Bioactivity of Essential Oils, Extracts and Powders of *Cupressus arizonica Greene*, *Juniperus communis* L. and *Mentha longifolia* L. on Three Stored Product Pests

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ABSTRACT

One of low-risk and less damaging strategies, is utilizing plant compounds for controlling stored product pests. In the present study extracts, essential oils and powders from *Cupressus arizonica* Greene, *Juniperus communis* L. and *Mentha longifolia* L. were used on reproductive inhibition of F_1-Progeny and damage (feeding deterrence) tests on three stored product pests such as *Callosobruchus maculatus* Fabricus, *Sitophilus granarius* L. and *Oryzaphilus surinamensis* L.. In feeding deterrence experiment, powder of *J. communis* on *O. surinamensis* with mean 15.00 ± 0.87 and the essential oil of *M. longifolia* on *C. maculatus* with mean 8.33 ± 0.58 had more and fewer effects, respectively. In F_1-Progeny experiment, essential oil of *C. arizonica* on *S. granarius* with 59.64 ± 0.45% and powder of *C. arizonica* on *S. granarius* with 45.13 ± 0.69% had more and fewer effects, respectively. Essential oils derived from *C. arizonica*, *J. communis* and *M. longifolia* were analyzed by gas chromatography indicated that the main compounds were as of α-Pinene (19.87%), Sabinene (24.55%) and Pulegone (31.26%), respectively. Present study showed that essential oils, extracts and powders of plants have considerable effects on feeding deterrence and F_1-Progeny of *C. maculatus, S. granarius* and *O. surinamensis*. Therefore, using botanical compounds as an integrated insect management program were recommended.

Keywords: F_1-Progeny, feeding deterrence, stored product pest, plant composition

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INTRODUCTION

The cereals have long been used as the main food source by human all over the world. Due to its importance, the people have been considered several protection methods for these stored products pests (Kaletun and Breslauer, 2003; Ebadollahi and Mahboubi, 2011). The granary weevil, *S. granarius* is one of the most worldwide harmful and damaging pests for stored up cereals. It causes considerable losses through its feeding activity and excrete (Laznik *et al.*, 2012). The saw-toothed grain beetle, *O. surinamensis* is also a common and secondary pest in stored up grain. Due to its inability to damage the whole grain; however, its status has changed due mainly to the mechanical damage during harvesting and drying procedure, which consequently results to broken and damaged grain transferred into the barns, depots and storage facilities (Mathlein 1971; Howe 1973; Pricket *et al.*, 1990). Cowpea weevil, *C. maculatus* is a cosmopolitan field-to-store pest ranked as the principal post-harvest pest of cowpea in the tropics. It causes substantial quantitative and qualitative loses manifested by seed perforation and reductions in weight, market value and germination ability of seeds (Bamphitlhi *et al.*, 2014). The control of these pests in storage systems mainly depended on fumigants such as Methyl Bromide

or Phosphine. However, in since 2004, because of its Ozone depleting properties, Methyl Bromide has been banned in many countries (Hansen and Jensen, 2002). The repetitive and intensive use of synthetic insecticides is one of the basic concerns for the environment and human health for several decades, mainly due to their slow degradation in the environment, toxic residues in the products, and the pest resistance to pesticides (Isman, 2006). Therefore, there is an urgent need to provide some safe, effective and easy use alternatives for the toxic fumigants (Ayvas *et al.*, 2008). Many spices and herbs and their extracts, essential oils and powders are known to have pesticides properties so that the demand for botanical insecticides has increased during the last fifteen years because of serious environmental concerns (Isman, 2000). At present botanical pesticides constitute 1% of the insecticide world market portion (Rozman *et al.*, 2007). The plants are considered as the richest bioactive sources containing some commercial chemicals which have secondary metabolites that play a key vital role in plant ecological relationships, especially in the interaction with the insects. Various recent studies have indicated that essential oil, extracts and also powder of several plants have significant insecticidal effects (Varma and Dubey, 2001; Ogendo *et al.*, 2004; Chebet *et al.*, 2013). Meanwhile**,** they have been documented as of some safe, non-polluting and bio-rational pest controlling agents (Rajendan and Srianjini, 2008). In particular, the composition, insecticide and antibacterial effects of *C. arizonica*, *J. communis* and *M. longifolia* has been widely investigated (Gilsic *et al.*, 2007; Sedaghat *et al.*, 2011; Ghaderi *et al.*, 2014; Torbatinejad *et al.*, 2014; Stoilova *et al.*, 2014; Hashemi and Roostaefar, 2014; Lohani *et al.*, 2015; Salman *et al.*, 2015; Al-Mohajer *et al.*, 2017; Okut *et al.*, 2017).

The main goal of this study evaluated bioactivity of essential oils, extracts and powders of *C. arizonica*, *J. communis* and *M. longifolia* against three stored product pests *C. maculatus*, *S. granarius* and *O. surinamensis.*

MATERIALS AND METHODS

Insects Rearing

The cowpea, wheat and rice (Kamran, Omid and Taram varieties), were used for rearing *C. maculatus, S. granarius* and *O. surinamensis,* respectively. Insects were transferred to rearing room at Plant Protection Department, Faculty of Agriculture, Urmia University with a temperature of 27 ± 2°C and a relative humidity of 65 ± 5% with absolute darkness in plastic containers, including their own food. The top of each plastic container was fitted with a grid for aeration.

Plants Preparation

C. arizonica and *J. communis* were collected from the campus of Urmia University and *M. longifolia* Aerial parts include leaves and fruits of *C. arizonica* (Cupressaceae; var. glabra), 17 years old, *J. communis* (Cupressaceae; var. depressa), 10 years old and leaves and flowers of *M. longifolia* (Lamiaceae; var. asiatica), 2 years old were collected from campus of Urmia University (West Azerbayjan Province, in Northwest of Iran) on May 2017. All plants were dried in shade and ventilated area at 28 ± 2°C temperature for 2–7 days. Finally**,** these parts of plants were chopped and prepared to be used in tests.

Essential Oils, Extracts and Powders

The fresh plant material (50.0 g) was placed in a round-bottomed flask and 500 milliliter distilled water was added. Hydrodistillation was performed simultaneously for 3 h by means of Clevenger-type apparatus. The obtained oils were dried over anhydrous sodium sulfate and stored at 4°C before the GC analysis. Analyses were repeated three times.

In order to prepare methanol extracts of plants, the plants were washed with distilled water and dried at room temperature 28 ± 2°C away from sunlight. Initially, a portion of each dried samples was ground, then were extracted with methanol by Soxhlet (Vogel, 1978). For this purpose, 30 grams of the powdered plant which was soaked in 300 milliliters of solvent (210 milliliter of water and 90 milliliter of methanol) for 12 h then added

to the cartridge. The extraction time was 8 hours at 40°C. In the next step, 300 milliliters of extract were concentrated by a rotary vacuum distillation apparatus at 40°C and 120 rpm so that the final volume of extract reduced to 100 milliliters. The extracts were stored in frigid dark glass containers at a temperature of 4°C were kept in the refrigerator for future (Akhtar and Isman, 2004). For powder preparation, the plants were dried in shade and ground then were kept in the refrigerator for the next use.

The Determination LC_{40} and LC_{50} Values

Bioassay tests with essential oils were performed based on the method of Negahban *et al.* (2007). For this purpose, cylindrical glass containers of 250–milliliter volume and wattman filter paper of the same size as the diameter plug of dishes were considered as the place to impregnate with the essential oil. Initial experiments were conducted to find appropriate concentrations. According to the results of these experiments, five concentrations were determined for each of the compounds and poured with water as control into the glass containers by the micropipette on smooth paper. Thirty insects, from 1–2 days for (*C. maculatus*) and 2–3 days for (*S. granarius* and *O. surinamensis*) were placed in any glass containing 20 grams of diets. Control glass lacked essential oil. To prevent spray penetration, the essential oil was blocked outside the cap with the parafilm strip. The number of dead insects in the treated and control dishes was counted and recorded after 24 hours. Insects do not move its leg or two posterior segments of the antennae or abdomen were considered dead. Similar methods used for extracts and powder effects of three plant**s** against three pests without filter paper by mixing plant compounds with diets then mortality recorded after 48 hours for extracts and seven days for powders.

F_1-Progeny Test

For F_1-Progeny test, two pair survival adults (females and males) of *C. maculatus*, *S. granarius* and *O. surinamensis* by LC_{40} (from dose-response test) of essential oils, extracts and powders (Table 1) added to each glass container (Kliner 250 milliliter) with 20 grams of the cowpea, wheat and rice were weighted and transferred in a glass container. The test was repeated three times for each treatment through a complete randomized procedure. The top of each glass container was fitted with a grid for aeration. The units were stored at 28 ± 2°C and relative humidity of 65 ± 5%. For the progeny enumeration, the appearance of matured and emerged adult insects were recorded after 25, 44- and 34-days lifetime for *C. maculatus*, *S. granarius* and *O. surinamensis*, respectively. Reduction in the percentage of insect or reproduction inhibition rate calculated by using the (Tapondjou *et al.*, 2005) method according to the following formula:

$$\text{Reproduction inhibition rate (\%)} = \frac{(C_N - T_N)}{C_N} \times 100$$

C_N- Number of newly emerged adult insects in the untreated control

T_N- Number of newly emerged adult insects in the treated grains

Feeding Deterrence Index

The cereal samples were counted, weighted (20 grams) and placed in 250 milliliter glass containers (Kliner) then 30 adults (15 females and 15 males) of *C. maculatus* 1–2 days, *S. grarnarius* and *O. surinamensis* 2–3 days (Table 1) added to each glass container include amount of LC_{40} from each compound to fed and reproduced. The feeding deterrence test was evaluated in three replicates for each treatment at 27 ± 2°C and relative humidity of 65 ± 5%. After the appearance of a new generation of adult insects, the amount of grain powder, waste matter, undamaged and damaged seeds were counted and weighted. The weight loss percentage of cereals was calculated by the (Doble, 1991) method according to the following formula:

$$\text{Weight loss \%} = \frac{(UN_d - DN_u)}{U(N_d + N_u)} \times 100$$

U- Weight of undamaged grains
D- Weight of insect-damaged grains
Nu- Number of undamaged grains
Nd- Number of insect-damaged grains

Statistical Analysis

The all experiments were arranged in a completely randomize design and the data were analyzed with one way-ANOVA. The means were separated using the HSD-Tukey's test at the 5% level. The LC_{50} values with confidence limits were calculated by Probit analysis using the SPSS ver. 22 software package.

RESULTS AND DISCUSSION

Gas Chromatography Analysis

The chemical composition of the essential oils obtained from leaves of *C. arizonica* had 43 compounds, the major of them were α-Pinene (19.87%), Thriphenyphosphine oxide (13.12%) and Umbellulone (11.08%). While the essential oil derived from *J. communis* were 55 compounds, the major of them were Sabinene (24.55%), Limonene (20.99%) and Bornyl acetate (7.70%). The essential oil from *M. longifolia* had 37 compounds, the major of them were Pulegone (31.26%), Menthone (8.79%) and Piperitenone (6.74%) (Figure 1).

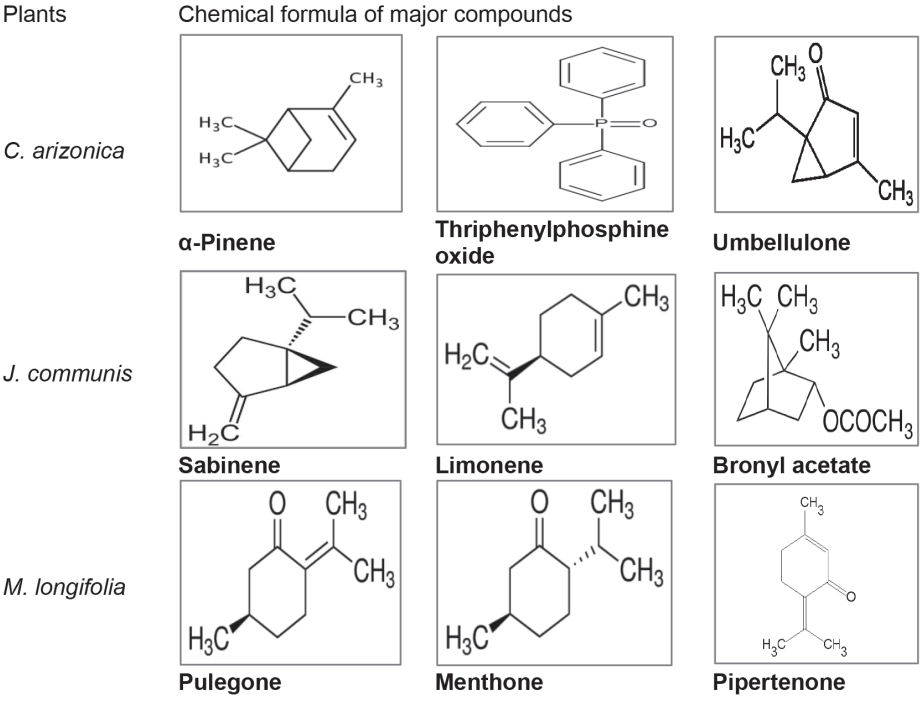

Figure 1 Chemical formula of three major compounds of *C. arizonica*, *J. communis* and *M. longifolia*

Comparison of Major Compounds in Essential Oil of Three Plants

Comparison of major compounds in the essential oil leaves of *C. arizonica*, *J. communis* and *M. longifolia* this experiment with other authors were showed in Figure 2, 3 and 4.

In the present study, the percentage of α-Pinene in *C. arizonica* was more than Sedaghat *et al.* (2011) and Lohani *et al.* (2017), but in other cases, our major compounds were less (Figure 2).

In this study percentage of α-Pinene and β-Caryophylla in *J. communis* were less than essential oil derived by Hashemi and Roostaefar (2014) and Stoilova *et al.* (2014). However**,** the percentage of Limonene and Sabinene were more than the others (Figure 3)

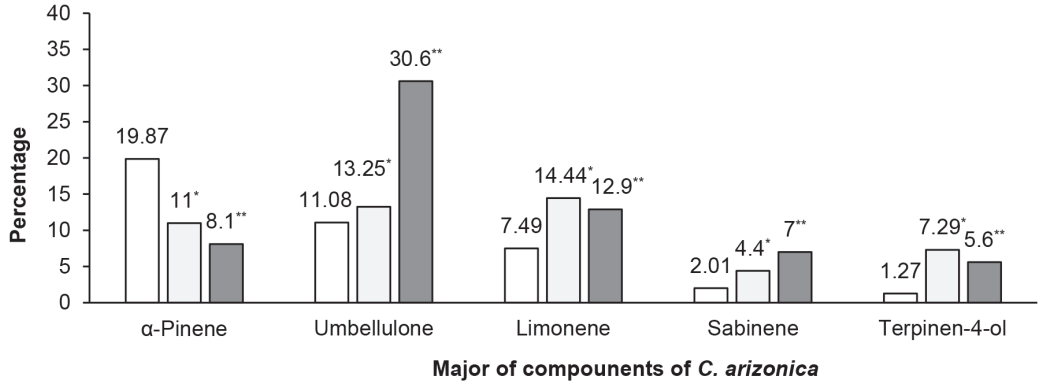

Figure 2 The comparison of major compounds of essential oil derived from *C. arizonica* by GC/MS analyses

Note: * Sedaghat *et al*. (2011), ** Lohani *et al.* (2017)

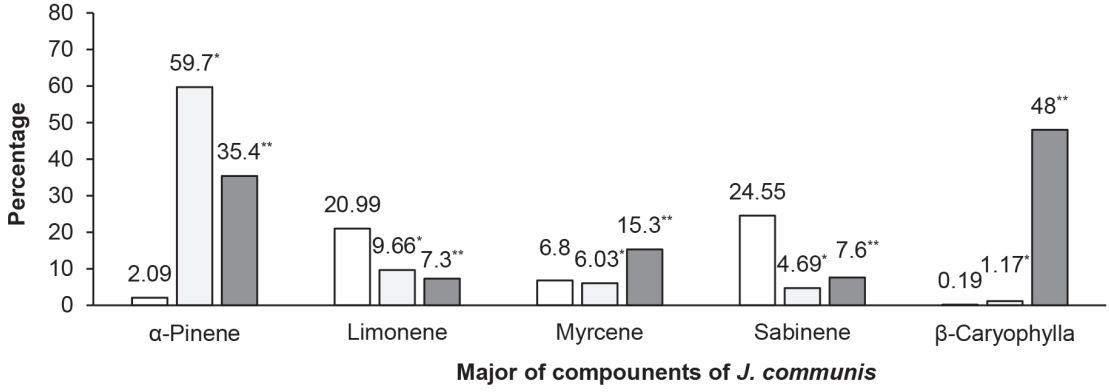

Figure 3 The comparison of major compounds of essential oil extracted from *J. communis* by GC/MS analyses

Note: * Sedaghat *et al*. (2011), ** Lohani *et al.* (2017)

According to the present study, the percentage of Pulegone in *M. longifolia* was more than essential oil derived by Salman *et al.* (2015) and Okut *et al.* (2017) while the Menthone percentage was less than other two researchers. Percentage of Menthol and α-Terpineol was less than Salman *et al.* (2015) but more than Okut *et al.* (2017). Percentage of Pipertenone was less than (Okut *et al.*, 2017) but more than (Salman *et al.*, 2015) (Figure 4).

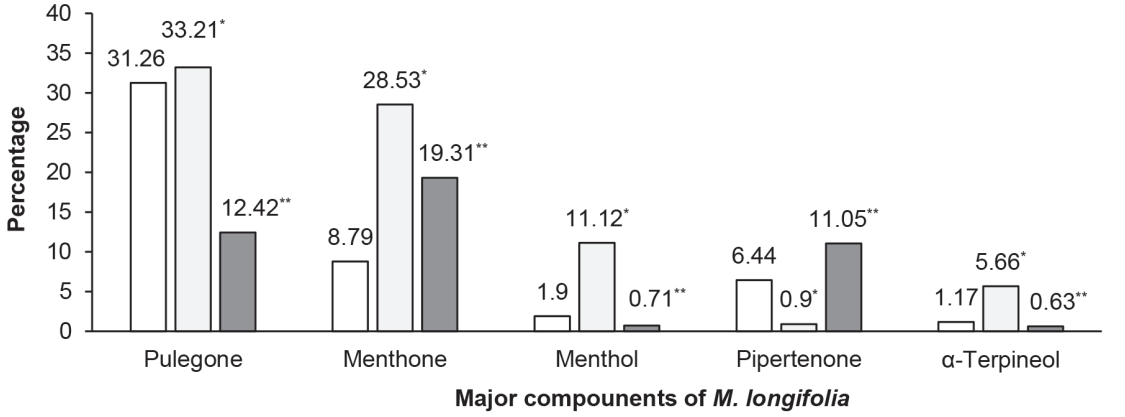

Figure 4 The comparison of major compounds of essential oil derived from *M. longifolia* by GC/MS analyses

Note: * Sedaghat *et al*. (2011), ** Lohani *et al.* (2017)

Bioassay Results

Probit analysis (Table 1) showed that LC_{50} value resulted from the essential oils of *C. arizonica*, *J. communis* and *M. longifolia* after 24 hours on *C. maculatus, S. granarius* and *O. surinamensis* were 2.88, 4.35, 14.15 and 2.48, 3.50, 13.73 and 1.19, 8.03, 16.91 microliter on 250 liters of air and for extracts after 48 hours were 35.33, 268.83, 650.10 and 34.25, 193.90, 506.35 and 9.63, 189.57, 545.23 PPM and for powder after 7 days were 1.41, 1.51, 3.98 and 2.16, 1.71, 4.62 and 3.36, 2.30, 4.58 grams, respectively.

Feeding Deterrence Results

In feeding deterrence experiments, results showed that there were significant differences between treatments and control, with 95% CL in all assay. The comparison between the mean insect damages (Means ± SE) which is raised from the three pests during the mixing plant compounds with pest foods shown in Table 2. Means in a column followed by different letters are significantly at α = 0.05 by Tukey test. (The comparison of essential oils, extracts, and powders is independent from each other).

Table 1 LC_{40} and LC_{50} values resulted by Probit analysis in different essential oils, extracts and powders concentrations on three pests

Compound	Plant	Insect	LC_{40} (µl/ 250 liters of air)		LC_{50} (µl/ 250 liters of air)		Compound	Plant	Insect	LC40 (PPM)		LC50 (PPM)		Compound	Plant	Insect	LC_{40} (Grams)		LC_{50} (Grams)	
			Lower bond	Upper bond	Lower bond	Upper bond				Lower bond	Upper bond	Lower bond	Upper bond				Lower bond	Upper bond	Lower bond	Upper bond
Essential oil	*C. arizonica*	*C. maculatus*	2.24		2.88		Extract	*C. arizonica*	*C. maculatus*	27.57		35.33		Powder	*C. arizonica*	*C. maculatus*	0.92		1.41	
			1.81	2.56	1.14	3.35				19.68	31.05	31.84	40.59				0.54	1.26	1.32	2.08
		S. granarius	2.59		4.35				*S. granarius*	213.80		268.83				*S. granarius*	1.12		1.51	
			2.18	3.68	4.08	4.87				197.54	226.39	231.25	291.02				0.87	1.28	1.33	1.85
		O. surinamensis	11.60		14.15				*O. surinamensis*	425.71		650.10				*O. surinamensis*	2.70		3.98	
			11.17	12.25	13.76	14.92				398.52	463.69	601.65	689.34				2.15	2.97	3.45	4.53
	J. communis	*C. maculatus*	1.75		2.48			*J. communis*	*C. maculatus*	22.70		34.25			*J. communis*	*C. maculatus*	1.57		2.16	
			1.32	2.16	2.27	3.04				15.69	28.58	29.57	39.21				1.02	1.85	1.97	2.64
		S. granarius	2.47		3.50				*S. granarius*	168.15		193.90				*S. granarius*	1.22		1.71	
			1.98	2.94	3.06	3.87				135.24	183.36	189.01	200.35				0.95	1.38	1.44	1.96
		O. surinamensis	11.31		13.73				*O. surinamensis*	264.58		506.35				*O. surinamensis*	3.28		4.62	
			10.73	12.26	13.39	14.38				203.58	302.82	455.05	539.52				2.86	3.57	4.13	4.95
	M.longifolia	*C. maculatus*	0.96		1.19			*M. longifolia*	*C. maculatus*	7.64		9.63			*M. longifolia*	*C. maculatus*	2.75		3.36	
			0.24	1.08	1.02	1.64				6.97	7.95	8.87	10.36				2.02	3.14	3.28	3.89
		S. granarius	6.01		8.03				*S. granarius*	149.44		189.57				*S. granarius*	1.82		2.30	
			5.39	6.67	7.52	8.61				123.56	185.69	121.36	224.58				1.54	2.09	2.18	2.65
		O. surinamensis	14.01		16.91				*O. surinamensis*	365.69		545.23				*O. surinamensis*	3.02		4.58	
			13.47	15.06	16.45	17.67				301.54	405.95	489.25	597.65				2.68	3.54	4.02	4.97

Table 2 Mean comparison (Means ± SE) of total feeding deterrence of three stored up pests in the mixture of three plant compounds

Compound	Plant	Feeding deterrence (Means ± SE)		
		C. maculatus	***S. granarius***	***O. surinamensis***
Essential oil	*C. arizonica*	10.66 ± 0.23^{b}	10.66 ± 0.83^{c}	11.33 ± 0.84^{c}
	J. communis	9.66 ± 0.15^{bc}	9.33 ± 0.40^{c}	9.66 ± 0.57^{d}
	M. longifolia	8.33 ± 0.58^{c}	12.66 ± 0.25^{b}	13.33 ± 0.58^{b}
	Control	16.66 ± 0.55^{a}	17.33 ± 0.85^{a}	16.00 ± 0.85^{a}
		F (3, 8) = 122.00 P = 0.001	F (3, 8) = 110.33 P = 0.001	F (3, 8) = 89.22 P = 0.001
Extract	*C. arizonica*	13.66 ± 0.73^{b}	13.66 ± 0.75^{b}	14.66 ± 0.87^{b}
	J. communis	12.33 ± 0.83^{bc}	13.00 ± 0.96^{bc}	11.33 ± 0.21^{c}
	M. longifolia	11.33 ± 0.71^{c}	12.00 ± 0.21^{c}	13.33 ± 0.87^{b}
	Control	16.33 ± 0.43^{a}	17.33 ± 0.65^{a}	16.33 ± 0.54^{a}
		F (3, 8) = 42.25 P = 0.001	F (3, 8) = 97.33 P = 0.001	F (3, 8) = 40.25 P = 0.001
Powder	*C. arizonica*	12.33 ± 0.82^{c}	12.33 ± 0.68^{c}	13.00 ± 0.24^{c}
	J. communis	12.66 ± 0.53^{c}	13.66 ± 0.55^{bc}	15.00 ± 0.87^{b}
	M. longifolia	14.00 ± 0.42^{b}	14.66 ± 0.33^{b}	14.00 ± 0.57^{b}
	Control	16.33 ± 0.63^{a}	17.33 ± 0.39^{a}	16.66 ± 0.65^{a}
		F (3, 8) = 46.55 P = 0.001	F (3, 8) = 40.33 P = 0.001	F (3, 8) = 41.83 P = 0.001

F_1-Progeny Results

In F_1-Progeny experiments, all results showed that there was significant difference between treatments and control, with 95% CL. The comparison between the percentage insects F_1-Progeny (Means ± SE) raised from the three pests during the mixing plant compounds with pest foods is shown in Table 3. The means in a column followed by different letters are significantly at α = 0.05 by Tukey test (The comparison of essential oils, extracts**,** and powders is independent from each other).

In various societies, there has always been a strong desire to use food free from the synthetic residues and pesticides. This tendency has led researchers to challenge with looking for in some low-risk insecticides (Sayyed *et al.*, 2000). Essential oils, extracts and herbal powders in most studies have no side effects on humans, stored product, living organisms and environment (Talukder and Howse, 1993; Lee *et al.*, 2001). The insecticidal constituents of many plant extracts and essential oils are monoterpenoids. Due to their high volatility they have fumigant activity that might be of importance for controlling stored-product insects (Ahn *et al.,* 1998). Differences between our three essential oils components and other studies it appears that the percentage composition vary according to the

geographical growth site, season, environmental and climatic conditions. Rajashekar *et al.* (2010) studies on the impact of the root extract from *Decalepis hamiltonii* on F_1-Progeny of *Tribolium castaneum, Stigobium pancieum, Sitophylus oryzae, Rhyzopertha domonica* and *Callosobruchus chinensis* pests, results showed that decrease in fecundity and in the number of laid eggs within 3–4 months. Hence, in the present study, *C. arizonica* had the greatest decrease in F_1-Progeny (52.65%). Paranagma *et al.* (2003) indicated that the essential oils derived from *Alpinia calcarata, Cymbopogon citratus, Cinnamomum zeylanicum, C. nardus* and *Murraya koinigii*, have significantly inhibited fecundity and fertility in *C. maculatus*.

Table 3 The effects of plant compounds (Means ± SE) on F_1-Progeny pests

Compound	Plant	F_1-Progeny (Means ± SE)		
		C. maculatus	***S. granarius***	***O. surinamensis***
Essential oil	*C. arizonica*	50.81 ± 0.73[a]	59.64 ± 0.45[a]	49.99 ± 0.85[b]
	J. communis	48.50 ± 0.90[a]	56.83 ± 0.28[a]	54.16 ± 0.73[a]
	M. longifolia	52.26 ± 0.65[a]	56.52 ± 0.88[a]	49.75 ± 0.32[b]
	Control	3.11 ± 0.11[b]	2.90 ± 0.21[b]	2.91 ± 0.46[c]
		F (3, 8) = 552.96 P= 0.001	F (3, 8) = 470.69 P = 0.001	F (3, 8) = 1,281.39 P = 0.001
Extract	*C. arizonica*	49.74 ± 0.96[a]	47.24 ± 0.66[b]	50.65 ± 0.21[ab]
	J. communis	48.26 ± 0.53[a]	52.62 ± 0.78[a]	52.65 ± 0.52[a]
	M. longifolia	50.24 ± 0.86[a]	49.36 ± 0.94[b]	48.98 ± 0.53[b]
	Control	2.90 ± 0.69[b]	2.550 ± 0.29[c]	2.95 ± 0.63[c]
		F (3, 8) = 1,099.50 P = 0.001	F (3, 8) = 1,564.39 P = 0.001	F (3, 8) = 1,136.98 P = 0.001
Powder	*C. arizonica*	46.54 ± 0.72[a]	45.13 ± 0.69[b]	50.65 ± 0.52[ab]
	J. communis	48.68 ± 0.83[a]	48.90 ± 0.42[a]	52.65 ± 0.23[a]
	M. longifolia	47.25 ± 0.97[a]	47.93 ± 0.99[ab]	48.98 ± 0.31[b]
	Control	2.74 ± 0.22[b]	2.66 ± 0.28[c]	2.95 ± 0.63[c]
		F (3, 8) = 902.41 P = 0.001	F (3, 8) = 1,202.35 P = 0.001	F (3, 8) = 1,136.98 P = 0.001

In this study, the essential oil of *C. arizonica* treated on *S. granarius* with 59.64% had the greatest decrease in F_1-Progeny. According to Tiroesele *et al.* (2015) reports, powder of peppermint also showed the significant reduction in the F_1-Progeny of the cowpea weevils but with less effect on weevils than garlic and chilies. Similar researches performed by Pacheco *et al.* (1995) on oviposition and F_1-Progeny of *C. maculatus* in the presence of *Glycine max* and *Ricinus communis* oil had acceptable results. In this study, the effect of *J. communis* powder on reducing F_1-Progeny of *O. surinamensis* with

52.65 ± 0.23 was recorded too. In the study of Tripathi *et al.* (2001) on the impacts of essential oil derived from *Artemisia annua* on fecundity and oviposition on *S. oryzae* showed an acceptable affect either. Investigation of Mobarakyan *et al.* (2015) on the inhibitory effects on its egg laying, respiratory toxicity and repellency of extracts of *Ziziphora clinopodioiotes*, *Lavandula officinalis*, *Laurus nobitis, Rosmarinus officinalis, Salvia officinalis* and *Satureja hortensis* on *C. maculatus* showed that in the highest concentration of inhibiting fecundity test, the extract of all studied plants, the amount of female insect oviposition has decreased by more than 90%, while the highest amount of oviposition inhibitory belonged to *Rosmarinus officinalis* extract with 100% effectiveness.

The results also showed the high potential of these compounds in reducing the population of *C. maculatus*. Studies by Rana *et al.* (2013) on the effect of extracts from *Melia azedarach, M. spicata, M. longifolia, Artamisia roxburghii, A. annua* and *Tagetus evecta* on the oviposition inhibitory of adult *C. chinensis*, showed that the extract of the *M. azedarach* had got the most inhibitory effect of its oviposition with about 62.68% certainty rather than the amount of egg-laying inhibitory of *J. communis* on *O. surinamensis* in the present study with 52.65 ± 0.23%. Experiments of Adesina and Ofuya (2015) on inhibitory effects of oviposition of the leaf extract of *Secamone afzelii* on *C. maculatus,* showed that the extract of this plant had a considerable effect on inhibitory of oviposition this pest, which is similar to the results in the present study. Taghizadeh Saroukalayi and Moharramipour (2011) researches on inhibitory of oviposition effect of *Thymus persicus* extract, was less in comparing with *Prangos acaulis* extract on *C. maculatus*. Studies by Saleem *et al.* (2017) on the effectiveness of four medicinal plant essential oils including *Datura stramonium*, *Eucalyptus campaldulensis*, *Moringa oleifera* and *Nigella sativa* as feeding deterrent against *T. castaneum*, *Trogoderma granarium***,** and *Cryptolestes ferrugineus* showed stored products can be protected by applying essential oils as anti-feeding.

Significant reduction in weight loss of treated food as compared with untreated was observed due to the reduced feeding of insects. *D. stramonium* was the most active anti-feeding with higher feeding deterrence index. Surveys of Negahban and Moharramipour (2007) in regards with reviewing the efficiency of the essential oils of *Artemisia seiberi* and *A. scoparia* on inhibitory of oviposition, egg hatching and mortality of *C. maculatus,* showed that the essential oil of both plants had inhibitory effect on oviposition of this pest. It also indicated that the inhibitory effect of *A. scoparia* was higher than *A. seiberi*. Shakarami *et al.* (2004) surveys regarding the effects of essential oil on *A. aucheri, Salvia bracteata* and *Nepeta cataria* on the oviposition inhabitation, egg hatching and mortality of *C. maculatus* larvae, showed that all three essential oils had a relatively high probability of the mortality of eggs and oviposition inhibitory of this pest, so that the essential oil of *A. aucheri* was 100% effective compared with the two other essential oils.

Investigations of Akrami *et al.* (2011) on comparing the effects of oviposition deterrence and repellent effects of essential oil derived from these two plants, *T. kotschyanus* and *M. longifolia* on *C. maculatus,* indicated that essential oils had significantly reduced the fecundity and inhibition of oviposition in the adult pests. The essential oil of *M. longifolia* had a greater effect than *T. kotschyanus*. Geng *et al.* (2011) the screening of several Chinese medicinal herbs for insecticidal principles showed that *Euphorbia fischeriana* roots possessed significant feeding deterrent activity against *T. castaneum* and *Sitophilus zeamais*. All the essential oils showed the prominent feeding deterrence activities in comparing extracts and powders of plants. Similar investigations were made by (Tripathi *et al.*, 2003; Kiran *et al.*, 2007; Tewari and Tiwari, 2008; Cosimi *et al.*, 2009) who confirmed the feeding deterrence activities of essential oils.

The use of essential oils, extracts and herbal powders as grain protectants in storages

will help in sustainable control of insect pests of stored products; as these plant bio-pesticides are good contact toxicants, antifeedants, repellents and growth inhibitors. Our study suggests that *M. longifolia* essential oil may be a potential grain protectant according to its toxicity, feeding deterrence, F1-Progeny activity. Further research should be conducted to formulate *M. longifolia* oil to increase the efficiency before commercial application can be considered.

CONCLUSIONS

From above reports and study, in lethality case essential oil and extract of *M. longifolia* and powder of *C. arizonica* on *C. maculatus* had the highest mortality. In feeding deterrence case essential oil of *M. longifolia* on *C. maculatus*, extract of *J. communis* on *O. surinamensis* and powder of *C. arizonica* on *S. granarius* had the highest effect. Also, in F_1-Progeny case essential oil of *C. arizonica* on *S. granarius* and extract of *J. communis* on *O. surinamensis* and powder of *C. arizonica* on *O. surinamensis* had the highest effect. We can conclude that essential oils, extracts and powders of three plants have a potential power to lethality, inhibit F_1-Progeny and feeding deterrence against stored pests as alternative synthetic fumigants on integrated program of pest management.

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