Within-plant distribution of thrips and their predators: effects of cotton variety and developmental stage

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Abstract

Plant characteristics often influence the distribution of herbivores and natural enemies. In turn, the degree of their spatial association is likely to influence the ability of natural enemies to control pests. Also, an understanding of pest distribution patterns is important for the development of reliable and cost-effective sampling protocols. In this study, we assessed the effect of cotton variety and developmental stage on the within-plant distribution and degree of spatial overlap between populations of two thrips species and their predators. In the two studied varieties, cv. Pima and Acala, almost all *Thrips tabaci* Lindeman inhabited the leaves, while *Frankliniella occidentalis* (Pergande) colonized only the flowers. With respect to the predators, most *Chrysoperla carnea* (Stephens) were found on the leaves of both varieties, whereas predatory *Orius* spp. colonized mainly the flowering structures on Pima plants but the leaves on Acala. This variability in prey and predator distribution resulted in a significant and positive correlation between thrips and predator populations on Pima but not on Acala plants. The results also suggest that, overall, thrips are most likely to be preyed upon on squares and to be relatively safe in flowers. An intermediate but relatively high risk of predation apparently occurs on the leaves. The significance of these within-plant distribution patterns for the monitoring of thrips populations is discussed.

Introduction

The onion thrips, *Thrips tabaci* Lindeman, and the western flower thrips, *Frankliniella occidentalis* (Pergande) (Thysanoptera: Thripidae), are common in many field, vegetable, ornamental, and fruit crops in Israel. *Thrips tabaci* is an extremely polyphagous species that attacks several hundred plant species (Avidov & Harpaz, 1969). In cotton, this species attacks the cotyledons and leaves. Both adult and larval feeding retard leaf development and cause distortion of young shoots and silvery spots on young cotton leaves. Under heavy attacks, the leaf margins curl, infested leaves may drop, and stems of seedlings may split (Freidberg *et al.*, 1989). *Frankliniella occidentalis* is a major pest of vegetables and cut-flowers in greenhouses throughout the United States, Canada, and Europe (Robb *et al.*, 1988). This pestiferous species attacks over 200 species of vegetable and ornamental crops in about 60 plant genera (Brodsgaard, 1989) and may vector plant viruses. In cotton, young leaves that are attacked by *F. occidentalis*, appear raggedy and cup-shaped, with a silver shine to the lower surface (Presley, 1972).

Neither thrips species is considered a major economic pest in cotton in Israel (Klein *et al.*, 1986). However, sporadic heavy infestations of *T. tabaci* may occur, particularly in non-irrigated cotton and when cotton is grown near onion fields (Zax & Shoham, 1995). In some countries (e.g. Spain, India, Turkey) *T. tabaci* is considered a major pest of cotton seedlings, particularly in spring (Aston & Winfield, 1972; Green & Lyon, 1989; Mart *et al.*, 1994) and in the US, *F. occidentalis* may severely damage cotton when the weather is cool (Presley, 1972; Micinski *et al.*, 1990). In spite of their pestiferous status in some cotton systems, little is known about thrips biology in this crop and the relationship between their density and cotton yield. Therefore, thrips control often consists of automatic preventive chemical treatments early in the season (Bottrell & Adkisson, 1977).

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Table 1. Characteristics of short (< 0.5 m), medium (0.5–0.8 m), and tall (> 0.8 m) cotton plants (varieties 'Pima' and 'Acala-SJ2') sampled between 19 June and 12 July, 1995.[1]

Plant-height category	Variety	Mean plant height, m (1 SE)	Mean no. of main stem leaves/plant (1 SE)	Mean no. of squares/plant (1 SE)	Mean no. of flowers/plant (1 SE)	Mean no. of bolls/plant (1 SE)
Short	Pima	39.76 (0.80) a	8.46 (0.35) a	8.15 (0.42) a	0.00 (0.00) a	0.00 (0.00) a
	Acala	47.40 (0.60) b	7.50 (0.38) a	4.55 (0.39) b	0.00 (0.00) a	0.00 (0.00) a
Medium	Pima	64.32 (0.61) a	10.88 (0.27) a	13.16 (0.47) a	0.52 (0.18) a	0.44 (0.21) a
	Acala	65.16 (0.59) a	9.15 (0.34) b	7.52 (0.39) b	0.04 (0.09) b	0.00 (0.00) b
Tall	Pima	90.55 (0.72) a	15.28 (0.48) a	24.64 (0.74) a	1.71 (0.27) a	2.50 (0.37) a
	Acala	102.75 (0.53) b	12.09 (0.19) b	17.39 (0.37) b	0.69 (0.13) b	0.79 (0.15) b

[1]Means within a column and plant-height category followed by the same letter are not significantly different ($P < 0.05$, protected LSD).

Generally, chemical control of thrips is difficult because of their wide geographic distribution, high reproductive and dispersal rates, and wide host range (German *et al.*, 1992). The widespread occurrence of insecticide resistance and the inability of insecticides to reach the eggs in plant tissues and the fourth instars and pupae in the soil, further hamper chemical control efforts (Immaraju *et al.*, 1992). Insecticide applications also negatively affect populations of natural enemies, and thus may induce secondary pest outbreaks and resurgence of target pests (Ehler *et al.*, 1973; Dintenfass *et al.*, 1987; Hardin *et al.*, 1995). Therefore, an integrated pest management (IPM) approach should be adopted if thrips damage is to be minimized.

Host plant resistance and biological control are central components of any viable IPM programme. The degree of spatial association between pests and their natural enemies on plants is likely to influence the ability of these natural enemies to suppress pest populations. Thus, it is important to understand how host-plant architecture and surface structure influence the within-plant distribution of herbivorous pests and their natural enemies. Additionally, quantifying the within-plant distribution of pests and natural enemies is important for the development of reliable and cost-effective sampling protocols – the basis for all decision-making in IPM programmes.

The present study was undertaken to describe the distribution patterns of thrips and their predators on cotton plants and to assess the degree of spatial overlap between them. We were particularly interested in the effect of cotton variety and developmental stage on the within-plant distributions of these populations.

Experimental methods

To determine the within-plant distribution of thrips and their predators, three field sites, namely Einat, Revadim, and Negba, were visited seven times between 19 June and 12 July, 1995. All sites are in the central and southern areas of the coastal plain of Israel; Einat and Negba are about 58 km apart and Revadim is about half-way between them. At each site, fields of the two commonly grown cotton varieties in Israel, cv. 'Acala SJ-2' and cv. 'Pima,' were identified and on each visit, 10–20 cotton plants were randomly selected from each field (excluding a 5 m cotton buffer around each field). To reduce the diurnal variations in insect distribution, all samplings were conducted between 6:00 and 10:00 hours. The height, number of leaves on the main stem, and the number of fruiting structures were recorded for each plant. The plants were then assigned to one of three developmental stages: small (< 0.5 m in height); medium (0.5–0.8 m) and tall plants (> 0.8 m). Each plant was first inspected for thrips predators – eggs and larvae of the green lacewing, *Chrysoperla carnea* (Stephens) (Neuroptera; Chrysopidae); nymphs and adults of the predatory bugs *Orius* spp. (Heteroptera: Anthocoridae) and *Dereaeocoris pallens* Reuter (Heteroptera: Miridae); and adult predatory thrips of the genus *Aeolothrips* (Thysanoptera: Aeolothripidae). One leaf from the upper, middle, and lower third of the main stem of each plant was then examined in the field for adults and second-instar larvae of *T. tabaci* and *F. occidentalis*. To determine the distribution of thrips and predators on other plant structures, squares, flowers, and bolls were also inspected on each plant.

Table 2. Percent of cotton plants and flowers (varities 'Pima' and 'Acala-SJ2') infested with *Thrips tabaci* and *Frankliniella occidentalis*, respectively, and thrips densities (1 SE) in short (< 0.5 m), medium (0.5–0.8 m), and tall (> 0.8 m) plants sampled between 19 June and 12 July, 1995.

Plant-height category	Variety	*Thrips tabaci*			*Frankliniella occidentalis*		
		n^1	Infested plants (%)	Thrips per leaf	n^2	Infested flowers (%)	Thrips per flower
Short	Pima	13	85.0	0.83 (0.21)	0	–	–
	Acala	10	91.7	2.20 (0.85)	0	–	–
Medium	Pima	26	70.0	0.56 (0.18)	14	50.0	1.00 (0.40)
	Acala	25	96.4	1.37 (0.60)	1	100.0	1.00 (0.00)
Tall	Pima	34	71.4	0.87 (0.19)	24	95.8	0.87 (0.19)
	Acala	53	89.1	0.99 (0.49)	37	56.8	1.05 (0.49)

[1]Number of sampled plants.
[2]Number of sampled plants with flowers.

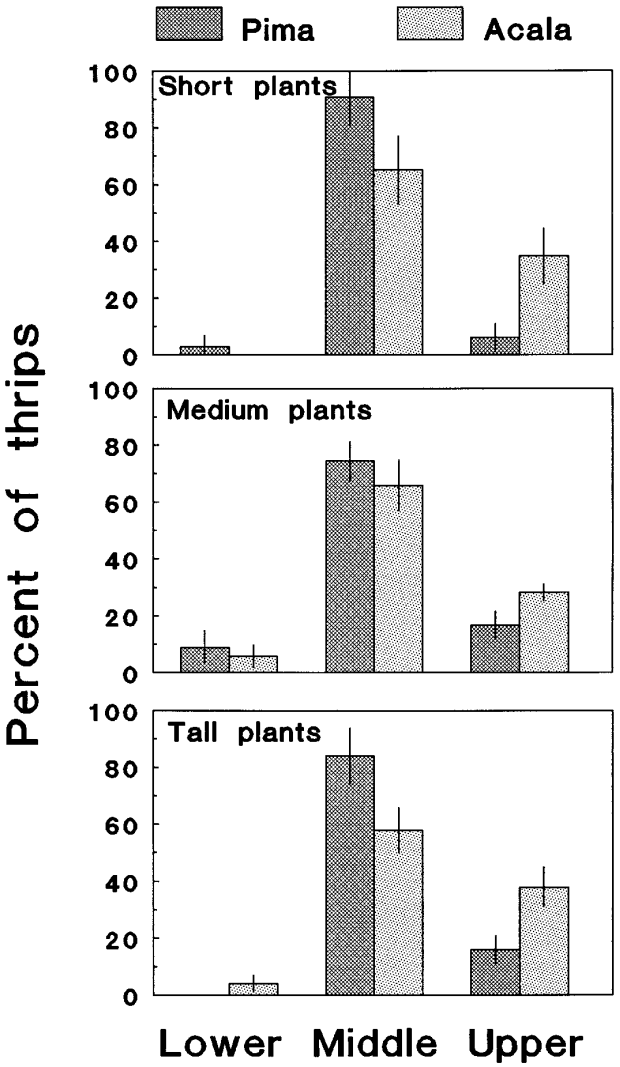


Fig. 1. Percent of phytophagous thrips in lower, middle and upper parts of short (<0.5 m), medium (0.5–0.8 m), and tall (>0.8 m) plants of two cotton varieties.

In the field, thrips species was determined using colour and size characteristics – individuals of *T. tabaci* being darker (light brown) and smaller than those of *F. occidentalis* (light yellow in colour). Verification of field-identified specimens under the microscope in the laboratory showed a minimal (<10%) degree of misidentification under field conditions. Further, there was considerable agreement between our results for the within-plant thrips distribution and previously published studies (Gonzales & Wilson, 1982; Yudin *et al.*, 1986; Pickett *et al.*, 1988; Freidberg *et al.*, 1989). It was considered that any identification errors that might have occurred were likely to be similar across cotton varieties and ages, and thus probably did not influence the main conclusions of the study.

Data were analysed using ANOVA's (SAS Institute, 1988). A correlation analysis (SAS Institute, 1988) was used to determine the degree of spatial overlap between thrips and their predators on each cotton variety. For the correlation, we used the frequency data for thrips and predators on leaves at each plant stratum and at each developmental stage (a total of nine data points per cotton variety).

Results and discussion

The two cotton varieties differed greatly in the number of leaves, squares, flowers, and bolls they bore during the study (table 1). The data indicate that, during our observations, Pima plants produced more leaves and fruiting structures, even when both plant varieties were of a similar height (vis. Medium; table 1). Such differences in plant structure are likely to affect the distribution of phytophagous thrips and their predators, either directly or indirectly. Direct effects may include, for example, the availability of more plant parts (e.g., flowers) suitable for the thrips and the predators in one variety than in the other (see discussion below). The higher density of leaves in Pima could have altered the microclimate within the plant canopy, and thus indirectly affected the strata the insects occupied on the plants.

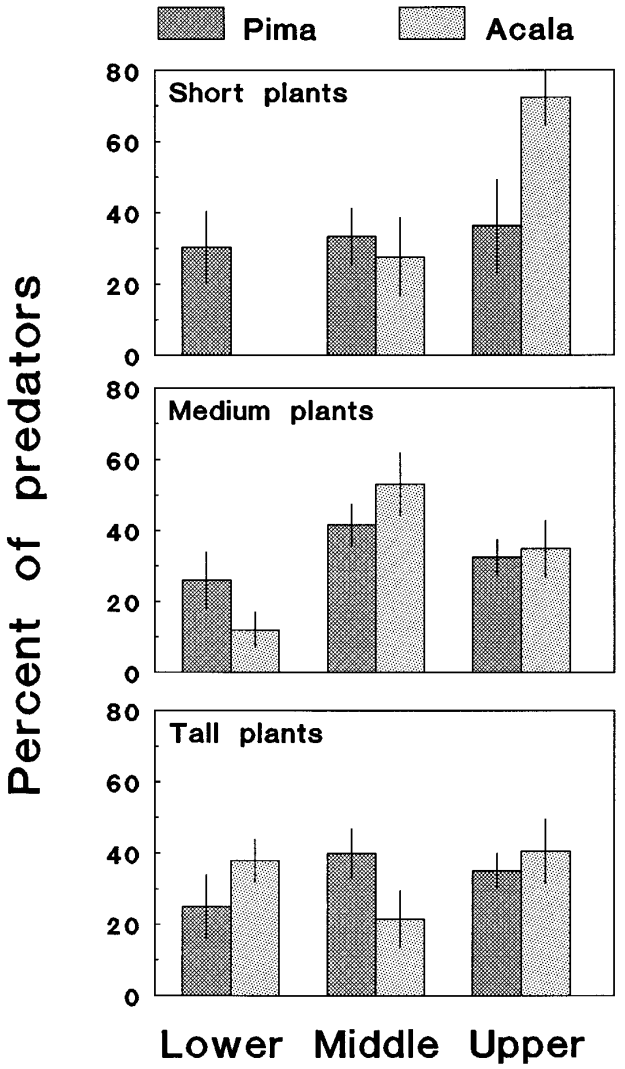


Fig. 2. Percent of all predator species in lower, middle and upper parts of short (<0.5 m), medium (0.5–0.8 m), and tall (>0.8 m) plants of two cotton varieties.

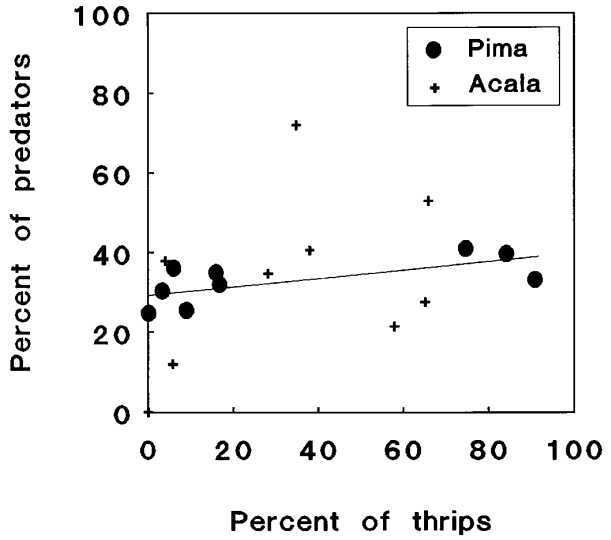


Fig. 3. Spatial relationship between thrips and their predators on two cotton varieties. Linear regression line is presented for populations on Pima plants (y=0.1x+30.1; R^2=0.43; $P < 0.05$). The regression for populations on Acala plants was not significant ($P > 0.28$).

Most thrips sampled in our study were at the adult stage (69.2%). *Thrips tabaci* infested almost all of the sampled cotton plants and it appears that infestation rate was higher on Acala than Pima plants (table 2). In contrast, *F. occidentalis* inhabited most flowers on Pima plants and only about half of the flowers on Acala (table 2). In southern North America, thrips control is recommended when their density reaches one to five thrips per young plant (Scott *et al.*, 1985; Leser *et al.*, 1986). In Turkey, thrips control is recommended when *T. tabaci* infests more than 15% of cotton plants or when *F. intonsa* (Trybom) (Thripidae), a congeneric of *F. occidentalis*, infests 15% of the flowers (Mart *et al.*, 1994). In our study, thrips infestation often exceeded these thresholds, as indicated by the mean density of thrips on young (short) plants and in flowers (table 2).

Over all plant developmental stages, most thrips were found on leaves in the middle part of both Pima and Acala plants (fig. 1). This distribution pattern was primarily due to the preference of *T. tabaci* for these leaves (see below). Only a few thrips occupied the lower leaves of the two varieties and a slightly higher proportion of thrips was found in the upper third of Acala than of Pima plants (fig. 1).

The overall distribution of predators (all species) on the leaves was similar on medium and tall Pima and Acala plants (fig. 2). On short plants, however, the predators avoided the lower part of Acala plants, whereas about 30% of the predators on Pima plants were found in this stratum (fig. 2). Likewise, about 70% of the predators colonized the upper part of short Acala plants, but only about 30% of them colonized the upper part of Pima plants (fig. 2). Overall, predator distribution was similar in the three strata on short Pima plants, but not so on the short Acala. Besides thrips, no other prey species were present on the plants during the sampling period. A comparison of predator distribution with that of their thrips prey showed that, over all three plant strata and developmental stages, predator and thrips distributions were significantly and positively correlated on Pima but not on Acala plants (Pima: $P < 0.5$, R^2=0.43, slope=0.10; Acala: $P > 0.28$, R^2=0.16; fig. 3).

A dramatic difference was recorded with regard to the plant structures colonized by the two thrips species. Whereas almost all *T. tabaci* were found on the leaves, *F. occidentalis* colonized only the flowers (fig. 4). Only a few thrips inhabited the squares. These distribution patterns were similar on Pima and Acala plants. Other researchers have also documented the attractiveness of cotton flowers to *F. occidentalis*. Populations of this species peaked at blooming time (Pickett *et al.*, 1988) and adults were strongly attracted to cotton flowers (Yudin *et al.*, 1986). Similarly, Gonzales & Wilson (1982) found that during peak bloom, adult *F. occidentalis* were more abundant in flowering structures than in other parts of cotton plants and Trichilo & Leigh (1988) found that cotton pollen enhanced the fecundity and development of *F. occidentalis*.

The various predators also showed preferential distributions on various plant structures. During the study,

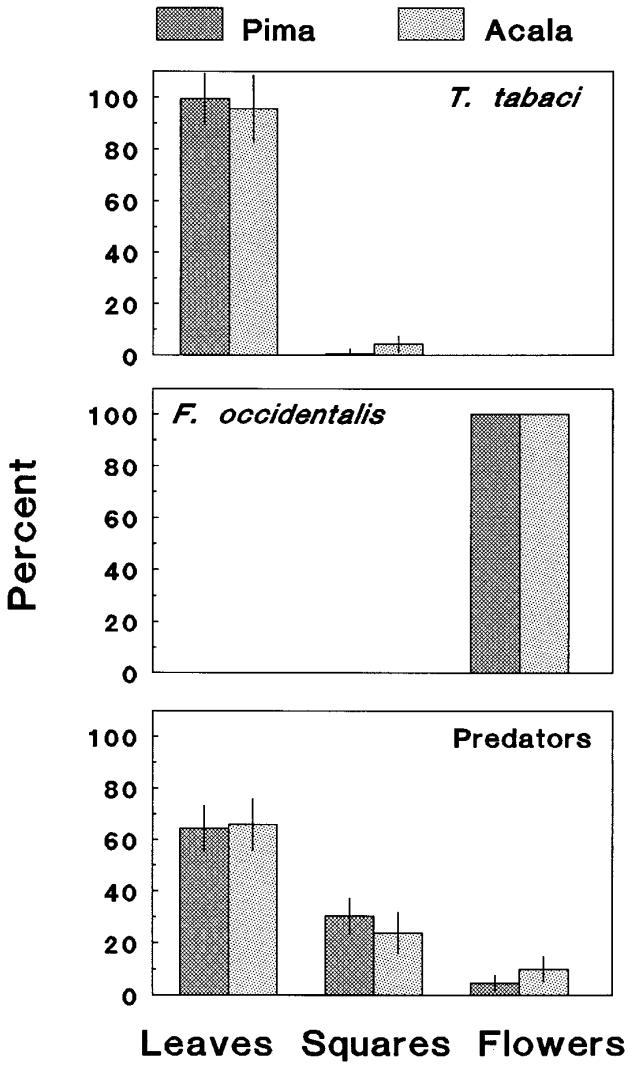


Fig. 4. Percent of *Thrips tabaci*, *Frankliniella occidentalis*, and their predators on leaves, squares and flowers in tall plants (>0.8 m) of two cotton varieties.

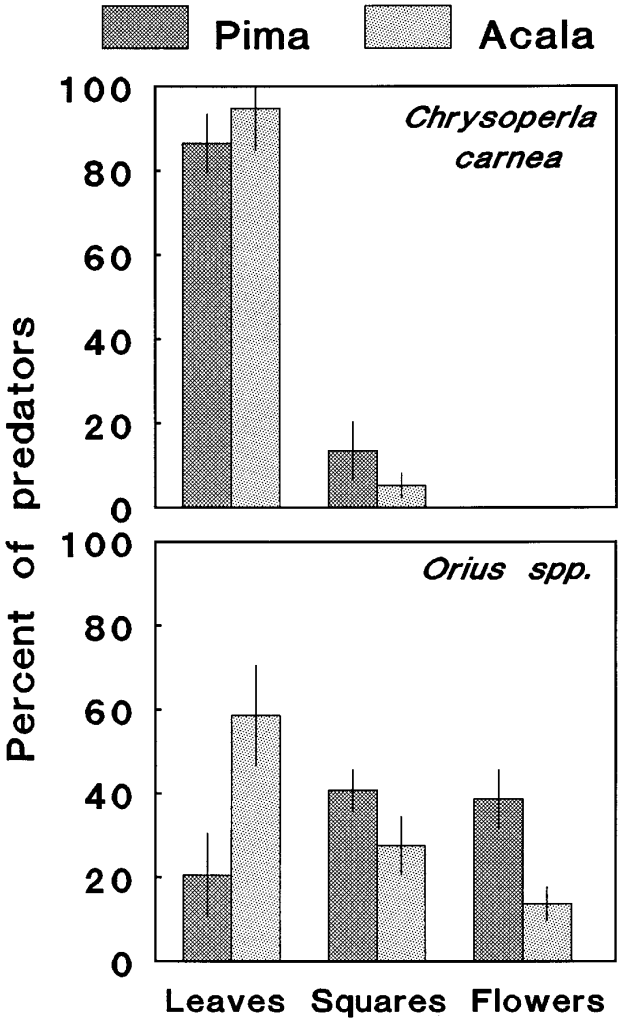


Fig. 5. Percent of *Chrysoperla carnea* and *Orius* spp. on leaves, squares and flowers on tall plants (> 0.8 m) of two cotton varieties.

densities of *Dereaeocoris pallens* and *Aeolothrips* spp. were too low to permit a separate analysis. Most *C. carnea* eggs and larvae were found on the leaves of both Pima and Acala plants (fig. 5). In contrast, *Orius* spp. colonized mostly the flowering structures (squares and flowers) of Pima plants but the leaves of Acala (fig. 5). The results for Pima agree with other studies that have reported that *Orius* species feed on plant pollen (Barber, 1936; Dicke & Jarvis, 1962; Salas-Aguilar & Ehler, 1977; Kiman & Yeargan, 1985) and that both nymphs and adults readily visit cotton flowers (Wilson & Gutierrez, 1980). In our study, almost 88% of the *Orius*-inhabited flowers were occupied by a single individual. These data, and the attraction of *Orius* to pollen, suggest that intraspecific interactions render flowers a limited resource for this predator. Thus, the lower abundance of flowers on Acala than on Pima plants (table 1, tall plants) probably led to the lower proportion of *Orius* populations in flowers in Acala compared to Pima plants.

Over all species, most predators were found on the leaves and in similar proportions on Pima and Acala plants (fig. 4). The ratios between thrips and predator abundance on different plant structures suggest that, for both varieties, thrips are most likely to be preyed upon on squares (0.28 thrips per predator) and appear to be relatively safe in flowers (12.4 thrips per predator). An intermediate but relatively high predation rate apparently occurs on the leaves (2.97 thrips per predator).

The higher abundance of fruiting structures on Pima compared to Acala plants probably affected the distribution of thrips and their predators. Female *F. occidentalis* visit the flowers to feed on nutritious pollen and nectar and to reproduce (Pickett *et al.*, 1988). Likewise, *Orius* species enjoy enhanced reproduction, development and survival when prey-diet is supplemented by plant pollen (Salas-Aguilar & Ehler, 1977; Kiman & Yeargan, 1985; and see discussion in Coll, 1996). These generalist predators of thrips are also important natural enemies of many other cotton pests (van den Bosch & Hagen, 1966; Stoltz & Stern, 1978; Isenhour & Yeargan, 1981; Letourneau & Altieri, 1983; Schoenig & Wilson, 1992). Thus, the effect of cotton variety on predator distribution is also likely to affect predation rates on other pests in the system.

Clearly, the within-plant distribution of thrips in cotton should be considered when sampling protocols are developed. The preference of *T. tabaci* for the leaves in the middle part of the plants suggests that cost-effective monitoring of populations of this pest could be achieved by sampling leaves from this stratum rather than from the whole cotton plant. Likewise, the population density of *F. occidentalis* could be estimated by examining the flowers. In respect to thrips–predator interactions, our data suggest that thrips populations are more likely to suffer a higher predation rate on Pima than Acala plants because (i) a positive correlation was found between the distribution of predator and thrips populations on Pima but not on Acala leaves, and (ii) *F. occidentalis* and *Orius* spp. aggregated in cotton flowers, which were more abundant on Pima plants.

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