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Effect of Diatomaceous earth (Silicosec®) on Mortality and Progeny Development of Lesser Grain Borer *Rhyzopertha dominica* (Fab.) (Coleoptera: Bostrichidae) on Stored Cowpea (*Vigna unguiculata* (Linnaeus))

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Abstract

Laboratory tests were carried out to evaluate the effect of Diatomaceous earth (Silicosec®) against *Rhyzopertha dominica* on cowpea. The test were conducted under ambient laboratory conditions (28-35^{O}c and 65-70% r.h.). Thirty adult insects of unsexed were bioassayed on 50g cowpea grain sample treated with the DE (Silicosec®) at five dose rates: 250, 500, 750, 1000 and 1500mg/kg. Mortality of exposed adults were assessed after 7, 14 and 21days exposure to treated grains. Number of progeny were assessed after 56 and 112days of removal of parent insects. Significance difference ($p<0.05$) in adults mortality were noted between dose rates and exposure periods on treated grain. Increase in dose rate and exposure period resulted in higher adult mortality and progeny suppression. After 14days exposure to the highest dose rate, 100% adult mortality was achieved. Progeny production was considerably suppressed even with lowest dose rate of 250mg/kg 3.0±1.0 and 10.8±1.4 was recorded when compared with untreated control with 86.0±3.8 and 145.0±6.9 after 56 and 112days of storage respectively. Moreover, the percentage of insect damage kernel, weight loss and germination loss decreased with increase in dose rate. Thus at 1500mg/kg 0.4±0.4 and 0.0 was recorded against IDK and weight loss as compared to 100% and 82.4% in the untreated control. Similarly, the result shows that there were significant differences between the treated grain and untreated grain on the germinated seeds, highest germinated seed was recorded on seed treated with 1500mg/kg 99.4% and the least was recorded on untreated seed with 6.0%, respectively.

Key words .Silicosec® . *R. dominica* . Cowpea . Adult mortality . Progeny

Introduction

Cowpea; *Vigna unguiculata* its grain and vegetative parts, make major nutritional contributions to diets (Egbadzor *et al.*, 2015). The mature grain contains 23-25% protein, 50-67% starch, vitamins B such as folic acid which is important in preventing birth defects. Cowpea plays a critical role in the diets of many households, in Africa, Latin America and Asia, providing nutrients that are deficient in cereals (James, 2013).

Despite this importance of cowpea in food security, trade and poverty reduction, increased cowpea production, storage and marketing face many constraints that need attention from research and development (Egbadzor *et al.*, 2014). Although cowpea represents an economical source of protein, calories and B-vitamins, to the extent that it was regarded as "the poor man's meat" (Egobule *et al.*, 2017). On-farm storage of dry cowpea for domestic use or local marketing is a major problem in the tropics (Pasquet, 2012).

Insect pests are well-known problem during storage of cowpea, and the lesser grain borer, *Rhyzopertha dominica* (Fab) is one of the major insect pests of stored grains, especially pulses in Nigeria and other parts of the world (Diganggana, 2013). It is one of the most destructive insect pests of stored grains (Idin *et al.,* 2016). It infests other stored food items such as *Triticum*, beaten rice (Poha), millet, maize, dry fruits etc. (Edde, 2012). The adults are sturdy fliers, which fly from warehouse to warehouse, causing severe infestation and convert the stored grains to mere frass (Manal *et al.*, 2015). The larvae and adults both infest and produce frass and cause weight losses by feeding on grains (FAOSTAT, 2011).

R. dominica infestation result in loss of quantity and quality of stored grain, and the cost involved to prevent or control this infestation was very high (Ozkaya *et al.,* 2009). Larvae consume both the germ and endosperm during their development in grain and thus produce more frass than other stored grain insect pests and these feeding activity leads to reduction in germination rates and the vigour of the grains (Arthur *et al.,* 2012). Khamis *et al.* (2010) reported that *R. dominica* infestation causes weight loses of up to 40%, compared to other stored grain insect pests. *R. dominica* can be controlled effectively with non-synthetic insecticide such as Diatomaceous earth (DE). Diatomaceous earth has been used as a traditional method of insect control (Otitodun *et al.,* 2015). Its dehydrates the insect body by cuticle lipid absorption and abrasion (Kabir and Lawan, 2016). It's also reported that DEs have low mammalian toxicity (Kabir *et al.,* 2012), hence these formulations are used as effective insect pest control (Misbah *et al.*, 2016). DEs are also applied as a surface or "top-dress" treatments immediately after grain were stored. It also provides a protective barrier from migrating insects that may enter grain bins from the top (Ngatia *et al.,* 2015). The present work was to examine the insecticidal effect of Diatomaceous earth (Silicosec®) against *R. dominica* on stored cowpea; evaluate the effect of application dose rate and exposure periods on the adult mortality and progeny production.

Materials and Methods

Experimental Site and experimental material

The experiment was carried out in the Entomology and Nematology Laboratory, Department of crop protection, Faculty of Agriculture, University of Maiduguri, Borno State, Nigeria. The diatomaceous earth (DE) Silicosec® was obtained from Diatoms Research and Consult Incorporation Canada.

*DE formulation***:**

Silicosec® has been tested in various countries of the world as grain protectant in laboratory and field trials. Its contains approximately 92% SiO_2, 3% Al_2O_3, 1% Fe_2O_3 and 1% Na_2O. The median particle size is between 8-12µm. the DEs (Silicosec®) was stored in the laboratory at ambient condition until commencement of the experiment.

Rearing of *R. dominica*: The *R. dominica* adults used were taken from a culture that was kept in the laboratory on 500g Borno-brown cowpea variety obtained in BOSADP, Maiduguri, Borno State, Nigeria and kept at 30^{0}C and 55% r.h. in a plastic container with their tops opened and covered with a muslin cloth for aeration and left undisturbed, the adults were sieved out after 15 days of feeding and oviposition. The set-up was left on the laboratory shelf undisturbed for the emergence of F_1 progeny of similar age. Freshly emerged one to two days old adults of *R. dominica* were then used for the experiment.

Experimental set up and Bio-assay

The Diatomaceous earth (Silicosec®) were tested at rate of 250, 500, 750, 1000 and 1500mg/kg. for each treatment 250g lots of grain were place in 1litre capacity jars and appropriate amount of DEs (Silicosec®) was added. The jars were then shaken manually for five minutes to achieve equal distribution of the dust in the entire mass. The lots were then divided into five samples of 50gram for each treatment combinations and untreated control. The experiment laid out in Completely Randomized Design with five treatment replicated five times. To determine the efficacy of Silicosec® as post-treatment effect on *R. dominica*, a bio-assayed at 7, 14 and 21days intervals was conducted by carefully emptying the content of each jar on a separate tray and any insect that remained motionless was considered dead. The number of F_1 and F_2 progeny, grain weight and germination loss attributed to *R. dominica* activity was assessed.

Data Analysis

All data collected were subjected to analysis of variance and significant means were separated using Tukey Kramer HSD Test at 5% level of probability.

Results and Discussion

Table 1: Effect of DE (Silicosec®) on mortality of *R. dominica* adults after 7, 14 and 21 days of exposure

Mortality (%±SE)			
Dose (mg/kg)	7days	14days	21days
0.0	1.9±1.3c	3.3±1.0c	3.9±1.2c
250	54.7±12.6b	86.0±5.5b	93.3±2.7b

500	78.0±8.1ab	94.7±1.3ab	100.0±0.0a
750	89.3±5.3a	98.0±1.3a	100.0±0.0a
1000	90.7±3.5a	100.0±0.0a	-
1500	97.3±1.2a	100.0±0.0a	-
F	28.8	248	971
P	<0.0001	<0.0001	<0.0001

Effect of DEs (Silicosec®) on mortality of *R. dominica* adults after 7, 14 and 21 days of exposure.

The results presented in Table 1 indicate that DE (Silicosec®) cause high mortality of *R. dominica*. Significant differences in adult mortality were observed among different dose rates of DEs (Silicosec®). Increased with increase in dose rate in all cases cause high mortality of test insect. DEs (Silicosec®) at a rate of 250mg /kg gave 54.7±12.6 mortality of *R. dominica* after 7 days of exposure, while as the dose rate increases, the rate of mortality also increases, at 1500mg/ kg mortality was 97.3±1.2 also at 7 days of exposure (Table 1). However, after 14days exposure the result showed significant differences among the different doses of DEs (Silicosec®) on the test insect and as well as the cowpea. Generally, after 14 days of exposure interval to high mortality was 86.0±5.5% was observed at the lowest dose rate of 250 mg/kg. Thus at the highest dose rate of 1500 mg/kg 100% mortality was recorded. Moreover, after 21days of exposure, even at dose rate of 250mg/kg 93.3% mortality was recorded, thus even at 750mg/kg 100.0% mortality was achieved when compared with untreated control of 3.9% (Table, 1).

Table 2: Mean number (%±SE) of live progeny, percent dead progeny and progeny inhibition of *R. dominica* adults exposed to cowpea treated with diatomaceous earth (Silicosec®)

	56days			112days		
Doses (mg/kg)	Mean no. of progeny	% Dead progeny	% Progeny inhibition	Mean no. of progeny	% Dead progeny	% progeny inhibition
0.0	86.0±3.8a	11.4±1.4a	-	145.0±6.9a	12.8±1.2a	-
250	3.0±1.0b	4.8±2.2b	96.0	10.8±1.4b	7.4±2.7b	93.0
500	2.6±1.2c	1.6±1.1c	97.0	4.8±0.7c	0.2±0.2c	97.0
750	0.0±0.0d	-	-	0.2±0.2d	-	99.9

1000	0.0±0.0d	-	-	0.0±0.0e	-	-
1500	0.0±0.0d	-	-	0.0±0.0e	-	-
F	413	14.4		404	20.5	
P	<0.0001	<0.0001		<0.0001	<0.0001	

Effect of DE (Silicosec®) percent live and dead on progeny production and percent progeny inhibition of *R. dominica* adults on treated cowpea

Effect of DE (Silicosec®) on progeny production and percent progeny inhibition of *R. dominica* adults on treated cowpea

The data on progeny development and progeny inhibition of *R. dominica* showed significant differences among the different level of DEs (Silicosec®) after 56 and 112 days of storage (Table 2). The results show that there were very few F_1 progeny 3.0 and high progeny inhibition of 96.0% was recorded at dose rate of 250 mg/kg of DE after 56 days of storage. At the highest dose rate of 1500 mg/ kg no F_1 progeny were developed when compared with 86.0% recorded on untreated control. After 112 days of storage, the result reveal that at the least dose rate of 250 mg/kg only 10.8 adults developed and inhibition of 93.0% of adult progeny emergence was recorded. As the dose rate increases to 1000 or1500 mg/kg, no F_2 Adult progeny were developed (Table 2). When compared with 145.0±6.9 in the untreated control and the inhibition rate was 93.0%. However, in some instance an ordered pattern was observed (Table 2).

Table 3: Effect of DE (Silicosec®) on grain damage kernel, weight loss and percentage germination caused by *R. dominica*

Doses (mg/kg)	Damage percentage	Percentage weight loss	Germination percentage
0.0	100.0±0.0a	82.4±2.4a	6.0±1.9d
250	3.2±1.3b	5.8±1.4b	77.0±4.6c
500	1.4±0.9c	2.0±0.6bc	88.61±.9ab
750	1.0±0.4d	0.0±0.0c	95.6±1.8ab
1000	0.6±0.4d	0.0±0.0c	98.2±0.7ab
1500	0.4±0.4d	0.0±0.0c	99.4±0.4a
F	3226	782	243
P	<0.0001	<0.0001	<0.0001

Effect of DE (Silicosec®) on grain damage kernel caused by *R. dominica*

The result presented in Table, 3 show that the percentage of insect damage kernel (IDK) weight loss and germination percentage was significantly affected by DEs (Silicosec®) treatments. There were significant differences in the number of damage kernel, weight loss and germination percentage among dose rates (Table, 3). In the untreated control after 112 days of storage complete kernel damage was recorded and this was significantly higher than values in all other treatments. The result revealed that at the lowest dose rate of 250 mg/kg of DEs (Silicosec®) (3.2%) kernel damage were recorded; and as the dose rate increases the rate of kernel damage decreased, thus very few (0.4%) were damaged at 1500 mg/kg. (Table, 3). Similarly, highest weight loss was recorded on untreated control after 112days of storage with 82.4%. The result also reveals that at the least dose rate of 250mg/kg 5.8% were recorded; and as the dose rate increases even at 1000mg/kg 0.0% weight loss was recorded (Table, 3). Moreover, the result shows that there were significant differences between the treated grain and untreated grain on the germinated seeds, highest germinated seed was recorded on seed treated with 1500mg/kg 99.4% and the least was recorded on untreated seed with 6.0%, respectively.

Discussion

The trials in the study indicate that SilicoSec can be used successfully as a protectant against adults of the *R. dominica*. In the present study, the rates of 1500mg/kg produced high mortality levels, 100% was achieved in most of the cases examined. However, higher dose rates or longer exposure intervals are needed to achieve 100% mortality for adults of this species. The efficacy of SilicoSec is determined by the type of the product the dust is applied to. as in the case of residual insecticides used as grain protectants. Formulations of this type would have the advantages of reducing levels of toxic residues and of having greater activity against insect populations with low levels of resistance to the chemical component of the formulation. Athanassiou *et al*. (2003), found that using SilicoSec in dose-response tests against *S. oryzae* adults in peeled rice, paddy rice, barley and maize, found that mortality notably varied in different types of grain.

Several previous studies have reported the use of DE and its formulations for the protection of stored products from insect infestations. Moreover, this insecticide has a long persistence after treatment (Kabir and Lawan, 2016).

Fields and Korunic (2000) have confirmed the effectiveness of several DE-based formulations on adults of *Tribolium castaneum*. These authors reported that the dose of 600 ppm of Protect-it® achieved a mortality of 78%. In addition, Korunic and Ormesher (1996) reported that the use of DE formulation at the dose 2000 ppm accomplished a mortality rate of 98% on *T. castaneum*. Additionally, Athanassiou *et al.* (2003) have confirmed the effectiveness of this product on several insect pest species including: *Liposcelisbos trychophila*, *L. decolor, L entomophila*, and *L. paeta*. Moreover, Haubruge *et al.* (2000) showed the effectiveness of the Protect-it® powder formulation against *T. castaneum* adults. Chaieb and Mediouni (2012) reported the efficacy of the application of diatomite on *T. castaneum* adults. Khemira (2012) demonstrated the efficacy of the DE-based formulation on all larvae instars and adults of *E. ceratoniae*. Strong ovicidal toxicity was observed with the use of DE-based formulations Protect-it® on eggs of *E. ceratoniae,* providing data to support the use of this product as an alternative to synthetic fumigants for treating stored commodities. Indeed, Korunic (2013) mentioned that a principal benefit of DE is their removal by normal processing methods. Therefore, further investigations, including the impact of DE-based formulations at the dose levels needed for control of pests are necessary. Increased exposure time is highly important for DE efficacy (Subramanyam & Roesli, 2000).

Conclusion

DEs is a potential alternative to be used in the development of strategies for management of resistance in insect pests of stored products, since a uniform response was observed among populations of *R. dominica*. In the present study, the rates of 1500mg/kg produced high mortality levels, 100% was achieved in most of the cases examined. However, in Nigeria still there are little literature available on the efficacy of diatomaceous earth (Silicosec®) against *R. dominica* on cowpea. Moreover, lot of work is needed to be done on the use of diatomaceous earth as an alternative of the fumigants and other residual insecticides and they can play a very vital role in the effective stored grain management programs. In the present studies the results provide very strong evidence that the diatomaceous earth can be used with success in stored products. Even though some conclusions can be drawn, but they may not be generalized, as in the present study a very specific DE formulation (Silicosec®) was used. Our results could lead to open up newer pass of using DEs for the control of stored grain insects.

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