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Comparative Effects of Rice and Melon Wastes on *Sitophillus Zeamais,* Storage Pest of Maize Grains in Nigeria

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Authors' contributions

This work was carried out in collaboration among all authors. Author RTO designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors TIO and JEI managed the analyses of the study. Author RTO and BAO managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

World's calories supply from maize accounts for 20% but global postharvest grain loss caused by insect pests was estimated to be 10%. Control is mostly by synthetic insecticides with consequences such as insect resurgence and resistance and negative effect on non- target organisms. Maize grain losses to weevils are so enormous that effective local solution has to be sought. Thus this research aimed at assessing the effectiveness of powders and ash of rice husk and melon shell in controlling *Sitophillus zeamais (Mots)* in stored maize. Four treatments, Rice husk powder (RHP), Rice husk ash (RHA), Melon shell powder (MSP) and Melon shell ash (MSA) were applied at eight levels of 0 - 2.0 g 20 g^{-1} maize grain in three replicates. Five pairs (males and females) of freshly emerged *S. zeamais* were introduced into each treatment. Mortality test was carried out on the insects at 48 and 96 hours after introduction. Germination test was conducted on ten randomly selected grains after weevil emergence. Significantly higher ($p \le 0.05$) mortality was recorded in treated seeds than the control. Virtually 100% mortality of *S. zeamais* was attained in

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both RHA and MSA treated maize in 96hrs at all application rates. Mean adult emergence in maize treated with both RHA and MSA were zero, with no weight loss like those of grains treated with standard control of *P. guinensis*. Also maize grain treated with Rice husk ash (RHA) and Melon shell ash (MSA) recorded a mean WPI of zero irrespective of application rates as in *P. guinensis*. The mean percentage germination of maize grain was significantly higher (p≤0.05) in *P. guinensis* than those recorded on treatments, while germination of treated maize is higher than the control. Thus rice husk and melon shell are effective alternatives to insecticides against *S. zeamais* in stored maize.

Keywords: Rice husk; melon shell; Sitophillus zeamais; mortality; adult emergence.

1. INTRODUCTION

Maize (*Zea mays* L.) is an important cereal crop grown in different parts of the world including Africa, serving as a source of food and industrial raw materials (Abdul rahman, 2009), supplying about 20% of global food calories. Approximately 8.0 million tonnes of maize grains were reportedly produced in South Africa annually on about 1 million hectares of land, of which half of the production consists of white maize, for human food consumption. The International Institute of Tropical Agriculture, IITA [1], reported a projection of maize production to double in the developing countries by the year 2050 and its global production to surpass all crops by 2025.

However estimate showed that grain yield losses due to insect pests are within the range of 5-10% in the temperate zone and 50-100% in tropical regions [2]. During storage, these pests cause deterioration in the quality and quantity of the grains; about 30-50% annual loss was reported for tropical Africa [3].

The maize weevil, *Sitophilus zeamais* Motschulsky (Coleoptera: Curculionidae), is a major destructive insect pest of stored grains, processed and unprocessed stored products in Africa. *Sitophilus zeamais* damages stored produce both qualitatively and quantitatively, with grain weight loss ranging between 20 to 90% in untreated stored maize [4]. The damage severity depends on factors like storage structures, physical and chemical properties of the produce. Weevil infestation in stored maize is noticeable by the consumption of kernels, accumulation of exuviate, webbing, and cadavers which may lead to loss both in quality and quantity of the grain [5].

Heavy infestation of all growth stages of maize weevil, resulting in postharvest losses, poses threat to storage entomology and food security in the tropics. The common control methods for this pest are chemical, botanical and biological.

The use of synthetic pesticide to protect stored produce against insect pests had been reported effective by many authors but not without problems of pesticide residue, threat to man and the environment. There are also the problems of pest resistance, resurgence, extinction of non-target organisms, increased cost of application and handling hazards. [6,5] Chemical control is often reported to be effective, so less emphasis is placed on natural products with insecticidal properties that protect grains, retain their value in quality and quantity, and ensure the safety of the consumer of the grain or its products. Thus there is need therefore to explore inert materials that are safe alternatives from host of plants, in contrast to expensive and hazardous synthetic chemicals.

Many botanical preparations and ash had been investigated by different researchers in Nigeria. Powders and ash of rice husk and melon shell were reported effective in the control of *Callosobruchus maculatus* in stored cowpea. At 48hours post-treatment, significantly high (100%) mortality of *C.maculatus* was recorded with 1.0g and above of rice husk ash treatment, while cowpea treated with melon shell ash killed at least 73.33% with 1.0g and above application rate [7].

1.1 Objective of the Study

This study will research into the control of *S. zeamais*, using powders and ashes from rice husk and melon shell.

2. MATERIALS AND METHODS

This research was conducted at the Cocoa Research Institute of Nigeria (CRIN), Entomology laboratory in Ibadan, Oyo State Nigeria (07°10'N, 03°52'E, 122 m ASL). Ambient laboratory conditions at the period of this research were 28 ± 4°C temperature, 68 ± 10% relative humidity and an average daily twelve hour light/darkness exposure.

2.1 Maize Variety Used for the Experiment

Five kilogrammes of non-infested and clean maize, *Zea mays* (SWAN HY variety) was purchased from the Institute of Agricultural Research and Training (IAR&T) seeds store Ibadan. Subsequent disinfestation of the seeds was achieved by keeping it in an air-tight container in the deep-freezer for two weeks. The seed for the experiment was taken from the freezer each time and the remaining returned after use.

2.2 Culturing of Insect

Weevil-infested maize grains were purchased from Bodija market in Ibadan through which the culture of *Sitophillus zeamais* was set-up in the laboratory. Fifty unsexed adults of *S. zeamais* were introduced into 250 grams of sterilized un-infested maize (SWAN HY) samples in a plastic container and removed after the seventh day. The cultures were maintained in the laboratory where daily emerging adult weevils were collected and used for the bio-assay.

2.3 Collection and Preparation of Materials

Rice husk and melon shell were sourced for from Bodija market in Ibadan. Each was separately ground into fine powders using Nulux mills (Model RPM SR 400-061, Bombay India). Rice husk powder (RHP) and melon shell powder (MSP) were kept in separate air-tight plastic containers and stored in the refrigerator until when needed. Some of the RHP and MSP were heated to ash in the furnace at about 550°C, 24 hours before use to obtain rice husk ash (RHA) and melon shell ash (MSA) respectively.

2.4 Bioassay of Powder and Ash Botanicals

The experiment was a Completely Randomized Design (CRD) with eight levels of treatment at 0.2, 0.4, 0.6, 0.8, 1.0, 1.5 and 2.0 g of RHP, MSP, RSA and MSA separately applied to 20 g of uninfested maize in sterile air -tight plastic containers. A standard control using 0.4 g of *Piper guinensis* in 20 g of uninfested maize and an untreated control were also set up. Each of the treatment and the controls were replicated thrice. The treated grains in each plastic container were shaken manually for about five minutes to attain even spread of the treatment (powders and ashes). Five pairs (male and female) of newly emerged *S. zeamais* were collected from the culture of insects reared in the laboratory and introduced at the same time into each treatment. Adult mortality at 48 and 96 hours after introduction of the adult weevils into each experimental container was counted, recorded and removed during the day when the weevils were very active.

Examination of the maize for adult emergence from 30days after weevil infestation was done. The emerging adult weevils were counted and recorded for ten consecutive days. Ten randomly selected grains were tested for germination. Percentage mortalities, weevil perforation index (WPI) and germination percentage (GP) were calculated as indicated in Equations:

Percent Mortality = No. of dead weevil / No. of weevils introduced X 100(%) [Eq. 1].

WPI (Weevil Perforation Index) = %treated seeds perforated / %treated seeds perforated+%control seeds perforated x 100 [8] [Eq 2].

Percent Germination = No. of seed germinated / Total seeds sampled) ×100(%) [9]. [Eq. 3]

2.5 Data Analysis

Data obtained from this experiment were analyzed using two-way Analysis of Variance (ANOVA) aided by SAS version 9.1 software packages. Separation of means was done with Duncan's Multiple Range Test at 5% probability level. Some data were presented using chart.

3. RESULTS AND DISCUSSION

3.1 Results

In this study, adult mortality of *S. zeamais* in treated maize grain, no-treatment control and standard control of *P. guinensis* differ significantly at 48hrs post treatment. Significantly greater mortality ($p \le 0.05$) was obtained in the maize grains treated with rice husk ash(RHA) and melon shell ash (MSA) with as little as at least 0.2g of ash, attaining 63.33 and 73.33% kill of *S. zeamais* than their respective powders (Table 1). A 100% mortality of *S. zeamais* was attained in both RHA (1.5g and above) and MSA (1.0g and above) treated maize samples At 0.4-2.0 g application rates, powders of rice husk and melon shell had significantly greater kill ($p \le 0.05$)

of *S. zeamais* while the control had zero kill. Both RHA and MSA treated maize at 96hrs post-treatment, showed significantly greater mortality ($p \leq 0.05$) with 100% mean mortality attained almost in all rates of application than the standard control of *P. guinensis* (Table 1).

Treatment effect on mean adult emergence of *S. zeamais* showed a significant difference ($p \leq 0.05$) in maize grain treated with both ashes (RHA and MSA) and their respective powders (RHP and MSP). Maize treated with both RHA and MSA recorded no adult emergence even at the lowest application rates which are similar to that recorded in the standard control treatment (Table 2).

Damage assessment of treated maize grains as reflected by mean percentage seed weight loss in Table 3 showed a significant difference ($p \leq 0.05$) among the treatments. There was no weight loss in maize grains treated with ashes of rice husk and melon shell at all application rates, also similarly observed in maize treated with *P. guinensis* powder. However, seed weight loss was significantly higher ($p \leq 0.05$) in maize grains treated with powders of rice husk and melon shell, as also observed in the control. Further damage assessment revealed that mean weevil perforation index (WPI) in maize grains treated with rice husk ash (RHA) and melon shell ash (MSA) showed significant difference ($p \leq 0.05$) as they both recorded zero at all application rates which is same with the standard control of 0.4g *P. guinensis* (Table 4). However the mean WPI in maize grains treated with rice husk powder and melon shell powder were incomparably higher.

The mean percentage germination of maize grains treated with different doses of ashes and powders of rice husk and melon shell is shown in Table 5. The highest percentage (96.67%) was recorded on maize grains treated with the standard control and this was significantly higher ($p \leq 0.05$) than percentage germination recorded on RHP, RHA, MSP, MSA and the control. Maize grains treated with ashes and powders of rice husk at 1.5g and above recorded 73.33% percentage germination (Table 5).

3.2 Effect of Powders and Ashes of Rice Husk and Melon shell in the Control of *S. zeamais* in Maize

S. zeamais showed a significantly higher percentage adult mortality ($p \leq 0.05$) in maize treated with ashes and powders of rice husk and melon shell than the untreated control. Both treatments with RHA and MSA recorded significantly higher ($p \leq 0.05$) mean percentage mortality of *S. zeamais*, than mortality recorded on maize treated with melon shell powder, rice husk powder and the standard control of *P. guinensis*. At 96hours, more than 90% kill of *S. zeamais* was recorded in maize treated with RHA and MSA. The mean adult emergence was significantly higher ($p \leq 0.05$) in the untreated control (20.00 emergents) than maize treated with MSP (11.81emergents) and RHP (11.38 emergents). The RHA and MSA treated maize both recorded zero adult emergences which are incomparable to the standard control of *P. guinensis* (1.42 emergents) as presented in Table 6.

The mean percentage seed weight loss (0.30%) recorded for the untreated control was significantly higher ($p \leq 0.05$) than those of RHP (0.24%) and MSP (0.23%). RHA and MSA both recorded zero percentage seed weight loss at all application rates. Mean Weevil Perforation Index showed that the number of holed maize grain was significantly higher ($p \leq 0.05$) on maize treated with rice husk powder and melon shell powder with mean weevil perforation index of 35.36 and 32.42 respectively, this is incomparable to maize treated with rice husk ash, melon shell ash and the standard control of *P. guinensis* with zero mean WPI. The mean percentage germination after F_1 (first filia) adult emergence of maize grain treated with ashes and powders of rice husk and the melon shell was significantly higher ($p \leq 0.05$) than the control treatments. However a significantly higher number of grains germinated from maize treated with standard control of *P. guinensis* than in all treatments. Among the treatments, seed germination was highest in maize grain treated with rice husk ash (62.86%) and lowest in grains treated with melon shell powder (Table 6).

3.3 Discussion

From this study, findings showed that tested powders and ashes of rice husk and melon shell showed insecticidal activity against maize weevil, *S. zeamais*. All the treatments showed efficacy in the control of *S. zeamais* in maize. The toxicity, feeding and reproduction inhibitory effects of the two ashes (RHA and MSA) on *Sitophilus zeamais* in the treated maize were distinctively revealed from the study. This research work discovered high potential of RHA and MSA to protect maize grain against weevils in storage.

The tested rice husk ash (RHA) caused 100% adult mortality of S.zeamais which contained more than 1.5 g dose at 48hrs post-treatment (Table 1) The tested MSA also killed 100% of *S. zeamais* with 1.0 g dose and above at 48hrs post-treatment. Rice husk powder (RHP) treatment killed 30-66.67% of *S. zeamais* at 48 hours from 0.4 to 2.0 g powder dose. The treatment with MSA recorded 73.33-100% mortality of *S. zeamais* from 0.4 to 2.0 g powder dose at 48 hours after treatment. At 96 hours, RHA and MSA treated maize had a 100% kill of *S. zeamais* in almost all application doses.

The high percentage mortality of *S. zeamais* recorded in maize treated with RHA and MSA can be attributed to effect of treatment on breathing system of weevil through blockage of spiracles which inhibits inhalation of oxygen. Many authors have reported high mortality and low insect population using wood ash, clay dust, silicates sand, diamaceous earths (diatomite) and botanical powders, [10,6,5].

Many research findings had shown reduced life span and oviposition of insects in grains treated with botanical powders [11,5]. Rice Husk Ash (RHA) as reported by Naito [11] is abrasive thus can hinder movement of male weevil to mate the female consequently inhibiting oviposition and infestation of the maize [12].

The potency of RHA was manifested in *S. zeamais* emergence with the mean F_1 emergence being zero at all application levels (Table 2; Fig. 1). Although weevil emerged from the treatments with rice husk and melon shell powders, this demonstrated that mating took place but there was low mean weevil emergence as against the control. Botanical preparations often weaken adult insects leading to fewer eggs being laid, reduced egg hatchability, lengthened larval and pupal period, reduced adult emergence, longevity and growth index [13,14].

Table 1. Effect of rice husk and melon shell treatments on mean percent mortality of *S. zeamais*

Application rates (g 20 g^{-1})	RHP		RHA		MSP		MSA	
	---------- hours ----------							
	48	96	48	96	48	96	48	96
0.0	0.00^{m}	0.00^{k}	0.00^{m}	3.33^{k}	0.00^{m}	0.00^{k}	0.00^{m}	0.00^{k}
0.2	0.00^{m}	0.00^{k}	63.33^{gh}	96.67^{a}	0.00^{m}	0.00^{k}	73.33^{ef}	100.00^{a}
0.4	13.33^{k}	30.00^{i}	63.33^{gh}	100.00^{a}	3.33^{lm}	13.33^{j}	83.33^{cd}	100.00 ^{a}
0.6	16.67^{jk}	36.67^{hi}	76.67^{de}	100.00^{a}	10.00^{kl}	30.00^{j}	86.67c	100.00 ^{a}
0.8	20.00^{j}	43.33^{gh}	76.67^{de}	100.00^{a}	16.67^{jk}	36.67^{hi}	90.00^{bc}	90.00^{bc}
1.0	20.00^{j}	53.33^{ef}	96.67^{ab}	100.00^{a}	20.00^{j}	46.67^{fg}	100.00 ^{a}	100.00 ^{a}
1.5	30.00^{i}	66.67^{d}	100.00^{a}	100.00^{a}	20.00^{j}	50.00^{fg}	100.00 ^{a}	100.00 ^{a}
2.0	30.00^{i}	66.67^{d}	100.00^{a}	100.00^{a}	30.00^{i}	60.00^{de}	100.00^{a}	100.00^{a}
P.guinensis	60.00^{gh}	83.33^{c}	63.33^{gh}	86.67^{bc}	56.67^{h}	80.00^{c}	66.67^{fg}	90.00^{bc}

Table 2. Mean Total Adult Emergence of *S. zeamais* in maize treated with different application rates of powders and ashes of rice husk and melon shell

Application rates (g 20 g^{-1})	RHP	RHA	MSP	MSA
0.0	20.00^{ab}	18.67^{bc}	21.33^{a}	20.00^{ab}
0.2	18.67^{bc}	0.00^{l}	17.67^{cd}	0.00^{l}
0.4	17.00^{d}	0.00^{l}	18.00^{bc}	0.00^{l}
0.6	12.00^{f}	0.00^{l}	13.33^{e}	0.00^{l}
0.8	11.00^{fg}	0.00^{l}	11.67^{g}	0.00^{l}
1.0	8.67h^{j}	0.00^{l}	7.00^{ij}	0.00^{l}
1.5	5.67^{jk}	0.00^{l}	5.33^{jk}	0.00^{l}
2.0	5.67 ^{jk}	0.00^{l}	0.00^{l}	0.00^{l}
P.guinensis	0.00^{l}	0.00^{l}	0.00^{l}	0.00^{l}

Means with the same superscripts are not significantly different at (P ≤ .05) using DMRT RHP-Rice husk powder, RHA-Rice husk ash, MSP-Melon shell powder MSA-Melon shell ash

Table 3. Mean Seed Weight Loss after adult emergence in maize treated with different application rates of powders and ashes of rice husk and melon shell

Application rates (g 20 g^{-1})	RHP	RHA	MSP	MSA
0.0	0.33^{a}	0.30^{ab}	0.28^{abc}	0.27^{bcd}
0.2	0.30^{ab}	0.00^{h}	0.28^{abc}	0.00^{h}
0.4	0.28^{abc}	0.00^{h}	0.28^{abc}	0.00^{h}
0.6	0.23^{abc}	0.00^{h}	0.22^{def}	0.00^{h}
0.8	0.25^{bcde}	0.00^{h}	0.23^{cdef}	0.00^{h}
1.0	0.23^{cdef}	0.00^{h}	0.23^{cdef}	0.00^{h}
1.5	0.22^{def}	0.00^{h}	0.20^{ef}	0.00^{h}
2.0	0.18^{fg}	0.00^{h}	0.15^{g}	0.00^{h}
P.guinensis	0.00^{h}	0.00^{h}	0.00^{h}	0.00^{h}

Means with the same superscripts are not significantly different at (P ≤ .05) using DMRT RHP-Rice husk powder, RHA-Rice husk ash, MSP-Melon shell powder MSA-Melon shell ash

Table 4. Mean Weevil Perforation Indexin maize treated with different application rates of powders and ashes of rice husk and melon shell

Application rates (g 20 g^{-1})	RHP	RHA	MSP	MSA
0.2	49.26^{a}	0.00^{h}	45.13^{a}	0.00^{h}
0.4	46.16^{a}	0.00^{h}	45.13^{a}	0.00^{h}
0.6	37.87^{b}	0.00^{h}	38.25^{b}	0.00^{h}
0.8	31.37^{c}	0.00^{h}	31.21^{c}	0.00^{h}
1.0	32.52^{c}	0.00^{h}	29.63^{cd}	0.00^{h}
1.5	26.66^{de}	0.00^{h}	21.18^{f}	0.00^{h}
2.0	23.68^{ef}	0.00^{h}	16.40^{g}	0.00^{h}
P.guinensis	0.00^{l}	0.00^{h}	0.80^{h}	0.00^{h}

Means with the same superscripts are not significantly different at (P ≤ .05) using DMRT RHP-Rice husk powder, RHA-Rice husk ash, MSP-Melon shell powder MSA-Melon shell ash

Table 5. Mean percentage germination of maize treated with different application rates of powders and ashes of rice husk and melon shell

Application rates (g 20 g^{-1})	RHP	RHA	MSP	MSA
0.0	23.33^{hi}	18.67^{bc}	23.33^{hi}	26.67^{hi}
0.2	26.67^{bc}	53.33^{def}	26.67^{hi}	46.67^{bc}
0.4	33.33^{d}	56.67^{bcde}	30.00^{bc}	53.33^{def}
0.6	36.67^{gh}	60.00^{cde}	36.67^{gh}	56.67^{bcde}
0.8	56.67^{bcde}	60.00^{cde}	50.00^{ef}	53.33^{def}
1.0	63.33^{bcd}	63.33^{bcd}	56.67^{bcde}	60.00^{cde}
1.5	73.33^{b}	73.33^{b}	63.33^{bcd}	56.67^{bcde}
2.0	73.33^{b}	73.33^{b}	66.67^{bc}	63.33^{bcd}
P.guinensis	96.67^{a}	96.67^{a}	96.67^{a}	96.67^{a}

Means with the same superscripts are not significantly different at (P ≤ .05) using DMRT RHP-Rice husk powder, RHA-Rice husk ash, MSP-Melon shell powder MSA-Melon shell ash

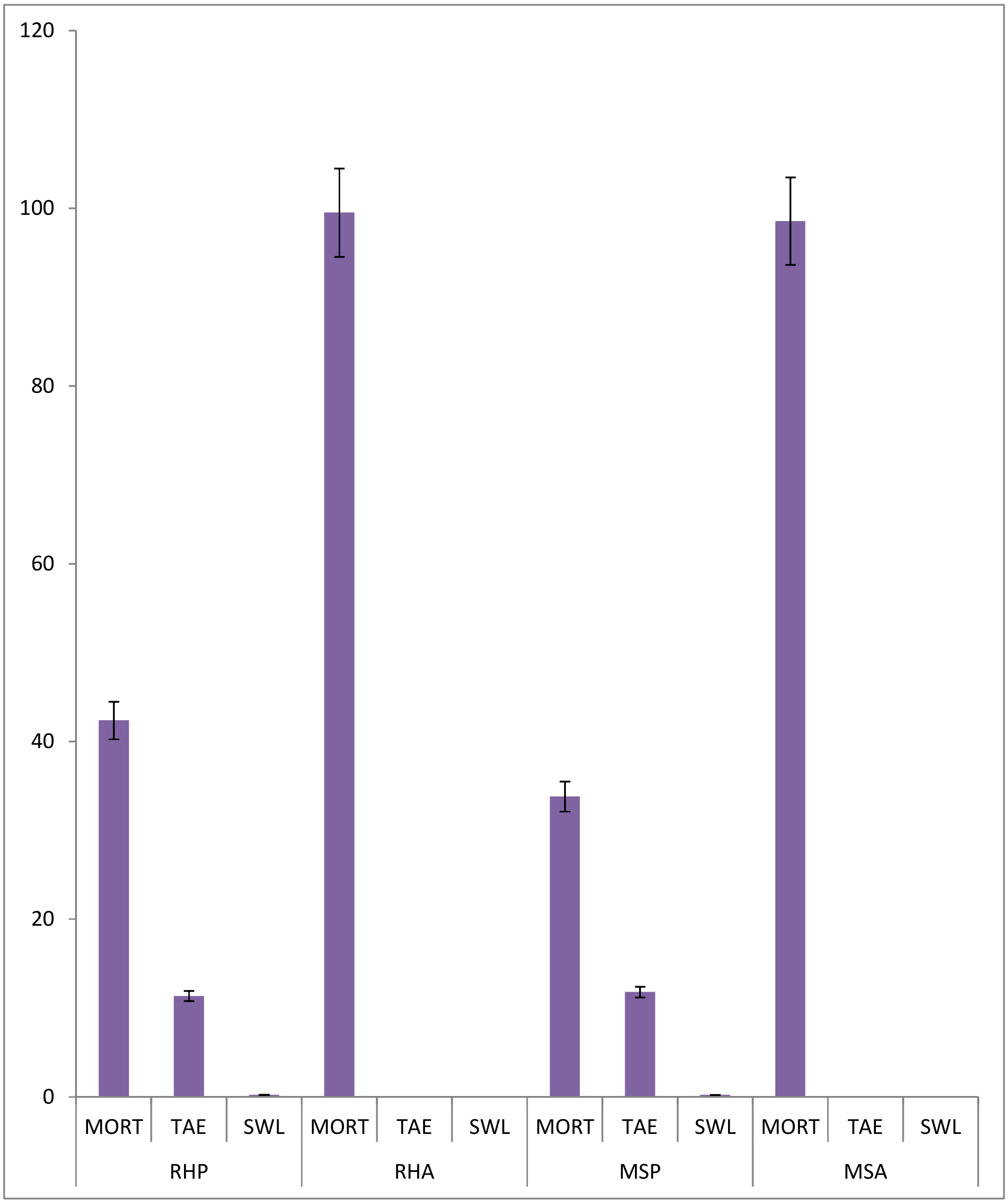

Fig. 1. Chart showing Mortality, Total adult emergence of S.zeamais and seed weight loss in treated maize

Research had shown the efficacy of botanical preparations against many storage insect pests [15,16,14]. Both RHA and MSA demonstrated effective reproduction inhibitory ability in adult emergence in RHP and MSP treatments. This could be due to high egg mortality and reduction in egg hatchability as affirmed by different authors that grains mixed with ash and sand inhibits free movement and mating in insect pests, [5,4,17].

From the result of this study, percentage seed weight loss in treated maize differed and was quite low as against the control. Rice Husk Ash protected treated maize as no loss in seed weight was recorded. Melon shell ash (MSA)

Table 6. Mean Effect of Powders and Ashes of Rice Husk and Melon Shell Powder and Ashes on *S. zeamais*

Treatment	MORT		TAE	SWL	WPI	GERM
	48 h	96 h				
RHP	18.57[c]	42.38[b]	11.38[b]	0.24[b]	35.36[a]	51.90[b]
RHA	82.38[a]	99.52[a]	0.00[c]	0.00[c]	0.00[b]	62.86[b]
MSP	14.29[c]	33.81[b]	11.81[b]	0.23[b]	32.42[a]	47.14[c]
MSA	90.48[a]	98.57[a]	0.00[c]	0.00[c]	0.00[b]	55.71[b]
CONTROL	0.00[d]	0.83[c]	20.00[a]	0.30[a]	-	25.83[c]
STANDARD	61.67[b]	85.00[a]	1.42[c]	0.00[c]	0.00[b]	96.67[a]

Means with the same superscripts are not significantly different at (P ≤ .05) using DMRT RHP-Rice husk powder, RHA-Rice husk ash, MSP-Melon shell powder MSA-Melon shell ash
MORT – Mortality TAE – Total Adult Emergence
SWL- Seed Weight Loss WPI – Weevil Perforation Index GERM- Germination

significantly protected treated maize in this study when compared with the control (Table 3). This agrees with the study of Oni [18], where reduced seed damage and percentage weight loss in cowpea and maize treated with pepper extract was reported. Different authors reported inhibition of oviposition and subsequent progeny production by *Callosobruchus maculatus*, in treated cowpea [19-21,6].

From this study, maize grains treated with both MSA and RHA were completely protected from *S. zeamais* as Weevil Perforation Index (WPI) was zero at all levels of application, as recorded in the standard control of *P. guinensis*. Both RHA and MSA impeded locomotive capacity, mating, oviposition and subsequent F_1 progeny emergence of *S. zeamais*. This conforms to the findings of Mekuria [22] and Dejen [23] that Chenopodium leaf powder mixed with maize and sorghum grains caused complete reduction in F_1 progeny production by maize weevil.

Mean percentage germination in treated maize showed that seeds could have at least 50% germination. The treatment effect on percentage germination in comparison with the standard control where value above 90% germination was recorded does not negate the fact that treated seeds were more viable than the untreated control seeds in this study. Dejen [23] showed that powders of *Datura stramonium, Jatropha curcas, Phytolacca dodecondra* and *Azadiracta indica* used in the control of *S. zeamais* did not show any significant effect on the germination capacity of sorghum when compared with control. Olorunmota et al reported insignificant adverse effect on germination capacity of cowpea treated with ash and powders of both rice husk and melon shell. Baier and Webster [24] also reported insignificant effect on germination of grains treated with vegetable oil, kitchen ash and black pepper.

4. CONCLUSION

The result of this study showed that rice husk and melon shell ash do not only kill but deters feeding, F_1 progeny emergence of *S. zeamais* The inability of *S. zeamais* to cause damage by holing or breaking of treated maize, in this research, which may result to losses is evidence that rice husk and melon shell ash can effectively protect stored maize against this major pest and thus can be recommended as affordable and safe potential protectant.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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