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An Analysis of Predatory Bugs (*Orius* spp., Hemiptera: Anthocoridae) and Pest Insects on Some Crop Plants: Their Distributions, Abundance and Population Developments

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ABSTRACT

The seasonal distributions of predatory bugs, specifically species of *Orius* (Hemiptera: Anthocoridae), and the population dynamics of some sucking pests including aphids, leafhoppers, and thrips in crops plants (i.e. winter and summer vegetables, fruit trees and field crops) in Balcalı, Adana Province, Turkey, were investigated during 2019–2020. A total of four *Orius* species were identified, which are: *Orius laevigatus* (Fieber), *Orius niger* (Wolff), *Orius albidipennis* (Reuter) and *Orius vicinus* (Ribaut). The most common species was *O. laevigatus*, constituting 78.36% of the total adult individual insects. Both *O. laevigatus* and *O. niger* were relatively more abundant on broad beans, beans and potatoes compared to fruit trees and open field crops, such as cotton, sesame and soybean. Very few *Orius* individuals were recorded on fruit trees. Those that were recorded were found mostly on apple trees. *Orius* and thrips individuals were collected mainly from the flowers of the plants, and their population patterns depended on the flowering phenology patterns of the plants. Significant correlations were detected between the population patterns of *Orius* individuals and thrips populations in winter and summer vegetables, fruit trees and field crops. This may indicate that thrips are the primary prey of *Orius* individuals throughout the year in agricultural ecosystems with rich plant diversity.

Keywords: Density, Broad bean, Distribution, *Orius laevigatus*, Pest thrips

1. Introduction

To maintain the population of harmful insects/mites at a rate below the economic damage threshold in plant production and increase yields, insecticides/acaricides have been widely used due to their biological effectiveness and rapid suppression of pests (De Waard et al. 1993). Pesticides were first introduced in the 1940s and, while their use has increased, as have their negative effects, the widespread commercial use of pesticides initially did not raise concerns about residue problems. Harmful organisms such as insects and mites have developed resistance to pesticides over time, potentially rendering them less effective in the future (Bass et al. 2015; Gould et al. 2018). The indiscriminate and intensive use of pesticides in modern agriculture has adverse effects on human and environmental health. It leads to pesticide resistance, a reduction in beneficial organisms, decreased biodiversity in agricultural ecosystems and crop residue problems (Carson 1962; Brammall & Higgins 1988; Dreistadt et al. 1994; Rosell et al. 2008; Pereira et al. 2016; Silva et al. 2019; Alengebawy et al. 2021). As an alternative to chemical control, there have been efforts to adopt more economical and environmentally friendly methods that promote the health of living organisms and minimise the unnecessary use of pesticides. Studies on biological control methods have been conducted for this purpose (Clausen 1958; Howarth 1991; Bueno et al. 2006).

Some predatory insect species, which belong to the Anthocoridae (Hemiptera) family, are commercially reared and used primarily to control harmful thrips in greenhouses (Riudavets & Castena 1994; Topakçi & Keçeci 2017; Van Lenteren et al. 2020). The genus *Orius* in the family Anthocoridae is common in nature, particularly in areas with high biodiversity, and six species of this genus have been recorded in Turkey (Önder 1982). Both nymphs and adults of the *Orius* species exhibit zoophagous behaviour, feeding on various insects and mites that are detrimental to plants, including whiteflies, aphids, spider mites, psyllids, Lepidoptera and Coleoptera, with a particular focus on species of thrips (order Thysanoptera) (Riudavets and Castane 1994; Önder 1982; Lodos 1986; Lattin 1999; Pehlivan & Atakan 2020). *O. laevigatus*, *Orius insidiosus* (Say), and *Orius tristicolor* (White) have been commercially used for controlling *Frankliniella occidentalis* (Pergande) in protected crops since 1990 (Chambers et al. 1993; Ferragut & Zamora 1994; Disselvet et al. 1995; Pozzebon et al. 2015). *Orius niger* (Wolff) has been found together with *F. occidentalis* on weeds in the Adana and Mersin Provinces, located in the Eastern Mediterranean region of Turkey (Atakan & Tunç 2010). In the Adana Province, *O. niger* was the most common species in fields where broad beans, clovers and strawberries were cultivated (Atakan &Tunç 2004; Atakan 2010a; Atakan 2011).

While polyphagous *Orius* species are generally associated with thrips, understanding their interactions with different types of prey in various crop plants throughout the season can provide valuable ecological information about their role in suppressing crop pests. This study aimed to examine the composition of predatory *Orius* species and the distribution of common pests, such as aphids, thrips and leafhoppers, in various agricultural crop plants products within a designated polyculture ecosystem. Additionally, it investigated the population changes and interactions among these pest insects. The results obtained about the importance of the *Orius* species as biological control agents of crop pests will be discussed. Overall, the study provides valuable insights into the seasonal dynamics of the *Orius* species and pest insects across various plant groups in different ecological areas, enhancing our understanding of their interactions and population fluctuations in agricultural areas.

2. Material and Methods

2.1. Definition of sampling area

The location Balcalı is a neighbourhood located in Adana Province, Turkey. It houses the Çukurova University, Faculty of Agriculture Research and Application Farm, situated approximately seven kilometers away from the main campus. This research area spans around 700 hectares where citrus, stone fruits, subtropical fruits and both cool and warm climate cereals are cultivated. In addition, wheat is grown in an area of approximately 400 hectares that is not irrigated. Flood irrigation is the predominant method used in irrigable sections. It is worth mentioning that the region also serves as a nature reserve, ensuring the protection of wildlife. The location Balcalı experiences a typical Mediterranean climate, characterised by warm and dry summers, mild and wet winters and overall moderate temperatures throughout the year.

2.2. Sampling of insects

Seasonal abundance and distribution of the *Orius* species, and its relationships with different types of prey (thrips, aphids and leafhoppers) were investigated in Balcalı at the Çukurova University Farm, in 2019–2020. Three ecological areas have been identified where different plant species are grown for both production and research. For this purpose, winter and summer vegetables and citrus were sampled in the Research and Implementation Area of the Plant Protection Department to check for numbers of pest insects such as aphids, leafhoppers and thrips, as well as predatory bugs. In the Field Crops Research and Implementation Area, various field crops, including cotton, soybean, sesame, peanuts, and temperate climate fruit trees such as apple, nectarine, and loquat, were sampled as part of the research conducted in Research and Implementation Area of the Horticulture Department. The sampling sites are about two or three kilometers apart from each other. Insect pests have been recorded on all these plants. Species-level distinctions were not done for the pest groups: Aphids, thrips and leafhoppers. Common species were found in vegetables and field crops. These included the cotton aphid, *Aphis gossypii* (Glover) (Hemiptera: Aphididae), western flower thrips, *Frankliniella occidentalis* (Pergande), cotton thrips, *Thrips tabaci* Lindeman (Thysanoptera: Thripidae) and cotton leafhopper, *Empoasca decipiens* Paoli (Hemiptera: Cicadellidae).

For winter vegetable plants, plots were created in four territorial units using a randomised block trial design. The plants included spinach (*Spinacia oleracea* L.), lettuce (*Lactuca sativa* L.), cauliflower (*Brassica oleracea var. botrytis* L.), red cabbage (*Brassica oleracea var. appitate f. rubra* L.), cabbage (*Brassica oleracea* L.), rocket (*Eruca vesicaria* L.), peppergrass (*Lepidium sativum* L.), radishes (*Raphanus sativus* L.) and broad beans (*Vicia faba* L.). Each plot consisted of four rows, with fifteen plants in each row. A free space of 1.5 meters was left between plots, and there were five meters between the blocks. A similar trial model was created for the following summer vegetable plant species: cucumber (*Cucumis sativus* L.), squash (*Cucurbita moschata* L.), beans (*Phaseolus vulgaris* L.), peppers (*Capsicum annuum* L.), tomatoes (*Solanum lycopersicum* L.), potatoes (*Solanum tuberosum* L.) and eggplants (*Solanum melongena* L.). To investigate the population density of thrips and predatory insects in some field crops, plots containing cotton (*Gossypium hirsutum* L.), sesame (*Sesamum indicum* L.) and soybean plants (*Glycine max* L.) were established according to the randomised block design with four replicates. The plot size for each plant species was designed as 96 square meters with a row length of ten meters, consisting of ten rows, with a distance of 0.80 meter between rows. A free space of two meters was left between the plots and five meters between the blocks. Nectarines (*Pyrus persicae* L.) and pomegranates (*Punica granatum* L.) were planted with 3 x 5 spacing, apples (*Malus domestica* L.) with 1 x 4 spacing, pears (*Pyrus communis* L.) with 4 x 6 spacing, plums (*Prunus persica* L.) lemons (*Citrus lemon* L.) and almonds (*Prunus dulcis* Mill. D. A. Webb) with 5 x 5 spacing and loquats [(*Eriobotrya japonica* (Thunb.) Lindl.)] with 7 x 7 spacing. Ten rows of each fruit tree species were planted, with twenty trees in each row. There was a 20-meter gap between the large plots representing each fruit species, and they were lined up next to each other. Each tree species planted was nearly fifteen years old. In the samplings, 20 plants from annual herbaceous crops (vegetable species and field crops) and 30 cm-long flowering or fruit-bearing shoots were randomly selected from each of the 20 fruit trees, positioned in the four cardinal directions. 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 decision was made because *Orius* and their primary prey, thrips, are found mostly on flowers, as these predatory species feed on the nectars and pollens in the flowers when there is no prey (Riudavets & Castane 1994; Hansen et al. 2003; Funderburk et al. 2000; Funderburk et al. 2018). Flowering or fruiting shoots measuring 30 cm-long in four different directions on the trees were randomly selected 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 centimeters, 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% ethyl alcohol. 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 genital organ and morphological characteristics, after which they were identified.

Table 1- Basic information on the insect samplings in various plant groups in Balcalı during the years 2019-2020

Plant group	*Number of sampling date*	*Number of plant species sampled*	*Total number of 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

2.3. Identification of Orius

The samples collected in the survey were first placed into Eppendorf tubes containing ethyl alcohol and their setae in the pronotum were examined under a stereo binocular microscope. Then the tips of the abdomens were cut off and transferred to glass containers containing 10% potassium hydroxide (KOH) solution and left at room temperature for one day. At the end of a day, it was put into clove oil for about five minutes, after which, using a needle, it was transferred to a slide prepared with Hoyer's medium and covered with a coverslip. In addition, nail polish was applied around the slide to prevent air from getting in. The preparation was dried in an oven heated to 45°C, where it remained for fifteen days (Silveira et al. 2003), after which the mating tubes of the females and the genital organs of the males of the *Orius* species were examined under a light microscope and a diagnosis was made according to the key identifications published by Péricart (1972) and Önder (1982).

2.4. Statistical analysis

The seasonal distributions of harmful insects and *Orius* species in various cultivated plants were calculated separately following the method of Karman (1971). The distributions, representing the ratios of total adult individuals, were calculated using the Microsoft Excel spreadsheet program. To analyse the seasonal averages of both *Orius* spp. and prey pests in the plant groups within the same ecological area, one-way analysis of variance (ANOVA) and the Tukey test were applied with a significance level of $P<0.05$ (SPSS 2016). The comparison of averages considered the same sampling dates for each plant group, including both winter and summer vegetables, fruit trees and field crops. To evaluate the population fluctuations of the predator and pest groups, as indicated in the methods section because the number of predatory and pest individuals in certain plant species within the plant group was very low or could not be found on some sampling dates. We calculated the average number of individuals collected from these plant species on each sampling date by adding up the counts and dividing by the number of samples. The combined data were then presented as total mean values for summer/winter vegetables, fruit trees and field crops. Since the cultivated plants sampled from different plant groups were grown in different ecological areas and had varying growing periods, the seasonal averages of beneficial insects (*Orius* spp.) and harmful insects on crop plants were not statistically compared. The prey/predator ratios were determined based on the number of harmful insects and *Orius* obtained from the plant groups. The total values obtained from 20 plants in each plant category (vegetables, field crops and fruit trees) were entered into the Excel program, according to the respective sampling dates. To assess the correlations between the mean numbers of predators (*Orius* spp.) and the numbers of pest insects (aphids, leafhoppers and thrips) within each plant group, a simple correlation analysis (Pearson correlation) was conducted at a significance level of $P<0.05$ (SPSS 2016). Specifically, we considered 21 sampling dates for winter vegetables, 19 for summer vegetables, 20 for field crops and 31 for fruit trees. The study's statistical analysis and tables provide information about the seasonal dynamics and interactions between *Orius* species and pest insects across different plant groups and ecological areas.

3. Results

3.1. Distribution of Orius species and harmful insects on the crop plants

The survey, conducted in the Balcalı region, yielded a total of 134 *Orius* species collected from winter vegetables (Figure 1a). Among these, *O. laevigatus* was dominant, with 105 individuals, making up 78.36% of the total adult population. Regarding pest insects, the survey revealed that, in winter vegetables, 735 individuals of thrips were collected, constituting 50.94% of the total number of adult pest individuals (Figure 1b). The second most common pest taxon was leafhoppers, with a rate of 43.73% and a total of 631 individuals collected (Figure 1b). A total of 77 aphid individuals were recorded, accounting for 5.93% of the total pest population. Thrips was most frequently found in association with *Orius* species, which aligns with previous studies indicating that *Orius* primarily prefer thrips as their prey and some *Orius* species are important predators of thrips. On fruit trees, *O. laevigatus*, *O. niger* and *O. vicinus* individuals were detected, with an incidence of 77.27%, 18.18%, and 4.55%, respectively (Figure 1c). However, *O. albidipennis* species was not found in the survey.

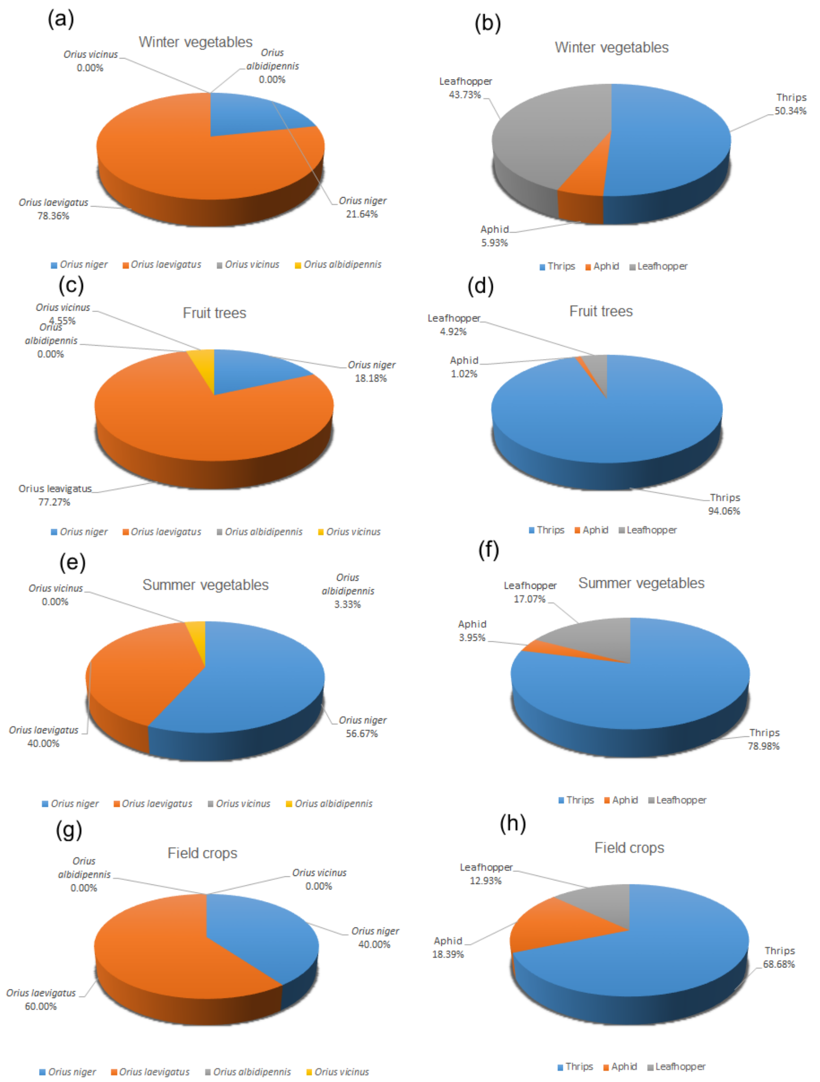

Figure 1- Distributions of *Orius* species and prey groups (aphids, thrips and leafhoppers) on different arable crops, a, b: winter vegetable, c, d: fruit tree, e, f: summer vegetable, g, h: field crop

On fruit trees, thrips were the most common insects, with 620 individuals, accounting for 94.06% of the total pest population (Figure 1d). Aphids and leafhoppers were collected in very low numbers, with three and thirteen individuals, respectively, accounting for 1.02% and 4.92% of the total number of individuals (Figure 1d). In summer vegetables, *O. niger* was the most common species, with 17 adults, representing 56.67% of the total adults (Figure 1e). *Orius laevigatus* was the second most common species, with 20 individuals, comprising 40% of the total individuals (Figure 1e). Individuals of aphids were observed in lower numbers in summer vegetables, constituting 3.95% of the total prey population species (Figure 1f). In field crops, *O. laevigatus* dominated the *Orius* populations (Figure 1g). Individuals of thrips (mainly *F. occidentalis*) were the most common pests, with 239 individuals collected, constituting 68.68% of the total adult herbivorous insect population (Figure 1h). These survey findings provide valuable insights into the population dynamics and interactions between *Orius* species and pest insects in different plant groups within the location Balcalı contributing to our understanding of natural pest control mechanisms.

3.2. Numbers of Orius and harmful insects on the crop plants

Table 2 presents a list of plant species, along with *Orius* species and total prey densities (pooled pest insects), collected in 2019–2020. *Orius* species were not found on plants belonging to the Amaranthaceae, Brassicae and Cucurbitaceae families, or were recorded only rarely (Table 2). Cauliflower had the highest total number of insect pests detected. Broad bean plants from the Fabaceae family had a high number of harmful insects in their flowers, and *Orius* species (especially *O. laevigatus*) were relatively more abundant in these plants. Leafhoppers were found in high numbers on the leaves of broad bean plants (Table 3). Although the number of pests in bean plants was high (301 individuals), the number of *Orius* individuals was lower (21 *Orius* individuals in total). During the flowering period of potato plants grown in Çukurova, the number of thrips was high (252 thrips individuals), and 23 *Orius* individuals were recorded alongside the thrips in the flowers (Table 2). Thrips and *Orius* numbers were relatively higher in loquat and apple blossoms compared to other fruit trees (Tables 2 and 3). The tables (Tables 4, 5, 6 and 7) show the total average numbers of harmful insects and *Orius* during the same sampling periods in crop plants grown in the same ecosystem. In winter vegetables (Table 4), the average number of *Orius* individuals was significantly higher (3.14 ± 0.92 individuals/20 plants) in broad bean plants, while the number of *Orius* was low and similar in other plant species. Thrips were detected in significant and high numbers in potato plants (11.45 ± 1.02 individuals/20 plants). In summer vegetables, *Orius* individuals were sampled in similar numbers in pepper (0.17 ± 0.09 individuals/20 plants) and bean (0.54 ± 0.22 individuals/20 plants) plants but significantly higher when compared to other plant species (Table 5). Similarly, the mean number of thrips was significant and higher in peppers (13.72 ± 0.87/20 plants) and beans (10.22 ± 1.00/20 plants). The total mean numbers of prey groups (thrips, aphids and leafhoppers) in fruit trees were similar and low among other plant species (Table 6). In field crops (Table 7), the total average numbers of *Orius* were generally low, but in sesame (0.71 ± 0.23 individuals/20 plants) and cotton (0.38 ± 0.12 individuals/20 plants) (Table 7), the numbers of *Orius* individuals were statistically significant and higher compared to other plant species. Thrips sampled from sesame flowers had significantly higher numbers (4.09 ± 0.46 individuals/20 plants) than those numbers found in other field crops.

Table 2- Total numbers of *Orius* species with pest insects in some cultivated plants sampled in Balcalı in 2019-2020

Family/English and Latin name	*Orius niger*		*Orius laevigatus*		*Orius albidipennis*		*Orius vicinus*		*Total no of pest insects*
	♀	♂	♀	♂	♀	♂	♀	♂	
Amaranthaceae									
Spinach (*Spinacia oleracea* L.)	0	0	0	0	0	0	0	0	10
Asteraceae									
Lettuce (*Lactuca sativa* L.)	0	0	0	0	0	0	0	0	30
Brassicaceae									
Cauliflower *(Brassica oleracea var. botrytis* L.)	1	0	0	0	0	0	0	0	167
Red cabbage (*Brassica oleracea var,appitate f. Rubra* L.)	0	0	0	0	0	0	0	0	142
Cabbage (*Brassica oleracea* L.)	0	0	0	0	0	0	0	0	106
Rocket (*Eruca vesicaria* (L.))	0	0	0	0	0	0	0	0	2
Peppergrass (*Lepidium sativum* L.)	0	0	0	0	0	0	0	0	15
Radish (*Raphanus sativus* L.)	0	0	0	0	0	0	0	0	44
Cucurbitaceae									
Cucumber (*Cucumis sativus* L.)	1	0	0	0	0	0	0	0	28
Winter Squash (*Cucurbita moschata* Duch.)	0	0	0	0	0	0	0	0	11
Fabaceae									
Broad bean (*Vicia faba* L.)	18	6	77	9	0	0	0	0	642
Bean (*Phaseolus vulgaris* L.)	6	6	4	4	0	1	0	0	301
Soybean (*Glycine max* L.)	0	0	0	1	0	0	0	0	60
Peanut *(Arachis hypogaea* L.)	1	0	0	0	0	0	0	0	27
Lythraceae									
Pomegranate (*Punica granatum* L.)	0	0	2	0	0	0	0	0	9
Malvaceae									
Cotton (*Gossypium hirsitum* L.)	6	0	0	2	0	0	0	0	100
Pedeliaceae									
Sesame (*Sesamum indicum* L.)	3	0	7	5	0	0	0	0	130
Rutaceae									
Lemon (*Citrus lemon* (L.) Osbeck)	0	0	0	0	0	0	0	0	48
Rosaceae									
Pear *(Pyrus communis* L.)	0	0	0	0	0	0	0	0	7
Almond (*Prunus dulcis* Mill. D. A. Webb)	1	0	1	0	0	0	0	0	2
Apple (*Malus domestica* L.)	1	0	6	2	0	0	1	0	76
Plum (*Prunus domestica* L.)	0	0	0	0	0	0	0	0	6
Nectarine (*Prunus persica* L.)	0	0	0	0	0	0	0	0	59
Loquat (*Eriobotrya japonica* (Thunb.) Lindl.)	2	0	4	1	0	0	0	0	81
Solanaceae									
Pepper *(Capsicum annuum* L.)	3	0	1	2	0	0	0	0	356
Tomato (*Solanum lycopersicum* L.)	0	0	0	0	0	0	0	0	23
Potato (*Solanum tuberosum* L.)	4	0	7	12	0	0	0	0	261
Eggplant (*Solanum melongena* L.)	1	0	0	1	0	0	0	0	67
Total	48	12	109	39	0	1	1	0	2809

Table 3- Total numbers of pest insects with *Orius* spp. in some cultivated plants sampled in Balcalı in 2019-2020

Family/English and Latin name	*Thrips*	*Aphid*	*Leafhopper*	*Total no of Orius*
Amaranthaceae				
Spinach (*Spinacia oleracea* L.)	9	1	0	0
Asteraceae				
Lettuce (*Lactuca sativa* L.)	17	11	2	0
Brassicaceae				
Cauliflower *(Brassica oleracea* var. botrytis L.)	152	15	0	1
Red cabbage (*Brassica oleracea* var. capitata f. Rubra L.)	138	4	0	0
Cabbage (*Brassica oleracea* L.)	103	3	0	0
Rocket (*Eruca vesicaria* L.*)*	0	0	2	0
Peppergrass (*Lepidium sativum* L)	1	13	1	0
Radish (*Raphanus sativus* L)	15	14	15	0
Cucurbitaceae				
Cucumis (*Cucumis sativus* L.)	23	4	1	1
Squash (*Cucurbita moschata* L.)	8	0	3	0
Fabaceae				
Broad bean (*Vicia faba* L.)	24	7	611	110
Bean (*Phaseolus vulgaris* L.)	225	8	68	21
Soynbean (*Glycine max* L)	59	0	1	1
Peanut (*Arachis hypogaea* L.)	44	54	2	1
Lythraceae				
Pomegranate (*Punica granatum* L.)	8	0	1	2
Malvaceae				
Cotton (*Gossypium hirsitum* L.)	18	5	4	8
Pedeliaceae				
Sesame (*Sesamum indicum* L.)	86	3	41	15
Rutaceae				
Lemon (*Citrus lemon* L.)	48	0	0	0
Rosaceae				
Pear (*Pyrus communis* L.)	5	1	1	0
Almond *(Prunus dulcis* Mill. D. A. Webb)	2	0	0	2
Apple (*Malus domestica* L.)	72	2	2	10
Plum (*Prunus domestica* L.)	6	0	0	0
Nectarine (*Prunus persica* L.)	58	0	0	0
Loquat (*Eriobotrya japonica* (Thunb.) Lindl)	77	0	4	7
Solanaceae				
Pepper (*Capsicum annuum* L.)	303	5	48	6
Tomato (*Solanum lycopersicum* L.)	12	0	11	0
Potato (*Solanum tuberosum* L.)	252	9	0	23
Eggplant (*Solanum melongena* L.)	50	14	3	2
Total	1815	173	821	210

Table 4- Total average number of *Orius* spp. and pest insects (mean ± SE/20 plants) in winter vegetables in Balcalı in 2019-2020

Winter vegetables	*Orius*	*Thrips*	*Aphid*	*Leafhopper*
Broad bean	3.14 ± 0.92a[a]	1.36 ± 0.29c	0.21 ± 0.10a	19.8 ± 5.87a
	(110)[b]	(24)	(7)	(611)
Spinach[b]	0.00 ± 0.00b	0.40 ± 0.32c	0.04 ± 0.04a	0.00 ± 0.00b
	(0)	(9)	(1)	(0)
Red cabbage[b]	0.00 ± 0.00b	6.27 ± 0.55b	0.18 ± 0.14a	0.00 ± 0.00b
	(0)	(138)	(4)	(0)
Cauliflower	0.02 ± 0.02b	6.59 ± 0.60b	0.68 ± 0.36a	0.00 ± 0.00b
	(1)	(152)	(15)	(0)
Cabbage[b]	0.00 ± 0.00b	4.69 ± 0.58b	0.13 ± 0.13a	0.00 ± 0.00b
	(0)	(103)	(3)	(0)
Lettuce[b]	0.00 ± 0.00b	0.77 ± 0.44c	0.22 ± 0.16a	0.09 ± 0.06b
	(0)	(17)	(11)	(2)
Rocket[b]	0.00 ± 0.00b	0.00± 0.00c	0.00± 0.00a	0.09 ± 0.09b
	(0)	(0)	(0)	(2)
Peppergrass[b]	0.00 ± 0.00b	0.04 ± 0.32c	0.59 ± 0.59a	0.04 ± 0.04b
	(0)	(1)	(13)	(1)
Radish[b]	0.00 ± 0.00b	0.68 ± 0.30c	0.63 ± 0.59a	0.68± 0.44b
	(0)	(15)	(14)	(15)
F	10.227	44.268	0.746	11.227
df	10,374	10,231	10,231	10,231
P	<0.0001	<0.0001	0.681	<0.0001

[a] When the columns are examined, means with the same letter are statistically insignificant according to the Tukey HSD test (P>0.05). [b]Values in parentheses indicate the total number of individuals

Table 5- Total average number of *Orius* spp. and pest insects (mean ± SE/20 plants) in summer vegetables in Balcalı in 2019-2020

Summer vegetables	*Orius*	*Thrips*	*Aphid*	*Leafhopper*
Pepper	0.17 ± 0.09a[a]	13.72 ± 0.87a	0.13 ± 0.09a	10.04 ± 2.53a
	(6)[b]	(303)	(5)	(48)
Tomato[b]	0.00 ± 0.00b	0.00 ± 0.00b	0.36 ± 0.23a	1.33 ± 0.28b
	(0)	(12)	(0)	(11)
Potato	0.65 ± 0.33a	11.45 ±1.02a	0.40 ± 0.23a	0.00 ±0.00c
	(23)	(252)	(9)	(0)
Bean	0.54 ± 0.22a	10.22 ±1.00a	0.45 ± 0.21a	3.04 ± 0.85b
	(21)	(225)	(8)	(68)
Cucumis	0.02 ± 0.02b	1,04 ± 0.65b	0.18 ± 0.12a	0.04 ± 0.04c
	(1)	(23)	(4)	(1)
Squash[b]	0.00 ± 0.00b	0.36 ± 0.36b	0.00 ± 0.00b	0.13 ± 0.09c
	(0)	(8)	(0)	(3)
Eggplant	0.00 ± 0.00b	1.54 ± 0.60b	0.00± 0.00b	0.13 ± 0.07c
	(2)	(50)	(14)	(3)
F	4.709	78.061	1.635	12.972
df	5,204	5,126	5,126	5,126
P	<0.0001	<0.0001	0.156	< 0.0001

[a] When the columns are examined, means with the same letter are statistically insignificant according to the Tukey HSD test (P>0.05). [b] Values in parentheses indicate the total number of individuals

Table 6- Total average number of *Orius* spp. and pest insects in fruits trees (mean ± SE /20 plants) in Balcalı in 2019-2020

Fruit trees	*Orius*	*Thrips*	*Aphid*	*Leafhopper*
Pear[b]	0.00 ± 0.00b[a] (0)[b]	0.12 ± 0.12a (5)	0.00 ± 0.00a (1)	0.02 ± 0.02a (1)
Plum	0.38 ± 0.19a (2)	0.05 ± 0.05a (2)	0.00 ± 0.00a (0)	0.00 ± 0.00a (0)
Apple	0.32 ± 0.26a (10)	1.84 ± 0.70 (72)	0.05 ± 0.03a (2)	0.05 ± 0.03a (2)
Plum[b]	0.00 ± 0.00 (0)	0.15 ± 0.15a (6)	0.00 ± 0.00a (0)	0.00 ± 0.00a (0)
Pomegranate	0.00± 0.00b (2)	0.20 ± 0.10a (8)	0.00 ± 0.00a (0)	0.02 ± 0.02a (1)
Nectarine [b]	0.00 ± 0.00b (58)	1.48 ± 0.79a (0)	0.00 ± 0.00a (0)	0.02 ± 0.02a (0)
Lemon[b]	0.00 ± 0.00b (48)	1.23 ± 0.62a (0)	0.00 ± 0.00a (0)	0.00 ± 0.00a (0)
Loquat	0.00 ± 0.00b (7)	1.97 ± 1.51a (77)	0.00 ± 0.00a (0)	0.10 ± 0.04a (4)
F	4.852	1.435	1.503	1.705
df	7,304	7,304	7,304	7,304
P	0.008	0.0191	0.166	0.107

[a]: When the columns are examined means with the same letter are statistically insignificant according to the Tukey HSD test (P>0.05). b: Values in parentheses indicate the total number of individuals.

Table 7- Total average number of *Orius* spp. and pest insects ((mean ± SE/20 plants) in field crops in Balcalı in 2019-2020

Field crop	*Orius*	*Thrips*	*Aphid*	*Leafhopper*
Cotton	0.38 ± 0.12a[a] (1)[b]	2.09 ± 0.86b (18)	2.57 ± 0.51a (5)	0.09 ± 0.00b (4)
Soybean	0.00 ± 0.00b (1)	2.66 ± 0.51a (59)	0.00 ± 0.00b (0)	0.04 ± 0.04b (1)
Sesame	0.71 ± 0.23a (15)	4.09 ± 0.46a (86)	0.14 ± 0.14b (3)	1.95 ± 0.52a (41)
Peanut	0.04 ± 0.04b (8)	0.85 ± 0.42c (44)	0.23 ± 0.15b (54)	0.19 ± 0.11b (2)
F	6.141	5.098	19.500	11.443
df	3,80	3,80	3,80	3,80
P	0.001	0.003	<0.0001	<0.0001

[a]When the columns are examined means with the same letter are statistically insignificant according to the Tukey HSD test (P>0.05). [b]Values in parentheses indicate the total number of individuals.

3.3. Population dynamics of Orius and harmful insects on the crop plants

The population dynamics of *Orius* in relation to pest species on various winter and summer vegetables, fruit trees and field crops are illustrated in Figure 2. In winter vegetables (Figure 2a), the number of thrips and aphids increased steadily since the first sampling date and, accordingly, *Orius* species were recorded. However, the densities of *Orius* remained lower than those of the prey insects. From 15th January to 15th March 2020, *Orius* populations showed fluctuations, likely influenced by the densities of both thrips and leafhoppers. In winter vegetable species, considering the average population densities of predatory and herbivorous insects, statistically significant and positive relationships were found only between *Orius* and thrips populations (*Orius*–Thrips: R= 0.55, P= 0.009; *Orius*–aphids: R= 0.20, P= 0.398; *Orius*–leafhoppers: R= 0.39, P= 0.443). On fruit trees (Figure 2b), *Orius* individuals were recorded alongside thrips and leafhoppers during the first sampling week. Relatively high thrips densities were detected in fruit trees on 22nd January and 29th April 2020, and the numbers of.

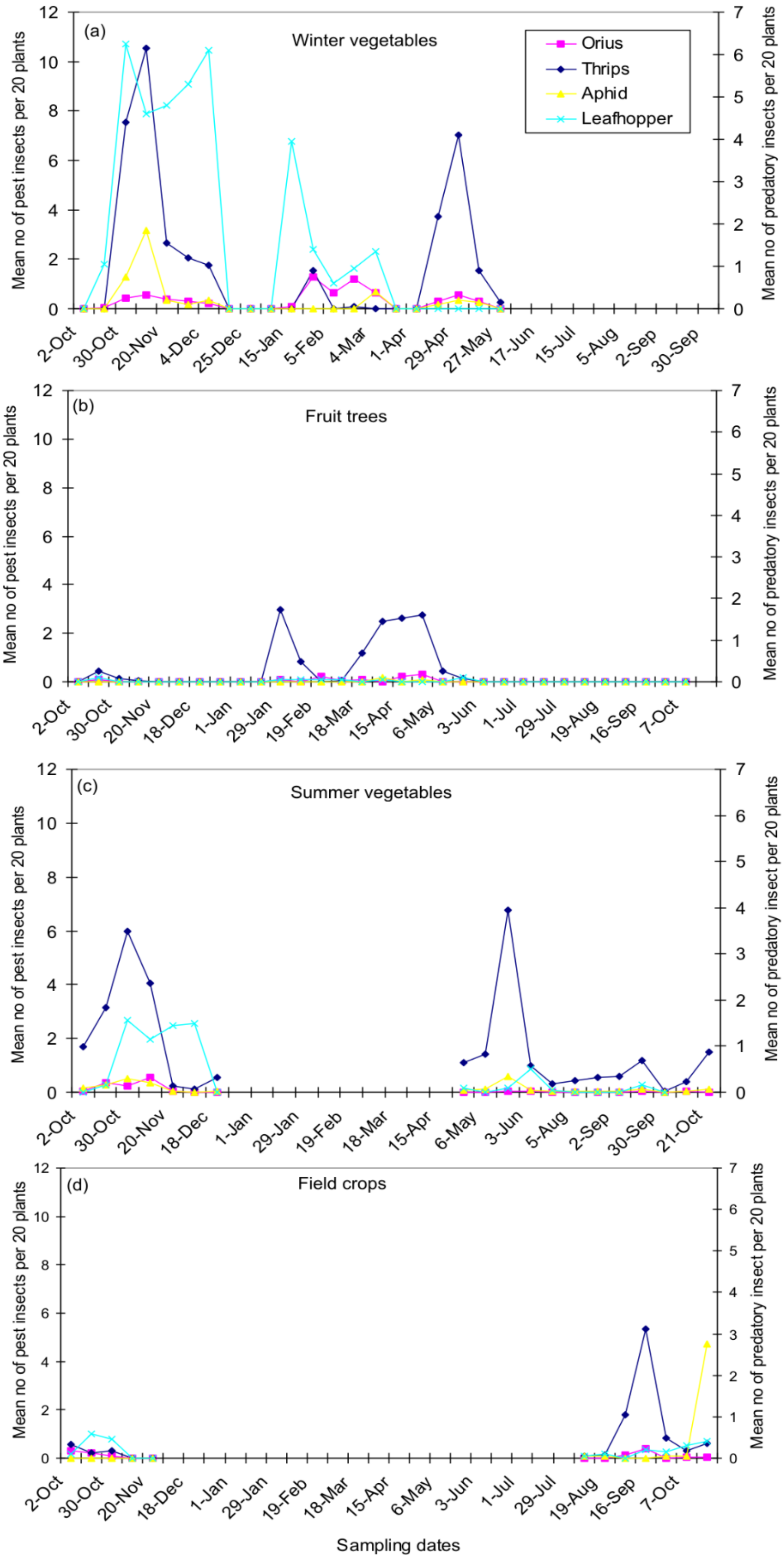

Figure 2- Seasonal densities of *Orius* spp. and different prey groups on different cultured plant groups; a: winter vegetables, b: fruit trees, c: summer vegetables and d: field crops.

Orius fluctuated in response to the thrips populations. In fruit trees, the *Orius* population showed a strong dependence on the thrips populations, and significant positive relationships were detected (*Orius*–thrips: R = 0.65, P = 0.0001; *Orius*–aphids: R = 0.22, P = 0.226; *Orius*–leafhoppers: R = 0.21, 0.316). In summer vegetables (Figure 2c), thrips and leafhoppers increased during the October–December period in 2019 and, correspondingly, the *Orius* population increased as well. In 2020, thrips and *Orius* exhibited similar population patterns until the last sampling date; the densities of *Orius* appeared to be lower than the thrips densities. However, statistically significant positive relationships were observed among the *Orius* and both thrips and aphid populations (*Orius*–thrips: R = 0.58, P = 0.009; *Orius*–aphids: R = 0.54, P = 0.007; *Orius*–leafhoppers: R = 0.43, 0.062). In field crops (Figure 2d), there was a short-term increase in the thrips population on 28th September 2020 and, during this period, the *Orius* density also increased temporarily, although it remained at a lower level than that of the thrips populations. At the last sampling date, although the aphid population increased on the leaves, *Orius* individuals were not found. A significantly strong and positive relationship was found only between the *Orius* and thrips populations (*Orius*–thrips: R = 0.73, P = 0.006; *Orius*–aphids: R = 0.14, P = 0.655; *Orius*–leafhoppers: R = 0.22, 0.488). Overall, the population dynamics of *Orius* seemed to be closely associated with the fluctuations in thrips populations in the different plant environments.

4. Discussion

Although the numbers of thrips were higher in winter vegetables than in other crop plants, except for broad beans, the reason that *Orius* individuals were found in very low numbers may be related to the absence of flowers during this period. It is worth noting that broad bean plants showed lower numbers of thrips than leafhoppers. 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 prey such as thrips. In the Çukurova region, broad bean plants remain in bloom 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 were detected in both winter and summer vegetables in the Çukurova region (Zeren & Düzgüneş 1983). To summarise, 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 widely found in summer vegetables in this region. *Frankliniella occidentalis* was abundant in eggplant and pepper flowers, but its presence was minimal in tomato flowers (Atakan 2010b). According to Bahşi (2011), the most common *Orius* species in Antalya was *O. laevigatus* (66%), followed by *O. niger* (33%). Additionally, *O. limbatus* (Wagner), *O. majusculus* (Reuter), *O. minutus* (L.) and *O. vicinus* were also recorded in this region. Thrips were the most prevalent pest group in various plant samples, often found alongside *Orius* species. While *O. laevigatus* was most common in winter vegetables (mainly broad beans), *O. niger* dominated in summer vegetables (mainly beans; Table 5). *Orius* populations were relatively low in fruit trees, indicating a preference for herbaceous habitats regardless of prey species and their densities. In Adana, *O. niger* played a crucial role in controlling pest thrips like *Frankliniella* flower thrips in unsprayed cotton fields (Atakan and Özgür 2001). A study conducted in a clover field in the same region revealed that *F. occidentalis* was the most harmful thrips species, with *O. niger* and *O. laevigatus* frequently found together with these pest thrips throughout the year (Atakan & Tunç 2004).

Although the number of thrips in pepper plant flowers was higher compared to other summer crops like tomatoes, eggplants and beans, only a few *Orius* specimens were detected (Table 5). In Florida, *O. tristicolor* effectively suppressed *Frankliniella* flower thrips in field-grown peppers (Funderburk et al. 2000). Researchers (Dissevelt et al. 1995) reported that eggplants and, more particularly, peppers due to their abundant pollen were more attractive to *Orius* species. The lack of *Orius* in tomato plants may be attributed to reduced mobility of nymphs or adults due to the plants' secretions negatively affecting *Orius*' searching ability and, thus, their predation on pest insects (Coll & Ridgeway 1995). *Orius* species densities were lower in field crops like cotton when compared to previous studies in the same ecological area (Table 7). Previous research in a pesticide-free cotton field in the region recorded a significant number of *Orius* adults preying on flower thrips in cotton flowers (Atakan 2006). *Orius 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; Atakan 2010a).

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 the field peppers (Funderburk et al. 2000; Hansen et al. 2003; Funderburk et al. 2018) and cotton (Atakan and Özgür 2001; Atakan 2006) confirmed that *Orius* plays an essential role in controlling *Frankliniella* flower thrips, leading to reduced thrips 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 limited 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 gathering in the same flowers infested by thrips, depending on thrips density (Ramachandran et al. 2001; Reitz et al. 2003). The scarcity of thrips larvae in the sampled plants 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, 40 thrips per predator were sufficient to keep the thrips population in control (Funderburk et al. 2000; Reitz et al. 2003).

5. Conclusions

The study reveals that *O. laevigatus* has been observed in both cold interior and warm regions of Turkey. The population dynamics of *Orius* and thrips were found to be influenced by the flowering patterns of the sampled crop plants. *Orius* populations showed fluctuations in response to changes in thrips populations. Notably, in regions where pesticide use is limited, *Orius* emerged as a significant biological factor in controlling thrips density, particularly in plants belonging to the Fabaceae family, such as broad beans. This indicates the potential of *Orius* as an important natural predator for managing thrips populations in agricultural settings without heavy reliance on pesticides.

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