Combined Use of *Eucalyptus salmonophloia* Essential Oils and the Parasitoid *Dinarmus basalis* for the Control of the Cowpea Seed Beetle *Callosobruchus maculatus*

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ABSTRACT

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This work aims to evaluate the possible combined use of *Eucalyptus salmonophloia* essential oils and the ectoparasitoid *Dinarmus basalis* for the control of the cowpea seed beetle *Callosobruchus maculatus,* a serious pest of economic importance on stored legumes including chickpea. This study carried out first investigation on the insecticidal potential of *E. salmonophloia* grown in Gabès (South Tunisia). Fumigant toxicity of the essential oils was tested against pest adults and larvae (L1, L2 and L3 larval stages). The parasitoid was introduced respectively 3 and 6 days after oil application against the fourth instar larvae and nymphs of the target pest. Results reported the interesting insecticidal potential of *E. salmonophloia* essential oils against *C. maculatus* L1, L2 and L3 larvae and adults. Oils significantly inhibited the parasitism potential of *D. basalis*. Indeed, at the concentration 12.5 µl/l air, the emergence rate of *D. basalis* adults decreased from 93.33% for the control to 40 and 28.33%, respectively, at 3 and 6 days following oil application. Storage of seeds using plant-based insecticides and essential oils is not always compatible with biological control strategies. Thus, identifying components that have lower effects on natural enemies is very important for a successful IPM program.

Keywords: *Callosobruchus maculatus*, *Dinarmus basalis*, essential oils, *Eucalyptus salmonophloia*, parasitism

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In Tunisia, a national chickpea improvement program has significantly contributed to yield increases during the last two decades (Amri et al. 2014; Khamassi et al. 2012). However, yield potential is seldom reached due to biotic and abiotic stresses (Solh et al. 1994). Chickpea seeds are vulnerable, particularly in storage, to attack by seed-beetles. Beetles of the genus *Callosobruchus* are major storage pests of

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chickpea crops and cause considerable economic losses worldwide (Sharma and Thakur 2014). The cowpea seed beetle *Callosobruchus maculatus* is the main field carryover storage pest of pulses including cowpea, chickpea, green gram, black gram, and red gram (Loganathan et al. 2011). In Tunisia, *C. maculatus* larvae feed on food legume seeds and cause major losses during storage (Haouel-Hamdi et al. 2017).

The efficient insect control in food commodities has long been the goal of producers and processors (El-Kady 1978). Chemical protection of stored food stuffs is the most available method. Fumigation treatments are the most common and economical tool for managing stored grain insect pests (Mediouni Ben-Jemâa et al. 2012; Mueller 1990). In addition, Tovignan et al. (2001) demonstrated that those insecticides acting as fumigants might be toxic for the users if not carefully handled. They could also have an adverse impact on arthropod predators or parasitoids of target pests (Van Huis 1991; Waage 1989) and it is well known that insecticide resistance may rapidly develop (Dales 1996; Georghiou 1990).

The use of plant materials can lead to the identification of new bioinsecticides. Essential oils for instance have been widely tested and have given promising results under laboratory conditions (Isman 2000; Regnault-Roger 1997). They have shown strong insecticidal activity against bruchid pests (Haouel-Hamdi et al. 2015; Mediouni Ben-Jemâa et al. 2012; Rahman and Schmidt 1999).

Eucalyptus, a large genus of the Myrtaceae family, has been subjected to various chemical and biological studies including insecticidal properties against stored product pests (Haouel et al. 2010, Mediouni Ben-Jemâa et al. 2013). In Tunisia, few references are available in the literature regarding the chemical composition of *Eucalyptus salmonophloia* growing in southern Tunisia. Previous study have demonstrated the antimicrobial (Ben Marzoug et al. 2010) and antioxidant (Haouel-Hamdi 2017b) properties of *E. salmonophloia* essential oils from southern Tunisia (Gabes).

Recently, stored pest control trends emphasize on the use of non-chemical procedures with the judicious use of pesticides. In this context, various researches demonstrated the efficacy of parasitoids and predators in controlling storage pests (Flinn and Schöller 2012; Titouhi et al. 2017). *Dinarmus basalis* is a notable parasitoid potentially used as biological control agent against *C. maculatus* (Dorn et al. 2002; Schmale et al. 2001). Besides, essential oils were found to be efficient replacement alternatives to synthetic pesticides (Mediouni Ben-Jemâa 2014). The complementary strategy of combining application of essential oils and use of natural enemies could be a better way to control bruchid development in storage conditions.

Therefore, this research aimed to assess the fumigant toxicity of *E. salmonophloia* essential oils from Métouia, Gabès (south Tunisia) and to evaluate its possible combined use with the ectoparasitoid *D. basalis* for the postharvest control of the cowpea weevil *C. maculatus*.

MATERIALS AND METHODS

Insect rearing.

Callosobruchus maculatus colony rearing. The *C. maculatus* colony was maintained in the laboratory. Insects were reared in chickpea, maintained at 27 ± 1 °C and 70 ± 5% RH in a 12:12 h cycle light:dark and renewed every three weeks according to the methods described by Haouel et al. (2017). Adult insects, 0-

1day old, were used for all bioassays. All trials were carried out under the same environmental conditions as the cultures.

***Dinarmus basalis* rearing.** The *D. basalis* colony was maintained in the laboratory. One- to 2-day-old adults of *D. basalis* were introduced into transparent plastic boxes in the presence of chickpea seeds containing *C. maculatus* larvae (L4 and nymphs). The 4th larval instars were obtained 16-18 days after the bruchid oviposition period. After 2 days, the seeds containing bruchid larvae, whether parasitized or not, were removed from the cages and placed in Petri dishes under the standard rearing conditions.

Plant material.

Fresh *E. salmonophloia* leaves were collected in May 2015 from El-Metouia (Gabès, Tunisia). Specimens were identified and air-dried in a shady place at room temperature for 10 days. After air-drying, the plant material was subjected to a hydro-distillation using a Clevenger-type apparatus.

Chemical analysis.

GC analysis was carried out using an Agilant 6980 gas chromatograph equipped with a flame ionization detector and split-splitless injector attached to Hp-Innowax polyethylene glycol capillary column (30 m × 0.25 mm). One micro-liter of the sample (dissolved in hexane as 1/50 v/v) was injected into the system. The constituents were identified by comparing their relative retention times with those of authentic compounds injected in the same conditions. The identification of the essential oils was performed using a Hewlett Packard HP5890 series II GC-MS equipped with a HP5MS column (30 m × 0.25 mm). The carrier gas was helium at 1.2 ml/min. Each sample (1 µl) was injected in the split mode (1:20), the program used was isothermal at 70°C, followed by 50-240°C at a rate of 5°C/min, then held at 240°C for 10 min. The mass spectrometer was a HP 5972 and the total electronic impact mode at 70 eV was used. The components were identified by comparing their relative retention times and mass spectra with the data from the library of essential oil constituents, Wiley, Mass-Finder and Adams GC–MS libraries.

Fumigant toxicity bioassays.

Toxicity bioassays against adults. A whatman filter paper (2 cm in diameter), impregnated with oils, was attached and hanged up to the screw caps of a 44 ml Plexiglas bottle with a support (2 cm length wire). Caps were screwed tightly on the vials, each of which contained 10 adults of *C. maculatus*. The tested oil doses were 0.5, 1, 2, and 3 µl providing equivalent concentrations of 12.5, 22.72, 45.45 and 68.18 µl/l air. Each treatment and check was repeated four times. Mortality was recorded hourly. Abbott correction formula (Abbott 1925) was applied to assess insect mortality. Probit analysis (Finney 1947) was used to determine lethal concentrations LC_{50} and LC_{95}.

Toxicity bioassays against larvae. The tests were carried out according Titouhi et al. (2017). The fumigant toxicity bioassays were applied against immature individuals developing inside the seed: neonate larvae L1 (3-day-old), second instar larvae L2 (5- to 6- day-old) and third instar larvae L3 (12- to 13-day-old). The different instars developing inside the seeds were determined subsequently by opening the seed and counting the number of exuvia (cephalic capsules) present inside. A sample of 20 seeds each containing one individual was removed from each culture of different ages (3-, 5- and 12-day-old) and treated with four oil concentrations: 12.5, 22.72, 45.45, and 68.18 µl/l air. The treated individuals inside the seeds were exposed during 48 h and then incubated until adult emergence. The assessment of oil efficiency was measured by the number of emerged adults. Comparison was made with untreated stage.

Host treatments with oils and parasitoids.

This test was conducted to evaluate the effect of *E. salmonophloia* essential oils on parasitoids *D. basalis*. The immature individuals of *C. maculatus* (forth instar larvae L4) and parasitoid treatment with oils was carried out according Ketoh et al. (2005) and Titouhi et al. (2017).

Three treatments were administered, each replicated 4 times: the first designates the control where no protection measures against bruchids were applied (20 infested chickpea seeds). In the second trial, experiments were conducted with 16-day-old host larvae (corresponding to the L4 developmental stage which is the most easily controlled by *D. basalis* wasps); for that, 10 pairs of *D. basalis* adults were introduced on 20 *C. maculatus* L4 larvae. For the third experiment, a lot of 20 forth instar larvae (L4) of *C. maculatus* (on 20 chickpea seeds) were treated with oils followed by the introduction of 10 pairs of *D. basalis* after two periods of 3 and 6 days. This period was chosen to overcome all the parasitization period. All treatments were observed until the emergence of bruchids and/or parasitoids.

Statistical analyses.

Statistical analyses were performed using SPSS statistical software version 20.0. All values given were the mean of three replications and were expressed as the mean ± standard deviation. Significant differences between the mean values ($P \leq 0.05$) were determined by using Student test.

RESULTS

Essential oil yields and composition.

Oil yield based on dry matter weight was 1.63%. Results of the GC and GC-MS analysis were reported in Table 1 and Fig. 1.

Chemical composition of *E. salmonophloia* essential oils is reported in Table 1 and Fig. 1. A total of 14 compounds were identified constituting 99.26% of the oils. The main constituents were 1,8-cineol (62.78%), cryptone (9.34%), p-cymene (5.46%), verbenene (5.23%), eremophilene (3.5%), p-cumic aldehyde (3.16%) and α-pinene (2.84%).

Fumigant toxicity bioassays.

Toxicity bioassays against adults. Toxicity bioassays results were presented as mortality percentage of *C. maculatus* adults exposed for various periods of time to *E. salmonophloia* essential oils and showed in Fig. 2.

Results showed that fumigant toxicity depends on concentration and exposure period. For the lowest concentration (12.5 µl/l air), mortality attained 53.33, 60 and 100% after respectively 24, 48 and 78 h of exposure to *E. salmonophloia* essential oils. However, for other concentrations (22.72, 45.45, and 68.18 µl/l air), a total mortality of *C. maculatus* adults was recorded after only 18 h of exposure.

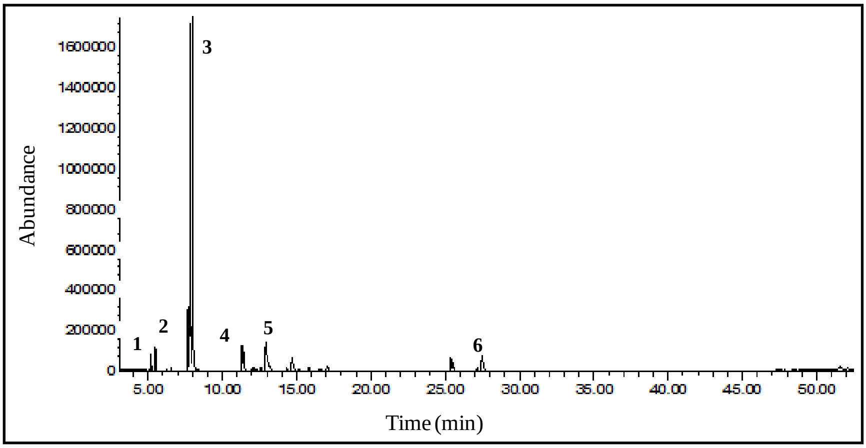

Fig. 1. GC-MS chromatogram of aerial parts of *Eucalyptus salmonophloia* essential oils on HP5MS column. *1 = α-pinene, 2 = p-cymene, 3 = 1,8-cineol, 4 = Verbenene, 5 = Cryptone, 6 = Eremophilene.

Table 1. Chemical fractions and total identified compounds (%) of essential oils obtained from *Eucalyptus salmonophloia* leaves

N°	Compound	TR	%
1	α-pinene	5.19	2.84
2	p-cymene	7.64	5.46
3	1,8-cineol	7.82	62.78
4	Verbenene	11.32	5.23
5	Pinocarvone	12.04	0.74
6	γ-Terpinene	12.59	0.37
7	Cryptone	12.86	9.34
8	p-Cumic aldehyde	14.71	3.16
9	Phellandral	15.84	0.73
10	o-cymen-5-ol	17.07	1.25
11	Isolongifolene	25.37	1.96
12	Aromadendrene	25.53	1.3
13	α-Amorphene	27.17	0.6
14	Eremophilene	27.47	3.5
	Total (%)	-	99.26

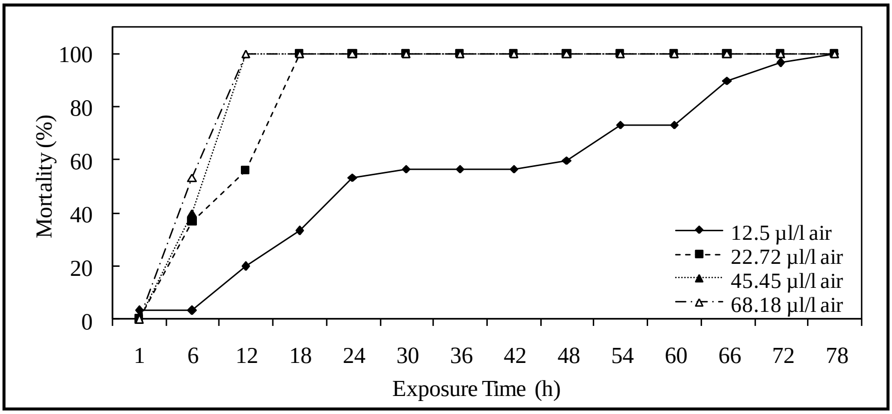

Fig 2. Mortality (%) of *Callosobruchus maculatus* adults exposed for various periods of time to different concentrations of essential oils from *Eucalyptus salmonophloia* leaves.

Results of the Probit analysis were given in Table 2. According to the median lethal concentration value, *C. maculatus* adults were very sensitive to *E. salmonophloia* essential oils. Probit analysis showed that LC_{50} and LC_{95} values were respectively 23.34 and 68.47 µl/l air. Results showed interesting potential toxicity of *E. salmonophloia* essential oils against target pest.

Table 2. LC_{50} and LC_{95} (µl/l air) values calculated for mortality within 24 h of exposure of *Callosobruchus maculatus* adults to various concentrations of *Eucalyptus salmonophloia* essential oils

essential oils	LC_{50}	LC_{95}	Chi square	d.f.	Slope
Eucalyptus salmonophloia	23.34 (9.40 - 64,07)	68.47 (45.57 - 228.34)	63.90	4	0.042

Toxicity bioassays against larvae (Immature stages).

Results of the toxicity bioassays against larvae (immature stages) were illustrated in Fig. 3 as percentage of mortality of *C. maculatus* larvae after 24 h of exposure to various concentrations of *E. salmonophloia* essential oils.

Results demonstrated that the effect of the essential oils on instars developing inside the seed was influenced by larvae age, developmental stage and essential oil concentration. Furthermore, results revealed the susceptibility of the three developmental stages (L1, L2 and L3) to *E. salmonophloia* essential oil fumigation.

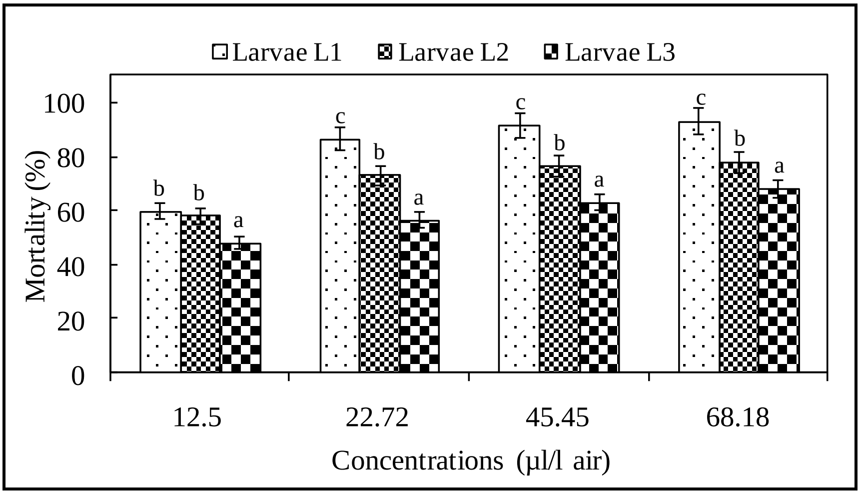

Fig. 3. Mortality (%) of *Callosobruchus maculatus* larvae (L1, L2 and L3) recorded after 24 h of exposure to various concentrations of *Eucalyptus salmonophloia* essential oils. * For each concentration, comparisons were made between the three larvae stage. Bars having different letters are significantly different according to Duncan's Multiple Range test at $P \leq 0.05$.

Statistical analysis showed that the larvae age affects significantly its susceptibility to essential oil fumigation. The neonate larvae (L1) were the most susceptible, with a mortality rates reaching 60, 86.66, 91.66 and 93.33%, respectively, for the concentrations 12.5, 22.72, 45.45 and 68.18 µl/l air. The third instar larvae (L3) were the most tolerant. For the lowest concentration (12.5 µl/l air), *E. salmonophloia* essential oils induced a mortality of 48.33% for the third larvae of *C. maculatus*. For the concentrations 22.72 and 45.45 µl/l air, percentage of mortality of the third instar larvae were 56.66 and 63.33%, respectively.

Host treatments with oils and parasitoids.

The results of the effect of *E. salmonophloia* essential oils on the parasitoid *D. basalis* were illustrated in Fig. 4. Results showed that for the two insects (*C. maculatus* and *D. basalis*) and for the two periods (3 and 6 days), adult emergence decreased significantly as oil concentration increased. Statistical analysis showed that the concentration affect significantly the number of emerged adults. When the introduction of *D. basalis* occurred after 3 days of the treatment with essential oils, the parasitoids emergence rate was more important than with a delay of 6 days. For the lowest concentration (12.5 µl/l air), the emergence rates of parasitoids were 40 and 28.33% after 3 and 6 days, respectively. Furthermore, for the highest concentration (68.18 µl/l air), the emergence rates of parasitoids were 13.33 and 11.67% after 3 and 6 days, respectively.

When the oils were applied 3 or 6 days before the introduction of *D. basalis* adults, the emergence rates of *C. maculatus* were 66.66 and 68.33% respectively for 3 and 6 days at 12.5 µl/l air. In addition, at the concentration of 68.66 µl/l air, the respective emergence rates were 10 and 18.33% for 3 and 6 days.

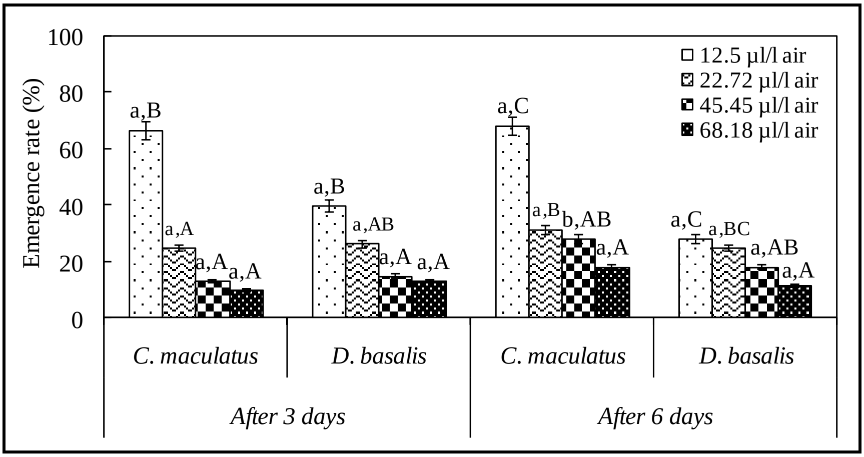

Fig. 4. Emergence (%) of *Callosobruchus maculatus* and *Dinarmus basalis* adults noted after exposure to various concentrations of *Eucalyptus salmonophloia* essential oils. * For each concentration, comparisons were made between the two periods (lowercase letters) and for each insect between concentrations (uppercase letters). Bars having different letters are significantly different according to Duncan's Multiple Range test at $P \leq 0.05$.

Fig. 5 reported the application effect of *E. salmonophloia* essential oils after 3 and 6 days on the emergence rate of *D. basalis* adults. Results revealed that the application of essential oils affected the parasitoid potential. In addition, results pointed toward the high susceptibility of *D. basalis* adults to oil vapors and to the residual oil vapors activity after 6 days. Statistical analyses showed significant differences between the two periods (3 or 6 days).

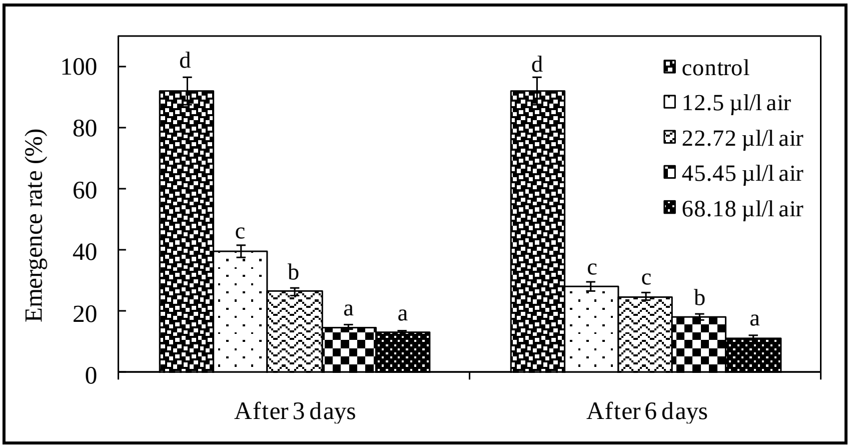

Fig. 5. Emergence (%) of *Dinarmus basalis* adults noted after exposure to various concentrations of *Eucalyptus salmonophloia* essential oils. * For each concentration, comparisons were made between the two periods. Bars having different letters are significantly different according to Student's test at $P \leq 0.05$.

DISCUSSION

Our results demonstrate that the success of the combination of *E. salmonophloia* essential oils from Métouia with the ectoparasitoid *D. basalis* was assured when the oil application is done at the beginning of the storage period and the introduction of the parasitoid was achieved after 6 days. In fact, White and Sinha (1990) observed that insecticides reduce the density and the diversity of natural enemies in stores. Similarly, Alzouma (1995) pointed out that *D. basalis* parasitism potential is affected when plant materials were added to stored cowpea. Previous related research reported that the use of *D. basalis* enabled effective control of *C. maculatus* population and limited weight losses of stored cowpea seeds at the beginning of the storage period (Sanon and Ouedraogo 1998; Sanon et al. 1998). Moreover, Corley et al. (2004) pointed out that parasitoids induced behavioral and physiological changes among their hosts. On the other hand, natural enemies play an important role in limiting potential pest populations and they are more likely to survive in case of application of eco-friendly biopesticides (Khater 2012). Actually, as an alternative pest control technology, essential oils have attracted particular attention (Liu et al. 2006). Caswell (1973) mentioned that in the presence of parasitoid wasps that parasitize the developing beetles, the percentage of damaged seeds does not exceed 60%. Additionally, Van Alebeek (1996) cited that in storage structures in West Africa, *D. basalis* induced 89% of parasitism on *C. maculatus* larvae. Furthermore, when *D. basalis* parasitoids were deliberately introduced into storage facility in large numbers, they effectively reduced the damage done by bruchid beetles (Sanon et al. 1998; Titouhi et al. 2017). Moreover, Boateng and Kusi (2008) reported that *D. basalis* adults were more susceptible to *Jatropha curcas* seeds' oil. Additionally, Aziz and Abbass (2010) showed the susceptibility of *C. maculatus* and its parasitoid *D. basalis* to essential oils of *Ocimum basilicum*, *Cymbopogon nardus* and *C. schoenanthus*. Contrarily, Ketoh et al. (2002, 2005) reported that *D. basalis* adults were more susceptible to essential oils from *Cymbopogon nardus*, *C. schoenanthus* and *Ocimum basilicum* than the adults of their host *C. maculatus*. They also indicated that the introduction of the essential oils into storage systems potentially could reduce density of parasitoid populations and increase seed losses.

In this study, the essential oil yields from *E. salmonophloia* leaves extracted by hydro-distillation and collected from south Tunisia was 1.63%. This results concord with those provided by Penfold and Willis (1961) who also observed that *E. salmonophloia* oil yield based on dry matter weight was 1.40%. However, according to Ben Marzoug et al. (2010), *E. salmonophloia* essential oil yield collected from south Tunisia was 4.6%. In the same context, Zrira et al. (1994) pointed out that extraction yield from *E. salmonophloia* oils collected from Morocco varied between 4.78 and 5% according the harvest area. Other studies have reported that the yield of *E. salmonophloia* from the mature leaves of plants native in Australia was 2.73% (Bignell et al. 1996). The variation of yield of some species growing in Tunisia could be attributed to the soil conditions and ecological and climatic conditions (Ben Marzoug et al. 2010).

Results of chemical composition of essential oils clearly demonstrated that *E. salmonophloia* essential oils were rich in 1,8-cineol (62.78%), cryptone (9.34%), p-cymene (5.46%), verbenene (5.23%), p-cumic aldehyde (3.16%) and α-pinene (2.84%). These compounds were known to possess insecticidal activity against various insect species (Haouel-Hamdi et al. 2015). In addition, as reported by Ben Marzoug et al. (2010), the major components of *E. salmonophloia* essential oils were 1,8-cineol (59.30%), α-pinene (10.70%), cumicaldehyde (5.00%), p-cymene (2.80%), and trans-pinocarveol (4.10%). However, according to Bignell et al. (1996), *E. salmonophloia* essential oils of Australian origin was reported to contain α-pinene (5.1%), β-pinene (9.7%), 1,8-cineol (10.3%), p-cymene (16.9%), trans-pinocarveol (2.3%), cryptone (10.5%), and spathulenol (2.0%). Compared to our result, Australian essential oils have a very low percentage of 1,8-cineol. As reported by Hussain (2009), insecticidal proprieties were dependent upon oils since the major components of the essential oils determine their biological properties. In this respect, highest percentages of α-pinene, 1,8-cineol and γ-terpineol in *E. lehmani* oils conferred it best insecticidal potential against *Rhyzopertha dominica*, *C. maculatus*, and *Tribolium castaneum* adult (Haouel-Hamdi et al. 2015). Indeed, the pesticide activity of *Eucalyptus* oils is attributed to various components such as 1,8-cineol, α-pinene and γ-terpineol (Liu et al. 2008; Lucia et al. 2007). Besides, among the various components of *Eucalyptus* oils, 1,8-cineole is the most important one and, in fact, a characteristic compound of the genus *Eucalyptus*, and is largely responsible for a variety of its pesticide properties (Batish et al. 2008; Haouel-Hamdi 2017a). In this study, *E. salmonophloia* essential oils displayed fumigant toxicity to larvae and adults of *C. maculatus*. It showed strong species-specific toxicity that was highly dependent upon the tested concentrations and the exposure durations.

Previous studies reported the efficacy of various *Eucalyptus* species essential oils for bruchid beetles control (Haouel-Hamdi et al. 2015). On the other hand, regarding the combined treatment of essential oils fumigation and parasitoids releases were largely discussed. In this respect, Boeke et al. (2003) indicated that parasitoids were affected by the botanical insecticides and that the powders of *Azadirachta indica* and *Blumea aurita* may be compatible with biological control by *D. basalis*. In addition, Sanon et al. (2006) showed that volatiles from *Hyptis suaveolens* crushed leaves and essential oils reduced host location behavior and reproductive activity of *D. basalis*. Similarly, Ketoh et al. (2002) pointed out that sub-lethal doses of essential oils reduce the life duration of both *C. maculatus* and *D. basalis* adults and decrease fecundity of females. In addition, Titouhi et al. (2017) reported that the release of parasitoids *D. basalis* and *Triaspis luteipes* could be better if it was combined with *Artemisia campestris* essential oils, as these oils had more pronounced effects on the beetles than on their parasitoids. Our results demonstrated that *E. salmonopholia* essential oils were effective against the beetle host, but they also prevented successful parasitization when the oils were applied 3 or 6 days before the introduction of *D. basalis* adults. This agrees with Van Huis (1991) who stated that biological control of bruchids should receive more attention in particular research on the introduction and conservation of natural enemies.

To summarize, biological control is often an underutilized component of integrated pest management in storage commodities since industrials always tended to look for chemical alternatives to manage insect pests. Recently, essential oils have been appraised as alternatives to chemical pesticides. However, seeds' storage using plant-derived insecticides and essential oils is not always compatible with biological control strategies. Thus, identifying components that have lower effects on natural enemies is a key feature for a successful IPM program.

RESUME

Haouel-Hamdi S., Abdelkader N., Hedjal-Chebheb M., Saadaoui E., Boushih E. et Mediouni-Ben Jemâa J. 2018. Utilisation combinée d'huiles essentielles d'*Eucalyptus salmonophloia* et du parasitoïde *Dinarmus basalis* pour la lutte contre la bruche du niébé *Callosobruchus maculatus*. Tunisian Journal of Plant Protection 13 (si): 123-137.

Ce travail a pour objectif d'évaluer la possibilité de combiner l'utilisation des huiles essentielles d'*Eucalyptus salmonophloia* et du parasitoïde *Dinarmus basalis* pour la lutte contre la bruche du niébé *Callosobruchus maculatus,* un ravageur d'importance économique sur les légumineuses stockées incluant le pois chiche. Cette étude présente la première investigation sur le potentiel insecticide des huiles essentielles d'*E. salmonophloia* poussant à Gabès (sud de la Tunisie). La toxicité par fumigation des huiles essentielles a été testée contre les adultes et les larves L1, L2 et L3 de *C. maculatus*. En outre, le parasitoïde a été introduit contre les larves L4 et les nymphes de son hôte 3 et 6 jours après l'application des huiles. Les résultats ont rapporté un potentiel insecticide très important des huiles essentielles d'*E. salmonophloia* à l'égard des larves L1, L2 et L3 et des adultes de *C. maculatus*. Toutefois, ces huiles ont inhibé d'une manière très remarquable le potentiel parasitaire de *D. basalis*. En effet, à la concentration 12,5 µl/l air, le taux d'émergence des adultes de *D. basalis* a passé de 93,33% pour le témoin sans huiles à 40 et 28,33% respectivement après 3 et 6 jours d'application des huiles. Le stockage des graines à l'aide d'insecticides à base de plantes et d'huiles essentielles n'est pas toujours compatible avec les stratégies de lutte biologique. Ainsi, l'identification des composants qui ont le moins d'effets sur les ennemis naturels est très importante pour un programme de lutte intégrée réussi.

Mots clés: *Callosobruchus maculatus, Dinarmus basalis, Eucalyptus salmonophloia*, huiles essentielles, parasitisme

ملخص

حوال-حمدي، سمية وندى عبد القادر ومريم حجال-شبهاب وعز الدين سعداوي وآمنة بوصحيح وجودة مديوني-بن جماعة. 2018. دمج استعمال الزيوت الروحية لنبتة *Eucalyptus salmonophloia* وشبه الطفيلي *Dinarmus basalis* في مكافحة خنفساء حب اللوبيا الجنوبية.

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يهدف هذا العمل إلى تقييم إمكانية دمج استعمال الزيوت الروحية لنبتة *Eucalytus salmonophloia* وشبه الطفيلي *Dinarmus basalis* لمكافحة خنفساء حب اللوبيا الجنوبية *Callosobruchus maculatus*. وقع اختبار الزيوت عن طريق التبخر ضد الطور البالغ وضد الأطوار اليرقية 1 و 2 و 3 للعائل. تم استعمال شبه الطفيلي ضد الطور اليرقي الرابع وضد العذارى. بينت النتائج أن الزيوت الروحية لنبتة *E. salmonophloia* تمتلك فعالية إبادة حشرية مرتفعة ضد الأطوار اليرقية 1 و 2 و 3 وضد الحشرة البالغة، غير أنها تعيق بطريقة بالغة القدرة التطفلية لشبه الطفيلي *D. basalis* حيث انه بالنسبة إلى الجرعة 12.5 مكل/لتر هواء، انخفضت نسبة ظهور شبه الطفيلي من 93.33 % بالنسبة للشاهد إلى 40 و 28.33% بعد 3 و 6 أيام على التوالي من استعمال الزيوت. إن تخزين البذور باستخدام المبيدات الحشرات النباتية والزيوت الروحية ليست دائما منسجمة مع استراتيجيات المكافحة البيولوجية. إن تحديد المكونات التي لها أقل تأثير على الأعداء الطبيعيين مهم جدا في برنامج المكافحة المتكاملة للآفات.

كلمات مفتاحية: تطفل، خنفساء حب اللوبيا الجنوبية، زيوت روحية، *Dinarmus basalis*، *Eucalyptus salmonophloia*

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