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Evaluation of oviposition deterrent activity of four oily substances against winterform females of pear psylla, *Cacopsylla pyri*

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Abstract

Pear psylla, *Cacopsylla pyri* (L.) (Hemiptera Psyllidae), is the most destructive insect pest of pears in Turkey. In recent years, pear psylla control programs, based largely on the use of synthetic pesticides, have failed due to development of resistance to many synthetic insecticides in psylla populations. As an alternative control tactic, use of oviposition deterrents, which deter insects from laying eggs, is important in the management of insect pests. Based on this concept, four oily substances (palm oil, liquid grease, liquid Vaseline and liquid paraffin) were evaluated for their oviposition deterrent activity against winterform females of *C. pyri* under field conditions in 2018 and 2019. Only one application was made each year, and all the substances were used at three different concentrations (1, 1.5 and 2 L/100 L water), including 0.01% Tween 20 for a good mixture. Control plots were sprayed with tap water + Tween 20 (0.01%). Applications in both years were made at the dormant period (just before the first eggs were deposited by winterform females). Oviposition deterrence of the substances was evaluated by weekly counts of eggs deposited by winterform females of *C. pyri* on treated dormant shoots throughout one month after application. The results showed that no oviposition was observed in the plots treated with liquid grease and liquid paraffin, indicating that these substances exhibited 100% oviposition deterrent activity at all the concentrations during the study period in both years. Palm oil had a lower level of deterrence than the other substances tested. In the control plots, first eggs were seen 3 days post application in both years. Results suggest that liquid grease and liquid paraffin were highly promising as oviposition deterrents and had the potential for early suppression of pear psylla populations.

Key words: *Cacopsylla pyri*, deterrence, oily substances, oviposition deterrent, pear psylla.

Introduction

Pear psylla, *Cacopsylla pyri* (L.) (Hemiptera Psyllidae), is the most serious insect pest of pears in Turkey just as in other parts of the world (Westigard and Zwick, 1972; Hodkinson, 1984; Julien, 1984; Staubli, 1984; Civolani and Pasqualini, 2003; Erler, 2004a). This insect is responsible for two major forms of damage to pears. First, direct injury caused by nymphs and adults as they suck plant sap from phloem. This feeding damage mostly causes ‘psylla shock’ resulting from toxic saliva injected into leaf tissues by nymphs. Secondly, indirect damages; ‘sooty mould’ caused by saprophytic fungi, growing on the honeydew excreted by psylla nymphs (russeting fruits), and also the possible transmission of phytoplasmas such as ‘pear decline’ or ‘Parry's disease’ (Julien 1984; Staubli 1984; Carraro 1998).

Over the past twenty years, considerably increased damage levels by *C. pyri* have occurred in leading pear-growing regions of Turkey (Kovanci *et al*., 2000; Erler, 2004a). Recently, *C. pyri* has caused severe outbreaks in pear orchards in the Antalya-Korkuteli district (in the southwestern part of Turkey), where more than 20% of all commercial pears of the country are produced. The district has suitable climatic conditions for the rapid development of pest.

Pear psylla control in Turkey is largely based on the use of synthetic insecticides, such as cypermethrin, deltamethrin, diflubenzuron, malathion, novaluron, phosmet, pyriproxyfen, spinetoram, spirotetramat and thiacloprid, and many of the pear growers make 8 to 10 spray applications per year for this insect pest. However, intensive spray applications with synthetic insecticides in pear orchards have greatly reduced the effectiveness of predators, including hemipterans (especially anthocorid species) that are the most abundant predator group, coccinellids and lacewings, and parasitoids, especially *Syrphophagus mamitus* (Walker) and *Trechnites psyllae* (Ruschka) (Hymenoptera Encyrtidae), as psyllid-control agents (Erler, 2004a; Souliotis and Moschos, 2008). Among the anthocorids, *Anthocoris nemoralis* (F.) (Hemiptera Anthocoridae), whose population was closely related to the dynamics of the pear psylla population, was generally the principal predator of *C. pyri* in leading pear-growing regions of Turkey (Kovanci *et al*., 2000; Erler, 2004a). Moreover, development of psyllid resistance against many registered insecticides and limited prospects for the registration of new materials make the chemical suppression of the pest more difficult, more expensive, and less reliable than before (Erler and Cetin, 2005). All these reasons have seriously reduced the confidence of pear growers to available pesticides in controlling pear psylla. Therefore, there is an increasing need to develop and implement alternative control tactics or materials against this pest (Erler, 2004b; Erler and Cetin, 2007; Erler *et al*., 2007; 2014).

Some previous studies indicate that if psyllid populations are allowed to reach high levels in early season, they become difficult to control (Erler and Cetin, 2005; 2007; Erler and Tosun, 2017). Since natural enemies, especially parasitoids *S. mamitus* and *T. psyllae*, are nearly absent in pear orchards early in the season (Erler, 2004a), many growers aim to keep psyllid populations at low levels during this period. Therefore, it is so important that winterform females are prevented from laying eggs in order not to allow early population growth.

Table 1. Specific information on the oily substances used in the present study.

Common name	Origin	Company	Purity
Palm oil	Botanical (Palm tree fresh fruits)	Sabunaria, Ankara, Turkey	Crude oil
Liquid grease	Mineral	Winkel, Istanbul, Turkey	Pure
Liquid Vaseline	Mineral	Kalender, Istanbul, Turkey	Pure
Liquid paraffin	Mineral	Ilk-end Industrial Oils, Istanbul, Turkey	Pure

Hence, the aim was to evaluate oviposition deterrence and deterrent stability of four oily substances (palm oil, liquid grease, Vaseline and liquid paraffin) against winterform females of *C. pyri* under field conditions.

Materials and methods

Oily substances

Commercially and locally available four oily substances (palm oil, liquid grease, liquid Vaseline and liquid paraffin) were evaluated for their oviposition deterrent activity against winterform females of *C. pyri* under field conditions. Specific information on these substances is given in table 1. The reason to work with these substances was our preliminary findings on dormant pear seedlings treated with them and placed in screened cages under controlled conditions (22 ± 1 °C, 65 ± 5 RH and 9L:15D photoperiod) in the laboratory, which had indicated their potent oviposition deterrent activity against winterform females of the pest. In addition, they are low cost and locally easy-available. All these substances were provided by a local supplier (Technic-Med, Antalya, Turkey). All of them were pure and applied as an aqueous (tap water) mixture. They were tested in both years at three different concentrations (1, 1.5 and 2 L/100 L water). Tween 20 (0.01% concentration) was used to enable their dilution with water during applications.

Study area and experimental design

Field trials were conducted in 2018 and 2019 in a 14-year old pear orchard (37°01'18"N 30°17'49"E, 884 m a.s.l.) located in the Antalya-Korkuteli district, with 0.3 ha of *Pyrus communis* cv. Ankara. Although intensive chemical control programs had been applied in the orchard in previous years, the trees had obvious black sooty moulds covering their surface, indicating the presence of a dense psyllid population. In both years, oil treatments were applied in a randomized complete block design in three replications, with a control plot in each replicate; each plot consisted of ten trees. Sufficient space (6 m) with guard rows was left between test plots to prevent contamination from spray drift.

Applications

In both 2018 and 2019, only one application was made at the dormant period (just before the first eggs were deposited by overwintered females, dated 7 and 9 February, respectively). The optimum time to spray was determined by dissection of the bodies of overwintered females, when more than 50% of them have mature eggs (Erler and Tosun, 2017). The oil treatments were applied as dilute sprays (approximately 1.5-2 L per tree). Control plots were sprayed with tap water, including Tween 20 (0.01%). The applications in both years were made by using a two-wheel, single-axle, motorized sprayer, at a spray pressure of 20 bars.

Data collection and analysis

In both years, treatments were evaluated by counting eggs deposited by overwintered females on treated dormant shoots (Erler, 2004c; Erler and Tosun, 2017). The counts were made 3, 7, 14, 21 and 28 days after the application. In each count, 40 shoots (35-40 cm long) from each plot (four per tree) were examined using a headband magnifier (30×), and the number of eggs laid in each plot was recorded separately.

Air temperature (°C) and relative humidity (RH) values were also recorded at daily intervals using a portable temperature/humidity data logger (HOBO 'H' Series; Onset HOBO Data Loggers, Cape Cod, Massachusetts, USA). The data are presented here in graphic form (figure 1).

All data obtained from egg counts were converted to mean number of eggs per shoot and analysed by the Statistical Analysis System ANOVA (SAS Institute, 2001). Treatment means were compared by Duncan's Multiple Range Test (DMRT) at $P \leq 0.05$.

Oviposition deterrence (o.d. %) of each oily substance was calculated by the following formula:

$$\text{o.d. } (\%) = (B - A) / (A + B) \times 100$$

where A is mean number of eggs laid on treated portion, and B is mean number of eggs laid on control portion (Lundgren, 1975; Erler, 2004c).

Results

All the oily substances tested had a high oviposition deterrent activity in both years (tables 2 and 3). However, the level and stability of this activity generally varied with the substance, the time elapsed after application and to some extent the concentration used. In both years, when compared with water-treated control, all the oily treatments caused significant reductions in number of eggs laid by winterform females or resulted in no oviposition ($P \leq 0.05$).

In the first year of study, oviposition by winterform females in water-treated control plots began 3 days after application (table 2). Of the plots treated with four oily substances, palm oil-treated plots had the first eggs laid by winterform females 7 days after application, and the oviposition deterrence of this oily substance decreased sharply on the 14th day and beyond. Liquid Vaseline-

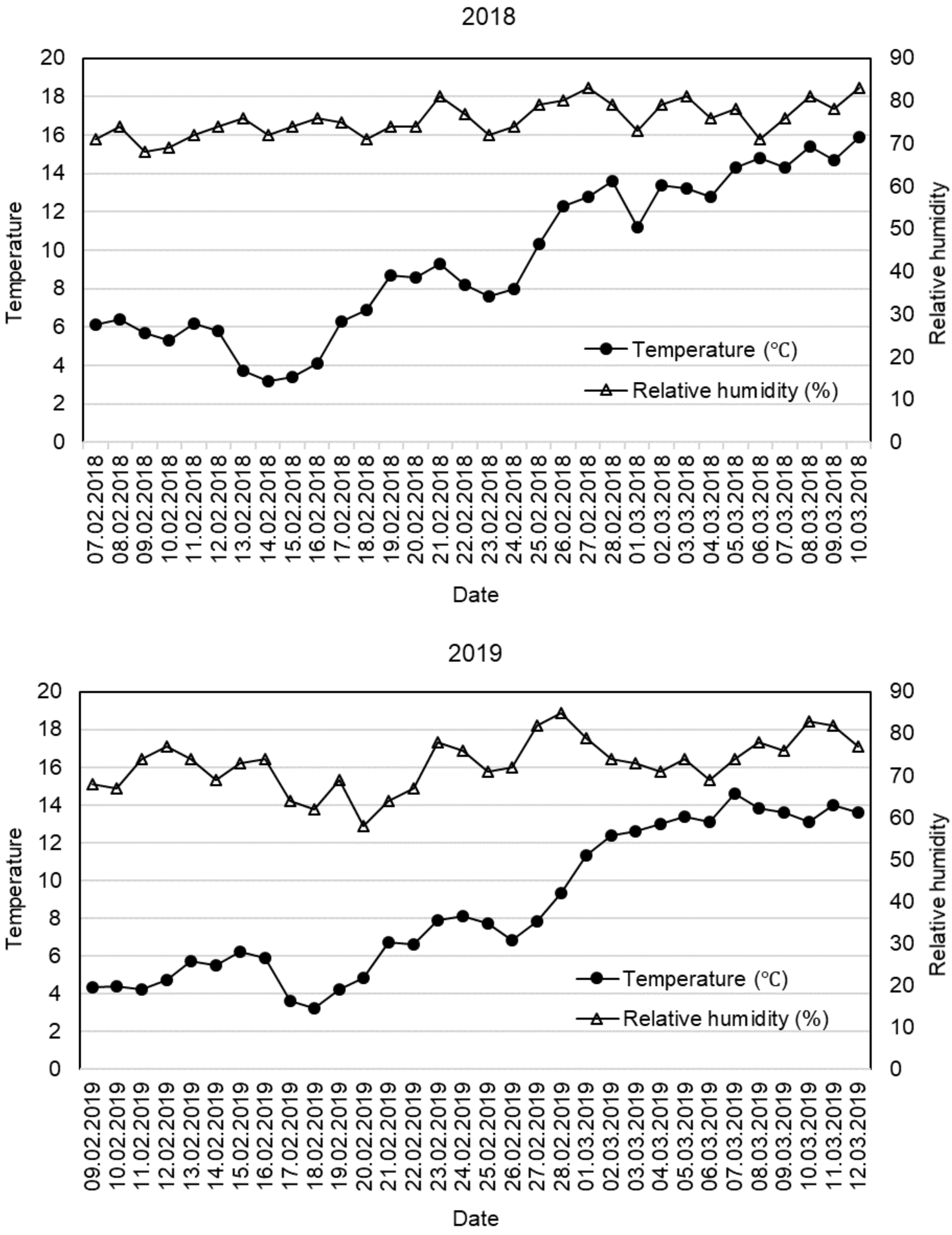

Figure 1. Temperature (°C) and relative humidity (%) data at daily intervals in the study area during the study period, from early February to early March, in both 2018 and 2019.

treated plots showed oviposition 21 days after application. Despite the decreases in its deterrence on the 21st and 28th days of application, liquid Vaseline achieved 89.1 and 82.1% oviposition deterrence, respectively, at the lowest concentration (1 L/100 L water) tested. This oily substance at the highest concentration (2 L/100 L water) showed an oviposition deterrence of 100% during the 4-week sampling period. No winterform oviposition was observed in both liquid grease and liquid paraffin-treated plots throughout the study period. These two oily substances exhibited 100% oviposition deterrent activity at all concentrations tested during the 4-week sampling period (table 2).

In the second year of study, the first eggs by winterform females were seen in water-treated control plots 3 days after application (table 3). Among the plots treated

Table 2. Oviposition by winterform females of *C. pyri* and oviposition deterrence (o.d.%) of the tested oily substances 3, 7, 14, 21 and 28 days after the application at the dormant period of 2018.

Treatments and concentrations (L/100 L water)	Mean (± SE) no. of eggs per dormant shoot and oviposition deterrence (o.d.%) 3 days no.	3 days o.d.%	7 days no.	7 days o.d.%	14 days no.	14 days o.d.%	21 days no.	21 days o.d.%	28 days no.	28 days o.d.%
Palm oil										
1	0.0±0.0eB	100	1.4±0.4dB	64.1	3.6±1.4cB	40.5	9.4±3.6bB	13.0	15.2±4.8aAB	6.5
1.5	0.0±0.0dB	100	0.2±0.1dC	93.9	1.8±0.8cC	65.0	8.8±3.5bB	16.2	12.9±3.7aB	14.6
2	0.0±0.0dB	100	0.0±0.0dC	100	1.6±0.8cC	68.3	6.4±3.4bC	32.2	9.8±3.6aC	27.7
Liquid grease										
1	0.0±0.0aB	100	0.0±0.0aC	100	0.0±0.0aD	100	0.0±0.0aD	100	0.0±0.0aE	100
1.5	0.0±0.0aB	100	0.0±0.0aC	100	0.0±0.0aD	100	0.0±0.0aD	100	0.0±0.0aE	100
2	0.0±0.0aB	100	0.0±0.0aC	100	0.0±0.0aD	100	0.0±0.0aD	100	0.0±0.0aE	100
Liquid Vaseline										
1	0.0±0.0cB	100	0.0±0.0cC	100	0.0±0.0cD	100	0.7±0.2bcD	89.1	1.7±0.5aD	82.1
1.5	0.0±0.0aB	100	0.0±0.0aC	100	0.0±0.0aD	100	0.0±0.0aD	100	0.8±0.2aE	91.2
2	0.0±0.0aB	100	0.0±0.0aB	100	0.0±0.0aD	100	0.0±0.0aD	100	0.0±0.0aE	100
Liquid paraffin										
1	0.0±0.0aB	100	0.0±0.0aC	100	0.0±0.0aD	100	0.0±0.0aD	100	0.0±0.0aE	100
1.5	0.0±0.0aB	100	0.0±0.0aC	100	0.0±0.0aD	100	0.0±0.0aD	100	0.0±0.0aE	100
2	0.0±0.0aB	100	0.0±0.0aC	100	0.0±0.0aD	100	0.0±0.0aD	100	0.0±0.0aE	100
Control										
Water + Tween 20	2.8±1.2dA	-	6.4±2.8dcA	-	8.5±3.1cA	-	12.2±3.4bA	-	17.3±4.7aA	-

Means within a line followed by the same lower-case letter are not significantly different (DMRT; $P \leq 0.05$). Means within a column followed by the same capital letter are not significantly different (DMRT; $P \leq 0.05$).

Table 3. Oviposition by winterform females of *C. pyri* and oviposition deterrence (o.d.%) of the tested oily substances 3, 7, 14, 21 and 28 days after the application at the dormant period of 2019.

Treatments and concentrations (L/100 L water)	Mean (± SE) no. of eggs per dormant shoot and oviposition deterrence (o.d.%) 3 days no.	3 days o.d.%	7 days no.	7 days o.d.%	14 days no.	14 days o.d.%	21 days no.	21 days o.d.%	28 days no.	28 days o.d.%
Palm oil										
1	0.0±0.0dB	100	0.0±0.0dB	100	5.3±2.2cB	26.9	8.6±3.1bB	16.5	14.1±3.8aB	8.7
1.5	0.0±0.0dB	100	0.0±0.0dB	100	4.7±1.9cB	27.1	7.4±2.2bC	23.7	11.6±2.4aC	18.3
2	0.0±0.0dB	100	0.0±0.0dB	100	3.6±1.3cC	39.0	7.1±1.9bC	25.7	10.3±2.3aC	24.0
Liquid grease										
1	0.0±0.0aB	100	0.0±0.0aB	100	0.0±0.0aD	100	0.0±0.0aD	100	0.0±0.0aF	100
1.5	0.0±0.0aB	100	0.0±0.0aB	100	0.0±0.0aD	100	0.0±0.0aD	100	0.0±0.0aF	100
2	0.0±0.0aB	100	0.0±0.0aB	100	0.0±0.0aD	100	0.0±0.0aD	100	0.0±0.0aF	100
Liquid Vaseline										
1	0.0±0.0bB	100	0.0±0.0bB	100	0.0±0.0bD	100	0.0±0.0bD	100	4.4±1.8aD	58.5
1.5	0.0±0.0bB	100	0.0±0.0bB	100	0.0±0.0bD	100	0.0±0.0bD	100	2.9±1.3aDE	70.6
2	0.0±0.0bB	100	0.0±0.0bB	100	0.0±0.0bD	100	0.0±0.0bD	100	2.3±0.9aE	75.9
Liquid paraffin										
1	0.0±0.0aB	100	0.0±0.0aB	100	0.0±0.0aD	100	0.0±0.0aD	100	0.0±0.0aF	100
1.5	0.0±0.0aB	100	0.0±0.0aB	100	0.0±0.0aD	100	0.0±0.0aD	100	0.0±0.0aF	100
2	0.0±0.0aB	100	0.0±0.0aB	100	0.0±0.0aD	100	0.0±0.0aD	100	0.0±0.0aF	100
Control										
Water + Tween 20	2.1±0.7eA	-	5.6±2.3dA	-	9.2±2.4cA	-	12.0±3.0bA	-	16.8±4.4aA	-

Means within a line followed by the same lower-case letter are not significantly different (DMRT; $P \leq 0.05$). Means within a column followed by the same capital letter are not significantly different (DMRT; $P \leq 0.05$).

with four oily substances, palm oil-treated plots showed high winterform oviposition 14 days after application, and the oviposition deterrence exhibited by palm oil was greatly reduced on the 14th day and beyond. Although liquid Vaseline exhibited 100% oviposition deterrent activity at all the concentrations within 21 days, first oviposition in liquid Vaseline-treated plots was seen 28 days after application. Nevertheless, oviposition deterrent activity of liquid Vaseline was higher than 70% at the concentrations of 1.5 and 2 L/100 L water (table 3).

As in the first year, no winterform oviposition was observed in both liquid grease and liquid paraffin-treated plots throughout the study period, i.e., the oviposition deterrence of these two oily substances remained 100% during the 4-week sampling period.

Discussion

Until now, many studies have been carried out on the management of pear psylla. While some of them evaluated insecticides belonging to different groups (Erler and Cetin, 2005; Kocourek and Stara, 2006; Nissar *et al*., 2017; Nottingham *et al*., 2019), some others tested botanicals and entomopathogenic fungi against the pest (Puterka *et al*., 1994; Erler, 2004b; Erler *et al*., 2007; 2014). However, all the products used in these studies were evaluated only for their toxicity against different stages of pear psylla. Although toxicity to various stages of the pest is very important in controlling pear psylla, behavioural effects such as repellence, oviposition and feeding deterrence, etc. may contribute to the management of pest.

This study showed that palm oil, liquid grease, liquid Vaseline and liquid paraffin exhibited oviposition deterrent activity against winterform females of *C. pyri*, but liquid grease and liquid paraffin being the most efficient. There have been several similar studies, evaluating oviposition deterrence of some oily materials against pear psylla. In one of them, Erler (2004c) tested a total of four oily substances, two of which (cotton seed oil and neem oil) were of vegetable origin, one (fish-liver oil) of animal origin and one (summer oil) of mineral origin, at a concentration of 1 L/100 L water for their oviposition deterrent activity against winterform females of *C. pyri*. Erler (2004c) found that fish-liver oil and summer oil had 100% oviposition deterrence and strongly deterred oviposition by winterform females of the pest during the 3-week period. Even after 4 weeks, these two substances had an oviposition deterrent activity more than 75%. Erler (2004c) reported that plant-based oils (neem oil and cotton seed oil) could delay winterform oviposition for only 1 and 2 weeks, respectively. Similarly, in the present study plant-based oil, palm oil, at 1 L/100 L water could deter winterform oviposition of pear psylla for only 1 and 2 weeks in 2018 and 2019, respectively. There is a parallelism between these two studies in terms of oviposition deterrence of plant-based oils. The same findings are valid in terms of mineral-based oils. Although both studies tested different mineral-based oils (summer oil *versus* liquid grease, liquid Vaseline and liquid paraffin), their findings on mineral-based oils are reasonably consistent. In another study, Erler and Tosun (2017) evaluated seed oils of maize, safflower, rapeseed and castor oil plant for their oviposition deterrent activity against winterform females of *C. pyri* in two successive years (2015 and 2016). Erler and Tosun (2017) reported that safflower and castor oils exhibited 100% oviposition deterrence at all the tested concentrations (1, 1.5 and 2 L/100 L water) for 3 weeks after application in both years, even after 4 weeks, the deterrence of these two oils was higher than 70%. Erler and Tosun (2017) also reported that maize and rapeseed oils had low level of oviposition deterrence and first eggs at maize oil- and rapeseed oil-treated plots were seen on the 7th and 14th days of application, respectively. Our findings on palm oil are parallel with their findings on maize and rapeseed oils, but different from their findings on safflower and castor oils. Although they are of the same origin, differences in oviposition deterrence of plant-based oils could be attributed to their different stability on plant surface, where they are applied (Erler and Tosun, 2017).

As for the mechanism(s) involved in the oviposition deterrence of oily substances, previous studies indicate that this behavioural effect is based on the formation of an oily surface (Lundgren, 1975; Zwick and Westigard, 1978; Larew, 1988; Erler, 2004c; Erler and Tosun, 2017). Similarly, our observations on winterform adults demonstrated that adult psylla had difficulties in walking on oily surfaces after application and preferred untreated portions of trees. Additionally, many insects don't like laying their eggs on oily surfaces (Anonymous, 2017).

Some previous studies also indicate that early suppression of winterform oviposition in pear orchards generally resulted in lower rates of population growth throughout the foliage season with the help of natural enemies (Lyousoufi *et al*., 1988; Solomon and Morgan, 1994; Erler and Cetin, 2005; 2007). For this behavioural psyllid management strategy to function well, it is essential to prevent winterform oviposition of the pest during the post-dormant period. Initial control efforts of Turkish pear growers against winterform adults of pear psylla have involved one to several late winter/early spring applications of synthetic insecticides. However, development of resistance to many insecticides from organophosphates and pyrethroids has been a serious obstacle for this approach (Bues and Boudinhon, 2002; Bues *et al*., 1999; 2003). The results from this study showed that liquid grease and liquid paraffin provided effective protection against winterform oviposition of pear psylla for about one month. In early season, the substitution of synthetic chemicals with these oily substances, may also allow to the pear psylla overwintering natural enemies to survive in pear orchards.

Conclusions

This study demonstrates that the tested mineral-based oily substances are effective and promising materials in the management of pear psylla as oviposition deterrents and can be useful in the search for new products. However, further studies are needed to determine oviposition deterrent activity of these oily substances against summerform females of the pest and their adverse effect on natural enemies when they are active in pear orchards.

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