Article

Powdered vegetables for the management of *Sitophilus zeamais* Motschulsky in storage

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Abstract

The loss of stored grains is a problem for farmers. *Sitophilus zeamais* Motschulsky, is the main pest in stored corn. The objective of the study was to determine the bioinsecticidal properties of pulverized vegetables recognized by producers of the Nueva and Rosario, Copainalá, Chiapas, Mexico, from September 2015 to April 2016. A completely randomized design was used, with 25 treatments, an absolute control and one chemical (aluminum phosphide) with three repetitions. In the laboratory, five plant species were evaluated as pulverized. *R. communis* L. at 4% generated the highest mortality (53.3%). *C. ambrosioides* L. at 1% and *R. communis* L. at 3 and 5% with repellence index (0.95) were the best. In stored corn, the best treatment of the laboratory test was evaluated; for mortality there were no significant differences between treatments. The percentage of germinated corn is not affected by the application of powders. *R. comunis* L. presented statistically similar results in damaged grain than aluminum phosphide. The weight loss of the grain was 0.97 kg. It can be concluded that castor spray has effects of mortality at 4% and repellency at 3 and 5% in laboratory conditions. While in storage conditions there were no differences which could be due to the loss of effectiveness of the active metabolites of castor, the germinative power of corn seeds is not affected by the application of the spray of *R. communis* L.

Keywords: diagnosis, mortality, repellency.

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Introduction

Corn (*Zea mays*) is an important crop because it is the basis for the production of numerous foods for humans and animals. It is the main crop in Mexico, with 18% of the value of the production of the agricultural sector and 33% of the area sown in the national territory (FND, 2014).

Among the pests associated with stored grains, the weevil (*Sitophilus zeamais* Motschulsky) of maize (*Zea mays*) is the main one because it causes more damage in the larval and adult stage, drilling the grain to oviposit, while the larvae form galleries in the endosperm when feeding.

In modern agriculture, it has been agreed that the current practice faces an environmental crisis. The decrease in yield due to pests reaches between 20-30% in most crops, despite the substantial increase in the use of pesticides (about 500 thousand tons of active ingredients worldwide) this is a symptom of the environmental crisis that affects agriculture (Altieri and Nicholls, 2000).

From the need to find a natural alternative for the control of insect pests and thus replace synthetic pesticides appear botanical insecticides offering security for the environment and an agronomic option. Its use as an alternative supports the paradigm shift: manage pests do not kill them.

More than 2,000 species of plants have properties for the control of pests, which support the reduction of environmental pollution and that can have a fairer treatment with living beings and with the natural resources that surround us, contributing to the development of a more sustainable organic farming (Iannacone and Quispe, 2004).

Due to the problems that arise in the agricultural production systems due to the attacks of pests, strategies have been sought that help the management of pests without damaging the environment, since there is an indiscriminate use of pesticides that not only kill pests but also beneficial insects within the production system. For which the present investigation had as objective to identify biological alternatives that have insecticide effects and help the handling of *Sitophilus zeamais* Motschulsky by means of the application of pulverized vegetables to stored corn and as hypothesis it was proposed that at least one of the five pulverized plants at different doses have effects on the mortality and repellency of *Sitophilus zeamais* Motschulsky.

Materials and methods

Application of a diagnosis in the The Rosario and The Nueva of Copainala, Chiapas, Mexico.

First phase: a diagnosis was made in the communities of The Nueva municipality of Copainala, Chiapas, located at coordinates 17° 02’ 57.90” north latitude and 93° 09’ 56.13” west longitude, at an altitude of 633 m and Rosario which is located at the coordinates, 17° 05’ 22” north latitude and 93°14’ 34” west longitude, at an altitude of 650 m.

For the application of the surveys, simple random sampling was used (Casal and Mateu, 2003). In these communities 10 surveys were applied by community to determine and identify plants with possible effect on insect pests in plant species.

Diagnostic analysis

After making the diagnosis, the results were analyzed to obtain the five most important plant species in insects, grouping the answers in an Excel spreadsheet (Microsoft office 2013).

Selection of five plant species of major importance on insect pests and obtaining the evaluated plant material

Second phase: in this stage, according to the results of the diagnosis, the five most important plant species on insect-plague were selected, which were analyzed in the laboratory to determine the effect of mortality and repellency of each of the five selected species. The plant material epazote (*Chenopodium ambrosioides*), holy grass (*Piper auritum* Kunth) was collected with housewives from the communities of The Nueva and The Rosario, in the case of castor (*Ricinus communis* L.) was obtained in the same areas communities where wild grows, the horsetail (*Equisetum arvense* L.) in the community Julian Grajales, Copainalá Chiapas and the ocote (*Pinus maximinoi* HE Moore) and L.) in the municipality of Coapilla, Chiapas, where the conditions are favorable for the development of this species. Subsequently, all the material collected was dried in a stove at a temperature of 65 °C until constant weight was obtained. To later be pulverized in a blender. Later it was sieved, in order to obtain a fine and homogeneous powder.

Obtaining the substrate and collecting *Sitophilus zeamais* Motschulsky

The substrate (maize) and the insects used were collected with the cooperating producer, Juan Francisco Pérez Pérez from the community Nueva, Copainalá, Chiapas. Later these were moved to the laboratory of the Mezcalapa School of Agricultural Studies, where the 1st phase of the research was carried out.

Treatments and doses evaluated

We evaluated 25 treatments corresponding to the sprays of the 5 most important plant species on the management of *S. zeamais* sprayed in doses of 1, 2, 3, 4 and 5%. More an absolute witness (without pulverized) and a chemical (aluminum phosphide) (Table 1). Each of the treatments with 3 repetitions.

Application of treatments

In plastic glasses, 100 g of corn was mixed with the different treatments with their respective doses. Once the mixture was made, each bottle was infested with 10 weevils for each experimental unit (plastic cups) (Silva and Hepp, 2004).

Mortality percentage

Mortality was evaluated every 24 h, for 21 days, for each treatment and its repetitions. For this, the following formula was used where: percentage of mortality= number of dead insects/total of insects x 100

Table 1. Treatments and doses.

Treatments	Species	Dose (%)
T1	Holy grass (*Piper auritum* Kunth.)	1
T2	Holy grass	2
T3	Holy grass	3
T4	Holy grass	4
T5	Holy grass	5
T6	Epazote (*Chenopodium ambrosioides* L.)	1
T7	Epazote	2
T8	Epazote	3
T9	Epazote	4
T10	Epazote	5
T11	Castor (*Ricinus communis* L.)	1
T12	Castor	2
T13	Castor	3
T14	Castor	4
T15	Castor	5
T16	Horse tail (*Equisetum arvense L.*)	1
T17	Horse tail	2
T18	Horse tail	3
T19	Horse tail	4
T20	Horse tail	5
T21	Ocote (*Pinus maximinoi* H. E. Moore)	1
T22	Ocote	2
T23	Ocote	3
T24	Ocote	4
T25	Ocote	5
T26	Absolute control	Without spray
T27	Chemical control	aluminum phosphide 0.003g 100 g^{-1} of maize)

Repellency index

For the evaluation of the repellency, four Petri dishes were used per treatment, the central box was connected with the others by plastic sleeves of 10 cm in length located diagonally. In the center box 10 insects of *S. zeamais* were released, in each of the three boxes next to it was placed 35 g of corn which were mixed with the respective treatments and after 24 h the number of insects was counted. each container. Each treatment had three repetitions and the formula proposed by Mazzonetto (2002), IR=2G/(G+P) was used.

Where: IR= is the repellency index; G= percentage of insects in the treatment and P= percentage of insects in the control. Plant dust is neutral if IR= 1, attractant if IR> 1 and repellent if IR< 1.

Experimental design

The experimental design was completely random, using a factorial arrangement of A x B where A= represents the five plant species and B= five different doses, for a total of 25 treatments plus two controls (absolute and chemical) and three repetitions, for a total of 81 experimental units. The data obtained were subjected to an analysis of variance and the Tukey test ($p \leq 0.05$).

Analysis of the best treatments in stored corn

Third phase: consisted in bringing to storage conditions the best treatment of phase 2, which was the castor at 4%.

Obtaining plant and spray material

The castor was obtained from the lands of the Nueva and Rosario communities of the municipality of Copainala, Chiapas, Mexico, where this species grows wild. For the spraying, castor leaves were used, which were dried in an oven at a temperature of 65 °C until constant weight was obtained. Then it was pulverized in a blender. Later it was sieved, in order to obtain a fine and homogeneous powder.

Treatment evaluation

Three repetitions were considered where each of them was composed of sacks with capacity of 25 kg, these were filled with harvested corn of the season and evaluated after three months.

Mortality percentage

Mortality was evaluated after three months of spraying for each treatment and its repetitions. Using the following formula where: percentage of mortality= number of dead insects/total of insects x 100.

Percentage of damaged grains

Regarding the evaluation of damaged grains, it was carried out at the end of the study, where damaged grains and good grains were quantified in a random sample of 100 grains taken from each of the experimental units. Using the following formula: percentage of damaged grain= total of damaged grains/100 x 100.

Weight of stored corn

It was evaluated by weight difference of each one of the experimental units at the beginning (25 kg) and at the end of the experiment, to check if weight is lost due to damages of *S. zeamais* after the application of castor spray at 4%.

Percentage of germinated corn

The germination test of each treatment was carried out. Taking at random 100 seeds of each experimental unit, placing them in wet napkins and after eight days the percentage of germination was determined using the following formula: percentage of germination= germinated seeds/100 x 100.

Experimental design

The experimental design was completely random. For the analysis of the data obtained, the variance analysis and the Tukey test ($p \leq 0.05$) were performed.

Results and discussions

Results of the diagnosis applied in the communities of The Nueva and The Rosario in the municipality of Copainala, Chiapas, Mexico.

The diagnosis in the Rosario, Copainala, Chiapas, Mexico, indicated that the respondents do not use plants for insect-pest management, so they did not continue applying the other questions of the survey.

Seventy percent of the people surveyed answered that, if they use plants for the management of insect pests, mentioning the species such as: epazote (25%), ocote (25%), castor (25%), holy grass (12.5%) and horsetail (12.5%). Of which the parts that use is the stem (37.5%), the whole plant (37.5%) and leaves 25%. The way they prepare it is in a liquid way 12.5%, drying the plant and pulverizing 25% and 62.5% uses the whole plant or part of it without transforming it. Applying them in quantities of 100 g, 500 g and 1 kg. The way it is applied by 62.5% of the producers is within the sacks, 25% mixed with the grain of corn in the form of pulverized and 12.5% in the form of aspersion. Coinciding the respondents that these species use them to manage the weevil in corn grains; obtaining positive effects against this plague insect (Figure 1).

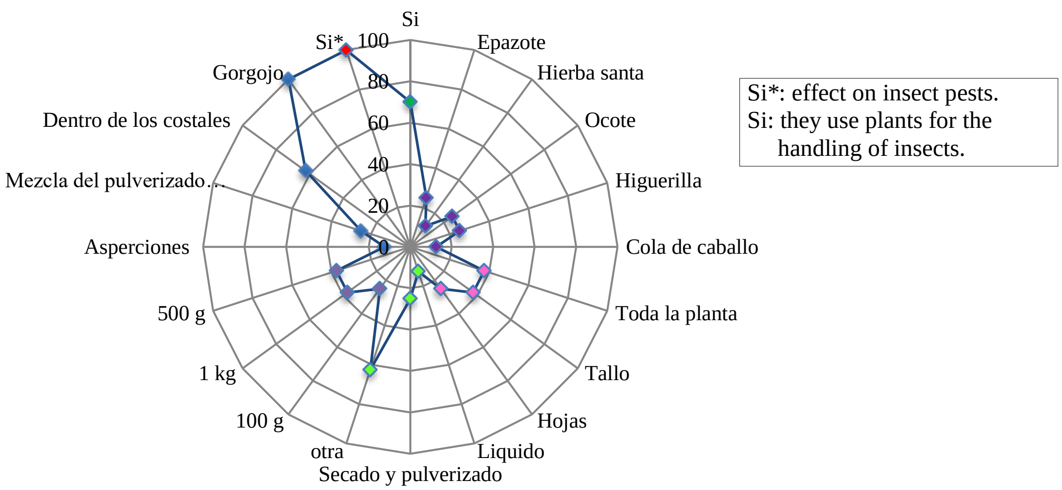

Figure 1. Data obtained from the application of a survey in the community of The Nueva, Copainalá, Chiapas.

Laboratory phase

Mortality of *Sitophilus zeamais* Motschulsky

The Figure 2 shows the percentages of mortality of *S. zeamais* this by the action of the powders of Holy grass, epazote, castor, ocote and horsetail at different concentrations. After having performed the analysis of variance and comparison of means by Tukey to 5%, the chemical control (aluminum phosphide 0.003 g 100 g^{-1} of corn) showed a higher mortality (96.7%). As for the pulverized, castor at 4% showed a greater effect on mortality (53.3%). On the other hand, Iannacone and Quispe (2004) mention that when applying *Chenopodium quinua* via 7.5% chloroform extract, 100% mortality is obtained 48 hours after exposure of the weevils to the extract. Juarez *et al*. (2010) when evaluating asteraceous powders found that when using leaves of *Chrysactinia mexicana* and *Zinnia peruviana* mortalities of 98 and 88.1% of weevils are obtained in the corn kernel respectively, being these the best treatments.

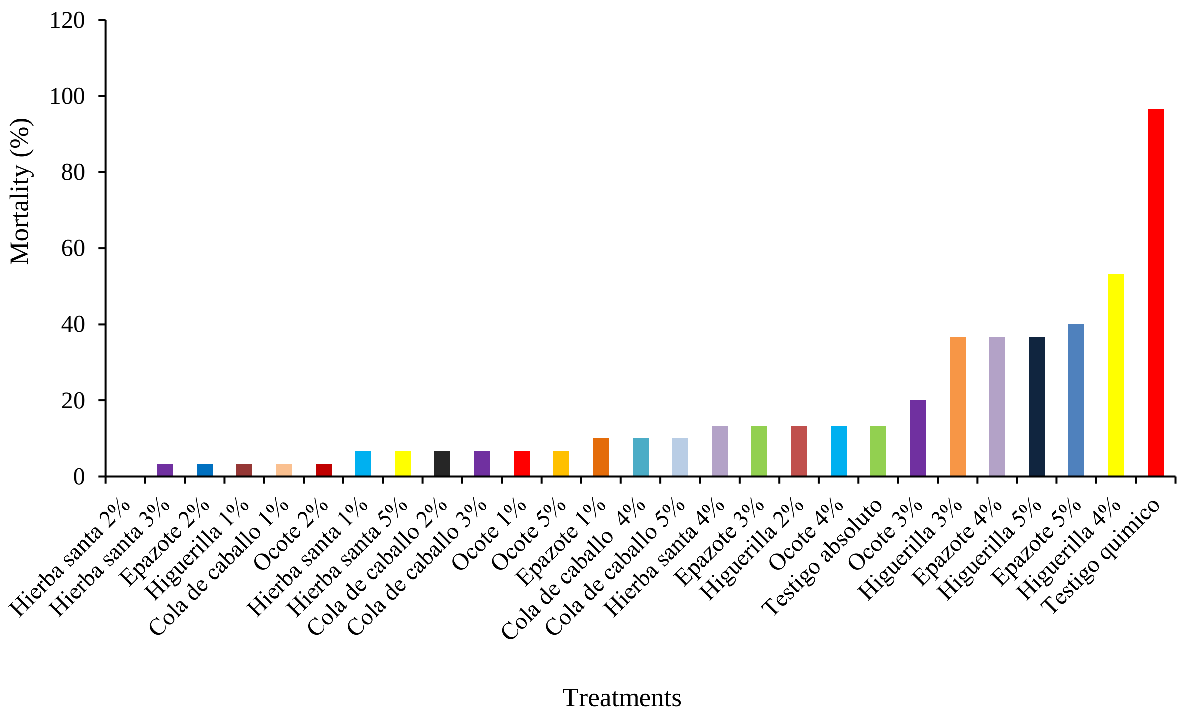

Figure 2. Effect of plant sprays on the mortality of *Sitophilus zeamais* Motschulsky in the laboratory.

Repellency of *Sitophilus zeamais* Motschulsky

The treatments evaluated and their respective results are shown in Table 2. In this table, it can be seen that epazote at 1% and castor at 3 and 4% had a repellence index of 0.95, this index being < 1; which indicates that these three treatments present repellency on corn weevils. In the rest of the powders IR= 1 indicating that the effect is neutral; that is, it is not attractive or repellent. González *et al*. (2011) when using *Lonchocarpus punctatus* powders of the different plant structures studied: stems, leaves and fruits showed repellent effect reaching values below the unit for all of them.

Table 2. Effect of plant sprays on the repellence of *Sitophilus zeamais* Motschulsky in the laboratory.

Treatments	Repellency index	Equation: IR= Neutral, IR>1, IR<1
Holy grass 1%	1	Neutral
Holy grass 2%	1	Neutral
Holy grass 3%	1	Neutral
Holy grass 4%	1	Neutral
Holy grass 5%	1	Neutral
Epazote 1%	0.95	Repellent
Epazote 2%	1	Neutral
Epazote 3%	1	Neutral
Epazote 4%	1	Neutral
Epazote 5%	1	Neutral
Castor 1%	1	Neutral
Castor 2%	1	Neutral
Castor 3%	0.95	Repellent
Castor 4%	1	Neutral
Castor 5%	0.95	Repellent
Horse tail 1%	1	Neutral
Horse tail 2%	1	Neutral
Horse tail 3%	1	Neutral
Horse tail 4%	1	Neutral
Horse tail 5%	1	Neutral
Ocote 1%	1	Neutral
Ocote 2%	1	Neutral
Ocote 3%	1	Neutral
Ocote 4%	1	Neutral
Ocote 5%	1	Neutral
Absolute control	1	Neutral
Chemical control (aluminum phosphide)	1	Neutral

However, the leaves achieved lower value, given that there was a marked difference in the number of insects present in the control and treatment 76 and 24%, respectively. This repellent effect could be determined by the presence of secondary metabolites, volatile substances that may be present in the parts studied. When these substances are detected by insects, they exert an effect on their behavior and cause migration to other places. The content of these substances in the plant can vary depending on the season and the plant structures used (Pérez *et al*., 2007).

Storage phase

Mortality of *Sitophilus zeamais* Motschulsky

In Figure 3 you can see the percentage of mortality of each of the treatments. Aluminum phosphide has a mortality of 7.2%, castor 6.4% and the absolute control 4.9%. After performing the analysis of variance and comparing Tukey's means at 5%, no significant differences were found. Gómez *et al*. (2009) using leaves of chan (*Hyptis suaveolens*) for the control of *S. zeamais* found that at concentrations of 25% of dry leaf mortality is 22.13% this within five days of the application. In the case of Hincapie *et al*. (2008) when making extracts applications using *Annona muricata* seeds obtained with ethyl acetate at a concentration of 5 000 ppm. on *S. zeamais*, better insecticidal activity is obtained when treating corn grains with a mortality of 97% at 72 h after the application of the treatment. According to the criterion indicated by Lagunes (1994), it qualifies as promising plant dust that exceeds 50% mortality.

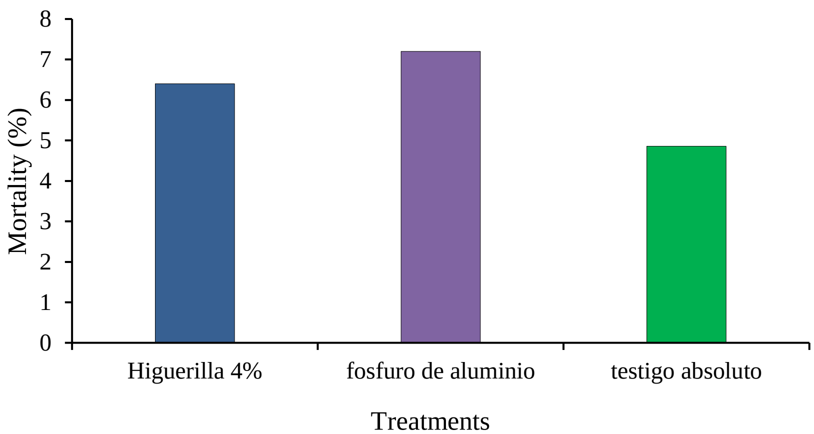

Figure 3. Mortality of *Sitophilus zeamais* Motschulsky after application of 4% castor powder.

Germination percentage before the application of the treatments

The germination of the grains before the application of the treatments was 100% in all the experimental units.

Germination percentage after the application of the treatments

The application of castor at 4% and aluminum phosphide did not generate differences with respect to the absolute control (germination of the seed of 86.3, 84 and 79.7%) (Figure 4). This means that none of the treatments incorporated into the storage of corn, drastically influenced the germination of stored grains. Noting that the castor did not affect the germination. Moreno (1996) mentions that the quality of the seed to germinate and produce a normal seedling is the main attribute to consider. On the other hand, the potential of germination can be affected by different biotic, abiotic and management factors, hence the desire to find products for the control of pests and diseases of stored grains can be the factor of low germination. A commercial seed with good germination percentages ranges between 90 and 100%. In a study conducted by Cerna *et al.* (2010) using castor oil, found percentages of germination ranging from 78 to 90%.

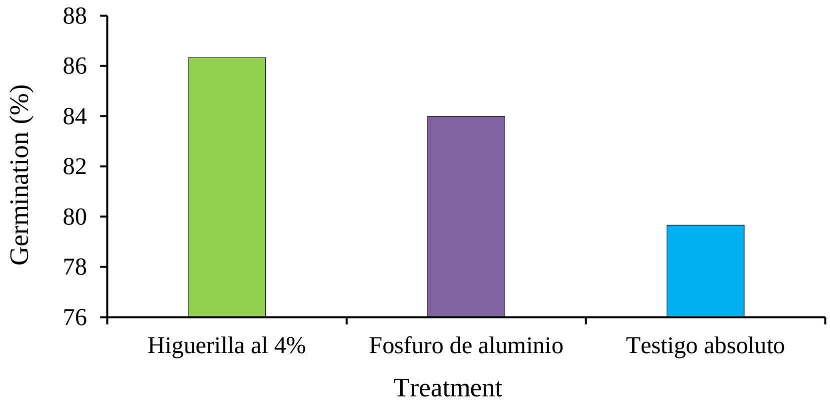

Figure 4. Percentage of germination of corn grains after the application of 4% castor spray to the management of *Sitophilus zeamais* Motschulsy.

Damaged grains

The counting of damaged grains was carried out three months after the experiment was started in each of the experimental units (Figure 5), resulting in the application of aluminum phosphide with 20% of damaged grains, followed by castor at 4 % with a value 24% of grains affected by the pest of the weevil; no significant difference was found between these, while the absolute control presented a percentage of damaged grains of 58.7, showing significant differences with respect to the treatments. In evaluations with natural insecticides Cuevas and Romero (2008) obtained promising results when using lime occupying the first place following the performance of *Valeriana oficinalis* and *Argemone ochroleuca* L.

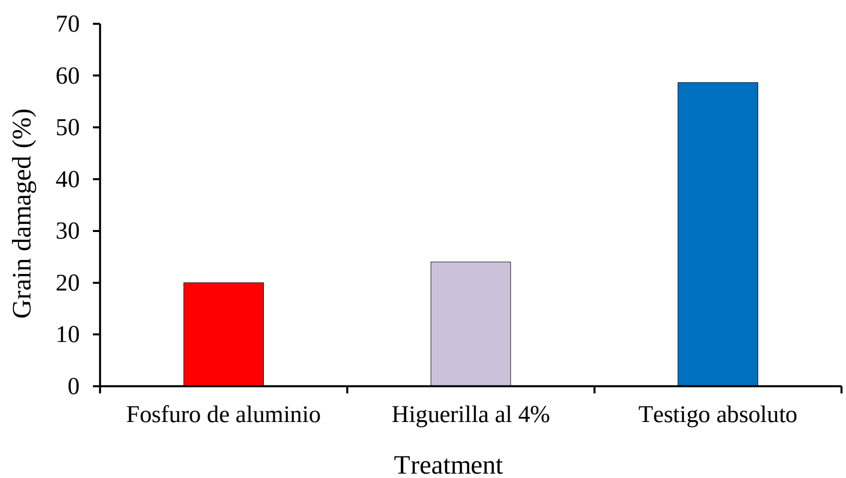

Figure 5. Percentage of grain damaged by castor 4% in the management of *Sitophilus zeamais* Motschulsky.

Grain weight loss

After performing the analysis of variance and the comparison of Tukey means at 5% in Figure 6, it is shown that there are statistical differences between the chemical control with respect to the 4% castor spray and the absolute control. Having less weight loss in aluminum phosphide (0.33 kg) followed by 4% castor with 0.97 kg. Losing greater weight in the control (2 kg). Aslam *et al*. (2002) using *Syzygium aromaticun* and *Piper nigrum* against *Callosobruchus chinensis* obtained a low weight loss, which could be due to the early mortality of insects with a consequent lower oviposition by grain.

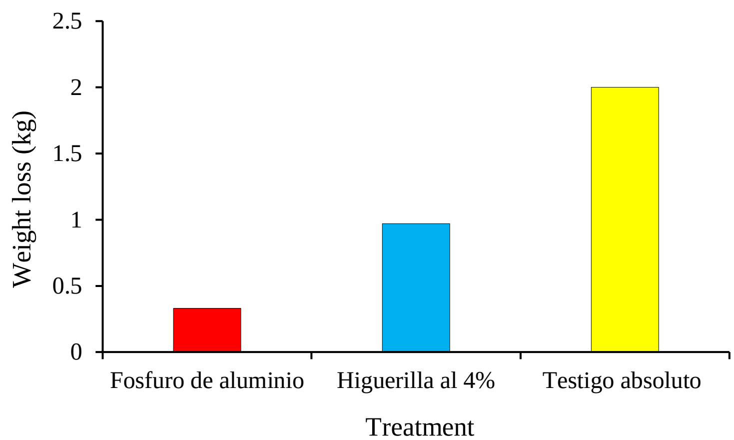

Figure 6. Effect of castor spray for the management of *Sitophilus zeamais* Motschulsky in corn weight reduction.

Silva *et al*. (2003) when performing tests with *Chenopodium ambrosoides* powders at 1% (w/w), they presented a weight loss of 0.2% and 6.3%, respectively, statistically different to the control in both cases. With seed powders and stems of a species of the family Fabaceae González *et al*. (2009) mention that minor weight losses are obtained with values of 9.63 and 9.89%, respectively. Vendramim and Castiglioni, (2000) mention that the loss of weight may be a consequence of the insecticidal effect in the adult or of the regulating effect of growth; It may also be due to the antifeedant effect of the metabolites present in the plant powders studied.

Conclusions

The castor spray application has mortality effects when applied to 4% and repellency at 3 and 5% in laboratory conditions. While in storage conditions there were no differences which could be due to the loss of effectiveness of the active metabolites of *R. communis* L.

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