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Research Article/Araştırma Makalesi

Insecticidal effects of wood vinegars produced from organic wastes on harmful almond leaf bee Cimbex quadrimaculata (Müller, 1766) (Hymenoptera: Cimbicidae)

Organik atıklardan üretilmiş odun sirkelerinin zararlı badem yaprak arısı Cimbex quadrimaculata (Müller, 1766) (Hymenoptera: Cimbicidae)'na insektisidal etkileri

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ABSTRACT

In agricultural activities, there is an increasing need for organic products as alternatives to chemical pesticides. Wood vinegar (WV, pyrolysis liquid) from these alternative potential products is produced as a result of the carbonization process in which it is obtained from organic wastes together with useful products such as energy and biochar. This study was carried out to determine the insecticidal effects of WVs produced from broiler chicken litter and nutshells on the harmful almond leaf wasp *Cimbex quadrimaculata* Müller, 1766 (Hymenoptera: Cimbicidae). The study was carried out in an almond orchard in Diyarbakır (Eğil district) and Elazığ (Keban district) in the 2019-2021 production seasons. WV mixed solutions (1%, 3%, 5%, 7%, 10% and 25%) were applied with a back sprayer at the beginning and end of leafing in contaminated almond orchards. The effects of the applications were determined by impact and visual control methods on the 1st, 7th, 14th and 21st. In the analysis of the obtained data, first of all, normality test was performed. In the analysis of the obtained data, the Kruskal-Wallis test was applied. In conclusion; It has been determined that WV-added solutions have a insecticidal effect against harmful almond leaf bees, and the highest decrease in the number of larvae occurs at doses of 10% to 25%. It is important to test these vinegars in different locations with more detailed studies and to conduct detailed bioecological studies depending on the climatic factors and population ecology of the pest in terms of alternative control of the pest. The data of this study contain basic data for almond integrated pest management (IPM) studies.

Key Words: Alternative control, Almond, *Cimbex quadrimaculata*, Insecticidal effect, Wood vinegar (pyrolysis liquid)

ÖZ

Tarımsal faaliyetlerde, kullanılan kimyasal pestisitlere alternatif organik ürünlere gün geçtikçe daha çok gereksinim duyulmaktadır. Bu alternatif potansiyelli ürünlerden odun sirkesi (OS, piroliz sıvı), organik atıklardan enerji ve Biyokömür (Biochar) gibi faydalı ürünlerle birlikte elde edildiği karbonizasyon işlemi sonucunda üretilmektedir. Bu çalışma, Broiler (etçil) tavuk yetiştiriciliği altlığı ve fındıkkabuklarından üretilmiş OS'ların zararlı badem yaprak arısı *Cimbex quadrimaculata* (Müller, 1766) (Hymenoptera: Cimbicidae)'na insektisidal etkilerini belirleme amacı ile yapılmıştır. Çalışma, Diyarbakır (Eğil ilçesi) ve Elâzığ (Keban ilçesi) illerinde bulunan birer badem alanında 2019-2021 üretim sezonlarında yürütülmüştür. OS karışımlı solüsyonlar (%1, 3, 5, 7, 10 ve 25), bulaşıklı badem bahçelerinde yapraklanma başı ve sonunda sırt pülverizatörü ile uygulanmış ve uygulamaların etkileri 1., 7., 14. ve 21. günlerde darbe ve gözle kontrol yöntemleri ile belirlenmiştir. Elde edilen verilerin analizinde, Kruskal-Wallis testi uygulanmıştır. Sonuç olarak; OS katkılı solüsyonların zararlı badem yaprak arısına karşı insektisidal etki gösterdiği ve larva sayısında ise en fazla düşüşün %10 ile %25'lik dozlarda gerçekleştiği tespit edilmiştir. Bu sirkelerin daha detaylı çalışmalarla farklı lokasyonlarda denenmesi, iklimsel faktörler ve zararlının populasyon ekolojisine bağlı olarak detaylı biyoekolojik çalışmaların yapılması zararlı ile alternatif mücadele açısından önemlidir. Bu çalışmanın verileri, badem entegre zararlı yönetimi (IPM)çalışmaları için temel veriler içermektedir.

Anahtar Kelimeler: Alternatif kontrol, Badem, *Cimbex quadrimaculata*, İnsektisidal etki, Odun sirkesi (piroliz sıvı)

Introduction

Almond, (*Prunus dulcis* L.), is a source of magnesium, riboflavin, manganese, copper, phosphorus, fiber, mono-unsaturated fatty acids, nutrient-dense vitamin E and protein (Chen et al., 2006). The countries producing almonds in the world are USA, Spain, Iran and Morocco, respectively (Şimşek and Gülsoy, 2017). Although commercial almond cultivation has increased significantly in Turkey, economic losses occur due to pests such as *Cimbex quadrimaculata* Müller, 1766 (Hymenoptera: Cimbicidae). It was determined that the pest is among the dominant species with a rate of 51% in the almond fields of Diyarbakır, Elazığ and Mardin provinces (Bolu et al. 2005). Studies about the population and population dynamics of the pest which causes damage to cherries, apricots, peaches, and pears apart from almonds, and how to control it in terms of organic agriculture (Çakıcı et al., 2015) are not enough in number. In the light of current information, there is no effective application in the control against pests and the information about the current situation of their natural enemies is quite limited (Özgen et al., 2010; Özbek, 2014). Farmers generally prefer the chemical warfare method to solve plant protection problems, and unconscious pesticide applications bring about much negativity in terms of human and environmental health (Kaplan and Saltuk, 2021). Synthetic insecticides used in the fight against pests are applied indiscriminately and these applications negatively affect non-target organisms in the agro-ecosystem and the environment. Because of this situation, alternative methods are used in the fight against pests. It has been stated that different doses of azadirachtin, a plant-derived preparation, could reduce the harmful effects or limit the use of chemical methods in the fight against some agricultural pests (Kaplan, 2019; Aşkın et al., 2022)

Among these methods, it was determined that wood vinegar (WV, pyrolysis liquid), which is an organic product that is still used for various purposes today, application was used for plant protection in the past (Tiilikkala et al., 2010). WV is a liquid by-product obtained by the condensation of the steam formed during the production of charcoal and the carbonization of plant and animal wastes. WV is effective on a number of pests in agricultural areas (Yatagai et al., 2002; Wititsiri, 2011; Pangnakorn et al., 2012; Hagner, 2013; Oramahi and Yoshimura, 2013; Yamauchi and Matsumoto, 2016; Omulo et al., 2017; Adfa et al., 2017; Özgen et al., 2018; Oramahi et al., 2018; Koç and Yardım, 2018; Koç, 2019; Koç, 2020). There are some scientific studies that show that the negative effects on non-target organisms are not at a level to worry about (Cai et al., 2012; Hagner, 2013; Rui et al., 2014; Koc et al., 2018; Koç et al., 2019; Koç and Yardım, 2019). Parameters include WV (Tiilikkala et al., 2010), the type of raw material used and carbonization temperature, which have the potential to replace synthetic pesticides, and their content and effects change. Wood vinegars (BCLWV and NWV) produced from broiler chicken litter and hazelnut shells have been used in various scientific studies both in the laboratory and in the wheat agro-ecosystem (Koç and Yardım, 2018; Özgen et al., 2018; Koç, 2020). The effects on harmful almond leaf bees have not been investigated. In this context, it is crucial to find an alternative way to combat this pest, which causes damage to cherries, apricots, peaches and pears as well as almond fields. In this study, the insecticidal effects of different doses of BCLWV and NWV on the harmful almond leaf bee *Cimbex quadrimaculata* Müller, 1766 (Hymenoptera:

Cimbicidae), which causes significant losses in almond fields, were investigated.

Material and Methods

This study was carried out in one almond field each in Diyarbakır (Eğil district) and Elazığ (Keban district) in the 2019-2020 and 2020-2021 production season (Figure 1-2).

Figure 1. Preparation of WV supplemented solutions

Figure 2. Field study

Figure. 3. *C. quadrimaculata* larvae

WV's used in the study; broiler chicken breeding litter and nutshell raw materials (BCLWV and NWV) were obtained from a commercial company obtained by gasification machine (Namlı et al. 2014). Back sprayer assistance (Hyundai Turbo 300 Gasoline Atomizer, 14 Lt, Blown Sprayer HIM.) (Figure 1-2) and at doses of 1%, 3%, 5%, 7%, 10% and 25%. Each dose of WV was applied to five trees and the effects were examined with impact and visual control methods on the 1st, 7th, 14th and 21st days of the applications. The population change of the pest was determined by the counts of 5 randomly selected wild almonds (*Prunus dulcis*) and grafted cultivated almond tree (*Prunus amygdali*) (ferragnez variety) in orchards in each trial orchard. The larvae that fell on the Japanese umbrella were counted by blowing on four different sides of the sample trees, and after counting, they were left to the sample tree again. The average height and crown projections of wild and grafted almond trees are 3.5 m / 2 m and 2.5 m / 1.5 m, respectively. In the statistical analysis of the obtained data, Kolmogorov Smirnov test was applied primarily to determine whether it showed a normal distribution. As a result of this test, Kruskal-Wallis test, which is one of the non-parametric tests, was applied since the assumption of normality was not provided. The p value < 0.05 was considered for statistical significance.

Results and Discussion

As regards Keban district, it can be seen in Figure 4 that all doses were effective in reducing the number of *C. quadrimaculata* by 25%, 10%, 7%, 5% and 1%, respectively, compared to the control group in the applications applied with BCLWV during the leafing period. Although it has been observed that the population change fluctuation in control applications is different compared to other dose parameters, there are no statistical differences (Table 1). It was determined that as the dose increased, the vinegar material used was more effective on the population change of the *C. quadrimaculata*.

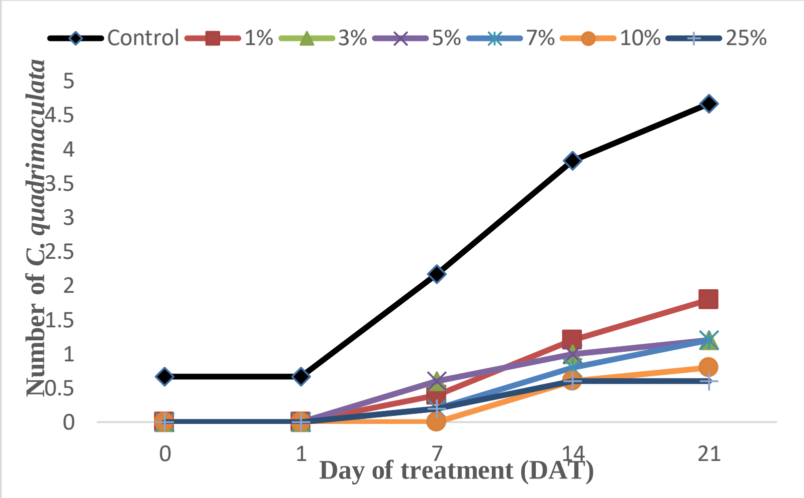

Figure 4. Change in the number of *C. quadrimaculata* depending on the time of the onset of foliation in Keban district where BCLWV was applied

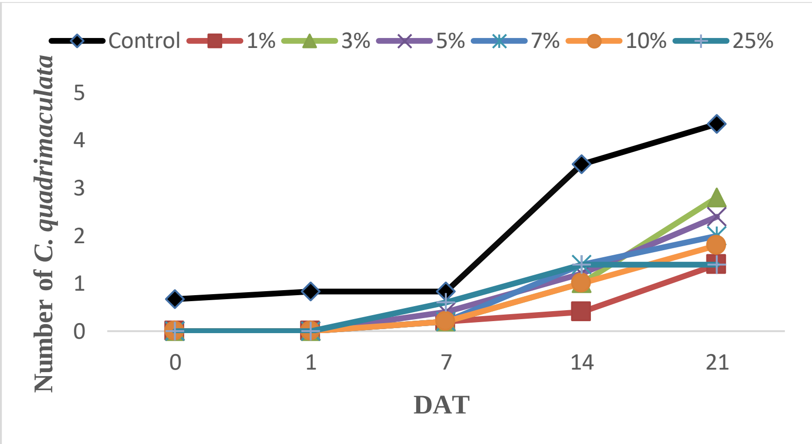

Figure 5. Change in the number of *C. quadrimaculata* depending on the time of the onset of foliation in Keban district in which NWV was applied

It was found that all doses were effective on the pest, compared to the control group, in the application of NWV treated start of foliation period in Keban district. In terms of reducing the number of pests, it was determined that the percentages were 25%, 1%, 10%, 7%, 5%, and 3%, respectively (Figure 5).

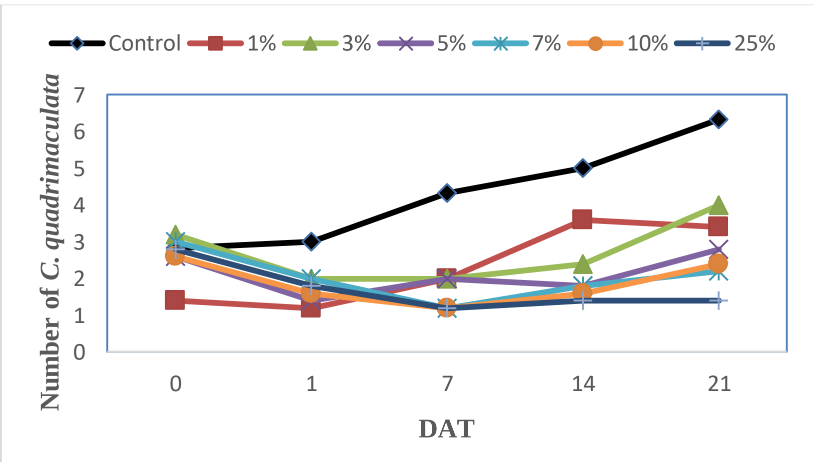

Figure 6. Change in the number of *C. quadrimaculata* depending on the time at the end of foliation in Keban district where BCLWV was applied

It was found that all doses were effective on the pest compared to the control group in the BCLWV treated end-of-foliation application in Keban district. In terms of reducing the number of pests, it was determined as 25%, 7%, 10%, 5%, 1% and 3%, respectively (Figure 6).

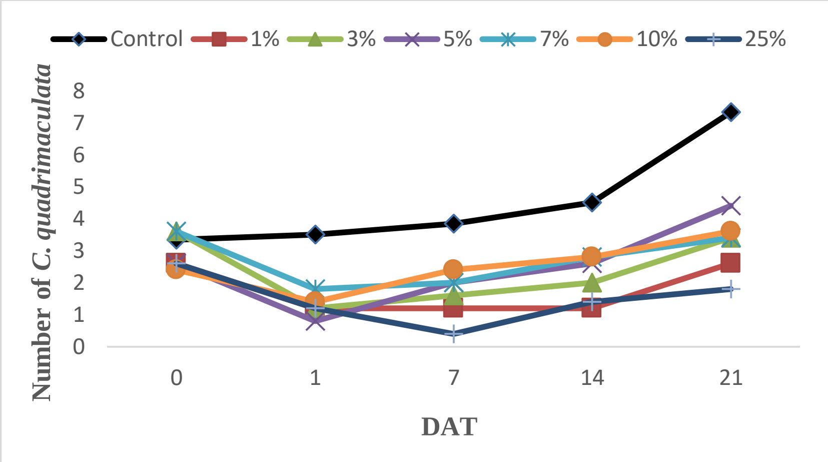

Figure 7. Change in the number of *C. quadrimaculata* depending on time after NWV applied in Keban district.

It was observed that all doses were effective on the pest compared to the control group in the NWV treated and-foliation application in Keban district. In terms of reducing the number of pests, they were found to be 25%, 1%, 3%, 7%, 10% and 5%, respectively (Figure 7).

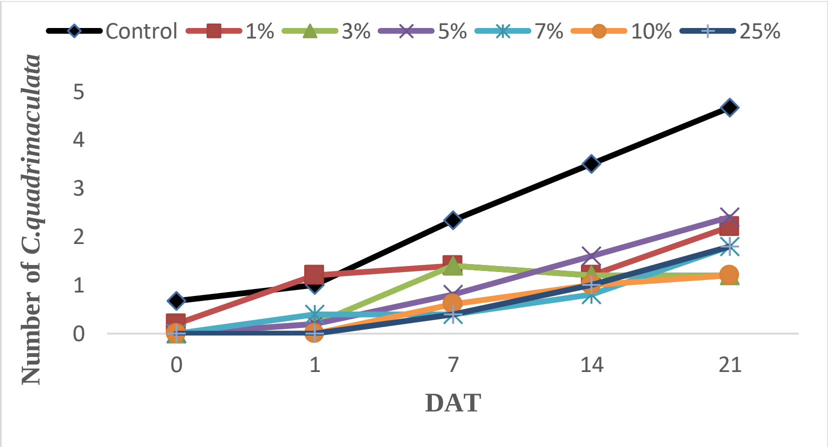

Figure 8. Change in the number of *C. quadrimaculata* depending on time per foliation applied to BCLWV in Eğil district

In the application of BCLWV treated foliage head in Eğil district, it was determined that all doses were effective on the pest compared to the control group. In terms of reducing the number of pests, they were recorded as 10%, 3%, 25%, 7%, 1% and 5%, respectively (Figure 8).

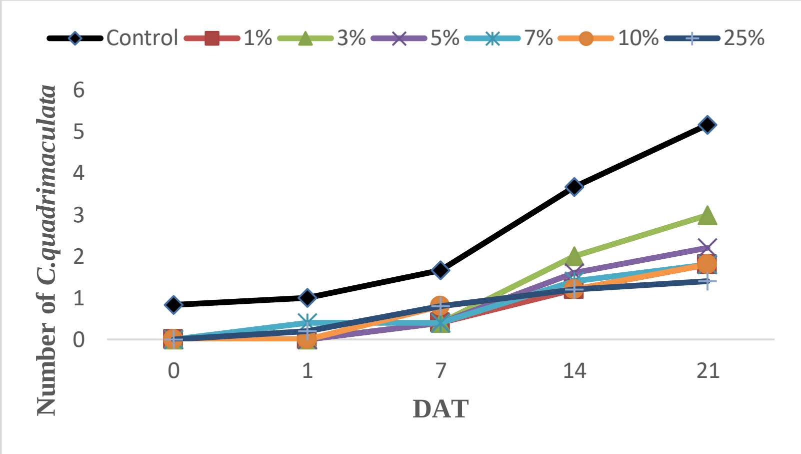

Figure 9. Change in the number of *C. quadrimaculata* depending on time per foliation applied to NWV in Eğil district.

In the application of NWV treated foliage head in Eğil district, all doses were found to be effective on the pest compared to the control group. In terms of reducing the number of pests, they were found to be 25%, 10%-7%, 5% and 3%, respectively (Figure 9).

It was determined that all doses were effective on the pest compared to the control group in BCLWV treated end-foliation application in Eğil district. In terms of reducing the number of pests, they were as 25%, 10%, 7%-1%, 5% and 3%, respectively (Figure 10).

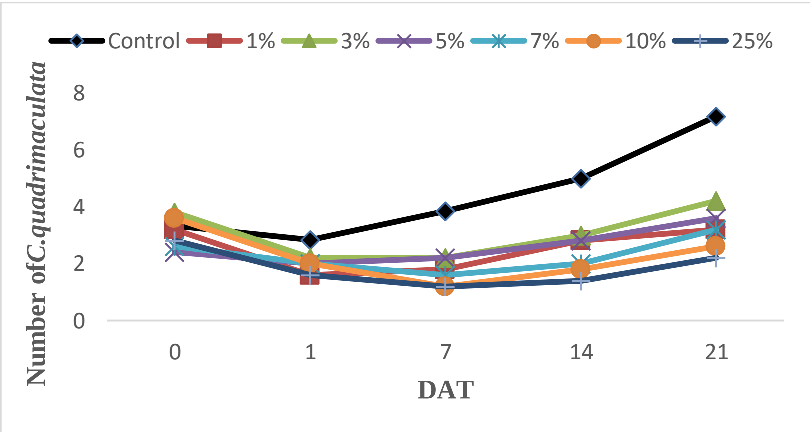

Figure 10. Change in the number of *C. quadrimaculata* depending on the end of foliation in Eğil district after BCLWV applied

It was observed that all doses were effective on the pest compared to the control group in the NWV treated end-foliation application in Eğil district. In terms of reducing the number of pests, they were found to be 3%, 25%, 1%, 7%, 10% and 5%, respectively (Figue 11).

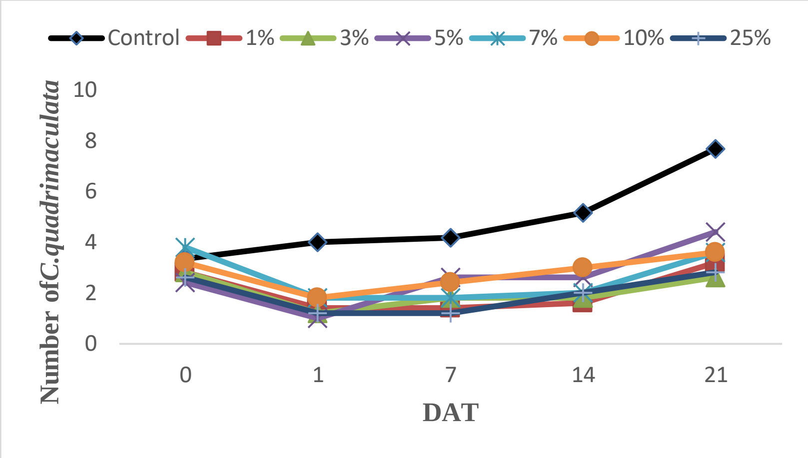

Figure 11. The change in the number of *C. quadrimaculata* depending on the time at the end of foliation in Eğil district where NWV was applied

According to Kruskal Wallis test, there was a statistically significant difference between the groups as the *P* value is <0.05 in the end of foliation treatments for BCLWV and NWV treatments in Keban district. Similarly, there was a statistically significant difference between the groups as the p value was <0.05 in the post-foliation treatments for BCLWV and NWV treatments in Eğil district (Table 1). When the Kruskal Wallis test pairwise comparison results were examined, there is a 25% difference between the control groups and the control groups at the end of foliation in Keban district BCLWV application, in Keban district NWV application at the end of foliation, in Eğil district at the end of foliation in BCLWV application and in Eğil district at the end of foliation (Table 1). Moreover; there was also a difference between the control group and the 1% group at the end of foliation of NWV application in Keban district (Table 1).

Table 1. Determining the differences between dosing and control averages using the Kruskal-Wallis Test

Applications	Group	Mean	Mean Rank	SD	*p*	Pairwise Comparisons
Keban district BCLWV application foliation start	Control	2.70	29.80	1.94	0.138	
	1%	0.68	18.30	0.79		
	3%	0.56	17.80	0.55		
	5%	0.56	17.80	0.55		
	7%	0.44	16.30	0.53		
	10%	0.28	12.70	0.38		
	25%	0.28	13.30	0.30		
Keban district NWV application foliation start	Control	2.03	26.40	1.74	0.620	
	1%	0.40	14.50	0.58		
	3%	0.80	16.80	1.19		
	5%	0.80	17.50	1.01		
	7%	0.72	17.20	0.92		
	10%	0.60	16.20	0.78		
	25%	0.68	17.40	0.70		
Keban district BCLWV application foliation end	Control	4.30	31.10	1.45	**0.032**	There is a difference between the control group and the 25% group.
	1%	2.32	17.20	1.11		
	3%	2.72	22.70	0.86		
	5%	2.12	16.30	0.57		
	7%	2.04	15.40	0.65		
	10%	1.88	12.90	0.59		
	25%	1.72	10.40	0.64		
Keban district NWV application end of foliation	Control	4.50	30.80	1.64	**0.025**	There is a difference between the control group and the 1% and 25% group.
	1%	1.76	11.00	0.76		
	3%	2.36	17.10	1.08		
	5%	2.48	17.80	1.30		
	7%	2.72	21.10	0.80		
	10%	2.52	19.00	0.79		

	25%	1.48	9.20	0.80		
Eğil district BCLWV application foliation start	Control	2.43	27.00	1.68	0.268	
	1%	1.24	22.50	0.71		
	3%	0.80	17.10	0.64		
	5%	1.00	18.10	1.00		
	7%	0.68	14.80	0.68		
	10%	0.56	12.80	0.55		
	25%	0.64	13.70	0.76		
Eğil district NWV application foliation start	Control	2.46	27.00	1.88	0.568	
	1%	0.68	15.20	0.79		
	3%	1.08	17.80	1.35		
	5%	0.84	16.60	1.00		
	7%	0.80	17.40	0.76		
	10%	0.76	15.90	0.77		
	25%	0.72	16.10	0.60		
Eğil district BCLWV application foliation end	Control	4.43	30.40	1.72	**0.026**	There is a difference between the control group and the 25% group.
	1%	2.52	17.10	0.76		
	3%	3.08	23.40	0.91		
	5%	2.60	18.50	0.63		
	7%	2.28	14.10	0.62		
	10%	2.24	13.50	0.90		
	25%	1.84	9.00	0.65		
Eğil district NWV application foliation end	Control	4.86	31.80	1.69	**0.033**	There is a difference between the control group and the 25% group.
	1%	2.08	13.10	0.85		
	3%	2.04	12.70	0.65		
	5%	2.60	17.30	1.20		
	7%	2.60	18.40	1.00		
	10%	2.80	20.70	0.70		
	25%	1.96	12.00	0.75		

It was determined that all dose applications of the vinegars (BCLWV and NWV) used were effective in reducing the harmful almond leaf bee, *C. quadrimaculata*, population in both locations in current study. With this situation, it was determined that the effect increased with the increading dose rate (Pangnakorn et al., 2012) and especially 10% to 25% dose applications reduced the number of eggs laid by the pest. Findings from this study of Yatagai et al. (2002) showed that WVs produced from different raw materials have high termiticide activity against *Reticulitermes speratus*. A similar finding that WV produced from coconut waste has a pesticidal effect was observed by Wititsiri (2011). Pangnakorn et al. (2012) stated that the OS they used in laboratory conditions (10, 15, 20, 25 and 30 doses) and the larval mortality rate of houseflies (*Musca domestica* L.) increased with increasing WV concentration and exposure time. Hagner (2013) reported that WV against molluscs provides strong evidence of its potential to be an effective, inexpensive and environmentally friendly method. Oramahi and Yoshimura (2013) revealed that three types of WV produced from *Vitex pubescens* at three different pyrolysis temperatures (350, 400 and 450 °C) showed antitermite activity against both *Reticulitermes speratus* and *Coptotermes formosanus*. Yamauchi and Matsumoto (2016) reported that some components of WV on red mites may cause death by inhaling through the stigma and peritreme in the red mite body. Adfa et al. (2017) revealed that WV has strong termicidal effect on *Coptotermes curvignathus*. Ozgen et al. (2018) determined that WVs produced from hazelnut shells and broiler chicken litter against *Tribolium confusum* du Val., 1863 showed a certain amount of insecticidal activity, but did not cause a great deal of mortality. Oramahi et al. (2018) reported that WVs produced from palm trunks (350, 400 and 450 °C) exhibit antitermite activity against *C. formosanus* workers. Koç and Yardim (2018) reported that the WV they used affects the average number of arthropods on the cultivated plant. Koç (2019) revealed that 100% dose of WV treatments on California red worm (*Eisenia* *foetida*) in vermicompost medium under in-vitro conditions had a toxic effect and WV had bio-pesticide potential. In another study, which is in line with the findings, Koç (2020) reported that WV produced from hazelnut shells caused a decrease in the average Opilionid (grass cutter) number and an increase in the average Arachnid number. The findings are thought to have a repellent and biocidal effect due to the content of WV (such as acetic acid, phenol) (Yatagai et al., 2002), the smell of vinegar and the residue left in the plant.

Conclusion

In conclusion; It has been determined that both BCLWV and NWV applications have a insecticidal effect against the harmful almond *Cimbex quadrimaculata*, and the highest decrease in the number of larvae occurs at 10% and 25% concentrations. The effective results of vinegars, which are pyrolysis products, will provide very important agricultural control gains for organic almond cultivation in the region. As a suggestion; the pest population should be carefully monitored between May and June, the pest creates a high population in newly established gardens and its control is important in these gardens of the pest; It has been concluded that the continuous monitoring of natural enemy biodiversity, and the use of organic-based compounds instead of synthetic chemicals in the control, will be an appropriate approach for environmentalist and organic agriculture.

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Conflict of interest: The authors declare no conflict of interest, financial or otherwise.

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