Whitefly population dynamics in okra plantations

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Abstract – The control of whitefly *Bemisia tabaci* (Gennadius) biotype B (Hemiptera: Aleyrodidae) on okra (*Abelmoschus esculentus* L.) consists primarily in the use of insecticides, due to the lack of information on other mortality factors. The objective of this study was to evaluate the spatial and temporal population dynamics of the whitefly *B. tabaci* biotype B on two successive *A. esculentus* var. "Santa Cruz" plantations. Leaf chemical composition, leaf nitrogen and potassium contents, trichome density, canopy height, plant age, predators, parasitoids, total rainfall and median temperature were evaluated and their relationships with whitefly on okra were determined. Monthly number estimates of whitefly adults, nymphs (visual inspection) and eggs (magnifying lens) occurred on bottom, middle and apical parts of 30 plants/plantation (one leaf/plant). Plants senescence and natural enemies, mainly *Encarsia* sp., *Chrysoperla* spp. and Coccinellidae, were some of the factors that most contributed to whitefly reduction. The second okra plantation, 50 m apart from the first, was strongly attacked by whitefly, probably because of the insect migration from the first to the second plantation. No significant effects of the plant canopy on whitefly eggs and adults distribution were found. A higher number of whitefly nymphs was found on the medium part than on the bottom part.

Index terms: *Bemisia tabaci*, *Abelmoschus esculentus*, natural enemies, plant phenology, temperature.

Dinâmica populacional de mosca-branca em quiabo

Resumo – O controle da mosca-branca *Bemisia tabaci* (Gennadius) biótipo B (Hemiptera: Aleyrodidae) em quiabeiro (*Abelmoschus esculentus* L.*)* consiste principalmente no uso de inseticidas, em virtude da falta de informação sobre outros fatores de mortalidade. O objetivo deste trabalho foi compreender a dinâmica populacional, espacial e temporal da mosca-branca em dois cultivos sucessivos de quiabeiro "Santa Cruz". Avaliaram-se a composição química foliar, os níveis foliares de nitrogênio e de potássio, a densidade de tricomas, a altura de dossel, a idade de planta, predadores, parasitóides, pluviosidade total, temperatura média e suas relações com a mosca-branca em quiabeiro. Estimou-se, mensalmente, o número de adultos e de ninfas (inspeção visual) e de ovos (lentes de aumento) de mosca-branca ocorridos nas folhas (uma folha/planta) localizadas nas partes basal, mediana e apical de 30 plantas/plantação. Os fatores que mais contribuíram com a redução da população mosca-branca foram a senescência de plantas e inimigos naturais, principalmente *Encarsia* sp., *Chrysoperla* spp. e Coccinellidae. O segundo cultivo de quiabo, a 50 m do primeiro, foi altamente atacado pela mosca-branca, provavelmente pela migração dos insetos do primeiro para o segundo cultivo. Não foi detectado efeito significativo do dossel de plantas sobre ovos e adultos. Foi encontrado maior número de ninfas na parte mediana do que na parte basal das plantas.

Termos para indexação: *Bemisia tabaci*, *Abelmoschus esculentus*, inimigos naturais, fenologia da planta, temperatura.

Introduction

Okra, *Abelmoschus esculentus* L. (Malvaceae), is a tall-growing, warm-season, annual crop cultivated in Brazil, southern USA and the West India for its long, many-seeded pods, used as a vegetable. The whitefly, *Bemisia tabaci* (Gennadius) biotype B (or *B. argentifolii*) (Hemiptera: Aleyrodidae), causes severe damage to okra plants by feeding on sap, secreting honeydew and transmitting virus diseases (Fishpool & Burban, 1994; Umaharan et al., 1998; Jose & Usha, 2003). This control consists, primarily, in blanket use of insecticides, due to the lack of information about other mortality factors (Dent, 1995).

Temperature and rainfall influence the whitefly population dynamics (Horowitz et al., 1984; Horowitz, 1986). Excess of nitrogen (N) and deficiency in potassium (K) can lead to higher attack rate, whereas younger plants are more attacked than older or slow growing plants, as related in *Lycopersicon esculentum* Mill. by Marschner (1995) and Leite et al. (1998).

Leaf position in the plant canopy and trichomes influences whitefly oviposition rates as well as parasitism, such as observed in *L. esculentum* (Stansly et al., 1997; Leite et al., 1998) and, therefore, natural enemies could contribute to pest control in several crops (*A. esculentus*, *Brassica oleracea* var. *acephalata* L., *Cucumis sativus* L., *C. melo indorus* Naud., *Cucurbita pepo* L., *Citrullus lanatus* (Thunb.) Matsum & Nakai, *Gossypium hirsutum* L., *Ipomoea batatas* (L.) Lam., *L. esculentum*, *Phaseolus vulgaris* L., *Solanum melongena* L., and *Vigna unguiculata* (L.) Walp (Stansly et al., 1997). However, these factors have been poorly studied on okra.

The aim of the present investigation was to evaluate the effect of predators, parasitoids, rainfall, temperature, leaf chemical composition, levels of N and K, leaf trichome density, height canopy height, plant age and their relationships on whitefly population dynamics.

Material and Methods

The experiment was carried out in two okra plantations of *A. esculentus* var. "Santa Cruz" from Guidoval, Minas Gerais, Brazil. Fertilization and cultural practices were used (Filgueira, 2000). The two okra plantations were spaced 50 m, and had gramineae of small height between them; each plantation comprised 3.6 ha with 10,000 plants, 0.30 m apart on the row and 1.2 m between rows. The 10 peripheral rows and 40 plants on each end of the row were not considered, leaving a useful area of 2.7 ha, i.e. 30 rows, 176 m long. The first 16-day-old plantation was evaluated from March 1st to June 30th 1999, while the second, a 50-day-old plantation, was evaluated from July 1st to November 30th 1999. After the final evaluation, the first plantation was eliminated. These plantations were far from other vegetable crops (i.e., *B. oleracea* var. *capitata* L., *C. sativus*, *C. pepo*, *L. esculentum*, *P. vulgaris*, *S. melongena*) at least 1,000 m.

Monthly number estimates of *B. tabaci* biotype B adults and nymphs (abaxial face), and predators (adults + larvae), both faces, occurred by visual inspection (Horowitz, 1986, 1993) on the bottom, middle and apical parts of 30 plants/plantation (one leaf/plant). *B. tabaci* biotype B eggs, and their spatial distribution on okra plants were evaluated monthly, with magnifying lens (Farias, 1994). One expanded leaf on each part of the canopy of 30 plants/plantation, one leaf/plant, was collected, sealed in transparent white plastic bags and transported to the laboratory for counting. As far as each sample is concerned the abaxial face, six fields (area of one field: 0.60 mm^2) in the median part, equidistant between the median vein and the margin, were analyzed. The beating tray method (Miranda et al., 1998) was used monthly to estimate the number of parasitoids present in one leaf from each of 10 plants/plantation. The first expanded leaf/apex of the plant was beaten on a 34x26x5 cm white tray to collect the insects with an aspirator or tweezer and placed individually in 8x2 cm glass flasks, containing 70% ethanol for identification.

One apical leaflet from each part of the canopy of nine plants/plantation was collected, monthly, on three occasions, and placed in white transparent plastic bags, sealed and stored in 70% ethanol, for analysis. Leaflets were cleared for 2 hours in 10% NaOH and 18 hours in sodium hypochlorite (20%). After washing and during the dehydration, leaflets were stained for 3 min in fast green and mounted between slides using Canadian balsam. The number of adaxial and abaxial trichome was counted under a light microscope on the apical leaflet's median part. In each sample, six fields of 0.60 mm^2, each between the median vein and the margin were analyzed.

One expanded leaf from the apex of each of 15 plants/plantation was monthly collected and taken to the laboratory for N and K determination. The leaves were placed in Kraft paper bags, dried in a forced air circulation oven at 67°C for three days and nitrogen ground in a Wiley mill (20 mesh). Potassium was determined with a flame photometer and analyzed by the Nessler method. Three evaluations, consisting of five leaves in each evaluation, were made for each collection of two plantations.

For gas chromatography/mass spectrometry (GC/MS) analysis, fully expanded apical leaves of 15 plants/plantation were sampled monthly, placed in plastic bags, sealed for and transported to the laboratory. A 10-g latch was cut with scissors, immersed in 100 mL of bidistilled hexane for 24 hours, dehydrated with anhydrous Na$_2$SO$_4$, evaporated to dryness at 30°C in a rotatory evaporator,

sealed in nitrogen and stored in a freezer until being analized.

The hexane extracts were analyzed by an autosampler, Model QP 5000, a computer-based system to accumulate data and a mass spectra database (John Wiley) with 160,000 compounds. The oven was programmed to develop a temperature gradient, from 33ºC to 80ºC, at 20°C/min, and when a higher temperature was achieved, a new gradient from 80ºC to 250ºC was carried through at 5ºC/min. The injector and transfer line temperatures were of 180ºC and 250°C, respectively. The split ratio was five, with He as the carrier gas. All analyses were carried out on a fused capillary column of 30 m/0.25 mm and film thickness of 0.25 µm. The ionization voltage was 70 eV and the mass spectrometer scanned between 40–550 amu (atomic mass unit). Retention times for peaks with total ion current (TIC) higher than $4x10^5$ ions/sec were recorded with a minimum area for peak integration of 400,000 ions/sec. The compounds were identified using the mass spectral database and only compounds with a similarity index (SI) greater than 83% were considered as positive identifications. Further identification through standards was not attempted.

Guidoval's climatic data, total rainfall and median temperature (minimum + maximum/2), were read daily from a pluviometer and thermometer, installed in the field at the beginning of the experiment. Canopy height effects on pedators, parasitoids, trichome densities, and *B. tabaci* population density were virified by variance analysis and the Turkey's multiple range test (P≤0.05). Regression analyses (P≤0.05) were used to evaluate the relationships of predators, parasitoids, total rainfall, median temperature, leaf chemical composition, leaf N and K levels, plant age and leaf trichome density with the whitefly number on okra plants.

Results and Discussion

In the first okra plantation, the whitefly adult population decreased from March to May and increased from May to June, while the number of nymphs peaked in April, and that of eggs, in May (Figure 1). In the second plantation, adult populations peaked in September and nymphs presented two peaks, the first in August and the second in October, the latter with large number of eggs. Median temperature and total rainfall did not correlate with whitefly density.

Peak populations of *Encarsia* sp. (Hymenoptera: Aphelinidae) were observed in April and September,

Chrysoperla spp. (Neuroptera: Chrysopidae) in June, August and October and ladybirds [*Cycloneda sanguinea* (L.), *Psyllobora lenta* (Mulsant) and *Sciminus* sp. (Coleoptera: Coccinellidae)] in April and October (Figure 1). Correlations were found between *Chrysoperla* spp., ladybirds, and *Encarsia* sp. with whitefly nymphs (y = -0.004 + 411.11 - 1482.32x², R² = 0.55; y = 0.20 + 0.02x, R² = 0.45; and y = 2.88 + 59.90x - 35.53x², R² = 0.36, respectively). No correlation was found between *Orius* sp. (Heteroptera: Anthocoridae) (0.01±0.01/leaf), Syrphidae (Diptera) (0.01±0.01/leaf) and the spiders (0.14±0.04/leaf) *Cheiracanthium inclusum* (Hentz) (Miturgidae), *Dictyna* sp. (Dictynidae), *Eustala* sp. (Araneidae), *Lyssomanes* sp. (Salticidae), *Misumenops* spp. (Thomisidae) and Theridiidae with whitefly populations.

A higher whitefly attack (Figure 1) was observed in the second okra plantation, planted 50 m apart from the first, probably due to the fact that part of the whitefly population migrated from the first plantation, or that the plants were older and, consequently, a greater amount of time was available to increase insect population, or there was a higher proportion between natural enemies/whitefly nymphs in the first okra plantation. At the beginning of the first and second plantations, natural enemies were not detected, except for ladybirds in the first, indicating that these natural enemies were latent in nearby areas until okra plants infested with nymphs appeared. Hirano et al. (1995) reported that one of the major factors responsible for whitefly population dynamics seems to be temporal variations in the quantity of host plants in the area.

Although no significant effects of plant age, total rainfall and median temperature on whitefly population were observed, in October, when plants were 140 days old, there was a drastic decrease in the insect population, probably due to plant senescence or associated with rainy season (Figure 1). According to Legaspi et al. (1996a) and Stansly et al. (1997), whitefly population dynamics was apparently determined by environmental factors and crop phenology, and natural enemy population tended to increase at the end of the cultivar cycle. This leads to a reduction in plant quality, accompanied by decreases in insect pests with its natural enemy population. Horowitz (1986) observed in Sudan that heavy rains were usually followed by a drop in whitefly population levels.

Natural enemies, mainly the parasite *Encarsia* sp. and the predators *Chrysoperla* spp. and Coccinellidae are
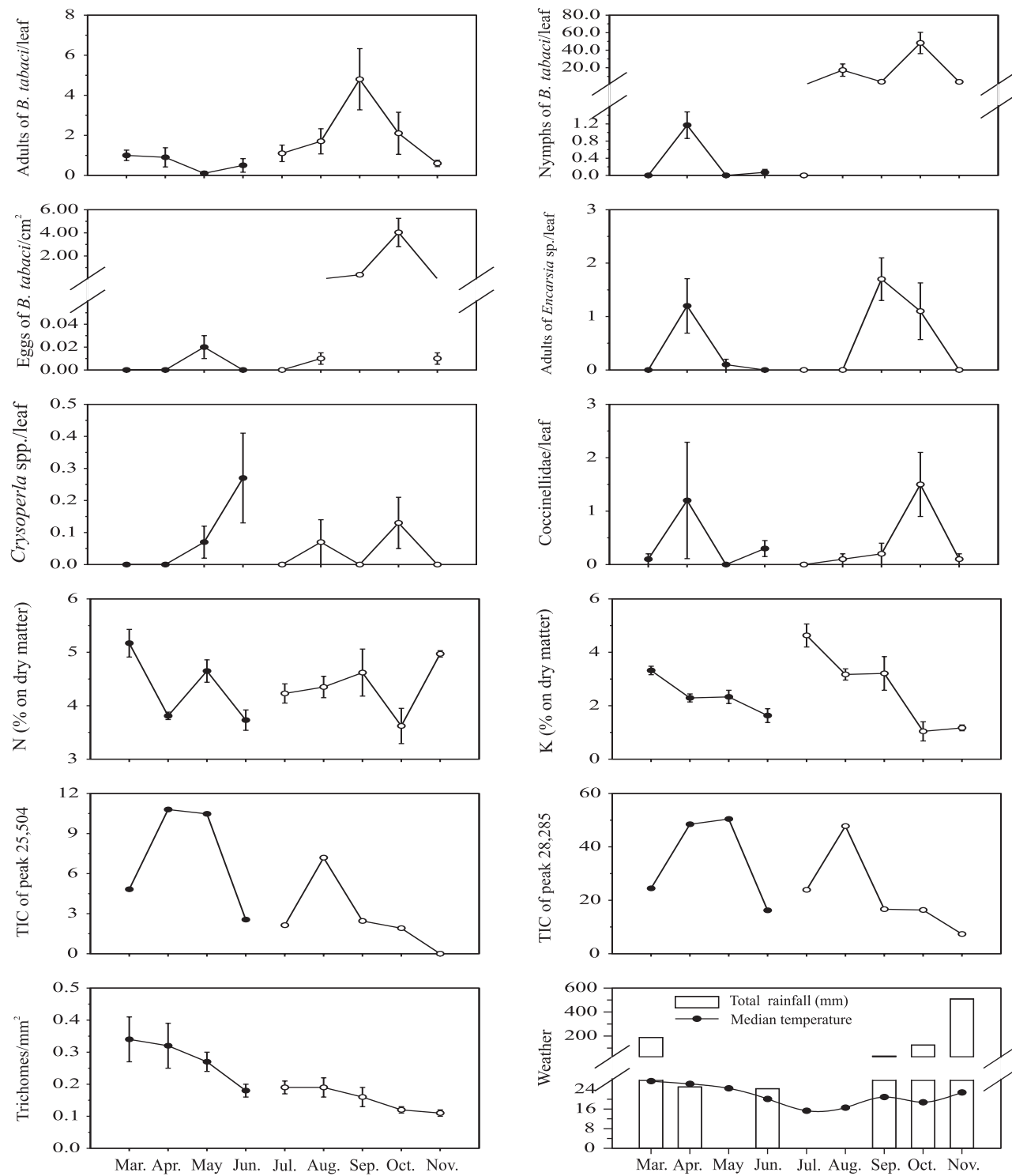
Figure 1. Fluctuations in populations of *Bemisia tabaci*, *Encarsia* sp., *Chrysoperla* spp. (adults + larvae) and Coccinellidae (adults + larvae), nitrogen and potassium content, total ion current (TIC) of peaks with retention times of 25,504 and 28,285 min and trichomes (adaxial + abaxial/2) of two okra plantations, 1 (●) and 2 (○), total rainfall (mm) and median temperature (ºC) in *Abelmoschus esculentus* crop. The symbols represent the average of 30 leaves for *B. tabaci* and Coccinellidae, ten leaves for *Encarsia* sp., three evaluations for the NK content and trichomes and one evaluation for the peaks, the rainfall accumulated and the average of the temperature of 30 days. Vertical bars indicate standard errors of the mean.

probably responsible for a decrease in whitefly population. Possibly some of the whitefly nymphs found in August were parasited by *Encarsia* sp., since there was a reduction in the number of whitefly nymphs and an increase in the number of *Encarsia* sp. in September. These natural enemies have been used to control whitefly population in several plants (Legaspi et al., 1996a, 1996b; Liu & Stansly, 1996a, 1996b) and, in some cases, a positive effect was obtained (Hoelmer et al., 1994; Heinz & Nelson, 1996). Hooks et al. (1998) reported high populations of coccinellids and syrphids in zucchini plants infested with high populations of aphids and whiteflies. On the other hand, Hagler & Naranjo (1994) observed that *Hippodamia convergens* Guérin-Menéville (Coleoptera: Coccinellidae) appeared to be capable of locating whitefly present in low density even at the beginning of the season.

Leaf N and K levels and leaf chemical composition were not correlated with whitefly population. A correlation between trichome density ($y = 0.35 - 0.002x$, $R^2 = 0.87$, $P<0.05$) and leaf K levels ($y = 4.07 - 0.02x$, $R^2 = 0.53$, $P<0.05$) was observed as plant age increased (Figure 1). Two peaks were observed in okra plants in both plantations. The first peak, with retention times of 25,504 min, was identified as palmitic acid with SI of 88%, and the second, with 28,285 min, was identified as 11,14,17 eicosatrienoic methyl ester acid with SI of 83%. Higher total ion current (TIC) for the peak 25,504 min were recorded for 46 and 76-day-old plants in the first and second plantations, respectively, and for the peak 28,285 min were recorded for 80-day-old plants in both plantations (Figure 1).

The 11,14,17 eicosatrienoic methyl ester acid, identified in the hexane extracts using the mass spectral data base, has not been reported for okra. However, palmitic acid was related in the seed oil content (28%) of okra (Camciuc et al., 1998) as well as from the internal lipids of *B. argentifolii* adults (Buckner & Hagen, 2003). Although these compounds were identified with a high SI, their identity should be confirmed by other methods. For this, it is necessary to isolate these compounds in large quantities and identify them through more precise spetroscopic methods.

A higher whitefly nymph density/leaf was recorded on the medium part (10.5 A) of the plant canopy, compared to the bottom (5.9 B) and apical (8.4 AB) regions. However, plant canopy and natural enemies did not affect the whitefly adults and eggs number. Higher density of non-glandular trichomes/mm^2 (100% of trichomes) was observed in the apical (0.21 A) part than in the medium (0.09 B) and bottom (0.10 AB) parts of *A. esculentus*, and in the abaxial (0.30±0.04) than in the adaxial leaf surface (0.08±0.01).

Although nutritional, chemical and morphological changes in plants have been reported to affect whitefly population in tomato, beans, and zucchini (Noortje & Lindhout, 1992; Hooks et al., 1998; Leite et al., 1998), leaf N and K, chemical compounds analyzed and trichomes were apparently not important in this study. The trichomes (% non-glandular) found in okra were of low density and did not contain toxic compounds, which could affect oviposition and present antibiotic effects. This was expected because this okra cultivar has been selected for a long time to maximise productivity of fruits, which reduces the frequency of glandular trichomes and its resistance from attack by herbivore arthropods. The NK fertilization can affect the degree of attack from insects. An excess of N and deficiency in K have been reported to lead to higher accumulation of amino acids in plants and a higher degree of insect attack, such as whitefly (Marschner, 1995; Leite et al., 1998). The effect of leaf N and K levels in okra with whitefly was not detected due to the small variation of these nutrients in the leaves during the experimental period.

The whitefly oviposited preferentially in young leaves which are generally located on the apical parts, with the last stage nymphs customarily found in the bottom leaves (Leite et al., 1998). However, whitefly eggs and adult numbers were not found to be significantly correlated with position in the okra canopy, but higher number of nymphs was observed in the medium rather than in the bottom part. A plausible explanation for the non-occurrence of oviposition preferentially on the apical leaves is that these leaves have more trichomes, which can make locomotion, feeding and oviposition of insects difficult (Dent, 1995), despite the absence of significant relationship between them.

Hence, to reduce whitefly population it is necessary: to plant okra in a discontinuous (space and time) fashion without offering other host plants for this pest; to colonize, quickly, okra plantations with natural enemies (e.g. refuge crops and weedy margins), in order to achieve success on biological control; and to utilize insecticides, always selective, only when whitefly reached nominal thresholds.

Conclusion

1. Whitefly population dynamics in okra is affected by crop senescence, natural enemies and adult migration from nearby okra plants.

2. Total rainfall can reduce the whitefly population.

3. Trichomes non-glandular or low density is not important for reducing whitefly population.

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