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Insecticidal Effect of Different Plants Extracts Against Wheat Weevil, *Sitophilus granarius* (L., 1985) (Coleoptera: Curculionidae)

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Abstract: The most common of the pest is *Sitophilus granarius* L. (Coleoptera: Curculionidae) which causes economically loss of important crops in stored grains. Chemical pesticides are commonly used to control *S. granarius.* Researchers have recently focused on alternatives to chemical pesticides. There have been a great number of studies on this issue. In this study, the plant extracts of *Achillea wilhelmsii* C. (Asteraceae), *Tanacetum vulgare* L. (Asteraceae), *Tanacetum parthenium* L. (Asteraceae) and *Capsicum annuum* L. (Solanaceae) were used to determine their toxic effects on *S. granarius.* Pertaining to the purpose each concentration was applied on 20g wheat. Adult individuals of *S. granarius* (one day old) were used for this experiment. Wheat applied extract were stored in jars. The experiments were conducted with randomized design with four replicates, including control. Pure water was used for control. Experiment was carried out in laboratory (24 ± 1°C and 60% ± 65 humidity) conditions. A commercial preparation called Gamma-T-ol obtained from the extract of *Melaleuca alternifolia* (Maiden & Betche) (Myrtaceae) was used as a positive control. As a result, none of the extracts had contact effect. F1 progeny effect of plants extracts on *S. granarius* was increased with an, increase in concentration. The highest suppression rate was determined at the highest concentration of *M. alternifolia.* It was followed by the high concentrations of *C. annuum, A. wilhelmsii*. *T. parthenium* and *T. vulgare* respectively. The lowest suppression rate was determined at the highest concentration of *T. vulgare* extract. It is thought that the plant extracts found to be effective as a result of this study can be used as organic insecticides in IPM programs against wheat weevil.

Keywords: Plant Extracts, Wheat Weevil, Contact Toxicity, Repellent Effect

1. Introduction

Stored products, which have an important place in human nutrition, are attacked by many insects. These insects can thrive wherever the favorable environmental conditions are present. Their spread is accelerated by increased international trade and intercontinental travel.

Many insects are harmful to stored products, especially in cereals insect species such as *S. granarius L. (*Col.: *Sitophilus oryzae* L. (Col.: Curculionidae), *Sitophilus zeamais* M. (Col.: Curculionidae) *Rhyzopertha dominica* F. (Col: Bostrychidae) can damage the product. Depending on the local conditions and characteristics, these losses can be as high as 50%. Insects account for 5% of the 10% loss in stored products according to Prevett [1] the most important among them is *S. granarius*. This pest causes the hollowing out of whole grains that were previously undamaged. Furthermore, *S. granarius* larvae develop covertly in cereal grains, with each larva consuming roughly half a wheat grain [2]. Insect infestation of stored grain leads to a build-up of heat and moisture, which promotes fungal growth [3, 4].

To limit the harm caused by insects in the stored product, chemical insecticides are applied. Insecticides and fumigants from the organic-phosphorus and pyrethroid groups, in particular, are commonly employed to control storage pests. Highly used insecticides enable pests of stored products to develop resistance toward these chemicals [5]. Due to resistance developed by the pests and insecticide residues observed in the products, alternative pest control methods in stored products such as plant-based insecticides have gained momentum in recent years.

Plant-based pesticides are a reliable alternative to synthetic insecticides since they are non-cytotoxic, biodegradable, environmentally beneficial, and mimic host metabolism. Plant-based insecticides are reliable alternative to synthetic insecticides since they are more environmentally friendly, simulator of host metabolism and non-cytotoxity biodegradable [6]. Warthen and Morgan [7] studying on plant extracts reported that they have repellent, antifeedant, ovicidal and toxic effects in insects. Relatedly, secondary metabolites synthesized by plants have an insecticidal effect on insects. In addition, secondary metabolites are natural and do not adversely affect the environment. Because of the growing emphasis on organic agriculture, the share of plant-based insecticides in the global insecticide market in industrialized countries has gradually increased in food production and post-harvest storage in recent years. More than 2000 plants have recently been found to be effective in various ways against harmful insects in agriculture [8]. Secondary metabolites, on the other hand, are classified in many different categories and the most important ones are phenols, alkaloids, terpenoids, glycosides, saponins, and tannins and some of these substances have been used in agriculture directly or indirectly for centuries against pests [6]. The introduction and widespread usage of natural chemicals (essential oils, glycosides, alkaloids and so on) in agricultural areas in recent years has been reported to result in a large reduction in pesticide consumption that is harmful to the environment [9].

The goal of this research is to determine the insecticidal toxicity of various plant extracts against *S. granarius.*

2. Materials and Methods

2.1. Plants

Information about the plants used in the study is given in Table 1. According to Table 1, all of plants were collected during the period of actively growing at the flowering stage in 2021. *A. wilhelmsii* was taken from province of Eskisehir. *C. annuum* was taken from province of Kahramanmaras and. *T. parthenium* and *T. vulgare* were collected from province of Ankara. The extract was made from the plants' leaves, flowers, and stems. In *C. annuum*, the fruit of was used for extract. Gamma-T-ol obtained from *M. alternifolia* were bought from (BioAust Pty. Ltd) Australia.

Table 1. *Information about the plants used in the experiment.*

Name	Fam.	Tissue used
Achillea wilhelmsii L.	Asteraceae	Flowers, leaves, buds
Capsicum annuum L	Solanaceae	Fruit
Tanacetum vulgare L.	Asteraceae	Flowers, leaves, buds
Tanacetum parthenium L.	Asteraceae	Flowers, leaves, buds

2.2. Preparation of the Plant Extracts

All plant material cleaned was air-dried in the shade. Plants were ground into small pieces after drying. To prepare the extract, the dried powder was mixed with 200 g of powdered plant components. Four hundred ml of ethanol (80% v/v) was poured to this mixture. After standing for 72 hours, the mixture was placed in a Soxhlet decoction for 5-6 hours. Bucher funnel and Whatman No. 1 filter paper used to filter the mixture. Rotary evaporator (50-60°C) under low pressure was used to concentrate the extracts. Plant extracts were prepared and stored at 4°C in glass vials to be used as stock.

2.3. Mass Rearing of Test Insect

The culture of *S. granarius* was obtained from the Central Research Institute of Plant Protection in Ankara. Gerek 79 wheat varieties was used for insect food and trials. Wheat (1/3) was put into 5-litre jars to make a sufficient stock. Before being used in the study, the wheat was stored at -20°C for one week to eliminate any potentially harmful infections. Adults from the stock culture were transferred to these jars and given 48 hours to lay eggs. All adults were removed from the jars at the end of the period, leaving only eggs and contaminated material. In the experiments, the adults were incubated in the dark at 27 ± 2°C, at 50% ± 10% relative humidity for 45 days.

2.4. Contact Toxicity of Different Plants Extracts

The experiments were carried out in accordance with the guidelines proposed by Ndomo et al. [10]. Four different concentrations of the plant extract 2.5, 5, 7.5, and 10% were prepared using Triton X100 and each concentration was applied to 20 g of wheat. The treated wheat was transferred into jars after drying for 30 minutes. Each jar contained twenty adult *S. granarius* individuals (one day old). The jars were placed in a climate chamber with a temperature of 25 ± 1°C and a relative humidity of 65 percent. The experiments, including the control, were carried out in a completely randomized design with four replicates, and measurements were usually taken daily for three days after treatment.

The inhibition rate was calculated using the following formula:

$$IR = Cn - Tn / Cn. 100$$

Where, % IR, inhibition rate: Cn: the number of newly emerged adults in the untreated (control) group; Tn: the number of newly emerged insects in the treated replicates.

2.5. Repellent Efficacy of Different Plant Extracts

Experiment for estimating the repellent effect were carried out by using 9 cm glass Petri dishes. Whatman filter paper was cut in half to make two 9 cm disc halves. Half part of the Petridis was augmented with plant extract while other part was augmented with distilled water using a micropipette. The petri dishes were kept open for 30 min to dry. Cellophane tape was attached on both treated and untreated halves. Each treatment was provided with 1-3 days old 20 *S. granarius* adults and petri dishes were covered and stored in the dark. The experiment was conducted in four replications for each extract concentration. After 24 hours in mild light, data on insects from both treated and untreated halves (H_2O) were collected. Percentage repellency was tabulated according to the formula given in [11].

$$PR= Nc-Nt/ Nc+Nt.100$$

PR: the percentage repellency value; NC: the number of insects in the untreated group; and Nt: the number of insects in the treated group.

2.6. Data Analysis

SPSS program version 20.6 was used to perform the statistical analysis of variance (ANOVA). Duncan's test (P=0.05) was applied for the comparison of the mean values.

3. Results

3.1. Contact Toxicity of Different plants Extracts

None of the extracts had mortality effect. There was no difference in mortality rate between the control and the treatment groups. The highest mortality rate (7%) was determined at 10% concentration of Gamma-t-ol obtained from the extract of *M. alternifolia*. This is followed by 6% mortality rate with the extract of *A. wilhelmsii*. No mortality was detected at low concentrations of the extracts. There was 1% mortality in the control group. It was observed that there existed contact effect in one of the extracts. Statistical analysis was not performed because the mortality rate was very low.

3.2. F1 Progeny Effect of Plants Extracts on S. granarius

The effects of some plant extracts on progeny reduction of *S. granaries* are depicted Table 2. It was observed that the more the concentration increased the higher the F1 progeny effect of plants extracts on *S. granarius*. The highest suppression rate was at the highest concentration of *M. alternifolia*. It was followed by the highest concentrations of *C. annuum* and *A. wilhelmsii*. The statistical analysis revealed that the highest concentration of all extracts except *T. vulgare* were from the same group. Additionally, 7.5% concentration of *M. alternifolia* was from the same group with the high concentration of extracts (F= 4.56; P<0.05).

Table 2. *F1 progeny effect of some plant extracts on Sitophilus granaries.*

Treatment	Concentrations (%)	F1 progeny (%)
	2.5	32.80±2.35c **
Achillea wilhelmsii L.	5	58.84±1.93c
	7.5	75.82±1.62b
	10	89.72±0.67a
	2.5	29.89±3.82d
Capsicum annuum L.	5	47.51±2.67c
	7.5	75.81±1.58b
	10	94.81±0.67a
	2.5	14.15±3.67e
Tanacetum parthenium L.	5	33.82±2.34d
	7.5	66.77±2.45c
	10	72.00±079b
	2.5	16.88±3.21d
Tanacetum vulgare L.	5	54.72±1.98c
	7.5	73.15±1.78ab
	10	80.37±0.56a
	2.5	58.29±1.89c
M. alternifolia (Gamma-T-ol)	5	76.05±1.32b
	7.5	89.98±0.46a
	10	95.47±0.24a

** Means within rows separated by the same uppercase letter are not statistically different (Duncan's multiple range test).

3.3. Repellent Effect of Different Plant Extracts

Figure 1 depicts the effects of some plant extracts on the repellent effect of *S. granarius.* According to figure 1, the highest effect was in *M. alternifolia* extract at the highest concentrations. This value was followed by *C. annuum*, *A. wilhemsii, T. vulgare* and *T. parthenium* extracts at the same concentrations respectively. The extracts' lowest repellent effect was determined at the lowest concentration. According to statistical analysis, Gamma-T-ol was in a different group from other extracts. *C. annum*, *A. wilhemsii, T. vulgare* extracts were in the same group (F= 3.27; P<0.05).

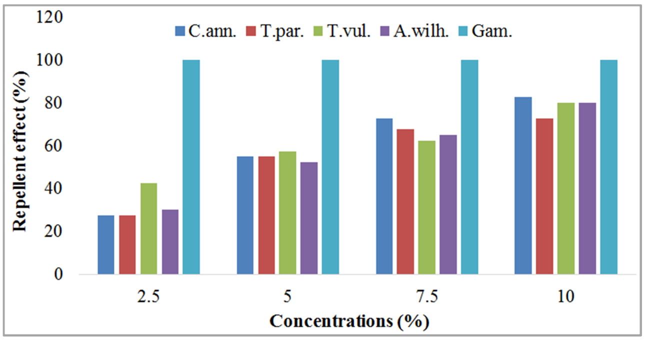

Figure 1. *Repellent effect of different plants extracts on Sitophilus granarius.*

4. Discussion

It has been suggested that plant extracts show repellent, antifeedant, ovicidal, and toxic effects toward insects [12, 6]. Several studies have shown that bioactive chemicals in plant extracts have insecticidal, repellant, and antifeedant properties against stored-product insect pests [13, 14-15]. The results our study showed that *C. annuum* extract had the highest F1 progeny effect on *S. granarius.* There are so many studies conducted on the extract of *C. annuum* effect on stored product pest. For example, Lorizzi et al. [16] carrying out the extract of *C. annuum* effect on stored product pest such as *Oryzaephilus surinamensis* L. (Col.: Silvanidae) *S. oryzae Tribolium castaneum* (Herbst.) (Col.: Tenebrionidae) maintained that the extract of *C. annuum* had repellent or attractive effects on insects and it could, and prevent or reduce the damage caused by insect pests. Previous studies reported that capsaicin had repellent effect on agricultural pests. In addition, it was reported that the extract of *C. annuum* contained capsaicin's and acyclic diterpene glycosides [17]. In a related study *C. annuum* fruit powder and leaf powder were used to control stored pests [18, 19]. However, Ashouri and Shayesteh [20] reported that the extract of *C. annuum* were not as effective as in causing complete mortality on two insects (*S.*

granarius, R. dominica) after 14 days, which corresponds with the results of our study. In addition, a great number of studies were conducted on the extracts of *C. annuum* on different agricultural pests. The highest extract concentration of *C. annum* caused the greatest mortality in *Myzus persicae* Sulzer (Hem.: Aphididae) (nymph and adult stages [21]. In another study, *C. annum* extract was found to significantly reduce the reproductive capacity of female *Tetranychus urticae* Koch (Arachnida: Tetranychidae). The same study discovered that the extract concentration of *C. annum* causes the greatest mortality in *T. urticae* larvae, nymphs, and adults [22]. Additionally, Devanad and Rani [18] reported that *C. annum* extract had 100% insecticidal effect on *T. castaneum* and *S. oryzae.* In the same study, it was suggested that the leaf extract of *C. annum* possessed antifeeding effect against *Spodoptera litura* Fab. (Lep. Noctuidae) and *Achaea janata* L. (Lep.: Erebidae).

The results of our study revealed that *A. wilhelmsii* extracts had a strong F1 progeny effect on *S. granarius.* According to Khani and Asghari [23] *A. wilhelmsii* oils had the highest insecticidal activity against *T. castaneum.* In another assay, At the highest concentrations, *A. wilhelmsii* extracts demonstrated the highest mortality in the larva dipping method. The extract of *A. wilhelmsii* at a concentration of 12 percent induced the most mortality in *T. urticae* nymph and adult stages in the leaf dipping method. At the same concentrations, the mortality of nymphs and adults was reported to be 83.81% and 80.00%, respectively [24]. Moreover, Erdogan and Yilmaz [25] who studied on the effect of plant extract on insect revealed that on Potato tuber moths [*Phthorimae operculella* Zeller (Lep.: Gelechiidae)], Using both the tuber dipping method and the larvae dipping method, *A. wilhelmsii* extract had the highest mortality at the highest concentration. Calmasur et al. [26] studying the effects of three different *Achillea* species (*Achillea biebersteinii, A. millefolium* and *A. wilhelmsii)* on *S. granarius* and *T. confusum* revealed that the *A. wilhelmsii* oil was the most effective on *T. confusum* and *S. granarius* when compared to controls. Kesdek et al. [27] discovered that *A. wilhelmsii* extract had a larvicidal effect on *Thaumetopoea pityocampa* (Denis & Schiffermuller) (Lep. Thaumetopoeidae) larvae in the second, third, and fourth in stars. The extracts of *A. wilhelmsii* and *A. biebersteinii* had the strongest insecticidal effect on *Leptinotarsa decemlineata* Say (Col. Chrysomelidae) [28]. *Achillea* species including substances such as α-pinene, α-thujone, β-caryophyllene, β-eudesmol, borneol, bornyl acetate, β-pinene β-thujone, camphor, chamazulene, 1,8-cineole, p-cymene, piperitone and terpinen-4-ol are thought to be toxic to harmful insects [29, 30].

We determined in our study that the *T. vulgare* extract have F1 progeny moderate effect on *S. granarius.* There have been a great number on studies about the insecticidal effect of this this plant extract on insects. Some of these studies were carried out on the highest mortality about different insects. For instance, Magierowicz et al. [31] stated that *T. vulgare* essential oil caused increased larval mortality as well as a decrease in the rate of pupation, emergence, and longevity of *Acrobasis advenella* (Zinck.) (Lep.: Pyralidae) moths. Furthermore, *T. parthenium* essential oil was found to be more effective against larvae, while *T. vulgare* essential oil was found to be more effective against adults of *L. decemlineata* compared to other essential oils in the study [32]. In another study, it was revealed that essential oil of *T. vulgare* caused adult and larvae mortality in *T. castaneum, T. confusum*, *T. molitor* and *O. surinamensis* [33]. The same study also was found that *T. vulgare* EO caused 100% mortality to *T. castaneum* larvae, and only 25.6% mortality to adults. Erdogan et al. [34] who studied the effects of plant extracts on insects, discovered that *T. parthenium* extract had a high mortality rate against *T. urticae*. Additionally, Erdogan and Yilmaz [25] determined that *T. parthenium* extract had the highest mortality (100%) at the highest concentration (12%) on Potato tuber moth. Additionally, *T. parthenium* extract also had the highest deterrence effect (98.29%) on *Tuta absoluta* Meyrick (Lep.: Gelechiidae) at the highest concentration (20%) [35]. *T. parthenium* contains eudesmanolides, germacranolides, and guaianolides. Parthenolide is a germacranolide [36].

M. alternifolia is a medicinal plant with different uses of its extract. In the related studies, tea tree oil was found to have antifungal, antimicrobial, anti-inflammatory, and insect repellent properties [37]. In our study, we observed that gamma-T-ol extracted from *M. alternifolia* showed the highest F1 progeny on *S. garnarius*. The findings of some studies are consistent with the findings of the treatments. For example, Abdel-Maksoud [38] reported that *M. alternifolia* oil have highly toxic effect on the larvae of *Dermestes maculatus* De Geer (Col.: Dermestidae) and a higher mortality rate than the others. Similarly, according to Liao et al. [39] *M. alternifolia* essential oil had fumigant toxicity against *S. zeamais* and was the most effective compound for fumigant toxicity. It was also found that terpinen-4-ol is the most effective compound showing fumigant toxicity to *S. zeamais*. In addition, Kasap et al. [40] investigated the gamma-T-ol extracted from *M. alternifolia*, concluding that it had a mortality rate of 48.9% in *Aphis gossypii* Glover (Hem.: Aphididae). The same study also reported that the mortality rate of *T. urticae* in gamma-T-ol was 93.3%. Moreover, Bayindir et al. [41] described that gamma-T-ol has an insecticidal effect on the third or fourth stage of *T. absoluta*. In another study conducted under laboratory conditions, Erdogan [35] revealed that highest deterrent effect on *T. absoluta* was due gamma-T-ol.

5. Conclusion

It was concluded that *A. wilhelmsii, C. annuum, T. vulgare* and *T. parthenium* extracts had the strongest F1 progeny and repellent effect and repellent effect on *S. granarius.* In this regard, these plants had an organic insecticide property to control stored crop pests as the extracts of these plants are less harmful to the environment. However, in order to use these plant extracts as insecticides, it is necessary to carry out detailed studies on the formulation of the extracts to make them available commercially.

Competing Interests

There is no conflict between the authors.

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