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The Insecticidal Activity of two Indigenous Plants (*Zingiber officinales* and *Plumbago zeylanica*) against *Sitophilus zeamais* (Motschulsky, 1985) of Stored Maize

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Abstract

This study is aimed at investigating the insecticidal activity of two indigenous plants (*Zingiber officinales* and *Plumbago zeylanica*) against *Sitophilus zeamais* (Motschulsky, 1985) of stored maize. The efficacy and toxicity of *Z. officinales* and *P. zeylanica* are studied as protectants of stored maize grains against damage by the maize weevil *S. zeamais*. The stock culture of *S. zeamais* used for this study was taken from infested maize obtained from the Postgraduate Research Laboratory, Department of Biology, Federal University of Technology, Akure, Nigeria. The study was conducted under laboratory conditions of 28±2^{o}C ambient temperature and 75±5% relative humidity. The ethanolic extract was prepared by weighing 100g of the pulverized powder in 100 ml of absolute ethanol, which was then allowed to stand for seventy-two hours, and later sieved using muslin cloth. The contact effect of plant powders of adult mortality of *S. zeamais* and contact effect of plant powders on adult emergence and reduction of *S. zeamais* were carried out by weighing twenty grams of the maize grains into a plastic container with 12.50 cm diameter and 13.50 cm depth. Separate portions of the pulverized powder of *Z. officinales* and *P. zeylanica* at 0.5, 1.0, 1.5, 2.0 and 2.5g were thoroughly mixed with the grains using the glass rod inside the plastic container. The results obtained from this study reveal that the varying concentrations of the two plant powders *Z. officinales* and *P. zeylanica* had significant effects on the mortality of adult *S. zeamais*. However, their effectiveness was dependent on concentration and exposure periods. Since mortality increased as the exposure periods increased, it was clear that the toxic components of *Z. officinales* and *P. zeylanica* powders exhibited some level of persistence.

Keywords: Botanicals, Efficacy, Infestation, Protectant, Toxicity

1. Introduction

The maize weevil, *Sitophilus zeamais* (Motschi.) (Coleoptera: Curculionidae) had constituted a serious threat to stored grains in Africa resulting in the abysmal decline in food security and productivity (Sofowora, 2008, Ukeh *et.al*., 2008, Abdelgaleil, 2009). The damage caused by this primary pest, occasioned by infesting the kernels, had resulted in a decrease in the nutritional and seed value thereby reducing its market value both locally and internationally (Asawalam *et. al*., 2001, Zhang, 2004, Isaman, 2006). However, the storage of agricultural products is not as important as the protection of the products during storage (Arabi, 2008). Adeyemo *et al*. (2013), stated that post-harvest is directly proportional to the backwardness of a nation. Hence, protection of farms' production becomes imperative to combat food insecurity and enhance sustainability. Meanwhile, the use of chemicals to control this pest had been a recurring decimal, but not without its attendant implications including toxicity in the residue, health implications, safety of workers, and the development of resistant strains (Ogunleye, 2003, Arabi, 2008, Sachin *et al*., 2017). Grain storage is significantly constrained by insect damage which could hamper the projected achievement of food security in developing countries (IITA, 1995, Arannilewa *et al*., 2006, Rajendran, 2008). Unfortunately, the use of indigenous plants as botanicals in combating this scourge cannot be overemphasized yet. Because of the health and environmental implications posed by the use of pesticides, an alternative approach towards mitigating the damages caused by weevil on stored products need to be explored. Hence, this study was conducted to investigate the efficacy and toxicity of *Z. officinales* and *P. zeylanica* as protectants of stored maize grains against damage by the maize weevil *S. zeamais*.

2. Materials and Methods

2.1. Insect Culture

The stock culture of *S. zeamais* used for this study was taken from infested maize obtained from the Postgraduate Research Laboratory, Department of Biology, Federal University of Technology, Akure, Nigeria. This study was conducted under laboratory conditions of 28±2^{o}C ambient temperature and 75±5% relative humidity. The infested maize was weighed into a plastic container. An opening was then created and fitted tightly with a muslin cloth to

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allow ventilation while preventing the entry or exit of *S. zeamais* and other insects. The new generation of *S. zeamais* was then raised, and the culture was maintained by continually replacing the infested maize with fresh un-infested maize. The insects were reared for F1 and F2 generation at a temperature of 28±2^{0}C and 75±5% relative humidity in the Biology Laboratory of the Federal University of Technology, Akure, Nigeria.

2.2. Collection and Preparation of Extract

Fresh rhizomes of *Z. officinales* and fresh roots of *P. zeylanica* were purchased from Oja Oba Market in Akure, Ondo State, Nigeria. Each of the plant materials was washed, air-dried and pulverized into a fine powder using the electric grinder (Qlink QBL-15L40). The ethanolic extract was prepared by weighing 100g of the pulverized powder in 100 ml of absolute ethanol, which was then allowed to stand for seventy-two hours and was later sieved using a muslin cloth. The resultant extract was kept in a tightly fitted bottle and stored at -4^{o}C until use.

2.3. Contact Effect of Plant Powders on the Adult Mortality of S. zeamis (Motschi.).

Twenty grams of the maize grains were weighed into a plastic container with 12.50 cm diameter and 13.50 cm depth. Separate portions of the pulverized powder of *Z. officinales* and *P. zeylanica* at 0.5, 1.0, 1.5, 2.0 and 2.5g were thoroughly mixed with the grains using the glass rod inside the plastic container. The experiment was set up in a complete randomized design, and each treatment was replicated three times. The untreated grains served as the control. Five newly-unsexed emerged adult weevils (0-48) were introduced into the treatments, and were assumed dead when there was no response when probed with a forceps. Adult mortality was then assessed at 24, 48, 72, and 96 hours of the post-infestation period.

2.4. Contact Effect of Plant Powders on the Adult Emergence and Reduction of S. zeamis (Motschi.) in Stored Maize Grains

Twenty grams of the maize grains were weighed into a plastic container with 12.50 cm diameter and 13.50 cm depth. Separate portions of the pulverized powder of *Z. officinales* and *P. zeylanica* at 0.1, 0.2, 0.3, 0.4, and 0.5g were thoroughly mixed with the grains using the glass rod inside the plastic container. The experiment was set up in a complete randomized design and each treatment was replicated three times. Four newly-sexed (two males and females) adult weevils (0-48) were introduced into the treatments and were left for seven days. Insects were then removed after seven days in order to determine the egg plug of the weevil using acid fuchsine test. On the seventh day, the egg plugs were counted and recorded per concentration.

2.5. Contact Toxicity of the Ethanolic Extracts on Adult Mortality of S. zeamis (Motschi.)

Twenty grams of the maize grains were weighed into a plastic container with 12.50 cm diameter and 13.50 cm depth. Ethanolic extracts of 0.5, 1.0, 1.5, 2.0 and 2.5 mL concentrations were separately and thoroughly mixed with the maize grains and were allowed to stand for one hour for the solvent to evaporate. Five pairs of one day-old-adult maize weevils were separately introduced into the plastic containers containing the treated and untreated solvents. Each treatment was replicated three times and arranged in a completely randomised design. Mortality was observed and recorded after 24, 48, 72, and 96 hours.

2.6. Adult Emergence and Reduction Effect of Plant Powders on Development

All dead and live weevils were removed from the plastic containers, and were covered and kept in an incubator till new adults emerged. After seven weeks, all the emerged adults were counted and recorded. The percentage of the powders was calculated using the formula below

$$\frac{\text{No of F1 adults from the treated sample}}{\text{No of F1 adults from control}} \times 100$$

The percentage of damage (PD) and weevil performance index (WPI) for each plant treatment on the grains were calculated using the formula below

$$PD = \frac{\text{Percentage of treated grains perforated}}{\text{Total number of grains}} \times 100$$

$$WPI = \frac{\text{Percentage of perforated treated grains}}{\text{Percentage of control grains}} \times 100$$

2.7. Analysis of Data

Data obtained were subjected to one-way Analysis of variance (ANOVA) and the means were separated using Duncan Multiple Range Test (P<0.05).

3. Results

Table 1 shows the effect of the *Z. officinales* powder on the mortality of *S. zeamais* (Motschulsky). At twenty-four hours and forty-eight hours of exposure, mortality percentages of 20 % and 26.67 % was observed at 1.5g and 2.0g concentration levels. These mortality rates were not significantly (P>0.05) different from the mortality rates of 13.32 % and 26.67 % observed within seventy-two hours and ninety-six hours of exposure at 0.5g and 1.0g concentration levels.

Table 2 shows the effect of the *P. zeylanica* powder on the mortality of adult *S. zeamais.* The mortality percentage range of 6.675 %, 13.32 % and 26.67 % was noticeable at forty-eight hours and seventy-two hours of exposure periods at 1.5g, 2.0g and 2.5g of concentration levels which are apparently different from the 33.32 % mortality rate at ninety-six hours of exposure.

The effectiveness of the *Z. officinales* ethanolic extracts on the mortality of adult *S. zeamais* is shown in Table 3. The highest percentage of mortality (100 %) was observed at ninety-six hours of exposure and 2.5 mL of extract concentration. However, the lowest mortality was recorded after twenty-four hours of exposure at 0.5 mL of concentration. Also at forty-eight hours and seventy-two hours of infestation period, the highest percentage of mortality was observed at 2.5 mL of concentration evoking 60 % and 66.67 % mortality rates which are significantly different (P<0.05) from the mortality obtained with the concentration of 2.0 mL (40 %).

The range of mortality percentage of (6.67-40 %) was achieved at the exposure periods between twenty-four hours and seventy-two hours under a concentration of 1.0 mL of the ethanolic extract (Table 4). This, however, was not significantly different (P>0.05) from the results obtained after the ninety-six hours of exposure at the

concentration levels of 2.0 mL and 2.5 mL of the ethanolic extract which recorded 73.25 % and 80 % respectively.

The effect of the *Z. officinales* powder on the adult emergence and the percentage of reduction are shown in Table 5. The powder significantly reduced the adults' emergence of the weevil on maize grains. The number of adults emerged decreased with increase in the concentration of the *Z. officinales* powder. The concentration of the plant powder was increased in the order of magnitude 0.5>0.4>0.3>0.2>0.1 which decreased the number of adult emergences.

Table 6 shows the effect of the *P. zeylanica* powder on the adult emergence and percentage of reduction. This similar trend was observed under the influence of the *P. zeylanica* powder as adults' emergence decreased with the increase in the concentration of the plant powder. The percentage of reduction ranged between 81 % and 95.5 % at 0.1 mL and 0.5 mL of concentration levels respectively.

Table 7 presents the effect of *Z. officinales* on the ability of *S. zeamais* to cause seed damage in addition to the Weevil Perforation Index (WPI). The percentage of damage decreased with increasing the concentration of the plant powder. The WPI decreased in the order of magnitude 29.67, 21.9 while 3.69 was observed at the low concentration of 0.5 %.

The powder significantly reduced the infestation capacity of the weevil on the maize grains. The highest concentration of 0.5g recorded 1.92 % of seed damage and 8.32WPI. The percentage of damage decreased between 7.03 and 1.92 (Table 8).

Table 1. Effect of *Z. officinales* powder on the mortality of adult *S. zeamais.*

	% Mortality Period			
Conc.(g)	24h	48h	72h	96h
0.5	0.00 ± 0.00^{a}	6.67 ± 0.33^{ab}	13.32 ± 0.33^{ab}	20.00 ± 0.00^{b}
1.0	0.00 ± 0.00^{a}	13.32 ± 0.33^{bc}	20.00 ± 0.00^{b}	26.64 ± 0.33^{bc}
1.5	20.00 ± 0.57^{ab}	26.64 ± 0.33^{bc}	33.32 ± 0.00^{bc}	40.00 ± 0.00^{c}
2.0	26.67 ± 0.33^{b}	26.64 ± 0.33^{bc}	40.00 ± 0.00^{cd}	40.00 ± 0.00^{c}
2.5	33.32 ± 0.33^{b}	33.32 ± 0.33^{c}	46.67 ± 0.33^{d}	46.67 ± 0.33^{c}
Control	0.00 ± 0.00^{a}	0.00 ± 0.00^{a}	0.00 ± 0.00^{a}	0.00 ± 0.00^{a}

Mean values followed by the same superscript in the same column are not significantly different (P>0.05).

Table 2. Effect of *P. zeylanica* powder on the mortality of adult *S. zeamais.*

	% Mortality Period			
Conc.(g)	24h	48h	72h	96h
0.5	0.00 ± 0.00^{a}	0.00 ± 0.00^{a}	0.00 ± 0.00^{a}	0.00 ± 0.00^{a}
1.0	0.00 ± 0.00^{a}	0.00 ± 0.00^{a}	0.00 ± 0.00^{a}	0.00 ± 0.00^{a}
1.5	0.00 ± 0.00^{a}	6.67 ± 0.33^{a}	6.67 ± 0.33^{a}	6.67 ± 0.33^{a}
2.0	0.00 ± 0.00^{a}	13.32 ± 0.33^{ab}	13.32 ± 0.33^{ab}	20.00 ± 0.00^{c}
2.5	0.00 ± 0.00^{a}	26.66 ± 0.33^{c}	26.67 ± 0.33^{d}	33.32 ± 0.33^{c}
Control	0.00 ± 0.00^{a}	0.00 ± 0.00^{a}	0.00 ± 0.00^{a}	0.00 ± 0.00^{a}

Mean values followed by the same superscript in the same column are not significantly different (P>0.05).

Table 3. Effect of *Z. officinales* ethanolic extract on the mortality of *S. zeamais.*

	% Mortality			
Conc.(g)	24h	48h	72h	96h
0.5	6.66 ± 0.33^{ab}	13.32 ± 0.33^{ab}	20.00 ± 0.57^{bc}	20.00 ± 0.57^{ab}
1.0	13.34 ± 0.33^{ab}	13.32 ± 0.33^{b}	26.67 ± 0.33^{bc}	33.32 ± 0.88^{b}
1.5	20.00 ± 0.00^{bc}	20.00 ± 0.00^{b}	33.20 ± 0.33^{bc}	86.66 ± 0.33^{c}
2.0	33.32 ± 0.33^{c}	40.00 ± 0.00^{c}	40.00 ± 0.00^{c}	86.66 ± 0.16^{c}
2.5	53.20 ± 0.33^{d}	60.00 ± 0.00^{d}	66.66 ± 1.00^{ab}	100.00 ± 0.00^{c}
US	0.00 ± 0.00^{a}	0.00 ± 0.00^{a}	0.00 ± 0.00^{a}	0.00 ± 0.00^{a}
TS	0.00±0.00	0.00±0.00	13.32±0.33	13.20±0.00

Mean values followed by the same superscript in the same column are not significantly different (P>0.05).

Keys: US-untreated solvent, TS-treated solvent.

Table 4. Effect of *P. zeylanica*-ethanolic extract on the mortality of *S. zeamais.*

	% Mortality			
Conc.(g)	24h	48h	72h	96h
0.5	0.00 ± 0.00^{a}	0.00 ± 0.00^{a}	33.44 ± 0.88^{ab}	33.44 ± 0.88^{bc}
1.0	6.66 ± 0.33^{ab}	13.44 ± 0.33^{ab}	40.00 ± 0.57^{ab}	40.00 ± 0.57^{bc}
1.5	13.44 ± 0.33^{ab}	13.44 ± 0.33^{ab}	46.66 ± 0.88^{b}	70.66 ± 0.88^{bc}
2.0	13.44 ± 0.33^{ab}	13.44 ± 0.33^{c}	46.67 ± 0.33^{b}	73.20 ± 0.66^{c}
2.5	20.00 ± 0.00^{b}	26.66 ± 0.33^{b}	46.66 ± 0.66^{b}	80.00 ± 0.57^{c}
US	0.00 ± 0.00^{a}	0.00 ± 0.00^{a}	0.00 ± 0.00^{a}	0.00 ± 0.00^{a}
TS	0.00±0.00	0.00±0.00	0.00 ± 0.00^{a}	20.00 ± 1.00^{ab}

Mean values followed by the same superscript in the same column are not significantly different (P>0.05).

Keys: US-untreated solvent, TS-treated solvent.

Table 5. Effect of *Z. officinales* powder on emergence of adult *S. zeamais* after 6 weeks of storage.

Concentration (% w/v)	Mean number of adult emergences	% Reduction
Control	17.33 ± 2.33^{b}	0.00 ± 0.00^{b}
0.1	3.66 ± 0.88^{a}	78.89 ± 0.88^{a}
0.2	2.33 ± 0.66^{a}	86.56 ± 0.66^{a}
0.3	1.00 ± 0.57^{a}	94.23 ± 0.57^{a}
0.4	0.66 ± 0.33^{a}	96.20 ± 0.33^{a}
0.5	0.33 ± 0.33^{a}	98.10 ± 0.33^{a}

Mean values followed by the same superscript in the same column are not significantly different (P>0.05).

Table 6. Effect of *Z. officinales* powder on emergence of adult *S. zeamais* after 6 weeks of storage.

Concentration (% w/v)	Mean number of adult emergences	% Reduction
Control	20.00 ± 2.33^{b}	0.00 ± 0.00^{b}
0.1	3.66 ± 0.33^{a}	81.70 ± 0.33^{a}
0.2	3.00 ± 0.00^{a}	85.00 ± 0.00^{a}
0.3	2.66 ± 0.66^{a}	86.70 ± 0.57^{a}
0.4	1.66 ± 0.88^{a}	91.70 ± 0.88^{a}
0.5	1.00 ± 0.57^{a}	95.10 ± 0.57^{a}

Mean values followed by the same superscript in the same column are not significantly different (P>0.05).

Table 7. Effect of *Z. officinales* powder on seed damage and weevil perforation index (WPI) caused by *S. zeamais.*

Conc. (%)	Total no of grains	Damaged Grains	Undamaged Grains	% Damaged	WPI
0.1	52	3.66±0.88	48.34	7.03[a]	29.67
0.2	52	2.33±0.66	49.67	4.48[a]	21.19
0.3	52	1.00±0.77	51.00	1.92[a]	10.33
0.4	52	0.66±0.33	51.34	1.28[a]	7.13
0.5	52	0.33±0.33	51.67	0.64[a]	3.69
Control	52	7.33±2.33	34.67	33.32[b]	33.32

Mean values followed by the same superscript in the same column are not significantly different (P>0.05).

Table 8. Effect of *P. zeylanica* powder on seed damage and weevil perforation index (WPI) caused by *S. zeamais.*

Conc. (%)	Total no of grains	Damaged Grains	Undamaged Grains	% Damaged	WPI
0.1	52	3.66±0.33	48.34	7.03[a]	24.94
0.2	52	3.00±0.00	49.00	5.76[a]	21.40
0.3	52	2.66±0.66	49.34	5.12[a]	19.48
0.4	52	1.66±0.88	50.34	3.20[a]	13.14
0.5	52	1.00±0.57	51.00	1.92[a]	8.32
Control	52	20.00±2.33	32.00	38.46[b]	38.46

Mean values followed by the same superscript in the same column are not significantly different (P>0.05).

4. Discussion

The tropical zones of the world are well-endowed with many medicinal plants with rich insecticidal potentials. Medicinal plants have played an important and integral role in the replacement of precarious, un-ecofriendly and expensive synthetic chemical insecticides (Ofuya, 2001). The results obtained from this study reveal that the varying concentrations of the two plant powders (*Z. officinales* and *P. zeylanica*) had significant effects on the mortality of *S. zeamais* adults (Table 1). However, their effectiveness was dependent on concentration levels and exposure periods. *Z. officinales* achieved a mortality range of 13 %-46 % at 0.5g-2.5g of concentrations respectively within seventy-two hours of the post-infestation period. The *Z. officinales* powder exhibited greater mortality than *P. zeylanica* powder at various exposures irrespective of the concentration level (Table 2). Since mortality increases as the exposure period increases, it was clear that the toxic components of the *Z. officinales* and *P. zeylanica* powders exhibit some level of persistence. Findings from this study are in agreement with Lajide *et al*., 1998, who admixed 1g/100g of maize and recorded 50 % mortality among *S. zeamais* within seven days. This study revealed that the *Z. officinales* and *P. zeylanica* ethanolic extracts are more effective than the powder (Tables 3 and 4). *Z. officinales* at the concentrations of 2.0 mL and 2.5 mL evoked 86.6 % and 100 % mortality within ninety-six hours of the post-treatment period. The performance of the ethanolic extract evaluated against *S. zeamais* in this study agreed with the findings of Echendu, 1991, who reported that the plant extract Rhizome of *Z. officinale* when admixed at the 2.5g rate /500g IFE brown cowpea variety caused an adult mortality of 96 % of *Callobroschus. Masculatus* compared to the control. The effectiveness of the ethanolic extracts of the plants over the powders suggests that the active components of the plants are contained in the oils rather than in their powders (Ogunbite and Oyeniyi, 2014; Ileke *et Al*, 2014). The powder significantly reduced the adult emergences capacity of the weevils on the maize grains (Table 5). As the concentration of the plant powder increased, the mean number of the adult emergence decreased with the increased percentage of reduction. The concentration of the plant powder increased in the order of magnitude 0.5g>0.4g>0.3g>0.2g>0.1g. The observed decrease in the adult emergence between 3.66 and 1.00 with respect to the control (Table 6) gave credence to the ability of the powders of both plants to significantly reduce or prevent the adult emergences because of the mortality of the insects recorded which could consequently reduce the rate of mating and oviposition (Ileke and Olotuah, 2012). Grains protected with a concentration of 0.5 % of the plant extract exhibited greater effectiveness against *S. zeamais* (Table 7) compared with 0.1 % (WPI recorded was 3.69) and 0.2 % where the percentage of damage to the grains was relatively higher (33.32 %). These findings are inconsistent with Adedire *et al*, (2005), who reported that grains protected with 2.0 % of the plant extract gave better protection against *S. zeamais* than 0.5 % as a zero index was recorded virtually in all of the grains with the concentration of 2.0 % of the plant extract. The observed higher WPI (38.46) and the percentage of damaged grains (38.46) under the control treatment in *P. zeylanica* against a 33.32 WPI and the percentage of damaged grains (Table 8) respectively are suggestive of its potency with a high mortality rate through blocking the spiracles of insects thus impairing the respiratory activities which could ultimately lead to premature death. Results from these investigations revealed that the extracts from *Z. officinales* ethanolic extract significantly (P<0.05) decreased the percentage of damaged grains compared to their respective powder. This result is in agreement with reports of Niber, 1994 and Adedire and Lajide, 2003, who reported that some tropical plants could be admixed with grains in storage in order to protect them from storage beetles. Findings from this study are similar to another study done by Mohammed *et al*, (2018), who reported that the effectiveness of the powders of *A. melegnata* and *Z. officinales* against the *S. zeamais* mortality increased by increasing the concentration. The mode of action of the botanicals was attributed to interference with the normal respiration. It could be inferred from this study that the extracts of both *Z. officinales* and *P. zeylanica* powders at a 0.5 % concentration had a greater degree of protection and effectiveness in preserving the grains against attacks by storage weevils.

5. Conclusion

These two botanicals have been proven to be effective against stored maize weevils. This could be suggestive of a rich deposition of secondary metabolites such as steroids, tannins and phenolics inherent in these plants with a wide range of insecticidal properties. Further investigations on the potency and efficacy of longer exposure periods together with higher concentrations of these extracts could

possibly help reduce the infestation capacity of stored maize grains.

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