SEASONAL AND WITHIN PLANT DISTRIBUTION OF FRANKLINIELLA THRIPS (THYSANOPTERA: THRIPIDAE) IN NORTH FLORIDA TOMATOES

SEASONAL AND WITHIN PLANT DISTRIBUTION OF *FRANKLINIELLA* THRIPS (THYSANOPTERA: THRIPIDAE) IN NORTH FLORIDA TOMATOES

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ABSTRACT

Frankliniella occidentalis (Pergande) (Thysanoptera: Thripidae)*,* the western flower thrips, is the primary insect pest of tomatoes and other vegetable crops in northern Florida and the rest of the southeastern USA. However, it is not the only flower thrips present in the region nor is it always the most abundant species. To determine the seasonal and within plant distribution of these various *Frankliniella* species, experimental tomato plants, grown under different nitrogen fertilization regimes, were sampled during the fall and spring growing seasons. Contrary to expectations, different levels of nitrogen fertilization did not affect the abundance of thrips species. Thrips were much more abundant in the spring than in the fall. In the spring *F. occidentalis* was the most abundant species, while in the fall *F. tritici* (Fitch) was the most abundant species. In both the fall and spring, significantly more adults occurred in flowers in the upper part of the plant canopy than in flowers in the lower part of the plant canopy. The sex ratio tended to be female biased, but with a greater percentage of males occurring in the upper canopy flowers. In contrast, significantly more immature thrips occurred in the lower part of the plant canopy than in flowers in the upper part of the plant canopy. Differences in seasonal patterns and within plant distribution should be considered in developing sampling protocols and management plans for thrips.

Key Words: Flower thrips*,* within plant distribution, seasonal trends, *Frankliniella occidentalis*, *Frankliniella tritici*, *Frankliniella bispinosa*

RESUMEN

Frankliniella occidentalis (Pergande) (Thysanoptera: Thripidae)*,* el trips occidental de flores, es principalmente una plaga de tomate y otras hortalizas en el norte de la Florida y en el resto del sureste de los Estados Unidos. Sin embargo, no es el único trips de flores presente en la región ni es siempre lo más abundante. Para determinar la distribución estacional y entre plantas de las varias especies de *Frankliniella*, mostramos plantas de tomate experimentales, cultivados bajos régimes de nitrógeno diferentes, durante las estaciones del otoño y la primavera. Al contrario de las expectativas, los niveles diferentes de fertilizante de nitrógeno no afectaron la abundancia de las especies de trips. Los trips fueron más abundante en la primavera que en el otoño. En la primavera, *F. occidentalis* fué la especie más abundante, mientras que en el otoño *F. tritici* (Fitch) fué la especie más abundante. En ambas estaciones, el otoño y la primavera, significativamente más adultos ocurrian en las flores en la parte superior de la copa de la planta que en las flores del parte inferior de la copa de la planta. La proporción de machos y hembras adultos recién emergidos tendia ser prejuiciada hacia la hembras, pero con un mayor percentaje de machos ocurriendo el las flores de copa de la planta superior. Al contraste, significativamente más trips inmaduras ocurrian en la parte inferior de la copa de la planta de la planta que en las flores en la parte superior de la copa de la planta. Se debe considerar las diferencias en los patrones estacionales y la distribución entre la planta al desarrollar un protocolo de muestreo y plan de manejo para los trips.

Several species of *Frankliniella* thrips are sympatric in the southeastern USA. Members of this complex commonly infest tomatoes and other vegetable crops, where they are considered primary pests (Bauske 1998). Some species, such as *F. occidentalis* (Pergande) and *F. fusca* (Hinds), are known vectors of Tomato Spotted Wilt Virus (TSWV) (Sakimura 1962, 1963). Other species, such as *F. bispinosa* (Morgan), are potential vectors of TSWV (Webb et al. 1997). Still other species present in the southeast, such as *F. tritici* (Fitch)*,* do not vector TSWV. In addition to differences in the capacity for virus transmission, these species differ in their phenology, population dynamics, host plant use, and behavior (Cho et al. 2000, Hansen 2000, Ramachandran et al. 2001).

These species-specific characteristics also can be mediated by variation within host plants. Although little is known of the nutritional ecology of thrips, Brodbeck et al. (2001) manipulated nitrogen content of plants through fertilization, and found that the peak abundance of *F. occidentalis* adults in tomato flowers is positively correlated with the concentration of the primary aromatic amino acid, phenylalinine, in the flowers. This correlation was most pronounced for females.

Higher rates of nitrogen fertilization also result in higher populations of *F. occidentalis* in chrysanthemums (Schuch et al. 1998). This phenomenon may be critically important to the management of thrips because southeastern tomato growers frequently apply unnecessarily high rates of nitrogen fertilizer to tomato crops (Castro et al. 1993), which may then induce higher populations of serious pests.

In addition the microhabitat within a plant can affect observed population dynamics. Salguero-Navas et al. (1991b) sampled commercial tomato fields and found that adults of *F. occidentalis* and *F. tritici* were more abundant in flowers in the upper canopy of tomato than in lower flowers. The opposite was true of immatures, with more being found in the lower flowers. They attribute part of this difference to rapid immigration into the crop by adults while immatures near the top would be more susceptible to frequent insecticide applications than those immature thrips located lower in the canopy. However, *F. occidentalis* adults also show significant differences in the vertical distribution within nectarine orchards, with more adults found at lower levels than at higher levels (Pearsall 2000), and cotton plants, with more being found in the middle section of plants (Atakan et al. 1996).

The specific objectives of the present research are to determine the seasonal dynamics and within plant distribution of male, female and immature *Frankliniella* thrips in tomatoes grown under different fertilizer regimes. By understanding the responses of *Frankliniella* thrips to fertilization regimes and plant architecture, more efficient sampling protocols for thrips in vegetable crops can be developed and management programs for tomato spotted wilt improved.

MATERIALS AND METHODS

Cultural Practices

The experiments were conducted at the Florida A&M University Research Farm in Gadsden County, Florida, from July 1999 to June 2000. Six week-old tomato plants (*Lycopersicon esculentum* Mill. cv 'Agriset') were transplanted mechanically into raised beds. Raised beds were 15 cm high and 91 cm wide and were covered with plastic mulch, with drip tube irrigation underneath the plastic. In the fall season of 1999, white plastic was used as the mulch, and plants were transplanted on August 12. In the spring 2000 season, black plastic was used as the mulch, and plants were transplanted on March 17. Plant spacing was 60 cm within beds, with a bed spacing of 180 cm. Beds were oriented north-south. Plants were treated with fungicides every 7-10 days, with at least a 72-hour interval between spraying and subse-

quent sampling. No insecticides were applied during these studies.

Experimental Design and Methods

To evaluate the impact of different nitrogen treatments on thrips populations, three different nitrogen levels were used. Three nitrogen fertilizer treatments (sub optimal 101 kg N/ha, optimal 202 kg N/ha, super optimal 404 kg N/ha) were applied to whole plots (Maynard & Olson 2000). One hundred and one (101) kg N/ha were administered in the form of 10-10-10 (N-P-K) fertilizer before the plastic mulch was laid. The remainder of the fertilizer was applied four weeks after transplanting. This fertilizer treatment was administered by hand in the form of ammonium nitrate (34-0-0, N-P-K) by cutting an opening in the plastic and placing a band of fertilizer around each plant approximately 15 cm from the base of the plant. Plots were one bed wide and 15.2 m long, and there was a 1.5 m buffer between plots within each bed. Plots were laid out in a randomized complete block design with each bed forming a block. In the fall 1999 season, the field was laid out with four blocks. In the spring 2000 season, the field was laid out with eight blocks. Flower position within plants was considered as a subplot within the fertilizer treatment whole plots.

Data Collection and Analysis

Samples were collected twice per week by taking one flower from the upper third of the plant canopy and one from the lower third on each of three plants per plot. Flowers were collected individually in 70% ethanol for later analysis. Sampling was conducted from the onset to conclusion of flowering. To reduce diurnal variation in sampling, all samples were collected between 1000 and 1300 hours. Thrips were extracted from flowers, and adults were identified to species and sex, using a stereomicroscope. Because it was not possible to identify thrips larvae to the species level, these were combined into a single group for analysis. The data were transformed to $\sqrt{(y + 0.375)}$ and then subjected to analysis of variance, by species and sex for adults. The independent variables of interest were fertilization treatment and flower location within a plant, and the interaction of these. Data were analyzed for each season as a randomized complete block—split plot over time (Steel & Torrie 1980).

RESULTS

Populations of all thrips species were considerably lower in the fall season (Fig. 1) than in the spring season (Fig. 2). The mean number of thrips per flower in the fall was 0.70 ± 0.05 (0.44 ± 0.03 adults, 0.26 ± 0.03 immatures) whereas in the
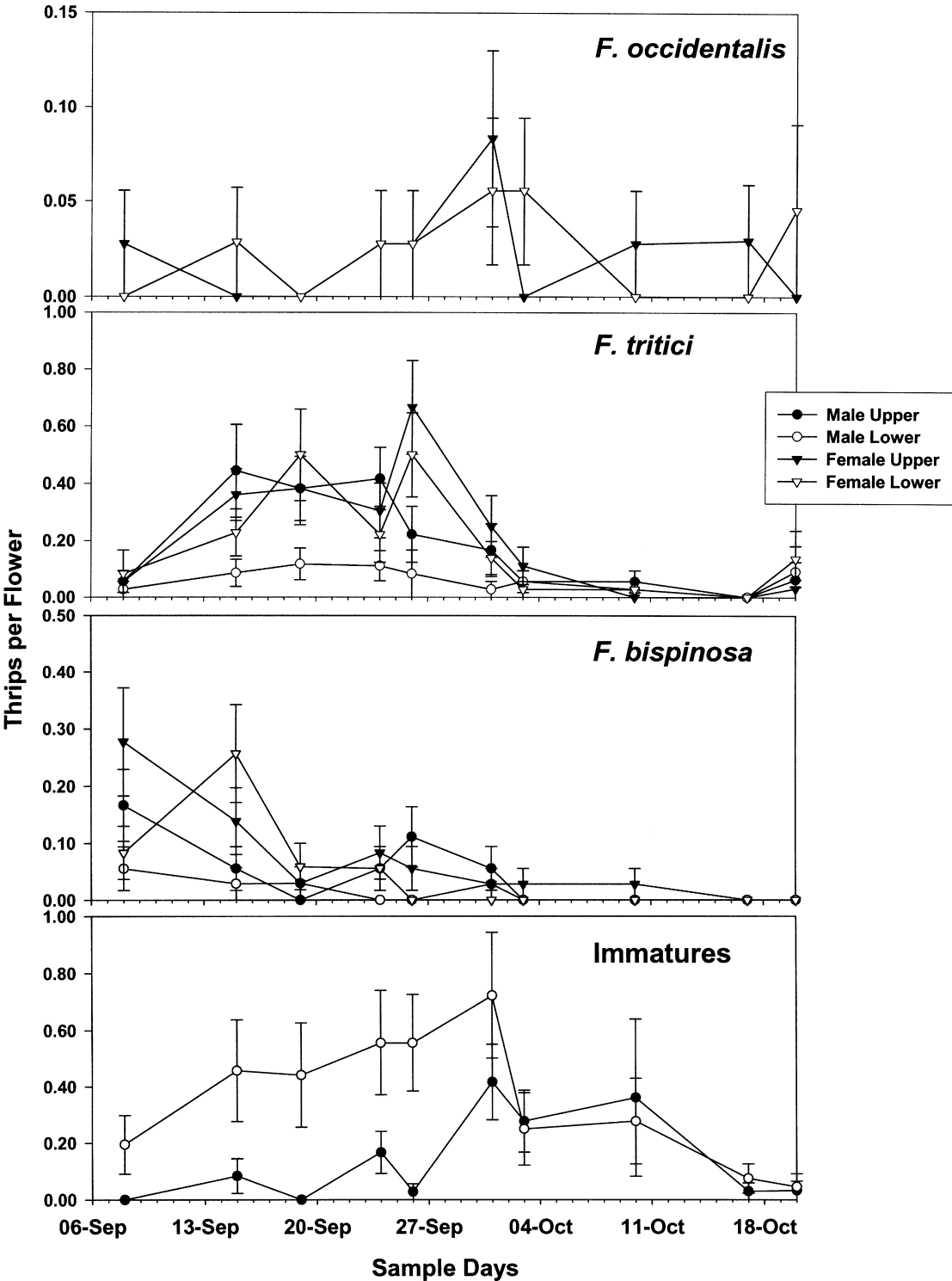
Fig. 1. Mean number of thrips per flower collected from the upper and lower canopy of plants during the fall season of 1999. Because there were no significant fertilizer treatment effects, data are pooled for all treatments. Data points are untransformed means plus their standard errors. Note different scales on the y-axes. Symbols for immatures denote means for all species and sexes combined.

Fig. 2. Mean number of thrips per flower collected from the upper and lower canopy of plants during the spring season of 2000. Because there were no significant fertilizer treatment effects, data are pooled for all treatments. Data points are untransformed means plus their standard errors. Note different scales on the y-axes. Symbols for immatures deno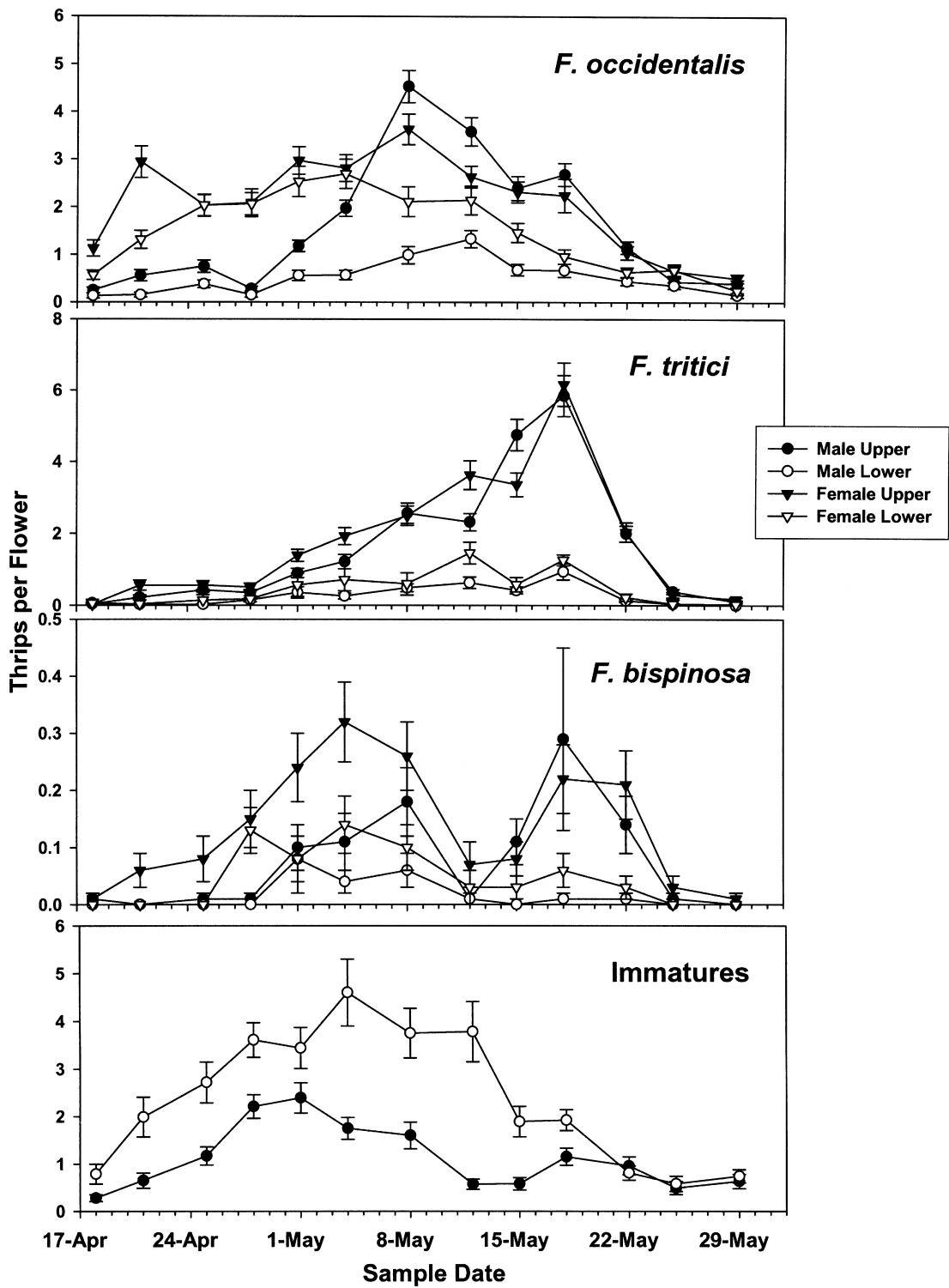te means for all species and sexes combined. Filled symbols are for the upper canopy, and open symbols are for the lower canopy.

spring the mean number of thrips per flower was 6.76 ± 0.16 (5.02 ± 0.15 adults, 1.74 ± 0.07 immatures).

Fall

In the fall season, the proportion of adult thrips in the population was 63.3%. Of the adults, *F. tritici* (75.0%) was the predominant species. *F. occidentalis* was uncommon in the fall, comprising only 5.3% of adult thrips. All of these *F. occidentalis* were female. The remaining adults that were collected (19.7%) were *F. bispinosa*. No *F. fusca* were collected in the fall. Thrips rapidly colonized plants soon after the onset of flowering in early September (Fig. 1). Populations peaked in mid September and declined until the end of this month.

There was no significant flower location by fertilization treatment interaction ($P > 0.05$), and there were no significant differences among the fertilization treatments in numbers of any of the three *Frankliniella* species or immatures (Table 1, $P > 0.05$). Significantly more *F. tritici* and *F. bispisnosa* adults were found in the upper canopy than in the lower canopy ($F_{1,24} = 7.81$, $P < 0.01$; $F_{1,24} = 7.10$, $P < 0.01$, respectively). These differences were the result of significantly more males of *F. tritici* and *F. bispinosa* being in the upper flowers than in the lower flowers (Table 2). This difference was most pronounced during the middle of the season and decreased as populations declined later in the season (Fig. 1). Females of *F. tritici* and *F. bispinosa* did not show any difference in vertical distribution during the fall (Table 2). In contrast to the distribution of adults, significantly more immature thrips were collected from flowers in the lower canopy compared with flowers from the upper canopy (Table 2). Again this difference was strongest in the middle of the season than at the beginning or at the end when immature populations were low overall (Fig. 1).

Spring

Of all thrips collected in the spring, 74.4% were adults and 25.6% were immatures. This overall age distribution was slightly different from the fall. However, the species composition was markedly different from that of the fall season. *F. occidentalis* was much more abundant in the spring and comprised 56.1% of the adults. *F. tritici* comprised 41.2% of the adults in the spring. *F. bispinosa* comprised 2.7%. The remainder (<0.1%) was *F. fusca*.

In addition to the species composition, the seasonal population patterns in the spring differed from those of the fall. In the spring, flowering began in mid April. *F. occidentalis* began colonizing in large numbers within a week of the onset of flowering. These early season *F. occidentalis* pop-

ulations were composed primarily of females. *F. occidentalis* populations did not peak until the first week of May (Fig. 2), but then their population decreased over the next three weeks. *F. tritici* did not begin colonizing in large numbers until almost a month after the onset of flowering. Populations of *F. tritici* peaked in the middle of May, but rapidly declined within another week. *F. bispinosa* numbers remained low throughout the season and never showed a significant peak and decline. The numbers of immature thrips peaked in early May, a time corresponding to the peak numbers of *F. occidentalis* but low numbers of *F. tritici* and *F. bispinosa*. These results suggest that most of these larvae were *F. occidentalis*.

As in the fall there were no significant differences among the fertilization treatments in numbers of thrips ($P > 0.05$, Table 1). However, there were, again, differences in the within plant distribution of thrips. Significantly more adults of the primary species, *F. occidentalis*, *F. tritici* and *F. bispinosa,* were found in the upper canopy flowers than in the lower canopy flowers (Table 2, Fig. 2). In contrast to the fall season, both females and males of each species were found in significantly greater numbers in the upper canopy flowers than in the lower canopy flowers. The opposite was true for immature thrips. Over the entire season, significantly more larvae occurred in the lower canopy flowers (Table 2, Fig. 2).

DISCUSSION

The results of this study indicate that *Frankliniella* flower thrips commonly occurring in north Florida have different seasonal population patterns. These results also show the importance of understanding individual species population dynamics when developing sampling protocols and management programs. *Frankliniella* species overwinter on numerous uncultivated plants (Chellemi et al. 1994, Toapanta et al. 1996), and thrips from these hosts can then rapidly colonize crops as they begin to flower (Groves et al. 2001). However, populations of flower thrips in tomato and other crops typically occur in large numbers for a relatively short period of time (Webb et al. 1970, Salguero-Navas et al. 1991b, Brodbeck et al. 2001), and the timing of population peaks vary according to species. In northern Florida and southern Georgia, these peaks occur in the spring from April through May. *F. occidentalis*, a primary vector of TSWV, is the predominant species early in the spring. Its populations peak earlier than those of *F. tritici* (Salguero-Navas et al. 1991b, this study). *F. occidentalis* is virtually absent from late spring through the fall. In the fall, *F. tritici*, a nonvector of TSWV, is the predominant species. Populations of *F. bispinosa* did not show any substantial peaks in either season. *F. bispinosa* was present throughout the spring

TABLE 1. SEASONAL MEANS OF THRIPS PER TOMATO FLOWER FOR DIFFERENT NITROGEN FERTILIZATION TREATMENTS DURING THE FALL 1999 AND SPRING 2000 SEASONS. DATA ARE POOLED FOR THE UPPER AND LOWER CANOPY FLOWERS. MEANS AND STANDARD ERRORS FOR UNTRANSFORMED DATA ARE GIVEN. F VALUES, AND ASSOCIATED P VALUES, ARE FOR THE COMPARISON OF TREATMENT MEANS OVER EACH GROWING SEASON.

Fall

Nitrogen fertilizer	*F. occidentalis*			*F. tritici*			*F. bispinosa*			
	Male	Female	Sex ratio[1]	Male	Female	Sex ratio[1]	Male	Female	Sex ratio[1]	Immatures
Low	0	0.02 ± 0.01	0	0.11 ± 0.02	0.18 ± 0.04	0.41 ± 0.07	0.03 ± 0.01	0.04 ± 0.02	0.37 ± 0.13	0.25 ± 0.05
Middle	0	0.01 ± 0.01	0	0.17 ± 0.03	0.21 ± 0.01	0.39 ± 0.06	0.03 ± 0.01	0.05 ± 0.01	0.41 ± 0.11	0.30 ± 0.07
High	0	0.04 ± 0.01	0	0.10 ± 0.02	0.22 ± 0.04	0.31 ± 0.06	0.03 ± 0.01	0.08 ± 0.02	0.25 ± 0.09	0.22 ± 0.05
$F_{2,6}$	—	0.98	—	1.36	1.14	0.05	0.18	1.07	2.80	0.16
P		0.43	—	0.33	0.38	0.95	0.84	0.40	0.21	0.85

Spring

Nitrogen fertilizer	*F. occidentalis*			*F. tritici*			*F. bispinosa*			
	Male	Female	Sex ratio[1]	Male	Female	Sex ratio[1]	Male	Female	Sex ratio[1]	Immatures
Low	1.02 ± 0.07	1.70 ± 0.09	0.35 ± 0.02	0.88 ± 0.08	0.94 ± 0.08	0.45 ± 0.02	0.05 ± 0.01	0.09 ± 0.01	0.27 ± 0.05	1.60 ± 0.10
Middle	1.00 ± 0.06	1.72 ± 0.08	0.34 ± 0.02	0.98 ± 0.09	1.17 ± 0.10	0.41 ± 0.02	0.03 ± 0.01	0.08 ± 0.01	0.27 ± 0.05	1.80 ± 0.13
High	1.07 ± 0.07	1.93 ± 0.09	0.32 ± 0.02	1.00 ± 0.09	1.24 ± 0.10	0.41 ± 0.02	0.06 ± 0.02	0.10 ± 0.01	0.31 ± 0.05	1.80 ± 0.12
$F_{2,14}$	0.52	2.14	0.96	0.97	3.69	1.21	0.50	0.35	0.20	0.46
P	0.60	0.16	0.41	0.40	0.06	0.33	0.62	0.71	0.82	0.64

[1]Proportion of males on a per flower basis.

TABLE 2. SEASONAL MEANS OF THRIPS IN FLOWERS LOCATED IN THE UPPER AND LOWER CANOPY OF TOMATOES FOR THE FALL 1999 AND SPRING 2000 SEASONS. MEANS AND STANDARD ERRORS FOR UNTRANSFORMED DATA ARE GIVEN. F VALUES, AND ASSOCIATED P VALUES, ARE FOR THE COMPARISON OF UPPER AND LOWER FLOWERS OVER EACH GROWING SEASON.

Fall

Canopy location	F. occidentalis			F. tritici			F. bispinosa			
	Male	Female	Sex ratio[1]	Male	Female	Sex ratio[1]	Male	Female	Sex ratio[1]	Immatures
Upper	0	0.22 ± 0.01	0	0.19 ± 0.03	0.22 ± 0.03	0.45 ± 0.04	0.05 ± 0.01	0.05 ± 0.01	0.40 ± 0.10	0.14 ± 0.03
Lower	0	0.22 ± 0.01	0	0.06 ± 0.02	0.19 ± 0.03	0.25 ± 0.05	0.02 ± 0.01	0.07 ± 0.01	0.22 ± 0.10	0.38 ± 0.05
$F_{1,24}$	—	0.06	34.6	16.76	0.44	4.79	9.73	1.96	0.01	21.3
P		0.81	<0.001	<0.001	0.51	0.037	0.005	0.17	0.97	<0.001

Spring

Canopy location	F. occidentalis			F. tritici			F. bispinosa			
	Male	Female	Sex ratio[1]	Male	Female	Sex ratio[1]	Male	Female	Sex ratio[1]	Immatures
Upper	1.55 ± 0.07	2.08 ± 0.08	0.40 ± 0.01	1.63 ± 0.09	1.78 ± 0.09	0.46 ± 0.01	0.08 ± 0.02	0.14 ± 0.01	0.30 ± 0.04	1.07 ± 0.02
Lower	0.50 ± 0.03	1.49 ± 0.07	0.25 ± 0.01	0.27 ± 0.03	0.45 ± 0.04	0.34 ± 0.02	0.02 ± 0.01	0.05 ± 0.01	0.24 ± 0.06	1.40 ± 0.03
$F_{1,48}$	355.3	69.1	34.6	412.0	282.6	4.4	20.4	47.8	0.56	90.8
P	<0.001	<0.001	<0.001	<0.001	<0.001	0.04	<0.001	<0.001	0.50	<0.001

[1]Proportion of males on a per flower basis.

and fall, but in relatively low numbers. These seasonal patterns also can change according to geography. Cho et al. (2000) report that populations of *F. tritici* peak earlier than those of *F. occidentalis* in western North Carolina. However, the tomato-growing season there occurs from June through August. Although it has been argued that seasonality is more important than host plant phenology in determining abundance of thrips (Salguero-Navas et al. 1991b), the definite peak and decline in the spring and fall populations of *F. tritici* suggest that host plant phenology also plays an important role in *Frankliniella* population dynamics, with younger plants being able to support greater densities than older plants.

Contrary to expectations, the different fertilizer treatments did not have a significant impact on populations of any of the thrips species. Previous studies have found that increased nitrogen fertilization results in higher populations of *F. occidentalis* in tomato (Brodbeck et al. 2001) and chrysanthemum (Schuch et al. 1998). Brodbeck et al. (2001) found that *F. occidentalis*, especially females, were responding to higher levels of the primary aromatic amino acid phenylalanine. Higher overall levels of aromatic amino acids tend to promote development of *F. occidentalis* larvae (Mollema & Cole 1996). The lack of a fertilizer effect in the present study may result from the method of application. The delay in final application of fertilizer was done to keep from burning the plants. This procedure may not have given the plants sufficient time to assimilate the extra nitrogen before the peaks in thrips populations had passed, whereas in the study done by Brodbeck et al. (2001) all fertilizers were applied preplant.

There was a consistent significant difference in the within plant distribution of adult and immature thrips, and this variation should be accounted for in sampling protocols. Previous studies have shown that *F. occidentalis*, *F. tritici* and *F. bispinosa* are more likely to inhabit flowers than other plant parts (Cho et al. 2000, Hansen 2000). Therefore, part of the variation in the within plant distribution of *Frankliniella* spp. may be related to microhabitat differences at this scale. Salguero-Navas et al. (1991b) also found that adults were more likely to be found in flowers in the upper parts of tomato plants than in flowers lower in the canopy. Because thrips are thought to make flights just above the plant canopy (Brødsgaard 1989, Gillespie & Vernon 1990), it is reasonable to expect that most adults would be found in flowers in the upper part of the plant canopy. The greater proportion of males in the upper canopy may be related to mating aggregations (Terry 1997). Males tend to aggregate in certain locations for mating, while females tend to depart these aggregation sites after mating. It also seems likely that females make substantial within plant movements, because most larvae were found in the lower canopy flowers. Salguero-Navas et al. (1991b) attribute the greater numbers of larvae in the lower part of tomato plants, in the commercial tomato fields they sampled, to differential exposure to insecticides. However, the fact that no insecticides were applied in the present study suggests that there is a qualitative difference in resources within a host plant for immature thrips.

A better understanding of species-specific population dynamics will lead to improved sampling protocols and management plans for flower thrips. For example, the early spring predominance of *F. occidentalis* females and high proportion of thrips larvae in tomatoes that are *F. occidentalis* (Salguero-Navas et al. 1991a; SRR, unpublished) suggest that a secondary cycle of TSWV in tomatoes in the north Florida region will be an ongoing risk. This risk may be underestimated if sampling protocols do not adequately account for factors such as within plant sample location and species and sex identification.

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