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Comparative Bioactivity of Bamboo Leaf Ash and Bularafa Diatomaceous Earth against Maize Weevil (*Sitophilus zeamais* Motschulsky)

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ABSTRACT: Maize is one of the major staple foods in Sub-Saharan Africa and there is serious loss in maize storage due to insect damage. This study compared the bioactivity of Bamboo Leaf Ash (BLA) and Bularafa Diatomaceous Earth (BDE) against Maize Weevil (*Sitophilus zeamais* Motschulsky) under laboratory conditions. Insecto®, a commercialized DE was also tested as standard check. Adults of the insects were exposed on maize admixed with the BLA at dose rate of 5,000, 10,000 and 20,000ppm; BDE and insecto® at a dose rate of 1,000ppm, at 28.2^{0}C and 82.2% relative humidity. Mortality increased with increasing exposure duration and all treatments showed mortality of more than 80% after 14days post-treatment compared to negative control with 0%.The treatments suppressed F1 progeny. Treated grains have weight loss less than 4%, kennel damage less than 14% and grain germination showed no significant change. The decreasing efficacy of the dusts against this insect is Insecto®> BLA > BDE. BLA and BDE have potential for the management of insect pests of stored grain in Nigeria.

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Maize is one of the major staple foods in Sub-Saharan Africa (Ekpa *et al.*, 2018) and it is the third most important cereal grain worldwide after wheat and rice (Golob *et al*., 2004). Nigeria is the largest producer of maize in Africa (IITA, 2021) and also one of the major importers of maize in Africa (IITA, 2021). Jaspareet and Anita, (2013) reported that food wastage is higher than the food consumed, Nigeria's post harvest loss is estimated to be 20-30% of the total production (World Bank, 2011).Pests are the major setback in maize production as they affect the crop on the field and during storage (Ovharhe *et al*., 2021). During storage of maize, lack of control measures against insect pest and poor storage facilities are major setbacks affecting maize production in Nigeria (Abdulaleem *et al.*, 2017). *Sitophilus zeamais* is among major insect pests of maize in Nigeria (Nwaubani *et al., 2014*; Okonkwo *et al.*, 2017). Insect infestation in stored food commodities reduces quality and quantity of food available for human consumption (Okonwko *et al.*, 2017) and grain farmers throughout Nigeria and the entire West African sub-region suffer serious losses to their stored commodities due to insect damage (Nwaubani *et al.*, 2014). The lack of effective ways of controlling storage pests have frequently forced smallholder farmers and grain aggregators in sub-Sahara Africa to sell their grain at giveaway prices during periods of glut (Stathers *et al.*, 2008; Nwaubani *et al.*, 2014). The use of synthetic chemical pesticide such as Carbamate, organophosphate and pyrethroids against insect pests of stored product has long been used but not usually safe on human health and the environment (Ikpesu and Ariyo, 2013; Olayinka-olagunju, 2014). The effectiveness, inexpensive, nontoxic of the phytochemical components as well as the local availability of plant makes it an attractive

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choice in pest-management practices (Ito and Utebor, 2018). Crops have been protected against insect pests by the use of plants in areas with difficulties in accessing synthetic pesticides (Sruthi and Rao, 2021).BDE has proven insecticidal actions on grains (Nwaubani *et al.*, 2014;Otitodun*et al.*, 2015; Okonkwo *et al.*, 2018; Nwaubani *et al.*, 2020) but there is dearth information in insecticidal actions of BLA on grains. Therefore, this study compared the bioactivity of Bamboo Leaf Ash (BLA) and Bularafa Diatomaceous Earth (BDE) against Maize Weevil (*Sitophilus zeamais* Motschulsky) under laboratory conditions.

MATERIALS AND METHODS

This study was conducted using entomology and chemistry laboratories of the Nigerian Stored Products Research Institute (NSPRI), Port Harcourt, Rivers state, Nigeria.The average means temperature of 28.2^{0}C and 82.2% relative humidity were observed.

Maize preparation: The maize used for this study was sourced from a seller in NTA road, Port Harcourt, Rivers state. They were transported to NSPRI Port-Harcourt zonal office where they were processed; dehusked, sundried, shelled and dried. The initial moisture content of the used was 13.1%.

*Bamboo Leaf Ash (BLA) preparation:*The leaf of Bamboo was obtained within the compound of NSPRI Port-Harcourt zonal office. The dried leaf was dried using laboratory oven at temperature of 40˚C and then burnt. It was then ashed completely in furnace at temperature of 600˚C for 5hours and then sieved using a U.S standard #200 sieve (0.075mm openings). The sieved Bamboo Leaf Ashwas kept in airtight container prior to use.

Bularafa Diatomaceous Earth (BDE) and Insecto® preparations: BDE is a crude ore of DE obtained from Bularafa community in Yobe State, Nigeria. It was ground to dust using laboratory mortar and pestle and sieved using a #200 sieve (0.075mm openings) U.S. Standard (Seedburo Equipment Company, Chicago, IL). Insecto (Insecto Natural Products, Costa Mesa, CA) is a commercially available DE formulation containing 10% food-grade additives.

Insect culture: Adults *Sitophilus zeamais* were reared on pesticide free maize in the insectary of the Nigerian Stored Products Research Institute (NSPRI), Port Harcourt. Unsexed adult *S. zeamais* were taken from cultures that were previously maintained in the insectary and introduced into uninfested 100g of maize inside 360ml kilner jars. The insects were allowed to mate and lay eggs for 15 days, thereafter, all adult insects (live and dead) were sieved out and the culture diets retained for F1 progeny emergence. The lots were kept for another 35 days and newly emerged adults *S. zeamais* were used for the study.

*Bioassay:*Thirty gram of maize grains were weighed and added to plastic vials. The weighed maize grains in each plastic vials were treated with 0.5, 1, 2% (5,000, 10,000 and 20,000ppm respectively) Bamboo leaf ash; Insecto; and Bularafa Diatomaceous Earth (D.E) powder/dust at the rate of 0.1% (1,000ppm weight/weight) concentration, and each plastic vials were then manually shaken vigorously for approximately 5 minutes to ensure proper and uniform coating of the grains with the dusts, where applicable. The grains in one of the plastic vials were left without treatment as negative control. Both treated and untreated grains in the plastic vials were replicated thrice. Twenty newly emerged adults of *S. zeamais* were introduced into each plastic vials. The cap lids were closed back with the muslin cloth to allow aeration and prevent insects from escaping. The vials were arranged on the table in laboratory using Complete Randomized Design (CRD).

The mortality of the insects was observed at 7 days and 14 days post-treatment using (Dyte and Forster, 1973) and insects that didn't move spontaneously and those that did not response to slight pressure were considered dead. On the fourteenth day post-treatment, contents in the vials were sieved to remove all insects (dead and alive), then closed back and returned for an additional 35 days (49 days post-treatment). On the additional 35th day (49 days post-treatment), number of F1 progeny in each vial was determined and the Reduction in Progeny Production (RPP) by the treatment relative to the control was also determine using formula(Arthur and Throne, 2003);

$$RPP(100\%) = \frac{1 - Number\ of\ F1\ treatment}{Number\ of\ F1\ in\ control}\ x\ \frac{100}{1}$$

The number of damaged and undamaged kernels, new weight, percentage kernel damaged and percentage weight lost were also recorded.

The Percentage weight loss was calculated by Gwinner *et al.*, (1996) formula;

$$\%Weight\ loss = \frac{(Wu\ x\ Nd) - (Wd\ x\ Nu)}{[Wu\ x\ (Nd + Nu)]}\ x\ \frac{100}{1}$$

Where; Wu= weight of undamaged kernel, Nu= Number of undamaged kernel, Wd= weight of damaged kernel, Nd= Number of damaged kernel

The Percentage Insect Damage Kernel (%IDK) is calculated by;

$$\%IDK = \frac{Number\ of\ damaged\ kernels}{Total\ number\ of\ the\ kernels}\ x\ \frac{100}{1}$$

The moisture content was also determined using the procedure of Association of Official Analytical Chemists (AOAC), 2010.

Also, ten randomly selected undamaged kernels from each sub-sample per treatment after F1 progeny count was planted. Percentage germination was determined.

The Percentage seed germination was calculated by;

$$\%\ GM = \frac{Number\ of\ kernels\ germinated}{Total\ number\ of\ the\ kernels\ planted}\ x\ \frac{100}{1}$$

Where GM – germination

Statistical analyses were performed using a computer program (SPSS 11.01, SPSS Inc.) by Analysis of Variance (ANOVA)and mean calculated and separated using the Duncan's test when significant (P < 0.05).

RESULTS AND DISCUSSION

The results of this study shows that maize treated with varying concentrations of BLA, BDE and insecto® have effect on the mortality of *S. zeamais*. The percentage mortality of 0% was observed by the control (untreated grains) at 7d and 14d post treatment whereas, the percentage mortality of >30% and >80% were observed by BLA, BDE and insect (treated grains). The highest percentage mortality of 90% was observed in insecto® at the 7d post treatment and highest percentage mortality of 100% were found in insecto® and 2% BLA dusts within 14d post-treatment.

The efficacy of the BLA at all the concentrations, BDE and insecto® on weevil (*S. zeamais*) mortality was higher at 14d post-treatment than the 7d post-treatment (Figure 1). There were significant differences in the mean percentage mortality of *S. zeamais* due to activity of the treatments at 7d post treatment (F=53.187, P=0.00) and 14d post treatment (F=7.553, P=0.02).

The mortality results indicated that almost all the concentrations of the BLA, BDE and insecto® dusts used were effective in controlling infestation by *S. zeamais* when compared with the untreated control; due to the facts that the mortality of the weevil increased with an increase of the treatment and the duration of the days (Figure 1).

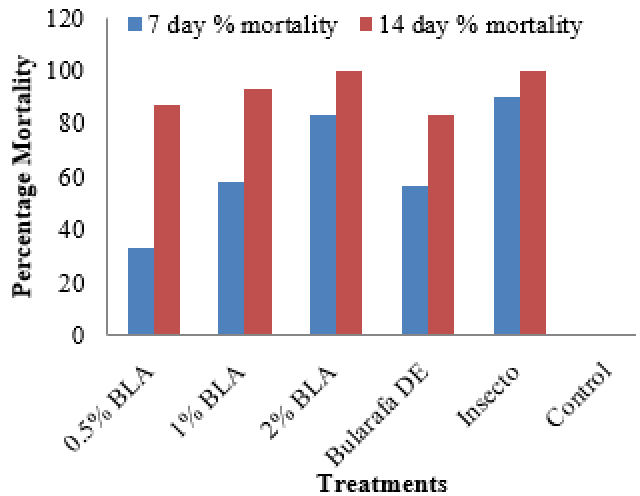

Fig 1: Percentage Mortality for *S. zeamais* after 7d and 14d post-treatment

The percentage mortality of >30% and >80% after 7d after 14d post-treatment respectively in all treatment is in accordance with; Martini and Baldassari, (2014); Nwaubani *et al.*, (2014), who reported mortality of DE at all time of exposure differed significantly from the control by >70% and >80% respectively. Udo (2005) has reported high mortality of plant powders against insect pest and Nwaehujor & Olatunji, (2011) also reported that plant powder gave adequate protection to cowpea seeds. Otitodun *et al.*, (2015), observed that both plant powder and DE have high mortality in grain weevils. Pinto Júnior, (2008) & Nwaubani *et al.*, (2014) reported that longer periods of exposure at high doses promoted better control of the insects.

The high insecticidal values of these dusts (BLA and BDE) have been attributed to; particle sizes (smaller and uniform) and high level silica content (Nwaubani*et al., 2014;* Otitodun *et al.*, 2015). There is increase in area of contact between the particles and insect cuticle because there is greater surface volume ratio in smaller particles (Korunic 1998; Nwaubani *et al., 2014;* Otitodun *et al.*, 2015).

Table 1.ANOVA Percentage F1 progeny and RPP for *S. Zeamais* after 49d post-treatment

Treatments	F1 Progeny	RPP (%)
0.5% BLA	47.67±4.41[b]	67.5
1% BLA	15.00±7.94[a]	89.5
2% BLA	11.00±7.02[a]	92.3
Bularafa DE	40.67±13.45[ab]	71.4
Insecto	11.00±6.11[a]	92.3
Control	142.33±11.89 [c]	-

Means±SE and means followed by the same subscript letter(s) within firstcolumn are not significantly different according to Duncan Post Hoc test at 5% level ofprobability

High silica content of more than 70% has been reported in BDE (Nwaubani*et al., 2014;* Otitodun*et al.*, 2015) and BLA (Dwivedi *et al.*, 2006; Mohapatra *et al.*, 2011; Olawale, 2020), which kills the insects by absorption of the epicuticular wax of the insect, leading to desiccation and death (Subramanyam and Roesli, 2000; Athanassiou and Steenberg, 2007). Table 1 of this study reveals that all the test dusts were observed to have potentials of reducing adult emergence. Least adult emergence (mean value=11.00) was observed when the maize grains were treated with 2%BLA and insecto®, while control gave the highest emergence (mean value=142.33). The effect of these dusts on adult emergence of *S. zeamais* grown on maize grains was significantly (F=31.044, P=0.00) different among the treatments and the control. Adult emergence decreased with increase in the concentration of the BLA. The result of this study also shows that all the treatments were effective at suppressing progeny production by *S. zeamais*. Insecto® and 2% BLA have highest (92.3%) suppression in percentage reduction in progeny production and 0.5% BLA has the lowest (67.5%) suppression in progeny production.High reduction in F1 progeny from this study could be due to the fact that the insects have been kill based on high percentage mortality observed and this is similar to results of (Subraamanya and Roesli, 2000; Athanassiou *et al.*, 2003; Silva-Aguayo *et al.*, 2004; Nwaubani *et al., 2014;* Otitodun *et al.*, 2015). For 2% BLA and Insecto® with highest mortality percentage, the F1 emergency percentage of 11.0 was observed and this is criterion mentioned by Paez *et al*., (1990) and Lagunnes (1993) that when the quantity of powder is increased, the protection is greater.

Table 2.ANOVAPercentageweight lossfor *S. zeamais* after 49d post-treatment

Treatments	Percentage Weight Loss
0.5% BLA	3.04±0.36[a]
1% BLA	1.45±1.08[a]
2% BLA	1.28±0.59[a]
Bularafa DE	2.86±0.75[a]
Insecto	0.68±0.52[a]
Control	16.35±5.16[b]

Means±SE and means followed by the same subscript letter(s) within the column are not significantly different according to Duncan Post Hoc test at 5% level of probability

Table 2 shows the mean percentage weight loss of the maize grains under the effect of the BLA, BDE, insecto® dusts and control treatments against maize weevil. The result of this study shows that maize grains treated with the dusts have low value of mean percentage weight loss when compared with the untreated maize grains in the control sample. The application of the dusts statistically had a significant (F = 7.45, P< 0.05) effect on the mean percentage weight loss of the maize grains. The data presented in Table 2 revealed also that maize grains treated with insecto® gave the lowest mean percentage weight loss (0.68%) and the highest mean percentage weight loss (16.35%) observed in the negative control. The percentage weight loss reported in this study is similar to the report of Fufa *et al.*, (2021). The decrease in percentage weight loss of the grains with dusts that have high percentage mortality and least F1 progeny observed in this study is similar to the findings of Tefera *et al.*, (2011), who reported that decrease in percentage weight loss with decrease in insect density and Silva-Aguayo *et al.*, (2004), who reported that a lowest grain loss is observed in treated grains with the greatest mortality and lowest emergence.

Table 3.ANOVA Percentage Insect Damage Kennel (% IDK) for *S. zeamais* after 49d post-treatment

Treatments	Percentage IDK
0.5% BLA	12.61±1.15[a]
1% BLA	4.81±2.63[a]
2% BLA	4.17±2.13[a]
Bularafa DE	13.01±3.68[a]
Insecto	3.57±0.67[a]
Control	78.20±7.62[b]

Means±SE and means followed by the same subscript letter(s) within the column are not significantly different according to Duncan Post Hoc test at 5% level of probability

The results of this study shows that maize treated with BLA, BDE and insecto® dusts have effect on the mean percentage IDK of the maize grains when compared with the untreated control (Table 3) and this can be linked to the facts that the dusts decreased the progeny production of the maize weevil that cause havoc by boring holes on the kennels of the maize grains.

There were significant differences in the mean percentage IDK(F=59.90, P<0.05). Insecto® was found to have the lowest percentage IDK of 3.35% while the control has the highest percentage IDK of 78.20%. The decrease in percentage IDK of the grains with dusts that have least F1 emergence as observed in this study is similar to report of Tefera *et al.*, (2011), who also reported decrease in percentage grain damage with decrease in insect density.

The result of seed germination from this study reveals that all the treatments have percentage seed germination more than 70%. There was no significant different (F=1.482, P=0.27) percentage seed germination from all the treatments. The high values of percentage seed germination obtained for all the treatments in this study is crucial to crop yield and quality (Muhammad *et al.*, 2019) and were closed to the level (90% germination) required for seed export (Silva-Aguayo *et al.*, 2004).

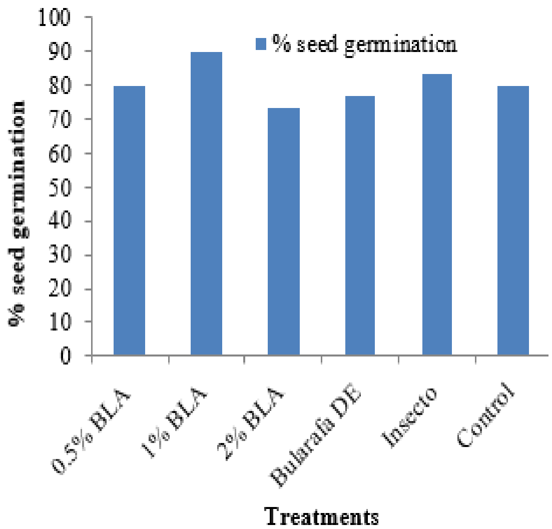

Fig2:Percentage Seed Germination

Table 4.ANOVA Moisture Content for *S. zeamais* after 49d post-treatment

Treatments	Moisture Content
0.5% BLA	15.3833±0. .09[c]
1% BLA	15.6000±0.06[c]
2% BLA	15.7167±0.17[cd]
Bularafa DE	14.4333±0.23 [b]
Insecto	13.3167±0.04[a]
Control	16.0667±0.06[d]

Means±SE and means followed by the same subscript letter(s) within the column are not significantly different according to Duncan Post Hoc test at 5% level of probability

Table 4 of this study reveals that there was no significant different (F=1.482, P=0.27) in percentage moisture content from all the treatments after 49d post-treatment. Least mean percentage moisture content (13.32) was observed when the maize grains were treated with insecto®, while control gave the mean percentage moisture content (16.07). Lorini (1998) has observed that efficiency of inert dust on the grains is altered by high moisture content and Furquim *et al.*, (2014) reported that high percentage damage caused by insect on corn grains is attached to high moisture content. Le Patourel (1986) observed the effect of moisture content on the efficiency of control of sorptive silica dust in beetles, the author observed that increased in moisture content enhanced the tolerance of the beetle to silica dust treatment.

*Conclusion:*This study conducted under laboratory condition reveals that Insecto, BLA, and BDE dusts have potential to control *S. zeamais* in grains during storage. The dusts can provide farmers and grain aggregators with a safe, readily available and eco-friendly IPM tools in Nigeria and other Sub-Saharan Africa. The dusts can be used to treat seed grains in order to protect them from *S. zeamais* infestation and still retain the viability until planting time.

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