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COMPARATIVE STUDY ON PLANT OILS, PLANT POWDERS, INERT DUSTS AND MALATHION AS WHEAT GRAIN PROTECTANTS

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ABSTRACT: Current study was conducted to evaluate some plant oils (clove, spearmint and orange); plant powders (clove, spearmint and orange); two inert dusts (silica and katelsous) and the insecticide (malathion) as recommended standard reference against one of the most important stored grain insects, *Rhizopertha dominica*. Three methods of application, mixing with medium, residual and repellent activity were used to determine some criteria (toxicity, emergence, progeny reduction, which measure the susceptibility of the tested insect). In addition, the study included the damage of grains (% wheat loss) and the side effect on the germination. Results showed that toxicity of the tested materials were depending on insect species and bioassay methods. This variation may be regarding to feeding habit of tested insects and the vapor pressure and molecular weight of each compound, which influence the level of toxicity. Moreover, insecticidal activity in the tested materials was related to their chemical composition, and activity decreased with the time depends on the component volatility for oils. Moreover, clove oil showed to has the best effects among the oils in the present study, where it reduced the emerged adults, the percent of weight loss and increased the percent of reduction. However, the clove oil inhibited the percent of germination of *R. dominica*. Results also showed that the percent of germination did not influence by the method of mixing.

Key words: *Rhizopertha dominica*, mixing with medium, germination, progeny, repellent.

INTRODUCTION

The study carried out to find alternative methods and materials to chemical or synthetic pesticides and can be used in stored grain protection. As known synthetic pesticides cause many problems to mammals, human, natural enemies, bio balance and environment. Not only this problems but also insects during time it will gain resistance which lead farmers to increase the dose and the quantity of pesticides and as a result of this the environmental pollution and the control cost increase. One of the new fields is using natural products in plant protection. Essential oils are natural products which plants produce as a secondary product, many researches carried out last years on using essential oils and plant extracts as pesticides alternatives. Plant powders and inert dusts also can be used as plant protectants, their effect may refers to its physical properties and can be removed easily from grain before cooking and more safe than chemical pesticides. Poor and developing countries depend on grain and legume as the main source of protein (**Abouelatta *et al*., 2020**). Wheat grain for example produces in cold and rainy countries and exporting to developing countries. Countries which import wheat grain need to protect it all over the year during storage. Storage is a very important repeated process and complex logistics during transporting products from producer to consumer (**Anderson, 1973**). Its aim to protect products and management of harvested grain causes significant quantitative and qualitative postharvest food losses are estimated to range from 9% in the United States (**Pimentel, 1991**) up to 50% in some parts of the developing nations.

Some insects such as *Callosubrucus maculatus* have also been directly associated with seed damage, of cowpea seeds growth, and the yield

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(**Abouelatta *et al.*, 2016**). The weevil *S. oryzae* is an effective vector in the United States (**Barry *et al.*, 1985**).

Many major pests of stored wheat include *R. dominica* and *S. oryzae*. The two species cause the most grain damage because the immature stage develops inside the grain (**Hagstrum and Subramanayam, 2006**).

Heavy reliance on chemical control has led to widespread insecticide resistance and control failures and reduced interspecific completion in many countries.

Continuous research is needed to replace the conventional pesticides by cheaper and eco-friendly natural plant products with active safe components. Powdered plant parts, oils and extracts that result from secondary metabolism in plants are among these products (**Lale, 2002**).

Essential oils possess acute contact and fumigant toxicity to insects (**Sahaf *et al*. 2008; Kim *et al*., 2010; Suthisut *et al*., 2011**), repellent activity (**Nerio *et al*., 2010; Carroll *et al*., 2011; Nenaah, 2014**).

Adel *et al.* (2015) suggest the possibility of using essential oils as toxicant and fumigant against *Sitophilus oryzae* and *Callosobrucus maculatus* adults in storage facilities in Egypt. Essential oils showed to have a strong repellent effect against *Rhizopirtha dominica* (**Abouelatta *et al.*, 2020**).

Inert dusts such as ash, lime, various ground minerals and clays have a long history of use for grain protection (**Ebeling, 1971; Golob and Webley, 1980; Ross, 1981; Quarles 1992 a,b**).

Therefore the present study conducted to evaluate:

The insecticidal potency, the effect on biology, the residual activity and the repellent activity of tested materials compared to malathion as a reference insecticide against *Rhyzopertha dominica*.

MATERIALS AND METHODS

Tested Insects

Lesser grain borer (*Rhizopertha dominica*)

The adults of lesser grain borer *R. dominica* (*Coleoptera Bostrichidae*) were reared on wheat kernels (Masr 1) in jars (500 ml). About 300 adults of *R.dominica* were added to 300 grams wheat kernels and 40 grams wheat flour and covered with muslin. Jars were maintained under conditions of 32±2^{o}C and 70±5% R.H. After two weeks the parents were removed and the new emerged adults were used for experimental work according to **Abo-arab and El-Tawelah (2015)**.

Plant oils

Three plant oils used in the present study were:

a) Orange (*Citrus sinensis var valencia*) fruit peels.

b) Spearmint (*Mentha virides*) Leaves.

c) Clove (*Eugenia aromatic*) flower buds.

Oils were used at concentrations (5.0, 10.0, 15.0, and 20.0 ml/kg). The oils used were obtained from El-Nasr Pharmaceutical Co. Egypt (Huckstep, El Nozha, Cairo, Egypt).

Plant powders

Plants used as dusts against stored product insects are:

a) Peesls of orange (*Citrus sinensis var valencia*).

b) Leaves of spearmint (*Mentha virides*).

c) Flowers of clove (*Eugenia aromaticum* (L.)).

The target plant part was dried for 10 days in shadow and finely ground into a fine powder in an electrical blender for five minutes. The powder was thoroughly sieved (300 mech.).

Inert dusts

Katelsous

It consists of (triple phosphate rock 84% and Sulphur 16%).

Source: El- Nasr CO. 49MM+925, Huckstep, El Nozha, Cairo, Egypt.

Silica dust

Source: El- Nasr CO. 49MM+925, Huckstep, El Nozha, Cairo, Egypt.

The insecticide used

Malathion, (dust 1%) purchased from Kafr El-Zayat pesticides and chemicals CO (Kafr El-Zayat, Al-Gharbia, Egypt).

Insecticidal Activity of the Tested Materials

Mixing with feeding medium

This method was used to determine the insecticidal effect of tested plant products (oils and powders), inert dusts and Malathion against *R. dominica* on feeding medium. For seed treatment the considerable concentrations (0.04, 0.06, 0.08 and 0.1% w/w for malathion, 5.0, 10.0, 15.0 and 20.0 µl/kg for plant oils, 0.5, 1.5, 3.0, and 5.0% w/w for plant powders and inert dusts. The considerable concentrations of each tested materials were separately mixed with 20 grams of wheat grains and were placed in jars (250 ml.). The jar was shaken by hand to mix the grain with all tested concentrations. The jars without any tested materials used as control. Each concentration and control was replicated three times. Twenty of newly emerged adults of *R. dominica* (7-14 days old) were added to each jar, covered with muslin cloth and kept under laboratory conditions. Mortality counts were recorded after one and two weeks for *R. dominica*. All results were corrected with Abbot's formula (1925) as following:

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

Confidence limits and slope values were calculated for all tested materials.

Residual activity

To evaluate the residual activity of tested materials (malathion, plant powders, plant oils and inert dusts) on the reduction in progeny after 1, 2, 3, 4 and 5 months, LC_{50} and LC_{90} values arising from the toxicity experiment.

Sterilized wheat grains and cowpea seeds were treated with the LC_{50} and LC_{90} values, untreated control without any tested materials. The treated grains and were drawn at intervals of 1, 2, 3, 4 and 5 months post-treatment, *R. dominica* (1-2 weeks old) were exposed to all tested materials residues wheat grains (20 insect/20 grams grains).

Every treatment and control was replicated three times at each interval, the mean number of emerged adults in insect used was recorded, and the reduction in progeny was calculated according to equation of **El-Lakwah *et al.* (1992)**.

Repellency bioassay

The repellency of all tested materials (Malathion, plant oils, plant powders and inert dusts) were determined according to **Helen (1989)**. For this purpose a modified apparatus was used to measure repellency effect of all tested materials. It consists of small petri-dish 6 cm diameter × 1 cm height. Ten grams of treated wheat grains for with LC_{50}'s values were placed inside the small petri-dish which acts as a barrier for insects. Twenty adults of *R. dominica* (1-2 weeks old) were introduced to small petri-dish which placed in the center of a large petri-dish (12 cm diameter × 2.5 height) then the big petri-dish was covered with glass lid and replicated three times for each treatment or untreated control and kept at the laboratory conditions. Repellency was examined after 2, 4, 8, 12 and 24 hours after treatment according to the following equation:

% Repellent= (No. of adults outside small petri-dish / Total No. of adults used) × 100.

Statistical Analysis

The percentage of mortality in the different tests cumulated in time according to the concentrations of essential oil was analyzed using a one-way ANOVA and a subsequent least significant difference (LSD) test for mean separation at P= 5%, using the SPSS software program version 23. The 50% lethal concentrations (LC_{50}), slope and 95% confidence limits (CL) were calculated based on Finney's analysis (**Finney, 1971**) using the Pc Probit software program, and significant difference between LC_{50} values was estimated based on 95% CL overlapping.

RESULTS

Effect on the Progeny

The effect of plant oils on the progeny of *Rhizopirtha dominica*

Results in Table 1 demonstrated difference in mortality percentage between untreated and other treatments as well as between treatments. The mortality percentages increased with increasing of concentration and exposure periods.

Table 1. Effect of plant oils mixed with wheat grains on *Rhizopertha dominica*

Oil	Conc. ml/kg	% Mortality		Mean no. of emerged adults	% reduction F1 progeny	% loss of wheat weight after 3 months	% germination of wheat grains after 3 months post treatment
		After 3 days	After 1 week				
Orange	5.0	26.6	35.0	360.0 b	44.6 h	14.0 b	89.0 b
	10.0	36.7	48.3	281.0 c	56.8 g	9.0 c	91.0 b
	15.0	58.3	68.6	152.0 h	76.6 d	5.0 d	75.0 d
	20.0	70.0	78.3	90.0 k	86.2 b	3.7 def	81.0 c
Spearmint	5.0	30.0	41.3	295.0 c	54.6 g	10.0 c	81.0 c
	10.0	46.6	58.0	240.0 f	62.9 f	6.2 c	76.0 d
	15.0	61.7	75.0	132.0 i	79.7 d	4.5 cd	61.0 e
	20.0	75.0	90.0	72.0 L	88.9 a	2.1 fe	54.0 f
Clove	5.0	48.3	58.3	274.0 d	57.8 g	7.2 c	76.0 d
	10.0	65.0	70.0	180.0 d	72.3 e	4.7 cd	62.0 d
	15.0	70.0	88.3	106.0 j	83.7 c	3.9 cd	52.0 f
	20.0	85.0	93.3	64.0 m	90.2 a	1.8 fg	43.0 g
Control	0	0.0	0.0	650.0 a		54.0 a	98.0 a

Means followed by the same latter in the column are not significantly different ($P<0.05$).

Results showed that clove oil had the most toxic effect against *R. dominica*, where concentration 20 ml/kg gave 85.0% and 93.3% mortality after one and two weeks post-treatment.

The adult emergence was reduced with all tested plant oils and decreased with increasing concentrations compared to untreated control.

Data in Table 1 revealed that the reduction in progeny increased with increasing concentrations.

All plant oils had the highest reduction in progeny at concentration 20 ml/kg with values of 86.2, 88.9 and 90.2 for orange, spearmint and clove, respectively against *R. dominica*. The clove oil was more effect on progeny than the two other plant oils.

The percent of weight loss significantly reduced with plant oils compared to untreated control, where the values at 20 ml/kg concentration were 3.7, 2.1 and 1.8 for orange, spearmint and clove oils, respectively compared to 54.0 for untreated control.

Moreover, results in Table 1 showed significant differences for grain germination between oil treatments and untreated control and within oil treatments. The germination percentages decreased with increasing the concentration and exposure periods.

For example, the germination percentages at concentration 20 ml/kg were 81.0, 54.0 and 43.0% for orange, spearmint and clove oils compared to 98.0% for control after 3 months post-treatment.

The effect of plant powders on the progeny of *Rhizopirtha dominica*:

Data in Table 2 demonstrated the difference for mortality percentages between powder treatments. The percent of mortality increased with increasing concentrations and exposure periods. The adult emergence was reduced with

Table 2. Effect of plant powders mixed with wheat grains on *Rhizopertha dominica*

Powder	% Conc. w/w	% Mortality		Mean no. of emerged adults	% reduction F1 progeny	% loss of wheat weight after 3 months	% germination of wheat grains after 3 months post treatment
		After a week	After 2 weeks				
Orange	0.5	18.3	25.0	381.0 b	41.4 g	17.2 b	94.0 b
	1.5	33.3	36.7	301.0 e	53.7 f	14.1 c	90.0 c
	3.0	46.6	58.3	160.0 h	75.4 d	10.3 d	85.0 d
	5.0	61.6	70.0	101.0 k	84.5 c	6.2 e	80.0 e
Spearmint	0.5	20.0	33.0	341.0 c	44.8 g	16.1 b	95.0 b
	1.5	30.0	48.3	285.0 f	56.2 f	14.2 c	74.0 f
	3.0	61.6	70.0	141.0 i	78.3 d	9.6 d	61.0 h
	5.0	75.0	83.3	81.0 L	87.5 b	5.4 e	59.0 f
Clove	0.5	35.0	41.3	289.0 d	55.5 f	12.7 c	68.0 g
	1.5	46.6	60.0	194.0 g	70.2 e	9.6 d	77.0 f
	3.0	68.3	75.0	112.0 j	82.8 c	6.1 e	58.0 h
	5.0	78.3	86.7	56.0 m	91.4 a	3.0 f	51.0 i
Control	0	0.0	0.0	650.0 a		54.0 a	98.0 a

Means followed by the same latter in the column are not significantly different ($P<0.05$).

the all tested plant powders compared to control and also decreased with increasing concentration.

The reduction percentages in progeny significantly increased with increasing concentration. All plant powders achieved the highest reduction in progeny at concentration of 5.0% w/w with % reduction values of 84.5, 87.5, and 91.4% for orange spearmint and clove powders, respectively, against *R. dominica*. The clove powder had the highest effect on progeny among the three tested powders.

The weight loss of wheat grains significantly reduced with plant powders where 5.0% w/w concentration caused 6.2, 5.4 and 3.0 % loss for orange, spearmint and clove powders compared to 54% for untreated control.

The percent of grain germination showed significant difference between plant powders and within concentrations in comparison with untreated control.

The effect of inert ducts on the progeny of *Rhizopirtha dominica*

The results in Table 3 expressed differences in mortality percentages between powder treatments as well as within concentrations of treatments. Also, the percent of mortality increased with increasing concentrations.

The reduction percentages in progeny was increased with increasing concentrations. The high reduction was observed with concentration of 4.0% which caused 92.9 and 88.6% for silica dust and Katel-sous, respectively. Moreover, the silica dust was more effective than Katel-sous against *R. dominica*.

As shown in Table 3, the percent of grain weight loss decreased with increasing concentrations. For example, the % losses of grain weight at concentration 4.0% w/w were 2.7 and 3.2 for silica dust and Katel-sous, respectively compared to 54.0 for untreated control.

Table 3. Effect of inert dusts mixed with wheat grains on *Rhizoperth dominica*

Inert dusts	Conc. w/w	% Mortality		Mean no. of emerged adults	% reduction F1 progeny	% loss of wheat weight after 3 months	% germination of wheat grains after 3 months post treatment
		After a week	After 2 weeks				
Silica dust	0.5	50.0	58.3	289.0 c	55.5 g	9.3 b	95.0 a
	1.0	65.0	70.0	175.0 e	73.1 e	6.1 c	90.0 b
	2.5	75.0	83.3	116.0 g	82.2 c	4.0 d	83.0 c
	4.0	87.0	93.3	46.0 i	92.9 a	2.7 e	76.0 d
Katel-sous	0.5	41.3	53.3	298.0 b	54.2 g	10.1 b	97.0 a
	1.0	58.3	68.3	210.0 d	67.7 f	7.1 c	98.0 a
	2.5	71.3	78.3	140.0 f	78.5 d	4.1 d	97.0 a
	4.0	83.0	91.3	74.0 h	88.6 b	3.2 e	96.0 a
control	0	0.0	0.0	650.0 a		54.0 a	98.0 a

Means followed by the same latter in the column are not significantly different ($P<0.05$).

The percent of germination with the silica dust decreased with increasing concentration. While with Katel-sous there is no significant differences between treatments and untreated control.

The effect of Malathion insecticide

The protective effect of malathion for wheat grain against *R. dominica* adults was evaluated using different concentrations (0.04, 0.06, 0.08 and 0.1% w/w).

The results in Table 4 revealed that differences in mortality percentages were found between the untreated control and the other treatments, as well as within the treatments against *R. dominica* adults. The percentage of mortality increased with increasing of concentration and exposure period. Results showed that Malathion dust provided the most effective control against *R. dominica* compared to the other tested materials.

Also data summarized in Table 4 indicated that adult emergence was reduced with the all tested concentrations, where the reduction of progeny significantly increased with increasing of concentration to 0.1% w/w against *R. dominica*.

Results presented in Table 4 revealed that treatments significantly reduced the weight loss of wheat grain due to infestation with *R. dominica*. At the concentration of 0.1% w/w, the loss was 1.2% compared to 54.0% for untreated control after 3 months. In addition, the percent of germination with all concentrations used of Malathion did not have significant differences between treatments and untreated control.

Residual Activity

Residual effect of plant oils

Results in Table 5 showed the effect of wheat grains treatment with LC_{50} and LC_{90} for orange, spearmint and clove oils on the number of progeny after 1, 2, 3, 4 and 5 months post treatment.

The results revealed that with LC_{50} value the insect number in the progeny were (109.0, 94.0 and 87.0), (134.0, 106.0 and 97.0), (147.0, 120.0 and 118.0), (160, 136 and 131.0) and (181.0, 148.0 and 150.0) for orange, spearmint and clove oil after 1, 2, 3, 4 and 5 months, respectively compared to 650.0 for untreated control.

The results showed that with LC_{50} the insect numbers in progeny highly reduced directly after treatment and the effect decreased gradually with the time elapsed. Additionally, the effect of LC_{50} was still effective till 5 months post-treatment and the reduction percent

Table 4. Effect of Malathion dust mixed with wheat grains on *Rhizopertha dominica*

Pesticide	Conc. w/w	% Mortality After 3 days	% Mortality After 1 week	Mean no. of emerged adults	% reduction F1 progeny	% loss of wheat weight after 3 months	% germination of wheat grains after 3 months post treatment
Malathion	0.04	71.0	75.0	281.0 b	56.8 d	7.1 b	98.0 a
	0.06	78.3	88.6	220.0 c	66.2 c	4.0 c	99.0 a
	0.08	86.7	90.0	86.0 d	86.0 b	2.1 d	97.0 a
	0.1	91.3	96.7	34.0 e	94.8 a	1.2 d	98.0 a
Control	0			650.0 a		54.0 a	98.0 a

Means followed by the same latter in the column are not significantly different ($P<0.05$).

Table 5. Residual effect of plant oils on *Rhizopertha dominica* after indicated exposure period (months)

Oil	Conc. ml/kg	1: Mean no. of emerged adults	1: % Reduction	2: Mean no. of emerged adults	2: % Reduction	3: Mean no. of emerged adults	3: % Reduction	4: Mean no. of emerged adults	4: % Reduction	5: Mean no. of emerged adults	5: % Reduction
Orange	LC_{50} (8.3)	109.0 a	83.2 b	134.0 b	79.4 b	147.0 b	77.4 b	160.0 b	75.4 c	181.0 b	72.2 c
	LC_{90} (39.3)	24.0 d	96.3 a	37.0 e	94.3 a	52.0 d	92.0 d	66.0 d	89.8 a	77.0 d	88.2 a
Spearmint	LC_{50} (7.9)	94.0 b	85.5 b	106.0 c	83.7 b	120.0 c	81.5 b	136.0 c	79.1 b	148.0 c	77.2 b
	LC_{90} (23.8)	19.0 d	97.1 a	29.0 f	95.5 a	38.0 e	94.2 a	51.0 e	92.2 a	65.0 e	90.0 a
Clove	LC_{50} (7.1)	87.0 c	86.0 b	97.0 d	85.1 b	118.0 c	81.8 b	131.0 c	79.8 b	150.0 c	76.9 b
	LC_{90} (21.7)	15.0 e	97.0 a	24.0 f	96.3 a	31.0 f	95.2 a	41.0 f	93.7 a	55.0 f	91.5 a
Control	0	650.0 a		650.0 a		650.0 a		650.0 a		650.0 a	

Means followed by the same latter in the column are not significantly different ($P<0.05$).

in progeny of *R. dominica* adults were (83.2, 85.5 and 86.0), (79.4, 83.7 and 85.1), (77.4, 81.5 and 81.8), (75.4, 79.1 and 79.8) and (72.2, 77.2 and 76.9) for orange, spearmint and clove oils after 1, 2, 3, 4 and 5 months, respectively.

While, LC_{90} values of plant oils (orange, spearmint and clove) achieved high percent of reduction in progeny till 5 months especially with clove oil and also the effect was still clearly high and was closely near to completely reduction in progeny based on that of control.

Residual effect of plant powders on *Rhizopertha dominica*

Plant powders had the same trend of plant oils. The powders tested manifested moderate activity till 5 months post-treatment either with LC_{50} or LC_{90}. Clove powder was the premier among the tested powders where it achieved percent of reduction ranged between 77.7-86.8 and 90.9 to 97.4 with the concentrations of LC_{50} and LC_{90}, respectively followed by spearmint and orange powders with % reduction 76.7-86.2

and 89.1 - 96.8, 69.7-81.5 and 87.1-95.4 with the same concentrations at the all periods of experiment.

Also, results cleared that the effect of powders gradually decreased with time elapsed (Table 6).

Residual effect of inert dusts and Malathion on *Rhizopertha dominica*

Similarly as in the previous experiments results showed significant variation between the effect of inert dusts and malathion where the insect numbers of progeny for *R. dominica* were (101, 136 and 36), (120, 151 and 47), (142, 170 and 61), (164, 180 and 81.0) and (186, 201 and 103) for silica dust, katel-sous and malathion after 1, 2, 3, 4 and 5 months post-treatment, respectively, compared to 650.0 for control.

Malathion was the most effective compared to silica dust and Katel-sous. The effect stayed till 5 months but decreased gradually with time elapsed. Based on the insect numbers in control the percent reduction ranged between 69.1 - 94.5% for LC_{50} and 86.3 - 100% with LC_{90} with the tested materials from one month to five months of treatment (Table 7).

Repellent activity

According to the results obtained in Table 8 the all experimental groups of plant oils and plant powders, inert dusts and Malathion represented repellent potency against *R. dominica* adults. The plant materials had the highest repellent activity especially plant powders followed by Malathion insecticide and inert dusts which had the lowest repellent effect. The percent of repellency ranged between 60 – 100 % for plants materials, powders or oils followed by Malathion with 60- 96% repellency and lately inert dusts with 6- 60% repellent activity. Clove oil or powder achieved the most repellent efficiency among the investigated materials. In contrast, orange had the lowest effect while katel-sous was the best compared to silica dust.

Data obtained clearly showed significant differences between tested materials at all periods of experiment from 2 to 48 h. post treatment.

Table 6. Residual effect of plant powders on *Rhizopertha dominica* after indicated exposure period (months)

Powder	Conc. g/kg	Exposure period (months) 1: Mean no. of emerged adults	1: % Reduction	2: Mean no. of emerged adults	2: % Reduction	3: Mean no. of emerged adults	3: % Reduction	4: Mean no. of emerged adults	4: % Reduction	5: Mean no. of emerged adults	5: % Reduction
Orange	LC_{50} (2.0)	120.0 b	81.5 d	142.0 b	78.2 c	164.0 b	74.8 c	171.0 b	73.7 d	197.0 b	69.7 c
	LC_{90} (18.3)	30.0 e	95.4 a	42.0 e	93.5 a	61.0 e	90.6 a	76.0 e	88.3 b	84.0 e	87.1 a
Spearmint	LC_{50} (2.4)	90.0 c	86.2 c	102.0 c	84.3 b	121.0 c	81.4 b	136.0 c	79.1 c	151.0 c	76.7 b
	LC_{90} (25.2)	21.0 f	96.8 a	36.0 f	94.5 a	46.0 f	92.9 a	52.0 f	92.0 a	71.0 f	89.1 a
Clove	LC_{50} (1.2)	86.0 d	86.8 c	98.0 d	84.9 b	112.0 d	82.8 b	123.0 d	81.1 c	145.0 d	77.7 b
	LC_{90} (8.4)	17.0 a	97.4 a	26.0 g	96.0 a	33.0 g	94.9 a	47.0 g	92.8 a	59.0 g	90.9 a
Control	0	650.0 a		650.0 a		650.0 a		650.0 a		650.0 a	

Means followed by the same latter in the column are not significantly different ($P<0.05$).

Table 7. Residual effect of inert dusts and malathion on *Rhizopertha dominica* after indicated exposure period (months)

Dust	Conc. g/kg	Exposure period (months) 1: Mean no. of emerged adults	1: % Reduction	2: Mean no. of emerged adults	2: % Reduction	3: Mean no. of emerged adults	3: % Reduction	4: Mean no. of emerged adults	4: % Reduction	5: Mean no. of emerged adults	5: % Reduction
Silica dust	LC_{50} (0.9)	101.0 c	84.5 c	120.0 c	81.5 c	142.0 c	78.2 c	164.0 c	74.8 c	186.0 c	71.4 d
	LC_{90} (4.3)	27.0 e	95.8 b	39.0 e	94.0 b	59.0 d	90.9 b	71.0 c	89.1 b	82.0 f	87.4 b
Katel-sous	LC_{50} (1.1)	136.0 b	79.9 d	151.0 b	76.8 d	170.1 b	73.8 d	180.1 b	72.2 c	201.0 b	69.1 d
	LC_{90} (5.3)	30.0 e	95.4 b	41.0 e	93.7 b	58.0 d	91.1 b	73.0 e	88.8 b	98.0 e	86.3 b
Malathion	LC_{50} (0.05)	36.0 d	94.5 b	47.0 d	92.8 b	61.0 d	90.6 b	81.0 d	87.5 b	103.0 d	84.2 c
	LC_{90} (0.1)	0.0 f	100.0 a	0.00 f	100.0 a	0.0 f	100.0 a	6.0 f	99.0 a	18.0 g	97.2 a
Control	0	650.0 a		650.0 a		650.0 a		650.0 a		650.0 a	

Means followed by the same latter in the column are not significantly different (P<0.05).

Table 8. Repellent activities of plant oils, plant powders, inert dusts and malathion against *Rhizopertha dominica* after indicated periods post-treatment with LC_{50} values

Plant oils

Material	Conc. LC_{50} ml/kg	Hours 2	4	8	14	24	48
Orange	8.3	70.0^{f}	86.0^{d}	76.0f	85.0^{d}	66.0^{g}	60.0^{e}
Spearmint	7.9	86.0^{d}	93.0^{c}	97.0b	$95.0b^{c}$	88.0^{c}	94.0^{b}
Clove	7.1	70.0^{f}	97.0^{b}	100.0^{a}	97.0^{b}	100.0^{a}	100.0^{a}

Plant powders

Material	Conc. LC_{50} w/w	Hours 2	4	8	14	24	48
Orange	2.0	65.0^{g}	70.0^{e}	60.0g	86.0^{e}	86.0^{e}	60.0^{g}
Spearmint	2.4	80.0^{e}	86.0^{d}	100.0^{a}	100.0^{a}	95.0^{b}	100.0^{a}
Clove	1.2	90.0^{c}	100.0^{a}	90.0^{c}	86.0^{d}	100.0^{a}	100.0^{a}

Inert dusts

Material	Conc. LC_{50} w/w	Hours 2	4	8	14	24	48
Silica-dust	0.9	18.0^{i}	6.0^{h}	36.0^{i}	20.0^{h}	24.0^{j}	20.0^{f}
Kalel-sous	1.1	24.0^{h}	40.0^{g}	46.0^{h}	50.0^{g}	40.0^{i}	60.0^{e}

Malathion

Material	Conc. LC_{50} w/w	Hours 2	4	8	14	24	48
Malathion	0.05	87.4^{b}	60.0^{e}	88.0^{b}	96.0^{a}	70.0^{cd}	75.0^{c}

Means followed by the same latter in the column are not significantly different (P<0.05).

DISCUSSION

In the current study laboratory bioassays were conducted to evaluate some natural occurring materials, plant oils , plant powders , two inert dusts , and malathio) as recommended standard reference against one of the most important stored grain insects, *Rhizopertha dominica* beetle.

Eventually, the data obtained in the present study are in the line with **Zayed (2016)** who reported that the malathion and the three plant oils Aloe (*Aloe Africana*) leaves, lavender (*Lavandual officinalis*) leaves and bitter almond (*Prunus amygdolus*) seeds significantly affected on all tested parameters of *C. maculatus* adults, where it increased mortality percentage, % progeny reduction and decreased percent of seed loss with increasing concentrations. Malathion had the strongest effect on all parameters compared to the plant oils except to repellent effect where it had the lowest action. **Abouelatta *et al.* (2016)** evaluated the contact toxicity, fumigant and oviposition deterrent activities of the essential oils from four plant species, geranium (*Pelargonium graveolens*), anise (*Pimpinella anisum*), german chamomile (*Matricaria chamomilla*) and bitter orange (*Citrus aurantium*) *against C. maculatus* adults. They reported that the all tested oils had dramatically effect on the parameters tested, % mortality, mean number of emerged adults (F1 progeny) and % hatchability. **Zayed (2015)** studied the effect of four plant extracts, lupine, clove, dill and spearmint for controlling *C. maculatus* compared to malathion. Results presented that all tested materilas (plant extracts and malathion) had instant effect where they reduced numbers of eggs laying, percentage of hatching, emergence and increased reduction in progeny with increase of concentrations for six months. Also, they reduced weight loss and seed germination. Meanwhile, malathion had the strongest effect on the tested insect. **Hosny *et al.* (2015)** studied the efficiency of malathion and four plant oils barriers, *Juniper juniperus*, leaves of marjoram, *Origiunum marjorana*, seeds of mustard, *Brassica rapa* and bulbs of onion *Allium cepa* against *C. maculatus using* thin film residue and mixing with medium and in direct methods, fumigation. Data obtained showed that the all tested oils affected on, egg laying, hatchability, and percent of mortality, emerged adults and the loss weight of seeds and protected the cowpea seeds for two months. **Abo Arab *et al*. (2014b)** 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. **Zayed and Manal (2012)** found that malathion caused greater adult mortality and reduced egg laying, number of adult emerged of *C. maculatus* and weight loss of cowpea seeds. There is no significant difference between germination percentage of cowpea seed treatments and untreated control. The findings in the current study agree with that of **Kumar *et al.* (2011)** who studied the insecticidal activity of menthe against various stores grain pests (*Sitophilus oryzae*, *T. castaneum* and *Acanthoscelides obtecus*). Many research workers studied numerous plant oils belonging to different families against many stored product insect species as alternatives to chemical insecticides (**UI-Hassan *et al*., 2006; Mahfuz and Khalequezzaman, 2007; Yang *et al*., 2010; Mikhaiel, 2011, Jemaa *et al*., 2012**). The botanical pesticides have the advantage novel modes of action against insects that can reduce the risk of cross-resistance as well as offering new leads for the design of target-specific molecules (Isman, 2006). Laboratory investigation were carried out on the efficacy of hexane and ethanol extract of *Ergenia* aromatic and *P. anisum* against *S. oryzae* (L.), *C. maculatus* (F.) when mixed with wheat grain and cowpea seeds. The obtained results showed that adult emergence of *C. maculatus* and *S. oryzae* after various period of storage (i.e. 7 days, 1, 2, 3, 4 and 5 months post-treatment) were reduced compared to control (Abo-Arab *et al.*, 2004). Essential oils had toxicity effect against sored product insects and can be used as insecticide alternatives and also can be used in IPM programs (**Abouelatta *et al.*, 2020; Abu Arab *et al.*, 2022**).

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دراســـة مقــارنــة للـزيــوت النبــاتيــة، المســـاحيق النبــاتيــة، المســـاحيــق الخــاملــة والملاثيــون كــواقيـــات لحبــوب القمـــح

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أجريت الدراسة الحالية لتقييم بعض الزيوت النباتية (القرنفل، النعناع، والبرتقال)؛ مساحيق النباتات (القرنفل والنعناع والبرتقال)؛ اثنين من المساحيق الخاملة (السيليكا وقاتل السوس) والمبيد الحشري (الملاثيون) كمرجع قياسي موصى به ضد واحدة من أهم حشرات الحبوب المخزنة، *Rhizopertha dominica.* تم استخدام ثلاث طرق للتطبيق والخلط مع الوسط والنشاط المتبقي والطارد لتحديد بعض المعايير (السمية و الخفض في التعداد) والتي تقيس حساسية الحشرات المختبرة. بالإضافة إلى ذلك، شملت الدراسة تلف الحبوب (نسبة الفقد في الوزن) والتأثير الجانبي على الإنبات. اظهرت النتائج ان سمية المواد المختبرة اعتمدت على أنواع الحشرات وطرق التقييم الحيوي والذى قد يرجع الى العادة الغذائية للحشرة المختبرة.بالإضافة إلى عوامل أخرى مثل الضغط البخاري والوزن الجزيئي لكل مركب مما يؤثر على مستوى السمية، كما أن نشاط المبيدات الحشرية في المواد المختبرة كان مرتبطاً بتركيبها الكيميائي، كما وجد أن التأثير يتناقص مع الوقت. وكان لزيت القرنفل أفضل التأثيرات بين الزيوت في الدراسة الحالية، حيث خفض من ظهور الحشرات البالغة وخفض نسبة الفقد في الوزن وزاد من الخفض في التعداد. ومع ذلك، فقد وجد ان زيت القرنفل يثبط نسبة الإنبات . كما أظهرت النتائج أن نسبة الإنبات لم تتأثر بطريقة الخلط.

المحكمـــــان:

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