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Anti-Nutritional, Antifeedant, Development-Distorting, and Insecticidal Impacts of Three EOs on Box Tree Moth *Cydalima perspectalis* (Walker Lepidoptera: Crambidae)

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Abstract

Aim of study: Buxus plants are widely affected by the box tree moth, *Cydalima perspectalis*. This study was carried out to determine the activity levels (anti-nutritional, anti-growth and insecticidal activities) of *Tanacetum parthenium*, *Laurus nobilis* and *Lavandula officinalis* essential oils (EOs) on *C. perspectalis* larvae.

Area of study: The lavender, pyrethrum and Laurel bay plants were collected from the Karaçomak dam Azdavay Derelitekke and İnebolu Evrenye Ayvat in Kastamonu.

Material and method: Experiments were conducted to determine the biological effects of *T. parthenium*, *L. nobilis* and *L. officinalis* EOs on the potential influence of spawning preference in boxes. The EOs were applied to Buxus plants to prevent leaf eating by *C. perspectalis* pests because EOs have generally anti-nutritional, antifeedant, development inhibitive, and insecticidal activities.

Main results: EOs of *T. parthenium, L. nobilis, L. officinalis* indicated the greatest decrease in the Relative Growth Rate (RGR) of *C. perspectalis* pest in different treatment concentrations (%100, %50 and %25 mg/l). This study indicated that RGR reduced with the enhancement of the concentration of the tested oils.

Research highlights: T. parthenium, L. nobilis and *L. applications* of EOs in different concentrations (100%, 50% and 25% mg/l) showed promising results against the *Cydalima perspectalis*.

Keywords: Essential Oils, *Cydalima perspectalis*, Antifeedant, Growth İnhibition

Üç Esansiyel Yağın Şimşir Ağacı Güvesi *Cydalima perspectalis* (Walker Lepidoptera: Crambidae) Üzerinde Beslenme Karşıtı, Beslenmeyi Önleyici, Gelişimi Bozucu ve Böcek Öldürücü Etkileri

Öz

Çalışmanın amacı: Bu çalışma *T. parthenium, L. nobilis* ve *L. officinalis* uçucu yağlarının *C. perspectalis* larvaları üzerindeki aktivite seviyelerini belirlemek amacıyla gerçekleştirilmiştir.

Çalışma alanı: Çalışmanın Türkiye'de Kastamonu ili merkez, Azdavay (Derelitekke) ve İnebolu (Evrenye) ilçelerinde gerçekleştirilmiştir. Böcek çalışmaları için *C. perspectalis* larvaları ise Kastamonu ili Pınarbaşı ilçesi şimşir bitkilerinden toplamak suretiyle elde edilmiştir

Materyal ve yöntem: Çalışmanın materyallerini şimşir zararlısı *C. perspectalis* larvaları ve *T. parthenium, L. nobilis* ve *L. officinalis* esansiyel yağları oluşturmaktadır. Uçucu yağların analizi Kastamonu Üniversitesi Merkez araştırma laboratuvarında GC-MS (Gaz kromatografisi, kütle spektrofotometrisi) cihazı ile yapılmıştır.

Temel sonuçlar: T. parthenium, L. nobilis ve *L. officinalis* uçucu yağları, farklı konsantrasyonlarda (%100, %50 ve %25 mg/l) *C. perspectalis* zararlısının Bağıl Büyüme Hızında (RGR) en büyük azalmayı göstermiştir. Esansiyel yağlar *C. perspectalis* larvalarına karşı beslenmeyi önleyici aktivite sağlamıştır.

Araştırma vurguları: T. parthenium, L. nobilis ve L. officinalis uçucu yağlarının, farklı konsantrasyonlarda (%100, %50 ve %25 mg/l) uygulamaları C. perspectalis zararlısına karşı umut veren sonuçlar ortaya çıkarmıştır.

Anahtar kelimeler: Uçucu Yağlar, *Cydalima perspectalis*, Beslenme Önleyici, Büyüme İnhibisyonu

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Introduction

The box tree moth (BTM), *Cydalima perspectalis*, is a harmful incursive pest species in Europe and Asia Minor, causing significant damage to box trees (Buxus spp.) in various environments such as natural habitats, parks, gardens, and recreational areas. Many preventive methods (i.e. chemical insecticides and eco-friendly control methods) have been tried to control or stop the infection of *C. perspectalis*, while it was not found effective protection against the infection of box tree moth. The use of EOs could be a promising alternative method to prevent the laying of eggs and consequent larval damage of *C. perspectalis* (Szelényi et al., 2020).

Cydalima perspectalis Walker (Lepidoptera: Crambidae) is not a native species in Europe and has limited natural predators. It is difficult to control *C. perspectalis* larvae with chemical pesticides due to their secretive lifestyle and the adult's ability to move around easily (Wan et al., 2014). The *C. perspectalis* pest initiates from East Asia and has disseminated rapidly across Europe and Türkiye due to the high flight ability of the adult butterfly, which can produce multiple generations per year and travel long distances (Öztürk, 2016; Leuthardt, 2010). BTM has been found in several countries, including Spain, Portugal, France, Sardinia Islands, Germany, and Bulgaria. The *C. perspectalis* is a harmful defoliator affecting the *Buxus* spp. (*B. sempervirens*). It is a natural habitat for the species and grows inherently in the forests of the Black Sea region, Thrace, Southern Marmara regions, and Denizli, Muğla, Hatay, and Osmaniye of Türkiye (Öztürk et al., 2016). However, it tends to spread more in the lower layer of the forest, particularly in the Black Sea and Marmara Regions of Türkiye rather than the Mediterranean Region (Altunışık, 2017). Among the 105 species of boxwood in the world, in Türkiye, Anatolian Boxwood (*Buxus sempervirens*) is found in the provinces of Denizli, Kahramanmaraş, Osmaniye, Kocaeli, Bolu, Karabük, Bartın Kastamonu, Trabzon, Rize and Artvin, while Baleric Boxwood (Buxus balerica Lam.) is found in the provinces of Adana, Antalya and Hatay (Ak et al., 2021).

Boxwood (Buxus spp.) is a valuable resource for the local communities where it grows, contributing to the economy of the country through its wood and shoots. Additionally, since it is a popular species in landscaping, the public is concerned about its damage or drying out caused by the boxwood moth. In Türkiye, the distribution of *C. perspectalis* was first detected in parks and gardens in Istanbul in 2011, in Düzce and Artvin in 2015, and in Bartın in 2016 (Hızal et al., 2012; Öztürk et al., 2016; Göktürk, 2017; Yıldız et al., 2018; Kaygın & Taşdeler, 2019). Then, the other studies were conducted between 2016-2018 to determine the damage, life cycle, and number of generations throughout Türkiye, particularly in the Black Sea Region.

Volatile compounds are biosynthesized in various ways. They are associated with polyketides and lipids, shikimic acid derivatives, and terpenoids (hemi-, mono, sesquiterpenoids) (Brown & Hebert, 1997). This complex combination can include more than 300 different mixtures, often of low molecular weight (Pybus & Sell, 2007). Most of EOs are predominated by two or three main ingredients, while the other compounds are only available in trace quantities.

Insect repellents generally create a vapor barrier around the host to block arthropods to make connection with the plant surface (Brown & Hebert, 1997; Choochote et al., 2007). Using natural repellents to limit female BTM from laying eggs is an environmentally friendly approach to control the *C. perspectalis* pest. Different plant species have been observed as potential resources of repellent (Sukumar et al., 1991) to date and EOs (EOs) have recently come into focus. The composition is immensely dependent on the genotype (Baser & Buchbauer, 2010), plant part harvested, phenological stage, and extraction method (De Souza Junior et al., 2020). Szelényi MO et al. (2020) found that cinnamon, eucalyptus and lavender EOs had the greater impact on the BTM. However, cinnamon oil indicated the most vigorous effect. A previous study by Göktürk (2017) also determined the effect of different essential oil (EO). They found that the EOs provided insecticidal potential. They also found that particularly the EOs from *O.*

vulgare onites can be utilized in the control against *C. perspectalis*.

To date, various EOs have been tended to against *C. perspectalis*. However, *L. nobilis* EO was applied against *C. perspectalis* pests for the first time in this work. The source of the Laurel bay plant is the Eastern Mediterranean region, and from there it has spread to other temperate climates (Rodriguez-Sanchez et al., 2009). A plant of the Lauraceae family, Laurel bay is an evergreen shrub native to the Mediterranean region. It has been accounted that the laurel plant has antimicrobial and antioxidant effects due to its contents of eugenol and methyl eugenol. The EO acquired from the laurel plant finds use in the food industry as a flavoring. This study therefore aimed to determine repellent of three EOs against *C. perspectalis* pest chosen from various plant families. EOs from three varieties of Türkiye flora were examined in terms of toxicity and anti-nutrition activity against *C. perspectalis*, which is a common leaf eater of *Buxus sempervirens* (Boxwood) tree plantation and brings the plant to the point of drying, in many countries in the world as well as in Türkiye was done.

Materials and Methods

In this study, boxwood trees were selected because *C. perspectalis* (Box tree moth) larvae had a harmful effect on the box tree (*B. sempervirens*). *Tanacetum parthenium, Lavantula officinalis,* and *Laurus nobilis* medicinal and aromatic EOs were used to determine the activity levels (anti-feeding, growth inhibitory, and insecticidal activities) on the larvae of *C. perspectalis*.

Plant Material

The lavender plant was collected at 897 m altitude (411731 North, 334401 East) near the Karaçomak dam in the Kastamonu Akcakese location. Other adjacent vegetation in the habitat consists of sessile oak (*Quercus petraea*) and black pine (*Pinus nigra* Arnold.).

The pyrethrum plant was collected at the Kastamonu Azdavay Derelitekke location at 751 m altitude (414633 North, 3326 8 East). Other neighboring vegetation in the habitat consists of black pine (*P. nigra*) and fir (*Abies nordmanniana* subsp. *equi-trojani*).

Laurel bay plants were collected at 194 m altitude (415758 North, 335337 East) in Kastamonu İnebolu Evrenye Ayvat location. Other neighboring vegetation in the habitat consists of Black pine, Laurel Bay, Big Nut *(Arbutus unedo*), Laden (*Cistus* spp.), Alder (*Alnus glutinosa)* and broom bush (*Calluna* spp.) in the Laurel zone.

Collecting Insects

The research area was located at 36T 517330-4604333 (Kastamonu Forest Regional Directorate, Pınarbaşı Forest Management Directorate, Kurtgirmez Forest Management Chief at altitude 1126 m). The larvae of *C. perspectalis* were taken from *Buxus sempervirens* plants on May 26, 2022. They were brought to the laboratory and located in plastic boxes (40 x 30 x 30 cm).

Obtaining EOs of Plants

EOs were acquired by steam distillation method in the DB 2500 Steam distillation device in the laboratory of Anatolian Natural Cure Medical and Aromatic EOs company located in Kastamonu University, Kastamonu Teknokent A.Ş. The analysis of EOs was made in Kastamonu University Central research laboratory (MERLAB) with GC-MS (Gas chromatography, mass spectrophotometry) device.

Extraction of Essential Oil

EO was achieved by hydrodistillation handle utilization of Clevenger-type apparatus. Afterward, distillation operates EOs was discrete and preservation in the refrigerator at 4°C. EO was determined by hydro distillation handle using a Clevenger's type apparatus. The distillation process EOs was separated and preserved in the refrigerator at 4°C.

Gas Chromatography/mass Spectrometry (GC-MS)

For recognition of EO supplementals, GC-MS QP2010 Ultra (Shimadzu) was utilized. Recognition of the constitutive was founded on a comparison of the detention times and computer. GC-MS chromatograms were kept in the EO oil data library.

Antifeedant, Growth Inhibition, And Toxicity Testing

Monoterpenes, phenylpropenes, and sesquiterpenes were estimated for their nutritional inhibitive, developmental, restrictive, and toxic influences on the sixth larval stage of *C. perspectalis* using the non-selective diet method (Abdel-Raheem et al., 2020). Solutions of essential oil compounds were first placed in ethanol and then introduced to fresh boxwood shoot leaves (*B. sempervirens*) with different concentrations (100%, 50%, and 25% mg/ml) (Morimoto et al., 2006). After that, control leaves were kept in water mixed. After complete evaporation of the solvent, 1.75-1.29 g of treated fresh shoot boxwood leaf diet was placed in each special clear plastic insect pot (15.0 cm diameter). Eighteen pre-weighed sixth-stage larval stages were then placed in each insect receptacle. Three replications were made for each concentration (100%, 50%, and 25% mg/ml). The diet eaten by every larva was decided after 3, 5, and 7 days of nutrition by weight the remaining diet in each insect bowl. Then, antifeedant index was determined using Equation 1 (Szelényi et al., 2020).

$$Antifeedant\ Index = \frac{C-T}{C} x\ 100 \quad (1)$$

Where C determines heaviness of diet spent by each larva in control and T determines heaviness of diet use upped by each larva in the treatment (Abdel-Raheem et.al., 2020). All larvae were then retained under the laboratory circumstances at 23±2°C, 70-65% ± 7% R.H., and a photoperiod regime of 12: 8h (light/dark). The development prevention of larvae was assayed notional to control situated on larval weightiness winning through 3, 5, and 7 days of nourishment on the treated diet. The larvae's growth inhibition was calculated using Equation 2 (Wan et al., 2014).

$$Developmenet\ Prevention= \frac{CL-TL}{CL} X\ 100 \quad (2)$$

Nutritional Indices

EOs were administered to newly hatched sixth-instar larvae of *C. perspectalis*. After the experiments, all larval feces and unexhausted food were calculated each 24-hour pending the (Öztürk et al., 2016) 5 and 7-day nutrition periods. Nutritional indices and concerned development ratio (RGR) were also determined and efficiency of conversion of digested food (ECD) was calculated using Klein & Kogan formulas of Farrar et al. (1989) (**Equation 3**). EOs were administered to newly hatched sixth-instar larvae of *C. perspectalis*. After the experiments, all larval feces and unconsumed food were weighed every 24 hours during the 3, 5, and 7-day feeding period. Nutritional indices, including relative growth rate (RGR), were defined by Miller and Miller (1988) and the efficiency of conversion of digested food (ECD) by Klein & Kogan 1974 formulas of Farrar et al. (1989) apply as follows (Equation 3-7):

$$RGR = \frac{\Delta B}{Feeding\ period} \quad (3)$$

$$\Delta B = \frac{\text{Final weight} - \text{Initial weight}}{No.of\ larvae} \quad (4)$$

$$ECI = \frac{\Delta B}{I\ x\ 100} \quad (5)$$

$$I = \frac{\text{Consumed food}}{\text{No.of larvae}} \quad (6)$$

$$ECD = \frac{\Delta B}{(I-F)\ x\ 100} \quad (7)$$

Where RGR is Relative Growth Rate, ΔB is change in body weight, ECI is the efficiency of conversion of ingested food, I is the weight of the food consumed, ECD is the efficiency of conversion of digested food, F is the weight of the feces produced during the feeding period.

Results

Chemical Composition of EOs

The decomposition of EOs is shown in Table 1. The significant components of EOs in *L. nobilis* were found Alpha-Pinene (4.46%), Sabinene (11.64%) revealed 1.8-Cineole (32.53%), 1.6-Octadiene-3-ol, 3.7-dimethyl- (4.34%), and Alpha-Terpinenyl Acetate (12.01%). The major components of EOs in *T. parthenium* were 1.8-Cineole (32.53%), beta-thujone (29.79%), p-mentha-E-2.8(9)-dien-1-ol (29.79%), [1,1'-Bicyclopentyl]-2-one (3.72%) and Phthalate <diethyl-> (6.44%). The major volatile compounds contained in *L. officinalis* were beta-Phellandrene (7.01%), Linalool (16.45%), 1,7,7-Trimethylbicyclo [2.2.1] heptan-2-ol (3.56%), Lavandulyl acetate (5.86%), Trans (Beta.)-Caryophyllene (5.66%), and Farnesene <(E)-, beta-> (7.88%). The main components of EOs primarily appertain to three communities: chemical groups of oxygenated monoterpenes (ie 1.8-cineol, α-citral, β-citronellol and terpinen-4-ol), monoterpene, and hydrocarbons (i.e. limonene, α- and sabinene) (Table 2).

Influences of EOs on the Nutritional Indices of C. perspectalis Larvae

The impact of EOs on nutritional indices on *C. perspectalis* larvae determined to nourish on green shoot boxwood leaves treated with three EOs extracted from *L. nobilis*, *T. parthenium*, *L. officinalis* (Table 1).

Effect on Relative Growth Rate (RGR)

The predicted RGR amounts for larvae treated by three different treatments (100%, 50%, and 25% mg/l concentrations) in Table 1. Each oil considerably decreased RGR, especially at greater concentrations of 100%, 50% and 25% mg/day. *L. officinalis* and *L. nobilis* oil disclosed the largest decline in RGR in different concentrations. In the control, the RGR was 41.72 mg/day, *L. officinalis* oil -103.26, -88.89, and -67.73 mg/day, *L. nobilis* -40, -35.96' and -30.37 mg/day, 500, 1000 and 2000mg/l respectively. RGR values reduced with extension oil concentrations tested (Table 1).

Effect on Food Consumption

Conversion efficiency of ingested food (ECI) quantities was shown in Table 1. In three different treatments (100%, 50%, and 25% mg/l concentrations), an important reduction in ECI was obtained by the EOs tested, except for *L. officinalis* and *L. nobilis* EO at 100%, 50%, and 25% mg/l inhibits the sixth-instar larvae of *C. perspectalis* from the same larval age in control with ECI values of -0.4868%, -1.0613 and -0.4338 mg/l. can stimulate to overfeed and convert to body material, -0.0511% and -0.0349%, respectively, compared to Control (0.6258%). It was seen that the ECI values of the EOs tested against insects increased gradually as the percentage value increased. However, EO of *L. officinalis* showed the least ECI (-3.873%) at 100% concentration (Table 1).

Effect on Food Digestion

Conversion efficiency of digested food (ECD) was reduced at all concentrations tested. *L. officinalis, L. nobilis and T. parthenium* Eos importantly reduced ECD values at all concentrations tested. The decrease in ECD was concentration interdependent. Among the plants tested, *L. officinalis* and *L. nobilis* (each percentile mg/l) showed the biggest decreases in ECD.

Antifeedant Activity

Nutritional deterrent index (FDI) results of three EOs on sixth-instar larvae of *C. perspectalis* after seven days of application are given in Table 1. The findings indicated that tested oils had distinct levels of anti-nutritional activity. The 50% amount of *L. officinalis* oil showed the highest anti-nutritional activity of 58.33, followed by 50% *L. nobilis* oil at 50.00 with the same percentage amount. and the 25% concentration of *T. parthenium* oil elicited the most anti-nutritional activity with 34.16 units. In addition, each concentration of these oil exhibited more or less anti-nutritional activity.

Change in Body Weight of Larvae

Valuations of weightiness replacement of the tested larvae are stated as a percentage concerned with the dry control (Table 1). The greatest larval body weight income after 7 days was seen in the Control, 23.772%, in the experimental group containing *L. officinalis* oil, 50% concentration -8.6898% *L. nobilis* oil 0.3448 plus, and *T. parthenium* oil In the case of extracts, a negative body weight change of -14.177% was observed. It differs from the control group (significantly) by about 60-70 times lower (significantly) with a fairly large margin. In most cases, extracts from *L. officinalis*, *L. nobilis*, and *T. patrhenium* diluted with alcohol to a concentration of 100% 50% 25% ended up with a reduction in the food consumption of the larvae (instar 5-6) per mg, respectively, and the following body weight 0.3448% showed decreases between -53.5858%. The results differed significantly from the control experiments (Table 1).

Table 1. Effect of essential oils on relative growth rate (RGR) (mg/day ±SE), food consumption (ECI) (% ±SE), food digestion (ECD) (% ±SE), Antifeedant activity (FDI) (% ±SE) and growth inhibition index (GII) (%±SE) of five-six instar larvae of *C. perspectalis* (Walker Lepidoptera: Crambidae) after 7 day of treatment with different essential oil concentrations

Plants	Relative growth rate (RGR)	Conversion efficiency of ingested food (ECI)	Conversion efficiency of digested food (ECD)	Growth inhibition index	The feeding-deterrence index (FDI)	Percentage weight loss of a single larva at the end ofthe 7th day	Abbott %	Food consumption per larva (in mg)	Karber-Behrens method: LD_{50}=LD_{100}
Tanacetum parthenium	Mean ± SE	Mean ± SE	Mean ± SE	Mean ± SE	Mean ± SE	Mean ± SE	Mean ± SE	Mean ± SE	Mean ± SE
100% essential oils	-3.268±0.005	-0.0511±0.054	-0.00158±0.036	-14.101±0.043	4.166±0.943	-35.312%±0.123	75%±0.005	0.0630*g±0.987	87.887±0.273
50% essential oils	-2.681±0.342	-0.0349±0.093	-0.00062±0.094	-11.567±0.026	-115.09±0.432	-27.158% ±0.843	81.3%±0.005	0.0766±0.345*	90.633±0.164
25%essential oils	-2.386±0.067	-0.0543±0.045	-0.0408±0.0115	-57.198±0.062	34.16±0.342	-14.177%±0.765	87.5%±0.094	0.0438±0.063g	89.333±0.347
Laurus nobilis									
100% essential oils	-40.350±0.045	-0.4868±0.985	-0.0312±0.734	1.5109±0.234	29.16±0.645	0.3448%±0.074	100%±0.096	0.04720±0.063g	94.166±0.921
50% essential oils	-35.96±0.078	-1.0613±0.017	-0.1736±0.019	-10.776±0.321	50.87±0.705	-0.2506%±0.345	100%±0.643	0.0338±0.043g	95.166±0.345
25% essential oils	-30.37±0.064	-0.4338±0.032	-0.0848±0.011	-10.635±0.853	2.5±0.009	-26.4579%±0.435	1000%±0.074	0.06830±0.063*g	96.166±0.532
Lavantula officinalis									
100% essential oils	-103.26±0.142	-3.873±0.754	-1.1630±0.421	-16.238±0.043	1.725±0.021	-53.5858%±0.742	1000%±0.025	0.0266±0.063g	99.85±0.231
50% essential oils	-88.89±0.073	-3.200±0.074	-0.1235±0.072	-20.826±0.092	58.33±0.086	-8.6898%±0.653	1000%±0.074	0.03330±0.123g	99.95±0.045
25% essential oils	-67.73±0.126	-1.088±0.123	-0.0441±0.642	-20.826±0.067	6.666±0.976	-37.523%±0.084	81.30%±0.074	0.06220±0.063*g	97.16±0.053
Control	41.72±0.082	0.6258±0.062	0.01125±0.061	0.00000	0.000	%23.772±0.073	0.000	0.0666±0.063*g	000.00

**Data are means of three replications of 18 insects each. Values within a column sharing the same letter are not significantly different at the 0.05 probability level.

Karber-Behrens method:

$$7 \text{ day } LD_{50} = LD_{100} - \frac{\Sigma(ab)}{n} \qquad (4)$$

LD_{100} = the dose that produced 100% mortality in the trial,
n = number of animals in each group,
a = the difference between two consecutive doses,
b = the arithmetic mean of deaths from two consecutive doses.

Table 2. Essential oil components of lavender, laurel and pyrethrum

Essential Oil	Components	Relative Area %	Essential Oil	Components	Relative Area %	Essential Oil	Components	Relative Area %
Lavender	Linalool	16.45	Laurel	1,8-Cineole	32.53	Pyrethrum	1,8-Cineole	32.53
	Farnesene <(E)-, beta->	7.88		Alpha.-Terpınenyl Acetate	12.01		beta.-thujone	29.79
	Phellandrene	7.01		Sabinene	11.64		p-mentha-E-2.8(9)-dien-1-ol	29.79
	Lavandulyl acetate	5.86		Alpha.-Pinene	4.46		Phthalate <diethyl->	6.44
	Trans (Beta)-Caryophyllene	5.66		1,6-Octadiene-3-ol, 3,7-dimethyl	4.34		[1,1'-Bicyclopentyl]-2-one	3.72
	1,7,7Trimethylbicyclo [2.2.1]heptan-2-ol	3.56						

Toxicity to Larvae

The results of *T. parthenium*, *L. officinalis* and *L. nobilis* at 100%, 50%, and 25% dilution with Ethanol to *C. perspectalis* larvae (5-6 instars) are shown in Table 1. *T. parthenium* LC50s 75%, 81.3% and 87.5%, *L. nobilis* LC50s 100%, 100% and 100%, and fatty alcohol extracts from *L. officinalis* LC50s% 100%, 100%, and 81.3% showed such a large toxicity. No mortality was detected in the control groups. Equations of regression lines from accuracy to mortality against log dosage plots and lower and upper confidence limits of the LC50s. each extract is also shown in Figure 1 and (Table 1).

Food Consumption per mg of Body Weight Gain

The highest consumption rates (0.0766* g; food used per g larva) were observed with 50% alcohol dilution extracts of *T. parthenium* oil. The greatest food consumption was observed with 0.0683*g, 25% alcohol dilution oil and *L. nobilis* oil extract. The least food consumption was 0.0333 g with the extracts diluted 50% with alcohol. In this study, all other plant oil extracts and control combinations tested showed almost similar activity (Table 1).

Effect of EOs on C. perspectalis Larva Growth

Table 1 shows the influence of three EOs tested on the reconstruction of 5-6 instar larvae of *C. perspectalis* after 7 days of remedy at distinct concentrations of 100%, 50% and 25% mg/l. Percent dilution of the tested oils with ethanol disclosed significant larval development prevention even at the fallenness concentration of 25%. The development prevention index (GII) worth gradually incremented as the essential oil concentrations tested incremented. The oil of *L. nobilis* reasoned the largest expansion restriction, chased by *T. parthenium* and *L. officinalis*, with index values of 1.5109, -10.776, -10.635, -14.101, -11.567, -57.198, and -16.238, respectively; -20.826, -20.826.

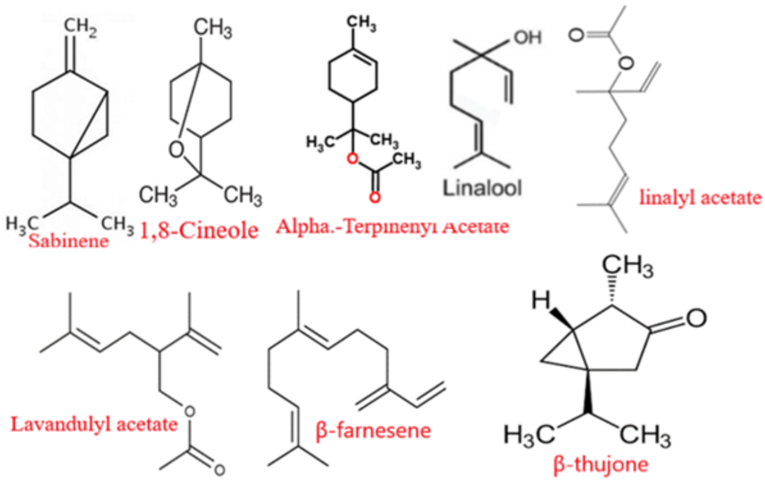

Figure 1. Important substances with insecticidal activity contained in essential oils

Discussion

This research indicated a resemblance concerning the chemical composition of the three EOs gathered from Türkiye. The three EOs showed common components in exchangeable percentages. Previous studies compared effect of *L. nobilis* EOs from Mediterranean zones in Italy against warehoused product pests (Cosimi et al., 2009). To date, various herbal EOs have been tried against *C. perspectalis*. However, *L. nobilis* EO was applied against *C. perspectalis* pests for the first time in this work.

Several researchers have demonstrated that there are large quantities of lactones, sesquiterpenes, parthenolides, and flavonoids in *T. parthenium* (Cosimi et al., 2009). Pyrethrum, the most widely used botanical insecticide is removed from the flowers of *Tanacetum cinerarifolium* (pyrethrum) (Casida & Quistad, 1995). The chemical compositions of the removed EOs from *L. nobilis, L. officinalis* and *T. parthenium* were in agreement with those before now recorded on the chemistry of these oils insulated from other countries. In this work, the EOs isolatszeed from *L. nobilis, L. officinalis* and *T. parthenium* demonstrated anti-nutritional influences on *C. perspectalis*. The testes oils in this study importantly diminished RGR, ECI and ECD. The EOs extracts have been recorded to alter nutritional indices of *C. perspectalis*.

Pavela et al. (2010) reported that the extracts acquired from *T. parthenium* were more productive antifeedants and development stoppers to *Spodoptera littoralis* (Boisduval) (Lep.:Noctuidae) larvae. The chemical compounds included in the three EOs tested in our work have proven their insecticidal activities in preceding research. The identical, oils from leaves and fruits of *Schinus molle* L. at concentrations of 0.04 and 0.4% w/w changed the nutritional physiology of *Sitophilus oryzae* L., changing RGR, RCR, and ECI (Benzi et al., 2009). The isolated compounds, estragole, linalool and sabinene also exhibited toxicity opposite *S. zeamais*. Alternative primary compound of EOs, limonene only exhibition toxicity to *S. zeamais* (Fang et al., 2010). Compared with the famous botanical insecticide, pyrethrum extract, the EOs were active against *S. zeamais* (Liu et al., 2010). The insecticidal influences of some compounds of many EOs have been recorded. For example, the good insecticidal efficiency of α-terpinolene, which is the main compound in the EO of *Ocotea longifolia* Kunth has been found (Prieto et al., 2014). The essential oil of *Rosmarinus officinalis* L. was used to influence the nutritional indices of fourth instar larvae of *Glyphodes pyloalis* Walker (Yazdani et al., 2013).

The oils in our work including linalool, acetylcholine, and limonene have been recorded to have good fumigant toxicity to and insecticidal record on the nervous system, rice weevils. These oils may influence the motility and the nervous system of the insects as well (Re et al., 2000; Tripathi et al., 2009). The effectiveness of *L. nobilis, L. officinalis* and *T.parthenium* oil as a larvicide and mosquito *C. quinquefasciatus* repellent is presumably owing to the presence of the parent compound estragole, linalool sabinene and1,8-cineol. Small compounds and their combinations perhaps withal have an insecticidal business (Pavela et al., 2010; Jemâa et al., 2012; Papachristos & Stamopoulos, 2004). Linalool, a monoterpene discovered in EOs from some plants, has been demonstrated to be an influential insecticide against some pests (Regnault-Roger & Hamraoui, 1994). The greatest larvicidal activity was monitored with methyl cinnamate, and the lowest one with linalool, which are parallel to outcomes obtained in previous study by Jantan et al. (2005). These conclusions, and those recorded earlier, symbolize that the insecticidal business of the EOs modifies depending on the stage of the insect, the types and the plant origin of EO (Tunç et al., 2000). The most toxic was Lavandula acetate from the EO of *Heracleum sprengelianum* (Apiaceae) which reported an LC_{50} that was two-fold greater than the concentration required to indicate larvicidal activity(100mg/mL) (Luz et al., 2020). In contrast, linalool, terpineol, thymol, perillaldehyde, 1,8-cineole, and thujone demonstrated a sequence of adulticidal activities between 0.09 and 0.18 mg/cm2.51. The EOs from the effectiveness of *L. nobilis, L. officinalis,* and *T.parthenium* oil diminished the nutritional indices (RGR, ECI and ECD) of *C. perspectalis*. Tested oils also disclosed pronounced antifeedant, development inhibitive and insecticidal activities against the insect. The oils decreased chitin formation and distorted the female reproductive system.EOs reasoned their effects on insects through different modes of action, i.e. as toxicants, antifeedants, development inhibitors, and sterilants. These multi-modes of action of EOs delay the growth of reluctance.

Conclusion

T. parthenium, L. officinalis, and *L. nobilis* EOs showed good repellence properties against the *C. perspectalis* larvae. We can recommend that EOs can be improved as potential native insecticides for integrated pest management of *C. perspectalis*. Repellency of *T. parthenium, L. officinalis* and *L. nobilis* EO might be due to 1,8-Cineole, beta-thujone and Caryophyllene. The findings showed that these three EOs had larvicidal effects on *C. perspectalis* and acted as nutritional inhibitors at non-lethal concentrations. Their irreversible effects on metabolism and enzymes may make these oils a strong candidate for the search for environmentally friendly insecticides. It can be also suggested that further studies should consider the comparison of the repellent influence of *T. parthenium, L. officinalis* and *L. nobilis* oils with analytical grade 1,8-Cineole, beta-thujone and Caryophyllene in investigating the bioactive compounds. *T. parthenium, L. officinalis* and *L. nobilis* EOs have great potential to be used as supplements to other control methods in sustainable agriculture practices.

Ethics Committee Approval

N/A

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Author Contributions

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Conflict of Interest

The authors declare that they have no conflict of interest.

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