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Comparative activity of four selected plant oils against *Sitophilus oryzae* and *Tribolium castaneum*

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ABSTRACT
The rice weevil, *Sitophilus oryzae* (L.) (Curculionidae) (Coleoptera) and the red flour beetle, *Tribolium castaneum* (Herbst) (Tenebrionidae) (Coleoptera) are the most important insect pests that attack wheat grain during storage. In current study, the efficiency of nutmeg oil, watercress, cinnamon and parsley was evaluated compared to the recommended malathion pesticide through fumigation method and repellent, as well as studying the effect on the biology of *S. oryzae* and *T. castaneum*, in addition to study the effect on weight loss was also investigated. Results showed superiority of cinnamon oil over other oils against *T. castaneum* and parsley oil on *S. oryzae*. In general, these oils reduced the number of offspring of *T. castaneum*, with values ranging from 7.33 to 100, as well as the offspring of *S. oryzae*, from 62.89 to 100. In repellent activity, data obtained demonstrated surprising action against both *S. oryzae* and *T. castaneum* resulting**.**

1. INTRODUCTION

Stored grains are the end products of the agricultural activities of some crops. The rice weevil, *S. oryzae* (L.) is a serious pest of stored grains such as rice, maize, wheat and sorghum **(Rossetto, 1969; Gvodzenac *et al.*, 2020).** It is a destructive species that is widely spread in tropical, sub-tropical and worm zones **(Antunes *et al.*,2016; Mansoor-ul-Hasan *et al.*, 2017; Astuti, 2019).** *T. castaneum* is the most common and prevalent pest species of stored grain **(Zettler and Cuperus, 1990)**. The uses of synthetic pesticides on food materials possess many problems **(Golob and Webley, 1980; Subramanyam, 1995; Tarwotjo *et al.*, 2014).** Control methods other than chemical ones are important as they do not leave chemical residues and cause no resistance in insects **(Padin *et al.*, 2002)** plant oils integrated management of stored product pests relies on data to direct the management decision **(Barak *et al*., 1990; Abo Arab and El Tawelah, 2022)**. (**Campolo *et al.*, 2018**). In the same time botanical insecticides containing different compounds derived from plants secondary metabolism have been tested in order to control stored grain pests with promising results as an alternative to chemical insecticides (**Lale, 2002; Koul *et al.*, 2008; Isman, 2006**). The practice of using botanical insecticides in agriculture dates back at least two millennia in ancient China, Egypt, Greece and India (**Isman and Machial, 2006**). Also, botanical insecticides act on the physiology and behavior of insects and can be classified as repellent (**Abo-Arab et *al.*, 2014; Elbrense *et al*., 2021; Guruprasad and Pasha 2014; rahdri and Hamzei 2017**), Also reducing progeny F_1 (**Mahama *et al.*, 2018**) also they reduced the weight loss (**Wazid *et al.*, 2020**).

2. Materials and Methods

A. Insects used

1) *Rice weevil, Sitophilus oryzae (L.) (Curculionidae) (Coleoptera):*

Colonies of S. oryzae were obtained from Plant Protection Research Institute, Agriculture Research Center, Sakha, Kafr El-Sheikh, Egypt. Adult S. oryzae reared on whole wheat grains under the laboratory conditions of 27 ±2°C, 65 – 70% R.H. in large aquarium container. The subcultures and the tests were carried out under the same conditions. Before rearing process, the wheat grains were sterilized by using oven at 50˚C for 20 to 30 minutes because it considers a normal temperature to sterile the wheat grains.

2) *The red flour beetle, Tribolium castaneum (Herbst) (Tenebrionidae) (Coleoptera):*

A laboratory-susceptible strain of *T. castaneum* has been continuously reared in the laboratory of Plant Protection Research Institute. The strain was maintained as described on whole crush wheat grain (28 ± 1°C, 70 ± 5 R.H.). For the two insects The newly emerging adults (7-15 days) were collected by sieving the diets. Adult insects, used for all bioassays were of mixed sexes.

B. Essential oils used

Four natural essential oils; Nutmeg (*Myristica fragrans*.), cinnamon (*Cinnamomum zeylanicum* Blume), watercress (*Eruca vesicaria ssp. Sativa*) and parsley (*Petroselinum crispum*) were used. These oils, were procured from El Captain Company (CAP PHARM) For Extract Natural Oils And Cosmetics.

C. Chemical Insecticide

Malathion (EC 57%). Series of concentration were prepared ranged between 0.04 ,0.06,0.08, and 0.1%w/v.

Bioassay methods.

1. Fumigant toxicity

The fumigant toxicity of nutmeg, cinnamon, watercress and parsley oils against the two tested insects was tested as previously described by **Wang *et al.* (2006)**. The concentrations of the oils were 0.1, 0.15, 0.3 and 0.6w/v% prepared in acetone on filter papers Whatman No.1, diameter pieces of 5cm in each jars (170

cm^3). One ml of each concentration was distributed on filter paper. After complete dryness in the room temperature, each filter paper was adhered under surface of the jar cap of 170 cm^3 which contain 10 gm wheat grains or crushed wheat grains. Ten unsexed adults of *T. castaneum* or *S. oryzae* were put in each jar. Three replicates for each treatment and control were done. The control was treated with acetone only. The treatments were kept in an incubator set 28 1°C and 70±5 R.H. Mortality was recorded after1, 3- and 7-days post-treatment of exposure, for *T. castaneum* and *S. oryzae*. All results were corrected by **Abbott's formula (1925**) as follows:

% Correct mortality = (% mortality of treatment - % mortality of control) / (100-% mortality of control) X 100

LC_{50}, confidence limits and slope values were calculated for all tested materials**.**

Confidence limits and slope value were calculated for all tested materials. Mortality counts were recorded after1, 3 and 7days and the adults were sieved out and discarded after twenty days for *S. oryzae* and *T. castaneum*. The emerged adults were counted until 60 days after treatment of the newly adult emergence was used to calculate the reduction percentages in *S. oryzae* and *T. castaneum* progeny from the use of tested materials (plant oils) as well as malathion compared to the control as shown in the following equation:

$$\text{Reduction\%} = \frac{\text{No.of emerged adults in control} - \text{No.of emerged adults in treated}}{\text{No.of emerged adults in control}} \times 100.$$

Weight loss in wheat grains and crushed wheat grains

The weight loss of wheat grains and crushed wheat grains due to infestation with *S. oryzae* and *T. castaneum* was determined after three months post-treatment by sieving the insects from the wheat grains and crushed wheat grains. Three replicates were done for each treatment and control. The weight loss was calculated as dry weight loss according to equation of **Harris and Lindblad (1978).**

$$\%\text{Loss} = \frac{\text{IWg} - \text{dwg after 3 months}}{\text{IWg}} \times 100$$

IWg = Initial dry weight grains.

dwg = dry weight grains after three months.

2.Repellent assay

According to **(McDonald *et al.*, 1970)** Petri dishes (9 cm in diameter) were used to confine insects during the experiment. Filter paper with a 9 cm diameter was cut two halves and ½ ml of each concentration was applied separately to one half of the filter paper as uniformly as possible with a micropipette. The other half (control) was treated with ½ ml of acetone. Both of the treated half and the control half were then air-dried to evaporate completely. A full disc was carefully remade by attaching the tested half to the control half with tape. Care was taken so that the attachment did not prevent free movement of insects from the one half to another, but the distance between the filter paper halves remained sufficient to prevent seepage of test sample from one half to another. Ten insects were released in the center of each filter paper disc and a cover was placed over the Petri dish. Three replicates were used. Counts of the insects present on each strip were made after 2 h, 4 h, 6 h, and 12 h. For all insects, concentration of 0.1, 0.15,0.3 and 0.6% of essential oils and 0.04,0.06.0.08 and 0.1% of malathion were used. The repellency percentage can be calculated by using the following formula of (**Talukder and Howse, 1995**):

repellency % =2×(C-50).

3. RESULTS AND DISCUSSION

Essential oils considered safer and more eco-friendly than synthetic pesticides and insecticides; additionally, essential oils are with a lower toxicity for mammalians **(Mossa, A. T. H., 2016).**

Fumigant activity of tested oils.

- **On S. oryzae:**

Table 1: Fumigant activity of tested oils against *S. oryzae* after 24 h of treatment.

Plant Oil	LC_{50} w/v%	95%confidence limits for LC50		Slope Value	Toxicity Index
		Lower	Upper		
Nutmeg	1.92	1.14	2.95	1.84	20.8
Cinnamon	0.68	0.53	0.93	1.80	58.8
Parsley	0.40	0.35	0.49	2.02	100
Watercress	0.48	0.37	0.68	1.41	83.3

Fumigant activity is one of the most important bioassay which elucidate efficiency of a compound against *S. oryzae* adults. In this experiment results presented in table (1) showed that parsley was the strongest oil among the tested oils with LC_{50} value of 0.40 followed by watercress, cinnamon and nutmeg with LC_{50} value of 0.48, 0.68 and 1.92 % w/v, respectively after 24 h. There was no significant difference between cinnamon, watercress and parsley, where there is an overlap between their confidence limits.

Table 2: Fumigant activity of tested oils against *S. oryzae* after 72h of treatment.

Plant Oil	LC_{50} w/v%	95%confidence limits for LC50		Slope Value	Toxicity Index
		Lower	Upper		
Nutmeg	0.57	0.43	0.89	1.34	31.5
Cinnamon	0.23	0.17	0.35	2.52	78.2
Parsley	0.18	0.16	0.21	2.59	100
Watercress	0.18	0.08	0.34	2.23	100

Similarly, the results after 72 h of exposure had the same trend of that of 24 h where the tested oils may divide to two groups based on their LC_{50} and confidence limits. The first, includes watercress, parsley and cinnamon oils while the second groups contains nutmeg which has a weak fumigation activity against *S.oryzae*.

Table 3: Fumigant activity of tested oils against *S.oryzae* after 7days of treatment.

Plant Oil	LC_{50} w/v%	95%confidence limits for LC50		Slope Value	Toxicity Index
		Lower	Upper		
Nutmeg	0.10	0.06	0.13	3.01	100
Cinnamon	0.12	0.10	0.17	2.92	83.3
Parsley	0.10	0.08	0.11	3.30	100
Watercress	0.12	0.07	0.17	2.76	83.3

Results explained here in table (3) stated that the fumigant activity increased when the time of exposure increased. For example, LC_{50} values of the tested oils decreased from 1.92, 0.68, 0.40 and 0.48 after 24 h to 0.10, 0.12, 0.10 and 0.12 % W/V for nutmeg, cinnamon, parsley and watercress after 72 h, respectively. Also results illustrated that the all oils have the same activity where their LC_{50} of the four oils overlapped with each other in terms of confidence limits.

In agreement with our study many essential oils and their constituents may have potential as alternative compounds to currently used compounds as fumigants **(Huang *et al.*,2000; Tunc *et al*., 2000; Lee *et al*., 2001; Chayengia *et al.*, 2010)**. Worthily, the essential oil of plants is less harmful to human and environment **(Yegen *et al*., 1998)** in the same insects. Other results **Ebadollahi A, Ashouri S. (2011**) discovered that essential oils extracted from *Azilia eryngioides* have an effect on *S. oryzae* and *T. castaneum* as fumigant. Additionally **(Madhusudhanamurthy *et al.*,2013)** reported that the essential oils, especially basil and clove, can be used as an effective control agent for stored grain pests by fumigation. Active compounds in botanical EOs have some limitations such as low bioavailability, high volatility, and photo degradation that restrict their use on several occasions. Previous reports are available on the fumigation activity related to various concentrations of plant EOs against pest insects *Sitophilus zeamais* **(Li *et al.*,2013)** while the fumigant effect of investigated EOs in *S. zeamais* was enhanced by increasing the dose or exposure time of EOs, **(Abdelgaleil *et al.*,2016) (Tak *et al.*,2017).** Another study on cinnamon oil showed the greatest contact and fumigant toxicity amongst the tested essential oils. Cinnamon oil and trans-cinnamaldehyde, the most abundant constituent of the oil, are known to have insecticidal activity against several other coleopteran stored product insects including the rice weevil, *S. oryzae* L., Chinese bruchid, *Callosobruchus chinensis* L. **Kim *et al*. (2003). Abdelgaleil *et al*. (2016)** tested Artemisia judaica, *Callistemon viminals, Cupressus sempervirens,* and *Origanum vulgare against S. oryzae.* In the fumigation assay, the oils of *O. vulgare* (LC50 = 1.64 mg/L air), *Citrus lemon* (LC50 = 9.89 mg/L air), *Callistemon viminals* (LC50 = 16.17 mg/L air), *C. sempervirens* (LC50 = 17.16 mg/L air), and *C. sinensis* (LC50 = 19.65 mg/L air) showed high toxicity to S. oryzae. In the same field **Nattudurai *et al*. (2017)** tested fumigant activity against *C. maculatus* and *S. oryzae*. The development stage of *C. maculatus* fecundity, adult emergence and also ovicidal activities were studied by the treatment of *Atalantia monophylla* oil. The oil exhibited considerable fumigation toxicity against *C. maculatus* and *S. oryzae*. Similarly **(Nattudurai *et al.*,2014)** evaluated the fumigant toxicity of *Toddalia asiatica* essential oil on *S. oryzae, C. maculatus* and

*T. castaneum***.** Results showed a strong fumigation toxicity. **HalitGÖKÇE *et al*. (2012)** studied that the essential oil of different Mentha species (*M. spicata, M. villosonervata, M. piperita*) which showed fumigant toxicity against granary weevil. In addition to 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 **(Wijayanti *et al.*,2019)** In another study **(Karakas, M., and Bolukbasi, E., 2017)** in space 95% filled up with wheat mortality was found to be only 34%. Also, essential oils toxicities are used as fumigants from Iranian Moraceae species **(Lee *et al.*, 2004). (Kim and Lee, 2013)** tested basil and orange oils contact activity against *S. zeamais* and *T. castaneum*. They found that strong effect on the tested insects. On this basis, Lamiaceae were the most effective plant family. For instance, EOs from *Origanum vulgare*, *Salvia fruticosa*, *Salvia officinalis*, *Salvia pomifera*, *Thymbra capitata*, and *Thymus persicus* showed high fumigation toxicity toward *S. oryzae*, with LC_{50} values ranging between 1.5 and 9 μL/L (**Abdelgaleil *et al.*,2016), (Koutsaviti *et al.*,2018), (Saroukolai *et al.*,.2010).** Another study **(Sriti Eljazi *et al.*,2017)** showed the possibility of using coriander essential oil in controlling stored grain insect. **Binseena *et al*. (2018)** studied the Effect of lemongrass on the mortality of rice weevil, under laboratory conditions. they found that lemongrass oil had moderate effectiveness against the studied stored grain insect. Also, **Hamza and Hamza (2018)** revealed that clove oil alone showed high efficiency to *R. dominica* concerning mortality, the progeny of the adults, and weight loss of wheat grain. **Soe *et al.* (2020)** concluded that clove oil can be used as a safe alternative to the use of pesticides in integrated stored grain pest management programs. **Erdogan, P., and Mustafa, Z. (2021)** neem AzalT/s was used as a standard product against *Sitophilus granarius* L. (coleoptera: curculionidae). The results of the study showed that all the applied essential oils caused 100% death with the highest fumigant effect. In Neem AzalTS trial similar results were obtained as with essential oils.

- **On *T.castaneum*:**

Table 4: Fumigant activity of tested oils against *T. castaneum* after 24 h of treatment.

Plant Oil	LC50 w/v%	95%confidence limits for LC50		Slope Value	Toxicity Index
		Lower	Upper		
Nutmeg	2.73	1.37	3.27	1.26	39
Cinnamon	1.10	0.77	1.96	1.79	94.5
Parsley	1.04	0.75	1.77	1.90	100
Watercress	2.09	1.17	3.83	1.51	77

Results presented in table (4) obviously clear that nutmeg oil continuously has the weak effect on both *S. oryzae* or *T.castaneum* adults, parsley oil had the most fumigant effectuation against *T.castaneum* followed by cinnamon and watercress with LC_{50} values of 1.04, 1.10 and 2.09 % w/v respectively . Oils in table (4) may be divided into two groups according to their LC_{50} and confidence limits, the first include the strongest oil parsley and cinnamon and the other group contains least effective oils, watercress and nutmeg.

Table 5: Fumigation activity of tested oils against *T. castaneum* after 72 h of treatment.

Plant Oil	LC_{50} w/v%	95%confidence limits for LC50		Slope Value	Toxicity Index
		Lower	Upper		
Nutmeg	0.74	0.49	1.48	1.04	24.3
Cinnamon	0.25	0.20	0.34	1.73	72
Parsley	0.18	0.16	0.21	0.61	100
Watercress	0.52	0.39	1.76	1.67	34.6

Results involved in table (5) illustrated that cinnamon had the distinct activity compared the other oils follow it parsley, watercress and nutmeg. However, parsley and cinnamon occupy the same first position among the tested oils while watercress and nutmeg have the same least effect according to the confidence limits of the two groups.

Table 6: Fumigation activity of tested oils against *T. castaneum* after 7days h of treatment

Plant Oil	LC_{50} w/v%	95%confidence limits for LC50		Slope Value	Toxicity Index
		Lower	Upper		
Nutmeg	1.56	0.99	4.27	1.43	30.7
Cinnamon	0.48	0.39	0.62	1.85	100
Parsley	0.71	0.56	0.99	2.04	67.6
Watercress	1.31	0.84	2.90	1.41	36.6

Results in table (6) showed that the period of exposure was the main factor regarding the action of oil where the activity of fumigation increased with the increasing of the exposure. For example, LC_{50} decreases from 2.73, 1.10, 1.04 and 2.09 % w/v after 24 h to 0.74, 0.25, 0.18 and 0.52 after 7 days for nutmeg, cinnamon, parsley and watercress, respectively, knowing the parsley was the strongest oil while nutmeg was the least one.

Also, the results clarified that *T. castaneum* beetle was more tolerant than *S. oryzae* weevil.

This variation between the two insects probably depend on the type of species, feeding habit and picked amount of oil according to the exposure surface area of both insects.

Plant-derived natural are known to have relatively low mammalian toxicity, and they tend to be rapidly degraded in the environment, making them potential alternatives to conventional fumigants

(Rajendran and Sriranjini, 2008). Furthermore, investigating the fumigant toxicity of EOs extracted from different plant parts has demonstrated that their toxicity may be deeply altered. As an example, the EOs from *Cinnamomum camphora* (Lauraceae) and *Platycladus orientalis* (Cupressaceae) fruits presented an insecticidal activity almost close to zero, compared with that recorded for EOs extracted from leaves and barks in the same plants **(Guo *et al*., 2016; Hashemi and Safavi, 2012)**. Hence, the volatile essential oils of both the variants of *C. verum* Presl. can be used safely as fumigants **(Kalita *et al.*, 2014)**.

The plant oils showed adult mortality when tested for fumigant toxicity. The fumigant toxicity effects of plant essential oils have been widely reported against pests of stored products (**Chaubey, 2011; Suthisut *et al.*, 2011).** Overall, exposure to residual *Kaffir lime* peel achieved the highest mortality or fumigants to control stored products insects (**Pangnakorn and Chuenchooklin, 2018)**. Another study **(Khalil *et al.*, 2022**) studied evaluation the fumigant effect of *Ocimum basilicum* and *Jasminum grandiflorum* essential oils against *R. dominica* and *T. castaneum*.

They found that *R. dominica* was considerably more susceptible than *T. castaneum* in fumigant experiment. Similarly, **Rajendran and Sriranjini, (2008**) studied the fumigant toxicity of essential oils against *T. castaneum* the oils had significant fumigant toxicity. Geranium oil tested as a fumigant against *R. dominica*, mortality was 100%, toxicity bioassays showed that *R. dominica* is more sensitive towards these EO than *T. castaneum*, *T. castaneum* was more tolerant **(Ncibi *et al.*,2019)**.

In the same field **(Abouelatta *et al.*,2020**) studied the chemical composition of geranium essential oils and studied the fumigant and repellent and contact toxicity of geranium essential oils against *R. dominica* and found that all tested essential oils had fumigant and repellent effect against *R. dominica*. Mode of action for the essential oils against insects may be due to inhibition of acetyl-cholinesterase (AchE) (**Ryan and Byrene, 1988**) determined five monoterpenes which inhibited AchE activity. The two commercialized basil and orange oils showed stored fumigant activity against *S. zeamais* and *T. castaneum* **(Kim and Lee, 2013)**.

Fumigant activity on % reduction and %weight loss

Effect on % reduction

Table 7: Fumigant activity of oils on % reduction and %weight loss arising of *S. oryzae*

Plant Oil	Conc. w/v	Mean of emerged adult	% reduction	Weight loss
Nutmeg	0.1	74±2.0abc	7.5	1.09±0.01h
	0.15	68.6±2.0abc	14.25	0.9±0.1gh
	0.3	57.3±0.66de	28.37	0.8±0.08fg
	0.6	24.6±3.9fg	69.25	4.9±0.02 def
Cinnamon	0.1	88±0.57a	10	1.04±0.12h
	0.15	76.3±5.9abc	5	3.9±0.00bcde
	0.3	61.6±3.5cd	26	4.0±0.10cde
	0.6	25.3±5.8fg	68.37	1.8±0.02abc
Watercress	0.1	24±3.0g	70	6.2±0.07efg
	0.15	20±2.5g	75	6.1±0.04efg
	0.3	13.3±20gh	83.37	5.9±0.09ef
	0.6	0.0±0h	100	4.1±0.06cdef
Parsley	0.1	71±6.4abcd	11.25	2.7±0.02abcd
	0.15	42.6±8.2ef	46.75	0.9±0.03ab
	0.3	0.0±0h	100	0.1±0.00a
	0.6	0.0±0h	100	0±0.00a
Control	Control	80±2.7ab	0	8.3±0.06i

Results obtained in table (7) manifested that all the different concentrations increased the percent of reduction increased when the concentration increased. The chemical insecticide malathion completely prevented any emerged adults with 100% reduction of F_1. The highest concentrations (0.3-0.6) of parsley achieved 100% reduction in progeny followed by the rate of 0.6 of watercress which caused 100 reductions, while 0.3 rate gave 83.33%.

Meanwhile, the highest concentrations (0.3-0.6) of both cinnamon and nutmeg presented moderately %reduction (68.33-26),(69.25 -28.37) ,respectively.

Effect on weight loss:

The results of weight loss presented in table (7) parallel with the % reduction corresponded. According the value of weight loss, malathion was the first agent followed by parsley, watercress, nutmeg and cinnamon at the highest concentration (0.6). In general, the oils tested increased the reduction of progeny and reduced the weight loss of wheat grain compared to control which had 17% weight loss.

Fumigant activity (*T. castaneum*.)

Effect on % reduction:

Results obtained in table (8) revealed that all oils reduced the mean of emerged adults ranged between zero to 157 individuals with the all tested oils compared to 174 individuals with the control. The % reduction ranged between 9.59 to 100% of control with all oil treatments. Malathion toxicity prevented the new emerged adults.

Effect on % weight loss.

All the tested oils and malathion reduced or prevented the adults, where the % weight loss ranged between 0.5% to 20.4% with the concentrations of oils, compared to 23% weight loss of control. Malathion reduced the weight loss of crushed weight grain to zero%.

Highlighting on current results showed that *T. castaneum* adults were more susceptible than *S. oryzae* concerning the fumigant activity of the tested materials. For S. *oryzae* parsley was the one, while cinnamon had the highest fumigant effect with *T. castaneum*. This different response may due to the type of species and its nutrient behavior besides the surface area of insect body exposure to the external action.

T able 8: Fumigant activity of oils on % reduction and weight loss of *T.castaneum*

Treatment	Conc. w/v	Mean of emerged adult	% reduction	Weight loss
Nutmeg	0.1	121.6±0.33cd	30.11	2.04±0.12hi
	0.15	119±1.1cd	31.6	1.96±0.23hi
	0.3	112±1.7cd	35.63	1.45±0.02ghi
	0.6	105.6±1.2d	39.3	1.23±0.06efgh
Cinnamon	0.1	78.6±6.8e	54.82	4.2±0.07abcde
	0.15	37.6±7.5f	78.39	2.3±0.04abcd
	0.3	0.00±0g	100	1. 4±0.02abc
	0.6	0.00±0g	100	0. 5±0.00ab
Watercress	0.1	5.6±0.88g	96.78	1.24±0.17fgh
	0.15	5.6±2.4g	96.78	1.05±0.09efg
	0.3	4.6±1.7g	97.35	0.87±0.07cdefg
	0.6	4.3±1.6g	97.53	0.83±0.06bcdefg
Parsley	0.1	157.3±4.2ab	9.59	1.04±0.22defg
	0.15	152±2.0b	12.6	0.98±0.16defg
	0.3	129.3±6.3c	25.6	0.94±0.08defg
	0.6	117.3±5.0cd	32.58	0.53±0.11abcdef
Control	Control	174±4.8a	0	2.3±0.25i

Repellent activity of four plant oils against *S. oryzae* and *T. castaneum*.

Insect repellents are chemical Substances that cause the insect to make oriented movements away from the source of the substance. Repellents have the potential to exclude stored product pests from grain, and have been used to prevent insect feeding and oviposition. In the present study, percentage repellency (PR) of the tested oils, cinnamon, nutmeg, watercress and parsley was assayed on *S. oryzae* and *T. castaneum* using filter paper technique. Data obtained demonstrated surprising action against both *S. oryzae* and *T. castaneum* resulting in watercress (all concentrations) (the highest concentration) which has attractant effect to both insects. These results are interestingly. Furthermore, except watercress oil, the other three oils, cinnamon, parsley and nutmeg had percent of repellence ranged between 3.3-87/% against the two insect species at the all tested concentrations. Based on percent of repellent activity in (table 9), the results showed that the repellent activity increased when the concentration within the same time. While the results flactuated through the periods of exposure, 2, 4, 6 and 12h post treatment. parsley oil is considered the premier agent against the two tested insects specially at the highest concentration (0.6) which achieved 87 and 80% repellent activity against *S. oryzae* and *T. castaneum*, respectively. Moreover, generally there are no Significant differences between the three active oils, parsley, cinnamon and nutmeg at the tested concentrations against the two tested insects. According to the current findings the present study suggests use parsley, nutmeg and cinnamon oils as an element of integrated pest management to repel the stored product insects away from the stored products Specially against *S. oryzae* and *T. castaneum*.

Table 9 : Repellent activity of four plant oils against *S. oryzae* and *T. castaneum* %.

Insects	Plant oil	Conc. (w/v)%	2h	4h	6h	12h
S. oryzae	Cinnamon oil	0.1	13.3±6.6c	26.7±13.3a	20±11.5bc	26.6±6.6ab
		0.15	20±11.5bc	33.3±6.6a	26.7±6.6abc	33.3±6.6ab
		0.3	33.3±17.6abc	53.3±6.6a	33.3±6.6abc	33.3±6.6ab
		0.6	53.3±6.6abc	53.3±6.6a	60±11.5a	66.7±13a
	Nutmeg oil	0.1	3.3±6.6ab	6.7±6.6ab	0.0±0.0e	20.0±0.0b
		0.15	33±6.6ab	20±6.7c	13.3±6.6de	20±11.54b
		0.3	40±0.0ab	33.3±6.6bc	33.3±6.6bcd	46.7±6.6ab
		0.6	40±11.5ab	66.7±13.3ab	46.7±6.6bc	46.7±13.3b
	Watercress oil	0.1	-13±11.5a	-47±11.5ab	-47±11.5b	-40±20ab
		0.15	-53±11.5bc	-60±20abc	-60±20bc	-60±20abc
		0.3	-73±11.5cd	-93±11.5c	-100±0.0c	-93±11.5c
		0.6	-100±0.0d	-100±0.0c	-100±0.0c	-100±0.0c
	Parsley oil	0.1	7±11.5abc	13±11.5cd	20±20ab	20±20bc
		0.15	33±80.2abc	40.0±20ab	27±11.5ab	27±11.5a
		0.3	53±11.5bc	47±11.5d	40.0±20c	73±11.5de
		0.6	53±11.5a	67±11.5a	73±11.5c	87±11.5e
T. castaneum	Cinnamon oil	0.1	20±11.5bc	20±11.5a	0.0±0.0c	6.7±6.6b
		0.15	26.7±13.3abc	20±0.0a	20±0.0bc	26.7±6.6ab
		0.3	66.7±6.6ab	33.3±6.6a	33.3±6.6abc	46.6±17.6ab
		0.6	73.3±6.6a	60±11.5a	46.7±6.6ab	53.3±13.3ab
	Nutmeg oil	0.1	13.3±6.6b	13.3±13.3c	13.3±6de	13.3±6.6b
		0.15	26.7±6.6ab	20±11.5 a	20±0.0cde	20±11.5b
		0.3	33.3±6.6a	40±0abc	53.3±13.3ab	53.3±13.3ab
		0.6	60±11.5a	80±11.5a	80±0.0a	86±13.3a
	Watercress oil	0.1	-13±11.5a	-20±20a	-7±11.5a	-20±20a
		0.15	-27±11.5ab	-40±20ab	-47±23.09b	-33±11.5ab
		0.3	-47±11.5bc	-67±23.9bc	-73±11.5bcd	-73±11.5bc
		0.6	-73±11.5cd	-100±0.00c	-93±11.5cd	-93±11.5c
	Parsley oil	0.1	20±20ab	7±31bc	13±11.5b	7±11.5ab
		0.15	40.0±20bc	33±11.5abc	47±11.5c	27±11.5bc
		0.3	53±11.5a	60.00±20d	53±11.5a	47±11.5cd
		0.6	87±11.5c	73±11.5a	67±11.5c	80.0±20de

Repellency=2 (C-50). Positive values (+) express repellency. Negative values (–) attractancy.
Means within a column followed by the same letters are not significantly (Duncans multiple range test at 0.05).

The repellent activity of malathion against *S. oryzae* and *T. castaneum*.

The results in table (10) showed that, malathion had repellent activity against *S. oryzae* more than *T. castaneum* when compared with the control, it was increased with increasing concentration, but it was decreased with exposure time. For example, the results showed that, the repellency values at the concentration 0.1% (w/v), were75, 69, 49, and 35% after 2,4, 6, and 12 h exposure times, respectively, against *S. oryzae*, and were 35, 33, 32, and 31%. respectively, after the same times against *T. castaneum*. At 0.1 concentration value in table 9 and 10 showed that both oils and malathion cannot reach 50% repellence values were 31 and 35 with malathion at 0.1 concentration with *T. castaneum* and *S. oryzae*, respectively, while at the same concentration oils the % repellency ranged between 6.7-26% repellency. Generally, the chemical insecticide did not distinct action compared to oils consequently, the use of oils insect control is best where they relatively safe for human if compared with disadvantages of malathion on human and environment.

Table 10 :The repellent activity of malathion against *S.oryzae* and *T. castaneum.*

Insects	Insecticide	Conc. w/v%	%Repellency			
			Exposure period(hours)			
			2h	4h	6h	12h
S.oryzae	Malathion	0.04 0.06 0.08 0.1	19.0d 29.0c 59.b 75.0a	17.0d 33.0c 64.0b 69.0a	9.0c 19.0b 49.0a 49.0a	5.0d 14.0c 33.0a 35.0a
	Control		2.3e	-	-	2.7e
T.castaneum	Malathion	0.04 0.06 0.08 0.1	5.6d 19.0c 23.0b 35.0a	12.0d 16.0c 24.0b 33.0a	5.6d 19.0c 26.0b 32.0a	11.0d 17.0c 29.0b 31.0a
	Control	Control	2.3e	-	-	2.7e

In the same insects **(Abdul Majeed and Abidunisa, 2011)** evaluated the aqueous extract of *Argemone mixican* as a repellent for *S. oryzae* and *T. castaneum* adults. Results obtained showed that aqueous extract from the leaves of *A. mexican* had good biological control against insect pest of stored grain. Additionally**, Omar *et al.* (2012)** stated that repellent percentages of *Solanum nigrum* and *Datura stramonium* plant extracts against *Trogoderma granarium* reached to 91.45 and 91.87% in 4% concentration after 24 h of treatment, respectively. **Fouad (2013)** concluded that essential oils of camphor (Eucaluptus globules), cinnamon (*Cinnamomum zelanicum*), clove (*Syzygium aromaticum*) and mustard (Brassica rapa) repelled the adults of *C. maculatus* when applied at 1% w/w. Another study **(Abo Arab *et al.*, 2014)** they found that orange oil and spinosad had promising effect in respect to toxicity and repellent activity against *R. dominica* and *T. castaneum* depending on the concentration of tested materials and the exposure time. **(Du *et al.*, 2014)** evaluated *Myistic fragrans* against cigarette beetle *Lasioderma serricorne*. The results indicated that the essential oil of *M. fragrans* and its active constituents have potential for development as natural insecticides and repellents to control *L. serricorne*. *T. asiatica* essential oil showed repellency against *C. maculatus*, *S. oryzae* and *T. castaneum*. Also, **Nattudurai *et al.* (2014) and Seada *et al.* (2016)** evaluated repellent activity for *Pelargonium graveolens*, *O. basilicum* and *F. vulgare* essential oil on against *S. oryzae* and *C. maculatus*. They found that the repellency of the tested oils was proportional to their concentration. Other results **Khalil *et al.* (2022**) evaluated repellent effect of *Ocimum basilicum* and *J. grandiflorum* essential oils against *R. dominica* and *T.castaneum*. Results showed the highest concentration 0.24 mg/cm2 basil absolute had the lowest repellency with 65% against *T. castaneum*. Jasmine absolute achieved the highest repellency at concentration of 0.12 mg/cm2 with 95% repellency. Data also showed that all tested essential oils had a repellent effect on *R. dominica* the repellency percentage was increased with increasing exposure period and concentrations. The finding of the current study **(Vineesh *et al.*, 2023)** evaluated essential oils of cinnamon, turmeric and neem as potential control agents *Paederus fuscipes* and *Luprops tristis*. They found that the three plant essential oils, turmeric oil was the best repellent against both *P. fuscipes* and *L. tristis*. **(Wagan *et al.*, 2016**) they found that essential oils have a repellency effect on *T. castaneum*. **(Jayakumar *et al*., 2017)** studied the repellent effect of geranium oil on *S. oryzae* and geranium oil has a repellent effect on *S. oryzae*. Geranium oil has a repellent effect on *S. oryzae* **(Seada *et al*., 2016) (Azab *et al.*, 2017)** In the same field **(Mishra *et al.*, 2012)** used *Mentha arvensis* L. against *T. castaneum* and *S. oryzae*. The result revealed that essential oil strongly repels *T. castaneum* and *S. oryzae* even at low concentration, but its repellency was more marked towards *S. oryzae* **(Kumar *et al*. ,2011)**. Also, **Aumcharoen *et al*. (2012)** stated the repellent of a crude methanol extract of *Duabanga grandiflora* against adults of *S. oryzae*. The crude extract tested was found to have repellent activity against *S. oryzae* ranging from 37 and 83% at 5 min to 2 hrs after exposure and 100% after 24 hr. The exposure period appeared to be the most important factor affecting the repellent in this study, The inhibitory activity was most evident at 1 h post-treatment, with the average inhibition of 42.7%, and the most active treatment was *Eucalyptus radiata* oil followed by lemon and cinnamon oils. Most constituents of plant essential oils are highly volatile due to their low molecular weight in addition to **(Al-Harbi *et al*., 2021)** the highest repellence effects against *S. oryzae* were recorded by using basil EO with all concentrations and at different exposure times. This effect is related to the chemical composition of basil essential oil containing eugenol, linalool, and estragole.

4. CONCLUSION

The all tested oils had deterrent effects on the all test criteria compared to control. The current study suggests that these oils can use in the integrated insect pests of stored products especially against the two tested investigated.

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الملخص العربى
النشاط المقارن لأربع زيوت نباتية منتخبة ضد بالغات سوسة الأرز وخنفساء الدقيق الصدئية الحمراء

الملخص

يمثل محصول القمح أهمية كبيرة بالنسبة لتغذية معظم السكان في مصر وعلى مستوى العالم.
يتعرض محصول القمح للإصابة ببعض آفات الحبوب المخزونة بعد الحصاد حيث يؤدى ذلك إلى فقد كبير في المحصول وكذلك جودة الحبوب بالإضافة لخفض نسبة الإنبات.
كان لاستخدام المبيدات الكيماوية آثار ضارة وخطيرة على الإنسان والبيئة المحيطة به وكذلك على الكائنات الغير مستهدفة.
استهدفت الدراسة الحالية اختبار أحد بدائل المبيدات الآمنة نسبيا وهى الزيوت النباتية تم تقييم كفاءة كل من زيت جوز الطيب والجرجير والقرفة والبقدونس من خلال بعض طرق التقييم الحيوي وهي التأثير السام سواء عن طريق استخدام طريقة التبخير و طريقة الطرد وكذا دراسة التأثير على بيولوجى حشرتى سوسة الأرز وخنفساء الدقيق الصدئية بجانب دراسة التأثير على الفقد في الوزن.
اظهرت النتائج تفوق زيت القرفة على باقى الزيوت الأخرى ضد حشرة خنفساء الدقيق الصدائية وزيت البقدونس على سوسة الأرز.
بصفة عامة خفضت هذه الزيوت عدد الذرية الناتجة لحشرة خنفساء الدقيق الصدئية بقيم تتراوح من 7.33 إلى 100 وكذا ذرية سوسة الأرز من 62.89 إلى 100.
كانت حشرة خنفساء الدقيق الصدئية أكثر تحملا للزيوت المختبرة من حشرة سوسة الأرز.
بصفة أظهرت جميع الزيوت نتائج مبشرة على كل المعايير المدروسة مما يسمح بإمكانية استخدمها ضمن وسائل المكافحة المتكاملة لحشرات المواد المخزونة.