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Araştırma Makalesi/*Research Article (Original Paper)*

Insect Pests Complex of Common Sage (*Salvia officinalis* L.) (Lamiaceae) and Their Natural Enemies

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Abstract: Common sage, *Salvia officinalis* L., (Lamiaceae) has been economically cultivated in many countries due to its widely used as food and medicines. The sage's production, however, is still facing significant yield losses because of insect pest attacks including other arthropods. This research is aimed to determine insect pests of *S. officinalis* and their natural enemies. Insect species were collected in a year 2016 in the sage fields at Bornova and Menemen, Izmir-Turkey. In total 47 species consisted of 18 insect pests and 29 natural enemies belonging to 30 families in 11 insect orders were collected. The species namely *Aphis passeriniana* (Del Guercio) and *Eucarazzia elegans* (Ferrari) (Hem.: Aphididae); *Dysmicoccus angustifrons* (Hall) (Hem.: Pseudococcidae); *Eupteryx gyaurdagicus* Dlabola and *Micantulina (Mulsantina) stigmatipennis* (Mulsant & Rey) (Hem: Cicadellidae); *Chrysolina (Taeniochrysea) americana* (L.) (Col.: Chrysomelidae) and *Thrips tabaci* Lindeman (Thy.: Thripidae) were determined as key insect pests. *M. stigmatipennis* (Mulsant & Rey) was a new pest hosting for common sage whilst *E. elegans* (Ferrari) and *D. angustifrons* (Hall) were known as the new species recorded for Izmir province. In addition, the natural enemies of key insect pest were determined and discussed.

Keywords: Key insect pest, Natural enemy, Sage plant, *Salvia officinalis*

Tıbbi Adaçayı (*Salvia officinalis* L.) (Lamiaceae) 'nda Zararlı Böcekler ve Doğal Düşmanları ile Etkileşimleri

Öz: Adaçayı, *Salvia officinalis* L. (Lamiaceae) gıda ve ilaç sanayiinde yaygın olarak kullanıldığı için birçok ülkede ekonomik olarak yetiştirilmektedir. Bununla birlikte adaçayı üretimi böcekler ve diğer eklembacaklılar da dahil olmak üzere birçok zararlı türünden etkilenmektedir. Bu çalışma, *S. officinalis* üzerindeki zararlı ve yararlı böcek türlerini ortaya koymak üzere 2016 yılı üretim sezonu boyunca Ege Üniversitesi Ziraat Fakültesi Tarla Bitkileri Bölümü (Bornova) deneme alanlarında ve Ege Tarımsal Araştırma Enstitüsü (Menemen) deneme alanlarında gerçekleştirilmiştir. Çalışma boyunca *S. officinalis* üzerinde 11 ayrı takıma ait 30 familyaya bağlı 47 böcek türü saptanmıştır. Bu türlerden 18'i zararlı ve 29 tür doğal düşman olarak gruplandırılmıştır. Zararlı böceklerden Hemiptera takımına bağlı *Micantulina (Mulsantina) stigmatipennis* (Mulsant & Rey)*, Eupteryx gyaurdagicus* Dlabola (Cicadellidae), *Aphis passeriniana* (Del Guercio) ve *Eucarazzia elegans* (Ferrari) (Aphididae), *Dysmicoccus angustifrons* (Hall) (Pseudococcidae); Coleoptera takımından, *Chrysolina (Taeniochrysea) americana* (L.) (Chrysomelidae) ve Thysanoptera takımından *Thrips tabaci* Lindeman (Thripidae) adaçayı üzerinde en yoğun olarak görülen zararlı türler olarak saptanmıştır. Bu çalışma ile *M. stigmatipennis* (Mulsant & Rey) türünün ilk kez *S. officinalis* üzerinde beslendiği ve konukçusu olduğu saptanmıştır. Ayrıca, *D. angustifrons* (Hall) ve *E. elegans* (Ferrari)'ın ise İzmir'de bulunduğu ilk kez ortaya konulmuştur. Ek olarak, zararlı böceklerin doğal düşmanları belirlenmiş ve tartışılmıştır.

Anahtar Kelimeler: Zararlı böcekler, Doğal düşman, Adaçayı, *Salvia officinalis*

Introduction

The most representative species within the genus *Salvia* Linnaeus (Lamiaceae) is common sage, *Salvia officinalis* L. (Fu et al. 2013). The plant has been credited with a long list of food and medicinal uses (Grieve and Leyel 1992; Tosun et al. 2014). In Turkey, common sage is almost naturally distributed while the big plantations have been started by private companies in recent years (Bayram and Sönmez 2006). Nowadays, the sage production has been tending to increase gradually (Karabacak et al. 2009; Celep et al. 2010). The previous records showed that the worldwide production equalled 1.771 tons of sage in 2012 which Turkey has been one of the world's leading sage producers. It was one of most important medicinal and aromatic plants exports and, in 2013, 1.416 tons were exported with a market value of about 6.3 million USD (Arslan et al. 2015).

Whilst the sage's plant is a leading agricultural sector in the world, the yield is still not quite stable (Bazina 2015). The sage cultivations face unpredictable productions because of insect pests (CABI 2005). For last decades, the exploration of sage plants just focused on genetic variability, chemical contains, and their utilities in agriculture as well as in medical sectors (Mohammad 2011). Many studies result in various technologies to produce good quality of essential oil contents and encouraged several techniques to achieve a high quantity of productions (Lakušić et al. 2013; Bazina 2015), but very few study in faunal diversity associated with sage plant especially insect species. Corsi and Bottega (1999) observed that *Aphis passeriana* (Del Guercio) (Hem.: Aphididae) and *Eupteryx zelleri* (Kirschbaum) (Hem.: Cicadellidae) was living on common sage and CABI (2005) reported *Eupteryx melissae* Curtis (Hem.: Cicadellidae) as a main pest on sage in New Zealand. In addition insect pests such as *Aleurodicus dispersus* Russell (Hem.: Aleyrodidae), *Aonidomytilus albus* (Cockerell) (Hem.: Diaspididae), *Chrysodeixis eriosoma* Doubleday and *Trichoplusia ni* (Hübner) (Lep.: Noctuidae), *Coccus hesperidum* L. (Hem.: Coccidae), *Eupteryx atropunctata* Goeze (Hem.: Cicadellidae), *Frankliniella occidentalis* (Pergande) (Thy.: Thripidae), *Liriomyza trifolii* Burgess in Comstock (Dip.: Agromyzidae) and *Pseudococcus jackbeardsleyi* Gimpel and Miller (Hem.: Pseudococcidae) were recorded on *Salvia*. Blackman and Eastop (2006) described nine aphid species living on common sage, i.e. *Eucarazzia elegans* (Ferrari), *Aphis craccivora* Koch, *A. passeriniana* (Del Guercio), *A. fabae* Scopoli, *A. salviae* Walker, *Aulacorthum solani* (Kaltenbach), *Brachycaudus cardui* (Linneus), *B. helichrysi* (Kaltenbach), and *Myzus ornatus* (Laing) (Hem.: Aphididae).

This research determined insects attacking *S. officinalis* and their natural enemies in order to understand the pest species and their natural enemy complex. The timing of crop infestation by these insects and the key damage periods was also investigated. Early detecting insect populations and their diversities in the field habitat serve as a first step strategy toward integrated pest management on commercial sage plantings.

Materials and Methods

Sample and sampling methods

The insects living on common sage, *S. officinalis* were performed for a period of January to December 2016 with average minimum and maximum temperature of 9ºC and 32ºC, respectively. The investigations of insect pest were conducted in 2 ha sage's planting areas in the experimental farms of the Field Crops Department, Faculty of Agriculture, Ege University, Bornova and Aegean Agricultural Research Institute, Menemen, Izmir-Turkey. The sage plants were two-years-old cultivated organically without pesticide treatments. A total 50 blocks (3×4 m) from the two plantings were monitored using the incident random sampling. Insect diversity and population were recorded fortnightly on five selected point samplings each 0.5 × 0.5 meter square with X shaped routes in each block. The proportion of plants infested in a total population were calculated to measure the incidence rate of insect pests.

Observation, collection and preparation of the specimens

Observations were set up on the selected plant samplings which insect pests observed directly or using a loupe. In general, insect populations were calculated by counting the clumps one by one. Small flying insects on plants were collected using a 30 cm diameter sweep-net, taking 10 (back-forth) sweep samples per block. The natural enemies classified by direct observation in the field and parasitized-preyed test in the laboratory. Percent parasitism was calculated by comparing the number of parasitized insects to the total number of live and parasitized insects collected. Sampling took place between 09:00 a.m. and 05:00 p.m. to account for insect movement. All specimens preserved in the 70% alcohol or dried preserved by drying using a preheated oven at 60ºC. For small insects such as thrips, aphids and scale insects preparing the slide preparations refers to the Borror et al. (1981) Martin (1983), and Kosztarab and Kozár (1988), respectively.

Identification of insect pests and their natural enemies

The insect specimens were identified using the insect identification keys provided by Borror et al. (1981), Goulet et al. (1993), CABI (2005) and Speight and Sarthou (2011). Diagnosis of aphids species were supervised by Dr. Işıl Özdemir (Central Plant Protection Research Institute, Ankara). Leafhopper species were determinated by Prof. Dr. Hüseyin Başpınar (Adnan Menderes University, Aydın) and a mealybug species was carried out by Prof. Dr. M. Bora Kaydan (Çukurova University, Adana). Species of Coccinellidae, Thripidae, Miridae and Braconidae were identified by Prof. Dr. Zeynep Yoldaş (Ege University, Izmir), Dr. Tülin Kılıç (Bornova Plant Protection Research Institute, Izmir), Dr. Gülten Yazıcı (Central Plant Protection Research Institute, Ankara) and Dr. Serdar Akar (Trakya University, Edirne), respectively.

Results and Discussion

Insects complex of Salvia officinalis L.

In total, 47 insect species belonging to 11 orders and 30 families found on *S. officinalis* were collected from two locations, Bornova and Menemen, during the growing season in 2016 (Table 1). Eighteen insect pests and 29 natural enemies were determined complexing of common sage plants. Among insect pests, seven species namely *Aphis passeriniana* (Del Guercio), *Chrysolina (Taeniochrysea) americana* (L.), *Dysmicoccus angustifrons* (Hall), *Eucarazzia elegans* (Ferrari), *Eupteryx gyaurdagicus* Dlabola, *Micantulina (Mulsantina) stigmatipennis* (Mulsant & Rey) and *Thrips tabaci* Lindeman were determined feed on sage plants constantly. It is also recorded that a few number of grasshoppers, moths and leaf bugs attacking common sage randomly. Most of the insect pests were sap-sucking insects belonging to family Aphididae, Cicadellidae, Pseudococcidae, Cercopidae and Thripidae, whereas the remaining insect pests were leaf-chewing insects family of Chrysomelidae, Noctuidae and some families from Orthoptera.

The two highest incidence rate of plant plots were 52% and 46% belonging to species from Cicadellidae and Aphididae families, respectively (Table 2). These rates revealed the proportion of pest-attacked plants in a population undeliberating the lightness and weight of injuries. In Cicadellidae family, *M. stigmatipennis* and *E. gyaurdagicus* were dominant insect species attack on leaves. Both populations were found increasing directly aligned the increasing temperature in the early summer and achieving the highest incident rate in the mid-summer. Even in the winter both species still well-existed jumping within the plants and sunbathing on the leaves. This result was consistent with the reporting of Guistina et al. (1989) stated leafhoppers were mostly developed in temperate regions.

Moreover, in Aphididae, *A. passeriniana* and *E. elegans* populations started to build up at the end of winter and increased constantly towards the onset of spring and then decrease regularly when the temperature becomes higher in summer or lower in winter. The mint aphid, *E. elegans* tended to develop earlier in 1-2 weeks before than *A. passeriniana*. Generally, the insect population rates are positively correlated with plant growth rates in which the aphid species preferred to attack the young parts of the plant (Döring 2014). Here, it was clear that the older plant in growing season with slow-growing young leaves automatically resulted in a low incidence rate of pests. Importantly, *A. passeriniana* affects the shoots and young leaves while *E. elegans* infests the old leaves. Even though both species have a different niche, in some cases it would be overlap, especially in outbreak conditions.

Time related-developing insect pest on *S. officinalis* was described that the mint aphid *E. elegans* occurred earlier in late February to mid-April during the growing season (Figure 1). Furthermore, *A. passeriniana*, *C. americana* and *T. tabaci* occurred later in the early growing season during April to June and were more likely to affect young leaves, buds, flower, seed fill and seed quality. *D. angustifrons*, *M. stigmatipennis* and *E. gyaurdagicus* were mostly developed in mid-summer to winter and attacked the leaves and leaf pockets. In addition, the only beetle *C. americana* was found in aestivation stage along summer and becoming active until the first of autumn. The differential timing attack and niche is a kind of insect strategies to avoid competitors in term of surviving in the ecosystem of which species competing for habitat, food resources or hosting sites tend to partition thermal gradients, time of day, host species, host size classes and others (Brabec et al. 2014).

Table 1. A list of insect pests and natural enemies complexing of *Salvia officinalis* L. collected at Bornova and Menemen, Izmir-Turkey in 2016. Legend: *first record from Izmir province. **New hosting on sage plant

Ordo	Family	Species	Category
Coleoptera	Cantharidae	*Rhagonycha fulva* (Scopoli)*	Predator
		Rhagonycha nigritarsis Brulle	Predator
	Chrysomelidae	*Chrysolina (Taeniochrysea) americana* (L.)	Herbivore
	Coccinellidae	*Coccinella septempuctata* L.	Predator
		Hippodamia variegata (Goeze)	Predator
		Adalia bipunctata (L.)	Predator
		Scymnus frontalis (Fabricius)	Predator
		Exochomus nigromaculatus (Goeze)	Predator
		Cryptolaemus montrouzieri Mulsant	Predator
	Staphylinidae	*Creophilus maxillosus* (L.)	Predator
Dictyoptera	Mantidae	*Ameles heldreichi* Brunner von Wattenwyl	Predator
Diptera	Asilidae	*Machimus annulipes* (Brulle)	Predator
	Cecidomyiidae	*Aphidoletes aphidimyza* (Rondani)	Predator
	Shyrphidae	*Syrphus ribesii* (L.)	Predator
		Syrphus vitripennis (Meigen)	Predator
Hemiptera	Anthocoridae	*Orius niger* (Wolff)	Predator
	Aphididae	*Aphis passeriniana* (Del Guercio)	Herbivore
		Eucarazzia elegans (Ferrari)*	Herbivore
		Aphis craccivora Koch	Herbivore
		Aphis fabae Scopoli	Herbivore
	Cercopidae	*Philaenus spumarius* (L.)	Herbivore
		Philaenus signatus Melichar	Herbivore
	Cicadellidae	*Micantulina (Mulsantina) stigmatipennis* (Mulsant & Rey)**	Herbivore
		Eupteryx gyaurdagicus Dlabola	Herbivore
	Miridae	*Macrolophus caliginosus* Wagner	Predator
	Pentatomidae	*Acrosternum heegeri* Fieber	Herbivore
	Pseudococcidae	*Dysmicoccus angustifrons* (Hall)*	Herbivore
Hymenoptera	Braconidae	*Ephedrus persicae* Froggatt *	Parasitoid
		Cotesia yakutatensis Ashmead	Parasitoid
	Encyrtidae	*Anagrus* sp.	Parasitoid
		Gyranusoidea indica Shafee, Alam & Agarwal*	Parasitoid
	Formicidae	*Aphaenogaster* sp.	Predator
		Lasius brunneus (Latreille)	Predator
	Ichneumonidae	*Hyposoter ebeninus* (Gravenhorst)	Parasitoid
		Hyposoter exiguae (Viereck)	Parasitoid `
Lepidoptera	Noctuidae	*Spodoptera littoralis* (Boisduval)	Herbivore
		Trichoplusia ni (Hübner)	Herbivore
Neuroptera	Chrysopidae	*Chrysoperla carnea* (Stephens)	Predator
Odonata	Aeshnidae	*Anax imperator* Leach	Predator
	Gomphidae	*Onychogomphus farcipatus albotibialis* (Schmidt)	Predator
	Libellulidae	*Crocothemis erythraea* (Brulle)	Predator
Orthoptera	Acrididae	*Locusta migratoria* L.	Herbivore
	Gryllidae	*Gryllus campestris* L.	Herbivore
	Pyrgomorphidae	*Pyrgomorpha conica* (Oliver)	Herbivore
	Tettigoniidae	*Tettigonia viridissima* L.	Herbivore
Raphidioptera	Raphidiidae	*Raphidia raddai* Aspöck & Aspöck	Predator
Thysanoptera	Thripidae	*Thrips tabaci* Lindeman	Herbivore

The presence pattern of insect pest populations recorded in Table 3 revealed taxa of Aphididae, Chrysomelidae and Pseudococcidae have cluster pattern on every observing plot, but Cicadelidae has a homogenous distribution. Such pattern was different for Thripidae in which the population at the sage field in Bornova spread cluster but homogenously in Menemen. The presence patterns were a result of differentiation in insect density in a population. The differential insect distribution shows individual competition leads to sharing of living space and then cluster pattern emerges due to organisms need for the same physical factors (Baldwin 2001; Khan et al. 2008).

Table 2. The incidence rate of key insect pests of *Salvia officinalis* L. at Bornova and Menemen, Izmir-Turkey in 2016

Family	Species	Incident rate (%) ± SEM							
		Spring		Summer		Autumn		Winter	
		Bornova	Menemen	Bornova	Menemn	Bornova	Meneme	Bornov	Menemen
Chrysomelidae	*Chrysolina (Taeniochrysea) americana*	1.55±0.12	2.10±0.09	0.00±0.00	0.00±0.00	1.32±0.07	1.62±0.11	0.02±0.00	0.02±0.00
Aphididae	*Eucarazzia elegans*	9.50±0.23	8.22±0.98	1.14±0.09	0.90±0.07	1.21±0.06	1.10±0.08	0.43±0.09	0.12±0.04
	Aphis passeriniana	46.00±1.41	13.20±1.93	2.12±0.10	0.43±0.04	2.57±0.14	1.33±0.08	0.08±0.01	0.09±0.01
Cicadellidae	*Micantulina (Mulsantina) stigmatipennis*	10.23±1.02	1.45±0.04	52.04±4.32	3.65±0.31	10.03±0.96	0.98±0.05	1.34±0.08	0.47±0.04
	Eupteryx gyaurdagicus	1.32±0.23	9.92±0.92	2.72±0.21	24.32±2.01	1.06±0.01	7.03±0.36	0.34±0.26	1.93±0.09
Pseudococcidae	*Dysmicoccus angustifrons*	0.02±0.00	0.01±0.00	12.30±1.08	10.1±0.98	7.32±0.76	3.44±0.27	0.94±0.08	0.72±0.06
Thripidae	*Thrips tabaci*	0.43±0.04	0.12±0.01	1.01±0.05	0.59±0.06	0.32±0.01	0.12±0.01	0.00±0.00	0.00±0.00

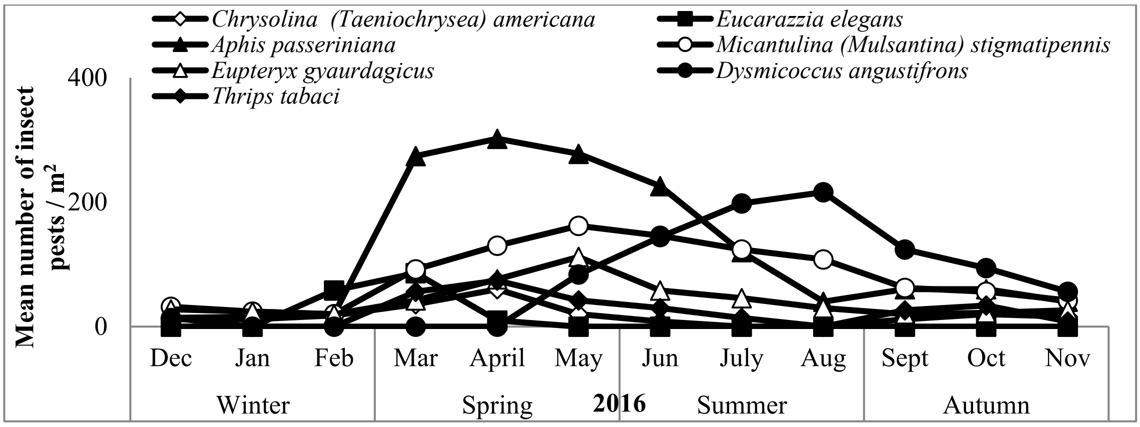

Figure 1. Population dynamic of key insect pest living on *Salvia officinalis* L. at Bornova and Menemen, Izmir-Turkey in 2016.

Key insect pests of Salvia officinalis L.

The present research work recorded seven potential insect pests living on common sage. The distinguishing features of each major-pest species were described in order as follows. Moreover, natural enemies records related to insect pest species were also included.

Table 3. Distribution pattern of the key insect pests living on *Salvia officinalis* L. at Bornova and Menemen, Izmir-Turkey in 2016

Family	Species	Bornova		Menemen		Pattern	
		Varians	Mean	Varians	Mean	Bornova	Menemen
Chrysomelidae	*Chrysolina (Taeniochrysea) americana*	2.05	1.03	1.56	1.10	Cluster	Cluster
Aphididae	*Eucarazzia elegans*	91.66	125.25	111.27	123.02	Homogen	Homogen
	Aphis passeriniana	318.27	366.08	99.64	130.01	Homogen	Homogen
Cicadellidae	*Micantulina (Mulsantina) stigmatipennis*	2.24	5.67	0.93	2.25	Homogen	Homogen
	Eupteryx gyaurdagicus	1.15	2.67	1.36	4.50	Homogen	Homogen
Pseudococcidae	*Dysmicoccus angustifrons*	1.10	2.03	0.48	1.63	Homogen	Homogen
Thripidae	*Thrips tabaci*	2.45	1.58	0.70	0.83	Cluster	Homogen

Note: V= Varians; M= Mean; V>M (Cluster); V=M (Random); V<M (Homogen).

Aphis passeriniana (Del Guercio)

The species does not host alternate, since it can also survive on *S. fructicosa*, *S. splendens* (scarlet-flowered sage) and *S. verticillata* (lilac sage) (Zarkani and Turanlı 2018). The symptoms of the aphid attack show distortion of leaves and young shoots with no wilting; honeydew on leaves and bud flowers with black sooty mold fungus; drawft plant; flowers and seeds undeveloped (Figure 2A). Thirteen species of natural enemies were found associated with *A. passeriniana*: *Adalia bipunctata* (L.), *Coccinella septempuctata* L., *Exochomus nigromaculatus* (Goeze), *Hippodamia variegata* (Goeze), *Aphidoletes aphidimyza* (Rondani), *Cryptolaemus montrouzieri* Mulsant, *Scymnus frontalis* (Fabricius) (Col.: Coccinellidae), *Chrysoperla carnea* (Stephens) (Neu.: Chrysopidae), *Macrolophus caliginosus* Wagner (Hem.: Miridae), *Orius niger* (Wolff) (Hem.: Anthocoridae), *Rhagonycha fulva* (Scopoli), *R. nigritarsis* Brulle (Col.: Cantharidae), *Syrphus ribesii* (L.), *Syrphus vitripennis* (Meigen) (Dip.: Shyrphidae), and parasitoid *Ephedrus persicae* Froggatt (Hym.: Braconidae).

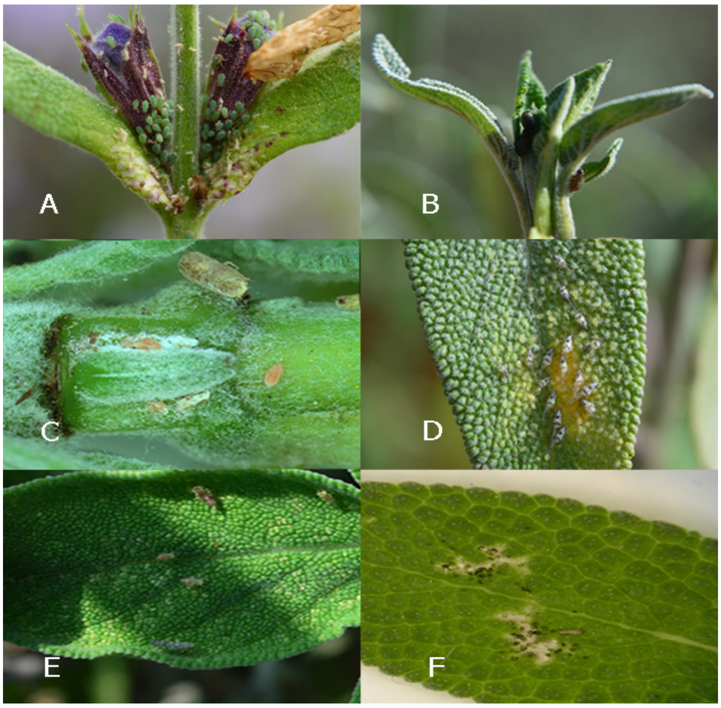

Figure 2. Key insect pests of *Salvia officinalis* L. (A) *Aphis passeriniana* (Del Guercio), (B) *Chrysolina (Taeniochrysea) americana* (L.) larvae, (C) *Dysmicoccus angustifrons* (Hall), (D) *Eucarazzia elegans* (Ferrari), (E) *Eupteryx gyaurdagicus* Dlabola and *Micantulina (Mulsantina) stigmatipennis* (Mulsant & Rey) and (F) *Thrips tabaci* Lindeman.

Chrysolina (Taeniochrysea) americana (L.)

Larva and imago feed on leaves (Figure 2B). The potential outbreak is probably in mid-March and April (see Figure 1). *Ameles heldreichi* Brunner von Wattenwyl (Dic.: Mantidae) was determined as a larvae predator.

Dysmicoccus angustifrons (Hall)

This is a new species recorded in Izmir province which the first record for the Turkish Pseudococcid fauna was reported by Kaydan et al. (2001) . Nymph and adult produce honeydew and ants, *Aphaenogaster* sp. and *Lasius brunneus* (Latreille) (Hym.: Formicidae) were found as symbionts. *D. angustifrons* also known an attack on the roots of *Rhazia stricta* (Apocynaceae) (Matile-Ferrero et al. 2015), but it was not the case in species recorded by our study. A high density of insects may result in leaf drop (Figure 2C). The predator coccinelidae, *C. montrouzieri*, and the parasitic wasps, *Anagrus* sp. and *Gyranusoidea indica* Shafee, Alam and Agarwal (Hym.: Encyrtidae) were found associated with this insect pest.

Eucarazzia elegans (Ferrari)

The aphid was recorded as a new species in Izmir province. The aphid emerged and attacked old leaves in the early spring and then they usually migrate to young leaves and blossoms at the beginning of the summer. The aphid produces less to no honeydew that it impacts to fewer ants found in the aphid colonies. Zarkani et al. (2017b) reported that the mint aphid, *E. elegans* population dynamic was particularly more impressed by temperature than humidity and rainfall. The aphids tend to infest old leaves and impact to excessive defoliated. Serious necrotic with yellow ringspot was clearly found at infected leaves (Figure 2D). There is no parasitoid recorded hosting on this aphid species. Some predator such as *C. septempunctata*, *C. carnea*, *H. variegata*, *S. frontalis R. fulva*, *A. aphidimyza*, *S. ribesii*, *S. vitripennis*, and *M. caliginosus* were found mostly in the aphid colonies.

Eupteryx gyaurdagicus Dlabola

The highest density was just found in Menemen (see Table 3). The insect feed by piercing surface tissues and suck up the exuded cellular contents, destroys chlorophyll, curls and necrotic leaves (Figure 2E). The necrotics are white, sometimes grey and are usually limited by leaf nerves. The white spots appear on the damaged leaf surface impacting to qualitative and quantitative losses and they become unmarketable. Mirid bugs, *M. caliginosus* and robber flies, *Machimus annulipes* (Brulle) (Dip.: Asilidae) were mostly found to attack this species. Some dragonflies, *Anax imperator* Leach (Odo.: Aeshnidae), *Onychogomphus farcipatus* albotibialis (Schmidt) (Odo.: Gomphidae), *Crocothemis erythraea* (Brulle) (Odo.: Libellulidae) and snakefly *Raphidia raddai* Aspöck & Aspöck (Rap.: Raphidiidae) also probably controlled the leafhopper population.

Micantulina (Mulsantina) stigmatipennis (Mulsant & Rey)

The species is monophagous insect that mostly has been collected from *Verbascum lychnitis* (Scrophulariaceae) (Świerczewski 2014). In our study, however, the species lived on the underside of the base sheets of *S. officinalis* (Figure 2E). This was the first report of *M. stigmatipennis* attacking plants out of Scrophulariaceae. Spiders were the most important predator of the species followed by predatorious insect such as mirid bugs, *M. caliginosus*, robber flies, *M. annulipes* and rove beetle, *Creophilus maxillosus* (L.) (Col.: Staphylinidae). We found parasitized cicadellid specimens but the adult parasitoids have never emerged.

Thrips tabaci Lindeman

We faced a big problem with *T. tabaci* when cultivating time in greenhouses (25 ± 2ºC, 65 ±5% RH and 16 h L: 8 h D photoperiod). The insect feeding damage on the leaves appears as a superficial silver or bronze scarring on the epidermis and cause distortions during growth and reduction in photosynthetic capacity (Figure 2F). *S. ribesii, S. vitripennis, M. caliginosus*, and some larva of lady beetles were found attacking this insect.

Other insects

A number of other insects were recorded on the plant throughout the season, including several species of froghoppers: *Philaenus spumarius* (L.) and *P. signatus* Melichar (Hem.: Cercopidae), moths: *Spodoptera littoralis* (Boisduval) and *Trichoplusia ni* (Hübner) (Lep.: Noctuidae), grasshoppers: *Locusta migratoria* L. (Orth.: Acrididae), *Gryllus campestris* L. (Orth.: Gryllidae), *Pyrgomorpha conica* (Oliver) (Orth.: Pyrgomorphidae) and *Tettigonia viridissima* L. (Orth.: Tettigonidae), true bug: *Acrosternum heegeri* Fieber (Hem.: Pentatomidae) and aphids: *Aphis craccivora* Koch and *Aphis fabae* Scopoli (Hem.: Aphididae). Those insects do not damage the plant economically and are not quarantine pests (CABI, 2005), and are therefore not of primary concern.

Natural enemies associated with insect pests of Salvia officinalis L.

All insect pests collected in the sage's field have a strong association with predators as natural enemies, but only taxa of Aphididae, Psudococcidae, Cicadellidae, and Noctuidae were found to be parasitized (Figure 3). The main predator was lady beetle species as a group of generalist predator and predominant entomophagy preyed on soft-bodied insects from Aphididae and Pseudococcidae. Other generalist predators were Neuroptera and Shyrpidae preyed on aphids while robertfly on leafhoppers. The biodiversity of Coccinellidae species observed in the survey areas was high of which *H. variegata* (Goeze) within five morphospecies were recorded (Zarkani et al. 2017a).

Furthermore, the incidence of insect parasitism in the sage field was found to be varying ranging from 1.61% to 80.29%. The highest parasitization occurred on aphid *A. passeriniana* (Del Guercio) that reached 80% and associated with parasitoid wasp, *Ephedrus persicae* Froggatt (Hym.: Braconidae). It might appear that the parasitoid population was higher than their hosts and it follows that the build-up of the population will be delayed until average temperatures increase and the host has become well established in spring. A low number of mummies were investigated in early summer with the generative development of the seed (seed-growing stage). In this case, environmental factors as well as food resources showed an impact on the insect density and also affected the rate of parasitization. Insect pest infestations were higher during the month prior to harvest and so was the incidence of parasitization. The real parasitization levels in the field, moreover, indicated the effectivity of natural pest controls in which the number of pests increases followed by the increase in the number of parasitization and so on.

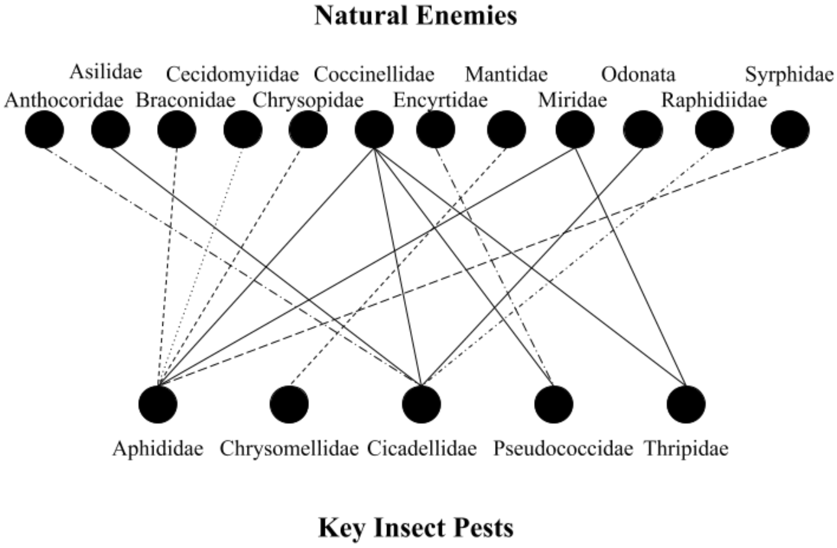

Figure 3. Graph network illustrates natural enemies associated with key insect pests of *Salvia officinalis* L.

The process of plant growth and development consequently causes canopy overlap by the time and it stimulates the movement and development of insect pests being high. The gradient of plant development made consequences to the complexity of plant vegetation. It would probably change the pattern of vegetation because the plant to be older, the canopy grew and enlarged, the shadow increased and the light intensity less absorbed. Then, it would impact the microclimate and change the feeding behaviour of predator and parasitoid as well (Mason 2017). Without population limiting factors such as biotic and abiotic, it probably resulted in an outbreak of insect pests. Also, the decline in the number of natural enemies impacts to increase pest population. Biological control of pests by natural enemies is absolutely important since it could be a major ecosystem service delivered to agriculture worldwide (Martin et al. 2013).

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