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Insecticidal Activity of Selected Agricultural Plant Ashes and Their Combinations with Clove Powder against *Sitophilus Zeamais* (Motschulsky) in Stored Maize

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ABSTRACT
Post-harvest grain loss due to infestation by storage pest remains a challenge for food security and smallholder livelihoods in the developing world, which can occur across the food supply chain from harvesting of crops till consumption. This study investigated the insecticidal efficacy of agricultural plant ashes both as single treatments and in binary combination with clove (*Eugenia aromatica*) plant powder, against *Sitophiluszeamais* infesting stored maize grain, the design used was a Completely Randomized Design (CRD) with three replications. The bioassays were conducted at different dosages (0.2 g, 0.4 g, 0.6 g, 0.8 g, and 1.0 g) per 20 g of grain seeds and monitored over exposure intervals of 120 hours. The results demonstrated that all treatments caused a significant (p>0.05) increase in adult mortality. PFRA and WSA exhibited the highest potency, of 91.67% and 90.00% mortality respectively at a 0.6 g dosage after 120 hours of exposure. RHA and MSA also showed high efficacy, while CPSA was the least toxic but still significantly superior to the control. The insecticidal mechanism of the ashes was identified as physical, acting as an abrasive inert dust that compromises the protective epicuticular wax layer of the insect, leading to fatal desiccation, alongside respiratory blockages. Incorporating *Eugenia aromatica* powder into the ashes to form a binary mixture of ratio 1:1 significantly accelerated weevil mortality. PFRA mixed with *Eugenia aromatica* powder emerged as the most potent formulation, achieving up to 20.13% mortality within 24 hours at the highest dosage and 33.31% after 48 hours. This dramatic increase in mortality is attributed to a highly positive synergistic dual-action. The physical abrasion of the insect cuticle by the ashes facilitating rapid penetration of eugenol the highly volatile neurotoxic constituent of *Eugenia aromatic* into the insect's system. These findings confirm that combining local agricultural plant ashes with *E. aromatica* plant powders is highly effective, low-cost, environmentally friendly, and accessible integrated pest management strategy for safeguarding stored maize.

Keywords: Infestation, Post-harvest, Food security, Mortality, Treatment

INTRODUCTION

Maize (*Zea mays* L.) is one of the three major cereal crops worldwide and ranks first in global production, serving as a primary source of food, fodder, and industrial products (FAO 2024). It is a vital crop for food security in Nigeria, contributing significantly to the livelihoods of millions of farmers and the nation's economy (Afolabi*et al.,* 2020). Maize ranks third in next to wheat and rice in cereal production, making it an important crop for food security that helps to increase per capita energy consumption and income, particularly in developing countries Marta, H. E. &Ruswandi, D. (2017). Maize belongs to the grass family, Poaceae (formerly Gramineae). It was domesticated approximately 9,000 years ago from a wild grass called teosinte (*Zea mays spp. parviglumis*) (Doebley, 2004). Maize is a cornerstone of the global economy, often referred to as "Yellow Gold." It is the primary staple for over 1.2 billion people in Sub-Saharan Africa and Latin America (Shiferaw*et al*., 2011). Beyond food, it is processed into high-fructose corn syrup (HFCS), citric acid, and biodegradable plastics (PLA) (Ranum*et al*., 2014). Maize is a C4 carbon fixation plant, which allows it to photosynthesize more efficiently than C3 plants (e.g wheat) in high-light and high-temperature environments (Abolusoro, 2024), and most varieties are short-day plants, meaning they require specific day lengths to trigger flowering. In tropical regions, "Early Maize" is planted between March and June, while "Late Maize" is planted between August and October to take advantage of the bimodal rainfall pattern. It thrives between 21°C and 30°C. Growth typically stops if temperatures drop below 10°C and requires 500 mm to 1200 mm of well-distributed rainfall. In tropical regions (like Nigeria), it is usually planted at the onset of the rainy season (March/April) and a second crop in July/August and performs best in well-drained, loamy soils with a pH of 5.5 to 7.0. Maize is often called the "Queen of Cereals" because of its high genetic yield potential and versatility. It is a primary raw material for starch, ethanol, corn oil, and corn syrup. Over 60% of global maize production is used as the energetic base for poultry and livestock feed (Rouf Shah *et al*., 2016).

While primarily a source of carbohydrates (starch), the nutritional value of maize is highly dependent on the variety (yellow, white, or purple) and processing methods (Ranum*et al*., 2014). Its composition is dominated by carbohydrates, which constitute about 72% to 73% of the kernel weight,

primarily in the form of starch (amylose and amylopectin), alongside smaller amounts of simple sugars like glucose, sucrose, and fructose (Ifie*et al*., 2025; FAO, 2024).
Composed mainly of amylopectin and amylose, providing 365 kcal per 100g (per 100g dry grain) Carbohydrates 72%, Protein ~8% - 10%, Contains Zein, a protein that is low in essential amino acids. This led to the development of Quality Protein Maize (QPM), which is biofortified with higher levels of lysine and tryptophan to combat malnutrition (Prasanna*et al*., 2020c). Fat (Lipids) ~4% - 5%, Fiber ~2%, Rich in Vitamin A (yellow maize), B-complex, and Vit E, Yellow maize is rich in carotenoids (lutein and zeaxanthin), which are essential for eye health and preventing macular degeneration (Rouf Shah *et al*., 2016).
The importance of maize in both domestic and industrial applications suggests that conscious efforts must be made to reduce crop losses along the value chain, especially in the post-harvest sector (Affognon*et al.,* 2015). The greatest losses are incurred during storage and particularly occur in developing countries (Kumar and Kalita, 2017). At the production level, there is evidence of seed and food insecurity arising from storage losses. One of the elements contributing to high storage losses is the problem of storage insect pests such as the maize weevil, *Sitophiluszeamais* (Motschulsky); rice weevil, *Sitophilusoryzae* (L.); Angoumois grain moth, *Sitotrogacerealella* (Olivier); and the larger grain borer, *Prostephanustruncatus* (Horn) (Tefera et al., 2011). They can cause 20–40% losses during cultivation and 30–90% postharvest and storage losses (Odendo et al., 2001). Maize weevil caused 60% weight losses and quality in terms of nutritional values in maize within 3–6 months in storage which directly affect food security in developing countries such as Nigeria (Adesina, 2012; Ileke et al., 2016). Insect pests destroy stored products by either direct feeding or reduction in grain quality (Berge et al., 2022). Insect species that feed on the endosperm cause weight and quality loss while those that feed on the germ, result in low seed viability (Nwosu*et al.,* 2015).
The important insect pest of maize in Nigeria is the maize weevil *Sitophiluszeamais* (Mostch), which are responsible for both field and stored maize damage (Abass*et al*., 2018; Van Duong et al., 2020). Infestations initiated in the standing crop continue after harvesting (Hamel *et al*., 2020). Farmers cannot entirely protect the maize in storage from the insect pest attack, which as a result, reduces the storage life, quantity, and quality of the stored maize (Tefera*et al*., 2011). There are several pest management practices that have been used to control infestation of seed beetles in stored maize which include; physical control, biological control, mechanical control, chemical control and use of plant extracts. Of these techniques, the most common and popularly used technique is the chemical control which is viewed to be effective, quick and secure. Though it is the most commonly used technique it has some major downsides which include; undesirable effect on seed grains and environment, constant danger of intoxication on humans and animal; and development of pesticide resistant pest (Fajinmi*et al.,* 2015). Besides, majority of farmer in many developing countries in the tropics and subtropics are resource poor and have neither the means nor the skills to obtain and handle these synthetic chemicals appropriately (Goudoungou*et al.,* 2018).
As a part of the quest for an alternative to chemical insecticides, research efforts are being focused on the use of plant products, such as ashes, plant powder, extracts and oil, which are cheaper, safe and eco-friendly (Adedirani*et al*,.2011). Their main advantage is that these materials are cheap and readily available to farmers and small-scale industries in form of crude or partially purified extracts. It was reported that when mixed with stored grains; leaf, bark, seed powder or oil extract of plants reduced oviposition rate and suppressed adult emergence of bruchids and also reduced seed damage rate (Onu and Aliyu 1995, Shaaya*et al*., 1997). Across the world, many of the plant species that are cultivated either as food or for medicinal purposes are still neglected and underutilized while they play a crucial role in food security, nutrition and income generation of the rural poor (Magbagbeola*et al*.,2010). In developing countries researchers have been screening materials from medicinal plants that may possibly replace the synthetic pesticides for the control of both field and storage insect pest (Anusha*et al.,* 2020). This study therefore aimed at evaluating the insecticidal action of some agro plant ash in the protection of maize grains against maize weevil (*Sitophiluszeamais*) infestations.

MATERIALS AND METHODS

Experimental Site

The experiments were conducted at the Department of Crop Science and Horticulture Laboratory Federal University Oye-Ekiti, Ikole Campus, Ekiti State, Nigeria, at temperature of 28± 2^0C and 75± 5% relative humidity. Ikole-Ekiti has a tropical climate with an average annual rainfall of 139 mm, (https://weatherandclimate.com/ nigeria/ekiti/ikole).

Sample Collection

The un-infested SUWAN-1 yellow susceptible variety of maize grains were obtained from newly harvested stock of Maize grains free of insecticides from Institute of Agricultural Research and Training (IAR&T), Ibadan, Oyo State, Nigeria. The uninfested Maize grains were air dried naturally in the laboratory for 72 hours (Adedire*et al*., 2011), *Sitophiluszeamais,* a major grain storage insect pest in Nigeria, gotten from a colony of infested maize grains at Ikole market was used for the study and its cultures was maintained throughout the study, following the methods described by Ofuya (1987) and Ofuya and Arogundade (2008). Plant parts from six different plants of tropical rainforest were collected within Ikole Local government area and processed to ash as described by Ofuya and Adler (2014). The final product were Rice Husk Ash (RHA), Walnut Shell Ash (WSA), Palm Fruit Rind Ash (PFRA), Cocoa Pod Shell Ash (CPA), Melon Shell Ash (MSA) and Maize Cob Ash (MCA). All processed plant ashes were kept in separate plastic containers with tightly fitting lids until needed

Collection and Preparation of Plant Powders

Eugenia aromatica plant part was collected from Odo Oro Market at IkoleEkiti. The plant materials was authenticated at the herbarium section of Crop, Soil and Pest Management Laboratory, Federal University of Technology Akure, Ondo State. The plant part was well dried and pulverized into fine powders of 300µm particle size as described by Ofuya and Dawodu (2002), and kept in a separate plastic container.

Insect Bioassay

The plant ashes were tested singly at the dosage of 0.2, 0.4, and 0.6 g /20 g of grain in a plastic container (8.5 cm, 6.0 cm diameter) with tight fitting lids over a pored of 120hrs, while the three most potent among the plant ashes were admixed with *Eugenia aromatic* plant powder at ratio 1:1. Twenty unsexed newly emerged (< 2 days old) adult of *S. zeamais*was introduced separately into each of the covered plastic container containing the treated seeds and shaken to ensure

that the powder contacted the insect. Mortality of the introduced adults was observed at 24, 48, 72, 96 and 120 hours post treatment respectively. There were three replication per treatment adopting a Completely Randomized Design (CRD) experimentally.

Data Analysis

Data were collected on adult mortality at 24, 48, 72, 96 and 120 hours post treatment. All data were subjected to Analysis of Variance (ANOVA) while significant difference means was separated using Duncan Multiple Range Test (DMRT)@5% level of significance.

RESULTS AND DISCUSSION

The insecticidal efficacy of agro plant ash at 0.2 g on mortality of adult *Sitophiluszeamais* over 120 hour post treatment is presented in Table 1. The results showed that mortality increased significantly (p>0.05) with increasing exposure time across all agro-plant ash treatments, when compared with control. At 24 hours post treatment, PFRA recorded a significantly higher (p>0.05) adult mortality of 5.00, while RHA, WSA, CPSA, MSA, and MCA recorded lower mortality values of 1.67. At 48 hours post treatment, mortality increased significantly in all treatments when compare with the control, while PFRA recorded a significantly highest mortality of 16.67.

At 72 hours post treatment, there were significant differences in all the treatments with PFRA having a significantly highest (p>0.05) mortality of 31.67, while CPSA had a significantly lower adult mortality of 16.67. Moreso at 96 hours post treatment, WSA had the highest mortality (51.67%), followed by PFRA (48.33%) and MSA (45.67%). By 120 hours, mortality further increased in all treatments. Walnut shell ash and palm fruit rind ash produced the highest mortality (73.33%), followed by melon shell ash (71.67%), rice husk ash (65.00%), maize cob ash (56.67%) and cocoa pod shell ash (48.33%). The untreated control recorded only 1.67% mortality.

Table 1: Percentage Mortality of *Sitophiluszeamais* Adult Exposed to 0.2 G of Some Agro-Plant Ashes Overtime

Agro-plant	of Exposure (%Mortality± Std Error) hours				
	24hrs	**48hrs**	**72hrs**	**96hrs**	**120hrs**
RHA	0.00±0.00a	8.33±1.67b	21.67±1.67bc	38.33±1.67bc	65.00±2.89cd
WSA	1.67±1.67ab	13.33±1.67cd	30.00±2.89d	51.67±3.33d	73.33±1.67de
PFRA	5.00±0.00b	16.67±1.67d	31.67±1.67d	48.33±1.67cd	73.33±1.67de
CPSA	1.67±1.67ab	6.67±1.67b	16.67±1.67b	30.00±2.89b	48.33±1.67b
MSA	1.67±1.67ab	10.00±0.00bc	25.00±2.89bcd	45.67±4.33c	71.67±3.33d
MCA	1.67±1.67ab	10.00±0.00bc	21.67±1.67bc	38.33±1.67bc	56.67±1.67c
Ctrl	0.00±0.00a	0.00±0.00a	0.00±0.00a	0.00±0.00a	1.67±1.67a

Mean follow by the same alphabet along column are not significantly different from one another (p>0.05) using Duncan Multiple Range Test (DMRT).

The insecticidal efficacy of agro plant ash at 0.4 g on mortality of adult *Sitophiluszeamais* over 120 hour post treatment is presented in Table 2. In all treatment, mortality increased significantly with increasing exposure time, when compared with control. At 24 hours after treatment, palm fruit rind ash had the highest mortality (6.67%), while cocoa pod shell ash (CPSA) and melon shell ash (MSA) recorded the lowest mortality (1.67%). At 48 hours, mortality increased significantly (p>0.05) across all treatments, PFRA had the highest mortality (18.33%), while CPSA recorded the lowest mortality (8.33%).

At 72 hours after treatment, there were significant differences (p>0.05) in all the treatment when compared with the control PFRA and WSA recorded the highest mortality (33.33%), while melon shell ash and maize cob ash recorded 25.00%. Cocoa pod shell ash had the least effective treatment with 18.33% mortality, more so at 96 hours of exposure, PFRA and WSA had a significantly higher mortality (55.00%), followed by rice husk ash (50.00%), melon shell ash (45.67%) and maize cob ash (43.33%) while Cocoa pod shell ash had the lowest mortality of 35.00%. At 120-hour exposure period, PFRA and WSA recorded the highest mortality (80.00%), while maize cob ash recorded a significantly lower mortality (63.33%).

Table 2: Percentage Mortality of *Sitophiluszeamais* Adult Exposed To 0.4 G of Some Agro-Plant Ashes Overtime

Agro-plant	Period of Exposure (%Mortality± Std Error) hours				
	24hrs	**48hrs**	**72hrs**	**96hrs**	**120hrs**
RHA	3.33±1.67abc	11.67±1.67bc	26.67±1.67cd	50.00±2.89cd	73.33±1.67cd
WSA	5.00±0.00bc	15.00±0.00c	33.33±1.67d	55.00±2.89d	80.00±2.89d
PFRA	6.67±1.67c	18.33±1.67d	33.33±1.67d	55.00±0.00d	80.00±2.89d
CPSA	1.67±1.67ab	8.33±3.33b	18.33±3.33b	35.00±2.89b	56.67±1.67b
MSA	1.67±1.67ab	10.00±0.00bc	25.00±2.89c	45.67±4.33c	71.67±3.33c
MCA	3.33±1.67abc	11.67±1.67bc	25.00±2.89c	43.33±4.41bc	63.33±1.67bc
Ctrl	0.00±0.00a	0.00±0.00a	0.00±0.00a	0.00±0.00a	1.67±1.67a

Mean follow by the same alphabet along column are not significantly different from one another (p>0.05) using Duncan Multiple Range Test (DMRT).

The insecticidal efficacy of agro plant ash at 0.6 g on mortality of adult *Sitophiluszeamais* over 120 hour post treatment is presented in Table 3. Mortality increased significantly (p>0.05) with increasing exposure time across all treatments, while control recorded no mortality until 120 hours when 1.67% mortality was observed. PFRA and WSA recorded a significantly (p>0.05) higher mortality throughout the study. At 24 hours, both treatments caused 8.33% mortality, which increased to 23.33% and 20.00% at 48 hours, 36.67% and 35.00% at 72 hours, 63.33% each at 96 hours,

and 91.67% and 90.00%, respectively, after 120 hours. RHA also exhibited considerable insecticidal activity, producing 81.67% mortality at the end of the experiment.

MSA, MCA, and CPSA showed significantly (p>0.05) lower mortality throughout the exposure period. At 120 hours, MSA recorded 76.67% mortality, followed by MCA (63.33%) and CPSA (61.67%).

Table 3: Percentage Mortality of *Sitophiluszeamais* Adult Exposed to 0.6 G of Some Agro-Plant Ashes Overtime

Agro-plant	Period of Exposure (%Mortality± Std Error) hours				
	24hrs	48hrs	72hrs	96hrs	120hrs
RHA	8.33±1.67c	20.00±2.89d	33.33±3.33cd	55.00±2.89d	81.67±4.41cd
WSA	8.33±1.67c	20.00±2.89d	35.00±2.89d	63.33±4.41e	90.00±5.00d
PFRA	8.33±1.67c	23.33±1.67e	36.67±1.67d	63.33±4.41e	91.67±6.01d
CPSA	3.33±1.67b	13.33±1.67bc	26.67±1.67bc	43.33±3.33b	61.67±1.67b
MSA	5.00±0.00bc	15.00±0.00c	30.00±0.00c	50.00±2.89c	76.67±1.67c
MCA	3.33±1.67b	11.67±1.67b	25.00±2.89b	43.33±4.41b	63.33±1.67bc
Ctrl	0.00±0.00a	0.00±0.00a	0.00±0.00a	0.00±0.00a	1.67±1.67a

Mean follow by the same alphabet along column are not significantly different from one another (p>0.05) using Duncan Multiple Range Test (DMRT).

The toxicity of binary combinations of the three most effective agro-plant ashes with *Eugenia aromatic* at ratio (1:1) against adult *Sitophiluszeamais* after 24 hours of exposure is presented in table 4. Mortality increased significantly (p>0.05) with increasing dosage for all treatment combinations, while no mortality was recorded in the untreated control.

In all the treatments, the combination of palm fruit rind ash and *E. aromatica* (PFRA + EAP) significantly (p>0.05) recorded the highest mortality across all dosage levels, increasing from 8.31% at 0.2 g to 20.13% at 1.0 g. Rice husk ash combined with *E. aromatica* (RHA + EAP) recorded intermediate mortality values ranging from 7.21% at 0.2 g to 16.32% at 1.0 g, while walnut shell ash combined with *E. aromatica* (WSA + EAP) recorded a significantly (p>0.05) lower mortality, ranging from 5.20% at 0.2 g to 13.17% at 1.0 g. In all, overall mortality increased significantly (p>0.05) with increasing dosage irrespective of the treatment applied.

Table 4: Toxicity of Binary Combination of Some Potent Plant Ash with *Eugenia Aromatica* plant Powder for Lethality to Adult *S. Zeamais* at Different Dosages within 24 Hours

Plant ash with plant powder mixture (1:1)	Concentration/dosage (g)					
	0.2	0.4	0.6	0.8	1.0	Control
RHA+EAP	7.21±3.12b	8.57±3.76b	11.31±3.17bc	12.33±1.46bc	16.32±1.64c	0.00±0.00a
WSA+ EAP	5.20±4.17b	6.87±4.14b	9.17±3.12bc	11.53±1.52bc	13.17±6.19bc	0.00±0.00a
PFRA+EAP	8.31±1.26b	11.62±5.15bc	14.17±2.14bc	16.34±7.12bc	20.13±6.18c	0.00±0.00a

Mean follow by the same alphabet across the row are not significantly different from one another (p>0.05) using Duncan Multiple Range Test (DMRT).

The toxicity of the binary combinations of agro-plant ashes and *Eugenia aromatica* against adult *Sitophiluszeamais* after 48 hours of exposure is presented in table 5. In all, mortality increased significantly (p>0.05) with increasing dosage in all treatment combinations, whereas no mortality was observed in the untreated control.

Palm fruit rind ash combined with *E. aromatica* plant powder (PFRA + EAP) remained the most effective treatment, with a significant (p>0.05) increase in mortality ranging from 13.14% at 0.2 g to 33.31% at 1.0 g, followed by Rice husk ash combined with *E. aromatica* (RHA + EAP) which recorded intermediate mortality values ranging from 9.24% at 0.2 g to 21.12% at 1.0 g, while walnut shell ash combined with *E. aromatica* (WSA + EAP) recorded a significantly (p>0.05) lower mortality, ranging from 5.20% at 0.2 g to 13.17% at 1.0 g. The results indicate a positive relationship between dosage and insect mortality after 48 hours of exposure.

Table 5: Toxicity of Binary Combination of Some Potent Plant Ash with *Eugenia Aromatica* plant Powder for Lethality to Adult *S. Zeamais* at Different Dosages within 48 Hours

Plant ash with plant powder mixture (1:1)	Concentration/dosage (g)					
	0.2	0.4	0.6	0.8	1.0	Control
RHA+ EAP	9.24±1.32b	11.47±6.16b	14.54±6.17bc	18.67±1.46c	21.12±2.17cd	0.00±0.00a
WSA+ EAP	5.20±4.17b	6.87±4.14b	9.17±3.12bc	11.53±1.52bc	13.17±6.19bc	0.00±0.00a
PFRA+ EAP	13.14±1.27b	16.67±2.61bc	23.17±1.16c	28.31±2.42d	33.31±1.47e	0.00±0.00a

Mean follow by the same alphabet across the row are not significantly different from one another (p>0.05) using Duncan Multiple Range Test (DMRT).

Toxicity of the binary combinations of agro-plant ashes and *Eugenia aromatic* plant powder against adult *Sitophiluszeamais* after 72 hours of exposure is presented in table 6. In all adult mortality increased significantly (p>0.05) with increasing dosage across all treatments, when compared with untreated control which recorded no mortality.

Palm fruit rind ash combined with *E. aromatic* plant powder (PFRA + EAP) recorded a significantly (p>0.05) higher mortality at all dosage levels, having 86.31% at 1.0 g. Rice husk ash combined with *E. aromatica* (RHA + EAP) also showed high insecticidal activity, with mortality increasing from 29.74% at 0.2 g to 59.72% at 1.0 g, while walnut shell

ash combined with *E. aromatic* plant powder(WSA + EAP) recorded a significantly (p>0.05) lower mortality values ranging from 22.17% at 0.2 g to 55.37% at 1.0 g. In all, mortality increased significantly (p>0.05) with increased in dosage and exposure time in all treatment combinations.

Table 6: Toxicity of Binary Combination of Some Potent Plant Ash with *Eugenia Aromatica* plant Powder for Lethality to Adult *S. Zeamais* at Different Dosages within 72 Hours

Plant ash with plant powder mixture (1:1)	Concentration/dosage (g)					
	0.2	0.4	0.6	0.8	1.0	Control
RHA+EAP	29.74±2.12b	31.47±3.17b	41.14±6.15c	50.17±1.64d	59.72±1.67e	0.00±0.00a
WSA+EAP	22.17±3.16b	27.37±1.24c	38.67±5.72d	43.53±1.52e	55.37±3.20f	0.00±0.00a
PFRA+EAP	39.34±1.17b	42.34±1.67bc	54.19±1.13c	74.23±1.43d	86.31±1.67e	0.00±0.00a

Mean follow by the same alphabet across the row are not significantly different from one another (p>0.05) using Duncan Multiple Range Test (DMRT).

Toxicity of the binary combinations of agro-plant ashes and *Eugenia aromatic* plant powder against adult *Sitophiluszeamais* after 96 hours of exposure is presented in table 7. Adult mortality increased significantly (p>0.05) with increasing dosage across all treatments, while no mortality was observed in the untreated control.

Palm fruit rind ash combined with *E. aromatica* (PFRA + EAP) had a significantly (p>0.05) higher mortality of 100% at 0.8 g and 1.0 g. Rice husk ash combined with *E. aromatica* (RHA + EAP) also exhibited high insecticidal activity, with mortality increasing from 63.14% at 0.2 g to 98.12% at 1.0 g. Walnut shell ash combined with *E. aromatica* (WSA + EAP) recorded mortality values ranging from 58.21% to 89.37%. These results demonstrate that prolonged exposure and higher dosages enhanced the efficacy of all treatment combinations.

Table 7: Toxicity of Binary Combination of Some Potent Plant Ash with *Eugenia Aromatica* plant Powder for Lethality to Adult *S. Zeamais* at Different Dosages within 96 Hours

Plant ash with plant powder mixture (1:1)	Concentration/dosage (g)					
	0.2	0.4	0.6	0.8	1.0	Control
RHA+EAP	63.14±1.32b	65.17±2.37b	71.24±3.35c	87.17±1.34d	98.12±2.17e	0.00±0.00a
WSA+EAP	58.21±2.76b	61.47±1.27bc	68.17±2.17c	78.19±2.12d	89.37±1.24e	0.00±0.00a
PFRA+EAP	71.24±2.67b	73.84±1.27bc	88.17±1.12c	100.00±0.00d	100.00±0.00d	0.00±0.00a

Mean follow by the same alphabet across the row are not significantly different from one another (p>0.05) using Duncan Multiple Range Test (DMRT).

The toxicity of binary combinations of agro-plant ashes and *Eugenia aromatica* plant powder against adult *Sitophiluszeamais* after 120 hours of exposure is presented in table 8. Mortality increased significantly (p>0.05) with increasing dosage across all treatment, while untreated control recorded no mortality.

Palm fruit rind ash combined with *E. aromatica* plant powder (PFRA + EAP) had a significantly (p>0.05) higher mortality of 97.17% at 0.2 g and 100% mortality at 0.4 g to 1.0 g. Rice husk ash combined with *E. aromatica* (RHA + EAP) and walnut shell ash combined with *E. aromatica* (WSA + EAP) also produced complete mortality at the higher dosages of 0.8 g and 1.0 g. The binary combinations became more effective with increasing dosage and exposure period, resulting in almost complete and complete mortality of adult *Sitophiluszeamais* at the higher application rates.

Table 8: Toxicity of Binary Combination of Some Potent Plant Ash with *Eugenia Aromatica* plant Powder for Lethality to Adult *S. Zeamais* at Different Dosages within 120 Hours

Plant ash with plant powder mixture (1:1)	Concentration/dosage (g)					
	0.2	0.4	0.6	0.8	1.0	Control
RHA+EAP	78.21±1.27b	83.67±1.34c	98.14±2.15d	100.00±0.00e	100.00±0.00e	0.00±0.00a
WSA+EAP	70.37±1.76b	79.17±1.67c	97.16±1.67d	100.00±0.00e	100.00±0.00e	0.00±0.00a
PFRA+EAP	97.17±1.61b	100.00±0.00c	100.00±0.00c	100.00±0.00c	100.00±0.00c	0.00±0.00a

Mean follow by the same alphabet across the row are not significantly different from one another (p>0.05) using Duncan Multiple Range Test (DMRT).

Discussion

The results obtained from this study showed that agricultural plant ashes and their binary combinations with *Eugenia aromatica* flower bud powder possess potent insecticidal properties on the survival of *Sitophiluszeamais* at different dosage. The progressive increase in adult mortality of *Sitophiluszeamais* observed across all treatments, may be as result of the inability of the weevil to move freely and unable to feed on the maize coated with these treatments thereby leading to starvation (Adedire*et al*. 2011; Idoko and Ileke2020; Ileke*et al.* 2020a), and death through desiccation. Among the sole treatments evaluated, palm fruit rind ash and walnut shell ash emerged as the most lethal, consistently achieving a significantly ($p < 0.05$) higher mortality rates across exposure times and dosages. At the lowest dosage of 0.2 g, both palm fruit rind ash and walnut shell ash achieved 73.33% mortality after 120 hours of exposure, which increased significantly ($p < 0.05$) at a 0.6 g dosage. Rice husk ash also exhibited substantial bio efficacy achieving 81.67% mortality at 0.6 g, the high mortality inflicted by rice husk could be attributed to the high silica content in it because silica has been reported as being insecticidal (Khot*et al.,* 2012). Conversely, cocoa pod shell ash (derived from *Theobroma cacao*) was consistently the least lethal among the

ashes, though still produced a significant mortality rate of 61.67% at the 0.6 g dosage.

The high potency of these agricultural ashes, particularly palm fruit rind ash, walnut shell ash, and rice husk ash, might be largely attributed to its toxic properties causing desiccation of the insects' cuticle as suggested by Tadesse and Basedow (2005). Plant and wood ashes function primarily as inert dusts. Rice husk ash, for instance, contains an extremely high amorphous silica content, while palm fruit rind ash and walnut shell ash are highly alkaline due to rich deposits of potassium, magnesium, and calcium oxides (Otitodun *et al*., 2017; Olaoye, 2019). When *Sitophiluszeamais* adults come into contact with these fine, abrasive particles, the dust mechanically abrades the protective lipid-rich epicuticular wax layer of the insect's exoskeleton. This cuticle damage disrupts the weevil's water-retention capability, causing rapid, fatal desiccation through uncontrolled transpiration (Stathers*et al*., 2008; Fening*et al*., 2015). Additionally, these micro-fine particles physically block the spiracles (respiratory openings) of the insects, leading to oxygen deprivation, asphyxiation, and a drastic reduction in metabolic activity (Suleiman, Rosentrater, 2015). The accumulation of ash in the intergranular spaces also acts as a physical barrier that restricts the mobility, mating, and host-finding behavior of the adult weevils, preventing them from accessing the endosperm of the *Zea mays* kernels to lay eggs (Ewete, 2007; Trematerra*et al*., 2013).

The incorporation of *Eugenia aromatica* plant powder with the three most potent ashes in a binary (1:1) mixture drastically enhanced the speed and efficacy of the insecticidal treatments. The combination of palm fruit rind ash and *Eugenia aromatica* plant powder consistently yielded a significantly ($p < 0.05$) higher mortality across all dosage levels and evaluation intervals. Within 24 hours of exposure, the binary mixture achieved mortalities ranging from 8.31% at 0.2 g to 20.13% at 1.0 g, which further increased to 13.14% and 33.31%, respectively, after 48 hours. This accelerated mortality trend demonstrates a highly positive synergistic relationship between the physical desiccant action of the mineral ashes and the rapid neurotoxic chemical pathways triggered by the botanical powder. The exceptional performance of the binary mixtures containing *Eugenia aromatica* is driven by its major volatile constituent, eugenol (Ileke, Oni, 2011). Eugenol acts as a rapid neurotoxin in insects by targeting their octopaminergic system and inhibiting acetylcholinesterase activity, leading to hyperexcitation, paralysis, and swift mortality (Adarkwah*et al*., 2017).

Because of its high volatility, *Eugenia aromatica* also exerts a strong fumigant action within the enclosed storage containers, enabling it to penetrate grain spaces and reach adult weevils effectively (Olotuah, 2013). Furthermore, while the abrasive particles of the ashes compromise the cuticle of *Sitophiluszeamais*, they increase the insect's vulnerability to the chemical penetration of the bioactive botanical compounds (Fayemiro and Abdul, 2024). This dual-action mechanism where physical desiccation by the ash and rapid neurotoxicity by the *Eugenia aromatica* powder occur concurrently represents a highly formidable defense system.

CONCLUSION

Agricultural waste ashes represent highly effective, environmentally friendly, and cost-efficient bio-rational alternatives for protecting stored *Zea mays* against devastating infestations by *Sitophiluszeamais*, they present antifeedant characteristics. Combining plant ashes with plant powder in mixture significantly accelerates adult mortality. This approach successfully repurposes discarded local agricultural by-products to secure critical grain reserves while entirely eliminating the ecological and health hazards associated with synthetic chemical protectants.

REFERENCES

Abass A.B., Fischler M., Schneider K., Daudi S., Gaspar A., Rüst J., Kabula E., Ndunguru G., Madulu D., Msola D. (2018): On-farm comparison of different postharvest storage technologies in a maize farming system of Tanzania Central Corridor. *Journal of Stored Products Research* 77: 55–65. https://doi.org/10.1016/j.jspr.2018.03.002

Abolusoro O.P, Moshibudi C.K., Washington W. Mechanical and microstructural characteristics of recycled aluminium matrix reinforced with rice husk ash [J]. *AIMS Materials Science*, 2024, 11(5): 918-934. doi: 10.3934/matersci.2024044

Adediran, J., Taiwo, L.B.,Akande, M., Sobulo, R.A. Application of Organic and Inorganic Fertilizer for Sustainable Maize and Cowpea Yields in Nigeria*Journal of Plant Nutrition* 27(7):1163-1181DOI:10.1081/PLN-120038542

Adesina J.M. Effectiveness of*Sennaoccidentalis*(L.) leaves powder in reducing F1 progeny development and seed damage by*Sitophiluszeamais Mots. (*Coleoptera: Curculionidae) in Stored Maize*. Intl. J. Appl. Res. Tech. 2012; 1:100–105.*

Affognon H., Mutungi C., Sanginga P., Borgemeister C. (2015): Unpacking postharvest losses in sub-Saharan Africa: a meta-analysis World Develop. 66: 49–68. https://doi.org/10.1016/j.worlddev.2014.08.002

Afolabi, M. S., Murtadha, M. A., Lamidi, W. A., Waheed, J. A. A., Salami, A. E., & Bello, O. B. (2020). Evaluation of yield and yield components of low n maize (zea mays l.) varieties under low and high nitrogen conditions. *African Journal of Agricultural Research*, 15(1), 66-72.

Doebley, J. 2004 seminal review article, "The Genetics of Maize Evolution," published in the *Annual Review of Genetics* (Vol. 38, pp. 37–59),

Fayemiro, S. S. and Abdul, K. O. (2024) Investigation of combined effect of three plant powders with diatomaceous earth against *Callosobruchusmaculatus. Journal of agripreneurshipand sustainable development* (JASD) 7(3), 2651-6365.

Fajinmi A, Fayemiro SS, Okonji C, Fajinmi OB Protectant effects of *Eugenia aromatica* and *Piper guineense* against *Callosobruchusmaculatus*. *Tropical Agriculture*, 2015; 92 (1):27-34

Hamel, D., Rozman V., Liška A. (2020): Storage of cereals in warehouses with or without pesticides. Insects 11: 846. http://dx.doi.org/10.3390/insects11120846

Ifie, S. E., Dangana, R.S., Swase, D., Ben Okon, M., Makena, W., Agunloye, M. O., Ugwu, C. N., Ifie, J.E., Odoma, S., Babangida, A.I.,& Aja P.M. Nutritional composition of *Zea mays* L: A comprehensive review of macronutrients, micronutrients, and bioactive compounds *Open Research Africa*, 8 (2025), p. 15

Ileke K.D., Adesina J.M., Obajulaye E.O. Synergetic effects of two botanicals entomocides as pest-protectants in maize grains. *J. Biol. Res.* 2016; 89(2):33–39.

Kumar D., Kalita P. (2017): Reducing postharvest losses during storage of grain crops to strengthen food security in developing countries. Foods 6: 8. https://doi.org/10.3390/foods6010008

Marta, H. E., Suryadi, E., &Ruswandi, D. (2017). Chemical composition and genetics of Indonesian maize hybrids. *American Journal of Food Technology*, 12(2), 72–85

Nwosu L.C., Adedire C.O. Ogunwolu E.O. (2015): Feeding site preference of Sitophiluszeamais (Coleoptera: Curculionidae) on maize grain. *International Journal of Tropical Insect Science* 35: 62–68. DOI: https://doi.org/10.1017/S1742758415000065

Odendo, M., De Groote, H., &Odongo, O. M. (2001). Assessment of farmers' preferences and constraints to maize production in Moist Midaltitude Zone of Western Kenya. *Paper presented at the 5th international conference of the African crop science society*, Lagos, Nigeria.

Prasanna BM, Palacios-Rojas N, Hossain F. (2020c) Molecular breeding for nutritionally enriched maize: status and prospects. *Front Genet* 10:1392. https://doi.org/10.3389/fgene.2019.01392

Ranum, P., Peña-Rosas, J. P., & Garcia-Casal, M. N. (2014). Global maize production, utilization, and consumption. *Annals of the New York Academy of Sciences, 1312*, 105–112. https://doi.org/10.1111/nyas.12396

Rouf, S., Tajamul& Prasad, Kamlesh& Kumar, Pradyuman. (2016). Maize a potential source of human nutrition and health: A review. *Cogent Food & Agriculture. 2*. 10.1080/23311932.2016.1166995

Shiferaw, B., Prasanna, B. M., Hellin, J., &Bänziger, M. (2011). Crops that feed the world 6: Past successes and future challenges to the role played by maize in global food security. Food Security, 3(3), 307–327.

Tefera, T., Mugo, S., Likhayo, P., &Beyene, Y. (2011). Resistance of three-way cross experimental maize hybrids to post-harvest insect pests, the larger grain borer (prostephanustruncatus) and maize weevil (sitophiluszeamais). *International Journal of Tropical Insect Sciences*, 63(1–2), 3–12.

Van Duong N., Khanh L.Q., Xuan B.T., Hung C.T. Que L.X. (2020): Using oxygen depletion to maize weevils without chemicals in a storage minienvironment. *Vietnam Journal of Chemistry* 58: 327–332. https://doi.org/10.1002/vjch.2019000168

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