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Insecticidal effect of essential oil and powder of *Mentha pulegium* L. leaves against *Sitophilus oryzae* (LINNAEUS, 1763) and *Tribolium castaneum* (HERBST, 1797) (Coleoptera: Curculionidae, Tenebrionidae), the main pests of stored wheat in Morocco

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ABSTRACT. Stored grains are threatened by several insects, leading to losses in quality and quantity. Several studies have revealed the risks of using chemicals that can cause serious health problems for humans. It is in this perspective that the objective of our work should be seen: It was to assess the effect of the essential oil and leaf powder of *Mentha pulegium* against *Sitophilus oryzae* and *Tribolium castaneum* adults attacking post-harvest cereals. The insecticidal activity of the essential oil against these two insects was evaluated by three methods: contact, inhalation and ingestion. The ingestion method was used in the case of the leaf powder. The essential oil and leaf powder of *Mentha pulegium* exhibited insecticidal activity against *Sitophilus oryzae* and *Tribolium castaneum* adults (*Mentha pulegium* essential oil caused up to 100% mortality of both insects). Both insects were influenced affected by the dose, exposure time and the method by which the insecticidal activity of the essential oil was demonstrated. Adults of *Sitophilus oryzae* were more sensitive to different concentrations of essential oil and leaf powder than those of *Tribolium castaneum*. The essential oil has no effect on the germination rate of soft wheat grains (*Triticum aestivum*). On the contrary, it acts positively by reducing the damage caused by these major stock

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pests. The data from this study could present an alternative solution for replacing synthetic insecticides for the protection of stored commodities.

KEY WORDS: Insecticidal effect, Essential oil, Leaf powder, *Sitophilus oryzae*, *Tribolium castaneum,* Germination rate.

INTRODUCTION

Cereals and pulses are the main agricultural crops in Morocco. In Africa, insects infesting stored commodities are numerous and highly diverse (DANHO et al. 2000). These stored product pests can be very damaging to grain and grain-based commodities for a variety of reasons; they can cause direct losses in product weight and also indirect losses (PIESIK & WENDA-PIESIK 2015). A significant part of the grains and seeds is lost a short time after their storageas a result of various depredations inflicted by beetles and lepidopteran insects (CISSOKHO et al. 2015).

Sitophilus oryzae (LINNAEUS, 1763) (Coleoptera: Curculionidae) and *Tribolium castaneum* (HERBST, 1797) (Coleoptera: Tenebrionidae) are considered major pests of stored grains, inflicting serious losses in stored commodities. Insects can cause substantial losses, often with significant consequences for the economy and food supplies in particular, when they grow at the expense of grain in a storage system, they can destroy a whole crop in just a few months (HUIGNARD et al. 2011).

Control of these insects relies heavily on the use of synthetic insecticides and fumigants. But their widespread use has led to some serious problems, including the development of insect strains resistant to insecticides (ZETTLER & CUPERUS 1990, WHITE 1995, RIBEIRO et al. 2003). For example, the first case of resistance of *Tribolium castaneum* appeared in 1961 in London as a result of the intensive use of malathion for the protection of grains (PARKIN et al. 1962, LINDGREN & VINCENT 1965, ARNAUD et al. 2001, HAUBRUGE et al. 2002).

However, chemical insecticides are dangerous to humans and domestic animals because of residues that can pollute the grains to a greater or lesser extent, depending on the doses that are applied (CHANTEREAU et al. 2013). Indeed, the delayed effects of pesticides on health can occur either following a single, usually intense, exposure, or as a result of repeated, usually less intense, exposure. The latter is by far more frequent and concerns the whole population, whether exposed professionally or from the environment (air, water, food) (MULTIGNER 2005). Therefore, there is an urgent need to develop safe alternatives that are of low cost and environmentally friendly.

Considerable effort has focused on plant-derived materials, potentially useful as commercial insecticides (ARNAUD et al. 2001, TAPONDJOU et al. 2002, PARK et al. 2003, HOU et al. 2004). Several studies have shown that plant essential oils have an insecticidal effect on some pests of stored products, either by direct contact or by inhalation (PERRUCCI 1995, COPPEN 2003).

RAJENDRAN & SPIRANJINI (2008) highlighted the insecticidal activity of the essential oils of some plants (Apiaceae, Lamiaceae, Myrtaceae) resulting from the presence of monoterpenol, their principal component, which exhibited fumigant toxicity against pests of stored commodities, including *Sitophilus zeamais* and *Tribolium castaneum.* That study subsequently enabled investigations of the insecticidal power of *Mentha pulegium* L., a plant belonging to the Lamiaceae family known for its therapeutic properties and insecticidal efficacy, attributed to its chemical composition in general, particularly to monoterpenes (HAJLAOUI et al. 2009, SARDASHTI & ADHAMI 2013, ABDELGALEIL et al. 2009).

The purpose of these biotests was to determine the lethal doses of the essential oil and leaf powder of *Mentha pulegium* against *Sitophilus oryzae* and *Tribolium castaneum* to find the most effective method (contact/fumigation) for achieving the highest insecticidal activity against both insects, as well as testing the effect of EO of *Mentha pulegium* on the germination of wheat seeds. These experiments were combined so as to optimize the use of *M. pulegium* extracts and improve the control of stored grain pests.

MATERIAL AND METHODS

Plant material

Samples of *M. pulegium* were collected during the flowering period in May and July 2015 in the Gharb region of north-western Morocco. The plants were identified in the laboratory of Kenitra University, Morocco, where the leaves were air-dried for one month in the absence of light at room temperature, after which they were stored in plastic bags in a refrigerator at 4°C until required.

Insects

Biological bioassays were performed to study the insecticidal effect of EO and leaf powder of *M. pulegium* on adults of *Sitophilus oryzae* and *Tribolium castaneum*. Both insects were reared in laboratory conditions (27 ± 1°C, 70 ± 5% RH) during a one-year period and respectively reared on whole wheat and barley (a blend of 50% soft wheat and 50% barley).

Preparation of plant extract

Essential oil (EO) was extracted from *Mentha pulegium* using a Clevenger-type apparatus in which the plant material was subjected to hydrodistillation for three hours. The extracted oil was stored away from air and light at a temperature of 4 °C.

Leaf powder

Once the leaves are dry, they are ground to a powder. This is stored in the shade and protected from dust in a plastic bag at a temperature of 4 °C.

Bioassays

The present work aimed to demonstrate the insecticidal effect of *M. pulegium* against *Sitophilus oryzae* and *Tribolium castaneum.* Three EO toxicity tests were performed using three different methods: contact, inhalation and ingestion. The efficacy of EO was compared with positive controls using malathion for contact toxicity (Malathion Insecticide Powder Insecticide with Marketing Authorization No. B 06-6-002) Malyphos Grain (2% Malathion), and a fumigant tablet of aluminium phosphide to test fumigation toxicity against *Sitophilus oryzae* and *Tribolium castaneum.*

EO toxicity by contact using filter paper

Different dilutions of the essential oil were prepared with acetone, four concentrations being tested: 2, 5, 10 and 20 µl/mL of acetone, corresponding to concentrations of 0.031, 0.079, 0.157 and 0.314 µL/cm² respectively. One millilitre of each concentration was spread uniformly with a micropipette over a filter paper disc (9 cm diameter, Whatman No. 1). The control was treated with acetone only. After complete evaporation of the solvent (5 minutes), the treated filter papers were carefully placed in Petri dishes of the same size. Three replications were performed for each essential oil. Then, 10 insects each of *Sitophilus oryzae* and *Tribolium castaneum* species were introduced into each Petri dish, which was then closed immediately. Dead insects were counted daily for a period of 6 days.

EO toxicity by fumigation

Fumigation with the essential oil of *Mentha pulegium* was carried out in transparent, hermetic 1L plastic boxes as exposure chambers to test the toxicity of the essential oil against adults of *Sitophilus oryzae* and *Tribolium castaneum*. The essential oil was spread over a 9 cm Whatman type filter paper, which was immediately placed inside the exposure chamber containing five Petri dishes (ensuring five replications). The following doses were applied: 2 µL, 5 µL, 10 µL, 20 µL (EL IDRISSI et al. 2014). Ten insects were introduced to each Petri dish and one untreated chamber served as the control. Dead insects were counted daily for a period of 6 days.

EO toxicity by contact in grains

The soft wheat seeds used in this test were not treated chemically and were stored in controlled conditions (T: 25°C, H: 75%).

For each test, 1 ml of each concentration, i.e. 2, 5, 10 and 20 µL EO/mL of acetone, was applied to 20 g of seeds, corresponding to the following concentrations: 0.1, 0.25, 0, 5 and 1 µL/g respectively. These treated seeds were placed in Petri dishes and thoroughly mixed. The trials were repeated three times for each dose. After 5 minutes, the time necessary to allow the solvent to evaporate, 10 adult insects of each species were placed in all the Petri dishes. The blank obtained only 1 ml of acetone. Dead insects were counted daily for a period of 6 days.

Contact toxicity of seeds treated with leaf powders

The powders obtained from dry leaves of *Mentha pulegium* were mixed with 20 g of seeds contained in Petri dishes in doses of 1%, 2.5% and 5% (m/m). The trials were repeated four times for each dose. 10 adults of both species were introduced into each Petri dish, which was immediately closed. Dead insects were counted after a period of 7 days.

Germination tests

These tests were performed to assess the effect of *M. pulegium* essential oil on the germination of soft wheat seeds (*Triticum aestivum* L.).

In the laboratory

In the germination test, the wheat seeds already applied in the EO contact test were used to assess the effect of essential oils on the germination of soft wheat seeds (*Triticum aestivum*). The germination test was conducted in 1L boxes, the bottoms of which were covered with two substrate papers (or solid absorbent paper) impregnated with distilled water. One hundred wheat seeds were collected at random and were spread evenly over the substrate papers. The boxes were placed in climate chambers at temperature of 20 °C and a 16:8 hour light-dark regime.

Under greenhouse conditions

Soft wheat seeds were treated with essential oil at the different concentrations mentioned above. After seven days of treatment, the wheat grains were transferred to sand-wetted containers with water to make their seeds (EL IDRISSI et al. 2014). Germination percentages were recorded by counting the number of sprouting grains in all batches.

RESULTS

EO toxicity by contact using filter paper

The effect of essential oil by contact on filter paper is shown in Fig 1. As expected, the essential oil of *Mentha pulegium* was active against *Sitophilus oryzae* and *Tribolium castaneum* in the different concentrations used. The mortality rate rose when the test doses were increased.

For *Sitophilus oryzae*, the lowest dose of 0.031 µL/cm² caused total insect mortality after 6 days of exposure, whereas in the case of *Tribolium castaneum*, mortality reached 100% only after 9 days and with a higher concentration of 0.079µL/cm². We also noticed that the 10 and 20 µL doses were very effective against *T. castaneum*, as happened with *Sitophilus oryzae*, and recorded 100% mortality after 24 hours.

For both insects, the mortality recorded in the positive control boxes treated with malathion is similar to that after 24 h exposure to 10 µL and 20 µL EO.

EO toxicity by contact using filter paper

The essential oil of *Mentha pulegium* induced insecticidal activity against adults of *Sitophilus oryzae* and *Tribolium castaneum* (Fig. 2).

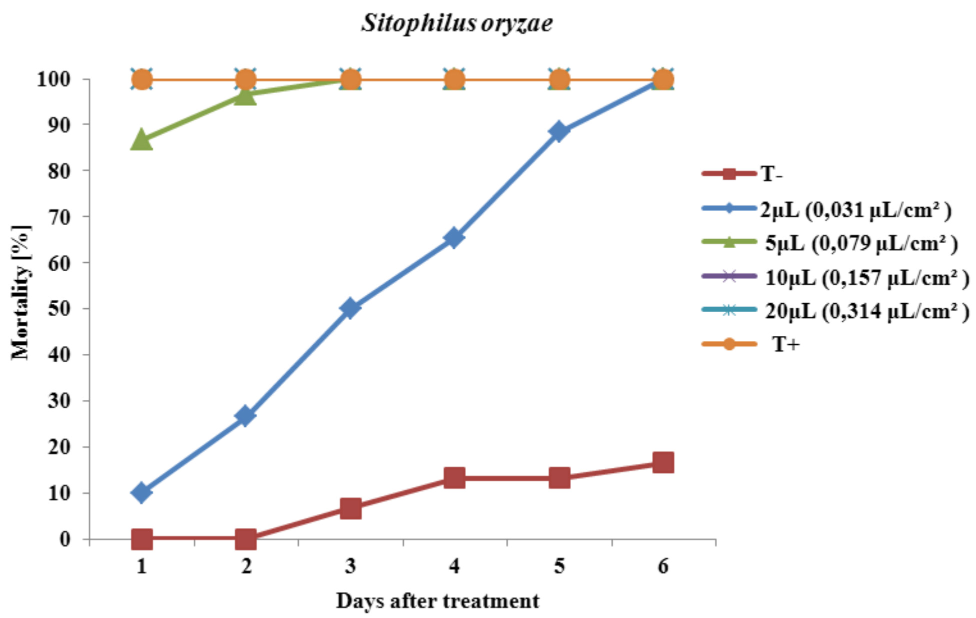
The concentration of 20 µL/L of air led to 100% mortality in both insects, but with different exposure times: after 24 h for *Sitophilus oryzae* and 48 h for *Tribolium castaneum*. The concentration of 10 µL/L led to a 100% mortality of *Sitophilus oryzae* after 3 days' exposure, but to 80% mortality, of *Tribolium castaneum* after 7 days. The doses of 2 and 5 µL/L of air achieved 100% mortality of *Sitophilus oryzae* after 7 days, but they were not as effective killers of *T. castaneum* with 42.30% and 73.07% mortality, respectively.

The mortality recorded in the positive controls was <50% after the entire duration of the treatment for both species. For *Sitophilus oryzae* and *Tribolium castaneum*, we observed that all doses tested yielded better results than the positive controls (fumigant tablet of aluminium phosphide), except for the dose of 2 µL/L of air for *T. castaneum*.

Toxicity by contact with essential oil in grains

The effect of EO toxicity by direct contact in the grains is illustrated in Fig 3.

The corrected mortalities recorded for *Sitophilus oryzae* and *Tribolium castaneum* were very high, exceeding 50% for all the doses after 6 days. The lowest dose of 0.1µL/g induced 100% mortality of *Sitophilus oryzae* in 6 days and caused 73.08% mortality of *Tribolium castaneum* during the same period. In this bioassay, we noted a high sensitivity of the two insects at doses of 5, 10 and 20 µL and a rapid response to the EO of *Mentha pulegium* compared to the positive control.



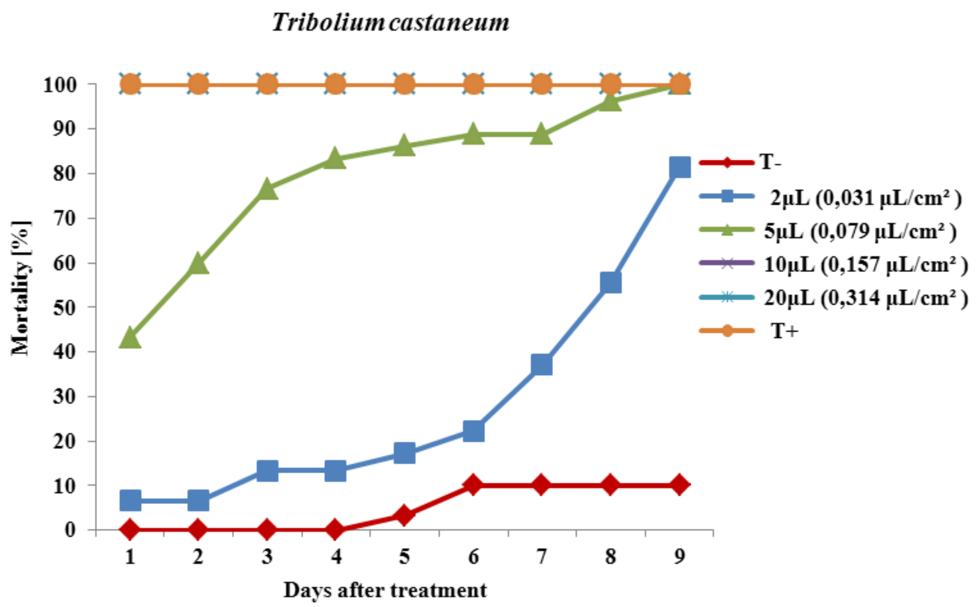


Fig. 1. Mortality of *Sitophilus oryzae* and *Tribolium castaneum* relative to the doses of essential oil of *Mentha pulegium* on filter paper.

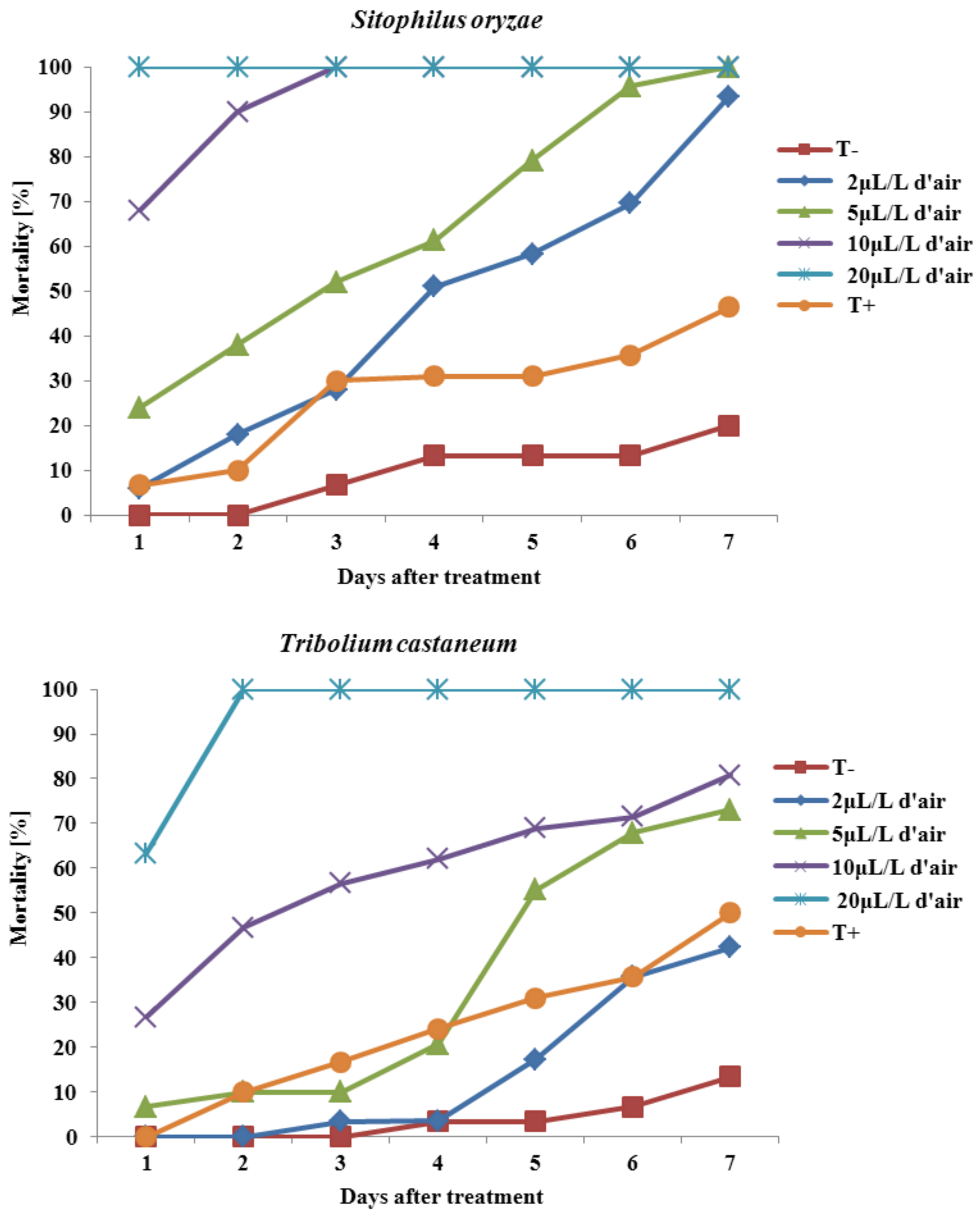


Fig. 2. Mortality of *Sitophilus oryzae* and *Tribolium castaneum* relative to the doses of essential oil of *Mentha pulegium* by fumigation.

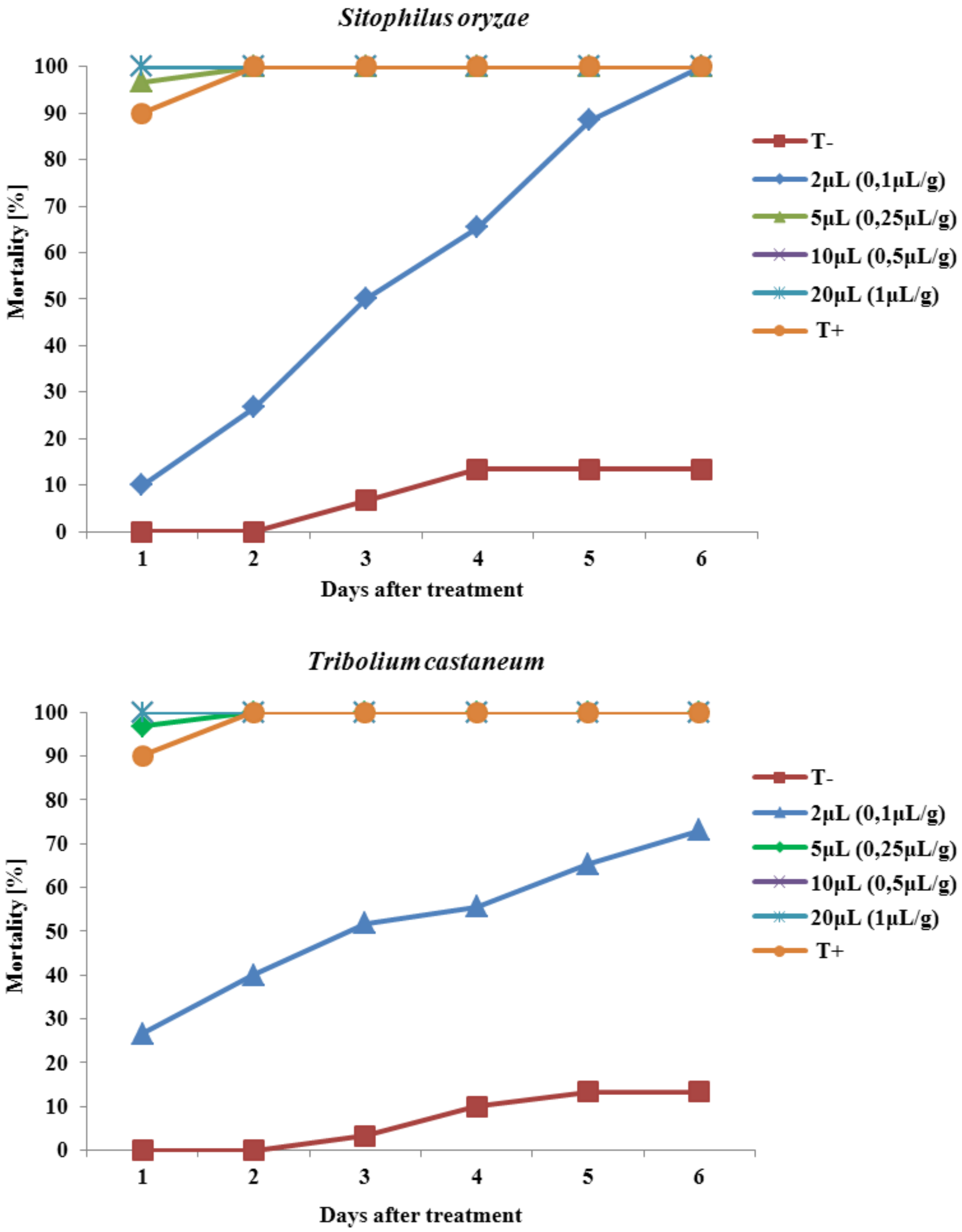
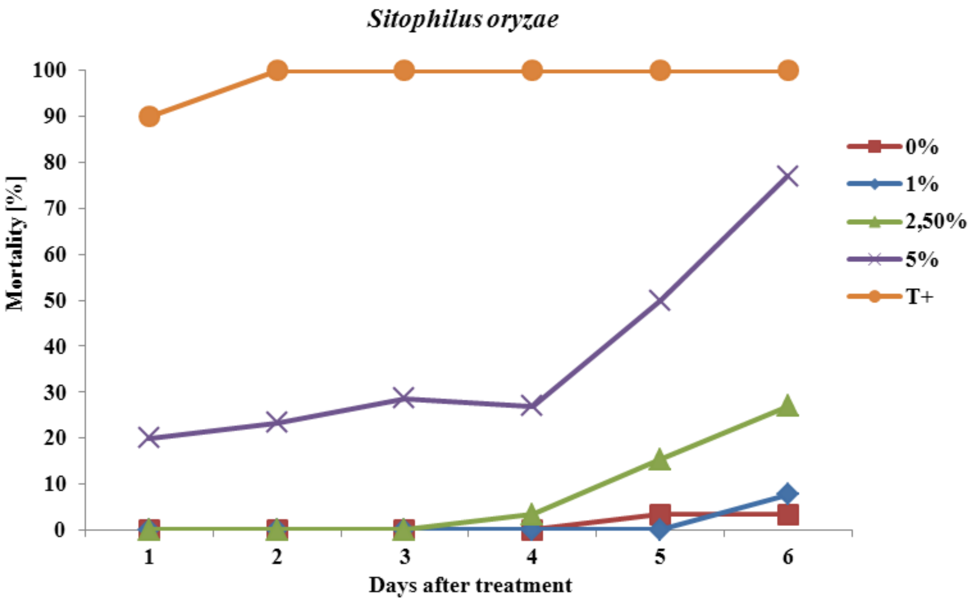


Fig. 3. Mortality of *Sitophilus oryzae* and *Tribolium castaneum* with respect to the duration of exposure to doses of essential oil of *Mentha pulegium* in soft wheat grains.



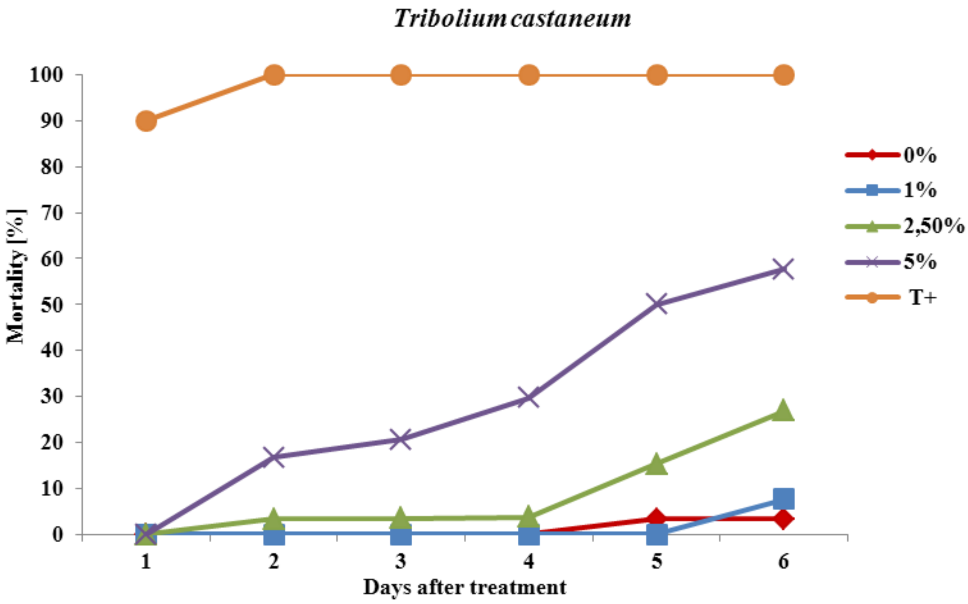


Fig. 4. Mortality of *Sitophilus oryzae* and *Tribolium castaneum* with respect to the duration of exposure to doses of leaf powders *Mentha pulegium* in soft wheat grains.

Contact toxicity of seeds treated with leaf powders

The susceptibility of the adults of both species increased over time with different doses of *Mentha pulegium* powders (Fig 4).

The experiments carried out for *Sitophilus oryzae* and *Tribolium castaneum* achieved a mortality of about 76.92% and 57.69% (at the 5% dose), respectively, after 6 days of exposure. The positive control was more effective against adults of both insects 100% mortality recorded in 2 days.

Evaluation of the toxicity of essential oil of *Mentha pulegium* on the germination of wheat seeds (*Triticum aestivum*)

The percentages of sprouted seeds (already treated with EO) as a function of the concentration of essential oil are shown in Fig 5.

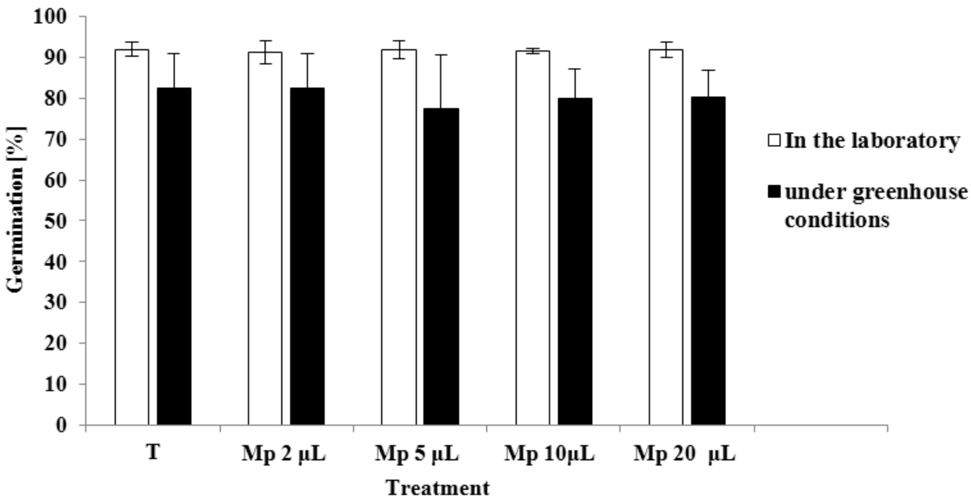


Fig. 5. Evaluation of the germination rate of wheat seeds in the laboratory and under greenhouse conditions.

There are no significant differences in the percentages of germination for the different EO concentrations of tested. The results show a slight difference in the percentage of seed germination in all treated groups compared to the control group, both in vitro and in the greenhouse.

DISCUSSION

The adult populations of *Sitophilus oryzae* and *Tribolium castaneum* in the present study were significantly reduced by the use of the essential oil and leaf powder of *Mentha pulegium*. In some cases, the results were similar or better than the positive controls owing to their faster response and shorter exposure time. In our experimental conditions, the two insects were influenced by the dose, the time of exposure and the method by which the insecticidal activity of the essential oil was demonstrated. Adults of *Sitophilus oryzae* were more sensitive to different concentrations of essential oil and leaf powder than *Tribolium castaneum* adults.

In fact, in the test where the adult insects were in direct contact with EO (using filter paper), the doses of 0.157 µL/cm² and 0.314 µL/cm² were as effective against both insects as treatment with malathion. These results correspond to several studies highlighting the insecticidal activity of *Mentha pulegium* against various pests of grain stocks (GEORGE et al. 2009, BOURARACH et al. 2011).

Another study showed that *Mentha microphylla* oil as a contact product was highly effective against *Sitophilus oryzae* and *Tribolium castaneum* with an LC50 of 0.01 mg/cm2; in the fumigant toxicity test, too, the *Mentha microphylla* essential oil exhibited strong insecticidal activity against these two insects with LC50 = 0.21 µL/L and LC50 = 4.51 µL/L, respectively (MOHAMED et al. 2008). The similar results obtained with the present fumigation test using *Mentha pulegium* essential oil exhibited an interesting insecticidal power against both insects compared to the positive controls. The 20 µL dose of EO recorded up to 100% mortality: it was fully lethal against *Sitophilus oryzae* after 24 hours and against *Tribolium castaneum* after 48 hours of treatment. However, the results obtained with the positive control could have been due either to the development of forms of resistance by *Sitophilus oryzae* and *Tribolium castaneum* to aluminium phosphide (because this is intensively used under Moroccan conditions), or to the experimental conditions, which differ from those of grain stocks.

Results similar to ours were reported by LAMIRI et al. (2001), who demonstrated that the oil of *Mentha pulegium* L. led to 100% mortality of *Mayetiola destructor* (SAY, 1817), one of the main pests in Morocco. Another study, by BENAYAD et al. (2008), showed that a concentration of 3 µl *Mentha pulegium* oil (73.33% pulegone) killed all *Sitophilus oryzae* weevils after one day of treatment. The fumigation activity of *Mentha* oil against several storage pests has been widely investigated (KUMAR et al. 2011). Indeed, according to ZEKRI et al. (2013), the fumigation toxicity of the essential oil of this plant has an insecticidal effect against *Sitophilus oryzae* adults, causing 100% mortality after four days of treatment at a concentration of 2 µL/ L. In our experiments, we achieved only 51.02% mortality for *S. oryzae* and 3.44% for *Tribolium castaneum* after the same exposure period. This may be due to the different populations of *Sitophilus oryzae* and *Tribolium castaneum* or to the different composition of the *Mentha pulegium* oil used in this study.

According to ABDELLI et al. (2016), the essential oil of *M. pulegium* caused 100% contact mortality against the food pest *Sitophilus granarius* (LINNAEUS, 1758) with a dose of 20 µL EO/ml of acetone after 4 days. This inhaled oil led to a mortality of 100% within 24 hours. In contrast, use of the wheat grain ingestion method resulted in complete mortality after 3 days with a dose of 5 µL EO/ml of acetone. In our study the high sensitivity of *Tribolium castaneum* and *Sitophilus oryzae* adults to ingestion of *Mentha pulegium* essential oil caused the total mortality of both insects at doses of 10 and 20 µL, and the response was faster than that caused by the positive control. On the other hand, the positive control remains more effective than the leaf powder, with which 100% mortality was unattainable, even at its highest concentration of 5%. Our results are in agreement with those of several authors who have evidence of the insecticidal activity of the powders of aromatic plants on the pests of stored seeds while preserving their germinability (AIBOUD et al. 2011). The essential oil of *M. pulegium* greatly reduced the survival of adults of *Sitophilus oryzae* and *Tribolium castaneum* using the different methods tested in this work without affecting the germinability of the treated wheat seeds.

These experiments show that at low EO doses, the EO contact method is the most effective; this is followed by the ingestion method and then EO inhalation, while ingestion of the leaf powder is effective only at higher doses. Hence, the direct contact method is to be preferred: it is the most toxic towards both insects and requires only low EO concentrations.

The most interesting finding in this study is the potent toxicity of *Mentha pulegium* essential oil relative to the powder made from those leaves against *Sitophilus oryzae* and *Tribolium castaneum*.

We can conclude that the use of the powder and the essential oil of *Mentha pulegium* by fumigation or direct contact or ingestion demonstrate insecticidal properties against adults of *Sitophilus oryzae* and *Tribolium castaneum*. On the basis of these results, this method is strongly recommended as an alternative to chemical control for preserving the quality of stored seeds.

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REFERENCES

ABBOTT W.S. 1925. A method of computing the effectiveness of an insecticide. Journal of Economic Entomology, **18** (2): 265–267.

ABDELGALEIL S.A., MOHAMED M.I., BADAWY M.E., EL-ARAMI S.A. 2009. Fumigant and contact toxicities of monoterpenes to *Sitophilus oryzae* (L.) and *Tribolium castaneum* (HERBST) and their inhibitory effects on acetylcholinesterase activity. Journal of Chemical Ecology, **35** (5): 518–525.

ABDELLI M., MOGHRANI H., ABOUN A., MAACHI R. 2016. Algerian *Mentha pulegium* L. leaves essential oil: Chemical composition, antimicrobial, insecticidal and antioxidant activities. Industrial Crops and Products, **94**: 197–205.

AIBOUD K. 2011. Etude de l'efficacité de quelques huiles essentielles à l'égard de la bruche de niébé *Callosobruchus maculatus* (Coleoptera; Bruchidae) et impacte des traitement sur la germination de *Vigna anguiculata*. M.Sc. Thesis, Université Mouloud Mammeri de Tizi Ouzou, Tizi Wuzu, Algieria.

ARNAUD L., GAGE M.J.G., HAUBRUGE E. 2001. The dynamics of second- and third-male fertilization precedence in *Tribolium castaneum*. Entomologia Experimentalis et Aplicata, **99** (1): 55–64.

BENAYAD N. 2008. Les huiles essentielles extraites des plantes médicinales marocaines. Moyen efficace de lutte contre les ravageurs des denrées alimentaires stockées. Research Project. University of Sciences, Rabat (Maroc).

BOURARACH K., SEKKAT M., LAMNAOUER D. 2011. Activité insecticide de quelques plantes médicinales du Maroc. Revue Marocaine des Sciences Agronomiques et Vétérinaires, **14** (3): 31–36.

DANHO M., HAUBRUGE E., GASPAR C., LOGNAY G. 2000. Sélection des grains-hôtes par *Prostephanus truncatus* (Coleoptera, Bostrychidae) en présence de grains préalablement infestés par *Sitophilus zeamais* (Coleoptera, Curculionidae). Belgian Journal of Zoology, **130** (1): 3–9.

CHANTEREAU J., CRUZ J. F., RATNADASS A., TROUCHE G. 2013. Le sorgho. Éditions Quæ, Versailles.

CISSOKHO P. S., GUEYE M. T., SOW E. H., & DIARRA K., 2015. Substances inertes et plantes à effet insecticide utilisées dans la lutte contre les insectes ravageurs des céréales et légumineuses au Sénégal et en Afrique de l'Ouest. International Journal of Biological and Chemical Sciences, **9** (3): 1644–1653.

COPPEN J.J.W. (Ed.). 2003. Eucalyptus. The genus *Eucalyptus*. CRC Press, Boca Raton, FL.

EL IDRISSI M., ELHOURRI M., AMECHROUQ A., BOUGHDAD A. 2014. Étude de l'activité insecticide de l'huile essentielle de *Dysphania ambrosioïdes* L. (Chenopodiaceae) sur *Sitophilus oryzae* (Coleoptera: Curculionidae). Journal of Materials and Environmental Science, **5** (4): 989–994.

FINNEY D.J. 1971. Probit Analysis, 3rd ed. Cambridge University Press, New York, NY.

GEORGE D.R., SMITH T.J., SHIEL R.S., SPARAGANO O.A.E., GUY J.H. 2009. Mode of action and variability in efficacy of plant essential oils showing toxicity against the poultry red mite, *Dermanyssus gallinae*. Veterinary Parasitology, **161** (3): 276–282.

HAJLAOUI H., TRABELSI N., NOUMI E., SNOUSSI M., FALLAH H., KSOURI R., BAKHROUF A. 2009. Biological activities of the essential oils and methanol extract of tow cultivated mint species (*Mentha longifolia* and *Mentha pulegium*) used in the Tunisian folkloric medicine. World Journal of Microbiology and Biotechnology, **25** (12): 2227–2238.

HAUBRUGE E., AMICHOT M., CUANY A., BERGE J.P., ARNAUD L. 2002. Purification and characterization of a carboxylesterase involved in malathion-specific resistance from *Tribolium castaneum* (Coleoptera: Tenebrionidae). Insect Biochemistry and Molecular Biology, **32** (9): 1118–1190.

HOU X., FIELDS P., TAYLOR W. 2004. The effect to repellents on penetration into packaging by stored-product insects. Journal of Stored Products Research, **40** (1): 47–54.

KUMAR P., MISHRA S., MALIK A., SATYA S. 2011. Insecticidal properties of *Mentha* species: a review. Industrial Crops and Products, **34** (1): 802–817.

LAMIRI A., LHALOUI S., BENJILALI B., BERRADA M. 2001. Insecticidal effects of Hessian Fly against *Mayetiola destructor* (SAY). Field Crop Research, **71** (1): 9–15.

LINDGREN D.L., VINCENT L.E. 1965. The susceptibility of laboratory-reared and field collected cultures of *Tribolium confusum* and *T. castaneum* to ethylene dibromide, hydrocyanic acid, and methyl bromide. Journal of Economic Entomology, **58** (3): 551–555.

MOHAMED M.I., ABDELGALEIL S.A. 2008. Chemical composition and insecticidal potential of essential oils from Egyptian plants against *Sitophilus oryzae* (L.) (Coleoptera: Curculionidae) and *Tribolium castaneum* (HERBST) (Coleoptera: Tenebrionidae). Applied Entomology and Zoology, **43** (4): 599–607.

MULTIGNER L. 2005. Effets retardés des pesticides sur la santé humaine. Environnement, Risques & Santé, **4** (3): 187–194.

PARK I.K., LEE S.G., CHOI D.H., AHN Y.J. 2003. Insecticidal properties of constituents identified in the essential oil from leaves of *Chamaecyparis obtusa* against *Callosobruchus chinensis* (L.) and *Sitophilus oryzae* (L.). Journal of Stored Products Research, **39** (4): 375–384.

PARKIN E.A., SCOTT E.I.C., FORESTER R. 1962. Increase resistance of stored-product insects to insecticides. The resistance of field strains of beetles. (c) *Tribolium castaneum*. Pest Infestation Research, **21**: 34–35.

PERRUCCI S. 1995. Acaricidal activity of some essential oils and their constituents against *Tyrophagus longior*, a mite of stored food. Journal of Food Protection, **58** (5): 560–563.

PIESIK D., WENDA-PIESIK A. 2015. *Sitophilus granarius* responses to blends of five groups of cereal kernels and one group of plant volatiles. Journal of Stored Products Research, **62**: 36–39.

RAJENDRAN S,. SRIRANJINI V. 2008. Plant products as fumigants for stored-product insect control. Journal of Stored Products Research, **44** (2): 126–135.

RIEBEIRO B.M., GUEDES R.N.C., OLIVEIRA E.E., SANTOS J.P. 2003. Insecticide resistance and synergism in Brasilian populations of *Sitophilus zeamais* (Coleoptera: Curculionidae). Journal of Stored Products Research, **39** (1): 21–31.

SARDASHTI A., ADHAMI Y. 2013. Chemical composition of the essential oil of *Mentha pulegium* L. from Taftan Area by means of gas chromatography/mass spectrometry (GC/MS). Journal of Medicinal Plants Research, **7** (40): 3003–3007.

TAPONDJOU L.A., ADLER C., BOUDA H., FONTEM D.A. 2002. Efficacy of powder and essential oil from *Chenopodium ambrosioides* leaves as post-harvest grain protectants against six-stored product beetles. Journal of Stored Products Research, **38** (4): 395–402.

WHITE N.D. 1995. Insects, mites, and insecticides in stored grain ecosystems. [in:] D.S. JAYA, N.D. WHITE, W.E. MUIR (eds.). Stored Grain Ecosystem. Marcel Dekker, NewYork, NY, 123–168.

ZEKRI N., AMALICH S., BOUGHDAD A., EL BELGHITI M.A., ZAIR T. 2013. Phytochemical study and insecticidal activity of *Mentha pulegium* L. oils from Morocco against *Sitophilus oryzae*. Mediterranean Journal of Chemistry, **2** (4): 607–619.

ZETTLER J.L., CUPERUS G.W. 1990. Pesticide resistance in *Tribolium castaneum* (Coleoptera: Tenebrionidae) and *Rhyzopertha dominica* (Coleoptera: Bostrichidae) in wheat. Journal of Economic Entomology, **83** (5): 1677–1681.

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