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Mortality Effect of *Origanum syriacum L.* (Lamiaceae) and *Satureja montana L.* (Lamiaceae) Essential Oils on *Pieris brassica L.* (Lepidoptera: Pieridae)

Başak ULAŞLI[1]✉ N. Pelin BAHADIRLI[2] Zhanerke AMANGELDİ[3] Asime Filiz ÇALIŞKAN KEÇE[4]
[1,2]Hatay Mustafa Kemal University, Department of Plant Protection, Faculty of Agriculture,31034, Hatay, Türkiye, [3,4]Çukurova University, Department of Plant Protection, Faculty of Agriculture, Adana, Türkiye
[1]https://orcid.org/0000-0002-0989-2020, [2]https://orcid.org/0000-0001-7321-5377, [3]https://orcid.org/0000-0002-9017-8106
[4]https://orcid.org/0000-0002-9330-1958
✉: basaktok@yandex.com

ABSTRACT

Cabbage, *Brassica oleracea* var. *capitata* L. (Brassicaceae), is one of the most widely consumed vegetables worldwide, and one of its most significant pests is *Pieris brassicae* L. (Lepidoptera: Pieridae). In recent years, the use of plant essential oils in pest control has significantly increased as an alternative control method. This study investigates the lethal effects of essential oils obtained from *Origanum syriacum* (Lamiaceae) and *Satureja montana* (Lamiaceae) on *P. brassicae* larvae. The main components of the essential oil of *O. syriacum* were identified as o-cymene (39.77%), carvacrol (28.16%), and thymol (12.78%), while the essential oil components of *S. montana* were determined as carvacrol (50.03%), o-cymene (15.12%), and γ-terpinene (13.02%). The essential oils were applied to different developmental stages (L1-L5) of *P. brassicae* using a spraying technique at various concentrations (5-10-20-50-100 µL mL^{-1}). The experiment was designed with 10 replicates, each containing 10 larvae from different developmental stages of *P. brassicae*, with water used as the control. To determine larval mortality rates, dead and living larvae were counted at 24-hour intervals for a total of 72 hours. The results showed that both *S. montana* and *O. syriacum* essential oils had a lethal effect ranging from 50% to 100%. However, *S. montana* essential oil was found to be more effective against *P. brassicae* larvae than *O. syriacum* essential oil.

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Origanum syriacum L. (Lamiaceae) ve *Satureja montana* L. (Lamiaceae) Uçucu Yağlarının *Pieris brassicae* L. (Lepidoptera: Pieridae) Üzerindeki Ölüm Etkisi

ÖZET

Lahana, *Brassica oleracea* var. *capitata* L. (Brassicaceae), tüm dünyada en fazla tüketimi yapılan sebzelerden birisi olup, en önemli zararlılarından birisi de *Pieris brassicae* L. (Lepidoptera: Pieridae)'dir. Son yıllarda zararlılarla mücadelede bitkisel uçucu yağların kullanılması alternatif mücadele yöntemi olarak önemli derecede artış göstermiştir. Bu çalışmada *Origanum syriacum* (Lamiaceae) ve *Satureja montana* (Lamiaceae) bitkilerinden elde edilen uçucu yağların *P. brassicae* larvaları üzerindeki ölüm etkisi araştırılmıştır. *O. syriacum* bitkisinin uçucu yağının ana bileşenleri o-cymene (%39.77), carvacrol (%28.16), ve thymol (%12.78) olarak belirlenmişken, *S. montana'* nın uçucu yağ bileşenleri carvacrol (%50.03), o-cymene (%15.12) ve γ-Terpinene (%13.02) olarak belirlenmiştir. Uçucu yağlar, *P. brassicae*'nin (L1-L5) dönemlerine, farklı konsantrasyonlarda (5-10-20-50-100 µL mL-1) spreyleme tekniği kullanılarak uygulanmıştır. Deneme 10 tekerrür olacak şekilde kurulmuş, her tekerrürde *P. brassicae*'nin farklı larva dönemlerinden 10'ar adet larva ile kontrol olarak su kullanılmıştır. Larvaların ölüm oranını belirlemek için toplamda 72 saate kadar 24 saatlik aralıklarla ölü-canlı sayımı yapılmıştır. Hem *S. montana* hem de *O. syriacum* uçucu yağlarının %50-%100 oranlarında ölüm etkisine sahip olduğu, ancak *S. montana* uçucu yağının *P. brassicae* larvaları üzerinde *O. syriacum* uçucu yağından daha etkili olduğu tespit edilmiştir.

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INTRODUCTION

Cabbage, *Brassica oleracea var. capitata* L. (Brassicaceae), is one of the most favorable vegetables in this group because it can be grown in almost any region. While Türkiye ranks 10th in world cabbage production, China is first and is followed by India, Russia, South Korea, and Japan (FAO, 2020). Türkiye produces approximately 965 tons of leaf cabbage annually (TÜİK, 2022).

Most of the common pests of cabbage belong to the order Lepidoptera. These are the tobacco caterpillar *Spodoptera litura* (F.), cabbage semi-looper *Trichoplusia ni* (Hübner), the cotton leafworm, *Spodoptera littoralis* (Boisduval), gram pod borer, *Helicoverpa armigera* Hbn. (Lepidoptera: Noctuidae); diamondback moth, *Plutella xylostella* L. (Lepidoptera: Plutellidae); cabbage leaf webber *Crocidolomia binotalis* Zell., the cabbage webworm, *Hellula undalis* (F.) (Lepidoptera: Pyralidae), cabbage butterfly *Pieris brassicae* L., small cabbage white butterfly, *Pieris rapae* L., (Lepidoptera: Pieridae), and the others as follows, cabbage aphid *Brevicoryne brassicae* L. (Hemiptera: Aphididae), painted bug *Bagrada hilaris* (Burmeister) (Hemiptera: Pentatomidae), flea beetle (Coleoptera: Chrysomelidae), *Liriomyza brassicae* Riley (Diptera: Agromyzidae) and the mustard sawfly, *Athalia lugens proxima* Klug (Tenthredinidae: Hymenoptera) (Ulusoy and Ölmez Bayhan, 2006; Kaya and Kornoşor; 2008; Ahuja et al., 2012; Diome et. al., 2019).

In regions where Brassicaceae vegetables are grown, synthetic pesticides are used intensively without tolerance to pest problems. Unfortunately, using chemicals to control pests does not always succeed. These conditions have a direct impact on human health, wildlife, the environment, and so on. For pests, it causes considerable problems (Long, 1987) and leads to the build-up of pest resistance to pesticides. These crops, which are harvested or placed on the market after intensive spraying, cause many negative effects on human beings in cases of chronic poisoning. For these reasons, the application of biological control methods, especially for vegetable pests, is being extensively studied in developed countries, and "Integrated Pest Management" is being adopted individually for each crop (Bayhan et al., 2002; Akdağcık., 2010; Paudel et al., 2022; Bayhan et al., 2020). Furthermore, the use of plant extracts and Essential oils (EOs) as, one of the alternative control options for both disease and pest control has increased significantly over recent years (Walia et al., 2017; Kaleeswaran et al., 2019; Mondédji, et al., 2021; Bahadirli, 2022; Çeliktaş et al., 2022; Erdogan Eliuz and Bahadirli, 2022).

The Lamiaceae family plays an important role in the food industry, cosmetics, medicine, pharmacology, and lately, the agrochemical industry. The genus *Origanum* L., which has 44 species and 19 hybrids, grows widely, especially in the Mediterranean basin (Duman et al., 1998; Dirmenci et al., 2018). Flora of Türkiye is very rich in terms of *Origanum* species, with 23 species including eight hybrids; furthermore, six species naturally occur in Hatay province. *Origanum syriacum* L. is a perennial herbal medicine, distributed in Lebanon, Syria, Jordan, Palestine, Palestine and Türkiye (Meyers, 2005). *O. syriacum* has been collected from flora to be used as a flavoring spice, fresh herb, folk-medicine applications, and an additive in other herbal products (Atar and Colgecen, 2020). The genus *Satureja* has 200 species that are distributed natively in the Middle East and Europe (Chorianopoulos et al., 2004; Macelli et al., 2020). According to recent studies, *Satureja* species from Türkiye has been increased to 17 and 7 of them are endemic (Dirmenci et al., 2019; Duman et al., 2023). *S. montana* is a perennial shrub, native to Albania, Austria, France, Greece, Italy, Spain and Yugoslavia (Anonymous, 2023). *S. montana* has been used in folk medicine, pharmacology, flavoring agent in foods (Redzic, 2006; Čopra-Janićijević et al., 2020).
The objective of the study is to evaluate mortality activity of the essential oils of *O. syriacum* and *S. monatana* on the larvae of *P. brassicae* under laboratory conditions.

MATERIAL ve METHOD

Origanum syriacum plants were in full flowering period from Yayladağı-Hatay province of Türkiye in July in 2021. *O. syriacum* plant samples were air-dried at room temperature for a week. *S. montana* EO's were hydro-distilled from aerial parts of the plants in a Clevenger-type apparatus for three hours. *S. montana* essential oil was obtained from the company Dropena, Hatay, Türkiye. Both EOs were kept in amber vials at 4^{0}C until analysis.

Mass breeding of test insects

Pieris brassicae caterpillars were collected from cabbage fields in Adana province. Mortality activity tests were carried out in the Vegetable and Ornamental Plant Pests Laboratory of the Plant Protection Department of Çukurova University. EOs were obtained from the Hatay Mustafa Kemal University, Department of Field Crops, Medicinal Aromatic Plants Laboratory.

Pieris brassicae were grown under laboratory conditions according to the standard methods described by (Firake et al. (2017). Infested plants and/or larvae were kept under optimal conditions (25±2°C temperature, 120 μmolm−2.s−1 light density, 70±5% relative humidity, and 16:8, light: dark period) to obtain the next-generation larvae to be used in this study. The taxonomic description of the pest was performed by the first author.

Gas Chromatography-Mass Spectrometry (GC-MS)

The essential oil composition was determined with GC-MS (Agilent 7890A-5975C) equipped with an HP5-MS 19091S-433 model column (30m X 250 μm film X 0.25 μm). Helium was a carrier gas. The detector transfer line temperature was 260 °C, and the detector ionization temperature was 250 °C. The analysis program was as follows: starting with 60 °C increased to 150 °C with 5 °C min-1, from 150 to 200 °C with 1.5°C min-1, from 200 °C to 240°C with 4 °C min-1. The EO components were defined using Wiley and NIST databases.

Mortality effects of *S. montana* and *O. syriacum* essential oils on *P. brassicae* larvae by spray assay

The EOs were evaluated against the second and/or third instar larvae of *P. brassicae* utilizing spraying. The bioassay of the plant extracts' essential oils (EOs) was carried out against the caterpillars of *P. brassicae* following a procedure similar to that described by Çeliktaş et al. (2022). Each treatment was replicated 10 times, and each replicate contained 10 larvae at a different stage and a control (water). Observations on the mortality of the larvae were made at 24-hour intervals for up to 72 hours. Mortality rates were estimated using the Abbott formula. Therefore, *S. montana* and *O. syriacum* were evaluated for their insecticidal potential against *P. brassicae* larvae (Fig 1).

Fig 1. General views after application *Origanum syriacum* essential oil to the living *Pieris brassicae* larvae on fresh cabbage leaves

Şekil 1. Origanum syriacum uçucu yağının taze lahana yaprakları üzerindeki canlı Pieris brassicae larvalarına uygulanması sonrasındaki genel görünümü

Application of Essential Oils against *P. barassicae* larvae

Essential oil solutions (5-10-20-50-100 μL mL^{-1} concentrations) were prepared with Tween 80 and applied on caterpillars which were grown on the cabbage three times. For this purpose, square Petri dishes (diameter 100 Ø) including 1.5% prepared on water agarose and a broad cabbage leaf were placed in as infection atmosphere in it. In addition, 10 larvae, which were L1-L5 stage, were infected with a watercolor brush. Essential oil solutions were sprayed on Petri dishes three times with equal flow caps. The edges of Petri dishes were covered with parafilm and placed into climate cabinets (Nüve TK 120). Dead individuals were checked at 24, 48 and 72 h after oil application.

Statistical analyses

The data was analyzed by Abbott tests (Abbott, 1925), and interactions within applications and application times were determined by Analysis of Variance (ANOVA). These tests were performed by using SPSS Statistics 23.0 (IBM Corporation, New York, NY, USA).

RESULTS and DISCUSSION

In this study, the mortality effect of EOs obtained from *Satureja montana* and *Origanum syriacum* plants were tested on *Pieris brassicae* larvae. The chemical composition of *O. syriacum* and *S. montana* EOs were determined with GC/MS method (Table 1). EO analysis for *O. syriacum* has resulted in 18 components with a total of 93.47%. *S. montana* EO contained 31 components with a total of 99.68%. The main components of *O. syriacum* were *o*-cymene (39.77%), carvacrol (28.16%), and thymol (12.78%), while in *S. montana* EO carvacrol (50.03%), o-cymene (15.12%) and *γ-Terpinene* (13.02%).

Table 1. The essential oil composition of Origanum syriacum and Satureja montana (%)
Çizelge 1. Origanum syriacum ve Satureja montana uçucu yağ bileşenleri (%)

#	RT	CAS-Number	Compound Name	*O. syriacum*	*S. montana*
1	5.89	002867-05-2	*α*-Thujene	1.02	1.55
2	6.08	000080-56-8	*α*-Pinene	*n.d.*	1.12
3	6.50	000079-92-5	Camphene	0.17	0.55
4	7.33	000127-91-3	*β*-Pinene	0.06	0.27
5	7.52	053907-72-5	1-Octen-3-ol	1.54	1.14
6	7.79	000123-35-3	*β*-Myrcene	0.47	1.76
7	8.23	000099-83-2	l-Phellandrene	0.09	0.28
8	8.41	013466-78-9	*δ*-3-Carene	0.06	0.10
9	8.63	000099-86-5	*α*-Terpinene	0.92	1.96
10	8.96	000527-84-4	*o*-Cymene	**39.77**	**15.12**
11	9.05	000535-77-3	Cymol	0.52	0.94
12	9.12	000470-82-6	1.8-Cineole	*n.d.*	1.03
13	10.13	000099-85-4	*γ*-Terpinene	6.50	**13.02**
15	11.16	006728-26-3	2-Hexanal	0.11	0.11
16	11.64	000586-62-9	*α*-Terpinolene	*n.d.*	1.21
17	14.03	000507-70-0	Borneol	0.65	1.87
18	14.30	998016-25-4	2-Isopropylfuran	*n.d.*	0.12
19	14.46	000562-74-3	Terpineol	0.04	1.13
20	15.07	000470-08-6	*β*-Fenchyl alcohol	*n.d.*	0.25
21	18.98	000089-83-8	Thymol	**12.78**	0.11
22	19.40	003228-02-2	Carvacrol	**28.16**	**50.03**
25	21.76	005208-59-3	*β*-Bourbonene	*n.d.*	0.15
26	22.93	998193-98-7	Trans *β*-Caryophyllene	0.04	2.78
27	23.25	023986-74-5	Germacrene-D	*n.d.*	0.11
28	23.58	000489-39-4	Aromandendrene	*n.d.*	0.11
29	24.06	006753-98-6	*α*-Humulene	*n.d.*	0.84
30	24.81	000483-75-0	Naphthalene	*n.d.*	0.19
33	25.85	000495-61-4	*β*-Bisabolene	*n.d.*	0.82
34	26.04	000483-75-0	Naphthalene	*n.d.*	0.32
35	26.31	000483-76-1	*δ*-Cadinene	*n.d.*	0.35
36	28.25	000499-75-2	Caryophyllene oxide	1.13	0.34
Total				**93.47**	**99.68**

n.d.= not detected

Several studies show EO variation of *O. syriacum* according to the locality, plant parts, genetics, and ecology. *O. syriacum* samples from Egypt in different studies showed that the main components of EO carvacrol, thymol, and/or γ-terpinene (Fleisher & Fleisher, 1991; Baser et al., 2003; Viuda-Martos et al., 2010; Gendy et al., 2015). Alma et al. (2003) found EO main components of *O. syriacum* from Hatay, Türkiye as *γ*-terpinene (27.79%), carvacrol (26.97%), *p*-cymene (15.69%), and *β*-caryophyllene (12.59%). In addition to that, EO composition from Amman has resulted that carvacrol (41.1%), *p*-cymene (30.22%), *γ*-terpinene (4.27%), and *cis*-sabinene hydrate (3.22%) being the main components (Al-Kalaldeh et al., 2010). Furthermore, *p*-cymene was found as a main component of *O. syriacum* EO from Lebanon (El-Alam et al., 2019). Similar to that result, *p*-cymene, thymol, and carvacrol were found to be the most abundant components in Lebanon *O. syriacum* (Shehadeh et al., 2019). *S. montana* was found to have high genetic variability with 26 subspecies (Čopra-Janićijević et al., 2020). Compounds of *S. montana* from Bosnia-Herzegovina resulted in linalool and *α*-Terpineol being most abundant in steam distillation while linalool, cis-sabinene hydrate, and *p*-cymene were most abundant in headspace sampling (Čopra-Janićijević et al., 2020). Like this results, carvacrol was found at 45 % in *S. montana* samples from Croatia (Bezic et al., 2005). In addition, carvacrol was found at 1.1% in *S. montana* EO from Montenegro. These studies clearly show that *S. monatana* has great variation in terms of EO composition.

The efficacy of essential oils dissolved in Tween 80 on insect mortality is shown in Tables 2 and 3. The general view of these experiments after application is shown in Figure 2. The larvae at all stages (L1-L5) were randomly placed in Petri dishes, and it was determined that the highest mortality in *P. brassicae* larvae occurred in the second and third stages (L2-L3), while there was no mortality in the last two larval stages (L4-L5). Individual effects and interactions of concentrations and exposure duration are found to be significant on insect mortality by comparing them with the control during EO applications. Significant differences were obtained for inter-concentrations and an increase in exposure duration ($p<0.05$). The statistical analysis also showed that *O. syriacum* and *S. montana* EOs have different effects on *P. brassicae*, and *O. syriacum* essential oils' mortality activity results are given in Tables 2 and 3. All EO applications showed higher effects on *P. brassicae* larvae than the control. The mortality averages ranged between 0.0644 to 1.5708 in all EO applications. The mortality activity of *O. syriacum* EOs showed more variation according to different hours and inter-concentration concentrations compared to *S. montana* EOs. The higher concentrations, 50% and 100%, showed the highest mortality activity, therefore, it could be said that 50% with the same effect should be preferable. When the application hours increased, the accumulated amount, their impact was reduced to low doses. *S. montana* EOs' mortality activity is shown in Table 3. The results showed that 50 % and 100% of applications' mortality activity was not changed according to hours.

Figure 2. General view of dead Pieris barassicae larvae on cabbage leaves after applying essential oils at different concentrations
Şekil 2. Farklı konsantrasyonlardaki uçucu yağ uygulamasından sonra lahana yaprakları üzerindeki ölü Pieris barassicae larvalarının genel görünümü

In this study, which evaluated the efficacy of *O. syricaum* application on *P. brassicae* larvae in terms of concentration and time, it was found that the most effective concentrations over 24 hours were 50% and 100%, with no statistical difference between these two concentrations. In the 48-hour period, there were no statistical differences between the 20%, 50%, and 100% concentrations. However, in the 72-hour application, all concentrations were effective, and there was no statistical difference between them except the control application (Table 2).

When the effect of *S. montana* essential oil was investigated on *P. brassicae* larvae, similar results were observed of *O. syriacum* essential oil. No statistical difference was observed between the 50% and 100% concentration applications after 24, 48, and 72 hours. For this essential oil, the most effective treatment, like with *O. syriacum* essential oil, was found as a 50% concentration applied over a 24-hour period (Table 3).

Table 2. Mortality activity of different consantration of Origanium syriacum essential oil against Pieris brassicae larvae

Çizelge 2. Origanium syriacum esansiyel yağının farklı konsatrasyonlarının Pieris brassicae larvalarına karşı ölüm aktivitesi

Concentrations	Average Deaths		
	24h	**48h**	**72h**
Control	0.1893±1.00d*	0.2536±0,113c	0.2536±0,104b
% 5	0.6532±0.329c	0.8937±0.586b	1.1902±0.80a
% 10	0.8850±0.126c	1.0541±0.586b	1.3362±0.80a
% 20	1.1746±0.126b	1.3696±0.837a	1.4545±0.80a
% 50	1.4413±0.958a	1.4877±0.837a	1.5320±0.332a
% 100	1.5368±0.958a	0.0000±0.113a	0.0000±0.104a

*Results were given as averages±SE (standard error). F (2,60)= 5.00, p<0.01 Data in the same column were lettered.

Table 3. Mortality activity of different concentration of Satureja montana essential oil against Pieris brassicae larvae

Çizelge 3. Satureja montana esansiyel yağının farklı konsantrasyonlarının Pieris brassicae larvalarına karşı ölüm aktivitesi

Concentrations	Average Deaths		
	24h	**48h**	**72h**
Control	0.0644±1.00c*	0.1429±1.00c	0.1429±0.530d
% 5	0.7189±0.167b	0.8918±0.99b	1.1444±0.83c
% 10	0.7939±0.167b	0.9570±0.99b	1.2574±0.83b
% 20	0.9268±0.167b	1.1141±0.99b	1.3733±0.83b
% 50	1.2667±0.108a	1.4009±0.582a	1.5368±0.379a
% 100	1.4923±0.108a	1.5368±0.582a	0.0000±0.530a

*Results were given as averages±SE (standard error). F (2, 60)= 5.00, p<0.01 Data in the same column were lettered.

In recent years, there has been a rapid increase in bioinsecticide studies on economically important lepidopteran and other insect species. Although the mortality rates of 10 different EOs on *Cydalima perspectalis (*Walker) (Lepidoptera: Crambidae) at different larval stages. Greatly vary the highest effect on the 2nd and 5th instar larvae was obtained by using the EO of *Origanum onites*, with a mortality rate of 80.0-71.6%. The results confirmed that the EOs from *O. vulgare* can be used in the control against *C. perspectalis* (Göktürk et al., 2020). In this study, both EOs were found to be most effective during the L2-L3 stages, while, in contrast, the Göktürk et al. (2020) study found that they had no lethal effect on the L5 stage larvae. Besides, these studies, the EO of *O. syriacum* was evaluated for insecticidal activity against adults of *Sitophilus oryzae* (L.) (Coleoptera: Curculionidae) and *Rhyzopertha dominica* (F.) (Bostrychidae) by the fumigation method. The essential oil showed an excellent fumigant effect on *R. dominica* than *S. oryzae* at 48 h and 72 h. The authors concluded that *O. syriacum* EO has the potency to be a natural insecticide (Karan et al., 2018) Our results were also indicating that *O. syriacum* was effective at 50% dose EO on *P. brassicae* at 24 hours, like the Karan et al. (2018).

Satureja essential oil was assessed against a diverse group of insects from Coleoptera to Diptera, Hemiptera, Homoptera, Lepidoptera, Phthiraptera, and Thysanoptera orders, and similarly, on other arthropods, including mites and ticks, and plant pathogenic nematodes. Among the large species of *Satureja* studied, the EOs of *S. hortensis, S. montana*, and *S. thymbra* are considered the most promising species in pest management (Ebadollahi et al., 2021; Valcárcelet al., 2021). It can be seen that successful results have been obtained in various studies with the aqueous suspension of *S. montana* on a variety of organisms. *S. montana* EO showed significant larvicidal activity fourth stage larvae of the common house mosquito (*Culex pipiens* L.) (Diptera: Culicidae) (Michaelakis et al., 2007). Likewise, it was found to be a potential nematicide against *Bursaphelenchus xylophilus* Nickle, and 100% mortality was observed 24 hours after application (Barbaso et al., 2012). Complete repellency (100%) against western flower thrips (*Frankliniella occidentalis*) (Pergande) (Thysanoptera: Thripidae) treated at 2.0 % concentration was obtained after 1 hour on green bean leaves in petri dishes (Picard et al. 2012), and high larvicidal efficacy was also observed against *Culex quinquefasciatus* third instar larvae (Benelli et al., 2017). In a study of the contact assay (topical application) against the fruit fly *Drosophila suzukii* (Matsumura) (Diptera: Drosophilidae), a high level of toxicity was found in both sexes (Park et al., 2016). In the contact test against *Leptinotarsa decemlineata* Say. (Coleoptera: Chrysomelidae), a high mortality rate was observed in the first (100 %), second (97.7 %), third (95.5 %), and fourth (97.7 %) larvae and in the 96-h adult (88.8 %) at the concentration of 20 L/cm^2 after 96 h (Usanmaz-Bozhuyu, 2018). *Satureja montana* was detected as both ixodicidal agents and insecticidal (Valcárcel et al,. 2021). In addition, *Origanum* species, with carvacrol being one of the most important compounds responsible for the larvicidal effects on *Anisakis simplex* (Nematelmintos: Anisakidae) (Lopez et al., 2019).

Beyond the essential oils tested in this study, various botanical insecticides have been tested on different lepidopteran species or *P. brassicae* larvae for pest control purposes (Ali et al., 2017; Hossain et al., 2020; Kardian, 2021). Two botanical insecticides, an aqueous extract of tobacco leaves (*Nicotiana tabacum*) and tuber roots (*Derris elliptica*), were tested for their mortality (contact and residual) and feed reduction impacts against the fall armyworm, *Spodoptera frugiperda*. These insecticides have the potential to be used by farmers in the field as they are easy to prepare and use (Kardian-Maris, 2021). In addition, the effects of several commonly used botanicals (Mahogany seed kernel, tobacco leaf, garlic, neem leaf, neem seed kernel extracts, neem oil, and control) on the main lepidopteran pests found in summer cabbage have been investigated. It has been reported that neem oil is the most effective of the other botanical insecticides in use, in terms of many of the factors which have been studied. So, botanicals could be used sensibly to improve the production of summer cabbage, which would be safe for farmers and the environment (Hossain et al. 2020). There are promising results when looking at current studies on *P. brassicae*. The efficacy of various new synthetic (thiamethoxam 25% SP, acetamiprid 20% SP, and pyriproxyfen 10.8% EC) and botanical insecticides *Aloe vera* (L.) Burm. f. leaves, grapefruit (*Citrus* × *paradisi* Macfad.) bark, spearmint (*Mentha spicata* L.) leaves, and neem (*Azadirachta indica* A. Juss.) leaves have been studied on cabbage butterflies in terms of larval feeding, behavior, development, and mortality. The neem extract (7%) combined with pyriproxyfen also caused significant larval stress. Thus, neem extracts at 7% alone can be used to control *P. brassicae* in vegetable crops to ensure a safe food supply (Ali et al., 2017).

Based on the above literature information, it is known that various plants, including neem oil, have been studied in the mentioned research, and some of these have even been converted into commercial products (Isman, 1997; Mordue et al., 1998; Ujvary, 2001). However, as in this study, it is considered important to investigate plants with high concentrations of active compounds in their essential oils, such as *S. montana* and *O. syriacum*, as potential alternatives. This research will provide a diversity of methods for pest control. It is anticipated that these studies will pave the way for future research and contribute to the creation of a database in the field.

According to this study, it was possible to observe different or similar effects in each of the organisms, even though the studies were carried out on different insects. Contrary to the study by Michaelakis et al. (2007), it was found that *S. montana* EO did not have a lethal effect on *P. brassicae* larvae during the L4 and L5 stages; rather, it was ineffective in terms of insecticidal activity. Additionally, although it was effective for a shorter duration and dose compared to the Barbaso et al. (2012) study, it did not achieve the same level of effectiveness in as little as 1 hour or at a very low dose of 2% as observed in the Picard et al. (2012) study. Furthermore, similar to the study by Lopez et al. (2019), it was determined in this study that carvacrol was the most effective component of the *S. montana* essential oil. Eroğlu et al. (2023) in study, three several doses (0.75, 1, and 1.25 mg/mL) of *N. meyeri* extract were given to the third instar larvae using the droplet feeding method. as a result of feeding the larvae with the highest dose of 1.25 mg/mL *N. meyeri* extract, the level of increase in the detoxification genes p450 and udp genes was at the highest level at the 12 hours. The results demonstrate that *N. meyeri* extract (1.25 mg/mL) was determined to be a promising botanical extract for the control of *P. brassicae* larvae. In addition to Zakaria (2016), in this study, the results showed that the yield of essential oil of *Capparis* species leaves from *Damascus* (Syria) province was 0.052 % v/w. Also, these results suggest that Caterpillars of *P. brassicae,* which attack caper it's not harmful for *Capparis* species wild growing in *Damascus*, because they are suppressed by the parasitoid, *Cotesia glomerata*.

CONCLUSION

This study demonstrated that both *Satureja montana* and *Origanum syriacum* essential oils (EOs) exhibit insecticidal activity against *Pieris brassicae* larvae, with *S. montana* EO proving to be more effective. The observed differences in efficacy can be attributed to the chemical composition of the essential oils, particularly the presence and proportions of active compounds such as carvacrol, o-cymene, thymol, and γ-terpinene. While both essential oils share carvacrol and o-cymene as major components, their varying concentrations and additional compounds contribute to their differential effectiveness. The findings of this study provide valuable insights into the potential use of plant-derived essential oils as biopesticides. The laboratory-based results indicate that these essential oils could serve as promising alternatives to synthetic insecticides, offering a more sustainable and environmentally friendly approach to pest management. However, further research is necessary to validate these findings under field conditions. Future studies should focus on optimizing application methods, determining long-term effects on pest populations, assessing the impact on non-target organisms, and evaluating the economic feasibility of large-scale application. Given the increasing concerns about pesticide resistance and environmental contamination caused by chemical insecticides, the development of botanical insecticides derived from essential oils presents a viable solution. The use of *S. montana* and *O. syriacum* essential oils could potentially be integrated into pest management programs, reducing reliance on conventional pesticides and promoting ecological balance. Overall, this study contributes to the growing body of research on plant-based insecticides and highlights the potential of essential oils in sustainable agriculture. Further interdisciplinary collaboration between entomologists, chemists, and agronomists will be essential in translating these preliminary findings into practical applications for agricultural pest control.

Contribution Rate Statement Summary of Researchers

The authors declare that they have contributed equally to the article.

Conflict of Interest

The authors of the article declare that they have no conflict of interest.

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