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ENTOMOTOXIC EFFECT OF SOME BOTANICALS ON *CALLOSOBRUCHUS MACULATUS* (FABRICIUS) (COLEOPTERA: CHRYSOMELIDAE): AN ANALYSIS OF STORAGE WEIGHT AND ECONOMICS LOSSES OF NINE SELECTED COWPEA VARIETIES IN NIGERIA.

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Abstract

Storage weight and economic losses were analyzed following the evaluation of powders from ten plant materials for their entomocidal effects on cowpea beetle. The evaluation of the insecticidal effects of the powders was based on percentage weight loss and naira economic loss of seeds occasioned by C. maculatus. The concomitants economic losses were estimated as the Naira value of the lost seed weight. It was observed that percentage weight loss was significantly lower (P<0.05) in seeds treated with Zanthoxylum zanthoxyloides with the exception of one variety which could be as a result of varietal differences. However, in cowpea varietyIT97K-499-35-8 treated with Zanthoxylum zanthoxyloides (0.00) Zero percent weight loss was observed. The economic losses correlated with the weight losses to a large extent. However, some discrepancies were recorded due to price differentials across varieties. Zanthoxylum zanthoxyloides showed great promise in the 8 of the 9 cowpea varieties and stands out among all botanicals except in cowpea variety IT89K-288. It is almost completely eliminated economic losses in cowpea variety IT97K-499-35-8. The efficacies of the various botanicals varied across varieties, hence, the need for careful consideration of options in any plan to apply botanicals. Thus, the deployment of economic analysis is important in making or reinforcing the final choice of what botanical protectant to apply, and what variety to invest in. For instance, economic considerations may cause an investor who is interested in the storage, and future sales of cowpea to adopt Zanthoxylum zanthoxyloides for use on variety IT97K-499-35-8.

Key words: Varietal differences, insecticidal effect, economic analysis, entomocidal effects.

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Introduction

Field and storage pests destroy approximately one-third of the world's food production, valued annually at more than $100 billion with the highest losses (43%) occurring in the developing world

(Farid Talukder, 2009). In the developed counties, the loss is estimated at 5-10%. A more recent report by Gottlieb *et al*., (2018) put the figure of the quality and quantity loss of stored grains at between 30-50% for developing countries. Food grain losses due to insect infestation during storage are a serious problem, especially in the developing countries (Dubey *et al*., 2008). The quantitative and qualitative damage to stored grains and grain products from the insect pests may amount to 20–30% in the tropical zone and 5–10% in the temperate zone (Talukder 2004, Rajendran and Sriranjini, 2008). Grain losses due to storage pest continue to constitute a significant loss of agricultural output leading to large economic losses (Bell, 2014). Storage loses lead to a reduction in available output for sale and consumption, resulting in income and food security problems. In fact, where, in a bid to avoid losses due to pest infestations, the grains are quickly sold, loss of profit and loss of future food supplies are experienced **(**Kadjo *et al,* 2013. Stephens and Barret, 2011). Insect pest infestation may also lead to health problems (*Government of western Australia Department of primary industries and regional development*), which in turn may affect productivity (Onuche *et al.,* 2014). Pests also increase costs in agricultural enterprises and marketing (Onuche, 2020). The efficient control and removal of stored grain pests from food commodities has for long been the goal of entomologists throughout the world.

The most prominent methodology applied to meet this objective is the use of synthetic insecticides. The use of synthetic insecticides is however associated with some problems. For instance, many synthetic insecticides have high mammalian toxicity, high level of persistence in the environment, health hazards and residual effects. Other problems associated with synthetic insecticides include complications arising from poor knowledge of their application, increased costs of application, and their eventual lethal effects on non-target organisms (Ajayi and Lale, 2000; Ashamo, 2007; Akinkurolere *et al.,* 2009; Oni and Ileke, 2008; Ileke and Oni, 2011).

Worldwide concerns on the arbitrary use of chemical fumigants by farmers have further led to the development of alternative strategies, among which are the development of resistant varietiesand the re-examination of using plant derivatives against agriculturally important insect pests. Plant-derived materials are more readily biodegradable, cheap, readily available, edible and ecologically safer in controlling insect pest infestations of stored cereal and grains, especially in the tropics (Adedire *et al*., 2011; Ileke and Oni, 2011; Adebayo and Ibikunle, 2014). In the last two decades, considerable efforts have been directed at screening plants in order to develop new botanical insecticides. When mixed with stored-grains, leaf, bark, seed powder, or oil extracts of plants reduce oviposition rate and suppress adult emergence of bruchids, and also reduced seed damage rate (Keita *et al*., 2001; Tapondjou *et al*., 2002). Bruchid beetles eat voraciously at the larvae, pupa and adult stage and are known to attack cowpea varieties both on the field and in storage.

The overall objective of the study was to evaluate the effectiveness of ten (10) botanicals against beetles in stored cowpea varieties, in order to add to the efforts of crop researchers in minimizing the use of synthetic chemicals and their negative consequences. Weight loss parameters were uses as direct methods of verifying the efficacies of these botanicals when used in the storage of grains. Estimates of attendant economic losses were made following the estimation of weigh losses. In sum, the study focused how these insecticidal active botanicals can reduce the weight loss of cowpea and the consequent economic implications on cowpea storage in Nigeria. The findings from this work will assist in storage decisions on the best botanicals to adopt as storage insecticide for specific cowpea variety and guide storage investment planning for optimum profitability. A study of this nature on cowpea is important because of the strategic role the crop plays in the Nigerian nutritional and economic spaces since cowpea constitutes one of the cheapest sources of protein in Nigeria, and is also profitable in terms of production and trade**.**

Materials And Methods

Experimental Site

The study was carried out in the Pest Management Laboratory of the Department of Crop, Soil and Pest Management of the Federal University of Technology, Akure, Ondo State Nigeria (Latitude 7° 16' N and Longitude 15° 12' E) under ambient conditions of 28 ± 2°C temperature and 70 ± 5% relative humidity.

Collection and preparation of legume seed types

Seeds of nine cowpea varieties were collected from the International Institute of Tropical Agriculture (IITA), Ibadan, Nigeria. The cowpea varieties were first cleaned and disinfested by keeping them in a freezer at -5^{0}C for 7 days to kill all hidden infestations.

Preparation of botanical powders used as treatment:

Ten well researched insecticidal plants, *Piper guineense, Eugenia aromatica, Nicotiana tabacum, Oryza sativa bran, Zanthoxylum zanthoxyloides, Zingiber officinale, Allium sativum, Mormordica charantia, Ocimum gratissimum, Xylopia aethiopica* were purchased from various locations at in Akure. The different parts of the plants were sun dried, separately milled into fine powders. The powders were sieved through a 4.5mm^{2} mesh and stored an air-tight nylon. They were all preserved under ambient conditions prior to use. Cypermethrin dust was also obtained and used as standard.

Insect culture

The initial culture of cowpea storage beetle, *C. maculatus* used was obtained from cowpea grains already infested with bruchids and was sub-cultured on a well-known susceptible cowpea variety -Ife Brown which was sourced from the International Institute of Tropical Agriculture (IITA). The seeds of these varieties were first disinfested by deep-freezing for two weeks and acclimatized in the open laboratory conditions for 24hours before subsequent use. Bruchid cultures were established according to Beck and Blumer (2011). Cleaned cowpea seed 400g were set aside in a plastic container and infested with twenty adult bruchids (10 males and 10 females) for oviposition. The condition was maintained at temperature of 28 ± 2°C and 70 ± 5% Relative Humidity. Adult *C. maculatus* were removed 5 days after introduction a plastic container with its content was then left undisturbed for twenty-one days for adult emergence. Day old teneral adults that emerged from the container were used to infest cleaned disinfested legume seeds. Insect culture was maintained for subsequent assay through regular re-culturing.

Entomotoxic test: sterilized petridishes (9-cm diameter) containing 40g of disinfected cowpeas were treated with 2g of plant powders separately. Each of the petridishes from both groups was

then infested with 10 newly emerged adult bruchids of both sexes. Each treatment and control were replicated three times. Temperature and relative humidity ranges between 25-30°C and 70- 75% respectively. Ten days after the death of the female, observations were made on number of eggs laid, hatched eggs, unhatched eggs were counted and the weight loss after the emergence ofadult.

Calculations and data analysis

Weight loss analysis: the weight losses across varieties were estimated as the difference between initial and residual weights of the cowpea varieties. This is expressed in percentage as

$$\frac{\textbf{Initial weight} - \textbf{Residua; weigh}}{\textbf{Initial weight}} \mathbf{*100}$$

Economic loss analysis: following Togola *et al* (2013) the economic losses across varieties following destruction by the beetle was estimated on the basis of the monetary value of weight loss. This is given as:

Economic loss= Weight loss (Kg)* Price (Naira per kg).

Data generated eggs were subjected to analysis of variance using SPSS version 16.0. Percentage data were arc-sine transformed and data based on count were square root transformed. Treatment means of the evaluated parameters were separated by Tukey at 5% level of significant.

Results

Percentage seed weight loss observed on cowpea varieties treated with botanical powders and cypermethrin.

Percentage weight loss of the different varieties of cowpea after treatment was summarized in Table 1. Cowpea variety IT89K-288 had percentage weight loss ranging from 34.03 to 0.23 and 39.10 with the control. Percentage weight loss was significantly lower (P<0.05) in seeds treated with *Oryza sativa* (0.23), *Piper guineense* (0.33), *Eugenia aromatica*(1.07) and cypermethrin (1.67). These have shown their ability to protect cowpeas for a long period of time.

Cowpea variety IT97K-568-18 had percentage weight loss ranging from 34.00% in the control to 0.00% in the seeds treated with Cypermethrin. Mean percentage weight loss were significantly lower (P<0.05) in seeds treated with *Zanthoxylum zanthoxyloides*(0.67), *Eugenia aromatica*(1.00) and *Piper guineense* (1.92). They were effective protectant for cowpea seeds. Also, Cowpea variety IT89KD-391on its part had percentage weight loss ranging from 45.60 to 1.77 across all the treatment and 32.17 with the control. It was observered that seeds treated with Cypermethrin (1.77), *Zanthoxylum zanthoxyloides*(1.77) and *Eugenia aromatica*(1.00) had significantly lower percentage seed weight loss among all the treatment.

It was also observed that IT81D-994 had percentage weight loss ranging from 27.97 to 1.23 across all the botanical powders and 27.33 with the control. Percentage weight loss was significantly lower (P<0.05) on seeds treated with *Zanthoxylum zanthoxyloides*(1.23), *Eugenia aromatica*(2.00), *Piper guineense* (2.03) and Cypermethrin (2.47). Furthermore, Cowpea variety T99K-573-7 percentage weight loss ranged from 39.10 to 11.30 and 36.87 with the control. Percentage weight loss was significantly lower on seeds treated with *Zanthoxylum zanthoxyloides*(11.30) and Cypermethrin (14.47) amongst other treatment. Percentage weight loss in the case of IT97K-499-35-8 ranged from 34.67 to 0.00 with the different treatments and 31.40 with the control. Zero percent weight loss was observed in seeds treated with *Zanthoxylum zanthoxyloides*(0.00), followed by Cypermethrin (14.87).

Furthermore, cowpea variety IT89D-941-1 had percentage weight loss ranging from 38.20 to 3.83. It was discovered that seeds treated with Cypermethrin (3.83) had the least percentage weight loss, followed by *Zanthoxylum zanthoxyloides* (9.83). Finally, in cowpea variety IT86D-719-9, there were no significant differences among all the treatment used. Ife Brown had percentage weight loss ranging from 30.3 in the control to 6.77 in seeds treated with *Zanthoxylum zanthoxyloides.* There were no significant differences (P>0.05) observed among all the other treatment

Table 1: Percentage seed weight loss observed on cowpea varieties treated with botanical powders and cypermethrin.

Plant species	**IT89K-288**	**IT97K-568-18**	**IT89KD-391**	**IT81D-994**	**IT99K-573-7**	**IT97K-499-35-8**	**IT89D-941-1**	**IT86D-719-9**	**IFE BROWN**
E. aromatic	1.07bc	1.00c	2.73d	2.00c	29.90abc	28.87ab	22.23abc	23.03a	20.57abc
P. guineense	0.33c	1.93c	11.57cd	2.03c	16.30bc	24.10ab	21.33abc	21.33a	10.33bc
X. aethiopica	19.40abc	28.40 a	27.60b	25.20ab	32.07abc	30.53ab	34.53a	30.00a	24.60abc
Z. officinale	30.10 a	7.7bc	31.50ab	27.90a	37.03ab	34.67a	27.70ab	27.50a	27.50ab
M. charantia	29.67 a	5.53c	26.40bc	27.97a	27.63abc	26.23ab	24.83ab	35.33a	17.83abc
O. gratissimum	28.10 a	30.23 a	30.63b	24.63ab	32.40abc	28.37ab	38.20a	28.23a	22.90abc
O. sativa	0.23c	3.3c	3.47d	11.60bc	22.07abc	24.17ab	27.97ab	24.47a	18.80abc
Z. zanthoxyloides	6.10bc	0.67c	1.77d	1.23c	11.30c	0.00c	9.83bc	16.20a	6.77c
A. sativum	21.97ab	26.50a	45.60a	23.93ab	39.10 a	34.07ab	34.37 a	34.27a	25.53abc
N. tabacum	34.03 a	15.30b	21.33bc	21.23ab	20.80abc	23.57ab	28.60ab	24.20a	27.93ab
Cypermethrin	1.67bc	0.00c	1.77d	2.47c	14.47c	14.87bc	3.83c	17.43a	10.67abc
Control	39.10 a	34.00 a	32.17ab	27.23a	36.87ab	31.40ab	30.10 a	29.83a	30.30 a

Means in each column bearing the same letter are not significantly different at the 5% level of probability by Tukey test.

Estimates of economic losses observed on cowpea varieties treated with botanical powders and cypermethrin.

Table 2 presents the economic losses arising from the weight losses caused by the cowpea beetles. Economic losses in the case of the cowpea variety IT89K-288 with a mean price of 662.33±10.8 Naira per kg, range from 1.52 Naira for the *O. sativa* treatment, to 228.97 Naira in the case of the control. Among the botanical powders, the *N. tabacum* performed the least losing as much as 225.39 Naira per kilogram. Cypermethrin *and Z. zanthoxyloides treated* IT97K-568-18 outperformed other treatments having only 0.2 and 4.5 Naira loses respectively. Of the botanicals, *E. aromatic follows Z. zanthoxyloides* closely with a loss of just 6.75 Naira while *O. gratissimum* had the least performance with a loss of 204.05 Naira. Analysis of economic data on the loss of minimization owing to the use of botanicals on IT89KD-391 indicates the highest value loss of 307.04 naira in case where the variety was treated with *A. sativum, and the least loss of* 11.91 Naira where *Z. zanthoxyloides was used. The performance of Z. zanthoxyloides does not differ from that of Cypemethrin.*

Furthermore, economic losses in IT81D-994 range from 8.73 naira to 190.31naira owing to treatments by *Z. zanthoxyloides* and *M. charantia respectively. The botanical Z. zanthoxyloides outperformed Cypermethrin in which case a loss of* 18.81naira was recorded per kilogram. In the case of IT99K-573-7, *Z. zanthoxyloides accounted for the least loss of 81*.7naira while 282.69 Naira, the highest lost, was recorded in the case of treatment with *A. sativum. As for* IT97K-499-35-8, treatment with *Z. zanthoxyloides and Z. officinale led to the least (0.01 Naira and highest losses (*250.32 Naira) respectively.

Among the botanicals, the highest Economic losses recorded for cowpea variety IT89D-941-1 was 260.01which occurred in the case of treatment with *O. gratissimum* while the treatment with *Z. zanthoxyloides* yielded the least economic loss (66.91 Naira). Result of economic analysis on the IT86D-719-9 variety reveals a general level of high loses across all insecticides used, ranging from 109.2 to 230.98 Naira. The treatment with *Z. zanthoxyloides* recorded the least economic loss (109.2Naira) while the highest (230.98) was estimated from the case of treatment with *A. sativum*. Finally, *Z. zanthoxyloides which led to the loss of only 55.13* Naira per kilogram outperformed all insecticides in the minimization of losses in the case of *Ife brown*, while *N. tabacum* was the least effective, leading to a loss of 227.44 Naira

Table 2: Economic loss from selected cowpea varieties following the use of botanicals and Cypermethrin (₦/kg)

Powder Plant Species	IT89K-288	IT97K-568-18	IT89KD-391	IT81D-994	IT99K-573-7	IT97K-499-35-8	IT89D-941-1	IT86D-719-9	IFE BROWN
E. aromatic	7.09^{hi}	6.75^{j}	18.38^{j}	13.61^{fg}	216.18^{bc}	208.44^{c}	151.31^{g}	155.22^{g}	167.51^{ef}
P. guineense	2.19^{i}	13.03^{i}	77.9^{h}	13.81^{fg}	117.85^{e}	174.0^{e}	142.2^{h}	143.76^{g}	84.12^{g}
X. aethiopica	128.49^{f}	191.70^{c}	185.84^{e}	175.53^{b}	231.87^{b}	220.43^{b}	235.03^{b}	202.2^{c}	200.33^{cd}
Z. officinale	199.36^{c}	51.98^{f}	212.1^{c}	189.91^{a}	267.73^{a}	250.32^{a}	188.55^{e}	185.35^{d}	223.64^{abc}
M. charantia	196.51^{c}	37.23^{g}	177.76^{f}	190.31^{a}	199.76^{c}	189.38^{d}	169.0^{f}	238.12^{a}	145.2^{f}
O. gratissimum	186.12^{d}	204.05^{b}	206.24^{d}	167.65^{c}	234.25^{b}	204.83^{c}	260.01^{a}	190.27^{d}	186.5^{de}
O. sativa	1.52^{i}	22.75^{h}	23.36^{i}	78.96^{e}	159.6^{d}	174.51^{e}	190.38^{de}	164.93^{e}	153.1^{f}
Z. zanthoxyloides	40.40^{g}	4.52^{jk}	11.91^{k}	8.73^{g}	81.7^{f}	0.01^{g}	66.91^{i}	109.2^{i}	55.13^{h}
A. sativum	145.51^{e}	178.88^{d}	307.04^{a}	162.88^{c}	282.69^{a}	245.9^{a}	233.94^{b}	230.98^{b}	206.02^{bcd}
N. tabacum	225.39^{b}	103.28^{e}	143.62^{g}	144.51^{d}	150.38^{d}	170.17^{e}	194.67^{d}	163.92^{e}	227.44^{ab}
Cypermethrin	11.06^{h}	0.2^{k}	11.92^{k}	18.81^{f}	104.62^{e}	107.36^{f}	26.1^{j}	117.48^{h}	86.9^{g}
Control	228.97^{a}	229.5^{a}	216.61^{b}	185.35^{a}	226.57^{a}	226.71^{b}	204.88^{c}	201.05^{c}	246.74^{a}
Mean price/kg	662.3+10	675+10	673+6.1	680+13	723+25.4	722+15.1	680+8.3	674.0+9	814.3+44

Discussion

Literatures have shown that plant powders have insecticidal action against *C. maculatus* and other stored product insect pests (Yusuf *et al.*, 2019). The entomotoxic studies indicated that, there were significant difference in percentage weight loss between botanicals and the synthetic treatment over the control throughout the period of the experiment. However, among the various treatment of the botanicals, it was observed that percentage weight loss was significantly lower ($P<0.05$) in seeds treated with *Zanthoxylum zanthoxyloides* across the treated seeds with the exception of one variety which could be as a result of varietal differences. Other botanicals that were effective protectant were *Eugenia aromatica* and *Piper guineense*.

The superiority of *Zanthoxylum zanthoxyloides* over other botanicals in reducing weight loss of cowpea could be as a result of several classes of phytochemicals that have been detectedin *Zanthoxylum* species, such as terpenes, flavonoids, coumarins, phenolic acids, and alkaloids, the most reported among all the classes **(**Kosh-Komba, *et al.*, 2017). Although Ojo *et al.*,2013) opined that the reduction in weight loss caused by C. maculatus in treated cowpea seeds sometimesgoes beyond physical effect of the botanicals, but could also be as a result of egg/larval mortalityor reduction in hatching of the eggs. (Ojo*et al.*, 2013), the result in this study proved this assertion contrary, as numerous viable eggs were laid on the cowpeas but could not cause significant damage due to the insecticidal properties inherent in *Z. zanthoxyloides* showing effective control of *C. maculatus*.

Eugenia aromatica and Piper guineense were observed in this study as second to none in terms of its protective potential against C. maculatus, which is not different from established literatures about their bioactive compounds. Alkaloids, flavonoids, amides, tannins, triterpenoids, polyphenols, cardiac glycosides, and saponins are the secondary metabolites were found in both

E. *aromatica* and P. *guineense* (Uhegbu *et al.*, 2015). To a great extent, the level of economic losses correlated positively with the level of weight losses. Economic losses range from 0.01 Naira in *Z. zanthoxyloides treated* IT97K-499-35-8 to as much as 307 Naira in *A. sativum treated* IT89KD-391. The concomitant effects of the botanicals on economic losses indicate evidence of variety dependence as well. Furthermore, Augustine *et al.,* 2016 opined that Varietal resistance emerges as a potential option to minimize losses caused by C. maculatus during storage. In all however, *Z. zanthoxyloides* performed **well** in reducing economic losses arising from the weigh losses. It shows superiority in minimizing economic losses in 5 varieties (IT81D-994, IT99K-573-7, IT97K-499-35-8, IT86D-719-9 and *Ife brown*), pars with Cypermethrin in a variety (IT89KD-391), follows Cypermetrin closely in two others (IT97K-568-18 andIT89D-941-1) but comes a distant 5th in the case of IT89K-288. Hence *Z. zanthoxyloides* great promises in replacing the synthetic Cypermethrin in all but one case. It is also clear that *E. aromatic* and *P. guineense* hold promise in its use as replacements for synthetic insecticides as well.

While it appears plausible to generally conclude that economic losses correlate positively with weight losses, a number of deviations make the correlation imperfect, making an economic analysis a necessity for any study of this nature. For instance, while weight loss in IT89D-941-1 do not differ significantly in the case of *Z. zanthoxyloides* and Cypermethrin use, the analysis of the economic losses in the two cases indicate a significant difference. Similarly, while weight losses do not differ significantly in the use of these same chemicals in IT81D-994, the economic losses differ significantly. Also, while the economic losses in the IT99K-573-7 for after treatments with *Z. officinale* and A. sativum are statistically different, their weight losses are not. On the contrary, various discrepancies exist among matched losses for IT86D-719-9 across various treatments. The findings reveal that while the weigh losses do not differ significantly in this IT86D-719-9 at all treatment levels, there exists significant among the economic losses. Price differentials across varieties and markets make for these deviations.

Conclusion

There are great potentials in the use of botanical powders as protectant against cowpea seed damage by *C. maculatus*. The botanicals experimented with in this study show great promise in the reduction of weight and economic losses in cowpeas. *Z. zanthoxyloides*, especially, competed effectively well in 8 of the 9 (or about 89%) of the varieties. That the efficacies of the various botanicals vary across varieties raises the need for careful consideration of options in any plan to apply botanicals. The deployment of economic analysis may also be important in making or reinforcing the final choice of what storage chemicals to apply and what variety to deal in. Depending on the demand and other factors, varieties with the least economic losses may be considered as viable investment options. Economic considerations may cause an investor interested in the storage and future sales of cowpea to rule out the variety IT86D-719-9 as an option due to the substantial economic losses recorded across all the treatments.

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