Eco-friendly tools for controlling of the rice weevil *Sitophilus oryzea* (Coleoptera: Curculionidae)

Hassan A.Mesbahm[1], Ahmed A. Mahomed[1] and, Mohammed S. Aajel[1]

ABSTRACT

Rice weevil (*Sitophilus oryzea* L.) has been reported as one of the primary post-harvest severe pests of cereal grains and their products. The pest prefers soft varieties of wheat grains. The current investigation aimed to assay eco-friendly tools for control the rice weevil (*Sitophilus oryzea*). The insecticidal activities of the botanicals and certain mineral fine dusts were measured based on their effect on adult mortality of the rice weevil *S. oryzea*. Certain selected parts of different fresh plants were used for the present investigation i.e. camphor, marjoram, conocarpus, black pepper, orange peel, Brazilian pepper, coal ash and sulfur. All the tested plant materials showed significant insecticidal activity against the rice weevils, but black pepper was the efficient one showing the least LC_{50} and LT_{50} values estimated by 0.003 g / 50g grain in 1.12 day. Among evaluated admixtures, binary combinations of black pepper + coal ash, black pepper + sulfur, and black pepper + orange peel, were the most potent ones. Our study suggests that botanicals and mineral fine dusts in binary mixtures may enhance the potency of constituent components for effective control of the rice weevils (*S. oryzea*). the datasuggests future trust for use of plant products and mineral fine dusts as a bio control for integrated controlling rice weevil *S. oryzae* control

Key words: Rice weevil, plant products, toxicity, LC_{50} & LT_{50}

INTRODUCTION

Post-harvest loss caused by pests may exceed 20% in poorly developed and tropical countries due to inadequate management practices and environmental conditions that allow rapid reproduction of pests (Brader *et al*., 2002). Storage is the one of the important postharvest practices that when properly executed, helps in reducing food shortage problems. Among the different losses in post-harvest operation, storage holds a major share (7.5%). According to food and agricultural organization (FAO), approximately 70% of the farm produce is stockpiled by farmers for various purposes (Pandi *et al*., 2018). Cereals are the major source of dietary protein for humans, worldwide. Cereal grain losses during storage could reach 50% of total harvest in some countries; a worldwide quality loss of grain is caused by insects (Fornal *et al*., 2007). Insects are a problem in stored grain throughout the world because they reduce the quantity and quality of grain (Rajendran, 2002; Warchalewski and Gralik, 2010).

Concerns about rapid evolution of insecticide resistance and the environmental polluting impact of insecticide residues on ecosystems and human health intensified the search for alternative eco-friendly strategies of pest management. Scientists are equally putting their efforts and attempting to find ways and means to reduce losses in storage due to store insect pests. Likewise, *Sitophilus* spp. are one of the most serious stored grain pests, globally (Zaghloul *et al*., 2012). They feed internally by boring into stored grains. The adults feed mainly on the endosperm, thus reducing the carbohydrate content, while the larvae feed preferentially on the germ of the grain and remove a large percentage of proteins and vitamins (Belloa *et al*., 2000).

Control of the stored grain insects around the world depends primarily upon applications of organophosphorus, pyrethroid insecticides and the fumigants (i.e. Aluminum Phosphide and phosphine gas). Contact insecticides and fumigants have been used for a long time to protect stored products from insect pests (Daglish, 2006). In response to a growing market demand for food stuffs that are free of pesticide residues, and because stored-product insects are developing resistance to insecticides, such chemicals have been remained under increasingly restrictive policies over the past years (Kljajic and Peric, 2005). New trends and safe means in the management of stored grain insects are needed. Therefore, interest in has been shown plant-derived compounds as alternatives to the synthetic insecticides against the rice weevil *S. oryzea*. For long-term protection of stored products there is a growing demand to replace chemical insecticides due to their effects on human health and environmental safety. Particulate materials, such as photoproducts and mineral dusts have been extensively tested as viable alternatives (Collins, 2006). In the past two to three decades, researchers have attempted to identify botanicals with better insecticidal potential against storage pests (Saad etal.2017; Mohamed etal.2009). However, there is a lack of information on the potency of botanical combinations, their toxicology, and optimal application rates. They are biodegradable and are relatively safe to natural enemies and higher organisms (Bayih *et al*., 2018). Therefore, the efficacy of such eco-friendly materials have been evaluated in this investigation.

[1.] Department of Plant Protection, Faculty of Agriculture, Saba Basha, Alexandria University, Alexandria, Egypt
Received September 06, 2018, Accepted September 30, 2018

MATERIALS AND METHODS

The present research was carried out at the Faculty of Agriculture, Saba Basha, Alexandria University, Egypt, during the seasons of 2017 and 2018 to study new approaches for controlling the rice weevil under laboratory conditions.

Table 1. The evaluated natural plants in the carried-out laboratory tests and the principle chemical constituents of used plant parts

Common name	Scientific name	Part used	Chemical compounds *
Camphor	*Cinnamomum camphora*	Leaves	α-Pinene, camphene, β-pinene, sabinene, phellandrene, limonene, 1,8-cineole, y-terpinene, p-cymene, terpinolene, furfural, camphor, linalool, bornylacetae, terpinen-4-ol, caryophyllene, borneol, piperitone, geraniol, safrole, cinnamaldehyde, methyl cinnamate and eugenol
Marjoram	*Origanum majorana L*	Leaves	Flavonoides , Terpenes , Camphor , Ocimene and Cadinene
Conocarpus	*Conocarpus lancifolius*	Leaves	Trimethoxy-ellagic glycoside, 3,3',4'-tri-O-methylellagic acid 4-O-beta-glucupyranuronide and twelve phenolics compounds
Black pepper	*Piper nigrum*	Fruits	including beta-bisabolene, camphene, beta-caryophyllene, and many other terpenes and sesquiterpenes), up to 9% alkaloids (especially pipperine, largely responsible for the herb's acrid taste), abo]ut 11 % proteins, and small amounts of minerals. White pepper contains very little volatile oil.
Orange peel	*Citrus sinensis*	Fruit peels	Limonene, Linalool, Decanal, Octanal, Myrcene, α-Pinene, Sabinene, β-Pinene, δ-3-Carene .
Brazilian pepper	*Schinus terebinthifolius*	Fruits	amyrin, behenic acid, bergamont, bicyclogermacrene, bourbonene, cadinene, cadinol, calacorene, calamenediol, calamenene, camphene, car-3-ene, carvacrol, caryophyllene, cerotic acid, copaene, croweacin, cubebene, cyanidins, cymene, elemene, elemol, elemonic acid, eudesmol, fisetin, gallic acid, geraniol butyrate, germacrene, germacrone, guaiene, gurjunene, heptacosanoic acid, humulene, laccase, lanosta, limonene, linalool, linoleic acid, malvalic acid, masticadienoic acid, masticadienonalic acid, masticadienonic acid, muurolene, muurolol, myrcene, nerolhexanoate, octacosanoic acid, oleic acid, paeonidin, palmitic acid, pentacosanoic acid, phellandrene, phellandrene, phenol, pinene, piperine, piperitol, protocatechuic acid, quercetin, quercitrin, raffinose, sabinene, sitosterol, spathulene, terpinene, terpineol, terpinolene. and tricosanoic acid
Coal ash		Powder	phosphates, chlorides, sulfates, and halides
Sulfur		Powder	Sulfur

*Chemical compounds according for: Greenwood and Earnshaw (1997); Abdel -Mohsen and Maisa (2010); Toi *et al*. (2003); Durak, *et al*. (2004), Almeida, *et al*. (2007); Agarwal, *et al*. (2008).

Culturing and rearing conditions of *Sitophilus oryzea* (L.)

Parent stock of susceptible strain of *S. oryzae*, was originally obtained from an established laboratory culture Department of applied entomology Faculty of Agriculture, Shatby, Alexandria University, reared on disinfested wheat grains at ambient conditions of 28 ±2 °C and 75±5% R.H in a grain storage research laboratory, Faculty of Agric. (Saba Basha), Alexandria University, Alexandria, Egypt. The food medium (rice) was used for bioassay tests. *S. oryzae* adults were transferred onto the grains in cleaned and sterilized 1-liter jars, reared for several generations and from this, another established culture for the experiment was maintained as new generations emerged. The age of the adults that have been used for the test was about 7-14 days. The jars were sealed with filter paper and maintained at 28 ±2 °C and 75±5% R.H.

Evaluation of certain plant materials and sulfur as fine powders against *S. Oryzae*

Certain selected parts of different plants collected from Alexandria markets were used for the present investigation as recorded in Table (1). The used parts of each plant were dried in the open air and thereafter, were put in an electric oven at 60ºc till complete dryness. These dried parts of each plant species were ground by means of electric mill till the attainment of the completely desired fineness. The obtained final powdered parts of each plant species were sieved with 100-mesh sieve to obtain their fine before the application to the grains. Herein, the collected fine tiny particles, of sieved ground plant parts, from the pores 100-mesh of the sieve are considered the fine dusts. Soft plant powders were evaluated in four concentrations level (1, 2.5, 3.5, 5 and 2.0/50 g of rice). Four replicates per test concentration for each treatment were fixed by weight of rice (50 g) in the glass jar after sterilization of rice and glass jars as well as in the oven at 70 °C for one hour. The tested powder was mixed with rice seeds thoroughly to ensure that the entire surface of the seeds was covered with powder. Each jar was covered with a piece of Clingfilm®, then moved up and down (10 x) and rotated by hand for 2 minutes with short periods of vibration at 15, 30, 45, 60, 90 and 120 sec. The jars were closed for a few minutes after they were shaken to allow any free dust to stabilize. After that, 25 insects (non-abstract adults) were counted and replaced within the jar. Insects exposed to the treated surface. The jars were covered with the previous piece of Clingfilm®.

Evaluation of the admixtures of black pepper with the seven different fine dusts against the rice weevil *S. oryzae*

Preparation of mixtures of black pepper and other seven powders was carried out in the same previously mentioned laboratory conditions. The admixtures were as follows: (1: 1) (0.5 + 0.5) g, (1:2) (0.5 + 1.0) g and (1: 3) (0.5 + 1.5) g. The bioassay experiment was carried out according to the previously mentioned.

Statistical Analysis

Mortality/ time regression analysis for the treatments of the adults was done by a program adapted as a BASIC computer program to calculate LT and LC, and associated parameters (slope [b] and regression coefficient [r^2]). To determine the significant differences among treatments mean values at 0.05 probability level, all data were subjected to one-way analysis of variance (ANOVA) followed by Duncan multiple range test (Duncan, 1955). For bioassay under laboratory conditions, concentration-mortality regression was estimated by Probit analysis (Finney, 1971). Moreover, to determine the significant differences among two means, *t*-test was applied.

RESULTS AND DISCUSSION

Efficacy of certain natural plant products and sulfur as fine dusts against the rice weevils (*S. oryzea*)

Eight fine dust materials were evaluated against rice weevils (*S. oryzea*) as presented in Table (1), in four different exposure time i.e. 1, 3, 5 and 7 days. Data presented in Table (2) showed that application rate of (5 g/50 g grains) achieved the highest values of dead adults/25 adults ranged from 7.75 (Majoram and Conocarpus) to 15.25 (Orange peel) after one day post treatment. While the lowest application rate (1.0 g/50g grains) showed the lowest values. The general mean of dead adults showed that orange peel recorded the highest value (8.75) followed by camphor (8.56), black pepper (8.0) followed by Brazilian pepper (5.13) and the lowest mean value was 4.68 recorded to sulfur, 4.88 (majoram and conocarpus) (Table 2 and Figure 1).

After 3 days exposure time, the data was at the same trend of the 1st day of exposure time that increased with the concentration (Table 1). For the first application rate (1g/50 g grains) the data doubled three times and ranged from 3.0 (orange peel) to 6.25 (Black pepper). While with (2.5 g/50 g grains) ranged from 5.75 (majoram, Brazilian pepper and conocarpus) to 10.0 (coal ash). For the highest concentration (5g/50 g grains), the results showed increase in mortality ranged from 9.50 (camphor) to 16.75 dead adults/25 adults (coal ash) as recorded in Table (2) and Figure (1).

The overall values for the second treatment (3 days), the dead adults/25 adults ranged from 6.75 to 11.25 and the lowest values recorded to majoram and conocarpus by 6.75, while the highest values were 11 and 11.25 for Black pepper and coal ash, in respect (Table, 1). Results in Table (2) and Figure (1) for the five exposure days showed the highest values of dead adults/25 adults 21.75 (Black pepper) at the application rate (1g/50g grains), while the lowest values were 5, 7.75 and 8 for Orange peel, Coal ash and Brazilian pepper, respectively. With increase of concentration the mean of dead adults/25 adults increased under (5g/50g grains) from 14.75 to 25. The maximum values were 25 for Black pepper and Sulfur, while the minimum value was 14.75 detected to Brazilian pepper. The general mean was very high (24.19) with Black pepper forward by 20.50 (Sulfur) and 17.06 (Majoram and Conocarpus), respectively as shown in Table (2) and Figure (1).

Finally, under 7 days of exposure time, Black pepper showed the highest mean value (24.81), followed by sulfur (21.94), and the lowest mean were 13.13 (Brazilian pepper), 15.06 (coal ash), 15.75 (camphor) and 15.88 (orange peel) as found in Table (2) and Figure (1).

From the previous data, black pepper showed high significant efficacy against the rice weevil. Black pepper was mixed with the other seven materials by three mixture rates i.e. 1:1 (0.5 g black pepper: 0.5g other materials)/50 g rice, 1:2 (0.5 g Black pepper: 1.0 g other materials) and 1:3 (0.5 g Black pepper: 1.5 other materials) for three exposure time were 2, 5 and 7 days as shown in Table (3) and Figure (2). The results for 2 days exposure time in the mixture with Black pepper and other natural materials under high dose rate showed increase and decrease in mortality based on the mixing materials i.e. black pepper & camphor increased from 3.75 to 6, black pepper & majoram from 3.75 to 7.25, black pepper & Brazilian pepper from 3.75 to 6.75, black pepper & conocarpus from 7.75 to 12.75, black pepper & sulfur from 10 to 12.5 and black pepper & coal ash from 10 to 13.75. The general mean ranged from 5 (black pepper & camphor) to 11.83 dead adults/25 adults (black pepper & coal ash) as found in Table (3).

Concerning to the effect of mixture of black pepper and other materials after 5 days, results in Table (3) showed that at high mixture rate (0.5+1.5 g) detected the highest values of dead adults/25 adults ranged from 10.50 (black pepper & conocarpus) to 18.25 (black pepper & Ash), followed by 17.25 (black pepper & sulfur). The general mean ranged from 8.25 (black pepper & camphor) to 15.92 (black pepper & coal ash), forward by 15.58 (black pepper & sulfur) as shown in Table (3).

Finally, when using the mixture of Black pepper with other natural materials for seven days post treatment (Table 3), results indicated that Black pepper and Sulfur, and Ash recorded the highest mean values were 20.67 and 20.08, respectively, forward by black pepper with Orange peel (18.42). The lowest mixture recorded to black pepper with conocarpus (12.67), Black pepper with camphor (13.25), black pepper with majoram (13.33).

When comparing between the individual and mixture materials in Table (2&3) after 5 days of exposure time against the rice weevil's data showed that decrease in values in mixture comparing with the pure material i.e. majoram (17.06), majoram & black pepper (8.33), and camphor (13.75), camphor & black pepper (8.85), Brazilian pepper (11.13), Brazilian pepper & black pepper (8.50). While, some other computation showed increase such as orange peel (10.44) increased to (14.17), coal ash (11.25) to 15.92, sulfur (8.38) to (15.58), in respect. In the other hand, under 7 days of exposure time five mixture showed decrease in values comparing with pure material such as camphor (17.75) decreased to (13.25), majoram (17.68) to (13.33), Brazilian pepper (13.13) to (13.13), conocarpus (19.06) to (12.67) and sulfur (21.94) to (20.08), in respect for the single and mixing materials (Table 1&2). While, mixture of Orange peel and coal ash with black pepper showed high values (18.42) (15.88) and (20.67) (15.6), respectively.

LC_{50} and LT_{50} of natural plant fine dusts against the rice weevils (*S. oryzea*)

LC_{50} and LT_{50} were determined to the pure and mixture materials against the rice weevils (*S. oryzea*). Data in Tables 4-7 showed the LC_{50} (concentration to kill 50% of weevils) and Lt50 (time to kill 50% of weevils). When using Majoram the LC_{50} was 1.21 g/50 g grains range (0.95-1.49) and the mixture with Black pepper was 1.16 (range: 1.12-1.21 g) with no significant variation (Tables 4 &5), at the same time the LT_{50} for this sample was 2.27 day in range (1.90-2.69 days and 4.24 days (3.43-5.27 days) for the mixture. Thus, the mean results suggest to use the pure material of majoram due to the dose and time of exposure based on the results illustrated in Tables 6&7.

For camphor, data in Table 4 &5 indicated that the LC_{50} and LT_{50} for camphor and mixing with black pepper against the rice weevils (*S. oryzea*). Data indicated that using pure camphor is more efficient than mixture and the values were 0.97 g (range: 0.67-1.32 g), 1.18 g (range: 1.13-1.23 g), 1.67 day (range: 1.36-2.01 days) and 4.46 days (range: 3.46-5.78 days) for LC_{50} and LT_{50} in pure and mixture powder, respectively (Table 6&7).

LC_{50} and LT_{50} values for the Brazilian pepper were 2.19 g (3.41 days) and 1.7 g (4.43 days), while in conocarpus the value was 0.59 g (1.72 days), 1.20 g (5.63 days), in respect for pure and mixture conocarpus with black pepper (Table 4&5). No significant variation was observed between the orange peel as pure material (0.89 g) and mixture with Black pepper (0.99 g) in 1.72 days and 5.63 days, in respect.

For Ash, the results of LC_{50} were (1.71 and 1.03 g) for pure and mixture material, in respect, while for Lt_{50} the value were (1.76 and 1.42 days) as presented in Table 4&5. On the other hand, sulfur showed (1.86 and 1.01 g), (1.86 and 1.77 days) for both pure and mixing materials. Finally, black pepper showed the lowest LC_{50} and LT_{50} were 0.003 g and 1.12 days, that mean this material could be useful in control the rice weevils *(S. oryzea)* as recorded in the present investigation (Tables 6&7).

Therefore, the mortality percentages showed that the increase of mortality was dependent on application rate and exposure time in all tests. The obtained results of the present research was in agreement with Hussein *et al*., (2017) who evaluated that toxicity effects of three extracted fractions from black pepper fruits, *Piper nigrum* L, in four concentrations against stored grain pests, red rusty flour beetle *Tribolium castaneum* Hbst. and their stages, and *Sitophilus oryzae* L., the adult rice weevil. The obtained results revealed that the etheric fraction caused higher mortality than that of two other solvent fractions, towards all target pests. The adult rice weevil was the most susceptible, followed by the larvae, adult > eggs > pupae of red flour beetle. The mortality percentage reached to 100% at a concentration 2.5% (w/w) after 21 day of treatment of adult rice weevil, while was 100% at conc. 5% (w/w) in same period in case of adult red flour beetle, and the LC_{50} between both adult pests were 2.43 and 3.52, respectively. The reduction in F_1 progeny in all treatments were greatly significant and was higher than the mortality in low concentrations, ranged from 73% to 100% according to the concentration and insect. By using GC/MS analysis was found a functional groups and compounds in the oil, were

Table 2. Efficacy of certain natural plant and sulfur as fine dusts against the rice weevil *S. oryzae*

Application rate (g/50 g grain)	Mean No of dead adults/25 of *S. oryzae*					$LSD_{=0.05}$
	1	**2.5**	**3.5**	**5**	**Mean**	
After 1 day exposure						
Majoram	1.75	4.00	6.00	7.75	4.88	
Camphora	3.00	5.50	11.00	14.75	8.56	
Braziliun pepper	2.25	4.25	6.00	8.00	5.13	
Black pepper	4.25	7.00	7.75	13.00	8.00	
Orange peel	1.75	5.50	12.50	15.25	8.75	**0.502**
Coal ash	1.50	4.75	10.25	14.00	7.63	
Sulfur	1.25	3.00	6.25	8.00	4.63	
Conocarpus	1.75	4.00	6.00	7.75	4.88	
$LSD_{=0.05}$			0.443			
After 3 days exposure						
Majoram	4.00	5.75	7.00	10.25	6.75	
Camphora	5.75	7.50	12.25	16.25	10.44	
Braziliun pepper	4.00	5.75	7.00	9.50	6.56	
Black pepper	6.25	8.75	13.00	16.00	11.00	
Orange peel	3.00	6.25	14.75	17.75	10.44	**0.661**
Coal ash	6.00	10.00	12.25	16.75	11.25	
Sulfur	5.00	7.00	9.75	11.75	8.38	
Conocarpus	4.00	5.75	7.00	10.25	6.75	
$LSD_{=0.05}$			0.468			
After 5 days exposure						
Majoram	12.75	17.25	18.25	20.00	17.06	
Camphora	8.00	11.00	17.00	19.00	13.75	
Braziliun pepper	8.00	10.00	11.75	14.75	11.13	
Black pepper	21.75	25.00	25.00	25.00	24.19	
Orange peel	5.00	10.50	17.25	20.50	13.31	**0.892**
Coal ash	7.75	11.50	13.75	18.50	12.88	
Sulfur	14.75	18.50	23.75	25.00	20.50	
Conocarpus	12.75	17.25	18.25	20.00	17.06	
$LSD_{=0.05}$			0.512			
After 7 days exposure						
Majoram	14.75	15.00	19.00	22.00	17.68	
Camphora	9.25	13.25	18.50	22.00	15.75	
Braziliun pepper	9.25	11.75	14.75	16.75	13.13	
Black pepper	24.25	25.00	25.00	25.00	24.81	
Orange peel	6.00	12.50	22.00	23.00	15.88	**1.396**
Coal ash	10.00	13.00	16.25	21.00	15.06	
Sulfur	17.00	20.75	25.00	25.00	21.94	
Conocarpus	15.00	18.50	20.25	22.50	19.06	
$LSD_{=0.05}$			0.916			

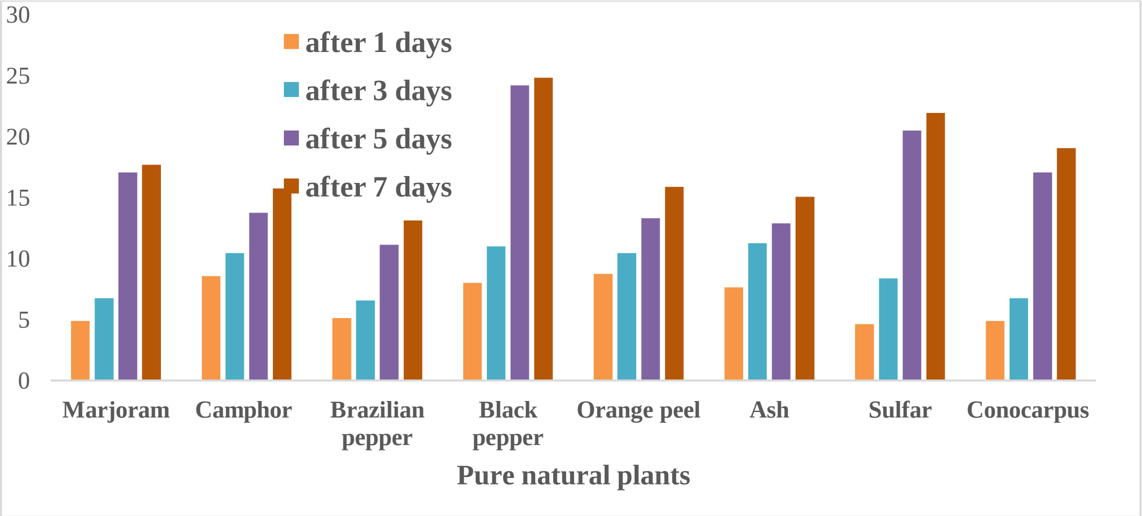

Figure 1. Effect of certain evaluated different plant fine dusts on the mortality percentages of rice weevil *S. oryzae* adults

Table 3. Efficacy of binary mixtures of used materials with the black pepper as fine dusts against the rice weevil *S. oryzae* under laboratory condition

Black Pepper with current materials	Mean No of dead insects/25 adults/ Tested mixture				
	after 2 days				
	1:1 (0.5+0.5) g	1:2 (0.5+1.0) g	1:3 (0.5+1.5) g	Mean	LSD=0.05
Camphor	3.75	5.25	6.00	5.00	
Majoram	3.75	6.50	7.25	5.83	
Brazilian pepper	3.75	6.25	6.75	5.58	
Orange peel	7.75	9.50	12.75	10.00	**1.24**
Conocarpus	4.00	6.00	6.75	5.58	
Sulfur	10.00	10.00	12.50	10.83	
Coal ash	10.00	11.75	13.75	11.83	
LSD=0.05		0.54			
	after 5 days				
Camfor	6.25	7.75	10.75	8.25	
Majoram	6.50	8.00	12.00	8.83	
Brazilian pepper	6.50	8.25	10.75	8.50	
Orange peel	12.00	14.25	16.25	14.17	**1.01**
Conocarpus	7.25	8.00	10.50	8.58	
Sulfur	14.25	15.25	17.25	15.58	
Coal ash	14.00	15.50	18.25	15.92	
LSD=0.05		0.6			
	After 7 days				
Camfor	10.50	13.50	15.75	13.25	
Majoram	10.50	13.25	16.25	13.33	
Brazilian pepper	11.00	12.75	15.75	13.17	
Orange peel	16.25	18.00	21.00	18.42	**1.19**
Conocarpus	10.75	12.00	15.25	12.67	
Sulfur	18.50	19.25	22.50	20.08	
Coal ash	18.50	19.75	23.75	20.67	
LSD=0.05		**0.74**			

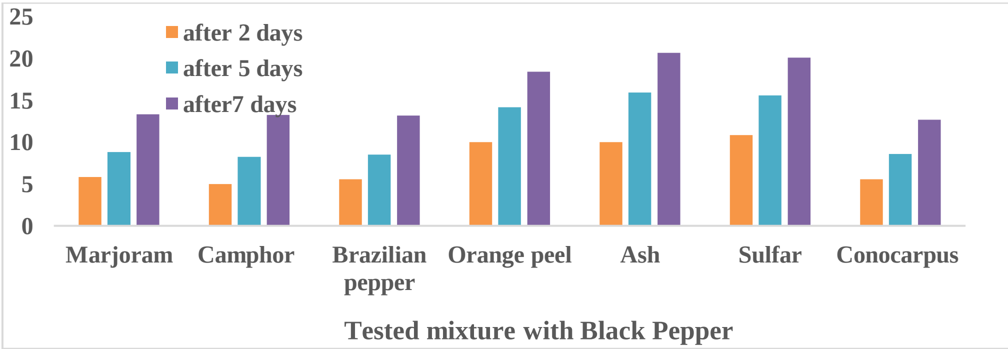

Figure 2. Effect of certain evaluated mixture of different plant fine dusts with Black pepper on the mortality percentages of rice weevil *S. oryzae* adults

Table 4. the calculated LC_{50} values of evaluated fine dusts against the rice weevil *S. oryzae* under laboratory conditions

Plant powder	Bioassay period (days)	LC05 (g / 50g grain)	LC50 (g / 50g grain)	LC95 (g / 50 g grain)	slope
Majoram	1	0.74 (0.38-1.30)	8.60 (5.47-14.45)	100.49 (25.87-485.2)	1.54 ± 0.099
	3	0.44 (0.20-0.86)	5.46 (4.04-7.67)	67.94 (22.26-250.87)	1.50 ± 0.078
	5	0.21 (0.10-0.40)	1.57 (1.27-1.91)	11.55 (7.58-18.87)	1.90 ± 0.068
	7	0.20 (010-0.36)	**1.21 (0.95-1.49)**	7.23 (5.30-10.39)	2.11± 0.073
Camphor	1	0.46 (0.18-1.00)	8.33 (5.07-14.98)	152.0 (29.28-1102.3)	1.30± 0.083
	3	0.25 (0.08-0.64)	4.85 (3.55-6.95)	93.53 (23.99-487.66)	1.27±0.069
	5	0.07 (0.01-0.24)	1.17 (0.79-1.63)	19.72 (9.36-50.14)	1.34±0.064
	7	0.10 (0.03-0.25)	**0.97 (0.67-1.32)**	9.33 (5.99-16.04)	1.66 ±0.071
Braziliun pepper	1	0.74 (0.38-1.32)	8.97 (5.57-15.51)	108.8 (26.50-563.09)	1.51± 0.095
	3	0.39 (0.16-0.86)	6.49 (4.41-10.16)	106.7 (26.16-572.63)	1.35± 0.078
	5	0.17 (0.05-0.46)	3.16 (2.51-4.05)	60.01 (19.01-244.41)	1.28± 0.065
	7	0.14 (0.04-0.38)	**2.19 (1.74-2.72)**	34.01 (14.07-99.44)	1.38± 0.06
Black pepper	1	0.63 (0.25-1.32)	12.52 (6.15-29.35)	250.6 (32.32-3000.3)	1.26±0.097
	3	0.25 (0.10-0.56)	3.33 (2.71-4.16)	43.68 (17.29-131.12)	1.47± 0.067
	5	0.02 (0.00-0.14)	0.19 (0.03-0.54)	2.17 (1.56-3.19)	1.55 ± 0.16
	7	0.0001 (0.0-106)	**0.003 (0.0012-152)**	0.73 (0.00002-26.38)	0.72 ± 0.26
Conocarpus	1	0.86 (0.38-1.68)	16.82 (6.90-49.26)	331.03 (32.0-5627.6)	1.27± 0.11
	3	0.55 (0.30-0.93)	4.75 (3.78-6.10)	41.33 (18.00-106.56)	1.75 ± 0.082
	5	0.03 (0.0-0.19)	0.95 (0.54-1.49)	26.21 (9.87-93.86)	1.14 ±0.064
	7	0.02 (0.0-0.15)	**0.59 (0.25-1.14)**	19.48 (7.60-69.76)	1.082 ±0.067
Orange peel	1	0.41 (0.14-1.0)	9.51 (5.28-19.33)	219.83 (31.8-2350.5)	1.20 ±0.083
	3	0.22 (0.07-0.61)	4.90 (3.53-7.18)	107.31 (24.86-644.4)	1.22±0.068
	5	0.07 (0.01-0.24)	1.17 (0.79-1.63)	19.72 (9.36-50.41)	1.34±0.064
	7	0.07 (0.02-0.22)	**0.89 (0.57-1.28)**	11.17 (6.53-21.8)	1.49± 0.069
Coal ash	1	0.93 (0.59-1.40)	6.30 (4.77-8.52)	42.85 (18.40-109.68)	2.59 ± 0.12
	3	0.28 (0.12-0.57)	3.17 (2.61-3.88)	36.12 (15.84-95.07)	1.55± 0.068
	5	0.20 (0.07-0.45)	2.46 (2.01-2.99)	30.58 (13.90-78.24)	1.50± 0.065
	7	0.15 (0.06-0.36)	**1.71 (1.35-2.12)**	18.98 (10.17-40.07)	1.57± 0.064
Sulfur	1	1.22 (0.90-1.62)	4.75 (4.21-5.35)	18.50 (13.24-26.30)	2.78± 0.094
	3	0.84 (0.61-1.13)	3.42 (3.03-3.85)	13.89 (10.58-18.57)	2.69 ± 0.068
	5	0.59 (0.43-0.78)	2.19 (1.92-2.48)	8.18 (6.68-10.19)	2.87± 0.062
	7	0.46 (0.32-0.63)	**1.86 (1.60-2.14)**	7.55 (6.11-9.54)	2.69± 0.059

Table 5. The calculated LC_{50} values of the evaluated mixtures of fine dusts against the rice weevil *S. oryzae* under laboratory conditions

Plant powders mixtures	Bioassay period (days)	LC_{05} (g / 50g grain)	LC_{50} (g / 50g grain)	LC_{95} (g / 50 g grain)	slope
Black pepper & Camphor	2	0.95 (0.79-1.10)	1.46 (1.29-1.68)	2.26 (1.54-3.50)	8.72± 7.72
	5	0.84 (0.65-1.05)	1.35 (1.24-1.49)	2.18 (1.51-3.33)	7.96 ± 6.6
	7	0.74 (0.53-0.98)	**1.18 (1.13-1.23)**	1.89 (1.44-2.59)	8.02± 6.2
Black pepper & Majoram	2	1.47 (0.66-1.04)	1.47 (1.29-1.70)	2.31 (1.53-3.74)	8.29±7.59
	5	0.93 (0.76-1.10)	1.33 (1.24-1.45)	2.12 (1.51-3.12)	8.22±6.54
	7	0.77 (0.59-0.97)	**1.16 (1.12-1.21)**	1.76 (1.44-2.21)	9.18±6.23
Black pepper & Conocarpus	2	0.92 (0.76-1.10)	1.45 (1.28-1.66)	2.27 (1.53-3.57)	8.42±7.47
	5	0.67 (0.30-1.23)	1.45 (1.18-1.89)	3.17 (1.17-11.44)	4.85± 6.42
	7	0.58 (0.25-1.13)	**1.20 (1.12-1.29)**	2.49 (1.27-5.87)	5.18±6.04
Black pepper & Orange peel	2	0.79 (0.59-1.02)	1.29 (1.21-1.37)	2.08 (1.49-3.07)	7.87±6.29
	5	0.64 (0.38-100)	1.13 (1.05-1.20)	1.98 (1.38-3.05)	6.72± 6.15
	7	0.60 (0.35-0.95)	**0.99 (0.85-1.13)**	1.62 (1.31-2.08)	7.67±7.12
Black pepper & Brazilian pepper	2	0.95 (0.81-1.09)	1.42 (1.29-1.58)	2.13 (1.55-3.06)	9.33±7.52
	5	0.83 (0.63-1.05)	1.34 (1.24-1.47)	2.17 (1.50-3.33)	7.86±6.52
	7	0.66 (0.39-1.01)	**1.17 (1.10-1.23)**	2.07 (1.40-3.33)	6.61±6.09
Black pepper & Sulfur	2	0.63 (0.32-1.10)	1.25 (1.17-1.36)	2.42 (1.07-7.13)	5.51±6.08
	5	0.42 (0.09-1.40)	1.01 (0.77-1.24)	2.49 (1.32-5.47)	4.35±6.23
	7	0.73 (0.56-0.92)	**1.01 (0.92-1.09)**	1.40 (1.28-1.55)	11.49±8.37
Black pepper & Coal ash	2	0.85 (0.65-0.72)	1.21 (1.16-1.25)	1.83 (1.462.35)	9.11±6.21
	5	0.80 (0.93-0.96)	1.06 (0.96-1.16)	1.76 (1.36-2.39)	7.49±6.45
	7	0.64 (0.40-0.96)	**1.03 (0.96-1.09)**	1.32 (1.25-1.40)	14.9±9.87

formulae and percentages. The main components were monoterpenes, Sesquiterpenes, fatty acids and alkaloids, and some of effective constituents were α-pinene, Linalool, α-Copaene, Linoleic acid and Piperin.

These results are in agreement with Chander *et al*. (2003) examined some extracts of the medicinal plant *Embelia ribes* for their insecticidal activity against eggs and larvae of *Musca domestica*, Arun *et al*. (2003) investigated *d*-Limonene for contact and fumigant toxicity, ovicidal effects, oviposition- deterrent, development inhibition, and feeding-deterrent activities against rice weevil, *Sitophilus oryzae* (L) by contact and fumigant toxicity decreased as larvae aged. Also, Roy *et al*. (2005) reported that leaf extracts of *Blumea lacera* showed botanical insecticidal activity against lesser grain borer and rice weevil. At the same line Pavela (2007) reported that botanical pesticides are biodegradable and are thus considered safer and more eco – friendly substancet. It is also that the botanical insecticides could replace expensive chemicals that are currently in use in many developing countries. The current results are agreeing with Dawit and Jembere (2010) tested the efficacy of products of orange (*Citrus sinensis*) peels in the control of the stored products beetle *Zabrotes subfasciatus* (L) in stored haricot beans (*Phaseolus vulgaris*). The results showed that powders from ground peels caused significant reduction in progeny emergence of *Z. subfasciatus* ($P< 0.05$). There was no progeny produced when essential oil was used, even at lower dosage levels of 30mg. Our results in the same line with Fekadu *et al*. (2012)

In fact, phyto-products or botanicals are promising alternatives to synthetic insecticides for stored grain protection due to their environment friendly nature (Copping and Menn, 2000). The plant products are indigenous and abundantly available at low cost and have wide spectrum of activity such as insecticide, anti-feedents, repellents, larvicidal, ovicidal and insect growth regulators (Guleria and Tiku, 2009). To deter the insect in storage, neem leaves were mixed with stored grains in earlier days and this practice is still followed in many developing countries. Plant products are generally harmless to the environment due to their rapid recycling; thereby preventing the development of resistance in insects as well as accumulating in the non-targeted organism and environment (Saroukolai *et al*., 2010). Thus, botanicals emerge as one of the leading approach to protect the grains in storage. Utility of plant products against insect pest of storage have been studied and important active components exhibiting potentiality as a grain protection agent had been reported earlier (Guleria

Table 6. The calculated LT_{50} values of the evaluated mixtures of fine dusts against the rice weevil *S. oryzae* under laboratory conditions

Plant powder	Application rate (g/50 g rice))	LT05	LT50	LT95	slope
Majoram	1	1.07 (0.74-1.52)	5.71 (4.86-6.74)	30.44 (18.52-51.76)	2.26±7.9-02
	2.5	0.66 (0.44-0.97)	3.75 (3.25-4.31)	21.10 (14.25-32.31)	2.19±5.8E-02
	3.5	0.45 (0.27-0.71)	3.06 (2.62-3.58)	20.83 (13.73-33.04)	1.98±5.0-02
	5	0.32 (0.18-0.53)	**2.27 (1.90-2.69)**	15.95 (10.95-24.31)	1.94±4.80-02
Camphor	1	0.65 (0.38-1.07)	5.88 (4.76-7.37)	53.14 (25.76-118.5)	1.72± 0.058
	2.5	0.29 (0.13-0.60)	4.14 (3.35-5.16)	48.56 (20.76-98.43)	1.42±0.046
	3.5	0.27 (0.15-0.44)	2.48 (2.00-3.04)	30.55 (16.57-62.00)	1.50±0.044
	5	0.20 (0.09-0.40)	**1.67 (1.36-2.01)**	10.45 (7.71-14.74)	2.06±0.049
Braziliun pepper	1	0.68 (0.31-1.36)	13.17 (7.8223.83)	312.1 (55.0-2500.5)	1.27 ± 0.065
	2.5	0.28 (0.08-0.78)	9.39 (5.9316.04)	255.3 (52.4-1590.0	1.08 ± 0.05
	3.5	0.18 (0.05-0.54)	5.83 (4.22-8.39)	186.3 (43.5-1071.8)	1.09 ± 0.045
	5	0.10 (0.02-0.35)	**3.41 (2.60-4.49)**	114.5 (32.35-533.0)	1.07 ± 0.042
Black pepper	1	0.85 (0.65-1.09)	2.75 (2.46-3.07)	8.89 (7.36-3.22)	3.22 ± 0.076
	2.5	0.57 (0.41-0.76)	2.12 (1.86-2.41)	7.94 (6.49-9.88)	2.87 ± 0.062
	3.5	0.48 (0.34-0.65)	1.80 (1.56-2.06)	6.72 (5.53-8.38)	2.87 ± 0.063
	5	0.20 (0.11-0.34)	**1.12 (0.88-1.39)**	6.21 (4.84-8.32)	2.21 ± 0.06
Conocarpus	1	1.08 (0.75-1.52)	5.64 (4.82-6.63)	29.4 (18.12-49.38)	2.29 ± 0.08
	2.5	0.57 (0.41-0.76)	2.12 (1.86-2.41)	7.94 (6.49-9.88)	2.1± 0.057
	3.5	0.48 (0.34-0.65)	1.80 (1.56-2.06)	6.72 (5.53-8.38)	1.94 ± 0.051
	5	0.20 (0.11-0.34)	**1.12 (0.88-1.39)**	6.2 (4.84-8.32)	2.01± 0.048
Orange peel	1	0.65 (0.38-1.06)	5.74 (4.67-7.15)	50.87 (25.12-111.0)	1.73 ± 0.059
	2.5	0.30 (0.13-0.61)	4.08 (3.32-5.06)	55.33 (25.00-137.6)	1.45± 0.046
	3.5	0.20 (0.09-0.42)	2.48 (2.00-3.04)	30.55 (16.57-62.00)	1.50± 0.044
	5	0.28 (0.16-0.46)	**1.77 (1.46-2.12)**	11.16 (8.17-15.87)	2.05± 0.049
Ash	1	0.79 (0.42-1.40)	10.2 (6.98-15.52)	130.9 (40.43-491.7)	1.48± 0.06
	2.5	0.18 (0.05-0.54)	6.09 (4.3-8.94)	120.4 (36.30-299.9)	1.07±0.05
	3.5	0.01 (00.0-0.22)	2.57 (1.55-4.04)	96.7 (24.38-260.35)	0.66±0.04
	5	0.01 (0.00-0.11)	**1.76 (0.33-1.47)**	54.75 (15.60-291.0)	0.88±0.042
Sulfur	1	1.22 (0.90-1.62)	4.75 (4.21-5.35)	18.50 (13.24-26.30)	2.78 ± 0.094
	2.5	0.84 (0.61-1.13)	3.42 (3.03-3.85)	13.89 (10.58-18.57)	2.69± 0.069
	3.5	0.59 (0.43-0.78)	2.19 (1.92-2.48)	8.18 (6.68-10.19)	2.87 ±0.062
	5	0.46 (0.32-0.63)	**1.86 (1.60-2.14)**	7.55 (6.11-9.54)	2.69 ±0.059

and Tiku, 2009). However, only a countable number of botanicals like neem have been extensively used as a commercial product in insect pest management programmes (Pavela, 2016).

The present study clearly exhibited that phyto-products and certain mineral fine dusts has the potential to manage the Rice weevil (*Sitophilus oryzea* L.) as equal to the chemical or synthetic insecticides. Likewise in direct toxicity trial also similar trend recorded. Though synthetic insecticides are more effective to manage the storage pest with less concentration, but phyto-products and certain mineral fine dusts will be a good management option against the storage insect pest. Considering all these results it can be an important factor that could substitute synthetic insecticide with eco-friendly tools under storage conditions.

Further research should be conducted before the commercial application of such botanical products admixtures for controlling Rice weevil (*Sitophilus oryzea* L.). Considering environmental and human health risks, as well as the need to prevent eventual negative effects on seed quality, the effective concentration of eco-friendly materials should be considered. Also, the most efficient of such materials could be improved by varying synthesis conditions to increase both specific surface area

Table 7. The calculated LT_{50} values of evaluated mixtures of the tested fine dusts against the rice weevil *S. oryzae* under laboratory conditions

Plant powders mixtrues	Application rate (g/50 g grain)	LT05 (g/100g grain) (2,5 and 7day)	LT50 (g/100g grain) (2,5 and 7day)	LT95 (g/100g grain) (2,5 and 7day)	slope
Black pepper & Camphor	1:1 (0.5 + 0.5) g	0.83 (0.33-1.95)	11.36 (6.83-19.77)	155.1 (27.5-1040.9)	1.44 ± 0.13
	1:2 (0.5+1.0) g	0.51 (0.15-1.52)	8.88 (5.76-14.27)	154.1 (25.9-1117.3)	1.32 ± 0.12
	1:3 (0.5+ 1.5) g	0.25 (0.06-0.96)	**4.46 (3.46-5.78)**	78.4 (19.57-370.38)	1.32 ± 0.10
Black pepper & Majoram	1:1 (0.5 + 0.5) g	0.93 (0.40-1.99)	10.73 (6.80-17.56)	124.2 (26.84-662.9)	1.54 ± 0.13
	1:2 (0.5 + 1.0) g	0.31 (0.06-1.35)	8.16 (5.18-13.46)	212.5 (24.61-2442.1)	1.16 ± 0.11
	1:3 (0.5 + 1.5) g	0.38 (0.13-1.01)	**4.25 (3.43-5.27)**	47.12 (17.70-138.11)	1.57 ± 0.10
Black pepper & Conocarpus	1:1 (0.5 + 0.5) g	0.75 (0.29-1.81)	10.31 (6.48-17.07)	303.84 (24.78-18.83)	1.44 ± 0.12
	1:2 (0.5 + 1.0) g	0.31 (0.05-1.49)	9.68 (5.51-18.19)	299.7 (18.83-5305.1)	1.09 ± 0.11
	1:3 (0.5 + 1.5) g	0.11 (0.01-1.15)	**5.63 (3.79-8.64)**	141.5 (26.95-878.70)	0.95 ± 0.10
Black pepper & Orange peel	1:1 (0.5 + 0.5) g	0.37 (0.12-1.03)	4.55 (3.63-5.72)	56.69 (18.87-190.54)	1.50 ± 0.10
	1:2 (0.5 + 1.0) g	0.28 (0.08-0.84)	3.30 (2.58-4.17)	38.95 (15.38-108.74)	1.53 ± 0.10
	1:3 (0.5 + 1.5) g	0.13 (0.02-0.59)	**1.90 (1.22-2.84)**	28.37 (11.40-79.19)	1.40 ± 0.10
Black pepper & Brazilian pepper	1:1 (0.5 + 0.5) g	0.88 (0.38-1.91)	10.27 (6.63-16.47)	221.03 (24.85-240.8)	1.54 ± 0.13
	1:2 (0.5 + 1.0) g	0.32 (0.06-1.38)	8.47 (5.29-14.24)	120.0 (26.57-624.3)	1.166 ± 0.11
	1:3 (0.5 + 1.5) g	0.16 (0.02-0.94)	**4.43 (3.30-5.96)**	119.09 (19.63-926.6)	1.15 ± 0.10
Black pepper & Sulfur	1:1 (0.5 + 0.5) g	0.34 (0.13-0.05)	3.29 (2.42-4.40)	71.19 (16.96-361.12)	1.23 ± 0.10
	1:2 (0.5 + 1.0) g	0.18 (0.05-0.60)	2.83 (2.24-3.55)	23.74 (12.39-48.33)	1.78 ± 0.10
	1:3 (0.5 + 1.5) g	0.15 (0.02-0.79)	**1.77 (1.19-2.54)**	17.03 (9.25-33.54)	1.67 ± 0.11
Black pepper & Ash	1:1 (0.5 + 0.5) g	0.26 (0.07-0.85)	3.50 (2.73-4.45)	47.51 (16.48-153.9)	1.45± 0.10
	1:2 (0.5 + 1.0) g	0.22 (0.06-0.70)	2.40 (1.76-3.21)	26.31 (12.16-61.87)	1.58± 0.10
	1:3 (0.5 + 1.5) g	0.18 (0.05-0.55)	**1.42 (0. b91-2.13)**	11.44 (7.13-19.32)	1.81± 0.12

and porosity and decrease particle size. The efficacy of such materials should be tested under different abiotic and biotic factors (temperature, humidity, host plant species and varieties, beetle rearing density) that have been shown to affect the insecticidal impact of inert dusts on stored pests to optimize the dose required to manage the storage insect pest in efficient manner.

REFERENCES

Abd El-Mohsen, M. and E. Maisa 2010. Sulfur concrete for the construction industry: Asustainable development approach. Fort Lauderdale: J. Ross Publishing. P. 109.

Agarwal, R. S. K., Gupta S. S. Agrawal, S. Srivastava and R. Saxena 2008. Oculohypotensive effects of *Foeniculum vulgare* in experimental models of glaucoma. Indian J. Physiol. Pharmacol., 52 (1): 77-83.

Almeida, I., D. S. Alviano and D. P. Vieira 2007. Antigiardial activity of *Ocimum basilicum* essential oil. Parasitol. Res., 101 (2): 443–52.

Arun K. Tripathi, Veena Prajapat, Suman Preet S. Khanuja and Sushil Kumar 2003 Effect of *d*-Limonene on Three Stored-Product Beetles, J. Econ. Entomol. 96(3): 990-995.

Bayih, T., Tamiru, A., and Chimdessa, M. 2018. Bioefficacy of Unitary and Binary Botanical Combinations Against Mexican Bean Weevil, Zabrotes subfasciatus (Coleoptera: Chrysomelidae). Int. J. Trop Insect Sci. 38(3): 205-215.

Belloa, G.D., S. Padina, C. L. Lastrab and M. Fabrizio 2000. Laboratory evaluation of chemical biological control of rice weevil (*S. oryzae* L.) in stored grain. J. Stored Prod. Res., 37: 77–84.

Brader, B., R. Lee, R. Plarre, W. Burkholder, G. B. Kitto, L. Polston, E. Dorneanu, J. Szabo, B. Mead, B. Rouse, D. Sullins and R. Denning 2002. A comparison of screening methods for insect contamination in wheat. J Stored Prod. Res., 38, 75-86.

Chander, S., P.K. Aggarwal, N. Kalra and D.N Swaruparani 2003. Changes in pest profiles in rice-wheat cropping system in Indo-gangetic plains. Ann. or Pl. Prot. Sci. 11 (2): 258–263.

Collins, P. J. 2006. Resistance to chemical treatments in insect pests of stored grain and its management. *In*: Proc. 9th Inter.Working Conf. Stored- Product Protection, Lorini, I.; B. Bacaltchuk; H. Beckel; D. Deckers; E. Sundfeld; J. P. dos Santos; J.D. Biagi; J.C. Celaro; L. R. D. Faroni; A., Bortolini; M. R.Sartori; M. C. Elias; R. N. C.Guedes; R.G. da Fonseca and V.M. Scussel (Eds.), 15–18 October 2006, Campinas, Sao Paulo, Brazil. Brazilian Post Harvest Association, Campinas, Brazil, pp: 277–282.

Daglish, G. J. 2006. Opportunities and barriers to the adoption of potential new grain protectants and fumigants. *In*: Proc. 9th Inter.Working Conf. Stored- Product Protection, I. Lorini, B. Bacaltchuk, H. Beckel, D. Deckers, E. Sundfeld, J.P. dos Santos, J.D. Biagi, J, C. Celaro, L.R. Faroni, O.F. Bortolini, M. R. Sartori, M. C. Elias, R. N. C. Guedes, R. G. da Fonseca and V. M. Scussel (Eds.), 15–18 October 2006, Campinas, Sao Paulo, Brazil. Brazilian Post Harvest Association, Campinas, Brazil, pp: 209–216.

Dawit Kidane Zewde and Bekelle Jembere 2010 Evaluation of Orange Peel *Citrus Sinensis* (L) as a Source of Repellent, Toxicant and Protectant against *Zabrotes Subfasciatus* (Coleoptera: Bruchidae). Mekelle University, 2 (1): 61-75, 2010.

Duncan, D. B. 1955. Multiple range and multiple F test.Biometrics, 11:1-42.

Durak, I., M. Kavutcu and B. Aytac 2004. Effects of garlic extract consumption on blood lipid and oxidant/antioxidant parameters in humans with high blood cholesterol. J. Nutr. Biochem., 15 (6): 373–7.

Fekadu G., S. Waktole, Dante R. Santiago 2012Evaluation of Plant Powders and Cooking Oils against Maize Weevil, *Sitophilus zeamais* M. (Coleopteran: Curculionidae) under Laboratory Conditions. Molecular Entomology, Vol.3, No.2, 4-14.

Finney, D.J. 1971. Probit Analysis. 3rd ed. Cambridge University Press, Cambridge, 318 pp.

Fornal J.T., J. Sadowska, S. Grunda, J. Nawrot, A. Niewiada, J. R. Warchalenski and W. Blaszak 2007. Detection of granary weevil *S. granaries* (L.) eggs and internal stage analysis. J. Stored Prod. Res., 43: 142-148.

Greenwood, N. N. and A. Earnshaw 1997. Chemistry of the Elements (ended.). Oxford: Butterworth-Heinemann. Pp. 645–662.

Guleria, S., Tiku, A.K. 2009. Botanicals in pest management: current status and future perspectives. In: Peshin, R., Dhawan, A.K. (Eds.), Integrated Pest Management: Innovation-Development Process, http://dx.doi.org/10.1007/978-1-4020-8992- 3-12.

Hussein, A. E., H. Abd Elhaseeb, R. A. Mohamed, M. Abdel-Mogib and Z. Abou Elnaga 2017. Toxicity of three chemical extracts of black pepper fruits against two stored grain insect pests. International Journal of Pharmaceutical Science Invention. Vol.6, No.10, 20-29.

Kljajic, P. and I. Peric 2005. Resistance of stored-product insects to insecticides. (Rezistentnost skladisˇnih insekata prema insekticidima). Pesticide and Phytomedicine (Pesticidi ifitomedicina), 20: 9–28. (In Serbian with English abstract).

Mohamed, M.I.E., S.A. M. Abdelgaleil, and M.A. Abdel Rasoul . 2009. Potential of Essential Oils to Control Sitophilus oryzae (L.) and Tribolium castaneum (Herbst) on Stored Wheat . Alex. Sci . Exch. J. 30: 419 - 426.

Padín, S., G. Dal Bello and M. Fabricio 2002. Grain loss caused by *Tribolium castaneum*, *S. oryzae* and *Acanthoscelides obtectus* in stored durum wheat and beans treated with *Beauveria bassiana*. J. Stored Prod. Res., 38: 69-74.

Pandi, G., Adak, T., Gowda, B., Patil, N., Annamalai, M., Jena, M. 2018. Toxicological effect of underutilized plant, Cleistanthus collinus leaf extracts against two major stored grain pests, the rice weevil, *Sitophilus oryzae* and red flour beetle, *Tribolium castaneum*. Ecotoxicology and Environmental Safety Ecotoxicology and Environmental Safety. 154: 92–99.

Pavela, R. 2007. Possibilities of botanical insecticide exploitation in grain protection. J. Pest Technol. 1:47-52.

Pavela, R. 2016. History, presence and perspective of using plant extracts as commercial botanical insecticides and farm products for protection against insects – a review. Plant Prot. Sci. 52 (4): 229–241.

Rajendran, S. 2002.Postharvest pest losses. *In*: Encyclopedia of pest management. Pimental, D. (Ed.), Marcel Dekker, Ine., New York, pp. 654-656.

Rajendran, S., & Sriranjini, V. 2008. Plant products as fumigants for stored-product insect control. *Journal of Stored Products Research*, *44*(2), 126-135.

Roy, B., R. Amin and M.N. Uddin 2005. Leaf Extracts of Shiyalmutra (Blumea lacera) as Botanical Insecticides Against lesser Grain Borrer and Rice weevil, J. Biol. Sci., 5(2): 201-204.

Saad, A. S. A., E.H. M. Tayeb, and H.L. Metraw . 2017. Botanical oils as eco-friendly alternatives for controlling the rice weevil Sitophilus oryzae . Alex. Sci . Exch. J. 38: 921 - 932.

Saroukolai, A.T., S. Moharramipour, M.H. Meshkatalsadat 2010. Insecticidal properties of Thymus persicus essential oil against *Tribolium castaneum* and *Sitophilus oryzae*. J. Pest Sci. 83: 3–8.

Toi, M., H. Bando and C. Ramachandran 2003. Preliminary studies on the anti-angiogenic potential of pomegranate fractions *in vitro* and *in vivo*. Angiogenesis, 6 (2):121-8.

Warchalewski, J. R. and J. Gralik 2010. Influence of microwave heating on biological activities and electrophoretic pattern of albumin fraction of wheat grain. Cereal Chem., 87(1):35-41.

Zaghloul, O. A., Magda B. El- Kady, Hossam F. El-Wakil, Salwa M. Ahmed, Marwa I. Mackled 2012 Biological and genetical studies on the rice weevil, *Sitophilus oryzae* (L.) (Curculionidae: Coleoptera), in Egypt. Research Journal of Agriculture and Biological Sciences, 8(2): 92-97.

الملخص العربي

طرق صديقة للبيئة لمكافحة سوسة الارز باستخدام المساحيق النباتية

حسن علي عبد الحميد مصباح ، احمد عبد الفتاح محمود ومحمد صالح عاجل

تعتبر سوسة الارز من اهم افات الاولية التى تصيب الحبوب المخزنة والتى منها القمح والارز والشعير والذرة بعد وتعتبر المساحيق النباتية واحدة من الاتجاهات الحديثة المعتمد عليها حاليا بصورة كبيرة و التي تستخدم فى مكافحة تلك الافة عوضا عن استخدام المبيدات والمواد الكيمائية. وعلية اجريت هذة الدراسة بمختبرات قسم وقاية النبات بكلية الزراعة سابابا شا – جامعة الاسكندرية فى الفترة من ٢٠١٧ –٢٠١٨ بغرض تطبيق بعض المساحيق النباتية مثل الكافور والبردقوش و ثمار الفلفل الاسود و اوراق الكونوكاربس وقشور ثمار البرتقال وثمار الفلفل البرازيلى والكبريت والرماد كبدائل امنة ضد حشرة سوسة الارز (سوسة الارز). ربيت الحشرات تحت درجات حرارة ثابتة ٢٨ ±٢ °C ودرجة رطوبة ثابتة ٧٥±٥% R.H بمختبر قسم وقاية النبات واختبرت هذة المساحيق النباتية فى الصورة الاصلية واوضحت النتائج وجود تاثير معنوى ملحوظ بينها ضد سوسة الارز وكان الفلفل الاسود الاكثر فاعلية عن باقى المساحيق الاخرى وعلية اجريت مجموعة من التوليفات المخنتلفة باستخدام نصف جرام من الفلفل الاسود مع نصف جرام من المواد الاخرى وواحد جرام وواحد ونصف جرام مع توحيد وزنة الفلفل الاسود حيث اظهرت النتائج ان هناك بعض المواد كان لها الاثر بالزيادة او النقص مقارنة بالمواد الخام. و أوصت الدراسة باستخدام مسحوق ثمار الفلفل الاسود مع مجموعة من المساحيق النباتية كبدائل طبيعيه و امنة عن المبيدات الكيميائية المصنعة فى مكافحة سوسة الارز.