

Fumigant activity of some essential oil against wheat weevil, *Sitophilus granarius* L. (coleoptera: curculionidae)

Abstract

The most important of the stored products pests is *Sitophilus granarius* L. (Coleoptera: Curculionidae). Chemical insecticides and fumigants are widely used to control *S. granarius*. In this study, fumigant effect of some essential oils was investigated against *S. granarius*. For this purpose, different concentrations essential oil of *Mentha piperita* L. (Lamiaceae), *Citrus cienensis* (L.), (Rutaceae) and *Nigella sativa* L. (Ranunculaceae) were used. Neem AzalT/s was used as a standard product. Glass jars were used for fumigant experiment. Each glass jar contained 50grams of wheat. Sponge pieces of 2x3cm size were cut and glued to the lower part of the jar lid. Then concentrations of 5%, 7% and 10% of each essential oil were applied on the sponge by an injector. For each solution 0.1ml was used. Twenty adults (1-3days old) were left in each of the jars. Afterwards the lids of the jars were tightly sealed and the jars were placed in the dark. The insects had no contact with the impregnated sponge. Control insects were kept under the same conditions without any application. Counts were carried out after 24hours. Neem Azal^{TS} was used by distilling with pure water. The results of the study showed that all the applied essential oils caused 100% death with the highest fumigant effect. In Neem Azal^{TS} trial similar results were obtained as with essential oils.

Keywords: wheat weevil, essential oils, fumigant effect

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Introduction

Products grown by mankind are stored for short or long periods according to food, feed, marketing and objectives and post-harvest seed production depending on the needs of the region. During this period, significant losses occur in terms of quality and quantity due to pests, disease factors, birds and rodents and adverse environmental conditions. To explain this numerically; the rate of loss in stored grain, legume, oilseeds and foodstuffs made from them during the storage period is accepted as 10% worldwide. These losses reach up to 50% depending on the regions and characteristics. It is reported that 5% of this 10% loss in stored products is caused by insects.¹ Product weight loss occurs as a result of pests feeding with stored products. In addition, the impurities and secretions formed as a result of their feeding create negative effects on the quality and quantity of the product. Moreover, the losses caused by the coexistence of more than one pest increase even more. The most important of the stored products pests is *Sitophilus granarius* L. (Coleoptera: Curculionidae). Feeding of *S. granarius* can also lead the grains to become vulnerable to the attack by other pests, by undermining their protection barrier which are otherwise are impenetrable to them. Females generally lay around 150 to 300eggs. Their life cycle is completed in six weeks in warm weather and can be prolonged to 17-21 weeks in cold weather. The pest can cause up to 5% of losses in stored crops if not controlled. Feeding of *S.garanarius* on grains significantly reduces their germination capacity from 93% to 7%. In addition, *S.garanarius* reduces the quality and quantity of the product.²

In order to reduce this damage, chemical insecticides and fumigants are widely used to control stored product pests. Stored product insects, which are stored dry and adapted to plant products that are important in human nutrition, have an important place in the insect kingdom. These insects spread wherever the climatic conditions are favorable for them. The increase in international trade and the

facilitation of intercontinental roundtrips have accelerated this spread even more. It is precisely known that many insect species harmful to stored products are of tropical or semi-tropical origin and were spread to other parts of the world through trade. Therefore, the fumigation process is crucial. Widely used insecticides to prevent the damage of stored product pests cause resistance to these chemicals³ Researchers have focused on the development of alternative control methods against pests in stored products due to resistance development of pests and insecticide residue in products. In this context, plant-based insecticide developments have been accelerated considerably.⁴⁻⁶ Plant extracts and essential oils have some advantages such as low toxicity in mammals, no residue in the products and high toxicity to storage pests.^{7,8} This study was carried out to determine fumigant activity of some plant essential oils on *S. granarius*.

Material and methods

Mass rearing of test insects

S. granarius culture was provided from Plant Protection Central Research Institute Ankara. For the stock culture of *S. granarius* 1/3 wheat was put into 2lt glass jars. Wheat's used in the study were kept at -20°C for one week just before being used in the study in order to make them clean from any harmful infection. Adult individuals obtained from the stock culture were transferred to these jars and allowed to lay eggs for 48hours. At the end of this period, all adults were removed from the jars and only eggs and contaminated material remained. Adults were incubated for 45 days at 27±2°C, 50± 10% relative humidity and dark conditions were used in the trials.

Essential oil

The essential oils (mint, orange peel, black seed, sesame and basil) were purchased from the local market. Different volumes of essential oils were dissolved in acetone fat test solution preparation (10, 20 and

30ml dissolved in 1ml acetone).⁹Neem Azal T/S was used as positive control. Neem Azal^{TS} was purchased from the related company. It contains 1% azadirachtin and was obtained from *A. indica*.

Fumigant effect of different plant extract

Glass jars (1liter) were used for fumigant experiment. In each glass jar 50grams of wheat were put. Sponge pieces of 2x3cm size were cut and glued to the lower part of the jar lid. Then concentrations of 5%, 7% and 10% of each essential oil were applied on the sponge by an injector. For each solution 0.1 ml was used. Twenty adults (1-3days old) were left in each of the jars. After that the lids of the jars were tightly sealed and the jars were placed in the dark. The insects had no direct contact with the impregnated sponge. Control insects were kept under the same conditions without any application. Counts were carried out after 24 hours. Four replicates were performed for each concentration and the untreated control. The experiment was set up according to the random plots and the trial pattern. These jars were placed in climatic cabin at 27±2°C, and 50 ± 10% humidity.

Neem Azal^{TS} was used by distilling with pure water.⁹

Data analysis

The effect was calculated according to Abbott.¹⁰ Variance analysis were applied to the obtained results and the mean values were compared by Duncan's test (P=0.05) calculated by the program SPSS 13.6. Mortality rate was calculated as follows:

Mortality=the number of died *S. granaries* adults after treatment / the number of *S. granarius* adults before treatment • 100.

Results and discussion

Fumigant effect of different plant extract

The data obtained as a result of the fumigant experiments are given in Table 2. According the Table 2, the highest fumigant effect was determined in the highest concentrations of different essential oils. Also, the lowest fumigant effect was determined in the first concentration of different essential oils. Similar results were obtained in the mortality rate. According to the statistical analysis, the second and third concentrations of all different plant essential oils were in the same group. First concentration of *C. cienensis*, *N. sativa* and Neem Azal T/S formed different groups. The first concentration of *M. piperita* was in a different group (F= 43.65) (P<0.05). All essential oils tested showed strong fumigant effect against *S. granarius*. In particular, 100% mortality was obtained at the second and third concentrations of all oils. In the first concentration, low mortality was obtained. The results are in tone with the findings of Cam et al.¹¹ who studied that the essential oil of different *Mentha* species (*M. spicata*, *M. villosa-nervata*, *M. piperita*) showed fumigant toxicity against granary weevil. In addition, it was revealed that the essential oils of mint species (*Mentha* spp.) had adulticidal, larvicidal, and growth and reproduction inhibitory effects, as well as repellent activity against various stored product pests and vectors.^{5,12,12} Also, Kimbaris et al.¹⁴ demonstrated that essential oil of *M. piperita* has strong fumigant toxicity against greenhouse pests such as *Trialeurodes vaporariorum*, *Tetranychus urticae* and several aphid species. In another study the extract of *M. piperita* was found to cause 63% mortality on *Sitophilus oryzae* L. and 44.33% on *Tribolium castaneum*.¹⁵ In another study, Karamaouna et al.¹⁶ reported that the essential oils of peppermint had more toxic to *Planococcus ficus* (Signoret) (Hemiptera: Pseudococcidae). According to results of GC/MS major components were found to be camphane (14.01%), menthone (13.89%), menthol (12.37%) β-pinene (7.62%), pulegone (6.41%), β-cubebene (4.95%), α-pinene (4.743%),

γ-terpinene (4.08%), delta-carane (3.81%), and piperiton (3.04%).¹⁷ Species belonging to the *Mentha* genus in particular monoterpenes have previously shown high fumigant activity against storage pest species.^{5,18} Abdelgaleil et al.¹⁹ determined that the main components of vegetable essential oils showed contact and fumigant effects on *S. oryzae* and *T. castaneum*. Oodeyemei et al.²⁰ revealed that essential oils have high repellent activity at all concentrations tested. For most concentrations, repellency values of as high as 100% were recorded making *Mentha longifolia* a potential agent to use as protection of stored agricultural products against *S. zeamais*.

Table 1 Names and families of the plants used in the experiment

| Plants name | Family |
|------------------------------|---------------|
| <i>Mentha piperita</i> L. | Lamiaceae |
| <i>Citrus cienensis</i> (L.) | Rutaceae |
| <i>Nigella sativa</i> L. | Ranunculaceae |

Table 2 Fumigant effect of some plants essential oil on *Sitophilus granarius* L

| Treatment | Conc. (%) | After 24 h exposure | |
|------------------------------|-----------|---------------------|----------------|
| | | Adult mortality (%) | Effect (%) |
| <i>Mentha piperita</i> L. | 5 | 42.50 | 43.09±0.90 c* |
| | 7 | 100.00 | 100.00±0.00 a |
| | 10 | 100.00 | 100.00±0.00 a |
| <i>Citrus cienensis</i> (L.) | 5 | 51.25 | 50.65± 1.45 b |
| | 7 | 100.00 | 100.00±0.00 a |
| | 10 | 100.00 | 100.00± 0.00a |
| <i>Nigella sativa</i> L. | 5 | 63.75 | 63.35± 0.60 b |
| | 7 | 100.00 | 100.00±0.00 a |
| | 10 | 100.00 | 100.00± 0.00 a |
| Neem Azal T/S | 0.1 | 86.25 | 86.05±1.00 a |
| | 0.2 | 100.00 | 100.00±0.00 a |
| | 0.3 | 100.00 | 100.00± 0.00a |
| Control | | 0.012 | |

*Within columns, means ± SE followed by the same letter are not significantly different (DUNCAN's multiple F-test)

Our results showed that essential oil of *C. cienensis* caused the highest mortality at rate highest concentrations (7% and 10%). The present findings are similar to the reports of Zewde & Jembere,²¹ where they found the essential oil of orange peel was toxic to *Zabrotes subfasciatus* (Coleoptera: Bruchidae). It is stated in the same study that the essential oil of orange peel has fumigant and repellent effect on *Z. subfasciatus*. Also, this essential oil had the highest mortality and protectant effect on *Z. subfasciatus*. Tripathi et al.²² reported that essential oil from orange peels is known to have toxic, feeding deterrent, and cause poor development effects on lesser grain borer, *Rhyzoperta domonica* (F.), rice weevils, *Sitophilus oryzae* (L.) and red floor beetle, *Tribolium castaneum* (Herbst). Additionally, the peel oil showed toxic effect to *Culex pipiens*²³ and cow pea weevils, *Callosobruchus maculatus* (F.).²⁴ Furthermore, the peel oil has fumigant action toward fleas²⁵ and house hold insects *Blattella germanica* (L.) and *Musca domestica* (L.) and stored product *Sitophilus*.²⁶ As it is seen in our study results, the fumigant effect has increased with the

increasement in concentrations. In all treatments, higher mortality rate was observed at high concentrations compared to low concentrations. The present results agree with previous research published by Tripathi et al.²² who found that the orange peel oil has 13 times higher fumigant toxicity than that of methyl bromide. Keita et al.²⁷ described that the mode of the action of fumigant toxicity of essential oil against insects might be due to the inhibition of acetylcholinesterase.

According to the results obtained in our study, the highest concentrations of *N. sativa* showed 100% mortality on *S. granarius*. The similar results were also obtained by Bekinwari & Roate²⁸ who reported that seed powder of *N. sativa* had insecticidal effect on *Dermestes maculatus* De Geer (Coleoptera: Dermestidae). Rasool et al. (2018)²⁹ reported that different concentrations of *N. sativa* had insecticidal effect against *Rhyzopertha dominica* F. (Col. Bostrychidae). *N. sativa* composed of styrol, thymoquinone and p-cymene, were effective on mosquito and that these substances can be used to control mosquitoes in the future.³⁰ Concentration of 25 mg/ml black cumin in empty space induced nearly 100% mortality. On the other hand, fumigation in space filled up with 50% wheat showed only 50% to 60% killing efficiency against granary weevil. In space 95% filled up with wheat mortality was found to be only 34%³¹ In another study, Ghoneim et al.³² demonstrated that seed extracts of *N. sativa* showed inhibitory effects on the oviposition efficiency and other parameters of reproductive potential of the desert locust *Schistocerca gregaria* (Orthoptera: Acrididae). In the same study, it was revealed that the majority of *N. sativa* extracts caused several morphological and intracellular disorders in some hemocytes.

Moreover, it was studied that *N. sativa* seed extracts affected negatively the vitelline envelope formation or the function of follicle cells or caused an adverse effect on the morphogenesis of ovipositor of adult females, ovarian growth and/or synthesis and metabolism of proteinaceous constituents during the oogenesis on *S. gregaria*.^{33,34} *N. sativa* seeds have medicinal properties such as bronchodilatory, hypotensive, antibacterial, antifungal, analgesic, anti-inflammatory and immunopotentiating.³⁵ *N. sativa* had acaricidal effect and caused 100% mortality at concentration 20% in shortest time (12 h) on *Rhipicephalus annulatus* (Acari: Ixodidae).³⁶ In addition, Zeeshan and Mazhar³⁷ revealed that essential oil of *N. sativa* showed insecticidal effect as high as 44.44% at concentration of 10% after 1 week on *R. dominica*. The essential oil of *N. sativa* seeds contains compounds that repellent *Anopheles gambiae* Giles (Diptera: Culicidae) and therefore can be used to control spread of malaria through prevention of the insect bites. Similarly, it was demonstrated that essential oil of *N. sativa* showed the highest fumigation and repellent effect on *Tribolium castaneum* Herbst (Coleoptera: Tenebrionidae).⁹ In the same study, it was reported that essential oil of *N. sativa* has strong repellent effect on *T. castaneum*. The essential oil of seed of *N. sativa* had insecticidal and insect repellent activities.³⁸⁻⁴⁰

There are also many studies on azadirachtin obtained from *Azadirachta indica* A. Juss (Meliaceae). For example, Kavallieratos et al.⁴¹ reported that azadirachtin-based insecticides, NeemAzal-T/S had the highest mortality on *T. confusum*, *S. oryzae*. Tofel et al.⁴² demonstrated that *A. indica* oil showed the highest mortality on *C. maculatus* and *Sitophilus zeamais*. Azadirachtin acts as an insect growth regulator. This might have contributed in progeny production suppression.⁴² Athanassiou et al.⁴⁴ reported that Azadirachtin A of NeemAzal-T/S caused 100% mortality to *Sitophilus oryzae* (L.) (Coleoptera: Curculionidae). Neem products are rich in alkaloids (azadirachtin) and other molecules like nimbine, salanine and melandriol, which reduce feeding, through chemoreception (primary anti-feedant) after ingestion, These molecules play role in blocking

the input from receptors that normally respond to phagostimulants, or from stimulation of specific deterrent cells or both.⁴⁵

Conclusion

Our findings revealed that the essential oil of *M. piperita*, *C. cienensis*, *N. sativa* and commercial product Neem Azal T/S had strong fumigant effect on *S. granarius*. Further studies are needed to be conducted to use these oils to control *S. granarius*.

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Conflicts of interest

The author declares that there is no conflict of interest.

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