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RESEARCH ARTICLE

Predatory insect species, and patterns of abundance of two common thrips species (Thysanoptera) and their predators on common crops

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Abstract

Aim of study: The seasonal distributions of the western flower thrips, *Frankliniella occidentalis* (Pergande) and the onion thrips, *Thrips tabaci* Lindeman (Thysanoptera: Thripidae), as well as their primary predators, predatory bugs, *Orius* spp. (Hemiptera: Anthocoridae), in the polyculture agricultural area were investigated in order to gain a thorough understanding of the prey-predator relationships on various crop plants.

Area of study: Adana Province, located in the eastern part of the Mediterranean Region of Türkiye.

Materials and methods: Thrips and predatory insects were collected from various plants using the tapping method during 2019-2020. Their diversity, seasonal densities, and distributions were investigated.

Main results: A total of 11 predator species were identified, with *Orius laevigatus* (Fieber) and *Orius niger* (Wolff) being the most prevalent species. The greatest diversity of predatory insect species was found among plant species from the Fabaceae family. With the exception of field crops, *T. tabaci* was found to be the most frequent thrips species in the examined cultivated plants when compared to *F. occidentalis* on common crop plants. Among winter vegetables, a significant number of predators, primarily *O. laevigatus*, were only collected from broad bean plants. The abundance patterns of thrips and predatory insects were closely associated with the flowering phenology of plants.

Research highlights: Strong relationships were observed between *Orius* spp. and *T. tabaci* adults. This study suggests that broad beans, a winter crop, could be included in crop rotations during the autumn-to-early spring period to support the populations of predatory insects in various ways.

Additional keywords: broad bean; *Orius leavigatus*; *Thrips tabaci*; *Frankliniella occidentalis*; prey-predator interaction.

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Introduction

What sets thrips apart from other piercing-sucking insects is their tendency to create silvery-tan scar tissue in the areas they feed upon. This scar tissue, particularly when found on fruits, can significantly reduce the commercial value of the product. Moreover, certain species of *Frankliniella* flower thrips pose significant economic threats by transmitting virus diseases, such as the *Tomato spot wilt virus* and the *Impatiens necrotic spot virus*, which can cause severe damage to both vegetable crops and ornamental plants (Atakan et al., 2013). However, there are predatory thrips species within the Thysanoptera, including some from the genera *Aeolothrip*s, *Scolothrips,* and *Franklinothrips*, which prey on other thrips as well as soft-bodied arthropods (Lewis, 1997).

Thysanoptera species in Türkiye have mostly been studied in the Mediterranean, Aegean and some parts of Central Anatolia, and the Turkish Thysanoptera fauna has been published (Tunç & Hastenpflug-Vesmanis, 2016). Thysanoptera species have been detected in some temperate climate fruits (Atakan, 2008), summer and winter vegetable species (Atakan, 2007a,b) on hard and pome fruit trees in the Eastern Mediterranean Region, as well as ornamental plants grown both in greenhouses and outdoors (Atakan, 2011). But due to recent climate shifts like rising temperatures, several tropical Thysanoptera species have migrated to temperate regions and are posing a major threat to native ecosystems. For example, *Thrips hawaiiensis* (Morgan) (Thysanoptera: Thripidae), known as Hawaiian flower thrips, is found in Spain and Türkiye (Goldaranzena, 2011; Atakan & Pehlivan, 2021). It causes serious damage especially to lemon trees. On the other hand, hot pepper thrips, *Scirtothrips dorsalis* Hood (Thysanoptera: Thripidae) introduced to Türkiye in 2020, has been found to have economic importance in some crops in the Mediterranean region of Türkiye (Atakan & Pehlivan, 2021).

Species of the genus *Orius* (Hemiptera: Anthocoridae), commonly known as minute pirate bugs, are polyphagous predators and are particularly significant in controlling thrips populations especially in flowering stages of crop plants. One of these species, *Orius laevigatus* (Fieber), is extensively utilized through repeated releases for the biological control of flower thrips, a prevalent issue in greenhouses in May-August across various ecological regions worldwide (Tavella et al., 1991; Tommasini et al., 2004). Another species, *Orius niger* (Wolff), has been highlighted as a crucial biological control agent, actively preying on thrips infesting cotton in July-August in Türkiye (Atakan, 2006).

The distribution of Thysanoptera species in agricultural production areas and their species composition may be impacted by changes in crop plant diversity and climatic conditions (Tekşam & Tunç, 2009). This issue can provide information about the research of species, their economic importance, in certain plant groups or generally at certain time intervals; in this context, it can influence control efforts by considering biological agents of natural balance, such as hemipteran predators. For instance, the western flower thrips, *Frankliniella occidentalis* (Pergande) (Thysanoptera: Thripidae) that damages numerous crops in our nation economically (Tunç & Hastenpflug-Vesmanıs, 2016). For this purpose, a variety of predatory insect species including Thysanoptera were examined in relation to arable crop plants at the Balcalı location (Adana, Türkiye) inside a particular agro-ecosystem with varying crop patterns.

Material and methods

Description of sampling sites

In 2019-2020, a study was conducted to investigate thrips and predatory insect species diversity, their seasonal densities, and distributions in location Balcalı, Adana Province, Türkiye. The study focused on three distinct ecological areas where various plant species were cultivated for both production and research purposes. Specifically, in the Research and Application Area of the Department of Plant Protection, University of Çukurova, field crops such as cotton, soybean, sesame, and peanuts were sampled. In the Research and Application Area of the Department of Field Crops, the study concentrated on citrus and temperate climate fruits, including apples, nectarines, and loquats. These efforts were complemented by detections of thrips species in fruit trees in the Research and Application Area of the Horticultural Department. The research application sites are located 500–1000 m apart at different distances from one another.

Experimental procedures and insect samplings

For winter vegetable plants, plots were created in four territorial units using a randomised block trial design. The plants included spinach (*Spinacia oleracea*), lettuce (*Lactuca sativa*), cauliflower (*Brassica oleracea* var. *botrytis*), red cabbage (*Brassica oleracea* var. *appitate f. rubra*), cabbage (*Brassica oleracea*), rocket (*Eruca vesicaria*), peppergrass (*Lepidium sativum*), radishes (*Raphanus sativus*) and broad beans (*Vicia faba*). Each plot consisted of four rows, with fifteen plants in each row. A free space of 1.5 m was left between plots, and there were 5 m between the blocks. A similar trial model was created for the following summer vegetable plant species: cucumber (*Cucumis sativus*), squash (*Cucurbita moschata*), beans (*Phaseolus vulgaris*), peppers (*Capsicum annuum*), tomatoes (*Solanum lycopersicum*), potatoes (*Solanum tuberosum*) and eggplants (*Solanum melongena*). In order to examine the prevalence of thrips and predatory insects in specific field crops, four replicates of a randomised block design were used to create plots of cotton (*Gossypium hirsutum*), sesame (*Sesamum indicum*) and soybean (*Glycine max*). The plot size for each plant species was designed as 96 m^2 with a row length of 10 m, consisting of ten rows, with a distance of 0.80 m between rows. A free space of 2 m was left between the plots and 5 m between the blocks. Nectarines (*Pyrus persicae*) and pomegranates (*Punica granatum*) were planted with 3 × 5 spacing, apples (*Malus domestica*) with 1 × 4 spacing, pears (*Pyrus communis*) with 4 × 6 spacing, plums (*Prunus persica*), lemons (*Citrus lemon*) and almonds (*Prunus dulcis*) with 5 × 5 spacing and loquats (*Eriobotrya japonica*) with 7 × 7 spacing. Ten rows of each fruit tree species were planted, with 20 trees in each row. There was a 20-m gap between the large plots representing each fruit species, and they were lined up next to each other. Each tree species planted was nearly 15 years old. In the samplings, 20 plants from annual herbaceous crops (vegetable species and field crops) and 20 plants from perennial woody crops (fruit trees) were randomly selected. In general, the plants with flowers were taken into consideration in the samplings, which started with the beginning of the flowering period of the different plant groups. This choice was taken because *Orius* and thrips, their main prey, are primarily located on flowers. When there is no prey, these predatory species feed on the nectars and pollens in the flowers (Riudavets & Castane, 1994; Hansen et al., 2003; Kasina et al., 2009; Funderburk et al., 2000; 2018); 20–30 cm flowering or fruiting shoots oriented in four directions on the trees were chosen at random for sampling. In herbaceous plants, the upper halves of the plants were considered in the sample. In the surveyed areas, shoots or plants were shaken for 5–10 seconds into a white container measuring 34 × 23 × 7 cm, and the *Orius* species and herbivorous insects that fell into the container were lifted out by a suction tube and/or fine brush and placed in Eppendorf tubes containing 70% ethanol. Insect samples collected from each plant species on each sampling date were placed in a tube. The information about the samplings of insects in various plant groups is summarised in Table 1. Sampling was carried out in three different ecological areas on the same day between 08:00 and 12:00. Insect samples (*Orius* and herbivorous pest insects) were brought to the laboratory and placed in petri dishes to be counted under a stereo binocular microscope, to classify them as thrips, aphids or leafhoppers without making any distinction between species. While making the diagnosis, nymphs of *Orius* and larvae of thrips were sampled from the most common broad bean plants but were not evaluated because they were found only in very small numbers. *Orius* adults were separated according to morphological characteristics, after which they were identified.

Thrips and predatory insects' identifications

Microscopic preparations were done for the identifications of the collected Thysanoptera species. The samples, which were kept in tubes containing ethanol (60%), were taken to the AGA solution including ethanol, glacial acetic acid, and glycerin (9:1:1), for 2 days in order to soften the body tissues and partially empty the body contents (Zur Strassen, 2003). For interim preparations, light samples were incubated at 60 ^{o}C for approximately 30 minutes in 10% sodium hydroxide (NaOH) medium, while dark samples were incubated at 60 ^{o}C for approximately one hour, or until a little color shift occurred. The body contents of the samples were completely discharged by rubbing their bodies from the ventral or dorsal side in 96% ethanol. Individuals were placed in Hoyer medium and microscopic slides were made. A key identification guide according to Zur Strassen (2003) was used to assist in the identification of the thrips specimens. Under a stereo-binocular microscope with 45 magnifications, the morphological traits of *Orius* species and other hemipteran predators were inspected. Their identifications were made using the key identifications published by Péricart (1972), Önder (1982), and Çakır & Önder (1990). The key identification provided by Uygun (1981) was used to help identify the Coccinellidae species.

Statistical analysis

Some of the identified hemipteran predators and coleopteran predators were not assessed because they were only occasionally collected in small numbers

Table 1. Knowledge about the insect samplings in various plant groups in Balcalı during the years 2019-2020.

Plant group	No. of surveys	No. of plant species sampled	Insects/ sample	Sampling unit	Sampling period
Winter vegetables	15	9	135	Leaves+flowers	Oct. 2, 2019 – Mar. 18, 2020
Fruit trees	20	8	160	Leaves+flowers	Oct. 2, 2019 - May 27, 2020
Summer vegetables	23	7	161	Leaves+flowers	Oct. 2, 2019 – Dec. 18, 2019 and Apr. 15, 2020 -Oct. 21, 2020
Field crops	15	4	60	Leaves+flowers	Oct, 2, 2019- Nov. 20, 2019 and Jul. 1, 2020- Oct. 21, 2020

from herbaceous plants and fruit trees. The abundance patterns of thrips and predatory insects (*Orius* spp.) were determined in plant species where the insect species commonly occurred, representing various plant groups, including winter and summer vegetables, fruit trees, and field crops. To compare the seasonal average population densities of both thrips and predatory insects in different plant species, we applied a homogeneity test by Shapiro-Wilk test, confirming their normal distribution. We used analysis of variance (ANOVA) on the means, and when significance was found, we conducted post-hoc analyses using the Tukey test (p<0.05). In different plant groups, we assessed plant, insect and *plant* × *insect* interactions through a two-way analysis of variance. Additionally, we evaluated the relationships between thrips and *Orius* population patterns using Pearson correlation analysis at the p<0.05 significance level. For this analysis, we considered 15 average values for winter vegetables, 20 for fruit trees, 23 for summer vegetables, and 15 for field crops. The data were analyzed by statistical package program SPSS© version 25 (IBM Corp., 2017).

Results

Predatory insect species identified on plants

Predatory insect species were collected in 28 plant species from 11 plant families, along with thrips (Table 2). A total of 11 predatory insect species were identified, including 3 Coccinellidae, 2 Lygaeidae, 2 Miridae, and 4 Anthocoridae (Table 3). Predatory insects were not detected in winter vegetable species, except for cauliflower. From the predatory insects, only those found on summer cabbage were recorded, with a total of 270 individuals.

The highest number of predatory insect species was found in plant species belonging to the Fabaceae with a total of 161 insects (Table 2). More individuals were collected from broad beans and beans in this family. In sesame plants, which are field crops, 5 predator species were identified, with a total of 23 individuals. Also, a total of 23 individuals were collected in potato which is grown as a rotation crop and harvested at the end of May in the Cukurova region. *O. laevigatus* (19 individuals) was mostly found on potato flowers. In fruit trees, generally 2-3 species were identified, and the number of individuals was quite low, with the highest number being 8 individuals of *O. laevigatus* in apple flowers.

Population densities and dynamics of two thrips species and predatory *Orius* spp. in plant species

Table 4 shows that in winter vegetables, the interaction between insect species and plant species was found to be significant, while insect species alone appeared as an important factor in fruit trees. For summer vegetables, plant species, insect species, and the interaction between them were identified as crucial factors influencing population densities. In the case of field crops, only insect species was recognized as a significant factor affecting population densities.

Winter vegetables

The population changes of two common harmful thrips species and *Orius* species in three winter vegetable species were recorded (Fig. 1). Very few thrips individuals were recorded in pea flowers. Mostly, adult *Orius* individuals were collected from pea flowers. The density of adult *Orius* individuals appears to be higher when the number of flowers is high (January-February) (Fig. 1a). On cauliflower plants, mainly *T. tabaci* adult individuals were recorded. The highest number of individuals in this plant was on November 6 (12.75±1.10 individuals/plant) and November 20 (10±1.08 individuals/plant) (Fig. 1b). On cauliflower, no *F. occidentalis* individuals were found. *Orius* spp. individuals were recorded only on January 29 (2.00±0.40 individuals/plant) (Fig. 1b). Cabbage plants only had *T. tabaci* individuals (Fig. 1b), and cabbage plants had its higher population densities in October-November than other sampling period. Thrips individuals were not observed in winter and early spring (March). The highest population density of *T. tabaci* was found on November 20, with 14.25±0.47 individuals/plant. Among the winter vegetables, only in pea plants, a statistically significant relationship was found between *Orius* and thrips (r (15) = 0.57, p = 0.024).

Overall, the seasonal mean population densities of *F. occidentalis* were similar in pea, cauliflower, and cabbage plants, while *T. tabaci* was significantly found on cauliflower ($F_{2,177}$ = 8.974, p<0.0001; Table 5). *Orius* individuals were collected in significant numbers from pea flowers ($F_{2,177}$ = 42.444, p<0.0001; Table 5).

Fruit trees

In fruit trees, the most common species was *T. tabaci* and it was recorded with the period of high flowering (**Fig. 2a**). During this period, *Orius* individuals were also recorded alongside thrips. *Orius* population showed a significant positive relationship with the thrips population (r (15) = 0.99, p<0.0001). In loquat trees, during the period of high flower density in the region, mostly *T. tabaci* individuals were found, and during this period (Fig. 2b), *Orius* individuals were also recorded alongside thrips (Fig. 2b). A high and significant positive relationship was found between *Orius* and thrips individuals (r (15) = 0.88, p<0.0001). During the fruiting period, thrips and *Orius* individuals were not found. Thrips individuals on nectarine were recorded at the beginning of flowering (Fig. 2c). *Thrips tabaci* showed a peak in the average number of individuals on April 1 (2.75± individuals/shoot) (Fig. 2c).

Table 2. Total number of species of predatory insects on common crop plants sampled in Balcalı in 2019-2020

Family/species	Cam	Coc	Exo	Gar	Nt	Orn	Orl	Ora	Orv	Per	Ste	Total
Amaranthaceae												
Spinach (*Spinacia oleracea*)	0	0	0	0	0	0	0	0	0	0	0	0
Asteraceae												
Lettuce (*Lactuca sativa*)	0	0	0	0	0	0	0	0	0	0	0	0
Brassicaceae												
Cauliflower *(Brassica oleracea* var. *Botrytis*)	0	0	0	0	0	1	0	0	0	0	0	1
Red cabbage (*Brassica oleracea* var. *capitate f. Rubra*)	0	0	0	0	0	0	0	0	0	0	0	0
Cabbage (*Brassica oleracea*)	0	0	0	0	0	0	0	0	0	0	0	0
Rocket (*Eruca vesicaria*)	0	0	0	0	0	0	0	0	0	0	0	0
Peppergrass (*Lepidium sativum*)	0	0	0	0	0	0	0	0	0	0	0	0
Radish (*Raphanus sativus*)	0	0	0	0	0	0	0	0	0	0	0	0
Cucurbitaceae												
Cucumber (*Cucumis sativus*)	0	0	0	0	0	1	0	0	0	0	0	1
Squash (*Cucurbita moschata*)	0	0	0	0	13	0	0	0	0	0	0	13
Fabaceae												
Broad bean (*Vicia faba*)	1	0	3	0	0	24	86	0	0	0	3	117
Bean (*Phaseolus vulgaris*)	0	4	0	5	0	12	8	1	0	0	0	30
Soybean (*Glycine max*)	0	5	0	3	0	0	1	0	0	1	0	10
Peanut *(Arachis hypogaea*)	0	3	0	0	0	1	0	0	0	0	0	4
Lythraceae												
Pomegranate (*Punica granatum*)	0	0	0	0	0	0	2	0	0	0	0	2
Malvaceae												
Cotton (*Gossypium hirsutum*)	0	0	0	1	0	6	2	0	0	0	0	9
Pedeliaceae												
Sesame (*Sesamum indicum*)	1	0	0	5	0	3	12	0	0	2	0	23
Rutaceae												
Lemon (*Citrus* lemon)	0	0	0	0	0	0	0	0	0	0	0	0
Rosaceae												
Pear *(Pyrus communis*)	0	0	0	0	0	0	0	0	0	0	0	0
Almond (*Prunus dulcis*)	0	0	0	0	0	1	1	0	0	0	0	2
Apple (*Malus domestica*)	0	0	0	3	0	1	8	0	1	0	0	13
Plum (*Prunus domestica*)	0	0	0	0	0	0	0	0	0	0	0	0
Peach (*Prunus persica*)	0	0	0	3	0	0	0	0	0	0	0	3
Loquat *(Eriobotrya japonica*)	0	0	0	0	0	2	5	0	0	0	0	7
Solanaceae												
Pepper (*Capsicum annuum*)	1	0	0	1		3	3	0	0	0	0	8
Tomato (*Solanum lycopersicum*)	0	0	0	0	2	0	0	0	0	0	0	2
Potato (*Solanum tuberosum*)	0	0	0	0	0	4	19	0	0	0	0	23
Eggplant (*Solanum melongena*)	0	0	0	0	0	1	1	0	0	0	0	2
Total	3	12	3	21	15	60	148	1	1	3	3	270

Cam: *Campylomma nicolasi,* Coc: *Coccinella semptempunctata*, Exo: *Exochomus quadripustulatus*, Gar: *Geocoris arenarius,* Nt: *Nesidiocoris tenuis*, Orn: *Orius niger*, Orl: *Orius laevigatus*, Ora: *Orius albidipennis*, Orv: *Orius vicinus*, Per*: Piocoris erythrocephalus,* Ste: *Stethorus gilvifrons*

Table 3. List of predatory insect species collected from common crops in Türkiye's Adana Province in 2019-2020

Order	Family	Insect species	No.
Coleoptera	Coccinellidae	*Coccinella semptempunctata* L.	12
		Exochomus quadripustulatus (L.)	3
		Stethorus gilvifrons (Mulsant)	3
		Orius albidipennis (Reuter)	1
Hemiptera	Anthocoridae	*Orius laevigatus* (Fieber)	148
		Orius niger (Wolff)	60
		Orius vicinus (Ribaut)	1
	Lygaeidae	*Geocoris arenarius* Jakovlev	21
		Piocoris erythrocephalus (Le Peletier & Serville)	3
		Campylomma nicolasi Puton & Reuter	3
	Miridae	*Nesidiocoris tenuis* Reuter	15
		Total	270

Table 4. Results of two-way ANOVA for winter vegetables, fruit trees, summer vegetables and field crops

Variation sources	df	MS	F
		Winter vegetables	
Plant	2	0.969	0.234 ns
Insect	2	108.291	26.177**
Plant × Insect	4	81.863	19.740**
Error	531	4.137	
		Fruit trees	
Plant	2	0.339	1.483 ns
Insect	2	1.468	6.422*
Plant × Insect	4	0.397	0.140 ns
Error			
		Summer vegetables	
Plant	2	19.948	6.470*
Insect	2	46.066	14.941**
Plant × Insect	4	21.448	6.956*
Error			
		Field crops	
Plant	2	0.535	0.398 ns
Insect	2	11.369	23.100**
Plant × Insect	4	0.891	0.125 ns
Error			

df: degrees of freedom. MS: mean square. ns: not significant, * p<0.05, ** p<0.0001

The mean numbers of *F. occidentalis* and *T. tabaci* individuals in apple, loquat, and nectarine trees were similar (p>0.05; Table 5). Seasonal mean numbers of *Orius* spp. adult individuals in apple and loquat flowers were statistically significant compared to nectarine ($F_{2,237}$ = 4.473, p = 0.024; Fig. 2b).

Table 5. Seasonal mean (±SEM)[a] numbers of two pest thrips species and *Orius* spp. in some plant species sampled in Türkiye's Adana Province in during 2019-2020.

Insect species	Winter vegetables		
	Cauliflower	**Broad bean**	**Red cabbage**
Frankliniella occidentalis	0.16±0.11	0.16±0.13	0.00±0.00
Thrips tabaci	2.35±0.52a	0.08±0.43b	2.21±0.51a
Orius spp.	0.00±0.00b	1.83±0.28a	0.00±0.00b
	Fruit trees		
	Apple	**Loquat**	**Nectarine**
Frankliniella occidentalis	0.02±0.01	0.05±0.03	0.07±0.02
Thrips tabaci	0.28±0.09	0.15±0.04	0.17±0.07
Orius spp.	0.16±0.06a	0.15±0.05a	0.00±0.00b
	Summer vegetables		
	Bean	**Pepper**	**Potato**
Frankliniella occidentalis	0.36±0.08a	0.13±0.04b	0.11±0.04b
Thrips tabaci	0.88±0.30ab	0.12±0.04b	1.78±0.44a
Orius spp.	0.29±0.06	0.18±0.05	0.15±0.05
	Field crops		
	Cotton	**Sesame**	**Soybean**
Frankliniella occidentalis	0.55±0.14	0.45±0.11	0.51±0.15
Thrips tabaci	0.00±0.00	0.00±0.00	0.16±0.01
Orius spp.	0.26±0.08a	0.36±0.09a	0.00±0.00b

[a] Means that share the same letter in the same row are not statistically significant at the significance level of p>0.05 according to the Tukey test.

Summer vegetables

In bean plants, both *F. occidentalis* and *Orius* individuals were collected during planting and November, even though there was low flower density (Fig. 3). In the following spring plantings, during the dates of intense flowering (April 29 to July 3), both thrips species and predatory individuals were observed to have high densities (Fig. 3a). On bean flowers during these dates, *F. occidentalis* had an individual count of 2 or more, and the density of *T. tabaci* reached its peak on June 3, recording 13.5±0.64 individuals. During these dates, *Orius* spp. had an average individual count ranging from 0.5 to 1.5 individuals/plant. However, in beans, population change was only observed in relation to *Orius* individuals and *F. occidentalis* individuals (r (15) = 0.57, p = 0.05). In pepper plants, the population densities of thrips species and *Orius* individuals remained below 1 individual on a random sampling date (Fig. 3b). No relationship was found between thrips and *Orius* individuals (p>0.05). In potatoes, mainly *T. tabaci* individuals were caught. During the mid-April to late May period when flowering was intense, the average number of *T. tabaci* individuals was just over 10 individuals/plant. When the thrips population decreased in early June, adult *Orius* individuals were observed for a short time. No relationship was observed between *Orius* individuals and the populations of the two thrips species (p>0.05).

Frankliniella occidentalis was collected more from bean plants ($F_{2,261}$ = 5.807, p = 0.003) than those found in other plant species, while *T. tabaci* was significantly recorded in potato flowers ($F_{2,261}$ = 7.024, p = 0.001; Table 5). Numbers *Orius* spp. were similar in vegetable species (p>0.05; Table 5).

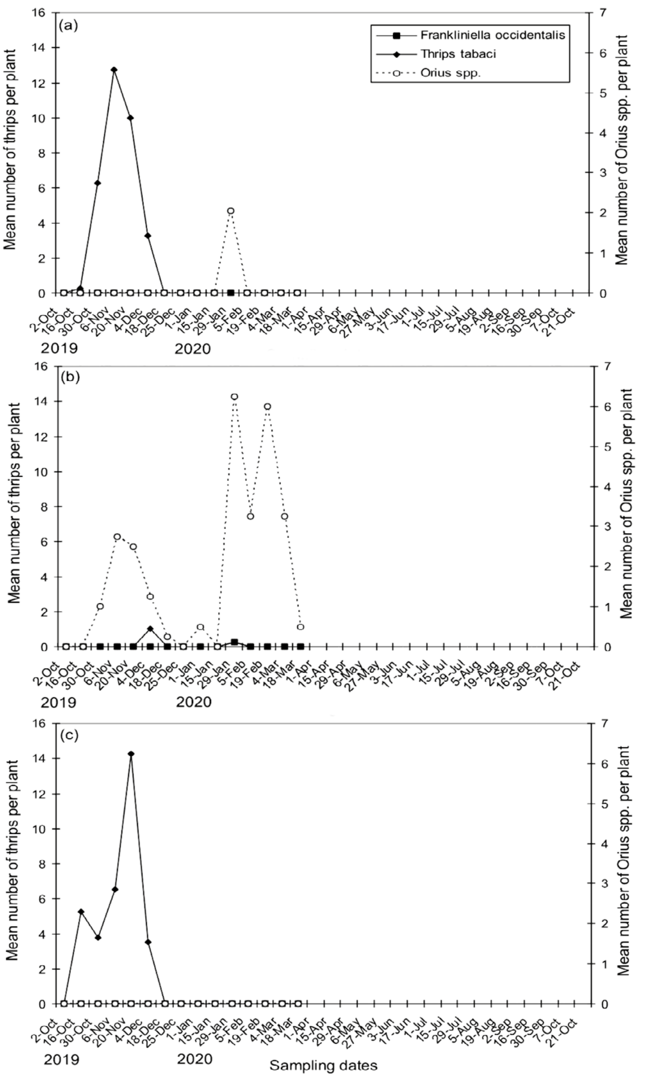

Figure 1. Mean numbers of two pest thrips species and *Orius* spp. on broad beans (a), cauliflower (b) and red cabbage (c) in Adana Province, Türkiye, during 2019-2020

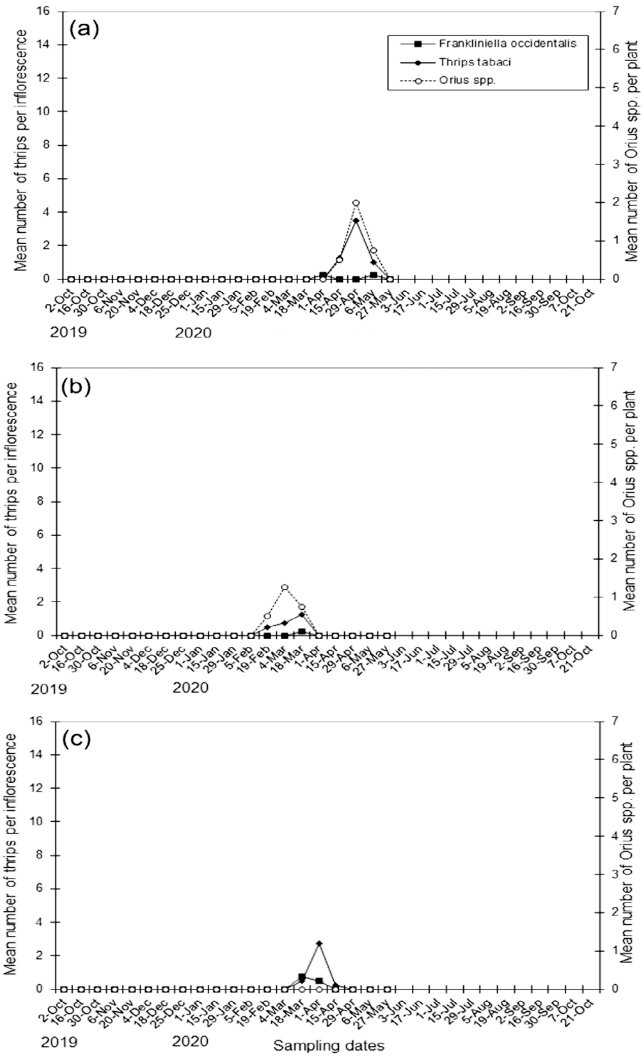

Figure 2. Mean numbers of two pest thrips species and *Orius* spp. on apple (a), loquat (b) and nectarine (c) in Adana Province, Türkiye, during 2019-2020.

Field crops

In the autumn month of 2019 (October), very few thrips and *Orius* individuals were collected from cotton, soybean, and sesame plants, and *T. tabaci* individuals were not found (Fig. 4a,b,c). In 2019, as flowering began in the plants, *F. occidentalis* was recorded in relatively higher numbers. On August 19, the numbers of thrips or *Orius* spp. in cotton (thrips: 2.50±0.64 individuals/plant, *Orius* spp. 2.00±0.40 individuals/plant), soybean (thrips: 4.25±0.62 individuals/plant), and sesame plants (thrips: 2.50±0.64 individuals/plant, *Orius* spp.: 1.00±0.40 individual/plant) were higher compared to those numbers found on other sampling dates. Positive correlations were found between *Orius* and *F. occidentalis* individuals in cotton (r (15) = 0.86, p<0.0001) and in sesame (r (15) = 0.61, p = 0.040) plants.

The seasonal mean densities of *F. occidentalis* and *T. tabaci* were similar in cotton, sesame, and soybean flowers, while *Orius* individuals were captured in significant numbers in cotton and sesame plants, but in soybean plants, they were significantly fewer ($F_{2,177}$ = 6.616, p = 0.020; Table 5).

Seasonal distribution of two thrips species and predatory *Orius* spp. on various plant species (%)

On broad beans among winter vegetables, it was observed that predatory *Orius* was the main predatory insect during the sampling period (Table 6). Thrips individuals were observed on cauliflower between October and January, and the main harmful thrips species was *T. tabaci*.

Thrips individuals and *Orius* spp. were recorded on apple trees in April and May, with the harmful *T. tabaci* being the most common species on the flowers, followed by predators at percentages of 26% and 38%, respectively (Table 6). In loquat flowers, predators were most commonly found

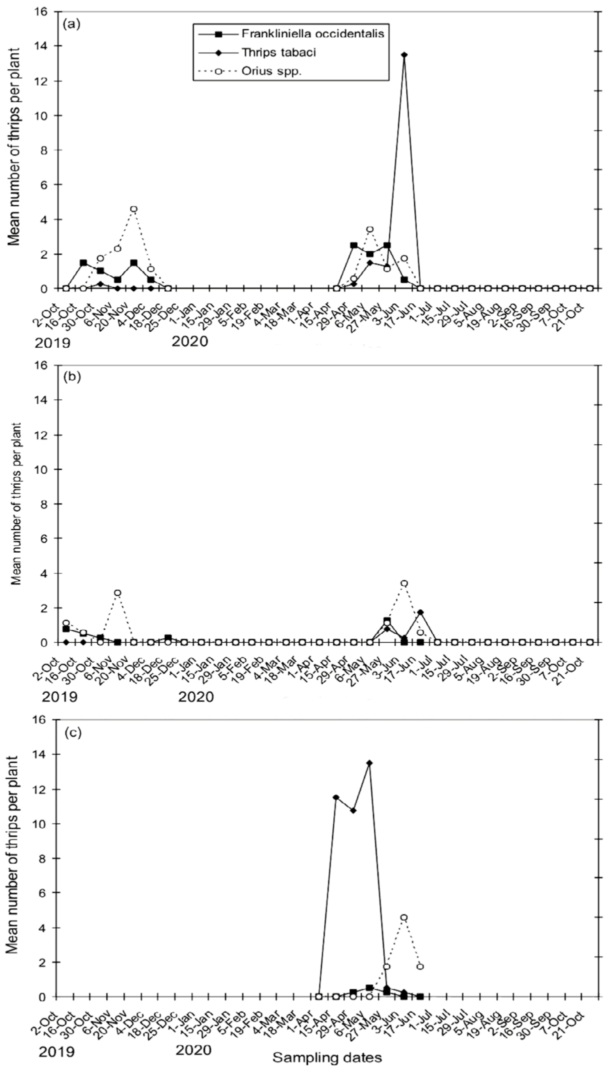

Figure 3. Mean numbers of two pest thrips species and *Orius* spp. on bean (a), pepper (b) and potato (c) in Adana Province, Türkiye, during 2019-2020.

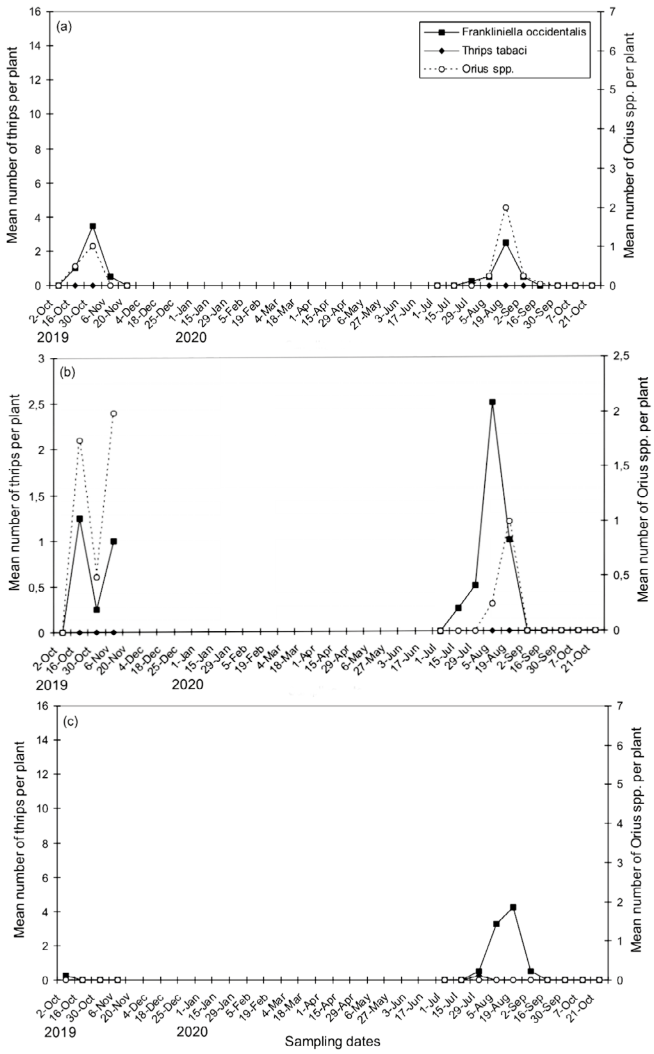

Figure 4. Mean numbers of two pest thrips species and *Orius* spp. on cotton (a), sesame (b) and soybean (c) in Adana Province, Türkiye, during 2019-2020.

in February (60%), while in March and April, *T. tabaci* was quite common (60% and 100%, respectively). *Thrips tabaci* was the predominant species in nectarine flowers only in April (77%).

On beans, *F. occidentalis* was more common in October to December, while *T. tabaci* became the main thrips species in April to June (Table 6). *Orius* spp. was only commonly found in November (60%). In pepper flowers, *F. occidentalis* was generally common in October to December, but in November, *Orius* individuals were mostly found (83%) (Table 6). *Thrips tabaci* was found in the highest percentage (58%) in May. In potato flowers, *T. tabaci* individuals were primarily recorded. In June, when *Orius* individuals were common (92%), thrips individuals were detected in small numbers.

Throughout the samples, *F. occidentalis* individuals were recorded at high rates in cotton flowers. In sesame, *Orius* individuals were mostly found in the autumn months, while *F. occidentalis* became the main thrips species in the summer months. In soybean flowers, only *F. occidentalis* was recorded (Table 6).

Discussion

The fact that *Orius* individuals were identified in extremely low numbers may be connected to the absence of flowers on the plants throughout the sampling periods, even though thrip counts were larger in winter vegetables than in other crop plants, with the exception of broad beans. It is worth noting that broad bean plants showed lower numbers of the both thrips species. The high number of *Orius* in broad bean plants could be attributed to the plants' morphological structure and chemical content such as the presence of extrafloral nectars for them to feed on, rather than relying solely on preys such as thrips. In the Çukurova

Table 6. Percentages of two pest thrips species and *Orius* spp. on common crop plants according to sampling months in Adana Province, Türkiye during 2019-2020

Month	*F. occidentalis*	*T. tabaci*	*Orius* spp	*F. occidentalis*	*T. tabaci*	*Orius* spp	*F. occidentalis*	*T. tabaci*	*Orius* spp
	Winter vegetables								
	Cauliflower			**Broad bean**			**Red cabbage**		
Oct	3	97	0	0	0	100	0	0	0
Nov	0	100	0	0	0	100	0	0	0
Dec	0	100	0	0	40	60	0	0	0
Jan	0	100	0	3	3	94	-	-	-
Feb	-	-	-	0	0	100	-	-	-
Mar	-	-	-	0	0	100	-	-	-
Apr	-	-	-	0	0	0	-	-	-
	Fruit trees								
	Apple			**Loquat**			**Nectarine**		
Oct	0	0	0	0	0	0	0	0	0
Nov	0	0	0	0	0	0	0	0	0
Dec	0	0	0	0	0	0	0	0	0
Jan	0	0	0	0	0	0	0	0	0
Feb	0	0	0	24	40	60	0	0	0
Mar	0	0	0	0	65	11	0	0	0
Apr	4	70	26	0	100	0	23	77	0
May	12	50	38	0	0	0	0	0	0
	Summer vegetables								
	Bean			**Pepper**			**Potato**		
Oct	71	8	21	63	0	37	-	-	-
Nov	40	0	60	17	0	83	-	-	-
Dec	100	0	0	100	0	0	-	-	-
Jan	-	-	-	-	-	-	-	-	-
Feb	-	-	-	-	-	-	-	-	-
Mar	-	-	-	-	-	-	-	-	-
Apr	0	91	9	50	40	10	2	98	0
May	24	57	19	0	58	42	10	85	5
Jun	3	94	3	-	-	-	8	0	92
Jul	4	92	4	-	-	-	-	-	-
Aug	0	0	0	-	-	-	-	-	-
	Field crops								
	Cotton			**Sesame**			**Soybean**		
Oct	75	0	25	100	0	0	37	0	63
Nov	65	0	35	100	0	0	30	0	70
Jul	100	0	0	100	0	0	100	0	0
Aug	57	0	43	100	0	0	71	0	29
Sep	67	0	33	100	0	0	100	0	0
Oct	0	0	0	0	0	0	0	0	0

-: No insect was found during the sampling periods region, broad bean plants are blooming from December to early March, providing large, covered flowers that may serve as protection, shelter and even sites for mating and egg laying for predatory species like *Orius*. Moreover, broad bean plants are known to be richer in extrafloral nectars, attracting many beneficial insects (Nuessly et al., 2004). Notably, *O. niger* and *O. laevigatus* species had been detected in both winter and summer vegetables in the Çukurova region (Zeren & Düzgüneş, 1983). In another study conducted in the same region, thrips were investigated, and their abundance and distribution patterns were documented. However, the information in the text was cut off before the study's specific findings could be mentioned. To summarize, the presence of flowers and extrafloral nectars in broad bean plants may have contributed to the higher number of *Orius* individuals, while their low presence in other winter vegetables could be attributed to the absence of these essential resources during that season.

Frankliniella occidentalis and *T. tabaci* were found in less numbers in the summer vegetables in current study. While *O. laevigatus* was most common in winter vegetables (mainly broad beans), *O. niger* dominated in summer vegetables (mainly beans). *O. laevigatus* was the most prevalent *Orius* species in Antalya (66%), according to the Bahşi (2011) survey, followed by *O. niger* (33%). Additionally, *Orius limbatus* (Wagner), *Orius majusculus* (Reuter), *Orius minutus* (L.) and *Orius vicinus* (Ribaut) were also recorded in that region. The number of thrips and *Orius* individuals on beans, among the summer vegetables, were higher compared to peppers and potatoes. Additionally, a significant relationship between *Orius* and thrips individuals was only observed on beans. This situation may suggest that flowering bean plants can serve as a trap plant for thrips and a banker plant for *Orius*.

Thrips were the most prevalent pest group in various plant samples, often found alongside *Orius* species. *Orius* populations were relatively low in fruit trees, indicating a preference for herbaceous habitats regardless of prey species and their densities. However, except for nectarine trees, a significant and positive correlation between the numbers of both thrips species and *Orius* were recorded on apple and loquat trees. This situation can be attributed to the fact that especially loquat trees provide thrips as a food source to predatory insects (especially for *Orius*) by remaining flowering during the autumn-winter period, allowing them to survive. Although especially during times when the populations of *T. tabaci* were high in winter vegetables predator populations were very low or absent. The absence of flowers on the plants during periods of high *T. tabaci* population, in other words, when plants were in their vegetative stage, may not be attractive to predators. While a significant interaction between *T. tabaci* and *Orius* was observed in Okitsu mandarin flowers, not found for *F. occidentalis* (Atakan & Pehlivan, 2020). Additionally, even though the densities of *T. tabaci* in the flowers of fruit trees were low and of short duration, a strong and positive relationship were detected between the *Orius* and its prey (Fig. 2). The smaller size of *T. tabaci* compared to *F. occidentalis* and its lower resistance to predator attacks may be one reason for this issue (Deligeorgidis, 2002).

Orius species densities were lower in field crops like cotton, and sesame (Fig. 4). Low thrips and *Orius* population densities in the sampled field crops could be attributed to insecticide applications made beyond our control. However, the significant and positive relationships between *Orius* and thrips population densities in both cotton and sesame plants suggest that under pesticide-free conditions, *Orius* individuals may be capable of controlling thrips. This is particularly important in late-planted cotton fields, as *Frankliniella* flower thrips maintain their significance as a pest. Previous studies in the same ecological area in pesticide-free cotton fields revealed that a significant number of *Orius* adults preying on flower thrips (mainly *F. occidentalis*) in cotton flowers (Atakan, 2006), and *O. niger* closely followed the populations of *Frankliniella* flower thrips, indicating that this predatory bug could effectively suppress pest thrips in unsprayed cotton fields (Atakan, 2006).

The distribution and population of *Orius* in different plant groups varied primarily due to thrips populations, which appeared to be their main prey. Studies on field peppers (Funderburk et al., 2000; Hansen et al., 2003; Funderburk et al., 2018) and cotton (Atakan & Özgür, 2001; Atakan, 2006) confirmed that *Orius* plays an essential role in controlling *Frankliniella* flower thrips, leading to reduced thrip populations in the absence of pesticide application. Thrips and leafhoppers, along with *Orius*, were recorded on summer vegetables and newly planted broad beans in autumn. In spring, the insects found on fruit trees were mainly thrips and low numbers of *Orius* individuals. After the flowering period of the sampled trees, thrips and *Orius* shifted together to summer vegetables, indicating similar distribution patterns and population dynamics throughout the year, according to the flowering cycle of cultivated plants.

Thrips and *Orius* were collected primarily from the flowers of the sampled cultivated plants, except for broad beans, where few predators were found during the winter months, likely due to the lack of blooming. *Orius* nymphs and adults were observed colonizing broad bean's flowers infested by the thrips, depending on thrips density (Ramachandran et al., 2001; Reitz et al., 2003). The scarcity of thrips larvae in all plants sampled may be because the predators prefer thrips larvae, as they are less mobile and easier to prey on than adult thrips (Funderburk et al., 2000; Baez et al., 2004). Despite low *Orius* numbers in the sampled plants compared to previous studies in the area, the prey/predator ratios were low in many plants, suggesting that thrips, in particular, were at risk of being preyed upon. For instance, in field conditions in Florida (USA), 40 thrips per predator were sufficient to keep the thrips population in control (Funderburk et al., 2000; Reitz et al., 2003).

As a result, hemipteran predators, especially *Orius* species were common in the ecosystem defined as a polyculture area. *Orius* spp. were particularly closely associated with thrips populations. Among the winter vegetables sampled, broad beans may be essential for the conservations of beneficial insects and as a source of alternative foods (both as thrips prey and for nectars and pollens). Therefore, broad beans should be included in habitat planning. Similarly, in the case of summer vegetables, beans can play a role in sustainable agriculture within the ecosystem. They can serve as a trap for thrips and a banker plant for beneficial insects. The presence of flowering and nectar-bearing plants throughout the year is believed to promote more dynamic and healthier trophic relationships, at least between thrips and their predators.

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