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ORIGINAL RESEARCH PAPER

Influence of weed management on the abundance of thrips species (Thysanoptera) and the predatory bug, *Orius niger* (Hemiptera: Anthocoridae) in citrus mandarin

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Abstract

Field trials were carried out in 2014 and 2015 in fields of Çukurova University Research and Implementation Area, Adana province, Turkey. The experiment was set up in an Okitsu mandarin orchard. Half of the mandarin orchard was left as weedy, and the other zone was mowed regularly and cleared of weeds. Two trees were selected in each plot, for a total of 10 trees in each main plot. One inflorescence representing four cardinal directions was tapped on a white tray. The common and naturally growing weed species were sampled at weekly intervals for thrips and predatory bugs in weedy plots. *Frankliniella occidentalis* (Pergande) (Thysanoptera: Thripidae) and *Thrips tabaci* Lindeman (Thysanoptera: Thripidae) were the most common thrips species on citrus and weed flowers. Both species were significantly more abundant on flowers of citrus in non-weedy plots throughout the sampling period. The predatory bug *Orius* spp. (Hemiptera: Anthocoridae) was significantly more common on flowers of mandarin trees in weedy plots. High densities of *F. occidentalis* and its predatory bug were often recorded on flowers of *Vicia villosa*. This study suggests that *V. villosa* could be used as a trap plant for thrips and a banker plant for *Orius*.

Keywords Weed · Management · Abundance · Thrips · Predatory bug · Citrus

Introduction

Agricultural systems do not provide suitable conditions for beneficial insects (predators and parasitoids) due to cultural practices and chemical insecticide applications (Landis et al. 2000). Habitat management practices, such as use of ground cover plants, provide additional food sources, alternative prey, hosts, nectar, pollen, microclimatic conditions, aestivation and overwintering conditions, and refuges from disturbances caused by agricultural practices (Bugg and Pickett 1998; Jonsson et al. 2008). Such supplementary possibilities may increase survival and fecundity; thus, they are effective for biological control of pest arthropods (Landis et al. 2000). Habitat management will enhance plant biodiversity in cropping systems and will create a different agricultural system (Andow 1991; Bugg and Pickett 1998; Landis et al. 2000; Russell 1989). Pest attacks can be reduced by increasing plant diversity and abundance and diversity of natural enemies in cropping systems. However, abundance and diversity of natural enemies often decreases in agricultural systems (Andow 1991; Bugg and Pickett 1998; Russell 1989).

Weeds are undesirable because of their competition with cultured plants and hosting harmful arthropods and pathogens that damage cultivated crop plants (Thresh 1981; Van Emden 1965). However, when crop plants are cultivated with weeds or inter-planted with other crops, population densities of harmful arthropods decrease (Altieri 1980). According to another hypothesis, non-host plants prevent chemical stimulants used by harmful insects to seek host plants. Non-host plants are recognized as a barrier. Increasing plant diversity can increase the influence of natural pest control as a means for reducing grower dependence on chemicals (Altieri and Whitcomb 1979; Dent 1991; Gurr and Wratten 1999). Weeds are important for preventing soil erosion, maintaining soil humidity, and nitrification of the soil (Gliessman et al. 1981; Weil 1982).

Citrus is an economically important fruit crop worldwide, with annual production exceeding 137 million tons (FAO

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2012). Thrips (Thysanoptera) use citrus as host plants, and some of them are economically important (Blank and Gill 1997; Childers and Nakahara 2006; Costa et al. 2006; Froud et al. 2001; Navarro-Campos et al. 2008; Teksam and Tunç 2009). For instance, immature thrips of *Pezothrips kellyanus* Bagnall (Thysanoptera: Thripidae) suck epidermal cells and cause silvery scars on the rind (Navarro-Campos et al. 2008). Fruits are sensitive to scarring after petal fall until they are 4 cm in diameter (University of California 2011). Scarred and damaged fruits reduce the economic value of the crops (Atakan et al. 2015; Jacas and Urbaneja 2010). Thrips species damaging fruits in the Mediterranean region are *P. kellyanus* (Jacas et al. 2010; Navarro-Campos et al. 2008, 2012; Vassiliou 2010) and *Thrips hawaiiensis* (Morgan) (Thysanoptera: Thripidae) (Atakan et al. 2015). Other thrips species visiting citrus, such as *Frankliniella occidentalis* (Pergande), *Thrips flavus* Schrank, *Thrips major* Uzel and *Thrips tabaci* Lindeman (Thysanoptera: Thripidae) damage the fruits and can approach the economic threshold (Jacas et al. 2010).

Thrips are usually controlled with chemical pesticides (Baker et al. 2004; Morse and Hoddle 2006; Navarro-Campos et al. 2012; Vassiliou 2007). Chemical applications are costly and need repeated applications, potentially causing resistance to develop and disturbance of IPM applications in the citrus ecosystem (Baker et al. 2004; Morse and Hoddle 2006). Therefore, alternative control strategies are needed. Recent studies have focused on ground cover management to enhance performance of natural enemies. This is a new approach to protect natural enemies (Aguilar-Fenollosa et al. 2011a, b, c; Jacas and Urbaneja 2010). Ground cover has been used to encourage populations of predatory mites (phytoseiids) in citrus for controlling *Scirtothrips citri* (Moulton) (Thysanoptera: Thripidae) in citrus (Grafton-Cardwell et al. 1999) and *Scirtothrips aurantii* Faure (Grout and Richards 1992). Most phytophagous thrips species or their natural enemies spend some part of their life in ground cover or in the soil (Aguilar-Fenollosa and Jacas 2013). *Frankliniella occidentalis* and *T. tabaci* and their natural enemies (mainly predators) have been detected on many weed species in the Çukurova region of Turkey (Atakan and Tunç 2010; Atakan and Uygur 2005).

The polyphagous predators *Orius* spp. (Hemiptera: Anthocoridae) are often considered important natural enemies of thrips (Riudavets 1995). In Turkey, *Orius niger* (Wolff) effectively suppresses the *Frankliniella* flower thrips in cotton fields not treated with insecticides in the Çukurova region (Atakan 2006). Role of naturally occurring predatory bugs, *Orius* spp. in suppressing thrips in fruiting orchards such as citrus has not yet been studied in the Mediterranean region. However, *Orius thripoborus* (Hesse) (Hemiptera: Anthocoridae) was considered as a potential biocontrol agent of *Heliothrips haemorrhoidalis* (Bouche) and *Selenothrips rubrocinctus* Giard (Thysanoptera: Thripidae) on avocado fruit in the Eastern Transvaal (Dennill 1992). Miliczky and Horton (2005) recorded the densities of beneficial insect including *Orius tristicolor* and mites within pear and apple orchards in Washington and the northern Oregon (USA). Rocha et al. (2015) reported 18 arthropod species including *Orius* spp. predating on *F. occidentalis* on mango inflorescences.

In Turkey, the thrips fauna in citrus production areas in the Mediterranean region has been well studied (Nas et al. 2007). However, no thrips damage was observed in previous studies in Turkey. *Frankliniella occidentalis* damages nectarines and plum fruits, causing considerable economic losses in Turkey. Additionally, *T. hawaiiensis* was introduced to Turkey after the current study was completed. This new thrips is now problematic for lemons, which flower year round in the southeastern Mediterranean region (Mersin province, Turkey). Investigation of abundance of thrips and predators in weedy and non-weedy plots may be a model for further studies. The findings may be used in integrated pest management of thrips (especially for *T. hawaiiensis*) in citrus.

In the present work, habitat management (i.e., weedy and non-weedy plots) through the manipulation of weedy vegetation in citrus orchards may enhance abundance and diversity of natural enemies. Weedy areas in a citrus orchard also may have a role as trap vegetation in controlling pest thrips. We aimed to determine how weedy and non-weedy vegetation affect abundance and the diversity of pest thrips and their natural enemies (mainly predators).

Materials and methods

Experimental design

Field experiments were carried out in the Research and Implementation Area of the Plant Protection Department (37°01.809′N; 35°21.694′E), Faculty of Agriculture University of Çukurova in 2014 and 2015. Experiments were established in an 'Okitsu' mandarin orchard with 10 rows and 20 trees per row (Fig. 1). Trees were 9 years old. Heights and canopy width of the trees varied between 3 and 4 m. Trees were planted as 5 × 5 m. Each row is 100 m long. The experimental area was divided into two main plots, weedy and non-weedy, with 4 rows of trees. There was a buffer zone with two rows of trees with bare soil. Two middle rows were selected as the sampling unit. Each main plot (two rows of trees) was divided into 5 subplots for replication. Each subplot size was 120 m^2 with 12 trees. Total orchard area was 600 m^2. To create weedy and non-weedy main plots, nearly half of the experimental area was tilled in mid- March in both years before citrus blossoming. During this time

Fig. 1 Map of the experimental area located at the Research and Implementation Area of Plant Protection Department, University of Çukurova, Turkey

most of the weeds were flowering, with different heights. The non-weedy plot was controlled during the experiments, and weeds were hoed when they appeared. This area was left bare permanently.

Sampling of thrips and predators on flowers of citrus

Two trees were selected for a total of 10 trees in each experiment (non-weedy and weedy main plots). One inflorescence 25 cm long, representing four cardinal directions, was tapped on a white tray for 5 or 10 s. Thrips and predators were collected with an aspirator or a fine brush. Samples were transferred to Eppendorf tubes (2 ml) containing 60% ethyl alcohol. Tubes were labelled and stored in an ice chest. Thrips were examined under a stereomicroscope (40×). Known thrips species, such as *F. occidentalis* and *T. tabaci*, were counted under the microscope. Other specimens were slide-mounted after clearing in 5% NaOH and transfer into absolute alcohol for washing. Preparations were made in Hoyer's medium.

Sampling of thrips and predators on flowers of weeds

Weeds with coverage of at least 10% included *Anthemis arvensis, Melilotus officinalis, Medicago polymorpha, Sinapis arvensis* and *Vicia villosa* were sampled at weekly interval during the period that thrips and predatory insects were sampled on citrus flowers. Four weeds representing each weed species in each subplot (20 total plants) were shaken into a plastic container for 5 s. Thrips were collected with an aspirator or a fine brush into labeled plastic tubes containing 60% ethyl alcohol and slide-mounted as before.

Thysanoptera species were identified by the senior author using identification keys of zur Strassen (2003) and Balou et al. (2012). Morphological (e.g., genitalic) characteristics of *Orius* species were used for identification. Identification keys of Önder (1982) were also used.

Data analysis

Generalized Linear Mixed Model (GLMM) analysis was used to determine effects of sampling date, year and vegetation (weedy and non-weedy plots) type on the abundance of thrips and predatory insects, mainly *Orius niger.* According to GLMM, thrips and *Orius* numbers were dependable variable. Vegetation type was fixed factor, and sampling date and year were random factor. All data used in this present study showed normal distribution. Mean insect numbers in weedy and non-weedy plots throughout sampling dates were compared using Student's t test at $p < 0.05$. Mean numbers from the weed species were evaluated with Tukey's HSD test at $p < 0.05$. Relationships between mean numbers of *Orius* spp. and *F. occidentalis* or *T. tabaci* on mandarin flowers in plots assessed by use of GLMM analysis ($p < 0.05$). We considered only adult individuals (female + male) of thrips species and *Orius* (female + male) in all analysis. We did not evaluate thrips larvae and nymphs of *Orius* because their numbers were very few throughout the samplings in both sampling years. All analyses were performed using the Microsoft Statistics Program SPSS 15.0. (SPSS 2006).

Results

Thrips and predatory insect species

A total of ten Thysanoptera species, one of which is predatory (*Aeolothrips*), were identified (Table 1). Total numbers of thrips were higher in citrus flowers of non-weedy plots. Species numbers of thrips were also high in weedy plots, with five thrips species in only weedy plots. Both *F. occidentalis* and *T. tabaci* were the two most common thrips species, and they were often recorded in citrus flowers in weedy plots. A total of four predatory insect species were detected. *Orius niger* was the most common predaceous insect and its numbers were relatively greater on citrus flowers in weedy plots (Table 1). Genus *Scymnus* (Coleoptera: Coccinellidae) was often recorded on flowers in weedy plots. Few numbers of *Synharmonia conglobate* L. (Coleoptera: Coccinellidae) were caught.

Table 1 Total numbers of thrips species and predatory insects on citrus flowers in two main plots of Okitsu mandarin

	No weeds (clean)	Weedy
Herbivorous Thysanoptera species		
Frankliniella occidentalis (Pergande)	1102	562
Thrips tabaci Lindeman	1176	536
Thrips major Uzel	67	29
Thrips meridionalis (Priesner)	0	3
Thrips angusticeps Uzel	0	2
Isoneurothrips australis Bagnall	0	2
Ceratothrips pallidivestis (Priesner)	0	4
Melanthrips spp.	5	11
Haplothrips sp.	0	7
Predatory insects		
Aeolothrips collaris Bagnall	17	10
Orius niger (Wolff)	33	87
Scymnus sp.	0	10
Synharmonia conglobate L.	5	1

Thrips and predatory insect population dynamics on citrus flowers

Effects of sampling date, year and vegetation type (weedy and non-weedy plots) on the abundance of thrips were analyzed. Vegetation type (weedy and non-weedy plots), date and year affected significantly abundance of *F. occidentalis* and *T. tabaci* ($p<0.0001$; Table 2).

Mean numbers of *T. tabaci* increased quickly at the beginning of April and then decreased due to low abundance of flowers on citrus trees in 2014 (Fig. 2a). Mean numbers of thrips on citrus flowers were significantly higher in non-weedy plots than in weedy plots on 8, 12, 16, and 20 April ($t=4.542$, $F_{1,18}=20.630$, $p<0.0001$; $t=4.413$, $F_{1,18}=19.471$, $p<0.0001$; $t=8.617$, $F_{1,18}=74.251$, $p<0.0001$; $t=3.273$, $F_{1,18}=10.714$, $p<0.0001$, respectively). *Thrips tabaci* and *F. occidentalis* showed similar population trends in abundance (Fig. 2a, c). Mean numbers of *F. occidentalis* were significantly higher on 4 April ($t=3.851$, $F_{1,18}=14.829$, $p<0.0001$), 8 April ($t=3.207$, $F_{1,18}=10.285$, $p<0.0001$), 12 April ($t=6.124$, $F_{1,18}=37.508$, $p<0.0001$), and 16 April ($t=5.800$, $F_{1,18}=33.641$, $p<0.0001$) in non-weedy plots than numbers found in weedy plots in 2014. A few *F. occidentalis* were recorded on flowers on 20 and 24 April (Fig. 2c) in 2014.

Table 2 Generalized linear mixed model (GLMM) analysis for thrips species on Okitsu mandarin

Species	Factors	*df*	MS	*F*	*p*
Frankliniella occidentalis	Fixed factor				
	Vegetation type	1	1260.078	34.444	< 0.0001
	Random factors				
	Year	1	5959.878	162.910	< 0.0001
	Sampling date	7	936.900	25.610	< 0.0001
	Error	310			
Thrips tabaci	Fixed factor				
	Vegetation type	1	874.503	23.760	< 0.0001
	Random factors				
	Year	1	7059.814	191.802	< 0.0001
	Sampling date	7	980.814	26.648	< 0.0001
	Error	310			

df degree of freedom, *MS* mean squares

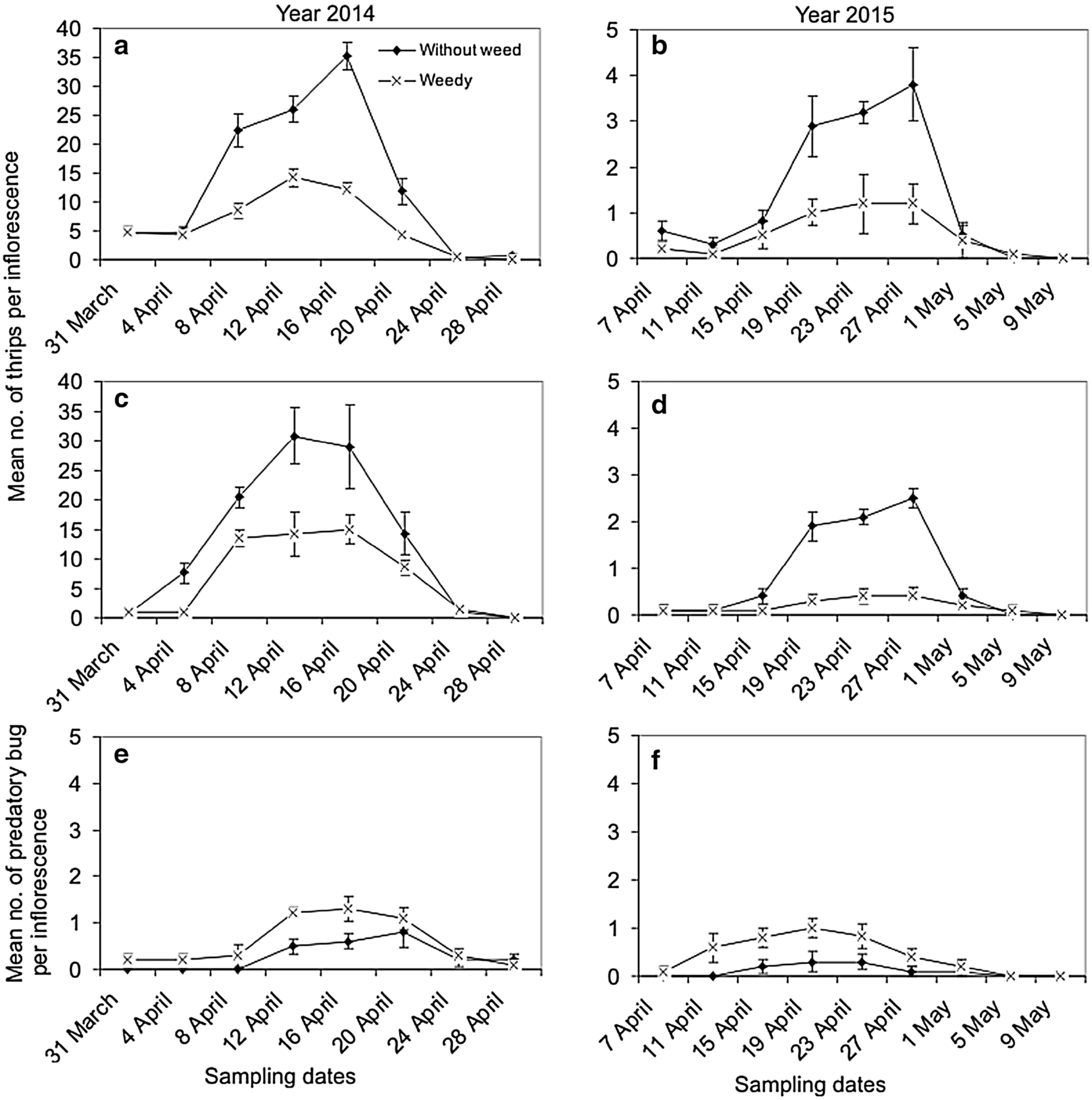

Fig. 2 Mean adult (female + male) numbers of **a**, **b** *Thrips tabaci*, **c**, **d** *Frankliniella occidentalis*, and **e**, **f** *Orius niger* in flowers of citrus mandarin in 2014 and 2015. Bars are showing averages and standard errors. Ten inflorescences were sampled in each sampling date in each plot

Abundance of *T. tabaci and F. occidentalis* in 2015 (Fig. 2b, d) was lower than in 2014 (Fig. 2a, c). The population of *T. tabaci* started to increase after 15 April. *Thrips tabaci* peaked on flowers (3.80 ± 1.81 individuals per inflorescence) in non-weedy plots, and numbers varied between 0.10 and 1.20 individuals per inflorescence in weedy plots. Mean numbers of *T. tabaci* in non-weedy plots were significantly greater on flowers on 23 April ($t = 4.575$, $F_{1,18} = 20.930$, $p < 0.0001$) and 27 April ($t = 3.509$, $F_{1,18} = 12.890$, $p < 0.0001$) than those in weedy plots (Fig. 2b).

Similarly, mean numbers of *F. occidentalis* in 2015 were significantly higher on 23 April (2.10 ± 0.17 individuals per inflorescence) and 27 April (2.70 ± 0.22 individuals per inflorescence) in non-weedy plots than those in the weedy plots (Fig. 2d) ($t = 7.005$, $F_{1,18} = 49.075$, $p < 0.0001$; $t = 7.584$, $F_{1,18} = 57.572$, $p < 0.0001$, respectively). Mean numbers of *F. occidentalis* in weedy

Table 3 Generalized Linear Mixed Model (GLMM) analysis for *Orius niger* on Okitsu mandarin

Factors	*df*	MS	*F*	*p*
Fixed factor				
Vegetation type	1	7.111	28.813	< 0.0001
Random factors				
Year	1	2.420	9.804	< 0.001
Sampling date	7	3.552	14.391	< 0.0001
Covariates				
Thrips tabaci	1	1.188	4.913	< 0.05
Frankliniella occidentalis	1	0.042	0.173	> 0.05
Error	314			

df degree of freedom, *MS* mean squares

Table 4 Interaction between numbers of *Orius niger* and thrips species according to Generalized Linear Mixed Model (GLMM) analysis

Interaction	B	Std. error	*t*	*p* value
Orius niger × *Thrips tabaci*	0.015	0.007	2.217	< 0.05
Orius niger × *Frankliniella occidentalis*	− 0.003	0.007	− 0.415	> 0.05

plots were low and ranged from 0.10 to 0.42 thrips per inflorescence.

Vegetation type, date, year and thrips species (*T. tabaci*) affected significantly abundance of *Orius* spp. (Table 3). In 2014, densities of *Orius* on flowers in weedy plots ranged from 0.10 to 1.30 individuals per inflorescence but varied from 0.0 to 0.80 individuals per inflorescence in non-weedy plots (Fig. 2e). Mean numbers of *Orius* in weedy plots on 12 April ($t = 3.280$, $F_{1,18} = 10.756$, $p = 0.004$) and 16 April in 2014 ($t = 2.278$, $F_{1,18} = 5.188$, $p = 0.035$) were significantly greater than numbers in non-weedy plots (Fig. 2e). In 2015, mean numbers of *Orius* varied from 0.10 to 1.00 individuals per inflorescence in weedy plots, whereas densities on flowers in non-weedy plots ranged from 0.10 to 0.30 (Fig. 2f). Mean numbers of *Orius* were significantly higher in weedy plots on 15 April ($t = 2.496$, $F_{1,18} = 6.231$, $p = 0.022$) and 19 April ($t = 2.689$, $F_{1,18} = 7.230$, $p = 0.015$) than numbers in non-weedy plots in 2015.

Interaction between numbers of *O. niger* and thrips species on flowers of citrus lemon are given in Table 4. There was a significant interaction between numbers of *O. niger* and *T. tabaci* ($p < 0.05$). No interaction was detected between numbers of *O. niger* and *F. occidentalis* (Table 4; $P > 0.05$).

Population fluctuations of thrips and *Orius* on weeds

A total of 15 weed species in flowering stage was detected in this study. All weeds were in flowering stage when samplings started. *Anthemis arvensis* (corn chamomile), *Calendula arvensis* (field marigold), *Capsella bursa pastoris* (shehard's purse), *Erodium molchatum* (musky storksbill), *Fumaria officinalis* (common fumitory), *Lamium amplexicaule* (henbit dead nettle), *Malva silvestris* (large-flowered mallow), *Melilotus officinalis* (field melilot), *Mercuryalis annua* (annual mercury), *Medicago polymorpha* (bur clover), *Senesio vernalis* (eastern ground sel), *Sinapis arvensis* (wild mustard), *Stelleria media* (common chick weed), *Vicia sativa* (common wetch), and *Vicia villosa* (winter wetch) were identified. Covering areas of the weeds did not differ between sampling years. *Anthemis arvensis* and *V. villosa* were the more common weedy species in both years (for *A. arvensis* 21% in 2014 and 18% in 2015; for *V. villosa* 16% in 2014 and 19% in 2016). Covering areas of nine weed species were less than 5% in both years.

Mean numbers of *T. tabaci* (Fig. 3a) were significantly higher on *V. villosa* than on other weed species until 16 April ($p < 0.0001$) in 2014. Mean numbers of *T. tabaci* on *V. villosa* were the highest (29.80 ± 3.53 thrips per plant) on 12 April ($F_{4,45} = 41.130$, $p < 0.0001$) but peaked in flowers of *A. arvensis* in the flowering stage (34.40 ± 1.58 thrips per plant) ($F_{4,45} = 150.718$, $p < 0.0001$) on 20 April. Significant mean numbers of *T. tabaci* were recorded on *V. villosa* ($p < 0.0001$), when data of 19 April 2015 were excluded (Fig. 3b). On that date, *T. tabaci* was most abundant on *A. arvensis* ($F_{4,45} = 140.127$, $p < 0.0001$). Mean densities of *T. tabaci* on *V. villosa* and *A. arvensis* on 1 May and 5 May were similar but significantly higher than those on other weeds in 2015 (1 May: $F_{4,45} = 6.792$, $p < 0.0001$; 5 May: $F_{4,45} = 12.905$, $p < 0.0001$). Individuals of *F. occidentalis* were recorded mostly on *V. villosa* and *M. officinalis* throughout 2014 (Fig. 3c). Fewer individuals were on *S. arvensis*, *M. polymorpha*, and *A. arvensis*. Individuals of *F. occidentalis* were less dense on all weedy species at the end of April. Mean numbers of *F. occidentalis* on *M. officinalis* were significantly greater on 16 April (19.60 ± 1.85 thrips per plant) and 28 April (14.80 ± 2.61 thrips per plant) than numbers found on other weed species ($F_{4,45} = 177.163$, $p < 0.0001$; $F_{4,45} = 25.410$, $p < 0.0001$, respectively) (Fig. 3c). Population densities of *F. occidentalis* on the weeds in 2015 were lower compared with the previous year (Fig. 3c, d). Significant differences among *F. occidentalis* populations were recorded on *V. villosa* on 5 and 9 May ($F_{4,45} = 11.138$, $p < 0.0001$; $F_{4,45} = 43.607$, $p < 0.0001$, respectively) than numbers found on other weed species.

Significantly higher numbers of the predatory bug *O. niger* were recorded on *V. villosa* on most sampling dates

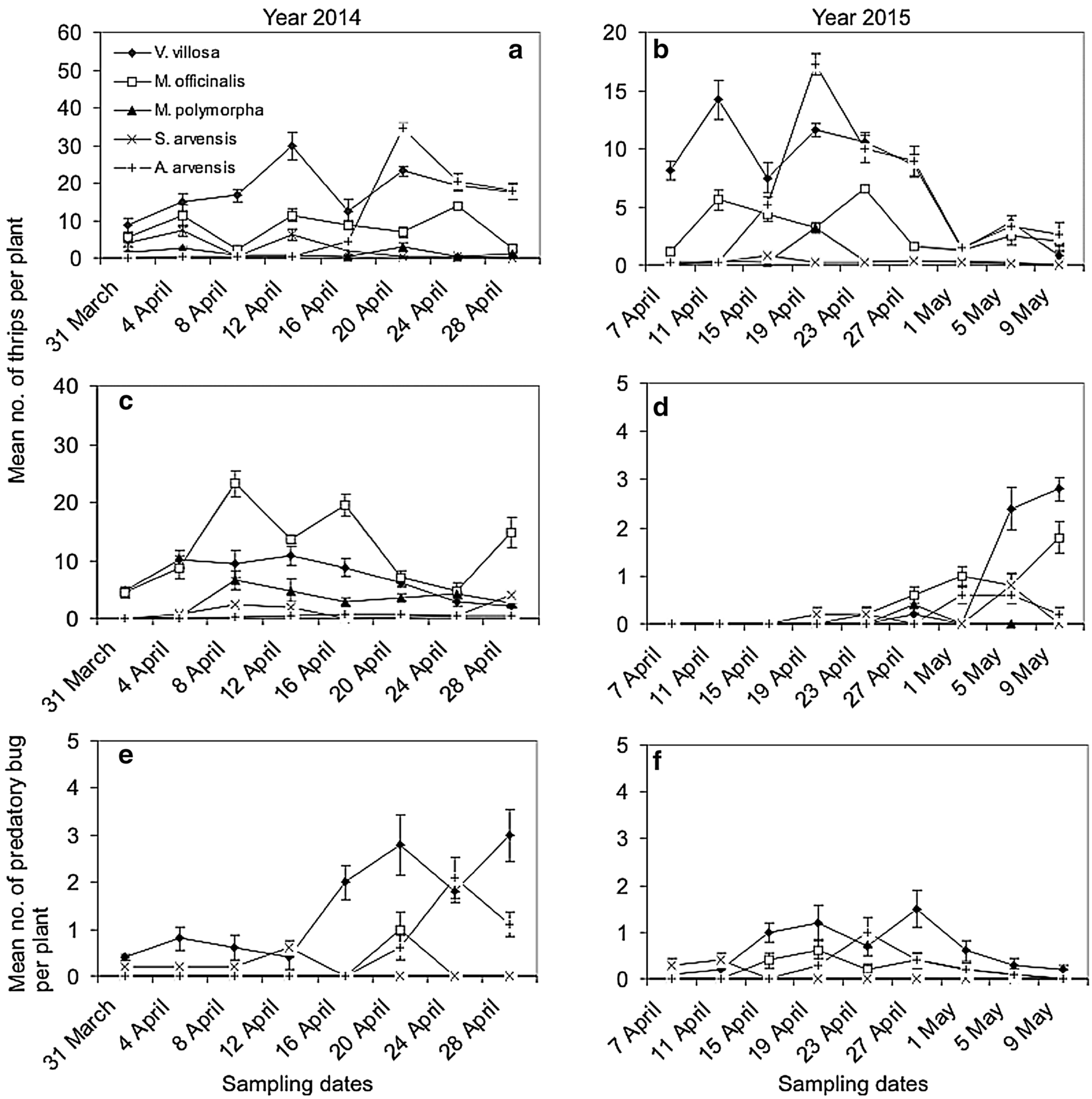

Fig. 3 Mean adult (female + male) numbers of **a**, **b** *Thrips tabaci*, **c**, **d** *Frankliniella occidentalis*, and **e**, **f** *Orius niger* on flowers of weed species in 2014 and 2015. Bars are showing averages and standard errors. Twenty plants of each weed species were sampled in each sampling date

than numbers found on other weed species ($p < 0.05$) in 2014 (Fig. 3e). The population of *O. niger* peaked on *V. villosa* flowers on 20 April (2.80 ± 0.64 individuals per plant) and 28 April (3.00 ± 0.55 individuals per plant) ($F_{4,45} = 10.704$, $p < 0.0001$; $F_{4,45} = 20.195$, $p < 0.0001$, respectively). Similar to results of the previous year, most individuals of *Orius* were extracted from *V. villosa* flowers in 2015 (Fig. 3f). Mean numbers of *Orius* varied from 0.10 to 1.50 individuals per plant throughout the sampling period in 2015 (Fig. 3f). *Orius* peaked on *V. villosa*, with a mean of 1.50 ± 0.40 individuals per plant on 27 April, and this value was significantly higher than the numbers on other weed species ($F_{4,45} = 8.813$, $p < 0.0001$).

Discussion

Weeds are often recognized as harmful because they host diseases and pests of plants and they compete with cultivated plants. Therefore, growers often control weeds in agricultural systems. Weeds influence insect communities (Way and Cammell 1981), and affect the composition, abundance, and population dynamics of arthropod communities, including herbivores and natural enemies. In the present study, we did not analyze yields of "Okitsu" mandarin fruits in the weedy and weed free plots. In some previous studies, ecological benefits of weedy community (providing alternative prey, food sources, shelter, oviposition and hibernation sides, mating area etc.) and their importance of integrated insect control were discussed rather than possible negative effects of weeds on crop yields (Aguilar-Fenollosa and Jacas 2013; Alhajes et al. 2011; Koger and Reddy 2005; Madeira and Pons 2015; Penagos et al. 2003; Silva et al. 2010). However, Bredell (1973) found that plastic mulching in a Valencia orchard affected yield positively. Controlling of all orchard-floor vegetation resulted in the highest fruit yield (Hogue and Neilsen 1987). Controlling weeds in lemon orchards enhanced flowering, fruiting, and fruit yield (Kalita and Bhattacharyya 1995). Inadequate management of weeds in apple may reduce yield about 32-36% (El-metwally and Hafez 2007). The age of the tree may also be important in influencing the yield by weeds. It was estimated that weeds can reduce growth of young trees by about 50% (Larsen and Ries 1960). Weeds compete with fruit trees until they are about 4 years old. As the orchard matures weed competition becomes less significant (Gilbert et al. 1965; Larsen and Ries 1960; Lange 1970; Mellenhin et al. 1966). In the present study, Okitsu mandarin trees were 9 years old. *Vicia villosa,* which it is called as a beneficial weed species in Turkey, fixing nitrogen in the soil, was a common herbaceous plant in both sampling years. Coverage of other weed species sampled were less than 5%. It is thought that weeds sampled may have negative effects on mandarin yield, but we do not know degree of yield loss. Yield loss due to the weeds may be insignificant besides ecological benefits of the weeds sampled. Nevertheless, this issue needs to be investigated.

Frankliniella occidentalis and *T. tabaci* were the most common thrips species in the current study. Both thrips species damage many crop plants in the Çukurova region of Turkey. Both thrips are sometimes a problem on citrus in the Mediterranean territories (Jacas et al. 2010). These harmful thrips were mainly on flowers of the citrus mandarin in the current study. They were not recorded during the fruiting stage when the trees are more vulnerable to thrips attacks. Therefore, we did not see typical thrips symptoms on the surface of the fruits. We did not find harmful thrips such as *Pezothrips kellyanus* and *Heliothrips haemorrhidialis* Bouche (Thysanoptera: Phlaeothripidae) in this study. Probably, they do not accept mandarin as a host (Blank and Gill 1997; Teksam and Tunç 2009). *Pezothrips kellyanus* caused scarring of 6–8% of lemon fruits in the Arsuz location, Hatay province, Turkey (Ölçülü and Atakan 2013).

Plant diversity provides alternative prey, refuges, and food sources for natural enemies. The presence of non-host plants also might cause chemical confusion and serve as a barrier (Risch 1981). Plant biodiversity could reduce dependency of growers on chemical insecticides by enhancing natural enemy activity (Altieri and Whitcomb 1979; Gurr and Wratten 1999).

Mean numbers of both thrips species and *Orius* on flowers of mandarin or weedy plant species were lower when compared data of previous experimental year. Mean temperature ranged between 14.3 and 18.4 °C in March–April period in 2014 (unpublished data). Mean temperature varied from 13.3 to 15.3 °C in March–April period in 2015. In 2015, there was a heavy rainy period in March–April. Lower mean temperature and rainy period in March–April in 2015 may have affected negatively the abundance of thrips and predatory *Orius*.

In the current study, densities of both thrips species on citrus flowers in non-weedy plots were significantly greater than on citrus flowers in weedy plots (Fig. 2). Relatively high numbers of predatory bugs were also collected from citrus flowers in weedy plots. The predatory bugs were attracted by the thrips species infesting citrus flowers in weedy plots. Plentiful numbers of *Orius niger* have been found on flowers of herbaceous plants, such as peppers and faba beans, rather than on flowers of fruit trees, such as citrus, in the region (Atakan 2007a, b). One reason for low populations of thrips on citrus flowers, particularly in weedy plots, may be the high *Orius* populations when compared to its densities in non-weedy plots.

Orius population was significantly and positively affected by *T. tabaci* population in citrus flowers (Table 4). This may indicate that *T. tabaci* individuals are an easier prey for *Orius*. Deligeorgidis (2002) found that *O. niger* preyed more on *T. tabaci* than *F. occidentalis* under the laboratory condition. He commented that this issue may be related to predatory ability and selective predating of *O. niger* on *T. tabaci*, due to its easy capture or to its smaller resistance to attacks of *O. niger* compared to *F. occidentalis*. There are limited studies associated with *Orius* being an important natural control agent in regulating arthropod populations in fruit orchards. *Orius vicinus* (Ribault) (Hemiptera: Anthocoridae) is regarded as a predator of phytophagous or predatory mites in Dutch orchard (Heitmans et al. 1986) and apple orchard in New Zealand (Lariviere 1994). The natural populations of the minute pirate bugs, mainly *Orius insidiosus* Say, were very effective predators of thrips in field peppers in Florida (USA) (Funderburk et al. 2000; Ramachandran et al. 2001; Reitz et al. 2003). It appeared that *Frankliniella* spp. in cotton blossoms in Florida could be managed by *O. insidiosus* (Mailhot et al. 2007). *Franklinella occidentalis* was controlled well by naturally occurring populations of *O. niger* in cotton (Atakan 2006) and faba bean (Atakan 2010, 2012) in Adana province, Turkey.

Hairy vetch, *V. villosa* is a winter leguminous plant that fixes nitrogen in the soil (Anugroho et al. 2009; Bongsu and Daimon 2008; Seo and Lee 2008). This weedy plant is also used as a cover crop and suppresses weeds in agroecosystem (Brandsaeter and Netland 1999; Ruffo and Bollero 2003). It is used as a winter cover plant, and when it is mowed and the dead mulch is left on the soil, it exerts allelopathic effects, and thus suppresses weeds (Bradow and Connick 1990; Hill et al. 2007; White et al. 1989). *Vicia villosa* is used for control of erosion. It is also regarded as animal feed because of its high protein content. Although this feature was not examined in this study, the plant was shown to have a significant number of thrips. The number of predatory *Orius* was also high on this weed. Increased plant diversity leads to higher beneficial insect density (Sotherton 1984, 1985; Thomas et al. 1991). Soil plowing and regular control of weeds prevent harmful natural enemy interactions from developing. Although the benefits of herbaceous habitats within or around the crop are known for the development of natural enemy populations (Altieri 1995; Risch 1981), farmers are reluctant to adopt such a strategy because of the harmful effects of weeds on crop yields.

The results of this study showed that weeds affected the abundance and composition of thrips in a citrus orchard. In citrus, the persistence of polyphagous thrips depends on their distribution among a succession of appropriate hosts. Ground cover of plants on which thrips can survive and breed, such as persistent vegetation, might sequester populations that could establish damaging levels. It also could ensure a range of appropriate hosts for potential or rarely pestiferous thrips species during the whole growing season.

In this study, fewer thrips were found in the flowers of citrus trees in the grassy areas. In other words, weeds played a role as a trap plant species. Weeds increased the number and species of beneficial insects. *Vicia villosa* hosted a high number of *F. occidentalis* and *T. tabaci* in the current study (Fig. 3). This plant species supported a higher abundance and diversity of predatory insects including *Orius*. This plant can be regarded as a trap plant for the thrips, and can be considered as a banker plant for beneficial insects. *Thrips hawaiiensis*, an invasive thrips species, was the first detected in lemons in Turkey in 2015 (Atakan et al. 2015). This thrips caused serious damage to the lemons and soon spread to the eastern Mediterranean region. Chemical control of this harmful thrips is difficult because it is in the flowers. Weed varieties and cover plants such as *V. villosa* can also be useful for this thrips and can be evaluated for control. Further research is needed to evaluate efficacy of the ground cover plants and protective biological control tactics against this new pest thrips in the region. *Vicia villosa* may be a suitable cover crop because it hosts higher numbers of both thrips species and predatory bugs.

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Compliance with ethical standards

Conflict of interest The authors declare no conflicting interests with regard to the work as carried out and reported in this manuscript.

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