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# Effects of clove and garlic oils, Malthion, Eco2fume® gas and Aluminum Phosphide on mortality and progeny production of two stored grain insect species, *Sitophillus oryzae* L. and *Tribolium castanum* Herbst

**Darwish, A. A. E[1]; M. A. El-Aw[1]; S. I. S. Askar[1]; and E. M. E. Al-Kodaby[2]**
[1]Plant Protection Department, Faculty of Agriculture, Damanhour University, Egypt.
[2]Agricultural Bank of Egypt.

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**ABSTRACT :** *The present study was carried out to evaluate the effect of clove and garlic oils as safe alternatives to chemical insecticides Malthion, Eco$_2$fume® gas and Gastoxin 57% Tablets (Aluminum Phosphide) in controlling two insect species; the rice weevil, Sitophillus oryzae L. (Coleoptera: Curculionidae) and the rust-red flour beetle, Tribolium castanum Herbst (Coleoptera: Tenebrionidae). In addition, the effects of tested plant oils and chemical insecticides on progeny production and seed germination percentages of wheat grains were also performed. The results showed a decrease in the number of progeny produced by S. oryzae and T. castaneum under all the treatments used. In general, the use of Gastoxin 57% (tablets) and Eco$_2$fume® gas led to the absence of progeny of both insects, where the percentage of reduction reached 100%, followed by garlic oil (reduction rates were 98.81 and 100% for S. oryzae and T. castaneum, respectively). The lowest reduction rates were under clove oil, as the reduction of progeny was 96.42 and 86.95% for S. oryzae and T. castaneum, respectively. On the other hand, the largest reduction in wheat grains germination was shown under Eco$_2$fume® gas treatment (81.00%) followed by Tablets (83.25%) then garlic oil (85.50%). In the contrast the highest grain germinations was presented in the control treatment (90.25%) followed by clove oil (86.50%).*

**KEY WORDS**: Malthion, Eco$_2$fume® gas, Aluminum phosphide, clove, garlic, oils, *Sitophillus oryzae* and *Tribolium castaneum*

## INTRODUCTION

Stored grains are considered one of the pillars of national security in Egypt. Through them, the Government can provide the main food grains from the time of their availability at harvest to the time of their decline at the end of the year. However, these stored grains suffer a large loss during the storage period. This loss may be due to improper storage or infestation by pests such as rodents or insects (Stejskal *et al.*, 2015). Globally, pests of stored grain cause the highest quality and quantity losses for stored goods (fields, 2006). FAO estimated that 10 to 25% of the food harvested worldwide is destroyed annually by insects. Insect pests cause damage to stored grains that would affect adversely on their nutritional value (Stejskal *et al*., 2015). In addition, changes caused by insects in storage environment may cause hot spots that provide suitable conditions for microorganisms that cause more losses makes the stored grains unsuitable for human consumption. In Egypt, the rust-red flour beetle, *Tribolium castaneum* (Herbst) (Coleoptera: Tenebrionidae) is coming on the top of stored grain pests (El-Desouky *et al*. (2018). According to Corrêa *et al*. (2013), the genus *Sitophilus* (Coleoptera: Curculionidae) encompasses species of great economic importance as stored grain pests worldwide. In order to better understand these pests and to find ways of managing them, numerous studies have been undertaken (Campbell, 2005).

Fumigation one of the most effective management method, in which insect pests are exposed to a poisonous gaseous environment, by applying a grain fumigant. Fumigants are chemicals available as gases, liquids and in solid formulations, but act on the insect pests of stored grains such as maize in gaseous state (Chakraverty *et al*., 2003). Fumigation is applied in buildings, warehouses; small bags, soil, seed and stored products, and fumes generated by fumigants enter the body of insect through the spiracles and spread to trachea and tracheoles and bind to the hemolymph components (Upadhyay and Ahmad, 2011). Accordingly, fumigation plays a key role in grain preservation as it controls insects developing inside and outside the grain, and crawling and hidden pests (Chakraverty *et al*., 2003).

The present study was carried out to evaluate the effect of clove and garlic oils as safe alternatives to chemical insecticides Malthion, Eco$_2$fume® gas and aluminum phosphide in controlling of *Sitophillus oryzae* and *Tribolium castanum*. Also, to compare the effective method of applied aluminum phosphide in controlling the two tested insects.

## MATERIALS AND METHODS

The present study was carried out at the experimental laboratory of plant protection department, Etay-Elbaroud agricultural Research Station during 2019 season to evaluate the efficiency of some essential oils (Clove and Garlic oils) compared with the traditional chemical insecticides (Malathion, Aluminum Phosphide and Eco$_2$fume® gas in controlling adults of rice weevil (*Sitophilus oryzae* L.) and Rust-red flour beetle (*Tribolium castaneum).*

### Stock culture of the insects

The two tested insect species were reared for a long period of years on whole wheat grains for *S. oryzae* and flour bran mixed with yeast 5% for *T. castaneum* under laboratory conditions in glass jars (1000 ml). In case of *S. oryzae*, the medium cultures were maintained under the same conditions in 500 ml glass jar containing 400-500 unsexed adults and approximately 500 g of grain wheat each according to (Halstead, 1963) where the adult weevils were oviposited for 7 days and then removed by passing the grains through a coarse sieve. The foods in the jars were renewed, when it was necessary. The weevil infested grains were then returned to stock cultures, which were maintained at rearing conditions (Chaisaeng *et al.*, 2010). Then, after 1-2 weeks old newly emerged weevils were used for experimental work. All experimental units (stock cultures, medium cultures, vials, …etc) were covered with pieces of muslin cloth fixed by rubber bands to prevent the insects from escaping and for air passage (Ahmed, 1996). Wheat grains (Giza-171) which used to culture the rice weevil were obtained from Etay El-Baroud, Agricultural Research Station, Egypt. The moisture content of the grains was about 12-14%.

## Insecticidal activity

### Plant oils:

The tested plant oils were purchased from El-Captain Company, Cairo, Egypt. Their information as well the used part is presented in (Table 1).

**Table (1): General information data of tested oils that have been used in this study.**

| Common name | Scientific name | Family | Part used |
|---|---|---|---|
| Clove oil | *Syzygium aromaticum* | Myrtaceae | Flower buds |
| Garlic oil | *Allium sativum* | Amaryllidaceae | Whole parts |

**- Clove oil:**

Clove is one of the most important herbs in traditional medicine and its scientific name is *Syzygium aromaticum*. It is locally know as Kronfol. This plant is belongs to the genus *Syzygium* and subfamily Myrtoideae of the family Myrtaceae. It is also an aromatic plant belongs to division of Magnoliophyta in the Kingdom Plantae (Alma *et al*., 2007).

**- Garlic oil.**

Garlic (*Allium sativum* Linn.) is an ancient medicinal plant that originated from Central Asia over 6000 years ago (Santhosha *et al*., 2013). Its strong pungent flavor potency is equal to that of 900 mg of fresh garlic/200 g of dehydrated powder. Sulfur compounds, mostly diallyl disulfide, diallyl sulfide, diallyl trisulfide, allylmethyl trisulfide, and diallyl tetrasulfide emit strong odor and are kept in GO as their active constituents (Casella *et al*., 2012).

### Application of plant oils:

Twenty grams of whole wheat grains were added in glass jars (350 ml). The whole wheat grains were mixed individually with the plant oils at concentrations series of (0.1, 0.3, 0.5, 1, 2, 4 and 6 ml/kg). The jars with their contents were gently shaken to ensure thoroughly admixture of the whole wheat grains and treatment plant oils. Whole wheat grains in the control group contained no plant oils. Each treatment and control was replicated three times. Twenty adults of *S. oryzae* and *T. castaneum* (1-2 weeks old) were introduced into the treated and control jars. All jars were kept at 30±2 $^{\circ}$C and 70+5% RH. *Sitophilas oryzae* and *T. castaneum* mortality was assessed 1, 3, 7 and 14 days post-treatment and the percentage of mortality were statistically computed for $LC_{50}$, confidence limits and slope for each oil.

## Insecticides used

### Malathion 1% Dust:

Malathion 1% dust was produced by Kafr El-Zayat chemical and pesticides company, Egypt. Malathion was used as a recommended insecticide for use in stored-grain insects control and as a reference for comparison with the two tested plant oils.
Recommended rate: 150 g/150 Kg grains.
Chemical name (IUPAC): diethyl (dimethoxythiophosphorylthio) succinate; *S*-1,2-bis (ethoxycarbonyl) ethyl *O, O*-dimethyl phosphoro-dithioate.

**Application of Malathion:**
Malathion formulation used in the tests contained 10 g of active ingredient (AI) per kilogram grains at concentrations of 0.25, 0.50, 0.75 and 1.00 (g/kg wheat) as well as the control group (0 g/kg wheat). The jars were shaken manually and overturned for 2 min to enhance the insecticide distribution in the entire grain mass. The treated glass jars were left to set for 30 min. Twenty adults of each of the two tested insect species, *S. oryzae and T. castaneum* (1-2 weeks old) were introduced to each jar and incubated at 30±2 °C and 70±5% R.H. Each concentration was replicated 3 times. Mortality of adults recorded after 1, 3, 7 and 14 days post-treatment. Log dose Probit (Ldp-Line) software was used to compute the toxicity index values.

**Fumigant gas:**
$Eco_2fume^{®}$ gas is a gaseous mixture of phosphine (2%) and carbon dioxide (98%). Wooden cages (1 $m^3$) covered with plastic fixed with snake sandbags were used for application of $Eco_2fume^{®}$ gas as a fumigation chambers. Three groups of periods were set up: 24, 48 and 72 h. Five concentrations of $Eco_2fume^{®}$ gas were prepared: 10, 20, 30, 40, and 50 g/$m^3$. Each concentration was replicated 3 times. Twenty adults of *S. oryzae* and *T. castaneum* (1-2 weeks-old) were added into each vial that contains 20 g grains of wheat. The vials were replicated three times and covered with muslin cloth for sufficient ventilation. The number of dead insects was recorded after exposure days ended. Insects were considered dead when no leg or antenna movements were observed after prodding with a fine brush. The percentages of mortality were statistically computed for $LC_{50}$, confidence limits and slope.

**- GASTOXIN 57% Tablets (Aluminum Phosphide):**
Tablets were used at a rate of 3 Tablet / $m^3$.
**The efficiency of application methods of aluminum phosphide against adults of *Sitophillus oryzae* and *Tribolium castaneum*:**

**A- Toxicity:**
In a wooden cages (1 $m^3$) covered with plastic fixed with snake sandbags were used for application of Gastoxin 57% (Tablets) as a fumigation chambers. Three groups of periods were set up: 24, 48 and 72 h. Four concentrations of Gastoxin 57% (Tablets) were prepared: 1, 2, 3 and 4 Tablets/$m^3$. The weight of one tablet is 1 gram. Each concentration was replicated 3 times. Twenty adults of *S. oryzae* and *T. castaneum* (1-2 weeks old) were added into each vial that contains 20 g grains of wheat. The vials were replicated three times and covered with muslin cloth for sufficient ventilation. The number of dead insects was recorded after exposure days ended. Insects were considered dead when no leg or antenna movements were observed after prodding with a fine brush. The percentages of mortality were statistically computed for $LC_{50}$, confidence limits and slope for Gastoxin 57% (tablets).

**B. Untreated grains + treated packages (3 tablet /1000 burlap bags):**
The same unit of wooden cages (1 $m^3$) covered with plastic fixed with snake sandbags were used as fumigation chambers. All storage burlap bags were fumigated with Aluminum phosphide at the rate of 3 tablets/$m^3$. All treated bags were lifted for 24, 48 or/and 72 h to enhance the insecticide absorbtion. Then, the untreated wheat grains were packged in the burlap bags. Weekly during the storage period that extended from April to July, samples (1 kg) of grains were taken for insect inspection and the number of each insect species of *Sitophilas*

*oryzae* and *T. castaneum* was counted. In Egypt, shounas open its doors to receive wheat quantities from farmers begining from April of each year.

**C. Treated grains (3 tablet /m$^3$) + untreated burlap bags:**
The same mannere was used as mentioned above where wheat grains were treated with Aluminum phosphide at the rate of 3 tablets Gastoxin /m$^3$ and then packged in the untreated burlap bags. Weekly during the storage period that extended from April to July, samples (1 kg) of grains were taken for insect inspection and the number of each insect species of *Sitophilas oryzae* and *T. castaneum* was counted.

**Progeny production test:**
The dead adult insects were discarded from the vials at various inspection periods, and then at the last inspection all insects were also removed from the media for studying the progeny production. The vials were left and incubated under the same conditions. Number of progeny production was inspected after 65 days from treatment and reduction percentages in progeny were calculated according to the following equation (Aldryhim, 1990):

$$\text{Reduction \%} = \left(\frac{\text{No. of adults emerged in control} - \text{No. of adults emerged in treatment}}{\text{No. of adults emerged in control}}\right) x100$$

**Seed germination:**
The germination test was conducted with slight modification. Where, undamaged wheat seeds were treated after seven days with clove and garlic oils at either $LC_{50}$ levels. After three months post-treatment, twenty wheat grains were transferred to cotton bed saturated with water in a sterile Petri dish (9 cm in diameter and 2 cm height). A parallel experiment was performed, however with untreated wheat grains. Three replicates were performed for each treatment. Germination percentages were recorded after seven days of treatment. Total germination percentages (GP) were calculated according the following equation:

$$\text{Germination \%} = \frac{\text{Number of normal seedlings}}{\text{Total number of seeds used}} \text{ x } 100$$

Germination was considered complete when both epicotile and root were present (Germination begins when the seed absorbs water and ends with the appearance of the radicle).

**Statistical Analysis:**
The data of mortality percentages from bioassays experiment were corrected by the natural control mortality according to Abbott's formula (1925). Then, the data of toxicity and biochemical experiments were submitted to the One-way (Completely Randomized Design) Analysis of variance (ANOVA). The Costat software (Version 6.400 for windows) was used for evaluating the statistical differences among means (Mean±SE) using the least significant difference (LSD test at 0.05). Bioassays results were subjected to the probit analysis program (Ldp-Line® software) to estimate $LC_{50}$ values, confidence limits (CLs), folds and slope for the examined tested compounds according to Finney (1971).

## RESULTS

### 1. Comparative between the relative toxicities of examined natural oils and malathion on adults of *S. oryzae* and *T. castaneum* under laboratory conditions.

By comparing the relative toxicity of garlic and clove oils with malathion on adult insects of *S. oryzae* during different periods of exposure (Table 1) it was found that there was a significant increase in killing efficiency for 50% of insects with the extension of the exposure period. In all tested periods, the malathion pesticide was the most efficient in killing 50% of the adult insects, as the lethal concentrations of 50% of the insects were 1.03, 0.58, 0.36 and 0.27 ppm after 1, 3, 7, 14 days of exposure, respectively, followed by garlic oil (16.84, 5.06, 1.76 and 0.89 ppm) under the same periods, while clove oil was the least efficient in the killing process, as $LC_{50}$ of it were 23.80, 6.24, 2.42 and 1.52 ppm after 1, 3, 7 and 14 days of exposure, respectively.

**Table (1): Relative toxicities of examined natural oils of clove and garlic compared to malathion on adults of *S. oryzae* under laboratory conditions.**

| Tested material | Line No. | $LC_{50}$ (ppm) | Lower Limit | Upper Limit | Index % | Folds | Slope |
|---|---|---|---|---|---|---|---|
| **Day 1** | | | | | | | |
| Malathion 1% D | 1 | 1.03 | 0.81 | 1.63 | 100 | 1.00 | 1.46 |
| Garlic oil | 2 | 16.84 | 10.08 | 38.18 | 6.09 | 16.41 | 1.02 |
| Clove oil | 3 | 23.80 | 12.90 | 67.02 | 4.31 | 23.20 | 0.97 |
| **Day 3** | | | | | | | |
| Malathion 1% D | 1 | 0.58 | 0.50 | 0.67 | 100 | 1.00 | 2.10 |
| Garlic oil | 2 | 5.06 | 3.41 | 15.61 | 11.40 | 8.78 | 1.10 |
| Clove oil | 3 | 6.24 | 4.39 | 21.09 | 9.24 | 10.82 | 1.20 |
| **Day 7** | | | | | | | |
| Malathion 1% D | 1 | 0.36 | 0.22 | 0.45 | 100 | 1.00 | 2.82 |
| Garlic oil | 2 | 1.76 | 1.48 | 2.13 | 20.26 | 4.94 | 1.40 |
| Clove oil | 3 | 2.42 | 1.72 | 3.80 | 14.78 | 6.77 | 1.50 |
| **Day 14** | | | | | | | |
| Malathion 1% D | 1 | 0.27 | 0.14 | 0.24 | 100 | 1.00 | 3.02 |
| Garlic oil | 2 | 0.89 | 0.74 | 1.08 | 30.89 | 3.24 | 1.35 |
| Clove oil | 3 | 1.52 | 1.24 | 1.91 | 18.06 | 5.54 | 1.35 |

The relative toxicity of garlic and clove oils was compared with malathion on adult insects of *T. castanum* during different periods of exposure (Table 2), it was found that there was a significant increase in killing efficiency for 50% of insects with the extension of the exposure period. In all tested periods, malathion pesticide was the most efficient in killing 50% of the adult insects, as the lethal concentrations of 50% of the insects were 0.81, 0.55, 0.30 and 0.13 ppm after 1, 3, 7, 14 days of exposure, respectively, followed by clove oil (32.15, 5.99, 2.21 and 1.27 ppm) under the same periods, while garlic oil was the least efficient in the killing process, as $LC_{50}$ of it were 124.02, 21.08, 4.17 and 1.35 ppm after 1, 3, 7 and 14 days of exposure, respectively.

**Table (2): Relative toxicities of examined natural oils of clove and garlic compared to malathion on adults of *T. castaneum* under laboratory conditions.**

| Tested material | Line No. | $LC_{50}$ (ppm) | Lower Limit | Upper Limit | Index % | Folds | Slope |
|---|---|---|---|---|---|---|---|
| **Day 1** | | | | | | | |
| Malathion 1% D | 1 | 0.81 | 0.66 | 1.12 | 100 | 1.00 | 1.50 |
| Clove oil | 2 | 32.15 | 15.75 | 114.11 | 2.52 | 39.74 | 0.92 |
| Garlic oil | 3 | 124.02 | 32.83 | 2416.99 | 0.65 | 153.30 | 0.57 |
| **Day 3** | | | | | | | |
| Malathion 1% D | 1 | 0.55 | 0.48 | 0.63 | 100 | 1.00 | 2.24 |
| Clove oil | 2 | 5.99 | 4.17 | 13.11 | 9.23 | 10.83 | 1.30 |
| Garlic oil | 3 | 21.08 | 9.63 | 89.72 | 2.62 | 38.12 | 0.58 |
| **Day 7** | | | | | | | |
| Malathion 1% D | 1 | 0.30 | 0.029 | 0.258 | 100 | 1.00 | 2.94 |
| Clove oil | 2 | 2.21 | 1.884 | 2.622 | 13.599 | 7.35 | 1.65 |
| Garlic oil | 3 | 4.17 | 3.011 | 6.457 | 7.201 | 13.89 | 0.88 |
| **Day 14** | | | | | | | |
| Malathion 1% D | 1 | 0.13 | 0.019 | 0.208 | 100 | 1.00 | 1.45 |
| Garlic oil | 2 | 1.27 | 0.655 | 4.565 | 10.142 | 9.86 | 1.15 |
| Clove oil | 3 | 1.35 | 1.136 | 1.637 | 9.556 | 10.47 | 1.55 |

**2. Progeny Production and reduction percentages for *S. oryzae* and *T. castaneum* under all tested treatments.**

The results shown in Table (3) and Fig. (1) confirmed a decrease in the number of progeny produced by *S. oryzae* and *T. castaneum* under all the treatments used. In general, the use of tablets and $Eco_2fume^{®}$ gas led to the absence of progeny of both insects, where the percentage of reduction reached 100%, followed by garlic oil, where the number of progeny reached about 1.5 and 0.00 with reduction rates of 98.81 and 100% for *S. oryzae* and *T. castaneum*, respectively. The lowest reduction rates were under clove oil, as the reduction of progeny was 96.42 and 86.95% for *S. oryzae* and *T. castaneum*, respectively.

**Table (3): Progeny production and reduction percentages for *S. oryzae* and *T. castaneum* 60 days after the removal of parental individuals on treated grains.**

| Treatment | Number of progeny (Mean±SE) | | | |
|---|---|---|---|---|
| | *S. oryzae* | % of R* | *T. castaneum* | % of R* |
| **Control** | $125.75^{a}$±6.48 | 112.76 | $5.75^{a}$±1.65 | --- |
| **Clove oil** | $4.50^{b}$±2.10 | 96.42 | $0.75^{b}$±0.25 | 86.95 |
| **Garlic oil** | $1.50^{b}$±0.64 | 98.81 | $0.00^{b}$±0.00 | 100.00 |
| **Tablets (GASTOXIN 57%)** | $0.00^{b}$±0.00 | 100.00 | $0.00^{b}$±0.00 | 100.00 |
| **$Eco_2fume^{®}$ gas** | $0.00^{b}$±0.00 | 100.00 | $0.00^{b}$±0.00 | 100.00 |
| **$LSD_{0.05}$** | **9.23** | | **2.25** | |

Means within each column followed by the same letter(s) are not significantly different; LSD test at 0.05.

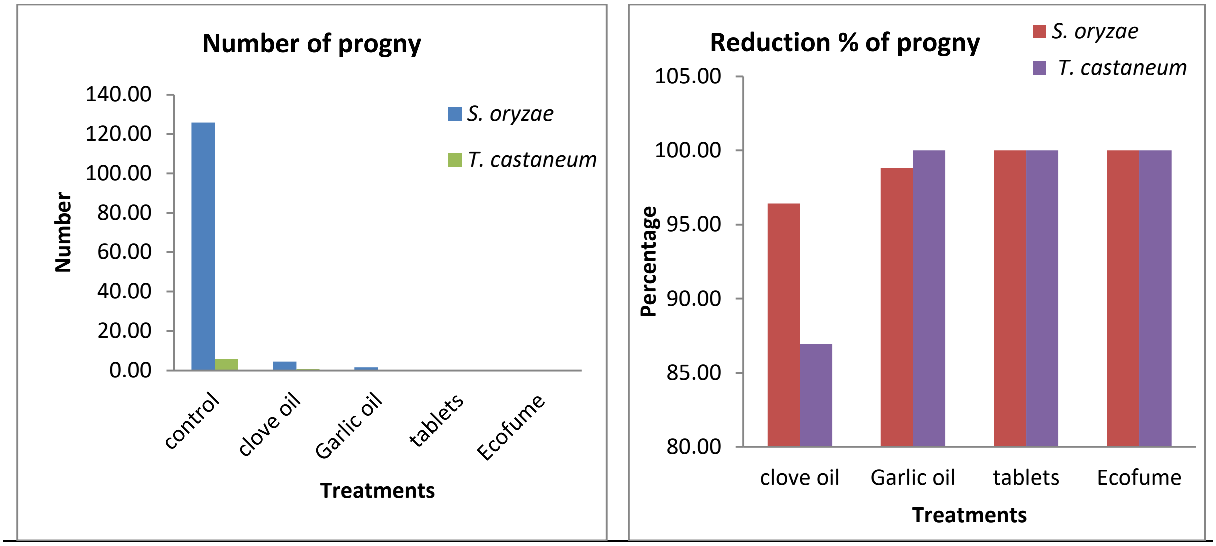


Fig. (1): Histogram of progeny production and reduction percentages for *S. oryzae* and *T. castaneum* 60 days after the removal of parental individuals in treated grains.

**2. Effect of different treatments on germination of wheat grains under different storage periods.**

The obtained results in Table (4) and Fig. (2) showed a wide difference among all tested treatments on their effect on wheat grains germination. All used treatments significantly decrease wheat grains germinations compared to control. The largest reduction in wheat grains germination was shown under Eco$_2$fume® gas treatment (81.00%) followed by Tablets (83.25%) then garlic oil (85.50%). In the contrast the highest grain germinations was presented in the control treatment (90.25%) followed by clove oil (86.50%).

The result also confirmed that wheat grains germination significantly decreased with the extended of storage periods where grains germinations were 92.25, 86.25, 80.75 and 76.50 % after 1, 2, 4 and 6 months of storage periods, respectively. In all cases treated wheat grains with Eco$_2$fume resulted in a large decrease in wheat grains germinations during all storage periods (90.00, 82.00, 78.00 and 74.00%) followed by tablets (93.00, 84.00, 80.00 and 76.00) then Garlic oil (93.00, 90.00, 82.00 and 77.00%) on the other hand, the lowest decrease in wheat grains germinations were presented in control with averages of 96.00, 93.00, 88.00 and 84.00% after 1, 2, 4 and 6 months, respectively.

**Table (4): Effect of different treatments on germination of wheat grains under different storage periods.**

| Treatment | Germinationm, % (Mean±SE) | | | | |
|---|---|---|---|---|---|
| | Month 1 | Month 2 | Month 4 | Month 6 | Mean±SE |
| **Control** | 96.00$^{a}$±1.63 | 93.00$^{a}$±1.00 | 88.00$^{a}$±1.63 | 84.00$^{a}$±2.83 | 90.25$^{a}$±2.66 |
| **clove oil** | 95.00$^{ab}$±1.15 | 89.00$^{b}$±1.91 | 83.00$^{b}$±2.52 | 79.00$^{b}$±1.91 | 86.50 $^{b}$±3.50 |
| **Garlic oil** | 93.00$^{bc}$±1.63 | 90.00$^{ab}$±3.46 | 82.00$^{bc}$±4.76 | 77.00$^{bc}$±1.91 | 85.50$^{bc}$±3.66 |
| **Tablets** | 93.00$^{bc}$±1.91 | 84.00$^{c}$±1.63 | 80.00$^{bc}$±3.65 | 76.00$^{bc}$±1.63 | 83.25$^{cd}$ ±3.64 |
| **Eco$_2$fume® gas** | 90.00$^{c}$±1.63 | 82.00$^{c}$±1.15 | 78.00$^{c}$±2.58 | 74.00$^{c}$±3.46 | 81.00$^{d}$±3.42 |
| **Periods mean** | 92.75 $^{a}$±0.85 | 86.25 $^{b}$± 1.66 | 80.75$^{c}$±1.39 | 76.50$^{d}$±1.41 | - |
| **LSD$_{0.05}$** | **2.86** | **3.13** | **4.69** | **3.38** | **3.04** |

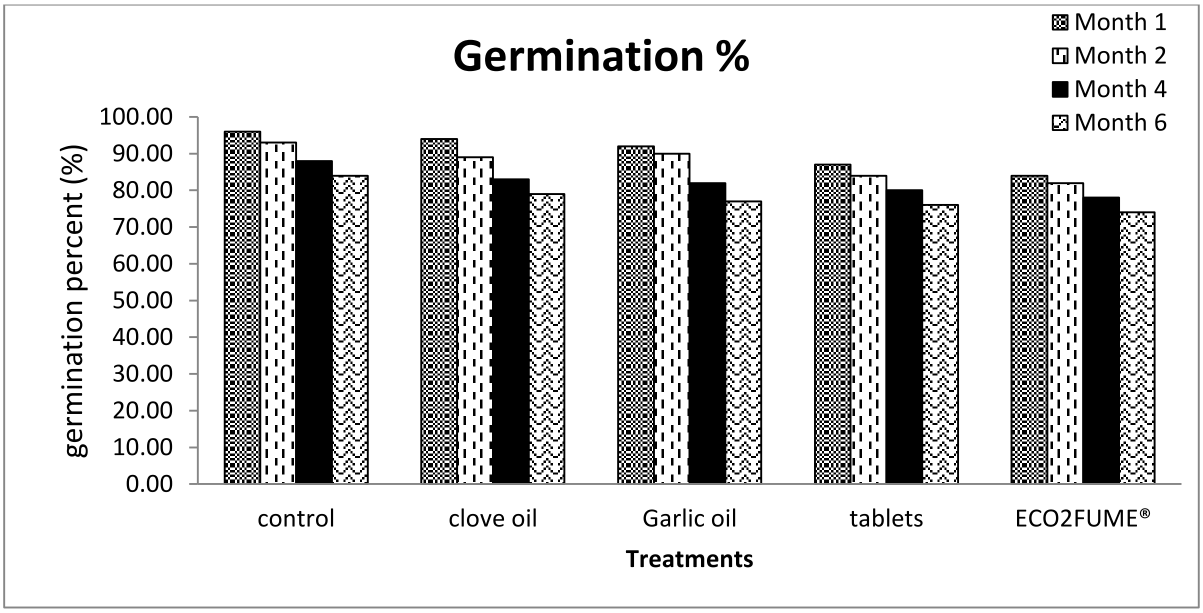


**Fig. (2): Effect of different treatments on germination of wheat grains under different storage periods**

## DISCUSSION

Use of the chemical control is the major elements on the integrated pest management for the granary insects because it had fast effect in reduce the infection. In this study the increase of clove oil concentrations resulted in significant increase in mortality percentage of *Sitophillus oryzae* and *Tribolium castanum* adults compared to the control after 1, 3, 7 and 14 days from exposure. Also, an increase in the mortality percentages in *S. oryzae* and *T. castanum* adults, with the extended of the period of exposure to clove oil at all rates. A higher mortality rate was observed after 14 days compared with all other exposure periods. In the previous studies cloves gave 90.0 % mortality at 8.0 and 16.0 µl /50 ml air, respectively, at exposure period of 24 hour for *S. oryzae* (Ahmed, 2010). This toxicity effect of clove oil may due to the main compound of clove were (83%) was 2-methoxy-4-(2-propenyl)-phenol the second most common compound (12%) was trans-caryophyllene. These two pure compounds showed high toxicity against *S. oryzae* and *T. castaneum*. The pure compounds were tested at the dosages found in clove oil. The mortality from 2-methoxy-4-(2-propenyl)-phenol was not significantly different from clove oil, suggesting that the activity of clove oil was solely due to this major compound (Zeng *et al*., 2010). Also, Abo-El-Saad *et al*. (2011) examined as a fumigant and repellent of clove oil agent against adults of the red flour beetle, *T. castaneum* and showed that various concentrations of the oil have revealed dramatic repellent activity against the tested insect, where it gave 100% repellency by 1.0, 0.8, and 0.2% clove oil at 4, 8, 10 min, respectively. The $RT_{50}$ and $RT_{95}$ were 1.1 and 8.0 min at 0.2% and 0.4, 2.6 min at 0.8%, respectively. In addition, fumigation assay has also exhibited strong fumigant activity toward the adults of *T. castaneum*. At 100 µL oil/L air, mortality was 75, 80 and 100% after 6, 7and 8 days exposure period with $LC_{50}$ and $LC_{95}$ 17 and 70 µL/L air, respectively. While, Ajayi and Olonisakin (2011) found that clove oil caused 100% mortality of both adult of *T. castaneum* at higher dosage rates. The $LC_{50}$ for clove was 0.40 (adults), 0.46 (larvae); WABP 0.21 (adults), 0.54 (larvae) and Ethiopian pepper 1.78 (adults), 0.67 (larvae)/ 20 g seed. Kalpana and Devi (2013) found that *S. oryzae* was susceptible to clove oil which resulting in 92% mortality.

Data confirmed that there was a significant difference in the effect of clove oil on *S. oryzae* and *T. castaneum* adult under all exposure periods. *S. oryzae* was more sensitive to clove oil than *T. castinum*, where the lethal concentration of 50% of *S. oryza* adults were lower than $LC_{50}$ values of *T. castaneum* adults. Similar results were obtained before by, Abo-El-Saad *et al*. (2011) who examined the fumigant toxicity of clove oil agent against adults of the red flour beetle, *T. castaneum* and showed that various concentrations of the oil have revealed dramatic repellent activity against the tested insect, where it gave 100% repellency by 1.0, 0.8, and 0.2% clove oil at 4, 8, 10 min, respectively. In addition, fumigation assay has also exhibited strong fumigant activity toward the adults of *T. castaneum*. At 100 µL oil/L air, mortality was 75, 80 and 100% after 6, 7and 8 days exposure period with $LC_{50}$ and $LC_{95}$ 17 and 70 µL/L air, respectively. Ajayi and Olonisakin (2011) found that the $LC_{50}$ for clove was 0.40 against *T. castaneum* adults.

The data revealed that the increase of garlic oil concentrations led to a significant increase in mortality percentage of *S. oryzae* and *T. castaenum* adults compared to the control after 1, 3, 7 and 14 days from exposure. An increase in the mortality percentages in *S. oryzae* and *T. castaenum* adults, with the extended of the period of exposure to garlic oil at all rates. A higher mortality rate was observed after 14 days compared with all other exposure periods. In the study of Yang *et al*. (2009) garlic essential oil coated in polyethylene glycol (PEG) NPs (nanoparticles) significantly control *T. castaneum* for 5 months after the application due to the slow release of the active components. Chaubey (2014) found that *A. sativum* oil caused fumigant and contact toxicity in *S. oryzae* adults. In fumigation toxicity assay, median lethal concentrations ($LC_{50}$) were found to 0.30 and 0.24 µl/cm$^3$ of *A. sativum* oil after 24 and 48 h exposure of *S. oryzae* adults respectively. In contact toxicity assay, $LC_{50}$ values were found to 0.17 and 0.13 µl/cm$^2$ of *A. sativum* oil after 24 and 48 h exposure of *S. oryzae* adults respectively. Abdel-Fattah and Boraei (2017) showed that the data represented that *Callosobruchus maculates* adults were more sensitive than *S. oryzae* adults for all tested oils except Garlic oil. Increasing the oils concentration and exposure time increased the fumigant toxicity of oils on insects. Omudu *et al*. (2018) evaluated powder of *Allium sativum* and *Ocimum gratissimum* leaf and admixture for comparative efficacy in controlling *S. zeamais*. And revealed that the plant materials tested showed significant adult mortality rate compared to control; as with the admixture material tested, the results indicates high significant differences among the treatments on mortality rate compared to control.

The results confirmed a decrease in the number of progeny produced by *S. oryzae* and *T. castaneum* under all the treatments used. In general, the use of tablets and Eco2fume led to the absence of Progeny of both insects. The toxicity of essential oils may due to their chemical components. Plant oils contained mono-terpenes such as 1,8-cineole, eugenol and camphor that can elicit mortality and inhibition of progeny production. For example the seed oil obtained from clove, (*S. aromaticum*) contains sesquiterpene, eugenol and caryophylline as major constituents. Piper species have been reported to contain piperricide, dihydropipe ricide and guineesine and Xyplopia aethiopica contains ß-phelladrene, α -pinene and eucalyptol (Olonisakin, *et al*. 2007). In another study, Ajayi and Olonisakin (2011) evaluated the toxic activities essential oil extracted from clove against the rust-red flour beetle, *T. castaneum* (Herbst.). The entire essential oil caused 100% mortality of both adult and larva of *T. castaneum* at higher dosage rates. The $LC_{50}$ for clove was 0.40 (adults), 0.46 (larvae); WABP 0.21 (adults), 0.54 (larvae) and Ethiopian pepper 1.78 (adults), 0.67 (larvae)/ 20 g seed. Ibrahim and Alahmadi (2015) studied the susceptibility of Rhinoceros beetle larvae, *Oryctes agamemnon*, to different concentrations of *Syzygium aromaticum* cloves under laboratory conditions and showed that clove oil is very promising for controlling *Oryctes* larvae.

A few studies evaluated the effect of essential oils in seed germinations such as in the present study the germinations wheat grains and cowpea seeds significantly affected the $LC_{50}$ value and $LC_{99}$ of all tested essential oils compared with control. In general grain germinations were less under $LC_{90}$ than $LC_{50}$ of all tested oil. Also, clove and camphor oil sharply decrease the viability of both wheat grains and cowpea seeds compared with garlic and mustard oils. One of the most dangerous effect of the essential oils their effect in seed germination several investigators studied the effect of essential oils in seed germinations. Devi and Devi (2013) who found clove at 0.59 μ l/cm$^2$ significantly reduce seed germination. In the same line, Adnan (2016) revealed that no significant differences were observed in germination rates of wheat seeds among treatments and control except in case of garlic oil. Sabina *et al.* (2017) found that, direct soaking of the wheat grain in common thyme (*Thymus vulgaris*) essential oil inhibited seed germination. In contrast, indirect treatment of the grain with the essential oil (i.e., fumigation) inhibited fungal growth without negative effects on seed germination. In the contrast of Priyani *et al.* (2003) showed that the percentage seed germination was not significantly different from that of the control in oil treated paddy in *C. citratus* treatment the seed germination was reduced. Also, Abo E l-Makarem *et al.* (2017) showed negligible decrease in germination of wheat grains treated with clove at $LC_{50}$ and $LC_{99}$ levels even 18 weeks post-treatment. Also, Yanaso *et al.* (2014) showed that clove powder was replaced by aloe (*Aloe vera (L.*) Burm.f.) powder because clove reduced the rice seed germination.

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