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Fatty acid composition and biological activity of four olive oils from Kabylia (Algeria) against *Rhyzopertha dominica* (Coleoptera: Bostrychidae) infesting wheat seeds

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Abstract. The use of conventional insecticides is one of the most widely used methods of controlling pests of stored grains. But the presence of toxic residues in treated commodities and the emergence of insect resistant strains are becoming a growing concern. Olive oil is well known throughout the world for its benefits to human health, but little known for its biological activity against insect pests.

The aim of this work is to study the fatty acid composition and the insecticidal activity of oils according to origin of plantation, against one of the main insect pests of stored grain *Rhyzopertha dominica* (Coleoptera: Bostrychidae). The olive oils were obtained using an oleodoser from olives of the 'Chemlal' variety harvested in 4 olive groves in Kabylia (Algeria) and the analysis of the fatty acid composition was carried out by gas chromatography. The main fatty acids found are oleic, palmitic and linoleic acids. Biological tests conducted under laboratory conditions, at a temperature of 30±1°C and a relative humidity of 70 ± 5 %, revealed that the 4 olive oils, applied on soft wheat grains, showed a contact toxicity against *R. dominica*. The toxicity of the oils varied as a function of the dose and the duration of treatments. After 24 h of exposure, all oils tested at the highest dose (0.4 mL/25 g) were found to be highly toxic to adults of *R. dominica,* with mortality rates ranging from 72.5 to 95 %. The toxicity of the 4 oils based on the LD_{50} (mL/25 g) values for 24 h mortality is established as follows: Maatkas (213), Bachloul (232), Tadmait (234) and M'Chedellah (263).

The number of the F1 offspring decreases as the dose of oil is increased to reach zero with the highest dose, for all treatments. All oils tested completely preserve soft wheat seeds from *R. dominica* attacks using the same highest dose. On the other hand, results also revealed that treatments with olive oil do not affect the germination capacity of soft wheat seeds.

Keywords: wheat grains, insect pest, *Rhyzopertha dominica*, olive oil, fatty acids, toxicity, damage.

Introduction

Cereals occupy a fundamental place in Algerian agriculture, with a surface area of 2.7 million hectares, i.e. nearly 40% of the country's overall agricultural area, and 3.3 million tons in 2014 (FAO, 2015).They also constitute a major part of the human diet worldwide (Chen and Dubcovsky, 2012; Merouche *et al.*, 2014).

Soft wheat (*Triticum aestivum* L.) is an important food crop worldwide due to its nutritional value (FAO, 2019; Valenzuela-Aragon *et al.*, 2019). In Algeria, it ranks third in terms of production after durum wheat (*Triticum durum* Desf.) and barley (*Hordeum vulgare* L.), with an annual cultivated area of 0.8 million hectares, representing 24.2 % of the area devoted to cereals country-wide (Bellatreche *et al.*, 2019; Kara *et al.*, 2020; Meziani *et al.*, 2020).

The conservation of these products is the only way to ensure the link between the year's harvest and continuous consumption. During storage, various biotic and abiotic factors depreciate it qualitatively and quantitatively, the most important being insect pests (Arve *et al.*, 2014; Hamdi *et al.*, 2015; Abdelli *et al.*, 2016; Aoues *et al.*, 2017; Brahmi*et al.*, 2017; Djidel *et al.*, 2018). According to the assessment of Algerian Inter-Professional Office of Cereals (AIOC), losses that can exceed 35 % have been recorded in recent years (Ahmed, 2016).

Among the pests of wheat grains during storage, *Rhyzopertha dominica*, is a serious pest of stored grain worldwide, due to the quantitative and qualitative losses that it causes (Bashir, 2002; Hagstrum and Flinn, 2014; Filomeno *et al.*, 2020). It is considered a highly destructive pest of wheat, sarrasin rice, maize, sorghum, barley, rye, millet, etc. (Aitken, 1975; Mason and McDonough, 2012; Eydozehi and Ravan, 2013; Kakde *et al.*, 2014; Ridley *et al.*, 2016). As a primary colonizer, *R. dominica* larvae and adults can infest sound kernels (Hill, 2002; Batta *et al.*, 2007); they spend most of their life inside the kernel, feeding on both the germ and endosperm, directly causing damage and changes the physical and

chemicalproperties of the grain. The adult is responsible for losses that are estimated to be eight times greater than those caused by the larvae (Toews *et al.*, 2000; Huchet, 2017). The infestation of stocks by *R. dominica* causes weight loss (Park *et al.*, 2008; Hendrival *et al.*, 2019; Arthur *et al.*, 2020), a decrease in essential amino acids (Jood *et al.*, 1995; Edde, 2012 ; Boukouvala *et al.*, 2020), a decrease in the germination capacity of grains used as seed and a reduction in plant vigor at emergence (Limonta *et al.*, 2011; Saad *et al.*, 2018; Waongo *et al.*, 2018). Grains infested by *R. dominica* are then vulnerable to attack by secondary pests and moulds (Srivastava and Subramanian, 2016; Win and Rolania, 2020).

Control measures are currently based on the application of chemicals because of their effectiveness and low cost (Boyer *et al.*, 2012; Kumar and Kalita, 2017). Nevertheless, the use of conventional insecticides has caused adverse effects on the agro-ecosystem such as the development of insect resistance, resurgence of secondary pests and environmental contamination, affecting target pests, domestic animals and human health (Mau *et al.*, 2012; Kim *et al.*, 2017; Collins and Schlipalius, 2018; Daglish and Nayak, 2018; Morrison *et al.*, 2019; Nayak *et al.*, 2020).

These drawbacks have highlighted the need for sustainable alternatives that are available, affordable, less toxic to mammals and less detrimental to the environment and plants such as botanicals (Kellouche and Soltani, 2004; Kellouche *et al.*, 2010; Hamdi *et al.*, 2015; García-Lara and Serna-Saldivar, 2016; Lougraimzi *et al.*, 2018; Righi *et al.*, 2018; Ekoja and Ogah, 2020; Nia *et al.*, 2020).

Recently, there has been an increasing interest in the use of natural oils, including vegetable, essential and mineral oils (Obeng-Ofori and Amiteye, 2005; Lal and Raj, 2012; Rayhan *et al.*, 2014;Rolania and Bhargava, 2015; Singh *et al.*, 2016; Baccari *et al.*, 2020; Chenni *et al.*, 2020; Ebrahimifar *et al.*, 2020; Haouel-Hamdi *et al.*, 2020; Yakhlef *et al.*, 2020).

Among vegetable oils, olive oil, due to its high oleic acid content, detected as an insecticidal component, could be used as a biopesticide in insect pest management (Abdallah *et al.*, 2001; Kellouche *et al.*, 2004; Uddin and Sanusi, 2013; Ekoja and Ogah, 2020; Zohry *et al.*, 2020).

The aim of the present work was to study the efficacy of four olive oils extracted from olives collected from four localities in Kabylia (Algeria), against *R. dominica.* The importance of this research resides in the development of a natural method of sustainable conservation that can be used locally to protect cereal seeds, which are strategic products in Algeria.

Materials and methods

Plant material and oil extraction

The extra virgin olive oils used in this work came from Chemlal, the main Algerian olive variety, at the same stage of maturity (maturity index = 3), in the 2016/2017 crop season (November). Four representative regions of olive oil production in Algeria were selected to obtain the EVOO samples Tadmaït (3. 98778 36° 36′ 44″ North, 3° 59′ 16″ East), Maatkas (3.90186 36° 44′ 34″ North, 3° 54′ 7″ East), M'Chedellah (4.24858 36° 23′ 50″ North, 4° 14′ 55″ East) and Bechloul (4.06667 36° 19′ 0″ North, 4° 4′ 0″ East). The olive fruits were randomly and manually picked from all parts of the selected fully grown olive trees (COI, 2011). The olive maturity index (MI) was determined according to the method developed by the agricultural station in Jaén (Uceda and Hermoso, 1998), on the basis of the evaluation of the olive skin and pulp colors. MI values range from 0 (100% intense green skin) to 7 (100% purple flesh and black skin).

Olive oil samples were obtained using a laboratory-scale oil mill (S.I.O.L. 20240 GHISONACCIA, France), consisting of three basic elements: a hammer crusher, a thermo-beater (mixer) and a pulp centrifuge. Olives were first crushed and the resulting paste was slowly mixed for 30 min at 25 °C. Olive oil was obtained after the centrifugation of the paste at 3000 rpm for 3 min (Bengana *et al.*, 2013).

The oil was separated by decanting, classified according to the origin of the olives; OO1 (Tadmaït), OO2 (Maatkas), OO3 (M'Chedellah), OO4 (Bechloul), and stored at 4 °C in darkness using amber glass bottles without headspace prior to use.

Fatty acid analysis

The analytical methods for the determination of fatty acid composition were described in regulation EEC 2568/91 (EEC, 1991). Fatty acids were converted to fatty acid methyl esters before analysis by vigorous shaking of a solution of oil in hexane (0.2 g in 3 mL) with 0.4 mL of 2 N methanolic potassium hydroxide and analyzed by a GC Chrompack CP 9002 (Les Ulis, France) equipped with a FID detector, an split–splitless injector and a DB23 (50% cyanopropyl) capillary column (30 m x 0.32 mL, 0.25 μm film; Agilent Technologies, Palo Alto, California, USA). The carrier gas was nitrogen (Linear velocity, 0.5 cm/min; split ratio of 1:30, v/v). The temperatures of the injector, detector and the oven were set at 250 °C, 280 °C and 200 °C, respectively. The injection volume was 0.8 μL (EEC, 1991). One replicate was prepared and analyzed per sample.

Insects rearing

The mass breeding of *R. dominica* was conducted in the laboratory, in a dark oven at 30±1°C and 70±5% relative humidity, on soft wheat (*Triticum aestivum*). The strain of *R. dominica* comes from the storage commodities of CCLS Tizi-Ouzou (Cooperative of Cereals and Dried vegetables). The same conditions of temperature and humidity were chosen to perform our experiments.

Bioassays

Soft wheat seeds of local origin, free of infestation and pesticides, were used for the biotests. Each olive oil extracted was mixed with soft wheat seeds in glass Petri dishes (13 cm diameter and 3 cm height), at three doses: 0.1, 0.2 and 0.4 mL/25 g. All trials were repeated four times for each dose and control. These Petri dishes were shaken manually for 15 min to achieve an equal distribution of the oils in the entire grain mass. Then, 20 unsexed adults <1 weeks old were introduced into each dish, which was immediately closed. Mortality was assessed 24, 48, 72 and 96 h after treatment application. Dead adults were removed and counted during each assessment. Dead insects from oil-treated grain showed signs of rapid immobilization, with their legs flexed and clinging to either the grain or the container surface. Since mean mortality in untreated control was less than 5 %, mortality data were not corrected for natural mortality (Abbott, 1925). LD_{50} values were determined after 24 h of exposure by Probit analysis (Finney, 1971).

At the end of the tests, all the adults (dead and alive) were removed and the Petri dishes were kept in the oven under the same conditions for an additional period of 45 days to assess emergence of F1 progenies. On day 45, samples of treated or control grains were taken to evaluate weight loss and germination capacity.

The weight loss was obtained using the formula described by Tefera *et al.* (2011): **Percent weight loss = (Initial weight - Final weight) × 100.**

In order to assess the viability of seeds, seed germination was tested using 50 randomly picked seeds from each Petri dish. The seeds were placed on moistened cotton in glass Petri dishes (13 cm in diameter and 3 cm in height) and incubated at room temperature (28-32°C) for 5 days (Kellouche *et al.*, 2004; Kumawat and Naga, 2013). The germination percentage was calculated as follows: **Germination (%) = (number of germinated seeds / total number of seeds) × 100.**

Statistical analysis

Data were expressed as mean values and standard deviations (SD) were calculated**.** All data were subjected to analysis of variance, using Stat Box Pro

(version 6.40). Significant differences between means were determined using Newman-Keuls test at 5% probability.

Results

Fatty acid composition

The results obtained (Tab. 1) show that the fatty acid composition of the olive oils analyzed meets the standards set by Commission Regulation EEC/2568/91 of July 11, 1991 for the EVOO category. The major fatty acids present in Chemlal olive oil were oleic (C18:1), linoleic (C18:2), palmitic (C16:0) acids (Tab.1). Oleic acid (C18:1) is the main monounsaturated fatty acid and is present in higher concentrations (59.08–63.59 %). Palmitic acid content, the major saturated fatty acid in olive oil, varied between 17.66 and 18.81% according to the plantation zones. Concerning linoleic acid (C18:2), the highest percentage was observed in EVO2 (15.06%), whereas the lowest was found in EVO1 (12.51%). Chemlal olives also contained low amounts of linolenic acid (C18:3), arachidic acid (C20:0) and traces of palmitoleic acid (C16:1) (Tab.1). Our results are in agreement with those of previous research (Bengana *et al.*, 2013; Bakhouche *et al.*, 2015; Laincer *et al.*, 2016; Medjkouh *et al.*, 2016; Boudour-Benrachou *et al.*, 2017; Guissous *et al.*, 2018).

Table 1. Fatty acid composition (%) of the four oils (C16:0, palmitic acid; C16:1, palmitoleic acid; C17:0, heptadecanoic acid; C18:0, stearic acid; C18:1, oleic acid; C18:2, linoleic acid; C18:3, alpha linolenic acid; C20:0, Arachidic acid; C20:1, eicosenoic acid;C22:0, behenic acid; MUFA/PUFA, monounsaturated fatty acids/ polyunsaturated fatty acids; UFA/SFA, unsaturated fatty acids/saturated fatty acids).

Fatty acid composition (%)					**Legal limits EEC/2568/91**
	EVO1	**EVO2**	**EVO3**	**EVO4**	
C16:0	17.8	18.81	17.97	17.66	7.5-20.0
C16 :1	2.32	3.13	2.26	2.26	0.3-3.5
C17:0	0.1	0.1	0.27	TR	
C18:0	1.88	2.19	2.12	2.58	0.5-5
C18 :1	63.59	59.08	62.28	60.39	55-83
C18 :2	12.51	15.06	13.68	14.81	3.5-21.0
C18 :3	0.68	0.38	0.52	0.51	≤1.0
C20:0	0.48	0.64	0.59	0.73	≤0.6
C20:1	0.44	0.27	0.27	0.27	≤0.4
C22:0	0.14	0.12	TR	TR	≤0.2
MUFA/PUFA	5.03	0.71	0.52	0.53	-
Oleic acid/ linoleic acid	5.08	3.92	4.55	4.08	-
UFA/SFA	3.89	2.25	/	/	-

Contact toxicity of olive oils against R. dominica

The results indicated that the four olive oils tested revealed contact toxicity as a function of the tested dose and the time of exposure. Variance analysis using 2 classification criteria shows that dose rate (F= 9599.58, *P*= 0,000) and origin of oil (F= 11.68, *P*= 0,000), as well as their interaction, act with a high degree of significance on the percentage of adult mortality.

In contact mortality assay after 24 h, 48, 72 and 96 h, the ascending concentrations of the four oils caused increased mortality of the beetles. After 24 h of exposure, all oils, at the highest dose (0.4 mL/25 g), are very toxic to *R. dominica*, the mortality rate ranging from 72.5 to 95%.

With the lowest dose (0.1 mL/25 g grains), all oils tested caused a low mortality rate ranging from 18.75 to 48.75%, even after 96 h of exposure (Fig.1A, B, C, D).The order of toxicity of the four oils, taking into account the LD_{50} (mL/25 g) calculated after 24 h of exposure, is as follows: OO2 (LD_{50} = 213), OO3 (LD_{50} = 232), OO1 (LD_{50} = 234) and OO4 (LD_{50} =263).

F1 progeny emergence

The four oils significantly reduced the emergence of adults, compared to the control. Variance analysis shows a highly significant effect of the factor dose (F= 1010.706, *P*= 0,000) on the number of emerged F1 progeny. However, the oil origin and the interaction (dose x oil origin) are not significant (F= 0.517, *P*= 0.676; F=0.424, *P*=0.915, respectively).

The highest numbers of emergence are observed in the control lots, with an average number of 92.5 adults. Moreover, the number of offspring is inversely proportional to the dose used. In fact, this number decreases as the dose is increased and becomes zero at the highest dose (0.4 mL/25 g grains), in all treatments (Fig.2).

Grain weight loss

All of the oils tested very significantly reduced the weight loss percentage, compared to the control. Variance analysis revealed a significant influence, at the 5% level, of the treatment dose on grain weight loss (F=749.465, *P*=0.000); however, the factor oil origin and the interaction between the two factors are not significant (F= 0.98, *P*= 0,411; F=0.681, *P*=0.723, respectively).

According to the results obtained (Fig.3), we observe that *R. dominica* caused higher weight loss in the control lots (9.62 %).On the other hand, in lots treated with oils from different regions, a considerable reduction in grain weight loss rates is observed as the treatment dose increases. For all oils tested, treatment with the highest dose 0.4 mL/25 g completely preserves the soft wheat seeds from pest attack.

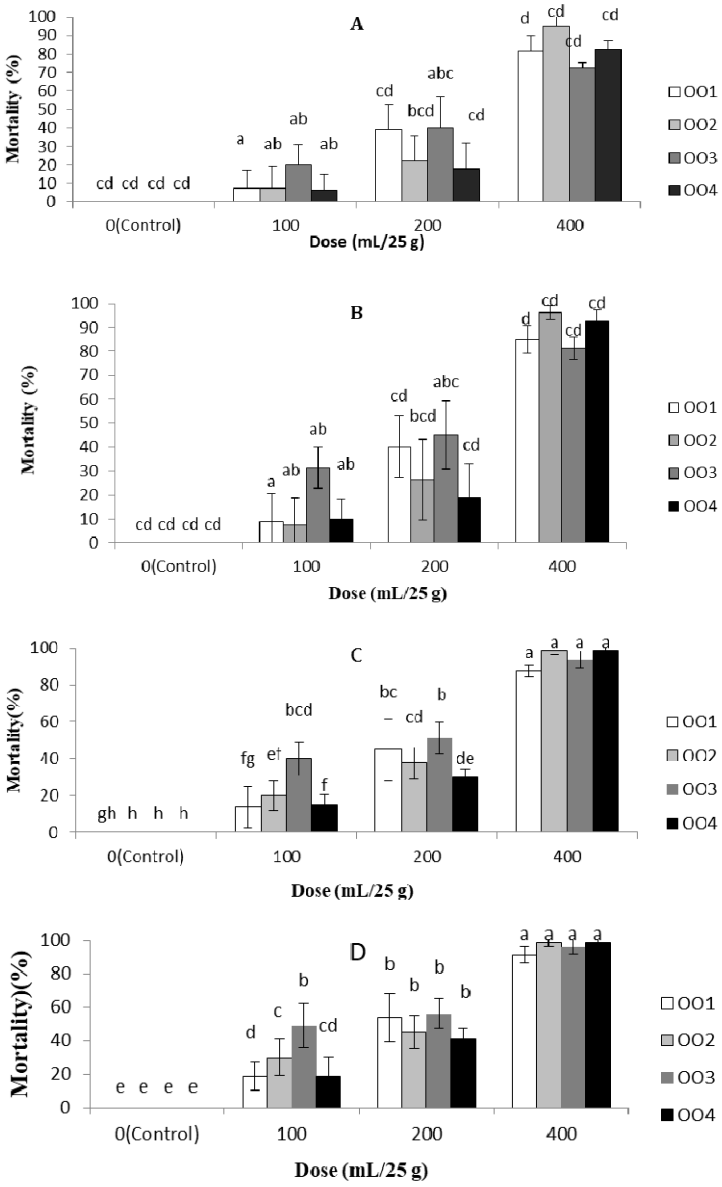

Figure1. Mortality of *R. dominica* in contact toxicity assay with four extra-virgin olive oils. (A)24h of treatment, (B) 48h, (C) 72h, (D) 96h. N = 80 (4 × 20 insects) for each treatment. Bars with the same letter are not significantly different.24h of treatment. Kruskal Wallis test with multiple comparisons, $P< 0.05$.

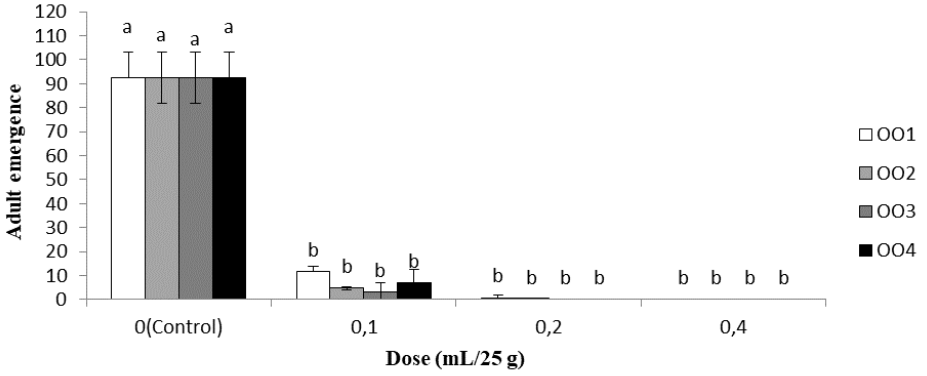

Figure 2. Mean progeny production (number of individuals/dish ±SE) on soft wheat treated with the four oils at three doses. Bars with the same letter are not significantly different. Kruskal Wallis test with multiple comparisons, *P*< 0.05.

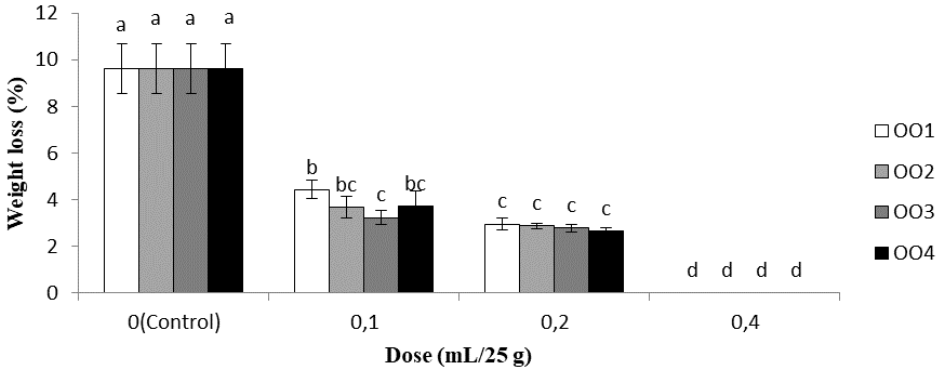

Figure 3. Percentage weight loss (%±SD) on soft wheat seeds treated with the four oils at three doses. Bars with the same letter are not significantly different. Kruskal Wallis test with multiple comparisons, *P*< 0.05.

Seed germination

According to the ANOVA, seed germination was significantly adversely affected as olive oil concentration increased (F=29.952, *P*=0.000). As the olive oil dose levels increased, the soft wheat seed germination rate decreased. But the oil origin factor and the dose-origin interaction do not influence germination, F=0.367, *P*=0.780 and F=1.153, *P*=0.345, respectively.

The tests carried out show that the germination capacity of wheat seeds from untreated and infected control lots reaches 92.50%, while this rate decreases as the dose increases in seeds treated with the various oils, ranging from 79.5% (0.1 mL/25g) to 45% (0.4 mL/25g) (Fig.4).

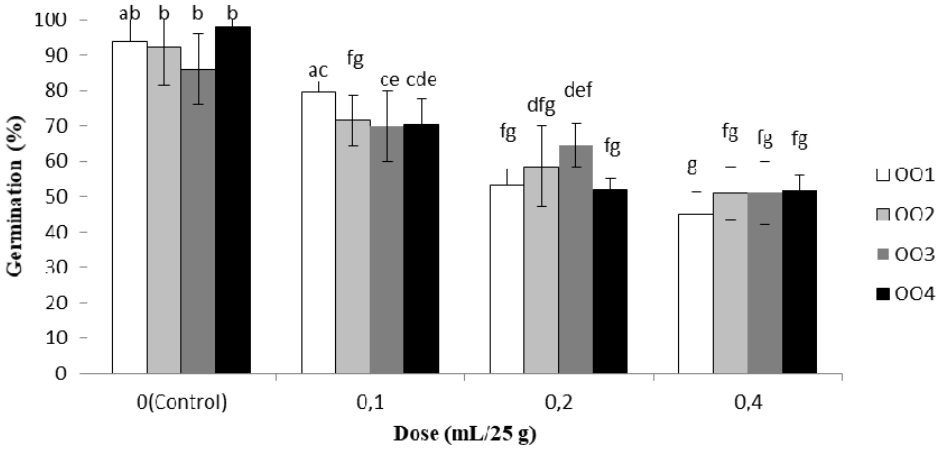

Figure 4. Percentage germination (%±SD) of soft wheat seeds treated with the four oils at different rates and infested by *R. dominica*. Bars with the same letter are not significantly different. Kruskal Wallis test with multiple comparisons, $P< 0.05$.

Discussion

This study showed the bioactivity of olive oils from different localities on one of the main insect pests of stored cereals, *R. dominica*. These oils showed contact toxicity against adults of this pest, a significant reduction of its offspring and consequently a reduction in weight loss caused to grains. Moreover, the effectiveness of treatments varies according to the dose of these natural substances. These results confirm those of previous studies that have highlighted the efficacy of different vegetable oils to protect cereal grains against damage caused by different species of insects in stored products (Saxena and Singh 1994; Abdallah *et al.*, 2001; Chander, 2003; Rahman *et al.*, 2003; Yadav *et al.*, 2008; Fogang *et al.*, 2012; Hossain *et al.*, 2014; Rayhan *et al.*, 2014; Gumaa and Elamin, 2015; Wahedi *et al.*, 2015; Chakravarty *et al.*, 2020).

The results obtained reveal that after treatment of soft wheat seeds, at the dose of 0.4 mL/25g, the adults of *R. dominica* live less than 24 h, thus preventing the females from laying eggs and, consequently, the emergence of new offspring.

Similar observations have been reported by other authors (Uvah and Ishaya, 1992; Ibrahim, 2012; Uddin and Sanusi, 2013; Parmar and Patel, 2015; Ekoja and Ogah, 2020) on the toxicity of olive oil and other vegetable oils against *Callosobruchus maculatus* (Coleoptera: Bruchidae) infesting cowpea seeds.

Other authors such as Wale and Assegie (2015) found that castor bean oil (*Ricinus communis*L.), applied at a dose of 4mL, against *Sitophilus zeamais* (Motschulsky) (Coleoptera: Curculionidae) caused 85% mortality after 1 h of exposure.In addition, groundnut, rape seed and sunflower vegetable oils, at 10 mL/kg of grain, caused considerable mortality in adults of *S. granarius* L. (Coleoptera: Curculionidae) (60-80%) in 14 days (Tembo and Murfitt, 1995). On the other hand, treatment of maize kernels with fixed oils from *Jatropha curcas* seeds (Euphorbiaceae) pretreated with different methods (cooking, roasting and raw) (1.50 µl / cm^2, for 3 h) induced47.52, 46.96 and 47.36% mortality for oil obtained from roasted, cooked and raw seeds, respectively, in *S. zeamais* (Babarinde *et al.*, 2019). Zohry *et al.* (2020) showed that black seed oil (*Nigella sativa*), sesame oil (*Sesamum indicum*) and olive oil (*Olea europaea*) at 1mL/100g are toxic to adults of *S. granarius* (83.33-100%) in 72h. The research of Kellouche *et al.* (2004) also reveals that olive oil causes total mortality of adults of *C. maculatus* after 2 h of treatment with 0.8 mL/50g cowpea seeds. The same is true for the work carried out by Gemechu *et al.* (2013) who demonstrated the efficacy of mustard and cottonseed oils (0.2 to 0.5 mL/250 g wheat), which cause mortality rates ranging from 25 to 100 % and reduce egg-laying in *S. zeamais*, without affecting the germination capacity of the seeds. According to the aforementioned authors, these treatments with olive oil induce the formation of a film that causes asphyxiation of the insect pest, as also demonstrated by Ait-Aider *et al.* (2016) in *C. maculatus*. In addition, adult mortality may have been caused by the action of saturated and unsaturated fatty acids that compose the chemical profile of olive oils (Hil and Schoonhoven, 1981). Moreover, some authors (Don-Pedro, 1990; Ait-Aider *et al.*, 2016) have highlighted the insecticidal effect of oleic acid and linoleic acid against *C. maculatus.* Regnault-Roger *et al.* (2002) also revealed the insecticidal activity of certain fatty acids such as oleic acid and undecylenic acid. These compounds cause the rupture of cell membranes, oxidative phosphorylation and insect cuticles (Weinzierl, 2000).

More recently, the insecticidal properties of certain volatile fatty acids (formic, acetic, propiopic, butyric and valeric acid) (Krzyżowski *et al.*, 2020) and a mixture of three free fatty acids, octanoic, nonanoic and decanoic acids (C8910) (Ramadan *et al.*, 2020) have been demonstrated against *C. maculatus, Lasioderma serricorne* (Coleoptera: Ptinidae) and *R. dominica*, respectively.

Variation in oleic and linoleic acid content observed in olive oil samples obtained from the Chemlal variety are probably related to both genetic factors and environmental conditions during fruit development and maturity (Arslan *et al.*, 2013; Essiari *et al.*, 2014; Rondanini *et al.*, 2014; Piscopo *et al.*, 2016; Borges *et al.*, 2017; García-Inza *et al.*, 2018).

Concerning the effect of treatments on the emergence of *R. dominica*, we observed a significant reduction in the number of first generation offspring when the dose is increased, regardless of the geographical origin of the oil tested. This may be a consequence of the reduction in oviposition and the ovicidal and larvicidal effects of the products tested (Shaaya *et al.*, 1997; Rolania and Bhargava, 2015).

This toxicity has also been observed by many authors such as Singh and Mall (1991) in *S. oryzae* exposed to soft wheat seeds treated with castor, neem, mustard and linseed oils (dose= 0.1%, v/w), Kellouche *et al.* (2004) with *C. maculatus* (reduction of emergence greater than 90%) in treatments carried out with 1st and 2nd pressing olive oils, and Singh *et al.* (2016) who demonstrated the biocidal activity of neem and castor oils and recorded a significant reduction in progeny in *R. dominica*.

In lots treated with olive oils, we observed a very significant reduction in weight losses of wheat seeds infested by *R. dominica*, which is most probably the consequence of the reduction in emergence of the insect pest as observed by Khinchi *et al.* (2017) in *Callosobruchus chinensis* (Coleoptera: Bruchidae), infesting chickpea grains treated with neem, groundnut, coconut and sesamum (4, 8 and 12 mL/kg grains), or Dey and Sarup (1993) with *S. oryzae* on maize seeds treated with mustard, soya bean, coconut, neem, groundnut, cotton seed, sesame and castor oils. The same observations were also reported by Kumawat and Naga (2013), Akter *et al.* (2019) and Chakravarty *et al.* (2020) on pests such as *R. dominica*, with wheat grains, and *C. chinensis*, infesting green mung pulse (*Vigna radiata*) or chickpeas, in treatments with several vegetable oils such as black seed (*Nigella sativa*), neem, castor, Karanj, coconut, sesame, soybean, and mustard, for example.

Regarding germination tests, the results obtained reveal that the treatments with the different oils affect the germination capacity of the wheat grains as olive oil concentrations increased, as reported by Tembo and Murfitt (1995) testing high doses of groundnut, rape seed and sunflower (10 mL/kg) against *S. granarius*, as also reported by Yun-tai and Burkholder (1981) with oils of cotton seed, soybean, maize and peanut (5 or 10mL/kg), and Ivbijaro (1984) obtaining a maize kernel viability ranging from 6 to 13% after treatment with groundnut oil (10 to 20 mL/kg), compared to the untreated control (100%). However, several authors have reported the safety of vegetable oils

as noted by Singh *et al.* (2016) testing neem and castor oils (0.1 to 0.20% v/w) on *R. dominica* infesting wheat grains, and Hassan (2001)testing sesame, sunflower and castor oils (0.1 to 1.25 % v/w) on *Trogoderma granarium* (Coleoptera: Dermestidae).

Conclusion

The results of our tests show that the four olive oils tested are highly toxic to *R. dominica.* In fact, his toxicity is increased as the dose increases. Comparison of LD_{50} indicates that olive oil extracted from Maatkas olives is more effective than oils from other olive groves (Bachloul, Tadmait and M'Chedellah).

This study confirmed the agro-phytosanitary potential of Algerian olive oil, which can be used locally as a bio-pesticide for the protection of wheat seeds whose preservation is a major challenge for Algeria.

Since Algeria has a diversified olive-growing heritage, the valorization of these plant extracts as part of an integrated control program in the eco-chemical fight against insect pests of stored grains, in order to reduce the significant economic loss recorded each year in storage warehouses, is an interesting option.

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