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INSECTICIDAL EFFECT OF BOTANICAL POWDERS *SYZYGIUM AROMATICUM* AND *MENTHA PULEGIUM* TO CONTROL *TROGODERMA GRANARIUM* (EVERTS) AND *TRIBOLIUM CONFUSUM* (DU VAL) ON WHEAT GRAINS

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ABSTRACT

Syzygium aromaticum and *Mentha pulegium L.* powders were tested for their insecticidal activity. Contact and fumigation toxicity tests of these powders were evaluated against adults and larvae of *Trogoderma granarium* (Everts, 1899) (Copleoptera : Dermestidae) and *Tribolium confusum* (du Val, 1863) (Coleoptera : Tenebrionidae) considered as the main pests of stored wheat. In the contact test, the LD50 values of *M. pulegium* were 1.045, 1.853 and 1.094, 1.963 g/100g grain, respectively for larvae and adults of *T. confusum* and *T. granarium.* The *S. aromaticum* fumigation toxicity test revealed a mortality rate of 53.22% for *T. confusum* larvae and 43.33% for *T. granarium* adults, at the dose of 2g/100g of seeds. On the other hand, wheat grains infested with *T. confusum* and *T. granarium* larvae and treated with *S. aromaticum* showed a high rate of weight loss of 2.41 and 3.66% respectively. Similarly, the highest germination (89%) was observed in the grains treated with *S. aromaticum* powder. On the basis of mortality, weight loss and germination, it can be seen that *S. aromaticum* powder can be considered as a treatment solution against the *T. confusum* and *T. granarium* population.
Keywords **:** Botanical powder, *Tribolium confusum*, *Trogoderma granarium*, contact, fumigant

Introduction

Stored grains are significantly damaged by insect pests. These pests cause damage to stored grain, leading to losses in quality and quantity Stejskal *et al*. (2015); Jeyasankar *et al*. (2014); Kumar D. and Kalita P. (2017) ; Benhalima *et al*. (2004) ; Rajashekar (2016). These pests can lead to loss of weight, poor seed germination, reduced viability and loss of commercial value, consumption or planting FAO (2001).

In Algeria, damage to cereals can reach 64%; these losses are due to the foraging activities of insects, micro-organisms and animals. In the event of intense infestation by these pests, important weight loss and quality deterioration are observed FAO (2019). International post-harvest economic losses caused by pests account for 10-36% of grain weight (Hagstrum and Phillips, 2017; Fox, 2013; Saldivar and García-Lara, 2015; Gitonga *et al*., 2013).

Beetles are the most economically damaging post-harvest insects. Khapra beetle (*Trogoderma granarium* Everts, 1899) (Copleoptera: Dermestidae) is one of the 100 important invasive pests species in the world Athanassiou *et al*. (2016), and one of the most destructive primary insect pests of stored grain products (Hagstrum and Subramanyam, 2009; Athanassiou and Arthur, 2018).

In addition to the fact, that *T. granarium* causes economic losses on stored products, affecting their quality and quantity. Grain contaminated with larval setae can be hazardous to public health Stibick (2009). The larvae are more damaging than the adults, as they are able to attack intact grain. Heavy infestations can cause heating of stored products, leading to mould growth and reduced flavor and quality of food Athanassiou *et al*. (2016).

In the case of secondary pests the beetle *Tribolium confusum* (Jacquelin du Val, 1863) (Coleoptera: Tenebrionidae) is one of the most serious pests of stored products prevalent. It attacks previously damaged grain both as larvae and adults (Scheff and Arthur, 2018; Stamopoulos *et al*., 2007), as it is found to be more difficult to kill than other stored product beetles Arthur (2000, 2008).

The protection of stored grains and seeds from insect pests has been a major issue due to the harmful and dangerous effects of conventional pesticides/insecticides on human health, animals and the environment Sh Abou-Elnaga (2015). However, the common use of chemical agents, namely synthetic insecticides and fumigants, in the control of insect pests in warehouses has led to serious problems such as the development of insect resistance to insecticides (Benhalima *et al*., 2004; Lorini and Filho, 2007).

Natural insecticides of low toxicity to mammals are used against a wide range of insect pests. Thus, they can be introduced in the framework of integrated pest management of stored grain as alternatives to synthetic pesticides (Kim *et* *al*., 2006; Miresmailli and Isman, 2014; Subramanyam and Roesli, 2000).

Clove (*S. aromaticum*) and spearmint (*M. pulegium* L.) are aromatic plants with medicinal importance with natural insecticidal effect (Barros *et al*., 2015; Cortés-Rojas *et al*., 2014; Ileke *et al*., 2014; Uehara *et al*., 2019).

S. aromaticum has been used for centuries as a food preservative and analgesic. It is also claimed to be the richest source of phenolic antioxidants (Pérez-Jiménez *et al*., 2010; Shan *et al*., 2005).

M. pulegium is a plant native to Europe, North Africa (Algeria), Asia Minor and the Middle East Chalchat *et al.* (2000). It is mainly cultivated as a condiment plant; currently, in medicine, it is still used as an antiseptic and as a stomachic and analgesic. *M. pulegium* has been the subject of numerous works dealing with the importance of its medicinal and aromatic virtues (Abdelli *et al*., 2016). The leaves are rich in aromatic menthol; their use as a condiment and at usual doses does not present any risk of acute or chronic toxicity Teuscher *et al.* (2005).

The aim of this study is to evaluate the effect of clove and spearmint powders on two pest species of beetles on stored wheat.

Materiel and Methods

Insect culture

The culture of *T. granarium* and *T. confusum* was obtained from infested wheat grains from the Union of the Agricultural Cooperative of Mostaganem and then the Cooperative of Grain and Pulses of Adrar (Algeria). Cylindrical glass jars with a capacity of 1 kg were used for rearing the insects. Approximately 500 g of grains were kept in the jars and about 100 adults were released. The jars were then covered with muslin to prevent the insects from escaping and to allow ventilation. After two weeks, the adults were removed and left in the grain medium until new adults emerged. These cultures were grown under laboratory conditions in an oven set at a temperature of 27±3°C and a relative humidity of 70±5% to allow favorable development of the insect. Cultures maintained in this way were used throughout the period of this study.

Collection of the plants studied

Clove flower buds were purchased from the local spice shop. The collection of pennyroyal mint is done by random sampling in the field in the region of Metarfa-Adrar (Algeria) in December and January 2021. The collected leaves were dried in the shade to avoid alteration of the active ingredients by light.

Toxicity of plant powders

The powders of *S. aromaticum* and *M. pulegium* were carefully mixed with 100 g of durum wheat grains in 500 ml glass jars containing 30 adults and 30 larvae of the tested specimens; six doses were chosen (0.25%; 0.50%; 0.75%; 1%; 1.50% and 2% of the weight of the powder per weight of grains), i.e. a powder weight of 0.25 g, 0.5 g, 0.75 g, 1 g, 1.5 g and 2 g respectively. Untreated wheat grains were defined as controls in the experiment.

The fumigation effect of the examined powders was carried out in 500 ml glass jars consisting of 100 g of the wheat grains and the tested individuals (30 adults and 30 larvae); then, the powders were put in a mini-bag attached by a thread to the lid of each jar.

The mortality of *T. granarium* and *T. confusum* was observed daily for 7 days. Tested individuals were considered dead when there was no response to palpation with a sharp pin on the abdomen. The tests were repeated five times for each dose and for the control.

Calculation of the LD_{50} of powders

The effectiveness of the toxic cloud is measured by the LD_{50}, which represents the amount of toxic substance that causes the death of 50% of the individuals in a batch. It was concluded from the regression line plot; taking into account the probit values of the corrected mortality rates, on the ordinate by the BLISS table, and the decimal logarithm of the dose on the abscissa; the corrected mortality rates are converted into probits. These probits are plotted against the logarithm to estimate the lethal dose (LD_{50}) according to the method of Miller and Tainer (1944). For this calculation, we were interested in the seventh days of treatment. The standard deviation (SD) of the LD_{50} is calculated using the formula of Ghosh (1984).

Germination test

After the contact treatments, the grains were subjected to the germination test, which consisted of taking 100 grains at random from each treated sample and placing them inside the water-soaked cotton in Petri dishes without lids. All Petri dishes were then placed in an oven at a normal room temperature of 27°C.

After one week, the germinated seeds are counted for each sample. The germination rate is given by the following formula:

$$\mathbf{Gp\ (\%) = (Sg/Tg) \times 100}$$

Sg : number of sprouted grains Tg : total number of grains tested

In addition, counts were also made for physically damaged and intact kernels for 100 randomly selected kernels, and a comparison of weight loss was also made for the grains used in the test after treatment.

Statistical analysis

Data on the percentage mortality of adults and larvae of *T. granarium* and *T. confusum* reconstituted were subjected to analysis of variance (ANOVA) and Tukey's test at $P < 0.05$. All statistical analyses were performed with the statistical software SPSS for Windows® (version 26.0).

Results

Effect of plant powders by contact

The results of the insecticidal effect of *S. aromaticum* and *M. pulegium* powders against *T. granarium* and *T. confusum* are shown in Table 1. The mortality of adults and larvae of both beetles tested increased with the concentration and time of exposure to the powders.

It was found that the *M. pulegium* leaf powder was the most effective, producing a maximum mortality of 89-93% on *T. granarium* larvae and adults and between 59-71% respectively on *T. confusum* adults and larvae. These results show a highly significant variation in mortality rates, depending on the dose of *M. pulegium* leaf powder for *T.*

granarium (p=0.000, p=0.001 respectively larvae'sandadults) and *T. confusum* (p=0.000, p=0.002 respectively larvae's and adults). On the other hand, *S. aromaticum* powder also has a very significant toxic effect against *T. confusum* larvae and *T. granarium* adults by exhibiting a mortality rate exceeding 80% and a mortality rate <50% recorded against *T. confusum* adults and *T. granarium* larvae. Consequently, the analysis of variance shows a significant difference in the susceptibility of the two beetles studied to the different tested doses of *S. aromaticum* powder (*T. confusum* P= 0.001; P=0.001 and *T. granarium* : P= 0.000; P=0.000 respectively larvae's and adults). The controls of *S. aromaticum* and *M. pulegium* powders showed no mortality during the study period.

The LD_{50} determined from the probit equations of the insecticide tests of *S. aromaticum* powder for adults and larvae of *T. confusum* were 1.045g/100g and 1.853g/100g grain respectively; while for *T. granarium* an LD_{50} of 1.094g/100g grain for larvae and 1.963g/100g grain for adults was recorded. The results obtained for the LD_{50} of the botanical species *M. pulegium* against larvae and adults of *T. confusum* were 1.041g/100g grain and 1.030g/100g grain respectively; in addition, LD_{50s} of 1.099g/100g and 2.104g/100g grain were recorded for larvae and adults on *T. granarium* respectively. These results show that *S. aromaticum* and *M. pulegium* powders are much more toxic to *T. granarium* and *T. confusum* adults than to larvae (Table-2).

Table 1 : Mortality of larvae and adults of *T. confusum* and *T. granarium* on wheat grains treated with *S. aromaticum* and *M. pulegium* powders by contact after seven days of exposure to the treatment

Powder	Concentration (g 100g^{-1}) wheat grains	Species			
		Tribolium confusum		*Trogoderma granarium*	
		Larve	Adulte	Larve	Adulte
S. aromaticum	0.25	$11.01±0.85^{ab}$	$6.66±0.43^{a}$	$33.22±0.87^{b}$	$43.89±0.11^{ab}$
	0.5	$32.22±0.46^{ab}$	$7.67±0.33^{ab}$	$41.22±0.38^{b}$	$73.33±0.77^{bc}$
	0.75	$50.55±0.39^{b}$	$6.12±0.63^{a}$	$26.28±1.15^{ab}$	$81.39±1.07^{bc}$
	1	$63.89±1.41^{b}$	$13.55±0.82^{ab}$	$37.78±0.31^{b}$	$85.67±0.33^{bc}$
	1.5	$75.55±0.48^{b}$	$15.44±1.78^{ab}$	$36.11±0.13^{b}$	$89.33±0.86^{bc}$
	2	$80.45±0.11^{b}$	$23±1.45^{b}$	$43.11±1.21^{b}$	$89.55±1.73^{c}$
M. pulegium	0.25	$14.89±1.82^{ab}$	$10.44±0.11^{ab}$	$39.44±0.94^{b}$	$47.50±1.06^{b}$
	0.5	$46.27±2.51^{abc}$	$23.89±1.19^{bc}$	$51.11±1.28^{bc}$	$76.58±0.58^{bc}$
	0.75	$34.33±1.74^{abc}$	$29.39±0.62^{abc}$	$51.89±1.14^{bc}$	$81.89±0.33^{bc}$
	1	$61.66±0.17^{bc}$	$39.55±1.26^{bc}$	$54.44±0.49^{bc}$	$86±0.52^{bc}$
	1.5	$60.11±1.05^{bc}$	$47.79±2.33^{bc}$	$70.39±1.06^{c}$	$86.67±1.52^{bc}$
	2	$71.23±0.75^{c}$	$59.55±1.93^{c}$	$89.89±2.05^{c}$	$93.05±1.63^{c}$
	Control	$0±0^{a}$	$0±0^{a}$	$0±0^{a}$	$0±0^{a}$

Each value is a mean ± standard deviation of five replications. Means in the same column followed by the same letter(s) are not significantly different at P > 0.05 using the Tukey test

Table 2 : LD_{50} and LD_{90} values of *S. aromaticum* and *M. pulegium* powders against larvae and adults of *T. granarium* and *T. confusum* by contact after 7 days of exposure.

Powder	Species	Stadium	Probitequation	X^2	DL_{50}	DL_{90}
S. aromaticum	*Tribolium confusum*	Larve	41.946*x*+4.1915	0.9611	1.045	1.124
		Adulte	10.765*x*+2.109	0.9705	1.853	2.438
	Trogoderma granarium	Larve	20.899*x*+4.1708	0.9371	1.094	1.262
		Adulte	41.196*x*+17.071	0.8601	1.963	1.828
M. pulegium	*Tribolium confusum*	Larve	35.253*x*+4.3839	0.9843	1.041	1.132
		Adulte	28.676*x*+4.6135	0.9744	1.030	1.143
	Trogoderma granarium	Larve	44.912*x*+3.154	0.9866	1.099	1.172
		Adulte	41.103*x*+18.271	0.8562	2.104	1.959

Fumigant toxicity of botanical powders

The analysis was carried out to test the insecticidal effect of powders of *S. aromaticum* and *M. pulegium* leaves by fumigation against adults and larvae of *T. granarium* and *T. confusum*. Table 3 showed that the powders tested had an average mortality after seven days of exposure to the different concentrations on *T. confusum* adults. Similarly, significant mortalities (P = 0.000, P = 0.001) of 53% and 40% were recorded for *S. aromaticum* and *M. pulegium*at the larval stage at the concentration of 2g/100g grain, respectively. On the other hand, the mortality of Khapra grains, clove powder was found to cause the highest mortality (19.11 and 41.33% respectively larvae's and adults) at 7 days after treatment (2g/100g grain), followed by the powdered leaves of the spearmint at an average mortality rate of 14.93 and 29% for larvae and adults respectively. These results show variable significance (P < 0.05) between the mortality rates and botanical powders studied.

The LD_{50} values were 1.355 and 2.432g/100g grains on larvae of *T. confusum* and *T. granarium* respectively, while the LD_{50} values on adults were 6.531 and 1.035g/100g grains for *T. confusum* and *T. granarium* respectively after seven days exposure to *S. aromaticum*. However, on *M. pulegium* the LD_{50} values were 1,450 and 7,673 g/100g grains respectively for larvae and adults of *T. confusum*; whereas, the LD_{50s} obtained on larvae and adults of *T. granarium* were respectively 6,382 and 1,233 g/100g grains for the same exposure periods (Table-4).

Table 3: Mortality of larvae and adults of *T. granarium* and *T. confusum* on wheat grains treated with *S. aromaticum* and *M. pulegium* powders by fumigation after seven days

Powder	Concentration (g $100g^{-1}$) wheat grains	Species			
		Tribolium confusum		*Trogoderma granarium*	
		Larve	Adulte	Larve	Adulte
S. aromaticum	0.25	8.41±1.04^{ab}	2±0.37^{a}	5±0.87^{ab}	20.5±0.08^{ab}
	0.5	13.22±0.53^{bc}	4.11±0.13^{ab}	6.89±0.38^{ab}	23.78±0.19^{ab}
	0.75	29.11±1.25^{abc}	5.33±1.65^{ab}	9.98±1.15^{ab}	31.88±0.95^{ab}
	1	33.33±0.45^{abc}	8.67±0.39^{ab}	12.38±2.31^{b}	32.89±1.51^{ab}
	1.5	43.11±0.81^{bc}	8.11±0.21^{ab}	14.33±2.13^{b}	40.99±0.36^{b}
	2	53.22±1.45^{c}	11±0.66^{b}	19.11±0.21^{c}	43.33±1.57^{b}
M. pulegium	0.25	7.89±1.82^{ab}	3.89±1.11^{ab}	1.67±0.04^{a}	6.88±0.11^{ab}
	0.5	14.27±0.51^{abc}	3.33±0.77^{ab}	4.56±0.53^{ab}	19.94±0.19^{ab}
	0.75	11.33±0.74^{abc}	1.39±0.07^{a}	3.11±0.07^{abc}	17.55±0.02^{ab}
	1	18.67±0.17^{abc}	5.67±0.33^{b}	5.11±0.42^{abc}	22.05±0.26^{ab}
	1.5	29.11±1.05^{bc}	9.33±0.86^{c}	6.33±0.03^{abc}	21.67±0.33^{ab}
	2	40.67±1.75^{c}	9.55±1.73^{c}	14.93±0.91^{c}	29±1.93^{b}
	Témoin	0±0^{a}	0±0^{a}	0±0^{a}	0±0^{a}

Each value is a mean ± standard deviation of five replications. Means in the same column followed by the same letter(s) are not significantly different at P > 0.05 using the Tukey test.

Table 4 : LD_{50} and LD_{90} values of *S. aromaticum* and *M. pulegium* powders against larvae and adults of *T. granarium* and *T. confusum* in fumigation after 7 days exposure

Powder	Species	Stadium	Probit equation	X^2	LC_{50}	LC_{90}
S. aromaticum	*Tribolium confusum*	Larve	27.206*x*+1.4095	0.9843	1.355	1.510
		Adulte	5.158*x*+0.7933	0.9775	6.531	11.588
	Trogoderma granarium	Larve	8.7727*x*+1.6092	0.9784	2.432	3.404
		Adulte	26.416*x*+4.603	0.9249	1.035	1.156
M. pulegium	*Tribolium confusum*	Larve	18.863*x*+1.9301	0.981	1.45	1.698
		Adulte	5.02*x*+0.556	0.9541	7.673	13.804
	Trogoderma granarium	Larve	7.3666*x*-0.9293	0.9517	6.382	9.506
		Adulte	14.247*x*+3.6986	0.9063	1.233	1.517

Effect of medicinal plants on weight loss rate and germination rate

Quantifying the percentage weight loss of wheat, the highest rate of weight loss was recorded in the control (Larva: 9.96 and 13.53%; Adult: 11.82 and 7.45% for *T. confusum* and *T. granarium* respectively). On the other hand, a higher rate of loss was recorded for Khapra larvae (3.66 and 3.89%) to wheat grains treated with *S. aromaticum* and *M. pulegium* and 2.53 and 3.66% for tribolium adults corresponding to *S. aromaticum* and *M. pulegium*. These results showed significance with P = 0.000 for the two treatments (Table-5).

The average germination of wheat was more than 60% recorded for the treated grains. When the germination test was performed at seven days, the germination percentage was significantly higher ($P < 0.000$) in wheat treated with *S. aromaticum* (80.67 and 89.67 %) at the dose of 2g/100 g of grain than in *M. pulegium* (80 and 84,66 %) corresponding to grains infested by the larvae of *T. granarium* and *T. confusum*. Also, the germination rate found on the grains contaminated by the adults of the two beetles mentioned above was more than 68%. A significant difference($P < 0.001$; $P < 0.000$ respectively *T. confusum* and *T. granarium*) was recorded for grains treated with *M. pulegium*, where, a germination percentage of 80.67 and 82 % to grains attacked by *T. confusum* and *T. granarium* was noted. The germination of grains treated with *S. aromaticum* was 88.67 and 79.33 % at the dose of 2 and 1.5g/100g of grains respectively for *T. granarium* and *T. confusum*. On the other hand, the control showed a lower germination of 66 and 60.67% for larvae and 59.33 and 62.67% for adults for *T. confusum* and *T. granarium* respectively (Figure-1).

Table 5 : Effect of botanical powders on weight loss of larvae and adults of *T. confusum* and *T. granarium* after seven days of exposure

Parameters /Species					
% weight loss					
		Larvae		Adult	
Powder	Concentration (g $100g^{-1}$) wheat grains	*Tribolium confusum*	*Trogoderma granarium*	*Tribolium confusum*	*Trogoderma granarium*
S. aromaticum	0.25	$2.41±0.34^{b}$	$3.14±1.61^{b}$	$2.53±0.85^{b}$	$1.71±0.60^{b}$
	0.5	$2.00±0.29^{b}$	$3.66±1.85^{b}$	$2.67±2.80^{b}$	$0.56±0.49^{ab}$
	0.75	$1.33±1.01^{b}$	$2.42±1.19^{b}$	$2.86±1.21^{b}$	$0.86±0.33b^{ab}$
	1	$0.33±0.15^{ab}$	$1.66±2.31^{ab}$	$1.78±0.39^{b}$	$0.00±0.00^{a}$
	1.5	$0.00±0.79^{a}$	$0.33±1.47^{a}$	$0.36±1.48^{a}$	$0.00±0.00^{a}$
	2	$0.00±0.11^{a}$	$0.00±0.78^{a}$	$0.77±0.62^{a}$	$0.00±0.00^{a}$
M. pulegium	0.25	$2.67±1.12^{b}$	$3.89±1.25^{b}$	$3.66±1.32^{b}$	$1.88±0.26^{b}$
	0.5	$2.24±0.27^{b}$	$2.67±0.91^{b}$	$1.33±0.77^{b}$	$0.67±1.33^{ab}$
	0.75	$1.73±0.90^{b}$	$2.36±0.74^{b}$	$1.23±0.52^{b}$	$1.33±0.58^{b}$
	1	$1.31±0.63^{b}$	$0.88±0.40^{ab}$	$0.88±1.97^{ab}$	$0.00±0.00^{a}$
	1.5	$0.00±0.00^{a}$	$0.72±0.16^{ab}$	$0.00±0.00^{a}$	$0.00±0.00^{a}$
	2	$0.00±0.00^{a}$	$0.00±0.00^{a}$	$0.00±0.00^{a}$	$0.00±0.00^{a}$
	Control	$9.96±0.59^{c}$	$11.82±1.08^{c}$	$13.53±0.72^{c}$	$7.45±0.80^{c}$

Each value is a mean ± standard deviation of five replications. Means in the same column followed by the same letter(s) are not significantly different at P > 0.05 using the Tukey test

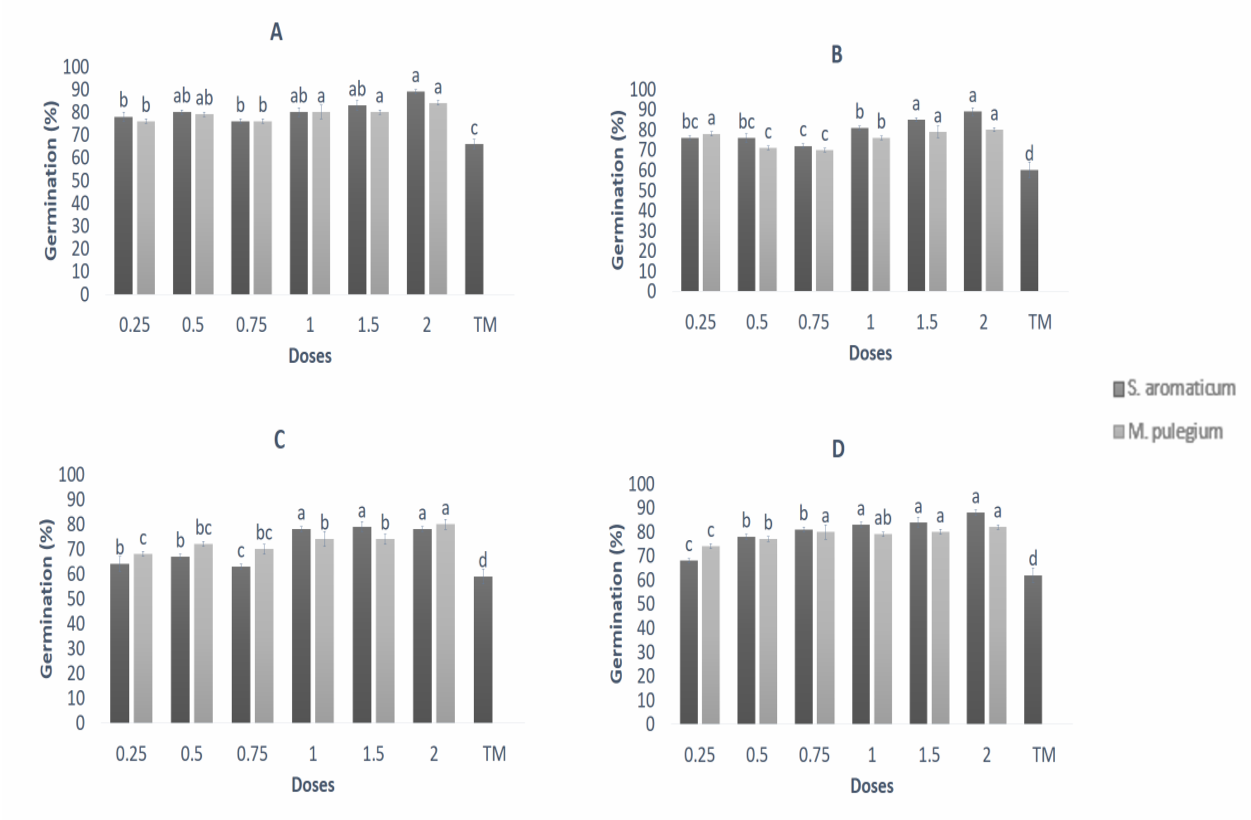

Fig. 1 : Effect of botanical powders on the percentage of germination of larvae and adults of *T. confusum* and *T. granarium* after seven days of exposure. A and C *T. confusum* larvae and adults; B and D*T. granarium* larvae and adults.

Discussion

Botanical powders have been extensively researched and successfully used to control pests in stored products. Plants produce active substances with insecticidal, aseptic or plant and insect growth regulating properties. Most often, these active substances are secondary metabolites that originally protect plants from herbivores Deravel *et al.*(2014).

In the present study, the tested plant species (applied as contact powder and fumigation) showed adulticidal and larvicidal activity against *T. confusum* and *T. granarium*. The toxicity of the contact powder varied according to the species tested, the dose used and the exposure time; this toxicity is much more important at high doses. *M. pulegium* showed stronger insecticidal activity than *S. aromaticum* against both beetles tested at an optimum dose of 2g/100g grain. Their toxic effect on the larval and adult stages did not differ significantly from the control after seven days of exposure.

An effect of cloves may be due to the death of insect larvae that could not completely shed their exoskeleton which generally remained attached to the posterior part of their abdomen Oigiangbe *et al*. (2010). In addition, clove powder has been studied as a solution against urban and agricultural pests, and has been found to possess pesticidal properties Kafle and Shih (2013). The mortality of adults and larvae of *T. granarium* and *T. confusum* observed in this study increased with the amount of clove applied, and the duration of exposure; this increase was due to secondary metabolites and volatile components that exert strong toxic effects on insects; These results are confirmed by work done on *Sitophilus oryzae* and *Callosobruchus maculatus* which reported mortality of up to 100% after 3 days of exposure to a low or high dose (Kellouche and Soltani, 2004; Ileke *et al*., 2014; Rasha *et al*., 2012; Ntonifor *et al*., 2010).

The leaf powders of *M. pulegium*have significant efficacy on the dermestid and tribolium tested. Law-Ogbomo and Enobakhare (2007) report that leaf powders of aromatic plants have an effect on insects as they can act as a physical barrier, blocking stigmas and preventing respiration. Thus the effectiveness of applying powdered leaves increased with increasing concentration Fernando and Karunaratne (2013). *M. pulegium* powders have good bio-insecticidal potential to control beetle infestations of stored commodities Kumar *et al*. (2011). Aimad *et al*. (2021) concluded that pennyroyal leaf powders have high toxicity on the different stages of *Callosobruchus maculatus*; this result is similar to the one obtained in our study, a potent toxicity on the larval and adult stage of *T. confusum* and *T. granarium* was demonstrated, causing very high mortality with increasing doses and exposure duration.

The results of this study indicate that clove powders have the ability to prevent weight loss of treated grains which may be due to high mortality of larvae and adults and the inability of larvae to complete their development thus preventing adult emergence and metabolic activities of the insects. These results are in agreement with preliminary research by Ileke *et al*. (2014) and Adedire *et al*. (2011).

The tested powders have a very significant fumigant effect on both storage pests. Plant powders with both fumigant and repellent properties are more effective against stored product pests than plant powders with only one mode of action (Farhana *et al*., 2006; Nenaah and Ibrahim, 2011).

Conclusion

The plant powders tested showed a high potential for protecting wheat grains from *T. confusum* and *T. granarium* damage; as well as larvicidal and adulticidal fumigation and contact toxicity properties against these pests. It was found that *S. aromaticum* was more toxic than *M. pulegium* in all tests studied. This study clearly indicated that the powders tested either by fumigation or by contact are effective with their natural substances. Indeed, they are considered important means of control for stored products against pests without the use of insecticides. Both plant species are part of research work for the formulation of new botanical insecticides, especially for the control of stored food pests. We have deduced that the powders of *S. aromaticum* and *M. pulegium* have significant insecticidal properties. However, this toxicity is highly variable depending on the plant species, the quantity used, the duration of treatment and the insect tested.

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