25 ± 180.88 g) with well-formed heads when sampled. Mean egg count was 0.17 ± 0.58 per plant and mean nymph count was 3.25 ± 5.43 per plant. Two fourth-instar *T. vaporariorum* nymphs were found. Roselle plants weighed 164.67 ± 150.92 g and were 49.33 ± 12.14 cm tall when sampled. No whitefly eggs were found on the roselle. Average per plant count of nymphs and fourth-instar *Bemisia tabaci* on roselle was 7.67 ± 6.89 and 0.89 ± 1.36, respectively. Velvetbean sampled on 3 May averaged 0.08 ± 0.06 eggs and 0.03 ± 0.04 nymphs per $cm^2$. Velvetbean sampled on 9 May averaged 0.01 ± 0.01 eggs and 0.05 ± 0.06 nymphs per $cm^2$.

**Diversity Study: Second Bean Crop.** There were no differences between monocropped and intercropped bean in the number of eggs or nymphs per plant during the first 2 wk of sampling. The number of whitefly eggs was higher in the monocrop than the intercrop treatment on 3 August ($F = 3.49$; df = 1, 3; $P < 0.1$) and 10 August ($F = 21.21$; df = 1, 3; $P < 0.01$) (Table 3). Egg numbers did not differ by treatment on other dates. However, intercropped bean plants had fewer trifoliates on 17 August ($F = 6.21$; df = 1, 3; $P < 0.05$) and 23 August ($F = 13.3$; df = 1, 3; $P < 0.01$) (Table 3). Overall egg and nymph densities were therefore higher on the intercrop plants during these weeks, because intercrop plants were smaller than monocrop plants. The smaller size of intercrop beans was probably due to shading from intercrops, particularly the roselle, which was ≈1.5 m tall by August.

There were no treatment differences ($P > 0.1$) on any sampling date for the second bean crop among numbers of nymphs (Table 3), parasitized nymphs (10 August: 0.25 ± 0.77 per plant, 17 August: 1.75 ± 2.89, 23 August: 6.12 ± 8.61), or fourth-instar *T. vaporariorum* (10 August: 0.44 ± 0.81, 17 August: 0.94 ± 1.12, 23 August: 4.38 ± 7.82). There were no statistical differences ($P > 0.1$) between treatments in the numbers of fourth-instar *B. tabaci* on 10 August (0.37 ± 0.81) or 23 August (0.37 ± 0.81). The number of fourth-instar *B. tabaci* was lower in the monocrop treatment (0.50 ± 0.53) than in the intercrop treatment (1.13 ± 0.99) on 17 August ($F = 8.32$; df = 1, 3; $P < 0.05$).

On 10 and 17 August, *B. tabaci* made up 46% of the observed fourth-instar whitefly immatures (ratio of *B. tabaci* to *T. vaporariorum* was 6:7 on 10 August and 13:15 on 17 August). On 23 August, *B. tabaci* comprised 7% of the observed fourth-instar whitefly immatures (1:15).

There were fewer plants per row in the intercrop treatment (60.13 ± 22.53) than in the monocrop treatment (82.19 ± 9.16) ($F = 3.09$; df = 1, 3; $P < 0.05$). Yield per row was higher in the monocrop treatment (2.47 ± 0.53 kg) than in the intercrop treatment (1.25 ± 0.39 kg) ($F = 11.72$; df = 1, 3; $P < 0.05$). The reason for the lower number of plants per row in the intercrop treatments is not clear. Possibly the weeding and fertilizing of the bean plants was impeded by the presence of intercrop plants, leading to reduced survival.

Leafhoppers and thrips were barely detectable on this second bean crop, although high populations of these insects decimated unprotected bean in the previous dry season. However, dense populations of chrysomelids (Coleoptera), primarily *Cerotoma* and *Diabrotica* spp., attacked the second bean crop early. *Cerotoma* and *Diabrotica* spp. are among the vectors of severe mosaic of bean, a comovirus (Morales and Cardona 1998). Francisco Morales of International Center for Tropical Agriculture, Cali, Colombia, identified symptoms of severe mosaic of bean among experimental plants in the field. Incidence of the virus was high among experimental plants. Leaf necrosis and deformation from severe mosaic of bean masked symptoms of bean golden mosaic, preventing an estimate of presence of bean golden mosaic at the end of the crop cycle.

**Mosaic Study: Bean.** Egg counts were lower on intercropped than monocropped bean on 22 October ($F = 6.82$; df = 1, 3; $P < 0.05$) and 27 October ($F = 19.23$; df = 1, 3; $P < 0.01$) (Table 4). Nymph counts were lower on intercropped than monocropped bean on 1 November ($F = 17.66$; df = 1, 3; $P < 0.01$), 5 November ($F = 18.89$; df = 1, 3; $P < 0.01$) and 17 November ($F = 4.70$; df = 1, 3; $P < 0.1$).

Lower numbers of eggs and nymphs among intercrop bean early in the study may be attributed to the emergence of intercrop plants into a cryptic environment. However, bean size and health were affected by shading from corn and roselle soon after emergence, and the overall plant area available for colonization

**Table 4. Whitefly immatures ($\bar{x}$ ± SD per plant) and plant parameters of bean monocropped and mix intercropped with field corn and roselle (mosaic study)**

| Date | Egg | | Nymph | | Plant height, cm | | No. trifoliate leaves | | Plant weight, g | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Monocrop | Intercrop | Monocrop | Intercrop | Monocrop | Intercrop | Monocrop | Intercrop | Monocrop | Intercrop |
| 18 Oct. | 31.83 ± 51.10 | 10.71 ± 13.32 | — | — | 11.56 ± 2.97 | 16.86 ± 2.49** | — | — | — | — |
| 22 Oct. | 46.56 ± 71.62 | 10.81 ± 11.84* | 8.00 ± 11.31 | 2.12 ± 2.75 | 14.34 ± 2.71 | 17.09 ± 2.31** | — | — | — | — |
| 27 Oct. | 75.25 ± 120.44 | 9.88 ± 18.22** | 17.69 ± 30.24 | 5.81 ± 7.79 | 17.19 ± 3.17 | 18.00 ± 4.43 | 1.13 ± 0.81 | 0.50 ± 0.52** | — | — |
| 1 Nov. | 111.13 ± 175.62 | 21.88 ± 18.02 | 43.19 ± 63.19 | 8.31 ± 7.89** | 21.13 ± 3.54 | 22.03 ± 4.17 | 2.88 ± 1.23 | 1.63 ± 0.62** | 10.97 ± 5.58 | 4.02 ± 1.56** |
| 5 Nov. | 33.88 ± 54.44 | 22.75 ± 51.55 | 65.88 ± 55.22 | 10.13 ± 5.4** | 22.19 ± 3.07 | 22.00 ± 4.06 | 4.50 ± 1.31 | 2.50 ± 0.76** | 13.94 ± 6.51 | 5.84 ± 2.66** |
| 17 Nov. | 7.25 ± 4.59 | 4.63 ± 5.78 | 133.25 ± 259.3*** | 29.50 ± 40.0*** | 27.75 ± 6.25 | 24.38 ± 7.86 | 6.25 ± 2.38 | 4.13 ± 2.17*** | 27.38 ± 17.85 | 11.14 ± 11.55** |

**, *, ***, indicate that intercrop mean is significantly different from corresponding monocrop mean at $P < 0.01$, $P < 0.05$, and $P < 0.1$, respectively.

was presumably less than in the monocrop treatment by the 27 October sample. From 27 October through 17 November, intercrop bean was stunted compared with monocrop bean, and whitefly densities were correspondingly lower.

A few *Encarsia pergandiella* individuals and one member of the *Encarsia meritoria* species complex were reared from bean in the mosaic experiment. There were no treatment differences among numbers of parasitized nymphs (1 November: 0.88 ± 2.03 per plant, 5 November: 0.88 ± 2.03, 17 November: 1.44 ± 2.66), fourth-instar *T. vaporariorum* (1 November: 0.13 ± 0.71, 5 November: 0.88 ± 1.71, 17 November: 4.19 ± 5.76), or fourth-instar *B. tabaci* (5 November: 0.06 ± 0.25, 17 November: 0.06 ± 0.25). On 5 November, *B. tabaci* fourth-instars comprised 7% of fourth-instar nymphs on bean. On 17 November, 1.5% of fourth-instar nymphs on bean were *B. tabaci.*

Number of bean plants per row averaged 5.15 ± 2.49 in the intercrop treatment, and 56.31 ± 5.88 in the monocrop treatment. Only two bean plants in the mosaic study showed symptoms of bean golden mosaic, both in the monocrop treatment.

**Mosaic Study: Tomato.** There were no treatment differences in egg density on any sampling date (Table 5). Numbers of whitefly nymphs on intercropped tomato were higher than on monocropped tomato from 29 October through 12 November, although monocropped tomato plants were shorter than intercropped plants during those weeks (Table 5). There were no treatment differences ($P > 0.1$) in numbers of fourth-instar *T. vaporariorum* on 22 November (36.33 ± 48.15 per plant) or 6 December (48.92 ± 71.19). Numbers of parasitized nymphs (19.67 ± 18.76 per plant) were not different ($P > 0.1$) between treatments on 22 November. Numbers of parasitized nymphs were higher on intercrop tomato (50.67 ± 46.80) than monocrop tomato (23.00 ± 26.01) on 6 December ($F = 3.56$; df = 1, 3; $P < 0.08$). Only one fourth-instar *B. tabaci* was found on tomato, comprising 0.08% of fourth-instar nymphs observed on 6 December.

Parasitoids reared from tomato in the mosaic experiment consisted of *Encarsia pergandiella,* members of the *Encarsia meritoria* species complex, and *Amitus fuscipennis* MacGown & Nebeker (Hymenoptera: Platygasteridae). Parasitoid adults (327) were reared from the monocropped tomato, of which 88.4% were *E. pergandiella,* 11% were *A. fuscipennis,* and 0.6% belonged to the *E. meritoria* complex. Of the 546 individuals recovered from intercropped tomato, 40.1% *were E. pergandiella,* 46.2% were *A. fuscipennis,* and 13.7% belonged to the *E. meritoria* complex. A Shannon-Weaver diversity index (H′) (Shannon and Weaver 1949) of 0.383 was calculated for the parasitoid complex collected from tomato grown in monoculture, and an index of 0.996 was calculated for parasitoids reared from tomato mixed with corn and roselle. In a concurrent study (Smith 1999), the Shannon–Weaver diversity index for parasitoids collected from tomato grown in monoculture was 0.054 and the index for parasitoids collected from tomato

**Table 5. Whitefly immatures ($\bar{x}$ ± SD per plant) and plant parameters of tomato monocropped and mix-intercropped with field corn and roselle (mosaic study)**

| Date | Egg | | Nymph | | Plant height, cm | | No. branches | | Plant weight, g | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Monocrop | Intercrop | Monocrop | Intercrop | Monocrop | Intercrop | Monocrop | Intercrop | Monocrop | Intercrop |
| 21 Oct. | 0.25 ± 0.77 | 0.56 ± 1.03 | 0 | 0 | 13.13 ± 3.42 | 15.50 ± 5.45 | — | — | — | — |
| 29 Oct. | 147.81 ± 171.18 | 113.06 ± 71.56 | 0.13 ± 0.34 | 3.44 ± 4.46** | 13.81 ± 2.79 | 19.06 ± 2.66** | 4.88 ± 0.72 | 4.88 ± 0.62 | — | — |
| 5 Nov. | 364.13 ± 505.88 | 347.75 ± 244.57 | 13.25 ± 15.58 | 41.63 ± 35.77* | 20.09 ± 4.94 | 26.88 ± 4.46** | 5.25 ± 0.89 | 4.88 ± 1.13 | 5.08 ± 3.49 | 5.00 ± 1.77 |
| 12 Nov. | 1,351.25 ± 998.20 | 1,788.25 ± 807.93 | 303.92 ± 334.91 | 502.0 ± 283.05*** | 29.71 ± 6.73 | 37.46 ± 6.71** | 6.58 ± 0.67 | 6.67 ± 0.65 | 15.00 ± 7.62 | 14.46 ± 6.31 |
| 22 Nov.[a] | 0 | 0 | 160.58 ± 90.62 | 206.75 ± 135.47 | 52.67 ± 10.62 | 50.67 ± 12.36 | 7.25 ± 1.29 | 8.83 ± 1.03** | 93.92 ± 49.78 | 31.00 ± 9.76** |
| 6 Dec.[a] | 0 | 0 | 115.92 ± 91.69 | 136.42 ± 187.32 | — | — | — | — | — | — |

**, *, ***, indicate that intercrop mean is significantly different from corresponding monocrop mean at $P < 0.01$, $P < 0.05$, and $P < 0.1$, respectively.
[a] Counts taken from lower third of plant only.

intercropped with field corn only was 0.119. The same three parasitoid species were recovered in this concurrent study (Smith 1999). We speculate that the presence of extra-floral nectaries on roselle (Standley and Steyermark 1949) favored the increased presence of the *E. meritoria* species complex and *A. fuscipennis*, resulting in increased parasitoid diversity on tomato intercropped with roselle and field corn compared with tomato grown in monoculture or intercropped with corn only.

Unlike bean, which emerged into the shaded intercrop environment, tomato seedlings were produced under the optimal conditions of a commercial nursery. Tomato size was not affected by intercrop shading until 5 wk after transplanting (Table 5). The mean number of tomato plants per row was 1.72 ± 0.85 for intercrop treatments and 15.25 ± 2.32 for monocrop treatments at the end of the study. The low final number of bean and tomato plants among the intercrop treatment was due to whole plant sampling of an initially small population.

As observed in the dry season, roselle was a poor whitefly host. The mean weight and height of the four roselle plants examined on 4 October was 150.75 ± 57.04 g and 70.75 ± 4.35 cm, and average number of leaves was 68.75 ± 36.59 per plant. The average number of eggs and nymphs per plant was 5.50 ± 5.80 and 3.25 ± 1.50, respectively. One fourth-instar *B. tabaci* was found.

## Discussion

Interpretation of results from these studies was made difficult by the high variability that characterized whitefly counts, and by the confounding effect of treatments on host plant size. It is possible that some of this variability might have been reduced had we been able to increase the number of replicates or the number of plants sampled per replicate. Whole plant sampling has the advantage of incorporating the effects of plant growth into the insect sample data while removing ambiguity concerning where to sample on the plant. However, it is extremely time-consuming, and it limits the number of sample units that can be processed per sampling date. In addition, our results may have been influenced by the size of the experimental plots, which were designed on a scale appropriate for evaluating intercropping in traditional small farmer cropping systems.

It is clear that under the conditions we tested, intercropping with poor and nonhosts did not consistently reduce whitefly numbers in an economically feasible manner compared with whitefly numbers on bean and tomato grown in monoculture. There was no difference in whitefly levels per plant on monocropped and intercropped bean for the first crop of the diversity experiment, when plant size was not affected by cropping system. The average number of eggs and nymphs did not tend to be different for the second bean crop, although intercropped bean plants became stunted in the last weeks of sampling. Egg and nymph counts were significantly lower on intercropped bean than monocropped bean during the first 4 wk of the mosaic experiment. However, the intercropped bean plants were initially spindly and after a few weeks were stunted compared with the bean plants grown under monoculture. The results of the mosaic study suggest that even under conditions of intense intercrop competition, where shading prevented bean and tomato from growing properly and producing a marketable yield, whitefly adults were still able to find and successfully colonize these preferred crops.

Evidence that a "fly-paper effect" influenced whitefly numbers was not apparent under the intercrop conditions tested. We examined the effect of intercropping with plant species of varying acceptability when whitefly populations were high (end of the dry seasons), low (early in the rainy season), and intermediate (end of the rainy season). Intercropping did not seem to reduce whitefly colonization at either low or high population densities compared with levels on crops grown in monoculture other than by reducing plant size. Previous efforts in north central Florida to reduce densities of *Bemisia argentifolii* Bellows & Perring on bean by trap cropping with host plants more suitable than bean were similarly unsuccessful (Smith and McSorley 2000, Smith et al. 2000). Our inability to reduce whitefly densities by intercropping with preferred hosts, poor hosts, and nonhosts suggests that these whitefly species may not be susceptible to management through intercropping alone. It is possible that the amount of energy invested by whitefly adults in assessing, rejecting, and moving on from unacceptable hosts is not sufficient to reduce colonization and feeding on acceptable hosts on an economically significant scale. Andow (1991) reported that intercropping tended to reduce densities of polyphagous herbivores far less often than densities of monophagous herbivores. Polyphagous whiteflies such as *T. vaporariorum* and *B. tabaci* may offer an additional example of this phenomenon.

Our results indicate that parasitoid diversity is greater in an intercrop system with crops such as roselle than in monoculture. The potential of increasing biological control of whiteflies using refugia crops as intercrops merits further study (Roltsch and Pickett 1995, 1996). Additional studies are needed to determine if integrated whitefly management programs such as those being developed at CATIE in Costa Rica (Hilje 1993, 1998) could be enhanced by increased biological control through intercropping.

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