

CROP PROTECTION

Does the Presence of Weeds Affect *Bemisia tabaci* (Gennadius) (Hemiptera: Aleyrodidae) Infestation on Tomato Plants in a Semi-arid Agro-ecosystem?

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A Presença de Plantas Invasoras Afeta a Infestação de Tomateiros por *Bemisia tabaci* (Gennadius) (Hemiptera: Aleyrodidae) em um Agro-ecossistema do Semi-árido?

RESUMO - O manejo integrado de *Bemisia tabaci* (Gennadius) exige o conhecimento quantitativo dos mecanismos de persistência de populações em hospedeiros não comerciais. Este trabalho investigou a preferência para oviposição de *B. tabaci* entre tomate e quatro espécies de plantas invasoras, e a flutuação populacional do inseto em condições de campo no semi-árido nordestino. Semanalmente, foram determinados o nível (número de ovos e ninfas por folha) e a densidade de infestação (número de ovos e ninfas por área foliar) nas cinco espécies. Observamos diferentes graus de atratividade, formando um gradiente de preferência para oviposição entre as espécies, sendo *Acanthospermum hispidum* a espécie mais infestada e *Amaranthus deflexus* a menos infestada. Foi detectada ainda uma infestação significativamente mais elevada em parcelas contendo apenas tomateiros, sugerindo um efeito de diluição da infestação do tomateiro quando na presença de invasoras. Plantas invasoras podem representar importantes reservatórios para a mosca branca e/ou seus inimigos naturais, ou ainda fontes de inóculo viral para plantas cultivadas. Sua inserção em programas de manejo integrado de *B. tabaci* em tomateiro depende de como estes fatores podem ser manipulados para a redução dos danos causados pelo inseto.

PALAVRAS-CHAVE: Mosca branca, planta daninha, preferência hospedeira, caatinga

ABSTRACT - Integrated *Bemisia tabaci* (Gennadius) management requires quantitative knowledge on the mechanisms of persistence of pest populations in non-commercial host plants. We investigated *B. tabaci* oviposition preference among tomato and four weed species, and the insect population fluctuation under field conditions in the semi-arid region. At weekly intervals, we determined the level (number of eggs and nymphs per leaf) and the density of infestation (number of eggs and nymphs per leaf area) in all species. We observed an oviposition preference gradient among the species, with different degrees of attractiveness; *Acanthospermum hispidum* was the most infested species whereas *Amaranthus deflexus* was the least infested one. We also detected a significantly higher infestation on tomato when planted solely, which indicates a dilution effect on tomato infestation in the presence of weeds. Weeds can act as important reservoirs for whiteflies and/or their natural enemies or even as viral sources for cultivated plants. Their incorporation in integrated *B. tabaci* management programs depends on how those variables can be manoeuvred for the reduction of insect damage.

KEY WORDS: Whitefly, weeds, host preference, caatinga

The *Bemisia tabaci* (Gennadius) species complex is currently the most devastating pest in tropical and subtropical countries, due largely to its role in the transmission of a variety of plant viruses (Perring 2001). According to Brown (1994), the distribution of the species is related to intensive agricultural production and the expansion of monocultural

practices, associated with indiscriminate use of chemical pesticides. *B. tabaci* is characterised by a remarkable phenotypical plasticity and diversity of strains in the field, which has facilitated the rapid development of insecticide-resistant populations (Perring 2001).

The most outstanding feature of the species is its ability

to adapt to a variety of host plants and to unfavourable environmental conditions. Registered hosts include at least 540 plant species from 77 botanical families (Basu 1995). These figures may be underestimated, since non-commercial plant species are seldom included in host range studies. Recent field surveys in the semi-arid region of Brazil resulted in the identification of at least 10 new species of weeds not previously listed as *B. tabaci* hosts (Vasconcelos et al. 1999). As a consequence of such polyphagy, insects can survive long periods in the absence of the commercial plants, using a wide variety of alternative species.

The establishment of *B. tabaci* in the Brazilian semi-arid region has decimated melon and tomato crops due to whitefly-transmitted viruses. This area now comprises a significant part of tomato, melon, grape and mango production in Latin America. The common denominator to *B. tabaci* control programs in the region is the use of insecticides; ecologically based management systems are a goal for the future. IPM methods, however, require thorough knowledge on bio-ecological factors that underlie the maintenance and fluctuations of insect populations in the field. The role of weeds as alternative hosts of *B. tabaci* and their impact on the infestation of cultivated species deserve careful consideration. Weed complex is diverse and abundant in the Brazilian semi-arid and can survive under extreme water stress conditions.

Field studies designed to quantify ecological aspects of whitefly-weed interaction are scarce despite the fact that weeds can harbour *B. tabaci* populations without any visible symptom of virus infection. On the other hand, field studies have underpinned the role of non-commercial plants in the maintenance of natural enemies (see Altieri 2002, for a review). In this context, we studied the short-term fluctuation of *B. tabaci* populations in a tomato-weed system, addressing the following questions: a) are there differences between a cultivated species (tomato) and native weeds as hosts for *B. tabaci* infestation?; b) does the presence of weeds affect the infestation of tomato plants when single and multiple-species plots are exposed to *B. tabaci* populations? and c) does the spatial distribution of plants in the plots influence the overall infestation of each species?

Material and Methods

Experimental Area, Insects and Plant Species. The experimental area was located in Petrolina (9°09'S; 40°22'W), State of Pernambuco, Northeastern Brazil, in the semi-arid biome known as "caatinga". The caatinga is a type of dry savannah characterised by high temperature (average 35°C), low relative humidity, and a low and irregular rainfall (< 700 mm/yr), concentrated in the months of January to March. Field trials were performed in a 500 m², non-cultivated, insecticide-free area.

After a preliminary survey on local weeds, four plant species, which were abundant in the area and upon which *B. tabaci* had been previously registered, were chosen: *Acanthospermum hispidum* (Asteraceae), known as "carrapicho-de-burro", *Amaranthus deflexus* (Amaranthaceae), one of several species commonly called

"brede", *Datura stramonium* (Solanaceae), known as "zabumba" and *Euphorbia heterophylla* (Euphorbiaceae), known as "leiteira". The commercial plant species used was tomato, *Lycopersicon esculentum* (Solanaceae) c.v. Heinz H2710.

In June 2000, we assembled fifteen 1.5 x 1 m plots, separated by 2 m of bare soil from each other. In each plot, plantlets from a separate, insect-free seedling were planted, and the plots were covered with a nylon mesh attached to a 60 cm high wire support, to prevent insect infestation. Each plot contained eight tomato plants with either: I - weeds located in the outer boundaries of the plot; II - weeds located between the tomato rows, and III - no weeds. Treatments I and II contained two plants from each of the described weed species. The combination of plant numbers and spacing between plants was attempted to mimic those of field conditions.

On alternate days, plots were irrigated, manually weeded and inspected for the removal of natural enemies. When plants were approximately 20 cm high, the nylon covers were removed and the populations of *B. tabaci* were left to establish naturally throughout the plots. In order to investigate differences between weeds and tomato as *B. tabaci* hosts when given a multiple choice use, and the effect of spatial arrangement of plants in the plot, we compared the infestation on treatments I and II. To estimate the impact of the presence of weeds on tomato infestation we compared treatments I and II to treatment III. Treatments were randomly assigned to experimental plots, with five replicates of each.

Sampling Procedures and Parameters Observed. Sampling started 10 days after removal of nylon covers and took place between 6-9 am. A plant of each species was randomly chosen from each replicate (plot). Three leaves, one from the apical, one from the middle and one from the basal part of the plant, were collected and transferred to the laboratory in individual paper bags. We repeated the sampling at 7-day intervals for 10 weeks. Within 24h, the number of immature stages (eggs and nymphs) of *B. tabaci* on the whole leaf was counted under a stereoscopic microscope. Two parameters were determined: the level of infestation (mean number of eggs plus nymphs per leaf) and the density of infestation (mean number of eggs plus nymphs per cm² of leaf). Leaf areas of each plant species were calculated using the method described by Paulilo & Felipe (1992). Total egg and nymph numbers were used to represent the combined effects of oviposition preference and survivorship over each 7-day period of sampling intervals. Statistical analysis was performed using the Program Statgraphics 5.1.

Results

Throughout the experiment, whitefly infestation clearly increased with time in all treatments, indicating successful establishment of insect populations on the plants, except on *A. deflexus*. The average number of eggs and nymphs per *E. heterophylla* leaf was at least 10 times higher in the last fortnight when compared to the first two weeks of the experiment (Tables 1 and 2). The mean numbers of eggs and

nymphs recorded per leaf varied from nearly nil (*A. deflexus* in almost all timepoints) to over 20 (*E. heterophylla*, by the end of the experiment). In the treatments where tomato and weeds were grown together (I and II), no strong preference for any plant species was detected in the first six weeks of experiment. However, from the 7th week onwards, *D. stramonium*, *E. heterophylla* and *L. esculentum* showed higher levels of infestation (Tables 1 and 2). *A. deflexus*, on the other hand, was the least infested species throughout the trial.

The density of infestation was low for most species, and varied from near zero (*A. deflexus* in almost all timepoints) to 2.2 (*A. hispidum*, at the beginning of the experiment) (Tables 3 and 4). In most plots, the density of infestation increased with time, although not as much as the level of infestation. For *A. hispidum* and *A. deflexus* no general pattern of increase in the mean numbers of eggs and nymphs per cm² of leaf was detected over time. *A. hispidum* was the most infested species in almost all timepoints. This was noticed when weeds were located either around or between the tomato rows. Again *A. deflexus* seemed to be the least infested species, although this difference was not significant. The density of infestation on *L. esculentum* was intermediate among the adjacent weeds (Tables 3 and 4).

The position of weeds in the plots did not seem to influence greatly the levels of infestation, as the general patterns of both the level and the density of infestation on weeds were similar in treatments I and II (Table 1 vs 2; Table 3 vs 4).

The analysis of tomato infestation in the absence of weeds

showed that whitefly population clearly increased as time progressed, with mean numbers of immature *B. tabaci* per leaf ranging from 5.0 (first sampling) to 44.0 (last sampling) (Fig. 1). Also, the level of infestation in tomato was lower in the presence of weeds: in the last weeks of the experiment the number of immature *B. tabaci* per tomato leaf in plots without weeds was almost three times higher when compared to plots containing weeds. This difference was significant in the last days of experiment (Fig. 1).

When the density of infestation was analysed, no general pattern of increase was observed on the leaves of tomato plants grown simultaneously with weeds (Fig. 2). When tomato was cultivated solely, a definite pattern of increase was observed, with the density of infestation on the last fortnight being at least twice as high as that observed in the first weeks of the trial. Similarly to the level of infestation, the density of infestation on tomato was significantly higher in plots without weeds for most of the trial. In the last weeks, the numbers of *B. tabaci* per cm² of tomato leaf was at least three times higher in weed-free plots when compared to treatments containing weeds.

Discussion

B. tabaci has a remarkable ability to develop on a wide variety of both commercial and non-commercial plant species in tropical countries. In this study, a gradient of oviposition preference was observed, in which the weed *A. deflexus* was the least infested species under the two parameters measured:

Table 1. Level of infestation [(mean number of eggs + nymphs/leaf) ± SD] by *B. tabaci* on tomato and weeds when grown in the same plot, with weeds located in the outer boundaries of the plot. For the sake of clarity, the weekly data were merged into fortnightly values. Petrolina, PE - Brazil, 2000

Plant species	Days post-exposure to infestation in the field				
	Day 1 - 14	Day 15 - 28	Day 29 - 42	Day 43 - 56	Day 57 - 70
<i>A. hispidum</i>	3.2 ± 3.60 b	7.4 ± 9.70 bc	3.8 ± 5.21 ab	4.1 ± 3.56 ab	4.5 ± 3.10 b
<i>A. deflexus</i>	0.2 ± 0.20 a	1.1 ± 1.20 a	0.6 ± 0.63 a	1.8 ± 2.01 a	0.9 ± 1.17 a
<i>D. stramonium</i>	3.2 ± 2.23 b	6.5 ± 4.94 abc	8.6 ± 9.17 b	10.4 ± 8.58 b	7.9 ± 4.50 bc
<i>E. heterophylla</i>	1.4 ± 1.00 ab	13.1 ± 11.02 c	9.3 ± 7.04 b	8.8 ± 6.20 b	6.0 ± 13.64 c
<i>L. esculentum</i>	4.7 ± 5.47 b	3.7 ± 3.25 ab	7.0 ± 8.46 ab	9.7 ± 8.06 b	11.2 ± 4.81 c

Means significantly different are followed by different letters, within columns. Tukey test, P < 0.05, d.f. = 14

Table 2. Level of infestation [(mean number of eggs + nymphs/leaf) ± SD] by *B. tabaci* on tomato and weeds when grown in the same plot, with weeds located between tomato rows. For the sake of clarity, the weekly data were merged into fortnightly values. Petrolina, PE - Brazil, 2000

Plant species	Days post-exposure to infestation in the field				
	Day 1 - 14 ¹	Day 15 - 28	Day 29 - 42	Day 43 - 56	Day 57 - 70
<i>A. hispidum</i>	1.3 ± 1.26	2.8 ± 2.70 ab	1.2 ± 1.26 ab	1.5 ± 1.11 a	1.4 ± 1.35 a
<i>A. deflexus</i>	0.3 ± 0.35	0.4 ± 0.70 a	0.6 ± 1.01 a	0.6 ± 1.01 a	0.6 ± 0.80 a
<i>D. stramonium</i>	0.4 ± 0.54	3.6 ± 4.67 ab	9.0 ± 14.17 bc	8.7 ± 5.87 b	9.2 ± 6.65 b
<i>E. heterophylla</i>	1.3 ± 1.08	7.4 ± 6.11 b	10.7 ± 10.06 c	10.7 ± 10.12 b	20.2 ± 15.37 b
<i>L. esculentum</i>	1.8 ± 2.77	8.6 ± 10.90 b	6.6 ± 5.92 bc	16.4 ± 9.95 b	18.4 ± 11.01 b

Means significantly different are followed by different letters, within columns. Tukey test, P < 0.05, d.f. = 14; ¹ não significativo

Table 3. Density of infestation [(mean number of eggs + nymphs/cm²) ± SD] by *B. tabaci* on tomato and weeds when grown in the same plot, with weeds located around tomato plants. For the sake of clarity the weekly data were merged into fortnightly values. Petrolina, PE - Brazil, 2000

Plant species	Days post-exposure to infestation in the field				
	Day 1 – 14	Day 15 - 28	Day 29 - 42	Day 43 - 56	Day 57 - 70
<i>A. hispidum</i>	2.2 ± 1.04 b	1.6 ± 0.72 b	1.2 ± 0.42 b	1.2 ± 0.36 b	1.7 ± 0.53 b
<i>A. deflexus</i>	< 0.1 a	< 0.1 a	< 0.1 a	< 0.1 a	< 0.1 a
<i>D. stramonium</i>	0.1 ± 0.08 a	0.3 ± 0.11 a	0.2 ± 0.07 a	0.3 ± 0.11 ab	0.2 ± 0.06 a
<i>E. heterophylla</i>	< 0.1 a	0.4 ± 0.11 ab	0.3 ± 0.07 a	0.2 ± 0.06 a	0.4 ± 0.13 a
<i>L. esculentum</i>	0.3 ± 0.18 a	0.1 ± 0.04 a	0.1 ± 0.07 a	0.2 ± 0.07 a	0.2 ± 0.05 a

Means significantly different are followed by different letters, within columns. Tukey test, $P < 0.05$, d.f. = 14

the level and the density of infestation. Comparatively, two weed species can be considered as more suitable hosts for *B. tabaci*, depending on the parameter analysed. When the level of infestation was assessed, *E. heterophylla* was the most infested species, although this preference was minimal when compared to the second most infested weed species, *D. stramonium*. When the density of infestation was considered, *A. hispidum* clearly harboured the highest population of immature *B. tabaci* populations.

Studies on the oviposition and development of *B. tabaci* on weeds are scarce. Calvitti and Remotti (1998) evaluated *B. tabaci* egg-laying behaviour on 18 weed species in central Italy and observed that *Sonchus oleraceus* (Asteraceae), *Solanum nigrum* (Solanaceae), *Conyza canadensis* (Asteraceae) and *Euphorbia helioscopia* (Euphorbiaceae) were the most infested species.

In the Brazilian semi-arid, weeds such as *Centrosema* sp. (Leguminosae), *Solanum ambrosiacum* (Solanaceae), *Pavonia cancellata* (Malvaceae) and *Herissantia crispa* (Malvaceae) are plentiful in and around tomato plantations, and are often severely infested with *B. tabaci* (Vasconcelos et al. 1999). In the present study, both the level and the density of immature whiteflies recorded were in accordance to those registered for other cultivated and wild plant species. For example, Byrne & Bellows (1991) reported that the average densities of eggs and nymphs on tomato varied from less than 1 to 10 insects per cm² of leaf. Likewise, Yee and Toscano (1996) reported mean densities ranging from 0.8 on alfalfa to 1.4 on broccoli and 6.1 on zucchini.

Quantitative data on *B. tabaci* oviposition preference

among cultivated plant species are relatively abundant. Chu et al. (1995) observed that *B. tabaci* preferred melon when compared to cotton, broccoli or lettuce. A strong preference for tomato compared to aubergine, cucumber, green pepper and squash was reported by Brewster et al. (1997). However, data on differential oviposition between cultivated plants and weeds are virtually non-existent. In this study, tomato suffered an intermediate level of infestation when compared to the weed species in the multiple-species plot. Interestingly, with the exception of the first weeks, tomato plants never harboured the highest levels of infestation in the field. The infestation was highest on *A. hispidum*, whereas tomato and the other weeds did not differ in terms of number of insects per cm².

The comparison between tomato infestation with and without weeds shows that the overall infestation was higher when tomato was the only species in the plot. This may initially suggest some kind of dilution effect, lessening the impact of a phytophagous insect on a cultivated species. In irrigated areas in the Brazilian semi-arid, farmers frequently keep a variety of weeds in coconut and mango plantations (S.D. Vasconcelos unpubl. data). Such plants contribute to the maintenance of the humidity in the root system of crops and absorb excess water, lessening the risk of soil salinisation, a common problem in the area. An interesting example is found among grape farmers in Petrolina, who claim that the maintenance of weeds reduces crop infestation by whiteflies. However, since, according to this study, weeds can also serve as substrate to the whitefly population, their contribution to whitefly population dynamics is far from being elucidated.

Table 4. Density of infestation [(mean number of eggs + nymphs/cm²) ± SD] by *B. tabaci* on tomato and weeds when grown in the same plot, with weeds located between tomato rows. For the sake of clarity the weekly data were merged into fortnightly values. Petrolina, PE - Brazil, 2000

Plant species	Days post-exposure to infestation in the field				
	Day 1 – 14	Day 15 - 28	Day 29 - 42	Day 43 - 56	Day 57 - 70
<i>A. hispidum</i>	0.9 ± 0.59 b	1.5 ± 0.61 b	0.3 ± 0.10	0.3 ± 0.68 b	0.4 ± 0.15 b
<i>A. deflexus</i>	< 0.1 a	< 0.1 a	< 0.1	< 0.1 a	< 0.1 a
<i>D. stramonium</i>	< 0.1 a	0.1 ± 0.05 a	0.3 ± 0.23	0.2 ± 0.03 ab	0.3 ± 0.09 ab
<i>E. heterophylla</i>	< 0.1 a	0.2 ± 0.06 a	0.3 ± 0.09	0.3 ± 0.09 b	0.6 ± 0.14 b
<i>L. esculentum</i>	0.2 ± 0.10 ab	0.3 ± 0.13 ab	0.2 ± 0.06	0.3 ± 0.06 b	0.3 ± 0.06 ab

Mean significantly different are followed by different letters, within columns. Tukey test, $P < 0.05$, d.f. = 14; ¹ não significativo

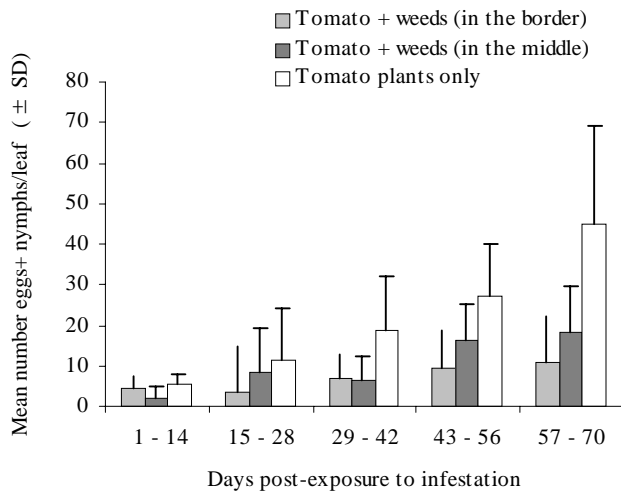


Figure 1. Level (number of eggs and nymphs per leaf) of *B. tabaci* infestation on tomato plants under three conditions: plots without weeds, plots with weeds located in the outer boundaries, and plots with weeds located between tomato rows. Means significantly different are followed by different letters, Tukey test, $P < 0.05$, d.f. = 14. Petrolina, PE-Brazil, 2000

The general pattern of plant infestation did not appear to be affected by the spatial arrangement of weeds in the plots. This was true for both tomato and weed species, which had similar levels and densities of infestation when weeds were located between and around tomato plants. Nevertheless, the influence of plant localisation on its infestation should not be completely ignored. In some sampling timepoints tomato infestation was slightly higher when weeds were located around the plots. The limited influence of the weed location in the plots may have been due to the small size of plots used, for logistical reasons. However, the plant spacing and general agronomic practices used in the trials closely mimicked field conditions. Weeding is performed manually in the semi-arid, and it is not uncommon to find weeds between tomato plants as well as around plots, with short distances between crops and the non-cultivated area.

The mechanisms that determine *B. tabaci* choice of a plant as substrate for progeny development have been only partially elucidated. Those include plant colour, texture, free metabolites in the sap, quantity of trichomes in the leaves, and nutritional state among others (Van Lenteren & Noldus 1990, Bentz *et al.* 1995, Chu *et al.* 1995, Andres & Connors 2003) and even predation risk for the offspring (Nomikou *et al.* 2003). The combination of these factors with abiotic agents for adult dispersal (wind, for example) may determine differential oviposition between plant species in the field (Byrne 1999). Additionally, whiteflies can show some degree of variability in the preference for host plants depending on the time, season, environmental conditions and agronomic practices (see Gerling 1990 for review). The degree of host suitability seems to depend on the insect biotype, as Muniz (2000) reported that biotypes B and Q preferred *D. stramonium* to *Amaranthus retroflexus* (Amaranthaceae).

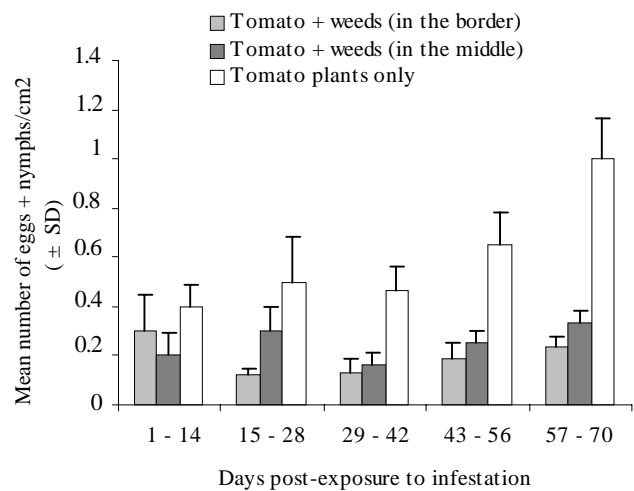


Figure 2. Density (number of eggs and nymphs per cm² of leaf) of *B. tabaci* infestation on tomato plants under three conditions: plots without weeds, plots with weeds located in the outer boundaries, and plots with weeds located between tomato rows. Means significantly different are followed by different letters, Tukey test, $P < 0.05$, d.f. = 14. Petrolina, PE-Brazil, 2000

Experiments with *B. tabaci* females demonstrated that when mixtures of host plants were available, the insect's biological performance was reduced relative to situations where the best of the host plants was presented alone (Bernays 1999). In that study, behavioural observations indicated that in the presence of a variety of plants, individuals moved more, switched between plants more frequently and fed on one plant for shorter periods of time, compared to plots with just one plant species. This phenomenon may have occurred in our experiments, where adults may have switched host plants for oviposition irrespective of the suitability of each. The apparent 'dilution' of attractiveness of tomato as a host plant may, under field conditions, reduce initial insect numbers on plants. However, such reduction might not be sufficient to prevent economic loss, since the main damage caused by *B. tabaci*, that is, the transmission of plant viruses is easily achieved even under low insect populations. Hilje *et al.* (2001) state that the importance of weeds in both *B. tabaci* population dynamics and viral epidemics vary with each cropping system and plant-virus combination, since weeds can consist of additional source of viral inoculum for some crops.

Weed management - a fundamental part in conservation biological control - is arguably one of the least studied components of integrated pest management. As stressed by Bernays and Chapman (1994), neighbouring plants in the community may affect host location and acceptance by a phytophagous insect, such as to make host finding difficult. "Alternative" hosts may have odours that mask that of the main host's, reduce the visual contrast between the host and its background, or simply hide the plants (Bernays & Chapman 1994). Weeds can be used as bait plants for selective insecticide application or as natural repellents when planted

among cultivated species. Most importantly, they can increase local plant diversity, enhancing the complex of natural enemies by providing predators and parasitoids with floral rewards, such as nectar and pollen, refuge for adverse environmental conditions and alternative hosts/prey (Nentwig 1998, Wratten et al. 1998, Landis et al. 2000, Naranjo 2001). The value of weed management in minimizing the impact of agricultural pests by increasing the population of natural enemies has been elucidated in a series of recent field experiments (Thomas et al. 1991, 1992; Gurr et al. 1998; Landis et al. 2000; Naranjo 2001; Showler & Greenberg 2003). Differences in plant infestation will thus be a combination of host preference for oviposition, host suitability for insect development, and the combined effects of natural enemies and other causes of death. In this study, a synergistic combination of such beneficial factors and a simple dilution effect may have contributed to the lower infestation of tomato plants in the presence of weeds.

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