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INSECTICIDAL EVALUATION OF SOME BOTANICAL POWDERS AS STORED MAIZE GRAIN PROTECTANTS AGAINST *SITOPHILUS ZEAMAIS* (MOTSCHULSKY) (COLEOPTERA: CURCULIONIDEA); A CONCERN FOR POSTHARVEST LOSS

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ABSTRACT

The loss of market values and problem of pests in the stored grains has contributed to the problem of food security in Africa. Post-harvest losses due to Sitophilus zeamais remain an important constraint to grain storage in Africa. Also, use of chemical insecticides have increased food poisoning thus there is resurgence need of using botanical pesticides to control insect pests in the field as well as in storage. This study investigated the insecticidal effects of some botanicals (Eucalyptus camaldulensis Dehnh., Mangifera indica L., Carica papaya L. and Nicotiana tabacum L. leaves) on Sitophilus zeamais (Motschulsky) (Coleoptera: Curculionidea) F1 progeny and mortality as well as weight loss of Maize. The botanicals at varying concentrations (0.1 g, 0.5 g and 1.0 g) were applied on 500 g of maize for 3 months. All the leaf powders used exhibited insecticidal properties against Sitophilus zeamais in stored maize grains. However, they are more effective at the 1.0 g/500 g of maize grain, with Nicotiana tabacum being the most effective. At 1.0 g/500 g of maize grain, the botanicals had effect on the proximate composition of the maize grains with Mangifera indica causing a reduction in the carbohydrate content of the maize grains. The results of the experiment revealed that leaf powders of Nicotiana tabacum, Mangifera indica, Carica papaya and Eucalyptus camaldulensis have great potential to be used as pesticides against Sitophilus zeamais in stored maize grain. Therefore, these botanical powders can be used as an alternative to synthetic chemical for the control of S. zeamais.

KEY WORDS: *food security, post-harvest, nutrition, botanicals, shelf life*

INTRODUCTION

The problem of food security is a major challenge facing humanity in the tropics and sub- tropics where the climate provides a favourable environment for a wide range of insects and massive efforts are required to suppress population densities of the different pests in order to achieve an adequate supply of food. According to Nyamandi & Maphos, (2013) the problem of insect pests in developing countries is exacerbated by the rapid increase in human population. In addition, insect infestation contributes largely to deterioration of quality of grains stored in warm and humid environment. These losses pose a major threat to the economy and food security (Ekeh *et al*., 2013).

Maize (*Zea mays* L.) is a major food security crop in Africa and it is usually stored to provide food reserves and seed materials for planting. It is one of the most popular crop plants all over the world, grown in over 140 million hectares all over the world. Maize is the first most important source of human dietary protein and the second most important source of calories after cassava and before beans. In the world, maize is ranked third after wheat and rice in terms of leading crop production (Muzemu *et al.*, 2013) and the third most important cereal in Nigeria (Adebayo & Ibikunle, 2014), as a result it is a staple food of most cultures in Nigeria and is widely grown by smallholder farmers who contribute 50% to national production. Apart from it being processed into forms for human consumption (grilled, boiled, roasted or made into various products), it also used as animal feed unprocessed and processed (Edelduok *et al.,* 2015) and a source of industrial raw material (Gemechu *et al*., 2010).

Despite high maize yields, losses in storage are high due to maize weevil, *Sitophilus zeamais* (Motschulsky) (Coleoptera: Curculionidea), especially among smallholder farmers. It causes huge losses in storage if grain is not protected and it adversely affects food security at smallholder farmer level. Weevil damage reduces the availability of maize and may reduce future maize production for farmers who use stored grains as seeds (Muzemu *et al.*, 2013, Edelduok *et al.,* 2015). The maize weevil, *Sitophilus zeamais*, is a serious cosmopolitan field-to-store pest of maize in tropical and subtropical regions such as Nigeria (Musundire *et al.*, 2015, Edelduok *et al.,* 2015). Its larvae are internal feeders on the maize grains and this affects seed viability which negatively affects seed germination where non-hybrid is used for new planting (Musundire *et al.*, 2015).

To overcome the problems of insect pests' damage in storage, different control measures have been developed, used worldwide and synthetic chemical insecticides have been used dominantly for many years (Tapondjou *et al.,* 2002). Synthetic chemical insecticides cause many problems including high persistence, poor knowledge of application, increasing costs of application, pest resurgence, genetic resistance by the insect and lethal effects on non-target organisms in addition to direct toxicity to users (Bekele *et al*., 1995, 1997; Bekele, 2002; Hubert *et al*., 2008; Oni & Ileke, 2008; Udo & Epidi, 2009; Feng-lian *et al.,* 2011; Ianovici *et al*, 2012; Misca *et al,* 2014). Thus, the search for benign storage insect pest management tools such as the use of botanical insecticides by entomologist all over the world has been continued (Shaaya *et al*., 1997; Tunc *et al*., 2000; Tapondjou *et al*., 2002; Emana *et al*., 2003; Araya & Emana, 2009). It is also believed that the botanical insecticides could replace expensive chemicals that are currently in use in many developing countries. Other factors such as availability, affordability, safety, and cost effectiveness have been cited as justifications for the use of botanical pesticides (Jide-Ojo *et al*., 2013). Hence, the current study was designed to test the efficacy of *Mangifera indica*, *Eucalyptus camaldulensis*, *Nicotiana tabacum* and *Carica papaya* in the control of *Sitophilus zeamais* in stored maize as well as their effect on the nutritional value of the stored grains.

MATERIALS AND METHODS

Source of plant material: The matured fresh leaves of *Eucalyptus camaldulensis* (Dehnh.), *Mangifera indica* (L.), *Carica papaya* (L.) and *Nicotiana tabacum* (L.) were obtained mostly from the University of Lagos environs and taken to University of Lagos Herbarium (LUH) for authentication. Then the leaves were air-dried for 2-3 wks in a room to minimize the degradation of volatile compounds and the dried leaves were ground into powder using electric blender then sieved to obtain fine powders. The plant powders were placed separately in airtight containers and stored in a cool dry place until when needed. About 7 kg of dried maize grains (*Zea mays* L.) was purchased from Bariga market and used for the experiment. The grains were kept in airtight containers and kept in the freezer for five days; to eliminate any weevil or eggs that might have been laid in the maize grains. Afterwards, the maize grains were taken out of the freezer and placed on a flat tray to acclimatize to the ambient room temperature.

Proximate Analysis: The proximate analysis of the maize grains was carried out before treatment with the powdered botanicals and three months after treatment following AOAC (2005). This was to determine the percentage nutrient (moisture, ash, fat, crude fibre, protein and carbohydrate) benefit or loses due to *Sitophilus zeamais* infestation and the effects of each botanicals on the nutrient composition of the maize grains.

Source of Insect: A culture of the *Sitophilus zeamais* was collected from the insectary of the Entomology Lab of the Nigerian Stored Products Research Institute, (NSPRI), Lagos, reared on the maize grain and kept under a fluctuating temperature of 30±2 °C and relative humidity of 70±5% and a photoperiod of 12h:12h.

Treatment of Samples: 0.1 g, 0.5 g and 1 g each of Tobacco, Mango, Pawpaw and Eucalyptus powder was measured and thoroughly mixed with 500 g of maize grain respectively as stock samples. From the respective stock samples, 50 g each of the maize grain was measured and put into a vial with three replicates each while grains without the leaf powders serve as control. Ten insects, 0 to 2 day old unsexed adult maize weevil were introduced into each of the replicate; the treatments were held in trays with its supports immersed in industrial oil to prevent infestation by other insects. Mortality of *Sitophilus zeamais* on the botanical powders was recorded at an interval of 3 dys for 14 dys. Insect is confirmed dead if the insects did not respond when probed with a camel brush. After the 14^{th} day the beetles (both dead and living) was counted, recorded and removed from the vials. The vials were examined for emergence of F_1 progeny of *Sitophilus zeamais* in both control and treated grains from 20-25 dys after the introduction of the adults. The number of F_1 progeny was counted and recorded daily. The weight of the maize grain was measured and recorded after introduction of the adult maize weevil and at the end of each month to determine the weight loss.

Data Analysis: Means were calculated for each treatment using Microsoft Excel. The data collected were subjected to one way analysis of variance (ANOVA) statistical analysis.

RESULTS AND DISCUSSIONS

The results of an experiment conducted to determine the effectiveness of four different botanical powders against *Sitophilus zeamais* with respect to adult mortality, F_1 progeny emergence, maize grain weight loss and nutritional value shows different trend.

The mean number of progeny emergence in each month for each of the botanical powders varied (Table 1). The number of progeny was significantly higher in the control compared to the different concentration for each of the leaf powder used. *Nicotiana tabacum* had the least number of progeny emergence compared to the other botanicals. The number of emerged adults from the grains treated with *Nicotiana tabacum* were significantly different from the grains treated with the other botanicals ($p<0.05$). The botanicals showed greater significant difference ($p<0.05$) compared to the control at 1.0 g/500 g of maize grain.

The mean mortality of adult *S. zeamais* was higher in the maize grains treated with the highest concentration (1.0 g) of all the leaf powders used while lower in the control and the lowest concentration (0.1 g). This indicates that the mortality of *S. zeamais* varied in a dose dependent manner. *Nicotiana tabacum* had effects on the adult mortality at both 1.0 g and 0.5 g per 500 g of maize grain in the first and second month. *Carica papaya*, *Mangifera indica* and *Eucalyptus camaldulensis* caused adult mortality at 1.0 g/500 g of maize grain. *Mangifera indica* also had effect at 0.5 g (Table 2).

The grain weight loss for each botanical was significantly different and higher at 1.0 g/500 g of maize grain ($p<0.05$) for each month. *Nicotiana tabacum* had the lowest weight loss across each concentration for the three months period, *Eucalyptus camaldulensis* showed low weight loss at 1.0 g/500 g of maize grain but this increased by the second month. *Carica papaya* and *Mangifera indica* also show lower weight loss in the first month with that of *Carica papaya* fluctuating in the second month and the weight in grains containing *Mangifera indica* was lesser down the month (Table 3).

TABLE 1. Mean No. of emerged F1 progeny ± SD of Adult *S. zeamais* treated with plant powders

Month	Conc.	Mango	Pawpaw	Tobacco	Eucalyptus
1	0.1 g	64.67 ± 4.04	55.33 ± 4.05	40.00 ± 1.00	56.33 ± 2.52
	0.5 g	53.00 ± 12.49	43.67 ± 4.05	18.00 ± 3.00	33.00 ± 3.00
	1.0 g	18.00 ± 2.65	9.33 ± 2.52	3.67 ± 1.53	22.00 ± 2.00
	Control	82.67 ± 5.51	82.67 ± 5.51	82.67 ± 5.51	82.67 ± 5.51
2	0.1 g	70.33 ± 9.02	56.00 ± 4.00	32.33 ± 6.51	60.67 ± 6.03
	0.5 g	50.33 ± 3.06	44.00 ± 13.08	18.67 ± 5.86	43.00 ± 12.77
	1.0 g	14.33 ± 4.51	12.00 ± 3.00	4.33± 2.52	17.00 ± 5.00
	Control	83.00 ± 8.89	83.00 ± 8.89	83.00 ± 8.89	83.00 ± 8.89
3	0.1 g	68.33 ± 6.03	61.33 ± 2.52	35.33± 6.03	65.67 ± 8.51
	0.5 g	57.00 ± 3.61	46.00 ± 7.55	24.33 ± 8.51	43.33 ± 6.66
	1.0 g	14.00 ± 5.29	14.00 ± 4.00	9.00 ± 3.00	17.00 ± 3.61
	Control	82.33 ± 8.51	82.33 ± 8.51	82.33 ± 8.51	82.33 ± 8.51

TABLE 2. Mortality (Mean ±SD) of Adult *S. zeamais* treated with plant powders

Month	Conc.	Mango	Pawpaw	Tobacco	Eucalyptus
1	0.1 g	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
	0.5 g	0.33 ± 0.58	0.00 ± 0.00	0.67 ± 1.55	0.00 ± 0.00
	1.0 g	1.33 ± 0.58	2.00 ± 1.00	2.67 ± 1.53	1.33 ± 058
	Control	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
2	0.1 g	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ±0.00
	0.5 g	0.00 ± 0.00	0.00 ± 0.00	1.33 ± 1.155	0.00 ±0.00
	1.0 g	0.67 ± 0.58	1.00 ± 0.82	2.67 ± 0.58	1.00 ± 0.00
	Control	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
3	0.1 g	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
	0.5 g	0.33 ± 0.58	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
	1.0 g	1.00 ± 0.00	1.33 ± 0.58	2.33 ± 0.58	0.67 ± 0.58
	Control	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00

TABLE 3. Mean weight loss ± Standard error of maize grains

Month	Conc.	Mango	Pawpaw	Tobacco	Eucalyptus
1	0.1g	0.63 ± 0.04	0.46 ± 0.05	0.30± 0.03	0.65 ± 0.03
	0.5g	0.41 ± 0.12	0.45 ± 0.06	0.22 ± 0.13	0.56 ± 0.23
	1.0g	0.14 ± 0.15	0.16 ± 0.15	0.00 ± 0.00	0.06 ± 0.10
	Control	0.83± 0.11	0.83 ± 0.11	0.83± 0.11	0.83 ± 0.11
2	0.1g	0.76±0.05	0.67±0.09	0.24±0.03	0.67±0.13
	0.5g	0.32±0.02	0.27±0.06	0.16±0.04	0.38±0.09
	1.0g	0.13±0.04	0.093±0.08	0.00±0.00	0.18±0.05
	Control	0.82±0.07	0.82±0.07	0.82±0.07	0.82±0.07
3	0.1g	0.74±0.04	0.67±0.06	0.29±0.10	0.68±0.15
	0.5g	0.48±0.03	0.32±0.08	0.19±0.01	0.30±0.05
	1.0g	0.13±0.04	0.14±0.04	0.04±0.07	0.15±0.05
	Control	0.83±0.12	0.83±0.12	0.83±0.12	0.83±0.12

Table 4 shows the results of the proximate analysis of the maize grains before and after the application of the botanical leaf powders. A significant increase in the protein content of the grains treated with *Carica papaya* and *Nicotiana tabacum* was observed. There was a decrease in the fat content of the grains especially those treated with *Mangifera indica* and *Carica papaya*. There was a decrease in the carbohydrate content of the grains treated with *Mangifera indica* and this is a negative result as this may affect the quality of the flour.

TABLE 4: Proximate values of the maize grains before and after infestation and treatment

Content	Control	Before infestation and treatment	After infestation and treatment			
			Mango	Pawpaw	Tobacco	Eucalyptus
Moisture	7.09	7.16	7.16	7.01	7.09	7.09
Ash	2.31	2.40	2.29	2.28	2.31	2.31
Fat	2.31	2.40	2.29	2.28	2.31	2.31
Protein	8.90	8.75	8.89	9.41	9.24	8.99
Carbohydrate	76.92	77.46	75.98	78.99	77.82	77.90
Crude fibre	2.43	2.40	2.40	2.43	2.73	2.63

The utilization of different plant products as stored crop grain protectants has been reported by Araya & Emana (2009). The effects of different botanical powders against *Sitophilus zeamais* infesting maize grains in storage were evaluated and the result revealed that there is a significant effect of the botanicals on *Sitophilus zeamais* mortality, F1 progeny emergency, percentage weight loss and proximate value of the grains.

Among the botanicals used in the study, leaf powder of *Nicotiana tabacum* at the dosage rates of 0.5 g and 1.0 g per 50 g of maize gave promising levels of control of *Sitophilus zeamais* in terms increase in mortality of weevils, lower weight loss percentage and less number of emergent of weevil. This then shows that the resource poor farmers can use botanicals in the control of maize weevils. The effects of different plant materials on maize weevils may depend on several factors such as chemical composition and maize weevil species susceptibility (Muzemu *et al.*, 2013). For the other three botanical leaf powder, *Carica papaya*, *Mangifera indica* and *Eucalyptus camaldulensis* had higher number of weevil mortality and lower number of emergence of *Sitophilus zeamais* at the dosage rate of 0.5 g and 1.0 g per 50 g of maize than the control. *Carica papaya*, *Mangifera indica* and *Eucalyptus camaldulensis* leaf powders might have exhibited low levels of insecticidal activities resulting in low mortality and high progeny emergence of *Sitophilus zeamais* compared to *Nicotiana tabacum* but they were more effective compared to the control at all dosage rate, thus an increase in the dosage rate may be effective. This is consistent with findings by Muzemu *et al.*, (2013), which showed that grinding the leaves of botanicals allows them to release their insecticidal effect on weevils more effectively.

Other reports with similar trends to this study have shown that the insecticidal activities of various plants parts and plant products on *S. zeamais* vary in degrees of success (Cobbinah & Appiah-Kwarteng, 1989; Obengofori *et al.,* 1997; Arannilewa *et al.,* 2006; Edelduok *et al.,* 2012). Adedire & Ajayi (1996) recorded 100% mortality of *S. zeamais* treated with C. *frutescens* 28 days after treatment on maize grains. The findings of this work is also similar to that of Ivbijaro (1983) who studied another botanical, the neem seed, *Azadirachta indica* and found out that the neem seed severely reduced egg-laying in female *S. oryzae*, while increasing the mortality of same. Ivbijaro (1984) also found out that groundnut oil reduced the oviposition and natality of *S. oryzae*, while increasing the mortality of same.

The result of the proximate analysis shows that the botanicals had effects on the proximate values of the grains. The effect of *Mangifera indica* on the carbohydrate content of the maize grain treated with it may need more research. The increase in the protein content of the content of the grains treated with *Carica papaya* and *Nicotiana tabacum* show that they can be used to fortify the nutrient value of stored maize grains.

CONCLUSIONS

The current findings demonstrate that the insecticidal activity of different botanicals varies and the powder of *Nicotiana tabacum* tested against *Sitophilus zeamais* proved to be more effective compared to other botanical powders. Therefore, these plant powders can be used as an alternative to synthetic chemical for the control of *S. zeamais*. It is believed that, some of these botanical powders could find a place in IPM strategies, especially where the emphasis is on environmental and food safety in terms of replacing the more dangerous toxic insecticides. However, further research investigation is needed on this regard to confirm the effects of this plant extracts regarding its practical effectiveness under natural conditions to protect the stored products without any side effects. If proved so, there is a scientific rationale for the incorporation of these botanical powders into the grain protection practice of resource-poor farmer to assure food self-sufficiency. The results obtained need to be validated in large-scale field studies before they can be widely adopted by farmers. Farmers often need information on botanicals to support their decision-making with respect to reliability of control of the particular plant material to reduced insect infestation.

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