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Control of Three Stored−Product Beetles with Artemisia haussknechtii (Boiss) (Asteraceae) Essential Oil

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Abstract. Fumigant toxicity of the essential oil of aerial parts from *Artemisia haussknechtii* (Boiss) (Asteraceae) was investigated against the cowpea weevil *Callosobruchus maculatus* (Fab.), the rice weevil *Sitophilus oryzae* (L.), and the red flour beetle *Tribolium castaneum* (Herbst). Dry ground plants were subjected to hydro−distillation using a Clevenger−type apparatus and the chemical composition of the volatile oil was studied by gas chromatography−mass spectrometry (GC−MS). The major components of the oil were camphor (29.24%), 1, 8−cineol (27.62%), yomogi alcohol (5.23%), and camphene (4.80%). The essential oil in same concentrations was assayed against (1−7 days old) adults of insect species and percentage mortality was recorded after 24, 48, and 72 h exposure times. LC_{50} values were varied between 19.84 and 103.59 μL L^{-1} air, depending on insect species and exposure time. *Callosobruchus maculatus* was more susceptible than other species. These results suggested that *A. haussknechtii* oil might have potential as a control agent against *C. maculatus*, *S. oryzae* and *T. castaneum*.

Key words: *Artemisia haussknechtii*, essential oil, stored−product beetles.

Introduction

Insects are one of the major causes of grain losses during storage (SCOTTI, 1978). Crop losses due to insect pests changed between 10 and 30% for major crops (FERRY *et al.*, 2004). The major insect pests of stored grains are members of Coleoptera that are the largest order in the animal kingdom, with over one−third of a million described species (BOOTH *et al.*, 1990). Insect pests of stored grain feed directly on commodities and can be conveniently divided into primary pests (such as *Callosobruchus sp.*, *Sitophilus sp.* and *Rhyzopertha sp.*) those that attack intact commodities, and secondary pests (such as *Oryzaephilus sp.*, *Cryptolestes sp.*, *Cadra sp.* and *Tribolium sp.*) which require the commodity to be damaged before they can attack it (REES, 2007).

Fumigation plays a very important role in insect pest elimination in stored products (ZETTLER & ARTHUR, 2000). Few chemicals are suitable for use as fumigants. They should be biologically active and control pest insects without damage to stored grain, sufficiently volatile to be removed by aeration, unabsorbed by the grain, inflammable and inert with metals. The use of phosphine (PH_3) is increasing due to the convenience of formulations, the relatively short−term hazard, and low retention of residues. However, PH_3 fumigation may become increasingly limited in use because resistance of stored grain insects to phosphine has now been discovered in more than 45 countries (BELL & WILSON, 1995; CHAUDHRY, 1995). The use of methyl bromide is being restricted because of its

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potential to damage the ozone layer (BUTLER & RODRIGUEZ, 1996). Plant essential oils and their components have been shown to possess potential for development as new fumigants and they may have advantages over conventional fumigants in terms of low mammalian toxicity, rapid degradation and local availability (ISMAN, 2008).

The genus *Artemisia* (Asteraceae family) with the common Persian name of 'dermane' and also with common English name of 'wormwood' includes 34 species that are found wild all over Iran of which two are endemic (MOZAFFARIAN, 1996). *Artemisia* species are popular plants that are used for the treatment of diseases such as hepatitis, cancer, inflammation and infections by fungi, bacteria, and viruses (KIM *et al.*, 2002). Local people in the western part of Iran use *A. haussknechtii* in dyspepsia and other gastrointestinal disorders (KHANAHMADI *et al.*, 2009).

The present work was carried out to determine the possible fumigant toxicity of the essential oil of *A. haussknechtii* against the cowpea weevil *Callosobruchus maculatus* (Fab.), the rice weevil *Sitophilus oryzae* (L.), and the rust−red flour beetle *Tribolium castaneum* (Herbst).

Material and methods

Insect culture.

Callosobruchus maculatus, *S. oryzae* and *T. castaneum* were reared on bean grains, whole rice and wheat flour mixed with yeast (10:1, w/w), respectively. Adult insects, 1–7 days old, were used for fumigant toxicity tests. The cultures were maintained in the dark in a growth chamber set at 27±2°C and 60±5% r.h. All experiments were carried out under the same environmental conditions.

Plant material.

Aerial parts of *A. haussknechtii* were collected at full−flowering stage in June 2010 in the region of karand in the west of Kermanshah (latitude: 37° 32', longitude: 45° 05'; altitude: 1313 m). Plant taxonomists in the Department of Biology at Urmia University, confirmed the taxonomic identification of plant species. The voucher specimens have been deposited at the herbarium of the Department of Plant Protection at Urmia University. The plant material was dried naturally on laboratory benches at room temperature (23−24ºC) for 5 days until crisp. The dried material was stored at −24 ºC until needed and then hydro distilled to extract its essential oil (NEGAHBAN *et al.*, 2007).

Extraction and analysis of essential oil.

Essential oil was extracted from the plant samples using a Clevenger−type collector where the plant material is subjected to hydro distillation. Conditions of extraction were: 50 g of air−dried sample; 1:10 plant material/water volume ratio, 2 h distillation. Anhydrous sodium sulphate was used to remove water after extraction. Oil yield (0.9% w/w) was calculated on a dry weight basis. Extracted oil was stored in a refrigerator at 4 °C.

The constituents of essential oil were analyzed by gas chromatography mass spectrometry (GC−MS) (Thermo−UFM). The GS conditions were as follows: capillary column 1−ph (30 m x 0.25 mm, film thickness 0.25 µm); helium as a carrier gas (0.5 ml/min); oven temperature program, initially 40°C rising to 250°C (80°C/min, 3 min); injector and detector temperature of 250°C. The identification of individual compounds were based on comparison of their relative retention times with those of authentic samples on a capillary column, and by matching their mass spectra of peaks with those obtained from authentic samples and published data (DAVIES, 1990).

Fumigant toxicity.

In order to test the toxicity of essential oil, concentrations 30, 38, 49, 63 and 80 µl.l^{-1} air of the oil were dissolved in 100 µl acetone, dried in air for 2 min and applied on a filter−paper (Whatman No.1) strip measuring 4 × 5 cm that was attached to the lower side of the jars lid. Twenty adults (1–7 days old) of insects were placed in small plastic tubes (3.5 cm diameter and 5 cm height) with open ends covered with cloth mesh. The tubes were hung at the geometrical center of 1 L glass jars, which were then sealed with air−tight lids. Thus, there was no direct contact between the oil and the insects. In the control jars, only acetone applied on the filter papers.

Mortality was determined after 24, 48 and 72 h from commencement of the exposure. Each experiment was replicated four times for each concentration. When no leg or antennal movements were observed, insect was considered dead.

Data analysis.

The mortality data were corrected using Abbott's formula (ABBOT, 1925) for the mortalities in the controls, and then subjected to probit analyses to estimate LC_{50} and LC_{95} values. The percentage mortality was determined for analysis of variance (ANOVA) according to the general linear model (GLM). Significant differences were identified by honest significant difference (HSD) tests at the 5% level and entered in the fig. Data processing was conducted by the SPSS 16.0 for Windows.

Results

Fumigant toxicity.

In all cases, considerable differences in mortality of insects to essential oil vapor were observed with different concentrations and times. Probit analysis showed that *C. maculatus* (LC_{50}=59.29 µl.l^{-1} air) was more susceptible to *A. haussknechtii* oil than *S. oryzae* (LC_{50}=84.49 µl.l^{-1} air) and *T. castaneum* (LC_{50}=103.59 µl.l^{-1} air). The corresponding LC_{95} values were 263.67, 303.8 and 286.75 µl.l^{-1} air, respectively. The 95% fiducial limits of the LC_{50} and LC_{95} values for three species are shown in Table 1.

Table 1. Result of probit analysis to calculate LC_{50} and LC_{95} values.

Insects	Time [h]	LC_{50}[a]	LC_{95}[a]	χ^2 [df = 3]	*p*	Inter-cept	Slope
C. maculatus	24	59.29 (46.72−101.42)	263.67 (131.09−9766.62)	0.79[b]	0.85	0.50	2.53
	48	37.53 (30.62−42.80)	79.72 (64.78−126.90)	2.06[b]	0.55	-2.91	5.02
	72	19.84 (0.07−27.35)	42.31 (34.18−236.29)	2.04[b]	0.56	−1.48	5.00
S. oryzae	24	84.49 (65.50−214.66)	303.80 (149.79−7822.18)	1.12[b]	0.77	−0.70	2.96
	48	53.02 (42.79−70.55)	188.80 (112.51−1253.75)	1.58[b]	0.66	−0.14	2.98
	72	29.19 (18.50−35.00)	68.01 (54.91−122.86)	1.77[b]	0.62	−1.56	4.47
T. castaneum	24	103.59 (78.11−328.17)	286.75 (149.26−5963.63)	0.33[b]	0.95	−2.49	3.72
	48	65.75 (54.84−95.75)	199.12 (121.65−971.56)	0.55[b]	0.90	−1.21	3.41
	72	31.54 (16.17−39.42)	109.37 (75.64−448.05)	1.00[b]	0.80	0.34	3.04

[a] Ninety−five percent lower and upper fiducial limits are shown in parenthesis.
[b] Since the significance level is greater than 0.150, no heterogeneity factor is used in the calculation of confidence limits.

From the graph in Fig. 1 it can be seen that, *A. haussknechtii* oil was relatively more toxic to *C. maculatus* than to *S. oryzae* and *T. castaneum*. The least concentration (30 µl.l^{-1} air) of the oil yielded about 27% mortality of *C. maculatus* after a 24 h exposure but the mortalities of *S. oryzae* and *T. castaneum* at the same concentration and time were about 5% and 1%, respectively. At the 72 h exposure time, kills of *C. maculatus* reached 100% with a 49 µl.l^{-1} air concentration. By contrast, 80% mortality was achieved for *S. oryzae* and about 63% for *T. castaneum* at the same exposure time and concentration.

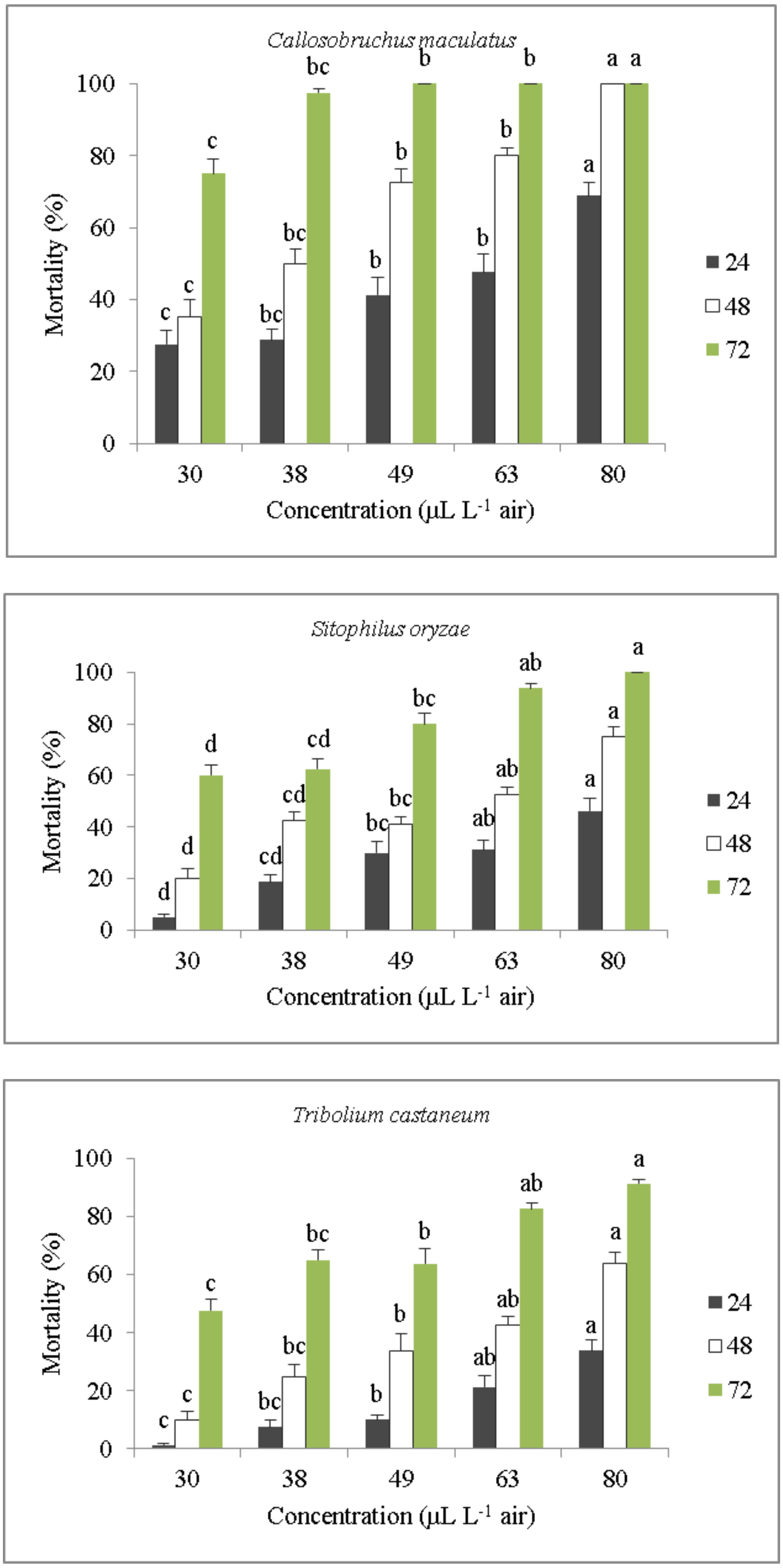

Fig 1. Mean mortality (%) of *Callosobruchus maculatus*, *Sitophilus oryzae*, and *Tribolium castaneum* exposed to different concentrations of *Artemisia haussknechtii* essential oil. Different letters over columns indicate significant differences according to Tukey test at α=0.05. Columns with the same letter are not significantly different. Vertical bars indicate standard error (±).

The essential oil of plant tested was toxic against insects. According to the results of ANOVA, the differences among all treated doses and exposure times of the essential oil were significant at $p<0.05$ (Fig. 1).

Chemical constituents of A. haussknechtii.

The oil from *A. haussknechtii* contained camphor (29.24%), 1, 8−cineole (27.62%), yomogi alcohol (5.23%), camphene (4.80%), p−cymene (3.35%) and α−pinene (2.36%) (Table 2).

Table 2. Main chemical components of *A. haussknechtii* essential oil.

No.	Constituents	Percentage
1	α−Pinene	2.36
2	Camphene	4.80
3	β−Pinene	1.68
4	1,8−Cineole	27.62
5	Camphor	29.24
6	Yomogi alcohol	5.23
7	p−Cymene	3.35
8	*Artemisia* alcohol	1.96
9	Linalool	1.73
10	Borneol	2.18
11	Caryophylene oxide	0.98
	Total	**98.36**

Discussion

The essential oil of *A. haussknechtii* was analyzed with different researchers (JALALI HERAVI & SERESHTI, 2007; SERESHTI & SAMADI, 2007; KHANAHMADI *et al.*, 2009). Extract and essential oil of *A. haussknechtii* have been shown to possess antioxidant and anti-microbial activities (KHANAHMADI *et al.*, 2009). In our best knowledge, studies have not been reported previously concerning the activity of *A. haussknechtii* as a fumigant on insect pests. The fumigant activity of essential oils from other *Artemisia* species has been evaluated against a number of stored product insects including oils from *A. annua* (L.) against *T. castaneum* and *C. maculatus* (TRIPATHI *et al.*, 2000), and from *A. tridentata* Nutt. ssp. *vaseyana* (Rydb.) against some stored−grain insects (DUNKEL & SEARS, 1998). *Artemisia sieberi* (Besser) had fumigant activity against some insect pests (NEGAHBAN *et al.*, 2006; 2007), and oils from three *Artemisia* species against *Sitophilus granarius* (L.) (KORDALI *et al.*, 2006).

One of the most valued properties of essential oils is their fumigant activity against insects, since it may involve their successful use to control pests in storage without having to apply the compound directly to the insects. Based on the results from fumigant bioassays the essential oil tested showed high toxicity when that was applied against insects with insecticidal activity dependent on oil concentration and exposure time. When *C. maculatus* were fumigated for 48 h, a concentration 38 $\mu l.l^{-1}$ air oil was necessary to cause 50% mortality (LC_{50}), while a concentration of 63 $\mu l.l^{-1}$ air for *S. oryzae* and for *T. castaneum* concentration near to 80 $\mu l.l^{-1}$ air was enough to cause equal mortality when were used (Fig. 1). Moreover, slopes of probit lines estimated that any increase in essential oil concentration, was imposed the highest mortality to *C. maculatus* when compared to other tested insects at 72 h exposure time. Furthermore, intercept of probit line for this pest at 24 h exposure time was higher than *S. oryzae* and *T. castaneum*, showing the higher response threshold (Table 1, Fig. 1).

Experiment showed that *C. maculatus* is more susceptible than *S. oryzae* and *T. castaneum* (Table 1 and Fig. 1). HASHEMI & SAFAVI (2012) studied fumigant toxicity of *Platycladus orientalis* (L.) Franco (Cupressaceae) against *C. maculatus, S. oryzae*, and *T. castaneum*. LC_{50} values of the leaf and the fruit oils at 24 h were estimated 6.06 and 9.24 $\mu l.l^{-1}$ air for *C. maculatus*, 18.22 and 21.56 $\mu l.l^{-1}$ air for *S. oryzae*, and 32.07 and 36.58 $\mu l.l^{-1}$ air for *T. castaneum,* respectively. NEGAHBAN & MOHARRAMIPOUR (2007) reported fumigant toxicity of essential oils from *Eucalyptus intertexta* R.T. Baker, *Eucalyptus sargentii* Maiden and *Eucalyptus camaldulensis* Dehnh (Myrtaceae) against *C. maculatus, S. oryzae,* and *T. castaneum*. The LC_{50} values to the selected essential oils were 2.55, 3.87, and 3.97 $\mu l.l^{-1}$ air for *C. maculatus*, 6.93, 12.91, and 12.06 $\mu l.l^{-1}$ air for *S. oryzae*, and 11.59, 18.38, and 33.50 $\mu l.l^{-1}$ air for *T. castaneum*, respectively. In another study by NEGAHBAN *et al* (2007), fumigant toxicity of *A. sieberi* essential oil was reported against *C. maculatus*, *S. oryzae*, and *T. castaneum*. *Callosobruchus maculatus* was significantly more susceptible than *S. oryzae* and *T. castaneum*; the LC_{50} values were 1.45 µl.l^{-1} air for *C. maculatus*, 3.86 µl.l^{-1} air for *S. oryzae*, and 16.76 µl.l^{-1} air for *T. castaneum*. These findings are consistent with the results of this study as *C. maculatus* was more susceptible to the essential oils, and *T. castaneum* was more tolerant than *S. oryzae* and *C. maculatus*.

GC−MS analyses of the oil revealed that the percentage of oxygenated monoterpenoids is higher than other compounds (Table 2). The loss of insecticidal activity of essential oil in the course of time may be attributed to rapid evaporation and degradation of the chemicals (OBENG−OFORI *et al.*, 1997). It was demonstrated that, oils with high content of hydrogenated compounds loss their activity quicker than those containing mainly oxygenated compounds (REGNAULT−ROGER *et al.*, 2002). Structure–activity relationships of plant compounds against stored product insects have been well studied. REGNAULT−ROGER & HAMRAOUI (1995) studied the structure–activity relationship between monoterpenoids and fumigant activity against *Acanthoscelides obtectus* (Say): the oxygenated structures prove to be the most active compounds. It could be demonstrated that toxicity of the essential oil of *A. haussknechtii* related to the high percentage of oxygenated compounds such as camphor (Table 2). In addition, the insecticidal activity of an essential oil could be attributed either to the major compound of the oil, or to the synergic and/or antagonistic effects of all the components of the oil. For example, KRISHNARJAH *et al.* (1985) demonstrated that the association of ρ−cymene and β−pinene resulted in a higher toxicity in *Sitotroga cerealella* (Olivier) than that of the components used separately.

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 (REGNAULT−ROGER & HAMRAOUI, 1995). The toxic effects of *A. haussknechtii* could be attributed to major constituents such as camphor (29.24%), 1, 8−cineole (27.62%), p−cymene (3.35%) and α−pinene (2.36%). The monoterpene camphor might have broad insecticidal activity against stored−product insects and act as the fumigant in *A. haussknechtii* oil. Camphor from several *Artemisia* species reported that is toxic against stored−product beetles (DUNKEL & SEARS, 1998; KORDALI *et al.*, 2006; NEGAHBAN *et al.*, 2007; TANI *et al.*, 2008). 1, 8 cineole isolated from *A. annua* is a potential insecticidal allelochemical that could reduce the growth rate, food consumption and food utilization in some post-harvest pests and house hold insects (JACOBSON & HALBER, 1947; KLOCKE *et al.*, 1989; OBENG−OFORI & REICHMUTH, 1997; TRIPATHI *et al.*, 2001). ρ−cymene had fumigant toxicity on *A. obtectus* (REGNAULT−ROGER & HAMRAOUI, 1995). OJIMELUKWE & ADLER (1999) found α−pinene was toxic to *Tribolium confusum* du Val.

In conclusion, our research revealed that the essential oil of *A. haussknechtii* possesses a potential for use in the management of *S. oryzae*, *T. castaneum*, and especially *C. maculatus*. In the light of recent interest by agrochemical companies in developing plant−based pesticides, this product would be an environmentally friendly chemical and safe for application. However, further studies also need to be conducted to evaluate the cost, efficacy and safety of this essential oil on wide range of pests in commercial store.

References

ABBOTT W. S. 1925. A method for computing the effectiveness of an insecticide. - *Journal of Economic Entomology*, 18: 265−267.

BELL C. H., S. M. WILSON. 1995. Phosphine tolerance and resistance in *Trogoderma granarium* Everts (Coleoptera: Dermestidae). - *Journal of Stored Product Research*, 31: 199–205.

BOOTH R. G., M. L. COX, R. B. MADGE. 1990. *Guides to insects of importance to man. 3.*

Coleoptera. International Institute of Entomology (An Institute of CAB International). The Natural History Museum. 77−79 pp.

BUTLER J. H., J. M. RODRIGUEZ. 1996. Methyl bromide in the atmosphere. In: Bell C. H., N. Price, B. Chakrabarti. (Ed.): *The Methyl Bromide*. Issue, vol. 1. Wiley, West Sussex, England, pp. 27–90.

CHAUDHRY M. Q. 1995. Molecular biological approaches in studying the gene(s) that confer phosphine−resistance in insects. - *Journal of Cell Biochemistry Supplement*, 21A: 215.

DAVIES N. W. 1990. Gas chromatographic retention indices of monoterpenes and sesquiterpenes on methyl silicone and Carbowax 20M phases. - *Journal of Chromatography*, 503: 1−24.

DUNKEL F.V., L. J. SEARS. 1998. Fumigant properties of physical preparations from mountain big sagebrush, *Artemisia tridentata* Nutt. ssp. *vaseyana* (Rydb.) beetle for stored grain insects. - *Journal of Stored Product Research*, 34: 307−321.

FERRY N., M. G. EDWARDS, J. A. GATEHOUSE, A. M. R. GATEHOUSE. 2004. Plant insect interaction: molecular approaches to insect resistance. - In: Sasaki, T., P. Christou. (Eds.), *Biotechnology*, 15: 155−161.

HASHEMI S. M., S. A. SAFAVI. 2012. Chemical constituents and toxicity of essential oils of oriental arborvitae, *Platycladus orientalis* (L.) Franco, against three stored−product beetles. - *Chilean Journal of Agricultural Research*, 72: 188−194.

ISMAN M. B. 2008. Perspective botanical insecticides: For richer, for poorer. - *Pest Management Science*, 64: 8−11.

JACOBSON M., L. HALBER. 1947. *The Chemistry of Organic Medicinal Plants*, Chapman and Hall, New York.

JALALI HERAVI M., H. SERESHTI. 2007. Determination of essential oil components of *Artemisia haussknechtii* Boiss. using simultaneous hydrodistillation−static headspace liquid phase microextraction−gas chromatography mass spectrometry. - *Journal of Chromatography A*, 1160: 81–89.

KHANAHMADI M., S. H. REZAZADEH, F. SHAHREZAEI, M. TARAN. 2009. Study on chemical composition of essential oil and anti−oxidant and anti−microbial properties of *Artemisia haussknechtii*. - *Journal of Medicinal Plants,* 8: 132−141.

KIM J.H., H. K. KIM, S.B. JEON, K. H. SON, E. H. KIM, S. K. KANG, N. D. SUNG, B. M. KWON. 2002. New sesquiterpene−monoterpene lactone, artemisolide, isolated from *Artemisia argyi*. - *Tetrahedron letter*, 43: 6205−6208.

KLOCKE J.A., M. F. BALANDRIN, R. B. YAMASAKI. 1989. Limonoids, phenolics and furano−coumarins as insect antifeedants, repellants and growth inhibitory components. - In: Arnason J.T., P. Morand, B. J. R. Philogene. (Ed): *Insecticides of Plant Origin*. American Chemical Society, Washington DC. pp 136−149.

KORDALI S., I. ASLAN, O. CALMASUR, A. CAKIR. 2006. Toxicity of essential oils isolated from three *Artemisia* species and some of their major components to granary weevils, *Sitophilus granarius* (L) (Coleoptera: Curculionidae). - *Industrial Crops and Products*, 23: 162−170.

KRISHNARJAH S.R., V. K. GANESALINGAM, U. M. SENANAYAKE. 1985. Repellency and toxicity of some plant oils and their terpene components to *Sitotroga cerealella* (Olivier) (Lepidoptera, Gelechiidae). - *Tropical science*, 25: 249−252.

MOZAFFARIAN W. 1996. *A dictionary of Iranian plant names*. Farhang Moaser, Tehran, Iran.

NEGAHBAN M., S. MOHARRAMIPOUR. 2007. Fumigant toxicity of *Eucalyptus intertexta*, *Eucalyptus sargentii* and *Eucalyptus camaldulensis* against stored−product beetles. - *Journal of Applied Entomology*, 131: 256−261.

NEGAHBAN M., S. MOHARRAMIPOUR, F. SEFIDKON. 2007. Fumigant toxicity of essential oil from *Artemisia sieberi* Besser against three stored−product insects. - *Journal of Stored Product Research*, 43: 123−128.

NEGAHBAN M., S. MOHARRAMIPOUR, F. SEFIDKON. 2006. Insecticidal activity and chemical composition of *Artemisia sieberi* Besser essential oil from Karaj, Iran. - *Journal of Asia−Pacific Entomology*, 9: 61−66.

OBENG−OFORI D., C. H. REICHMUTH, J. BEKELE, A. HASSANALI. 1997. Biological activity of 1, 8−cineol, a major component of essential oil of *Ocimum kenyense* (Ayobangira) against stored product beetles. - *Journal of Applied Entomology*, 121: 237–243.

OJIMELUKWE P.C., C. ADLER. 1999. Potential of zimtaldehyde, 4−allylanisol, linalool, terpineol and other phytochemicals for the control of confused flour beetle (*Tribolium confusum* J.D.V) (Col: Tenebrionidae). - *Journal of Pesticide Science*, 72: 81−86.

REES D. 2007. *Insects of stored grain: a pocket reference*. CSIRO Publishing. National Library of Australia Cataloguing in Publication entry. Second Edition. Australia.

REGNAULT−ROGER C., A. HAMRAOUI. 1995. Fumigant toxic activity and reproductive inhibition induced by monoterpenes on *Acanthoscelides obtectus* (Say) (Coleoptera), a bruchid of kidney bean (*Phaseolus vulgaris* L.). - *Journal of Stored Product Research*, 31: 291−299.

REGNAULT−ROGER C., B. J. PHILOGE`NE, C. VINCENT. 2002. *Biopesticides d'origines ve´ge´ tales*. Tec & Doc. (Ed.): Paris. 337 p.

SCOTTI G. 1978. *Les insectes et les acariens des céréales stokées*. ITCF/AFNOR, Paris, 238 p.

SERESHTI H., S. SAMADI. 2007. Comparison of hydrodistillation−headspace liquid phase microextraction techniques with hydrodistillation in determination of essential oils in *Artemisia Haussknechtii* Boiss. – *JUST*, 33: 7−17.

SHAAYA E., M. KOSTJUKOVSKI, J. EILBERG, C. SUKPRAKARN. 1997. Plant oils as fumigants and contact insecticides for the control of stored−product insects. - *Journal of Stored Product Research*. 33: 7–15.

TRIPATHI A. K., V. PRAJAPATI, K. K. AGGARWAL. 2000. Repellency and toxicity of oil from *Artemisia annua* to certain stored−product beetles. - *Journal of Economic Entomology*. 93: 43–47.

TRIPATHI A. K., V. PRAJANPATI, K. K. AGGARWAL, S. KUMAR. 2001. Toxicity, feeding deterrence, and effect of activity of 1, 8−cineole from *Artemisia annua* on progeny production of *Tribolium castaneum* (Coleoptera: Tenebrionidae). - *Journal of Economic Entomology*, 94: 979−983.

ZETTLER J. L., F.H. ARTHUR. 2000. Chemical control of stored product insects with fumigants and residual treatments. - *Crop Protection*. 19: 577−582.

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