Short communication

Control of *Sitophilus zeamais* Motschulsky with marble powder in stored corn grains

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Abstract

The objective of this research was to evaluate, under laboratory conditions, the effectiveness of the inert white marble powder as mineral pesticide in the control of *Sitophilus zeamais*, in corn grains (Tusón variety) stored to be used as feedstuffs. In the experiments (anti-insect effect, weight loss of the grains and repellent effect of the marble powder) a completely randomized design was used, with four treatments, three doses of powder (0,46; 0,81 and 1,74 g) and a control (without powder), with 12 replicas each; and in the case of the data from the first two experiments variance analysis was applied. The three tested doses of the inert white marble powder exerted an anti-insect effect on *S. zeamais*, because they caused it a mortality percentage higher than 70 % on the fourth day after application, and 100 % was reached on the sixth day. The highest dose (1,74 g) propitiated that there was no weight loss of the grains due to affectation caused by the coleopteran, and, in addition, its repellent effect was corroborated. Thus, this initial study can be a starting point to confirm the potentialities of marble powder for its use in the management of such insect in grain (especially corn) storehouses or other facilities aimed at the preservation of feedstuffs.

Keywords: *Zea mays*, pests of stored products, repellents.

Introduction

Corn (*Zea mays* L.) is the main crop for the support of different peoples of Central America, although its importance also lies on the fact that it is aimed at animal rearing and production as basis for forage and for commercial and homemade concentrate feeds (Jovel-López, 2012).

For the Cuban farmer it has high value, because he/she has had to use different alternatives to guarantee the diet of the animals in the dry season, among them the storage of large volumes of corn grains (ONE, 2013); and, in turn, face one of the problems of this practice: harmful insects.

Sitophilus zeamais Motschulsky (Coleoptera: Curculionidae) is considered the most important insect of corn post-harvest pests (Almeida *et al*., 2014), which is estimated to cause decreases from 4 to 25 % of its grains in Mexico, according to report by Ortiz-Rosales *et al*. (2015); while in Cuba the losses are higher than 10 % during corn production and from 10 to 20 % after harvest, during grain storage (Feitó-Cespón *et al*., 2015).

In recent years, in the international as well as the national context, in order to decrease losses in the stored corn grains which are caused by several pest coleopterans from the genus *Sitophilus* and others, studies have been conducted for their control using natural and mineral insecticides such as diatomaceous earth and zeolites; with these bioproducts the mortality rate reached between 30 and 85 %, and 96,09 %, respectively.

However, no information was found in the literature review (at international or national level) about the use of inert white marble powder as mineral pesticide or preservative of stored corn grains. Thus, for this study the experiences related to the control of populations of weevils and other coleopterans which affect seeds during storage (internationally as well as in Cuba) with other inert powders that have similar characteristics and components as the ones mentioned above, were taken into consideration.

Hence the objective of the study was to evaluate, under laboratory conditions, the effectiveness of the inert powder of white marble stones as mineral pesticide, for the control of *S. zeamais* in stored corn grains for animal feeding.

Materials and Methods

The study was conducted under controlled conditions, in the biology laboratory of the School of Agricultural Sciences of the University of Sancti Spiritus, Cuba, and in the facilities of the provincial plant health laboratory (LAPROSAV) of Sancti Spiritus.

The inert powder of white marble stones was collected in the third waste decanter, in the block cutter located in the Fomento municipality (Sancti Spiritus province), belonging to the Mármoles Centro (MC) enterprise of the Villa Clara province (Cuba). The physical-chemical characterization of the compound was made in the laboratories of the Geomina del Centro Enterprise, also located in Villa Clara.

Provenance of the grains. Grains from *Z. mays* L. var. Tusón, included in the official list of commercial varieties of the country (MINAG, 2016) were used, which were stored under ambient conditions in woven polypropylene sacks, during 7,5 months, in storehouses of the cooperative of credits and services Abel Santamaría of the Fomento municipality. The grains were examined in the LAPROSAV, through an Olympus SZ51 stereoscopic microscope, for their previous selection, taking into consideration that they were free from affectations by insects or microorganisms (specifically from their lesions and symptoms, respectively) or from any physical or mechanical damage.

Insect with which the grains were infested

The confirmation of the insect species that would be used in the trials, in this case *S. zeamais* Motschulsky (from which adults were collected in infested corn grains of the var. Tusón), was made in an Olympus SZ51 stereoscopic microscope with 50x magnification, in the LAPROSAV, based on taxonomic keys and on the consultation of the morphological descriptions of this insect published by Athié and Paula (2002) and Bergvinson *et al*. (2007).

In this laboratory the rearing was also carried out, under controlled conditions (specifically at temperature of 25 ± 2 ºC, relative humidity of 70 ± 5 % and photoperiods of 12 h light and 12 h darkness), of the *S. zeamais* population selected for the experiments, until obtaining the first filial generation.

Experimental design and treatments. A completely randomized design was used with four treatments, three doses of white marble powder (0,46; 0,81 and 1,74 g) and a control (without powder), with 12 replicas each.

Experimental procedure

Evaluation of the anti-insect effect of the inert white marble powder and influence on the weight of the grains of the affectation by *S. zeamais*

The methodology that was adopted to evaluate the anti-insect effect was the proposal by Lagunes and Rodríguez (1989), because it is used for inert powders similar to marble powder (regarding their chemical composition and physical characteristics), among which lime (Bustos-Figueroa *et al*., 2009) can be cited; as well as kaolin, talc, chalk, calcium carbonate, diatomaceous earth and coal ash (Silva-Aguayo *et al*., 2004).

In each replica a 285-g sterile plastic flask was used (with perforated cap that allowed aeration, but not insect escape), to which 105 g of corn grains and the doses of white marble powder were added, to mix later with agitation until all the grains were uniformly covered by the powder, and then eight couples of adult *S. zeamais*, not older than seven days, were incorporated.

Since 12 h after infestation, and later every 24 h until the inexistence of living insects, in order to know the time in which the white marble powder caused the lethal effect on the insects, the dead ones were counted. For the calculation of the corrected mortality the formula proposed by Abbott (1925) was used.

$$\text{Corrected mortality} = \frac{\text{Mortality treatment-Mortality control}}{\text{100-Motality control}} \times 100$$

The weight loss percentage of the grains was quantified at 55 days after infestation, and for its calculation the formula proposed by Adams and Schulten (1978).

$$Wl = \left(\frac{Ngl}{Ntg} \times 100 \right) \times C$$

Where:

Wl: weight loss (%)
Ngl: number of grains with lesions
Ntg: total number of grains
C: constant; 0,125 if the corn is stored as loose grain

Determination of the repellent effect of the inert marble powder on the performance of *S. zeamais*

The methodology that was adopted for the determination of repellence was the proposal by Mazzonetto (2002). Six circular plastic boxes (5 cm of diameter and 8,5 cm of height) and a central box

(7,5 cm of diameter and 8,5 cm of height) which was connected with the others through plastic tubes (0,8 mm of diameter and 7 cm of length) diagonally opposed between themselves (fig. 1a). the doses of white marble powder which was used in this trial was the one that caused higher mortality percentage on *S. zeamais* in the anti-insect effect test, and in turn the one that caused lower weight loss of the grains during that determination.

The treatments with the inert powder and the control were distributed in symmetrically opposed boxes. In the central recipient 60 non-sexed adults were released and, after 24 hours, the number of insects in each recipient was counted. Six replicas were made, with 10 insects in each case, and the number of peripheral plastic boxes was changed to create different conditions that allowed to test accurately the migration (distancing) or attraction of the insects in the presence of white marble powder (figs. 1b and 1c).

To determine the repellence index the formula indicated by Mazzonetto (2002).

$$RI = \frac{2G}{(G+P)}$$

Where:

RI: repellence index.

G: percentage of insects in the treatment.

P: percentage of insects in the control.

With the resulting data from the calculation of this index it was corroborated whether the tested mineral powder was neutral (RI = 1), attracting (RI > 1) or repellent (RI < 1).

Statistical analysis. The percentage data obtained from the calculation of corrected mortality due to the anti-insect effect of the white marble powder, as well as to the weight loss of the grains with the use of this powder for their protection, were transformed through arcsin (Vx/100); and on both groups of numerical values variance analysis was made with the statistical package Statgraphics version 5.0 for Windows®, with the difference that the mean comparison in the former was through Tukey's HSD test, and in the case of the latter with Duncan's test.

Results and Discussion

Anti-insect effect of the inert white marble powder and influence on the weight of the grains in case of the affectation by *S. zeamais*

In the test of the anti-insect effect of the white marble powder, the three doses mixed with the corn grains during their storage caused at 96 h (4 days) a mortality percentage of *S. zeamais* which oscillated between 70,83 and 87,50 %, which significantly differed from the control, because it was lower than 5 % (fig. 2).

The increase of the mortality rate of the insect until reaching 100 % on the sixth day after applying the white marble powder could have been related to the mineral-chemical composition of this white inert material, with density of 2,77 kg/dm^3, particle size of 0-1200 μ and presence of CaO (55 %), $CaCO_3$ (98,1 %), Mg (95 %), Al_2O_3 (0,14 %) and SiO_2 (0,1 %), in which perhaps certain compounds with insecticide characteristics stand out, for example $CaCO_3$. Such compound was used by Silva-Aguayo *et al*. (2004) for the control of *S. zeamais* in stored corn grains, and between 70 and 84 % of mortality was achieved.

Likewise, the lethal effect caused by the white marble powder on *S. zeamais* is related to the criterion expressed by McGonigle *et al*. (2002), who stated that the aggregates of powders strongly adhere to the body surface of insects and the wax layer of the cuticle is absorbed (sequestered) by them, due to the wide specific surface of their particles (14 m^{-2} g^{-1}), according to Mimani and Patil (2001). This causes the obstruction of the spiracles, limiting their respiration and movement until provoking their death, along with the dehydration of their body, as observed by Cook *et al*. (2008) and Stadler *et al*. (2010) in studies with different inert powders to control insects and mites that affect stored products. The signs of these affectations were observed in the dead insects, which showed their wings outstretched due to the retraction caused by desiccation.

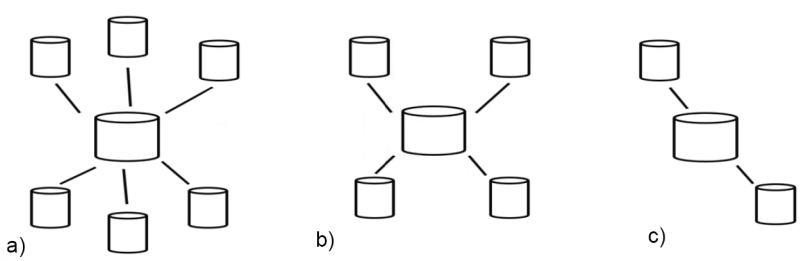
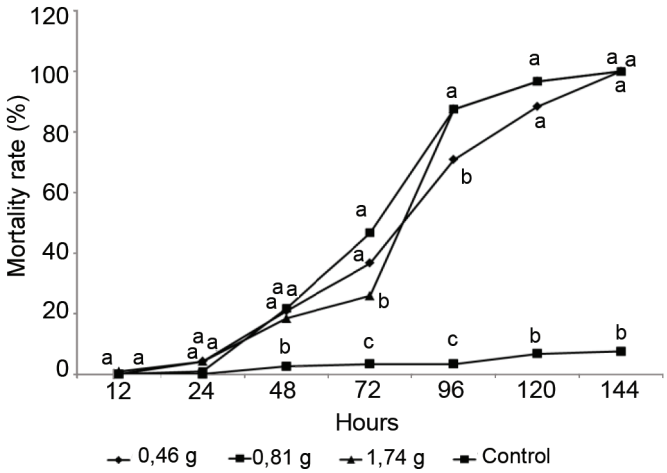


Figure 1. Diagram of the boxes for determining the repellent effect.

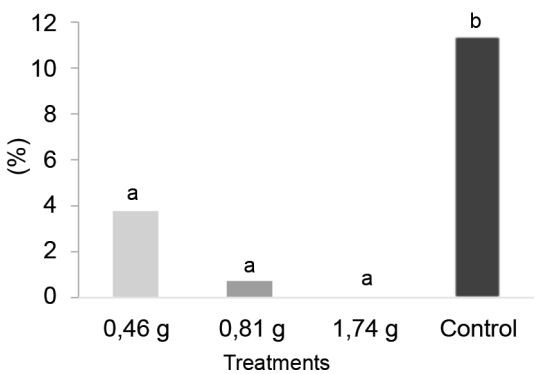


Different letters significantly differ at $p \leq 0,05$.

Figure 2. Mortality rate of *S. zeamais* due to the anti-insect effect of the tested treatments.

On the other hand, these results have certain similarity with the ones reported by Pérez *et al*. (2012), who used 2 g of zeolite as protective inert powder in chickpea grains which were infested with another coleopteran called weevil [*Lasioderma serricorne* (F.)], and between the fourth and fifth day after applying the bioproduct there was 70 % of mortality in this insect. Thus it is inferred that the white marble powder equally has certain anti-insect effect; hence to test this doses under storehouse conditions should be considered in order to validate their potential.

Regarding the percentage of weight loss of the grains, with the treatment of the highest dose no loses occurred in the seeds due to the affectation *by S. zeamais* (fig. 3). Nevertheless, the other two doses also differed significantly from the control in that period, in which 11,37 % of affected seeds was found.



Different letters significantly differ at $p \leq 0,05$.

Figure 3. Weight loss of the corn grains treated with the white marble powder.

This response coincides with the general trend of the effect caused by the different inert mineral powders on storehouse pest insects; the higher the dose of the evaluated powder, the lower the affectation by the noxious agent under study, which indicates that there will be lower economic loss in animal feeding when corn is used as grain. In that sense, there is correspondence with the result obtained by Silva *et al*. (2004), when evaluating different inert powders for the control of *S. zeamais* in corn grains, among which the one from diatomaceous earth stood out, because with a concentration of 2 % (highest dose) there was a weight loss of the grains of only 3,1 %, with regards to the other treatments (around 9 %).

Repellent effect of the inert marble powder on the behavior of *S. zeamais*

When the dose of 1,74 g of inert white marble powder was used to evaluate its repellent effect, which propitiated the highest mortality percentage of *S. zeamais*, a repellence index of 0,90 was obtained (a value lower than 1), indicating that this material has characteristics as repellent. Hence, like other inert powders, it acts as a physical barrier, according to the criteria expressed by Subramanyam and Roesli (2000), who in turn state that affectations in the grains and the subsequent economic losses are prevented, mainly by weevils.

It is concluded that the three tested doses of the inert white marble powder exerted an anti-insect effect on *S. zeamais*, because they caused it a mortality percentage higher than 70 % on the fourth

day after application, and 100 % was reached on the sixth day. The highest dose (1,74 g) stood out, which also propitiated that there was no weight loss of the grains due to affectation by the coleopteran, and also its repellent effect was corroborated.

Thus, this initial study can be the starting point to confirm the potentialities of the inert white marble powder for its use in the plant protection management of *S. zeamais* in grain (especially corn) storehouses or other facilities aimed at the conservation of feedstuffs.

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