



## **Efficacy of Herbal Essential Oils against Cowpea Weevil, *Callosobruchus maculatus* Fabricus, and Wheat Weevil, *Sitophilus granarius* L.**

**FARNAZ SHAFIAE<sup>1</sup>, SHAHRAM ARAMIDEH<sup>2\*</sup>, ORUJ VALIZADEGAN<sup>3</sup>,  
MOHAMMAD HASSAN SAFARALIZADEH<sup>4</sup> and ALI HOSSEINI-GHARALARI<sup>5</sup>**

<sup>1</sup>Department of Plant Protection, Faculty of Agriculture, Pardis of Urmia University, Urmia, Iran.

<sup>2,3,4</sup>Department of Plant Protection, Faculty of Agriculture, Urmia University, Urmia, Iran.

<sup>5</sup>Department of Research Agricultural Entomology, Iranian Research Institute of Plant Protection, Agricultural Research, Education and Extension Organization (AREEO), Tehran, Iran.

\*Corresponding author E-mail: shahramaramideh@gmail.com

<http://dx.doi.org/10.13005/ojc/350337>

(Received: February 06, 2019; Accepted: June 13, 2019)

### **ABSTRACT**

Susceptibility of adult Cowpea Weevil, *Callosobruchus maculatus* F., and wheat weevil, *Sitophilus granarius* L. to essential oils of *Cupressus arizonica* Greene, *Juniperus communis* L. and *Mentha longifolia* L. were studied in the laboratory. The chemical composition of the essential oils were identified by GC/MS. Eicosane (27.42%), Umbellulone (12.92%) and  $\alpha$ -pinene (10.51%) were major components of *C. arizonica* oil. Sabinene (31.93%), Limonene (25.62%) and Bornyl acetate (7.41%) were major components of *J. communis* oil. Pulegone (25.66%), L-menthone (13.43%) and Cis-para-Menthan-3, 8-diol (10.22%) were major components of *M. longifolia* oil. Based on the LC<sub>50</sub> values, *M. longifolia* (44.06  $\mu$ l/L) had the highest toxicity against *C. maculatus* adults, and *J. communis* (109.60  $\mu$ l/L) had the highest toxicity against *S. granarius* adults. The highest mortality of *C. maculatus* (96.23%) happened when treated with *C. arizonica* (LC<sub>25</sub>) + *J. communis* (LC<sub>25</sub>). The highest mortality of *S. granarius* (63.85%) happened when treated with *J. communis* (LC<sub>25</sub>) + *M. longifolia* (LC<sub>25</sub>). There is a promising potential for controlling the cowpea weevil and the wheat weevil by using the essential oils of the studied plants.

**Keywords:** Cowpea weevil, Wheat weevil, Essential oil, Insecticidal effect, GC/MS.

### **INTRODUCTION**

The world population will increase about 70% until 2050. Malnutrition, specifically in the developing countries is one of the most crucial problems.<sup>1</sup> As grains and cereal are important food

sources, there have been extensive research and actions to protect them from pests and diseases.<sup>2</sup> Damage caused by Cowpea weevil, *Callosobruchus maculatus* F. (Col.: Chrysomelidae) in Nigeria is estimated to be as much as 24% to 90% (up to 2900 tons of cowpea).<sup>3</sup> Cowpea weevil is



a cosmopolitan field-to-store pest ranked as the principal post-harvest pest of cowpea in the tropics. It causes quantitative and qualitative yield loss by seed perforation and reductions in weight, market value and germination potential of seeds.<sup>4</sup> It causes substantial quantitative and qualitative losses manifested by seed perforation and reductions in weight, market value and germination ability of seeds.<sup>5</sup> The Wheat Weevil, *Sitophilus granarius* L. (Col.: Curculionidae) is a key pest of cereals in the world. Its damage decreases yield, nutritional value, germination potential and market value.

Environmentally-friendly, cheap and effective methods are needed to control the store-grain pests.<sup>6</sup> Control of insect pests relies heavily on the use of synthetic insecticides such as methyl bromide or phosphine. However, their intensive use has led to development of genetic resistance by insect species, residual toxicity, environmental hazards, and serious problems arising from factors such as direct toxicity to predators, pollinators, fish, and man.<sup>7</sup> Moreover, the application of methyl bromide is being restricted due to its potential damage to ozone layer.<sup>8,9</sup> Therefore, one of the substituted for chemical control is application of herbal essential oils, which can kill, repel, deter or sterilize the insect pest.<sup>10</sup>

Recently, efficacy of active ingredients of 2000 species, from 2500 known herbs, against different pests was evaluated. The active ingredients of essential oils are alkaloids, glycosides, steroids, volatile oils, and terpenes. The insecticidal components of many plant essential oils are monoterpenoids, such as  $\alpha$ -Pinene, Limonene, Cineol, Thymol, Menthone and Menthol, which have high volatility, and can be applied as fumigants against stored-product insects.<sup>11,12,13</sup> Limonene is a neurotoxin that inhibits reproduction and has growth regulatory effects against insects.<sup>14</sup> The most important components of essential oil of *M. longifolia* are Menthol (32.51%), Menthone (20.71%) and Pulegone (17.76%).<sup>15</sup> Main component of essential oils of *C. arizonica*, *J. communis* and *M. longifolia*, cultivated in Iran, Italy and Argentina, is  $\alpha$ -pinene.<sup>16,17</sup> The  $\alpha$ -Pinene is a main component of essential oil extracted from leaves of *J. communis* in Estonia,<sup>18</sup> China<sup>19</sup> and Bulgaria.<sup>20</sup>

There are several studies showing the effective control of insect pests by essential oils of

plants, e.g. essential oil of *C. arizonica* against stored product pests,<sup>21,22</sup> essential oil of *M. longifolia* against *C. maculatus*<sup>23,24</sup> and essential oil of *J. communis* against *Rhizopertha dominica* F. and *Tribolium castaneum* Herbst.<sup>24,25</sup>

The goals of this study were to: 1) study the insecticidal effect of essential oils of *C. arizonica*, *J. communis* and *M. longifolia*, against *C. maculatus* and *S. granarius*; 2) analyze the chemical composition of essential oils by Gas Chromatography and Mass Spectrometry (GC/MS).

## MATERIALS AND METHODS

### Plants material

Aerial parts including leaves of *Cupressus arizonica* Greene (Cupressaceae), *Juniperus communis* L. (Cupressaceae) and *Mentha longifolia* L. (Lamiaceae) were collected from campus of Urmia University (West Azerbaijan Province, Iran) in May 2017. The samples were dried in a shadow (away from sunlight) and ventilated area ( $32\pm 2^\circ\text{C}$ ) for 2-10 days. Each plant sample was cut into small pieces using a blade and a chopping board, and was stored in a refrigerator.

### Insects rearing

Colonies of Cowpea weevil, *C. maculatus* Fabricius, and Wheat weevil, *S. granarius* L. adults were obtained from Toxicology laboratory of Department of Entomology (University of Urmia, Iran). The weevils were reared in plastic containers (20 cm length, 14 cm width, and 8 cm height), covered by a fine mesh cloth for ventilation, containing cowpea beans and wheat grains. The culture was maintained in dark, in a growth chamber ( $27\pm 1^\circ\text{C}$ ,  $65\pm 5\%$  RH). Adult insects (2-3 days old) were used in fumigant toxicity tests. All experiments were carried out under the same environmental conditions.

### Essential oil extraction

Plant materials were grinded into fine powder using a milling machine. Next, 650 ml of distilled water was added to 100 g of each plant samples. The mixture was subjected to hydrodistillation using a modified Clevenger-type apparatus for 3 hours. Anhydrous sodium sulphate was used to dry out the essential oils dried. The final mixture was transferred into amber-colored vials at were kept at  $4^\circ\text{C}$  for further tests.<sup>26</sup>

### GC/MS studies

The analyses were carried out in Jahad-e-Daneshgahi of Urmia, (West Azerbaijan Province, Iran). The chemical composition of essential oils of *C. arizonica*, *J. communis* and *M. longifolia* were analyzed by GC/MS using a gas chromatograph equipped with a flame ionization detector (FID) and with PH-5 capillary column (30 m × 0.1 mm; 0.25 μm film thickness). The oven temperature was held at 60°C for 3 min programmed at 20°C/min to 240°C and then held at this temperature for 8.5 minute. The carrier gas was Helium (99.99 %) at a flow rate of 1 ml/minute. Mass spectra were taken at 70 eV. The injector temperature was 280°C. Identification of the constituents of the oil was made by comparison of their mass spectra and Retention Indices (RI) with those given in the literature and those authentic samples.<sup>27</sup> Chemical compounds of essential oils include esters, aldehydes, alcohols, phenols, chetones and terpenes. Computer matching identified compounds used as references (Wiley and Mass Finder 3.1).<sup>28,29</sup> The relative concentrations of the separated compounds based on percentage were estimated based on chromatograms obtained from GC/FID/MS system.

### Bioassay tests

#### Estimating LC<sub>50</sub> value of essential oils

Bioassay tests with essential oils were performed based on Negahban *et al.*,<sup>26</sup>. Five concentrations of essential oils of the three plant species (8.88, 11.74, 29.99, 129.94, 200.70 μl/L) were applied on *C. maculatus* adults. Concentrations applied against *S. granarius* adults were 13.33, 77.76, 144.04, 203.66, 471.58 μl/L. Control treatment was distilled water. Each concentration was applied into a glass container by a micropipette on a filter paper. Twenty

insects (2 to 3 days old) were placed in each glass, containing 20 g of diet (cowpea beans and wheat grains). The glass containers were sealed with a parafilm strip. Treatments and control were kept at 27±1°C and 65±5% RH, in the dark. The number of dead insects in the treated and control dishes was counted after 24 h and the mortality rate was estimated. Insects that did not move the legs or two posterior segments of the abdomen were considered dead.

### Toxicity effects of essential oils

After estimating the LC<sub>25</sub> and LC<sub>50</sub> values for essential oils of *C. arizonica*, *J. communis* and *M. longifolia* against adults, the following treatments were applied against adults of *C. maculatus* and *S. granarius*: (LC<sub>50</sub> *C. arizonica*), (LC<sub>50</sub> *J. communis*), (LC<sub>50</sub> *M. longifolia*), (LC<sub>25</sub> *C. arizonica* + LC<sub>25</sub> *J. communis*), (LC<sub>25</sub> *C. arizonica* + LC<sub>25</sub> *M. longifolia*), (LC<sub>25</sub> *J. communis* + LC<sub>25</sub> *M. longifolia*) and control. The mortality rate was estimated after 24 hours.<sup>30</sup>

### Data Analysis

The LC<sub>25</sub> and LC<sub>50</sub> values (with 95% confidence limits) were estimated using Probit Analysis. Mean mortality rates were subjected to analysis of variance (One-way ANOVA) followed by Tukey test (α=5%) using SPSS statistical analysis software.

## RESULTS

### Gas chromatography-mass spectrometry of three essential oils

The essential oils obtained from *C. arizonica* had 23 compounds, the most abundant ones were Eicosane (C<sub>20</sub>H<sub>42</sub>): (27.42%), Umbellulone (C<sub>10</sub>H<sub>14</sub>): (12.92%) and α-Pinene (C<sub>10</sub>H<sub>16</sub>): (10.51%) (Table 1).

**Table 1: Essential oil composition (%w/w) of leaves of *Cupressus arizonica* Greene cultivated in Iran**

Component	RI	RT	%	Component	RI	RT	%
α-Pinene	934	5.28	10.51	Elemicin	1560	18.9	0.47
Sabinene	970	6.05	1.6	Cedrol	1608	19.84	1.27
β-Myrcene	990	6.38	0.71	1-Cubenol	1635	20.35	4.18
O-Cymene	1014	7.11	2.95	a-acorenol	1638	20.42	0.64
Limonene	1030	7.24	5.87	α-Cadinol	1657	20.78	0.78
Camphor	1148	9.92	1.41	Eudesm-7(11)-en-4-ol	1694	21.47	3.9
Umbellulone	1176	10.57	12.92	Eicosane	2158	28.96	27.42
Terpinene-4-ol	1179	10.64	4.08	Tetraatriacontane	2390	31.24	0.66
α-Terpineol	1193	10.97	1.38	Nonacosane	2606	33.54	4.82
Alloaromadrene	1467	17.03	3.34	Dotriacontane	3046	39.92	1.45
1s,cis-calamenene	1525	18.22	3.47	17-Pentatriacontene	3644	48.6	0.98
Candina-1(2),4-diene,cis	1538	18.46	0.86				

The essential oils obtained from *J. communis* had 25 compounds, the most abundant ones were Sabinene (C<sub>10</sub>H<sub>16</sub>): (31.93%), Limonene (C<sub>10</sub>H<sub>16</sub>): (25.62%) and Bornyl acetate (C<sub>12</sub>H<sub>20</sub>): (7.41%) (Table 2).

The essential oils obtained from *M. longifolia* had 29 compounds the most abundant ones were Pulegone (C<sub>10</sub>H<sub>16</sub>O) (25.66%), L-Menthone (C<sub>10</sub>H<sub>18</sub>O): (13.43%) and Cis-para-Menthan-3, 8-diol (C<sub>10</sub>H<sub>20</sub>O): (10.22%) (Table 3).

**Table 2: Essential oil composition (%w/w) of leaves of *Juniperus communis* L. cultivated in Iran**

Component	RI	RT	%	Component	RI	RT	%
Thujene 928	5.1	0.07	Terpinene-4-ol	1179	10.64	3.37	
α-Pinene	934	5.28	1.29	α-Terpineol	1193	10.97	0.51
Sabinene	970	6.05	31.93	Trans-carveol	1219	11.57	0.3
β- Myrcene	989	6.35	2.52	Isobronyl formate	1226	11.73	0.34
1,4-Cineole	1014	6.89	1.86	Caryone	1245	12.17	0.61
O-Cymene	1014	7.11	3.36	Bronyl acetate	1287	13.13	7.41
Limonene	1030	7.24	25.62	Laranduly acetate	1293	13.26	3.33
C-Terpinene	1057	7.84	1.87	A-Selinene,7-epi-	1517	18.05	0.67
Linolool 1098	8.78	2.13	Germacrene B	1551	18.73	3.42	
Limonene oxide,trans-	1122	9.32	0.51	Cubenol,1,10-di-epi-	1614	19.95	0.51
Terpen-1-ol	1134	9.61	0.49	A-Muurolol	1645	20.54	1.2
Camphor	1148	9.92	0.65	A-Cadinolii	1658	20.79	2.39
3-Hexenyl butanoate,(z)-	1168	10.4	0.41				

**Table 3: Essential oil composition (%w/w) of leaves of *Mentha longifolia* L. cultivated in Iran**

Component	RI	RT	%	Component	RI	RT	%
α-Pinene	934	5.28	5.49	Cis-piperitone oxide	1257	12.45	3.61
Sabinene	970	6.05	0.97	Thymol	1280	13.19	0.52
β-Myrcene	990	6.38	0.51	P-Cymen-7-ol	1294	13.28	0.66
O-Cymene	1014	7.11	1.19	Piperitenone	1343	14.37	0.79
Limonene	1030	7.24	2.91	α-Terpinyl acetate	1350	14.53	9.47
1,8-Cineole	1032	7.3	0.99	Piperitenone oxide	1368	14.92	2.17
Linalool 1	1099	8.8	0.33	Trans-Caryophyllene	1425	16.15	0.66
Camphor	1148	9.92	0.54	Alloaromadendrene	1467	17.03	1.36
L- Menthone	1157	10.15	13.43	1s,cis-Calamene oxide	1525	18.22	2.19
Isomenthone	1166	10.35	1.56	Caryophyllene oxide	1589	19.49	0.74
Cis-para-Menthan-3,8-diol	1175	10.56	10.22	Cedrol	1608	19.84	0.79
Terpinene-4-ol	1179	10.64	2.87	1-Cubenol,epi-	1635	30.35	2.42
α-Terpinneol	1193	10.97	0.96	α-Cadinol	1657	20.78	0.77
Cis-dihydrocaryone	1202	11.11	1	Eudesm-7(11)-en-4-ol	1694	21.47	2.74
Pulegone	1240	12.15	25.66				

**Bioassay tests**

**Fumigant toxicity**

The LC<sub>50</sub> values of *C. arizonica*, *J. communis* and *M. longifolia* essential oils against adult Cowpea Weevil after 24 h were 106.64, 96.83 and 44.06 µl/L air, respectively (Table 4).

The results of the analysis of variance of mean mortality of *C. maculatus* treated with the seven treatments showed that there was significant difference among treatments which included *M. longifolia* essential oils (F<sub>6,14</sub>=20.059; P≤ 0.001).; however, no significant differences was

observed between treatments of *C. arizonica* and *J. communis*.

LC<sub>50</sub> values of *C. arizonica*, *J. communis* and *M. longifolia* essential oils against adults of wheat weevil after 24 h were 171.08, 109.60 and 297.35 µl/L air, respectively.

The results of the analysis of variance of mean mortality of *S. granarius* treated with the seven treatments showed that there was significant difference among treatments (F<sub>6,14</sub>=116.848; P≤ 0.001) (Table 5).

**Table 4: Fumigant toxicity of three essential oils on adult Cowpea Weevil, *C. maculatus***

Treatment†	Slope (±SE)	Intercept (±SE)	Chi square§	95% confidence limits for dose	
				LC <sub>50</sub> (µl/L air) (lower-upper)	LC <sub>25</sub> (µl/L air) (lower-upper)
<i>C. arizonica</i>	2.356 (±0.074)	-0.291 (±0.821)	0.581	54.8 (31.84-71.83)	106.64 (81.16-145.27)
<i>J. communis</i>	1.675 (±0.004)	-0.846 (±0.743)	1.174	39.28 (30.69-48.87)	96.83 (65.18-124.05)
<i>M. longifolia</i>	2.843 (±0.062)	-1.698 (±0.957)	1.285	25.18 (19.99-29.62)	44.06 (29.14-55.99)*

\*95% lower and upper fiducial limits are shown in parenthesis.

† There were 60 insects n each treatment.

§ DF= 3

**Table 5: Fumigant toxicity of three essential oils on adult Wheat Weevil, *S. granarius***

Treatment†	Slope (±SE)	Intercept (±SE)	Chi square§	95% confidence limits for does	
				LC <sub>50</sub> (µl/L air) (lower-upper)	LC <sub>25</sub> (µl/L air) (lower-upper)
<i>C. arizonica</i>	1.163 (±0.054)	-0.978 (±0.561)	2.638	171.08 (149.53-237.89)*	64.47 (55.47-82.31)
<i>J. communis</i>	2.201 (±0.028)	-1.942 (±0.795)	3.374	109.6 (68.46-127.54)*	38.36 (15.14-48.13)
<i>M. longifolia</i>	1.326 (±0.116)	-0.615 (±0.870)	2.085	297.35 (261.39-378.64)*	137.38 (94.36-176.39)

\*95% lower and upper fiducial limits are shown in parenthesis.

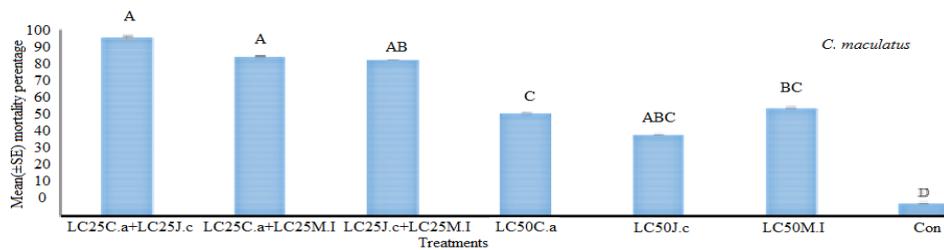
† There were 60 insects n each treatment.

§ DF= 3

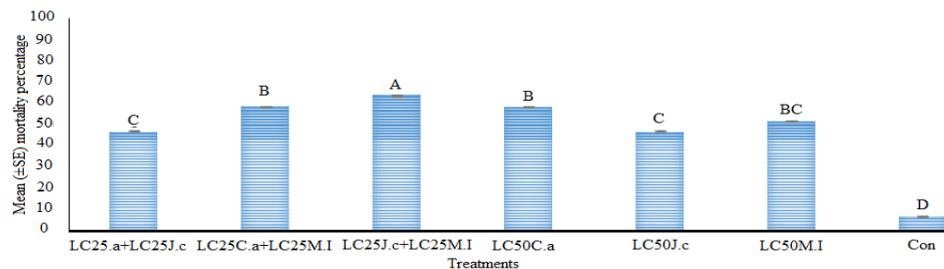
**Toxicity effects of essential oils**

The results of Tukey test indicated that the highest moratlity rate of *C. maculatus* was observed when treated with ‘LC<sub>25</sub> *C. arizonica* + LC<sub>25</sub> *J. communis*’ (96.23%) followed by ‘LC<sub>25</sub> *C. arizonica* + LC<sub>25</sub> *M. longifolia*’ (85.06%) (Figure 1).

The results of Tukey test indicated that the highest moratlity rate of *S. granarius* was observed when treated with ‘LC<sub>25</sub> *J. communis* + LC<sub>25</sub> *M. longifolia*’ (63.85%) (Fig. 2). Therefore the essential oils resulted in higher mortality rates when applied in combination compared to when applied alone.



**Fig. 1. Mean (±SE) mortality percentage of adult Cowpea Weevil, *C. maculatus*, 24 h after treatment with different essential oils obtained from three plant species. Columns which have at least one letter in common were not significantly different based on Tukey test (α=5%).**



**Fig. 2. Mean (±SE) mortality percentage of adult Wheat Weevil, *S. granarius* 24 h after treatment with different essential oils obtained from three plant species. Columns which have at least one letter in common were not significantly different based on Tukey test (α=5%)**

## DISCUSSION

In recent years, due to the excessive application of chemical pesticides which have had harmful effects on environment, much tendency has gone towards the application of less harmful compounds such as herbal extracts. In this study, three essential oils were tested for their fumigant toxicity against adults of *C. maculatus* and *S. granarius*. Monoterpenoids have strong toxicity to insects due to high volatility that can penetrate into insects rapidly and interfere in physiological functions.<sup>31,32</sup> *C. arizonica*, *J. communis* and *M. longifolia* are composed mainly of monoterpene (18.18, 45.89 and 50.16) % and cyclic monoterpene (5.87, 26.13 and 2.91) %, respectively.

There was difference in the percentage of the ingredients of the essential oils in our study compared to the other similar reports. The chemical constituents of *M. longifolia* oil collected by Monfared *et al.*,<sup>33</sup> from Iran (Tehran province), extracted by the same method as ours, included Carvone (61.8%) and Limonene (19.4%) as the major constituents out of 23 compounds. Salman *et al.*,<sup>34</sup> from Saudi Arabia (Taif), reported that *M. longifolia* oil has 38 compounds with Pulegone (33.21%) and Menthone (28.53%) being the major constituents. Another study showed that the essential oil components of *M. longifolia* are cis-epoxy piperitone (18.4%), pulegone (15.5%) and piperitenone oxide, (14.7%).<sup>35</sup> Another research by Saeidi *et al.*,<sup>36</sup> conducted using specimens collected from five different regions in South-West of Iran, showed that the major compounds of *M. longifolia* are Piperitenone oxide (7.41 to 59.67%) and Pulegone (3.61 to 49.43%). In our research, which was conducted using specimens collected from North-West of Iran, 29 compounds were found, among which, Pulegone (25.66%) and L-Menthone (13.43%) were the major constituents. Angioni *et al.*,<sup>37</sup> reported that the essential oils of leaves of *J. communis*, from Italy, included 35 components, among which Sabinene was the most abundant component (61.09%). Also Sabinene has been reported as the major component of essential oil in the plant species collected from North of Iran (19.2%).<sup>38</sup> The major components of *J. communis* are monoterpene (83.21%) and sesquiterpene (1.27%). Results of our study showed that the essential oil composition of *J. communis* included

25 components, among which Sabinene (31.93%), Limonene (25.62%) and Bronyl acetate (31.93%) were the main components. In our study, Sabinene was the dominate component was similar to report from Italy and Iran.<sup>37,38</sup> The composition of the essential oil from the leaves of *J. communis* in our research was different from reports of China, Republic of Macedonia and Albania, as in other studies  $\alpha$ -Pinene was the major component. Carroll *et al.*,<sup>19</sup> reported that the major component of *J. communis* oil in China was  $\alpha$ -Pinene (26.9%). Sela *et al.*,<sup>39</sup> reported that essential oil of junipers in the Republic of Macedonia included mainly  $\alpha$ -Pinene (15.59-43.19%),  $\beta$ -Pinene (1.65%-5.35%),  $\beta$ -Myrcene (2.89%-26.50%) and Sabinene (2.80-11.77%). Buci *et al.*,<sup>40</sup> reported that the chemical composition of *J. communis* essential oil in Albania included 56 compounds among which the major components were  $\alpha$ -pinene (35.8%),  $\beta$ -myrcene (44.9 %), Sabinene (10.0%) and Germacene D (4.59%). Also *J. communis* oil is composed mainly of monoterpenes (71.8%).

This study results showed that  $\alpha$ -Pinene (10.52%) was one of the main components of the essential oil of *C. arizonica*, which was similar to other reports. The essential oil of *C. arizonica* in Tunisia was mainly composed of  $\alpha$ -Pinene (20%), Umbellulone (18.4%) and Limonene (5.8%).<sup>41</sup> The  $\alpha$ -Pinene was one of the main components of the oil obtained from leaves of *C. arizonica* cultivated in Iran (19.2%)<sup>16</sup>, Italy (7.8%)<sup>42</sup> and Argentina (22.9%).<sup>17</sup>

In literature there are differences among the major compounds, the number and percentage of compounds in essential oils of plants. These differences can be due to factors such as geographic location, plant organs used, extraction methods, season of sampling and soil composition.<sup>43,44,45</sup>

Studies of Javadi Elmi *et al.*,<sup>46</sup> about the respiratory toxicity of *M. longifolia* essential oil against adults of *C. maculatus* indicated that this essential oil, at the highest concentration of 685.42  $\mu$ L air, caused 100 % mortality. They also reported the LC<sub>50</sub> value of *M. longifolia* essential oil as 134.04  $\mu$ L air. In our study, *M. longifolia* essential oil had a LC<sub>50</sub> value of 44.06  $\mu$ L air, which resulted in an acceptable control of *C. maculatus*. The study of Khani and Asghari<sup>47</sup> on insecticide

activity of essential oils of *M. longifolia*, *Pulicaria gnaphalodes* and *Achillea wilhelmsii* against *C. maculatus* and *T. castaneum* adults, showed that essential oil of *M. longifolia* (LC<sub>50</sub> value= 13.05 µl/L air) and *A. wilhelmsii* (LC<sub>50</sub> value= 10.02 µl/L air) had strong insecticidal activity. Our study showed that *J. communis* essential oil had a high insecticidal effect against *S. granarius* (LC<sub>50</sub> value=109.60 µl/L air). Hashemi and Roostaefar<sup>24</sup> study on the insecticidal effect of *J. communis* essential oil on *Rhizopertha dominica* and *Tribolium confusum* showed that this essential oil was efficient against both pests, while LC<sub>50</sub> value was 36.96 µl/L air for *R. domonica* and 107.96 µl/L for *T. confusum*. In our study, LC<sub>50</sub> value of *J. communis* against *C. maculatus* was 96.83 µl/L air, while it was 109.60 µl/L air against *S. granarius*. Therefore, *C. maculatus* was more susceptible than *S. granarius*.

In our study, *C. maculatus* adults were more susceptible to *M. longifolia* essential oil (LC<sub>50</sub> = 44.06 µl/L air) than to *J. communis* (LC<sub>50</sub> = 96.83 µl/L air) and *C. arizonica* (LC<sub>50</sub> = 106.64 µl/L air). In addition, *C. maculatus* was more susceptible than *S. granarius*. Saeidi and Moharrampour<sup>48</sup> reported that *T. confusum* adults were more susceptible to *Artemisia khorassanica* (LC<sub>50</sub> = 22.45 µl/L air) and *R. officinalis* essential oils (LC<sub>50</sub> = 22.14 µl/L air) than to *M. longifolia* oil (LC<sub>50</sub> = 39.96 µl/L air). Hesami Rad and Aramideh<sup>49</sup> studied the effects of essential oils

from *Juniperus polycarpus* L., wood vinegar and acetone on *C. maculatus* and *S. granarius*. The LC<sub>50</sub> values of *J. polycarpus*, wood vinegar and acetone on *S. granarius* and *C. maculatus*, after 24 h were 21.28, 93.72, 20.05 and 59.53, 96.23, 35.76 µl/L air, respectively. The results showed that acetone in mixed with *J. polycarpus* had the highest mortality on *S. granarius* and *C. maculatus*. The results of our research indicated that the highest mortality rate of *C. maculatus* was observed when treated with 'LC<sub>25</sub> *C. arizonica* + LC<sub>25</sub> *J. communis*' (96.23% mortality) while the highest mortality rate of *S. granarius* was observed when treated with 'LC<sub>25</sub> *J. communis* + LC<sub>25</sub> *M. longifolia*' (63.85% mortality). Therefore, the application of three essential oils of *C. arizonica*, *J. communis* and *M. longifolia* against Cowpea weevil and Wheat weevil, can be recommended as a suitable and safe control method in pest management programs.

#### ACKNOWLEDGEMENT

We thank the members of the laboratory of Entomology and the Department of Plant Protection of Urmia University and Jihad-e-Daneshgahi of Urmia for supplying the herbal essential oils and the assisting in chemical analysis.

#### Conflicts of Interest

The authors declare no conflict of interest.

#### REFERENCES

1. Talukder, F. *J. Agr. Mar. Sci.*, **2009**, *14*, 9-15.
2. Kim, S. I.; Roh, D. H.; Lee, H. S.; and Ahn, Y. *J. J. Stored. Prod. Res.*, **2003**, *39*, 293-303.
3. Tapondjou, A. L.; Adler, C.; Fontem, D. A.; Bouda, H.; and Reichmuth, C. *J. Stored. Prod. Res.*, **2001**, *41*, 91-102.
4. Bamphitlhi, T.; Kesegofetse, T.; and Seipati, S. *Int. J. Insect. Sci.*, **2014**, *6*, 77-84.
5. Oluwafemi, A. R. *SOAJ. Entomol.*, **2012**, *1*, 87-99.
6. Stejskal, V.; and Kucerova, Z. *J. Applied. Entomol.*, **1996**, *120*, 143-146.
7. Mahmud, M. K.; Khan, M. K. H.; Husain, M.; Alam, M. I.; and Afrad, S.I. *J. Asiat. Soc. Bangladesh.*, **2002**, *28*, 11-18.
8. Athanassiou, C.G.; Kavallieratos, N. G.; Vayias, B.J.; and Panoussakis, E. C. *J. Stored. Prod. Res.*, **2008**, *44*, 279-284.
9. Lolestani, F. A.; and Shayesteh, N. *J. Biologic. Sci.*, **2009**, *9*, 92-95.
10. Kieta, S. M.; Vincent, C.; Schmit, J.; Arnason, J. T.; and Belanger, A. *J. Stored. Prod. Res.*, **2001**, *37*, 339-349.
11. Coats, J.; Karr, L.; and Drewes, C. *ACS. Washington, DC.*, **1991**, 305-316.
12. Regnault-Roger, C.; and Hamraoui, A. *J. Stored. Prod. Res.*, **1995**, *31*, 291-299.
13. Ahn, Y.; Lee, B.; Lee, H.; and Kim, H. *J. Chem. Ecol.*, **1998**, *24*, 1-90.
14. Khani, M.; Muhamad, A. R.; and Omar, D. *J. Med. Plants.*, **2012**, *11*, 97-110.
15. Hafedh, H.; Fethi, B. A.; Mejdji, S.; Emira, N.; and Amina, B. *Afr. J. Microbial. Res.*, **2010**, *4*, 1122-1127.
16. Afsharypuor, S.; and Tavakoli, P. *J. Essent. Oil. Res.*, **2005**, *17*, 225-226.

17. Malizia, R. A.; Acardell, D.; Molli, J. S.; Gonzalez, S.; Guerra, P. E. and Grau, R. J. *J. Essent. Oil Res.*, **2000**, *12*, 59-63.
18. Orav, A.; Kailas, T.; and Murrisepp, M. *Nation. Pro. Res.*, **2010**, *24*, 1789-99.
19. Carroll, J. F.; Tabanca, N.; Kramer, M.; Elejalde, N. M.; Wedge, D. E.; Bernier, U. R.; Coy, M.; Becnel, J. J.; Demirci, B.; Baser, K. H. C.; Zhang, J.; and Zhang, S. *J. Vector. Ecol.*, **2011**, *36*, 258-268.
20. Adams, R. P.; and Tashev, A. N. *Phytologya.*, **2013**, *95*, 302-307.
21. Abad, M. K. R.; Besheli, B. A.; and Sharif, M. M. *Int. J. Agron. Plant. Pro.*, **2013**, *4*, 2531-2536.
22. Kabiri Raisabad, M.; Mohammadi Sharif, M.; and Kabiri Nasab, M. *Agric. Sci. J.*, **2014**, *3*, 1-11. (In Persian).
23. Almasi, S.; Shakarami, J.; and Fallahzadeh, M. *National. Con. Agric. Manage.*, **2011**.
24. Hashemi, S. M.; and Roostaefar, A. *Ecologia. Balkanica.*, **2014**, *6*, 87-93.
25. Gordien, A. I.; Gray, A. I.; Franzblau, S. G.; and Seidel, V. *J. Ethnopharmacol.*, **2009**, *79*, 57-67.
26. Negahban, M.; Moharramipour, S.; and Sefidkon, F. *J. Stored. Prod. Res.*, **2007**, *43*, 123-128.
27. Adams, R. P. *Allured. Pub. Co. Carol. Stream. IL. USA.*, **2001**, 456.
28. Koenig, W. A., Joulain, D. and Hochmuth, D. H., **2004**, 493.
29. Mc Lafferty, F.W.; and Stauffer, D. B. *J. Chem. Educ. New York.*, **1989**, *66*, 1-7.
30. Abbott, W. S. *J. Econ. Entomol.*, **1995**, *18*, 265-267.
31. Negahban, M.; Moharramipour, S.; and Sefidkon, F. *J. Asia Pac Entomol.*, **2006**, *9*, 381 - 8.
32. Lee, B. H.; Lee, S. E.; Annis, P. C.; Pratt, S. J.; Park, B. S.; and Tumaalii, F. *J. Asia Pac Entomol.*, **2002**, *5*, 237-40.
33. Monfared, A.; Nabid, M. R.; and Rustaeiyan, A. A. H. *J. Essent. Oils Res.*, **2002**, *14*, 51-5.
34. Salman, M.; Abdel Hamed, E. S. S.; Bazaid, A. S.; and Dabi, M. M. *Sch. Res. Lib.*, **2015**, *7*, 34-40.
35. Gulluce, M.; Sahin, F.; Sokmen, M.; Ozer, H.; Daferera, D.; Sokmen, A.; Polissiou, M.; Adiguzel, A.; and Ozkan, H. *Food Chem.*, **2007**, *103*, 1449-1456.
36. Saeidi, Z.; Babaahmadi, H.; Saeidi, K. A.; Salehi, A.; Saleh Jouneghani, S.; Amirshakari, H.; and Taghipour, A. *J. Med. Plants. Res.*, **2011**, *6*, 4522-4525.
37. Angioni, A.; Barras, A.; Russo, M. T.; Coroneo, V.; Dessi, S.; and Cabras, P. *J. Agric. Food. Chem.*, **2003**, *51*, 3073-3078.
38. Shahmir, F.; Ahmadi, L.; Mirza, M.; and Korori, S. A. A. *Flavour Fragr J.*, **2003**, *18*, 425.
39. Sela, F.; Karapandzova, M.; Stefkov, G.; and Kulevanova, S. *Maced. Pharm. Bull.*, **2011**, *57*, 43-51.
40. Buci, A.; Hodaj Celiku, E.; Manaj, H.; Abazi, S.; Drushku, S.; and Lazari, D. *J. Int. Env. App. Sci.*, **2018**, *13*, 15-19.
41. Che'raif, H.; Jannet, B.; Hammami, M.; Khouja, M. L.; and Mighri, Z. *Biochem. Syst. Ecol.*, **2007**, *35*, 813-820.
42. Flamini, G.; Cioni, P. L.; Morelli, I.; Bighilli, A.; Castola, V.; and Casanora, J. *J. Essent. Oil Res.*, **2003**, *15*, 302-304.
43. Farooqi, A.; Sharama, S.; Naqvi, A.; and Khan, A. *J. Essent. Oil Res.*, **1993**, *5*, 305-309.
44. Jaymand, K.; and Rezaie, M. B. *Iranian J. Med. Aro. Plants.*, **2001**, *9*, 2-145.
45. Bakkali, F.; Averbeck, S.; Averbeck, D.; and Idaomar, M. *Food. Chem. Toxicol.*, **2008**, *46*, 446-75.
46. Javadi Elmi, M.; Shakarami, J.; and Bandani, A. *New. Agric. Finding.*, **2007**, *2*, 75-81. (In Persian).
47. Khani, A.; and Asghari, J. *J. Insect Sci.*, **2012**, *12*, 1536-2442.
48. Saeidi, M.; and Moharramipour, S. *Crop. Prot.*, **2013**, *2*, 23-31.
49. Hesami Rad, Sh.; and Aramideh, Sh. *Master. Sci. thesis.*, **2014**.