

INSECTICIDAL EFFICACY OF DIFFERENT SOURCES OF BOTANICALLY DERIVED ASH AS A GREEN PROTECTANT OF STORED MAIZE SEED AGAINST MAIZE WEEVIL (*SITOPHILUS ZEAMAI*) INFESTATION SUPPRESSION

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ABSTRACT

*For several decades, insect infestation has been a major problem associated with the storage of surplus food grains, thereby threatening food security and self-sufficiency. Plant powder insecticides have yields accomplished green insecticides. The present study was conducted to evaluate the effect of different botanical ash sources in the control of *Sitophilus zeamais* on infested maize seeds (*Zea mays* L). The experiment comprised 10g each of four botanical ash sources; citrus lemon leaf, *Azadirachta indica* leaf, *Cymbopogon citratus* leaf and palm bunch ashadmixed with 100g maize seeds and untreated (control) in a one-litre jar, replicated six (6) times in a Completely Randomised Design. The results revealed that adult mortality, progeny emergence, exit holes and grain damage were inversely proportional to the botanical ash applied in relation to the untreated maize seeds. Adult mortality is exposure time-induced, and across the exposure time, *C. citratus* and *A. indica* leaf ashes exhibited the highest significant percentage mortality. However, progeny emergence was not significantly different between the ash sources, and the percentage of grains damaged by *C. limon* and *A. indica* leaf ash was statistically equal at 80%. All treatments showed statistically significant differences ($P < 0.05$) in terms of germination percentage, with untreated maize seeds having the lowest germination rate (10%), whereas palm bunch ash-treated maize seeds had the highest germination rate (75%). From the study, *C. citratus* leaf and *C. limon* leaf ashes displayed significant toxicity against *S. zeamais**

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as compared with the control. Thus, qualify as potential stored product botanical pesticides for incorporation into integrated pest management tactics in suppressing S. zeamais infestation and maize seed damage. Further investigation is recommended for the isolation and identification of the bioactive compounds responsible for the toxic nature of the ash sources.

KEY WORDS: ash sources, germination rate, progenies emergence, *Sitophilus zeamais*, toxicity

INTRODUCTION

Maize weevil *Sitophilus zeamais* Motschulsky (Coleoptera: Curculionidae) is one of the most important maize storage insect pests in tropical and subtropical regions (Holst *et al.*, 2000). The initial infestation most often occurs in the field, and the prevailing environmental conditions in traditional storage systems favour the survival, reproduction, and adult weevil emergence, causing considerable economic losses of stored grain, ranging from 20% up to 90% (Ojo & Omoloye, 2012). Thus constitute a major drawback in maize production as the insect pest attacks maize on the field and during storage (Ovharhe *et al.*, 2021) and poses a threat to food security in developing countries (Onuminya *et al.*, 2018) where improved storage facilities are practically unavailable or inadequate.

The weevil, being an internal feeder, damages the grain by boring a hole and laying eggs inside the grain (Paes *et al.*, 2012; Adesina, 2024). The larvae feed internally, making the grain unfit for human consumption. The weevils' feeding activity results in qualitative, nutritive, and weight losses, reduction in grain germination capability, and low market value (Ukeh *et al.*, 2012; Napaleao *et al.*, 2013; Wini *et al.*, 2015). In addition, the insect infestation leads to increased grain humidity and temperature, hence, eases mould development as well as various toxigenic species such as *Aspergillus flavus* (Chu *et al.*, 2013; Sujata *et al.*, 2019).

Despite the acknowledged negative effects of synthetic insecticides and fumigants, such as health hazards, development of resistant insect pest strains, negative environmental impacts, and their toxic residues contamination of food grains with toxic residues. It remains the most utilised control tactic employed by farmers, grain merchants and processors owing to its quick knockdown effect. These drawbacks of synthetic insecticides have stimulated rigorous exploration of alternative approaches to protect stored maize that minimise health risks and ecological problems (Obeng-Ofori, 2007; Adesina, 2022). This has led to the use of insecticidal plant resources readily available in local biodiversity (Gueye *et al.*, 2012) to solve storage insect pest infestation problems.

The utilisation of plant-based products like ash is one of the well-studied substitutes to conventional neurotoxic grain protectants because of its numerous distinct benefits. Many authors have documented the insecticidal potential of ashes as a grain protectant. Joseph *et al.* (2018) and Akinwumiju *et al.* (2024) reported that rice husk ash provides a significant economic advantage as a protectant against maize weevil. Wood ash from *Acacia polyacantha* and *Hymenocardia acida* caused significant reduction of progeny emergence, damaged grains and weight loss against *S. zeamais* (Wini *et al.*, 2015; Monday *et al.*, 2018; Goudoungou *et al.*, 2018). Abdulbaki *et al.* (2022) also reported the bioactivity potential of Bamboo leaf ash for the management of *S. zeamais* under laboratory conditions. Idoko *et al.* (2024) recorded success in the exploitation of *O. sativa* husk ash, *Zingiber officinale* stem ash, and *Arachis hypogaea* pod shell ash in the mitigation of damage to stored grain by *Callosobruchus maculatus*, *S. zeamais* and *Tribolium castaneum*. While Sulaiman (2022) reported the efficacy of cow dung ash in completely suppressing F1 *S. zeamais* progeny emergence. Since insecticidal properties of ashes vary according to the plant types and their bioactive chemical components, the evaluation of ash from various sources may lead to the identification of additional active ash, which may be applied in the preservation of food grains against storage insect infestation and damage. Therefore, this experiment was formulated to assess the efficacy of ash of some selected plant materials as a substitute for synthetic insecticides and fumigants for the control of maize weevil (*Sitophilus zeamais* Motschulsky) in stored maize grain to obtain high-quality stored grains.

MATERIAL AND METHOD

Experimental condition and location

The experiment was carried out under prevailing laboratory conditions of 65-70% R.H and 29-32°C in the Entomology laboratory of the Department of Pest Management Technology, Federal College of Agriculture, Ishiagu, Ebonyi State (Latitude 05°46'N and Longitude 07°41'E).

Collection and preparation of botanical ash

The botanicals evaluated for insecticidal efficacy: *Citrus limon* leaves, *Azadirachta indica* (Neem) leaves, *Cymbopogon citratus* leaves and oil palm bunches were sourced from within the premises of Federal College of Agriculture, Ishiagu, Ebonyi State, Nigeria. The identity of the plant materials was confirmed at the Federal College of Forestry Resource Management, Ishiagu, Ebonyi State, Nigeria, Herbarium, where voucher samples were deposited. The materials were sorted and washed with

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borehole water to remove dust and dirt particles. The botanicals were air-dried at room temperature until complete dryness, and separately placed in the muffle furnace at 550 °C and heated for 3 hours to produce ash (Suleiman, 2022; Akinwumiju *et al.*, 2024). The ash collected from each plant species, on cooling, was pulverised into fine powder and stored in a cool, dry place at room temperature in a tightly sealed container separately to prevent quality and active ingredient loss until needed for bioassay (Chayengia *et al.*, 2010; Wini *et al.*, 2015).

Mass culturing of Sitophilus zeamais

Adult *S. zeamais* were obtained from infested maize grains purchased from the Eke market, Ishiagu. This was introduced into jars containing uninfested maize grains under ambient laboratory conditions to develop, in order to obtain adult insects of the same age group and quantity of adult weevils for the experiment (Barre & Jenber, 2022). After the introduction of weevils, the jars were enclosed with fine mesh cloth fastened with a rubber band to minimise the chances of weevils escaping and to facilitate ventilation for copulation and oviposition (Ali & Rashid, 2022). After two weeks of introduction, the adult insects were removed by sieving out, and the culture was kept under prevailing laboratory conditions until the appearance of F1 progeny (Sani & Suleiman, 2017). The newly emerged adult weevils (5-10 weeks old) were used for the experiment.

Bioassay of insecticidal potential of botanical ashes in suppressing Sitophilus zeamais infestation and grain damage

Maize seeds with no history of insecticide use for the bioassay were sourced from the College Research Farm. The maize grains were thoroughly cleaned, and grains showing any kind of damage were discarded. They were subsequently sun-dried for a week to ensure a safe moisture content level and packed in polyethene bags before being decontaminated in a deep freezer for 2 weeks to ensure the absence of insects or eliminate any hidden insect developmental stages. The decontaminated grains were allowed to equilibrate to the ambient temperature in the laboratory before use (Sujata *et al.*, 2019).

A one-litre plastic jar filled with 100 g of decontaminated maize, and 10 g of each botanical ash was thoroughly mixed with the grains to ensure a good and uniform distribution of the ash. Ten unsexed newly emerged adult maize weevils from the culture were released into each jar with the aid of a small camel-hair brush. An additional jar was prepared with no plant ash as a check (control). Each plastic jar containing treated maize grains, control and weevil adults was firmly covered to

prevent weevils from escaping. The experiment was arranged on the laboratory table in a completely randomised design with five replications of each botanical ash treatment.

The adult mortality was observed daily for 3 days at intervals of 24 hours after infestation. An insect is confirmed dead if the insects did not respond when poked with a sharp object (Adesina & Aderibigbe, 2021). The dead adults were counted and discarded, while the live adults were left in the dish. The percentage of adult mortality was determined by counting the number of dead insects divided by the total number of insects introduced, multiplied by 100.

At the end of 40 days of storage, the contents of each jar were poured into a sieve, which allowed the weevils to pass through the sieve holes (Kadi Kadi *et al.*, 2025). Adults from the sieve were collected, counted and recorded as the number of adult emergence (F1 progeny). Removal of F1 progeny weevils was carried out after each count, and for 3 weeks, each F1 adult was counted once per week to eliminate generation overlap. To evaluate the most effective botanical ash in protecting treated grain against infestation and seed damage, damaged and undamaged seeds were counted from each dish at the end of the experiment. Seeds were considered damaged if they had a weevil emergence hole. The percentage of damaged seeds was calculated by counting the number of damaged seeds (seeds with adult emergence holes) divided by the total number of seeds multiplied by 100 (Wambugu *et al.*, 2009). The number of emergent holes was also determined by counting the number of adult exit holes on the grains in the dishes.

Seed Germination Determination

Twenty seeds randomly selected from each treatment and control were placed on cotton wool moistened with water in a plastic dish under ambient laboratory conditions suitable for germination, replicated five times. After 48 hours, the number of germinated seeds was counted, and the percentage germination was determined by counting the number of germinated seeds divided by the total number of seeds placed in the dish, multiplied by 100 (Ukeh *et al.*, 2011; Adesina & Aderibigbe, 2021).

Data Analysis

Analysis of variance (ANOVA) was carried out on data collected in accordance with the Completely Randomised Design technique. Least Significant Difference (LSD) was used to compare and differentiate significant treatment means. Every inference was drawn at a probability threshold of 5.0% (Williams & Abdi, 2010).

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RESULTS AND DISCUSSIONS

Effect of Different Sources of Ash on Mean Percentage Mortality of S. Zeamais on Stored Maize Grain

The mortality of *S. zeamais* treated with botanical ashes on stored maize grain is presented in Table 1. The result showed that there was a significant difference ($P<0.05$) among treatments in the number of hours during which *S. zeamais* were exposed to the treatments. At 24 hours of exposure, *C. citratus* ash recorded the significantly highest percentage mortality (69%), followed by *C. limon* and *A. indica* leaf ash at 10g (60%), respectively. Palm bunch ash recorded 59% mortality, while untreated (control) grains had zero percentage mortality (0.00%). Similarly, at 48 hours of exposure, untreated (control) recorded the lowest mortality (40%). While *C. limon* and *C. citratus* leaf ashes recorded the highest percentage mortality (78%), respectively, followed by *A. indica* leaf ash and palm bunch ash, which recorded 70% mortality. The highest percentage mortality (90%) at 72 hours was noted in the jars treated with *C. citratus* and *A. indica* leaf ash, followed by palm bunch ash and *C. limon* with 81 and 80% mortality, respectively, while the control recorded zero mean percentage mortality.

TABLE 1: Mean Percentage mortality of *S. zeamais* treated with different sources of Leaf ash on stored Maize grains

Treatments	Observed hours		
	24h (%)	48h (%)	72h (%)
<i>Citrus limon</i> leaf ash 10 g	60.00	78.00	80.00
<i>Cymbopogon citratus</i> ash 10g	69.00	78.00	90.00
<i>Azadirachta indica</i> leaf ash 10g	60.00	70.00	90.0
Palm bunch ash 10g	59.00	70.00	81.00
Control	0.00	40.00	70.00
LSD	0.67	1.42	1.63

LSD = Least Significant Difference

Effect of Different Sources of Botanical Ash on Mean Progeny Emergence of S. Zeamais

The result showed that the botanical ash source exhibited a significant ($P<0.05$) reduction in progeny emergence compared to the untreated grains. Untreated (control) recorded significantly the highest progeny emergence (25.00), followed by palm bunch ash (18.00). Ashes obtained from *A. indica* leaf ash (13.00), *C. citratus* leaf ash (12.00), and *C. limon* leaf ash had the least (11.00) progeny emergence.

Statistical analysis revealed that the progenies' emergence was not significantly different when compared.

TABLE 2: Progeny emergence, emergent exit hole and percentage grain damage by *S. zeamais* treated with different sources of botanical ash powder

Treatments	Emergent Exit hole (%)	Mean Progeny Emergence	% Grain damages
<i>Citrus limon</i> leaf ash 10 g	8.00	11.00	80.00
<i>Cymbopogon citratus</i> ash 10g	6.00	12.00	60.00
<i>Azadirachta indica</i> leaf ash 10g	8.00	13.00	80.00
Palm bunch ash 10g	9.00	18.00	90.00
Control	9.50	25.00	95.00
LSD	1.33	1.40	2.80

LSD = least significant difference

Toxicity Effect of Different Sources of Botanical Ash on the Number of Adult Emergent Holes and Percentage Grain Damages by *S. Zeamais*

The untreated maize seeds have the highest number of adult emerging holes (9.50) (Table 2). This did not, however, differ substantially from the emergent holes found in maize treated with *A. indica* ash (8.00), *C. limon* leaf ash (9.0), and palm bunch ash (9.0). Among the various sources of botanical ash, *C. citratus* leaf ash with 6.00 adult emerging holes had the least number of adult emergent holes (Table 2). When compared to untreated grains, the various botanical ash sources substantially lowered grain damage (Table 2). Research results showed that the leaf ash of *C. citratus* caused the least amount of grain damage (60%). The percentage of grains damaged by *C. limon* and *A. indica* leaf ash was statistically equal at 80%. However, compared to the percentage of grains damaged by *C. citratus* leaf ash, palm bunch ash, and untreated grains, which had the highest percentage of damaged grains (Table 2), the percentage of damaged grains was significantly different.

Percentage Germination of Maize Seeds Treated with Different Sources of Leaf Ash

Figure 1 results demonstrate that germination was not considerably hampered by the various types of botanical ash. However, untreated maize seeds had the lowest germination rate (10%), whereas palm bunch ash-treated maize seeds had the highest germination rate (75%). Seed germination rates were 60% for *C. limon* leaf and 60% for *A. indica* leaf ash, with 32% for maize seeds derived from *C. citratus* leaf ash

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coming in second. All the treatments showed statistically significant differences ($P < 0.05$).

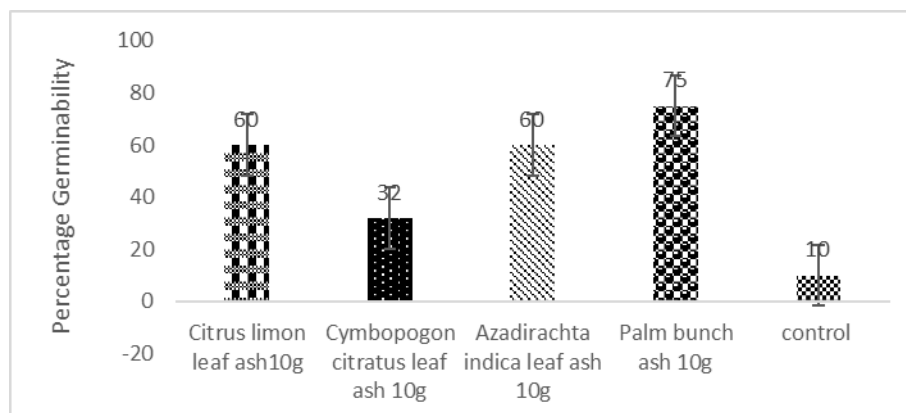


FIG 1. Percentage germinability of maize seeds treated with different sources of botanical ash

Maize is the third most important cereal grain after wheat and rice worldwide (Golob *et al.*, 2004) and one of the two most important cereals in Nigeria (Akinwunmiju *et al.*, 2024). It is one of the major staple foods in Sub-Saharan Africa (Ekpa *et al.*, 2018), including Nigeria. Post-harvest loss due to insect infestation is a major setback to successful food grain storage and availability. Many authors have reported that ash from various plant materials restricts infestation and suppresses damage and acts as a grain protectant (Akob & Ewete, 2007; Ofuya & Adler, 2014; Otitodun *et al.*, 2017).

The application of different botanicals ash killed adult weevils in varying proportions because the ashes might have acted as a physical barrier between weevils and grains. Also, the ash tends to block the insect spiracles, thus impairing respiration and leading to their death. This assertion supports Olawale (2020) and Athanassiou and Steenberg (2007), who specified that bamboo leaf ash kills adult *S. zeamais* by absorption of the epicuticular wax of the insect, leading to dehydration and death. The high insecticidal values detected in the study can be attributed to particle sizes of the ashes, which increase the area of contact between the ash particles and insect cuticle (Otitodun *et al.*, 2015). In addition, the exerted mortality might be associated with the enormous amount of incapacitating bioactive chemical compounds present in the

botanical sources. Thereby, confirming the insecticidal potentials of the various botanical ashes evaluated in the presented study. This established the findings of many authors who had reported the insecticidal activities of the different plant materials used to produce the ashes (Ogbedeh *et al.*, 2019; Barre & Jenber, 2022; Hassan *et al.*, 2023; Nurhajijah *et al.*, 2024; Kato-Noguchi & Kato, 2025; Memadji-Lo Allah *et al.*, 2025; Mukesh, 2025).

Regarding the potential killing effect of the botanical ashes, the study revealed that mortality is exposure time-induced and across the exposure time, *C. citratus* and *A. indica* leaf ashes exhibited the highest significant percentage mortality days the insects were in contact with the treated grains. Mortality of adult weevils due to admixture of ash indicated longer exposure periods are needed to achieve appreciable management of *S. zeamais* on stored maize grains. The general adult mortality increased as exposure time increased for all the botanical ash treatments. This is in accordance with Suleiman *et al.* (2012); the length of exposure has a clear correlation with the increase in mortality associated with *C. sinensis* treatment. Athanassiou *et al.* (2005) opined that exposure time is decisive for the efficacy of botanical powder/ash, since insects' movement increases the contact of the cuticle with botanical particles. This disproves the position of Ntonifor *et al.* (2011), who conveyed loss of effectiveness of plant leaf powder after a period of time.

The result of this study demonstrates that all the test ashes have potentials of suppressing progeny production by *S. zeamais*, reduce adult emergence holes and lower seed damage. The effect of these ashes on both adult emergence, emergence holes of *S. zeamais* and seed damage was significantly different among the treatments and the control (untreated), although the plant materials' effectiveness varies among the botanical sources. Gwinner *et al.* (1996) established that the insecticidal effect of ash varies according to the type of ash. Accordingly, leaf ash treatments of *C. citratus* and *A. indica* leaf ash were superior in reducing the production of the progeny, suppressing adult emergence holes and seed damage. The high reduction in progeny emergence, adult emergent holes and seed damage in maize seeds admixed with the ash might result from high percentage adult mortality, ovicidal and larvicidal properties of the tested leaf ash due to its bioactive chemical constituents. This aligns with the position of Abdulbaki *et al.* (2022), Barre and Jenber (2022) and Ibrahim *et al.* (2012). Aweke *et al.* (2020) reported that neem seed powder effectively mitigates the adult emergence of various stored grain insect pests.

The reduced adult emergence observed in the study suggested that oviposition inhibition and larvicidal properties of botanical ashes on adult bruchids, which reduce

insect movement and sexual communication and prevent oviposition, make them lay fewer eggs and kill the larvae hatching from eggs laid on grains (Adesina & Ofuya, 2011; Adesina *et al.*, 2011). The coating of the seed coat with the botanical ash may also hinder the surviving adult insects from laying eggs on treated seeds. The botanical ash is suspected to possess ovicidal properties. Monika *et al.* (2024) declared that botanical powders or ashes decreased oviposition due to spiracle blockage, thus causing respiratory impairment that affects the insect body metabolism. Respiratory distress in insects can cause them to be less active, affecting their ability to move to suitable egg-laying sites or perform the physical actions required for oviposition.

The decrease in percentage weight loss of the grains with botanical ashes has high percentage mortality, the least F1 progeny, and emergent holes observed compared to untreated maize seeds that suffered the highest percentage weight loss, exit holes and lowest adult mortality. The decrease in percentage weight loss is directly proportional to the decrease in insect density. The reduced damage recorded by the botanical ashes is an indication of their efficacy against weevil infestation, with resultant suppression in adult emergence, which suppressed larval feeding and metabolic activities within the grain, culminating in fewer adult emergent holes (Adesina *et al.*, 2024). The difference in weight loss caused by the insect might be due to the dissimilarity of botanical ashes having different toxic ingredients.

In terms of seed germination, there was no significant difference ($P < 0.05$) between the botanical ash sources. The treatments showed varying percentage seed germination, with the lowest percentage of seed germination shown in the untreated seeds. This was related to the development of weevils. The seeds used for the germination test did not show any visible signs of adult emergence holes; however, they might contain the immature stages of weevils that could destroy the parts of the seed embryo. This translates to mean that the germination test in this study established that the botanical ashes did not show any adverse effects on the germination capacity of the seeds. This report contradicts G/Silassie and Getu (2009), who reported a non-significant difference between treated and untreated seeds in an investigation on the effect of botanicals on germination ability. However, the result agreed with the outcomes of Yeshaneh (2015), Adesina *et al.* (2019) and Anaele *et al.* (2025), who stated that utilisation of botanicals as grain protectants against storage insect pest infestation that could have eaten the embryo of the seeds did not hinder seed germination.

CONCLUSIONS

The botanical ash derived from *C. citratus* and *C. limon*, rather than the palm bunch, was found to possess strong insecticidal and ovicidal properties, significantly reducing the adult emergence of *C. maculatus*, which could be attributed to their chemical content. Thus, effective in protecting stored cowpea grains against *S. zeamais* infestation. This supported the statements, as reported by many authors, that applied botanical plant materials served as protection to prevent storage insects from causing damage to stored products or foods. The moderate toxicity exhibited by the botanical ash sources shows promise for their successful recommendation in integration and incorporation as integrated pest management (IPM) strategies in suppressing *S. zeamais* infestation against stored cowpea seeds. The isolation and identification of the bioactive molecules responsible for the toxic nature of the product should be carried out. In addition, the insecticidal activity of the different particle sizes of the ash source should be painstakingly evaluated.

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