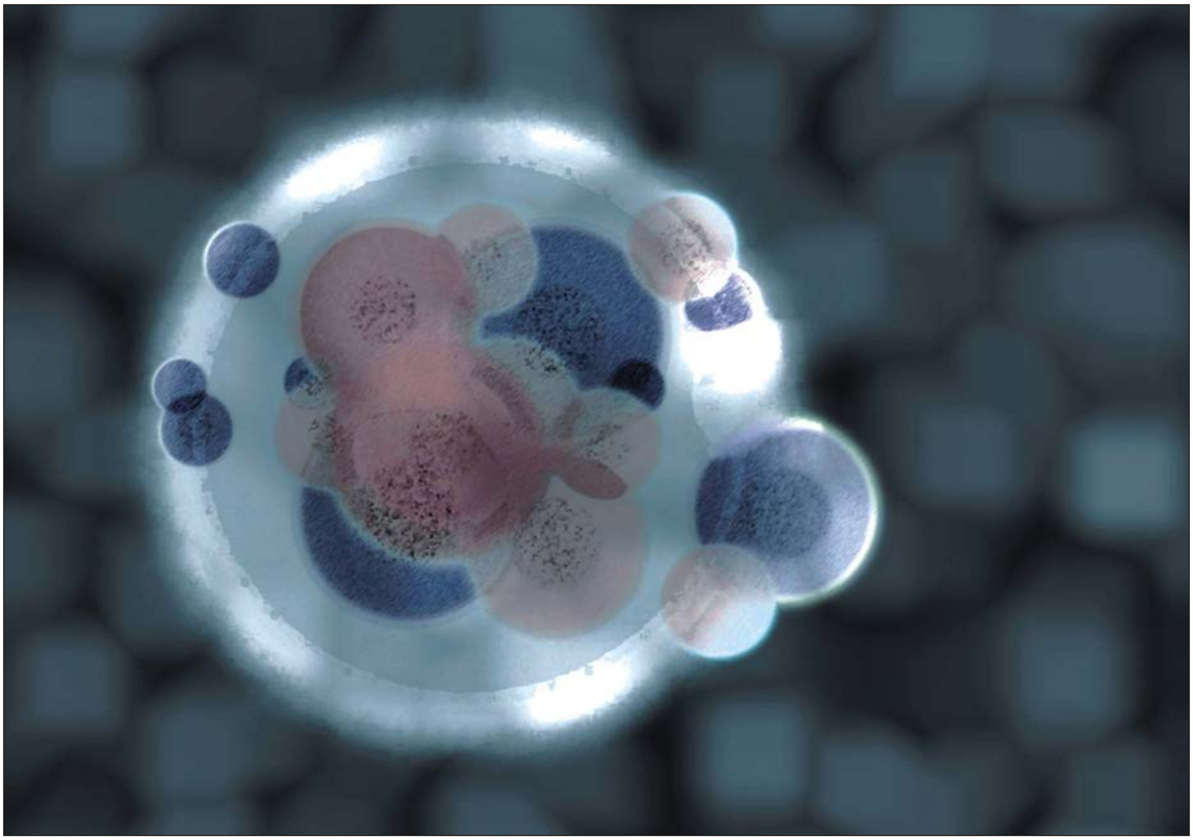

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Effect of Nitrogen Fertilization on Population Development of *Frankliniella* sp. (Thysanoptera: Thripidae) in Cotton in Eastern Mediterranean Region of Turkey

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Abstract: The effects of pure nitrogen fertilization at various rates on development of flower thrips, *Frankliniella occidentalis* (Pergande), *Frankliniella intonsa* (Trybom) (Thysanoptera: Thripidae) and plants were investigated in cotton fields in the Cukurova region of Turkey in 2000 and 2002. Three levels of nitrogen fertilization (kg pure N ha^{-1}): 70 (low rate), 140 (medium rate) and 210 (high rate) were applied to experimental plots. The high rate of nitrogen treatment positively affected the population development of both thrips until the mid-August, after which the abundance of thrips species was negatively associated with rates of nitrogen fertilization, when high colonization of flowers by *Frankliniella* thrips species from surrounding vegetation occurred. High nitrogen fertilization did not contribute to a consistent increase in the abundance of both thrips species. The relationships between nitrogen fertilization and abundance of flowers were positive and significant for most sampling dates in both years. The fruiting development of plants in medium and high fertilization plots was similar but significantly higher than in low fertilization plots.

Key words: Nitrogen, fertilization, *Frankliniella* sp., cotton

INTRODUCTION

Dietary nitrogen and carbohydrates are valuable elements for development, growth and reproduction of many insect species (White, 1984; Joern and Behmer, 1977). Plant nitrogen fertilization has been shown to affect population development of phloem-feeding insects (Janson and Smilowitz, 1986; Godfrey and Lesser, 1999).

Pollen contains comparatively high amounts of nitrogen (Slansky and Scriber, 1985) and preference of thrips for this plant part is often stated as a means of obtaining a higher protein diet (Kirk, 1997). Fecundity and growth of *Frankliniella occidentalis* (Pergande) were increased by the addition of pollen to diet mass (Trichilo and Leigh, 1988). An increased rate of nitrogen in the soil increases thrips populations (Vos and Frinking, 1997; Schuch *et al*., 1998).

Excessive nitrogen fertilization of cotton increases the speed of plant growth and extends the vegetative developmental period, creating more suitable microhabitats for development of *Bemisia tabaci Genn.* (Homoptera: Aleyrodidae) (Ozgur and Isler, 1992). Although *F. occidentalis* in USA (Reed and Reinecke, 1990), in Israel (Klein and Ben-dov, 1991) and *F. occidentalis* and *F. intonsa* in Greece, (Deligeorgidis *et al*., 2002), were reported as cotton pest, there are very limited knowledge about associations between these flower-dwelling thrips species and pure nitrogen (N) fertilization in cotton.

Frankliniella occidentalis and *Frankliniella intonsa* (Trybom) occur in cotton fields in the Cukurova region of Turkey. *F. intonsa* was of minor pest of cotton until the 1990s when it occurred at high population densities and caused severe damage to cotton, especially in late-cultivated cotton fields (Atakan and Ozgur, 2001). *F. occidentalis* was first found in 1994 in cotton fields in the Cukurova region and quickly spread to all cotton-growing areas of this region, replacing *F. intonsa* (Atakan *et al*., 1998). Both thrips species occur in cotton fields during the blooming period in mid-season. *F. intonsa and F. occidentalis* prefer the flowers and cause the shedding of young bolls. Damage by flower thrips was more severe in late-planted cotton fields in the coastal area of the Mediterranean region (Atakan and Ozgur, 2001). Insecticide applications have not effectively controlled either species in cotton (Kusdemir *et al*., 2000). Therefore, flower thrips control by cultural methods such as proper regulation of nitrogen fertilization to impede the population increase of the pests could be an important part of integrated pest management of thrips in cotton fields.

The objective of this study was to determine the effects of nitrogen applications at various rates in cotton on the population growth of *Frankliniella* sp. and the development of fruiting structures of cotton plants.

MATERIALS AND METHODS

Field experiments: Cotton (*Gossypium hirsitum* L., cv. Cukurova 1518) was planted on 17 April, 2000 and 10 May, 2002 in Adana province located at eastern mediterranean region of Turkey. The field experimental design was a completely randomized block with three treatments and four replications. Each plot consisted of 16 rows, 25 m long, with rows spaced 0.80 m apart. The blocks were separated by four rows of cotton. Three levels of pure nitrogen (kg pure N ha^{-1}), 70 (low rate), 140 [medium and recommended rate in Cukurova region (Mart, 2005)] and 210 (high rate), were used in the experiments. Half of each level of nitrogen was applied to the soil at planting as composed fertilizer, 20-20-0 (N-P-K). The remaining part, as 46%-urea, was applied to plots when the first squares on the plants were formed. Fields were furrow irrigated every three weeks after complete doses of each treatment was applied to the soil. No pesticides were used against any pest species in 2000 but in 2002, the experimental field was sprayed for leafhoppers [*Asymmetresca decedens* (Paoli) and *Empoasca decipiens* Paoli (Homoptera: Cicadellidae)] at the recommended doses of the active ingredient, acetamiprid 20% (100 g ha^{-1}) in mid-season because of high pest pressure.

Sampling of thrips: Flowers were targeted to sample the population of thrips. Sampling began when the first flowers were formed at the end of June or first week of July. The flowers were sampled between 9-10 am when mass movement of thrips from old flowers to fresh ones occurred. On each sampling date, 5 flowers were collected from the top half of plants within each plot and were placed in individual plastic cups (250 cc) and carried in an ice box at 10-15°C to the laboratory.

In the laboratory, flowers in cups were left in a deep freeze for one hour to break thrips activity. Flowers then were taped onto a white paper and extracted thrips were collected by a fine brush and put into plastic vials (2 cc) containing 60% ethyl alcohol. To remove the remaining thrips, flowers were submerged in detergent solution (2%), agitated for 25 sec and poured into sieves. Extracted thrips were counted individually under a stereomicroscope and adults were identified to species. Larval thrips could not be identified to species.

Effects of nitrogen fertilization on generative development of plants: To determine the effect of pure nitrogen treatments on the development of fruiting parts of cotton plants, 5 plants from each plot were randomly selected. The number of squares, flowers and bolls on each plant were recorded every week during the sampling period.

Statistical analysis: Populations of thrips were sorted by date and one-way analysis (ANOVA) was used to compare the effect of treatments. The means from fertilization treatments were separated by Duncan's Multiple Range test ($p \leq 0.05$). Effects of fertilization on development of plant parts (square, flower and boll) were similarly analyzed. The relationships among the numbers of flowers and densities of adult (female+male) *Frankliniella* thrips were examined by Pearson correlations ($p \leq 0.05$). Mean numbers of immature thrips were not assessed, except a few sampling date in each treatment in both years, because very low numbers on flowers.

All analyses were performed using SYSTAT ver. 13.0 (SPSS, 1999).

RESULTS

Effects of nitrogen treatments on population development of *F. intonsa* and *F. occidentalis*: The populations of both thrips species regularly increased at all treatments and were significantly higher on some dates in the high fertilization treatment than others until mid-August of 2000 ($p \leq 0.05$) (Fig. 1). On 24 August, population densities of *F. intonsa* and *F. occidentalis* were significantly higher ($F = 17.361$; $df = 3$; $p = 0.0001$ and $F = 17.923$; $df = 3$; $p = 0.0001$, respectively) in low nitrogen treatments than in medium and high nitrogen treatments.

Mean numbers of immature thrips on flowers in medium and high rates fertilization on 27 July were not different ($p>0.05$) but significantly greater than that of low rate treatments ($F = 13.236$; $df = 3$; $p = 0.005$) in 2000 (unpublished data).

Frankliniella occidentalis quickly colonized flowers and showed high population density in July and then quickly declined to low levels after the end of August in 2002 (Fig. 1). Population densities of *F. occidentalis* in high fertilization treatment were comparatively higher for three sampling weeks than those of the other two treatments and peaked on 23 July ($F = 4.282$; $df = 3$; $p = 0.024$). Mean numbers of *F. occidentalis* were significantly higher in the low treatment than in the other treatments on 13 August and 28 August ($F = 5.955$; $df = 3$; $p = 0.031$ and $F = 16.996$; $df = 3$, $p = 0.004$).

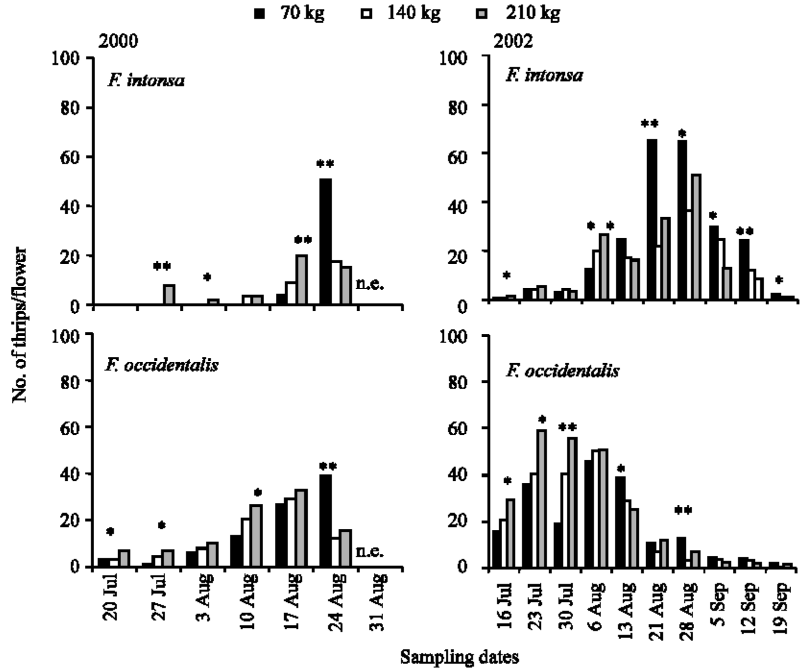

Fig. 1: Mean numbers of adult *Frankliniella intonsa* and *Frankliniella occidentalis* at various levels of nitrogen applied to cotton plants in 2000 and 2002. *,** denote significant differences by date determined by one-way ANOVA at $^*p \le 0.05$, $^{**}p \le 0.01$; n.e.: not evaluated

The population density of *F. intonsa* was low throughout July but increased considerably in August (Fig. 1) in 2002. Mean numbers of *F. intonsa* in the low fertilization treatment were significantly lower on the first sampling date than those of the medium and high treatments ($F = 4.654$; $df = 3$; $p = 0.018$). Mean numbers of *F. intonsa* were significantly higher in the low rate fertilization than in the medium and high fertilization on most sampling dates after 13 August ($p \le 0.05$).

Mean numbers of immature thrips on flowers in medium and high rates fertilization on 6 and 13 August were not different ($p>0.05$) but significantly greater than those of low rate treatments ($F = 12.431$; $df = 3$; $p = 0.005$ and $F = 6.824$; $df = 3$; $p = 0.012$, respectively) in 2002 (unpublished data).

The total numbers of *Frankliniella* sp. in the low treatments were similar to those in the high treatments but significantly higher than in medium treatments in 2000 and 2002 ($F = 4.202$; $df = 3$; $p = 0.042$ and $F = 5.150$; $df = 3$; $p = 0.036$, respectively) (Table 1).

A significant positive correlation was observed between rate of nitrogen and numbers of flowers on 5 of 6 sample dates in 2000 and 5 of 10 sample dates in 2002 (Table 2 and 3). The relationships between application rate of nitrogen fertilization and the abundance of thrips species were positive and significant until mid-August, but thereafter negative and significant on most sampling dates of both years (Table 2 and 3). Based on season-long effects of nitrogen treatment, the correlations between the numbers of flowers and *F. intonsa* or *F. occidentalis* were negative and significant in all treatments in 2000 ($p \le 0.05$) (Table 4). The numbers of flowers and *F. intonsa* were

Table 1: Seasonal mean numbers of adult *Frankliniella* sp. in various levels of N application in cotton in Adana province, Turkey, 2000 and 2002

Years[a]	Nitrogen levels (kg ha^{-1})	Thrips (Mean±SE) /per flower [b]
2000	70	25.9±0.19ab
	140	17.2±0.26b
	210	28.5±0.15a
2002	70	40.1±3.16ab
	140	33.2±2.43b
	210	44.2±2.47a

[a] Averaged over all samples in each year. [b] Within a column, means (±SE) followed by a common letter do not differ according to Duncan's multiple range test ($p \le 0.05$)

Table 2: Correlation analysis between N and number of flowers or adults of *F. intonsa* and *F. occidentalis* in cotton in Adana province, Turkey, 2000

	Flower and N		*F. intonsa* and N		*F. occidentalis* and N	
Dates	p	R	p	R	p	R
20 Jul	0.003	0.646**	-[a]	-	-	-
27 Jul	0.001	0.716**	0.001	0.770**	0.003	0.649**
3 Aug	0.001	0.810**	0.005	0.527**	0.170	0.209
10 Aug	0.047	0.208	0.013	0.288*	0.283	0.500
17 Aug	0.001	0.705**	0.001	0.616**	0.177	0.122
24 Aug	0.204	0.000	0.001	-0.857**	0.001	-0.798**

p: probability; R: correlation coefficient. [a]No assessment due to low numbers of *F. intonsa* and *F. occidentalis*. *,** denote correlations significant at $^*p \le 0.05$ and $^{**}p \le 0.01$, respectively

Table 3: Correlation analysis between N and number of flowers or adults of *F. intonsa* and *F. occidentalis* in cotton in Adana province, Turkey, 2002

	Flower and N		*F. intonsa* and N		*F. occidentalis* and N	
Dates	p	R	p	R	p	R
16 Jul	0.103	0.238	0.006	0.750**	0.011	0.634**
23 Jul	0.019	0.680*	0.208	0.154	0.005	0.705**
30 Jul	0.039	0.532*	0.064	0.284	0.001	0.741**
6 Aug	0.047	0.512*	0.005	0.710**	0.183	0.171
13 Aug	0.169	0.185	0.015	0.698**	0.005	0.664**
21 Aug	0.010	0.624**	0.005	-0.714**	0.354	0.071
28 Aug	0.173	0.178	0.122	-0.220	0.030	-0.547*
5 Sep	0.500	0.000	0.006	-0.657**	0.022	-0.570*
12 Sep	0.364	0.066	0.001	-0.764**	0.026	-0.558*
19 Sep	0.031	0.644*	0.021	-0.675**	0.279	-0.111

p: probability; R: correlation coefficient. *,** denote correlations significant at *p≤0.05 and **p ≤0.01, respectively

Table 4: Correlation analysis between the numbers of flowers and adults of *F. intonsa* or *F. occidentalis* in different level N application in cotton in Adana province, Turkey, 2000 and 2002

	2000				2002			
	Flower and *F. intonsa*		Flower and *F. occidentalis*		Flower and *F. intonsa*		Flower and *F. occidentalis*	
Nitrogen levels (kg ha^{-1})	p	R	p	R	p	R	p	R
70	0.010	-0.885*	0.001	-0.943**	0.012	-0.702*	0.351	0.139
140	0.010	-0.882*	0.078	-0.357	0.012	-0.700*	0.049	0.552*
210	0.025	-0.813*	0.070	-0.377	0.041	-0.576*	0.011	0.704*

p: probability; R: correlation coefficient. *,** denote correlations significant at *p≤0.05 and **p ≤ 0.01, respectively

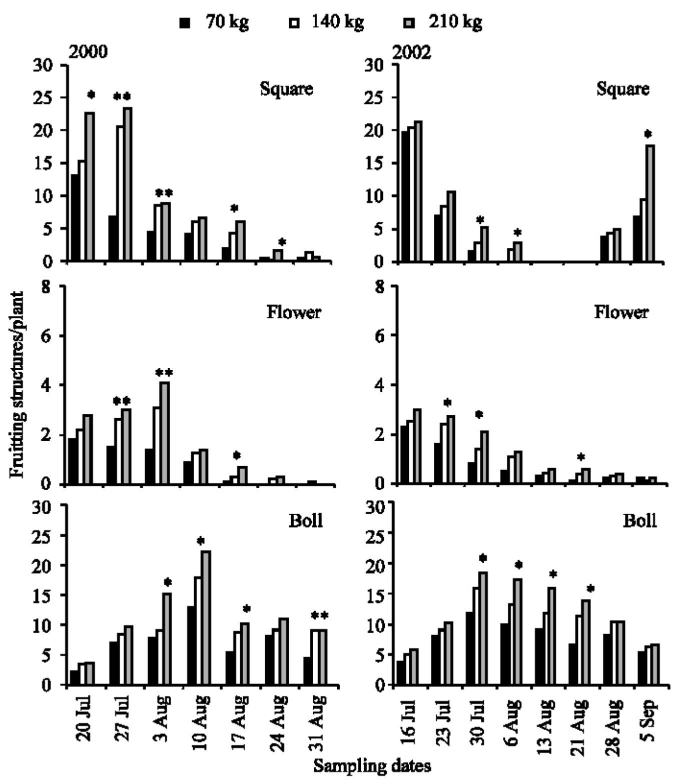

Fig. 2: Mean numbers of fruiting structures (square, flower and boll) at various levels of nitrogen applied to cotton plants in 2000 and 2002. *,** denote significant differences by date determined by one-way ANOVA at *p≤0.05, **p ≤ 0.01

negatively correlated in all treatments but positively correlated for *F. occidentalis* in the medium and high fertilization plots in 2002 (Table 4).

Effects of nitrogen treatments on fruiting development of plants: The fruiting development of cotton plants treated by applications of various doses of pure nitrogen in 2000

Table 5: Seasonal mean numbers of fruiting parts in various levels of N application in cotton in Adana province, Turkey, 2000 and 2002

Years[a]	Nitrogen levels (kg ha^{-1})	Fruiting parts (Mean±SE)/per plant[b]		
		Square	Flower	Boll
2000	70	6.5±0.66b	1.3±0.41b	8.8±0.65b
	140	10.5±1.00a	2.1±0.24a	9.1±0.97b
	210	13.3±1.36a	2.1±0.22a	12.3±1.32a
2002	70	4.7±1.20b	0.7±0.09b	8.4±0.83b
	140	8.9±1.17a	2.0±0.11a	10.3±0.78ab
	210	12.9±1.52a	2.2±0.12a	14.8±0.68a

[a] Averaged over all samples in each year. [b] Within a column, means (±SE) followed by a common letter do not differ according to Duncan's multiple range test ($p \leq 0.05$)

and 2002 is given in Fig. 2. The mean number of squares and flowers in medium and high fertilization plots was similar but significantly higher than in low fertilization plots for the majority of sampling dates ($p \leq 0.05$). Boll numbers were statistically higher in the high fertilization plots on a few sampling dates ($p \leq 0.05$) in 2000. The numbers of squares in the high fertilization plots were higher than in other treatments on 30 July, 6 August and 5 September ($F = 6.196$; $df = 3$; $p = 0.024$, $F = 10.740$; $df = 3$; $p = 0.007$ and $F = 10.580$; $df = 3$; $p = 0.007$, respectively) in 2002 (Fig. 2). The numbers of flowers in high fertilization plots were statistically different on 3 of 8 sample dates from others ($p \leq 0.05$) in 2002 (Fig. 2). Significant differences between high and low rate fertilization treatments for boll numbers were recorded on 4 of 8 sample dates in 2002 ($p \leq 0.05$) (Fig. 2).

The total mean numbers of squares and flowers were similar in medium and high fertilization plots but significantly higher than in low fertilization plots ($F = 11.166$; $df = 3$; $p = 0.0001$ and $F = 8.886$; $df = 3$; $p = 0.023$, respectively) in 2000 (Table 5). The total mean number of bolls at high fertilization was higher than those at low and medium fertilization in 2000 ($F = 7.647$; $df = 3$; $p = 0.028$) (Table 5). In 2002, the total mean numbers of squares and flowers were similar at medium and high fertilization but significantly higher than at low fertilization ($F = 6.336$; $df = 3$; $p = 0.047$ and $F = 8.062$; $df = 3$; $p = 0.007$, respectively) (Table 5). Similarly, the total mean number of bolls were similar at medium and high fertilization but significantly higher than at low fertilization ($F = 7.214$; $df = 3$; $p = 0.028$) (Table 5).

DISCUSSION

Frankliniella occidentalis and *F. intonsa* exhibited higher populations at high fertilization than at low and normal fertilization and the correlations between nitrogen levels and abundance of both thrips species were mostly positive until the first week of August in cotton in both years. High rates of nitrogen in the soil increased the population of *F. occidentalis* on chrysanthemums (Schuch *et al*., 1998) and *Capsicum* sp. (Vos and Frinking, 1997). Mollema and Cole (1996) pointed out that there was consistent relation between aromatic amino-acid (AAA) concentrations (phenlyalamine and trysone) of foliage and rate of damage caused by *F. occidentalis* in greenhouse experiments. Higher rate of nitrogen fertilization favoured the multiplication of sucking insect complex including *Thrips tabaci* Lindeman (Thysanoptera: Thripidae) (Rustamani *et al*., 1999). Hasan *et al*. (2000) concluded that the low levels of inorganic minerals including nitrogen contributed to cotton plant-resistance against thrips feeding. In this study, although mean numbers of immature thrips in high rate fertilization were significantly greater than those of other fertilization rates for a few sampling date, high rates of nitrogen fertilization did not contribute to consistent increases in abundance of either thrips species throughout the season.

The correlation between nitrogen fertilization and the numbers of flowers were significantly positive on most sampling dates in both years (Table 2 and 3). Contrary to the results obtained, Brodbeck *et al*. (2001) found that high nitrogen fertilization did not influence flower numbers of tomatoes, but the abundance of *F. occidentalis* in flowers was positively associated with the amount of the primary amino acid, phenlyalamine in the flower. The negative and significant correlations between nitrogen rates and numbers of thrips were found when the numbers of flowers were reduced proportionally to low levels in mid or late season. Occurrence of higher populations of thrips in low treatments may be a result of higher colonization of thrips from surrounding vegetation to flowers in less numbers in late-July or late-August. This situation shows as if higher adult population attacked the flowers. Seasonal trends in population growth of *F. intonsa* and *F. occidentalis* on cotton were not related to the number of flowers. Instead, population densities of both thrips were negatively correlated with densities of flowers in all treatments, although higher populations of *F. occidentalis* occurred in mid-July of 2002 (Table 4). The fruiting development of plants in medium and high fertilization plots was usually similar but significantly different from that in low fertilization plots (Fig. 2 and Table 5). Boll numbers for medium and high fertilization were not different in either year; this study, therefore, suggest that yields from medium and high fertilization treatments would not be different. Cotton plants fertilized by more than the recommended dose (120-160 kg pure nitrogen ha^{-1}) did not result in yield increases of cotton in previous work in the Cukurova region, but were more favorable for population increase of whitefly (Ozgur and Isler, 1992).

Season-long effects of nitrogen fertilization on the development of thrips were not consistent and in general, were based on the results of two years of experiments; nitrogen fertilization seems to have a short-term and positive effect on the abundance of both thrips species on cotton. A possible reason for negative effects seen for nitrogen fertilization after mid-August might be the massive colonization of flowers by thrips from outside. Thus, this situation may not reflect the actual seasonal fluctuation and population growth of flower thrips in cotton.

The absence or significant negative relationship between mean numbers of total thrips and of flowers, when main infestations of *Frankliniella* sp. occurred in the all fertilization treatments, may indicate that normal-planted cotton in the region serves as a temporary host for thrips species, rather than as a favorable host for their development. In Cukurova, cotton fields planted late (after 15 May) are more infested and damaged by higher populations of thrips than in pre-blooming or pink-blooming periods of plants (Atakan and Ozgur, 2001). Moreover, recently, it was noted that damage of *F. occidentalis* on seedlings of cotton plants were more severe in the late-planted cotton fields in the region. Thus, the effects of excessive nitrogen fertilization on growth of thrips populations might be more apparent. This study suggest that using insecticides to control the flower-inhabiting thrips species in normal-planted cotton fields is not meaningful because, (i) plants have plenty boll to recover and produce sufficient yield, when main infestations of *Frankliniella* sp. occurred and (ii) number of flower suffer to thrips feeding is low and most boll will mature.

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