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THE EFFICACY OF SELECTED PLANT POWDERS ON STORED MAIZE GRAINS AGAINST *SITOPHILUS ZEAMAIS* (MOTSCHULSKY) IN STORED MAIZE IN MAKURDI

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ABSTRACT

This study evaluated the insecticidal efficacy of cypermethrin and three botanical powders, *Azadirachta indica* (Neem), *Allium sativum* (Garlic), and *Afrostyrax lepidophyllus* against the maize weevil (*Sitophilus zeamais*). Parameters including cumulative mortality, F1 progeny emergence, grain damage, and weight loss were assessed at dosages of 3g, 5g, and 7g. Results revealed a clear hierarchy of efficacy ($p \leq 0.05$) with cypermethrin achieving 100% mortality and absolute suppression of progeny and grain damage by 5-7 days after treatment (DAT). Among the botanicals, *A. indica* was the most potent, reaching 82.45% mortality and reducing grain damage to 11.64% at the 7 g dosage. *A. sativum* showed moderate activity, while *A. lepidophyllus* was the least effective, with damage levels reaching 25.59%. Untreated controls exhibited severe degradation, including 56.45% grain damage and 33.42% weight loss. These findings demonstrate that while cypermethrin remains the most effective rapid intervention, *A. indica* and *A. sativum* serve as viable, dosage-dependent organic alternatives for the sustainable management of *S. zeamais* in stored maize.

Keywords: *Sitophilus zeamais*, *Azadirachta indica*, cypermethrin, progeny emergence, grain damage, stored maize, botanical insecticides.

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Introduction

The global population is projected to grow to about 9.1 billion by 2050, with the fastest growth happening in developing countries (FAO, 2013). Unfortunately, many of these countries are already struggling with hunger and food insecurity (Kitinoja *et al.,* 2011). According to Hodges *et al.*, (2011), about 70% more food will need to be produced to meet the needs of the growing population and support current production levels. Maize is one of the most widely grown cereal crops in West Africa, especially in Nigeria, where it is mainly cultivated during the rainy season. It is an important staple food in the region and is ranked as the fourth most preferred grain after sorghum, millet, and rice (FAO, 2019). Known scientifically as *Zea mays* L., maize is often called the "queen of cereals" because it can be used in many forms, from its early flowering stage to fully processed flour (FAO, 2020). It is considered an important food security crop in Africa, helping to address both present and future food shortages by providing a large share of the daily calorie intake (Nuss & Tanumihardjo, 2010)). Although maize is very important for food security and nutrition in many parts of the world, a large amount is still lost after harvest. These losses occur when pests feed directly on the grains, leave behind waste materials like shed skins, and reduce the weight and quality of the maize. This not only lowers its market value but also affects food security and the economy (Adarkwah *et al.,* 2018). On a global scale, maize is the third most important cereal crop, coming after wheat and rice in terms of importance (Ali and Rashid, 2022). Peasant farmers harvest large amounts of maize every year, often more than they can sell in the market. Unfortunately, a lot of this maize goes to waste because of poor storage conditions and attacks by insect pests like *Sitophilus* species. *Sitophilus zeamais* (maize weevil) is a field and storage pest of maize of economic importance in several parts of Africa (Olanrewaju *et al.,* 2024). The maize weevil (*S. zeamais*) is a common pest that damages maize both while it is still growing in the field and after it has been stored, and it is found in many parts of the world (Adedire, 2001).

The maize weevil is the main insect pest that affects stored maize and often causes serious losses after harvest during storage (Ileke *et al.,* 2020). Several control methods have been developed, and more are still being explored, to reduce the large losses that occur during storage. Chemical control has been especially effective in stopping damage caused by insects and other storage pests. These methods include fumigating stored produce with chemicals like carbon disulfide or phosphine, as well as applying insecticidal dusts such as malathion, carbaryl, pirimiphos-methyl, and permethrin (Ileke & Oni, 2011). According to Acharya, (2023), chemical pesticides are often non-selective, meaning they can affect more than just the target pests, and many are harmful to both the environment and human health. Over time, the continuous use of synthetic insecticides has proven to be unsustainable because it leads to environmental pollution, buildup of chemical residues in food, development of pest resistance, harm to beneficial organisms, and negative effects on human health and the ecosystem (Khan *et al.,* 2023). As a result, there is a growing need to find safer, more effective, and environmentally friendly alternatives for controlling pests in stored grains. In the search for safer alternatives to chemical pest control, research into bio-prospecting has intensified, enabling countries rich in natural resources to harness these potentials for improved and safer storage of agricultural products against insect pests, while also supporting economic development (Danho *et al.,* 2002). When proper storage structures and practices are lacking, the maize weevil becomes the most common problem affecting stored maize, leading to significant nutritional and economic losses for farmers often ranging from 20% to 40% (Rashid and Kurt, 2015). Hence, it became important to evaluate the use of botanical materials as a management option against maize weevil in Makurdi, Benue State.

Materials and Methods

Experimental Site

The experiment was carried out in the Department of Biological Sciences, Rev. Fr. Moses Orshio Adasu University, Makurd MOAUM, Benue Statem Nigeria. The study was designed to assess the toxicity of powdered leaves of *Azadirachta indica, Allium sativum* bulbs, *and Afrostyrax lepidophyllus* seed at different dosages (3, 5 and 7 g) against *Sitophilus zeamais* infesting stored maize grains. MOAUM is situated within Benue State, which is located in the North Central region of Nigeria, has a total population of 4,253,641 in the 2006 census, with an average population density of 99 persons per km^2. This makes Benue the 9th most populous state in Nigeria. However, the distribution of the population according to Local government areas shows marked duality.

Collection and Preparation of Botanicals and Insecticide

1 Test Plants

Leaves of *Azadirachta indica, Allium sativum* bulbs, *and Afrostyrax lepidophyllus* seed were selected based on their ethnomedicinal properties and local availability (Ogban *et al.,* 2015). The plant materials were collected from fields within Benue State. Each plant sample was washed separately to remove dirt and other impurities and then air-dried in a well-ventilated area for two weeks. After drying, the materials were ground into fine powders and sieved to obtain uniform particle size. The resulting plant powders were stored in clean, air-tight, opaque containers to preserve their effectiveness.

2 Synthetic Insecticide

Cypermethrin powder (Trade Name: Pestox, Ingredients: Cypermethrin 2.3%, Talc 97.5% and Fragrance 0.2%. Manufacturing date, 04-2025 and Expiry date, 12-2027) was bought from Appolos Agro Industrial Enterprises, Shop No. 5 Dabo Shops, along New Otukpo road, Makurdi, Benue State and stored in a cool dry place in the laboratory as directed by the manufacturer to effectively maintain its shelflife.

Test Insects and Maize Cultivar

Following a modified method described by Zakka *et al.* (2010), adult *Sitophilus zeamais* used in this study were initially obtained from infested maize grains and cultured for six weeks, after which only healthy adults were selected for the experiment. The maize cultivar employed was a local landrace sourced from freshly harvested cobs in Makurdi, Benue State, Nigeria. To prevent prior chemical or post-harvest interference, the maize grains were manually de-threshed and sun-dried for three weeks before being stored in airtight containers. The grains were subsequently disinfested by oven treatment at 60 °C for 5 hours to eliminate any hidden infestations. The cultured *S. zeamais* adults were maintained on the sterilized maize grains in a 20 L plastic container under ambient laboratory conditions. After seven days, the adults were removed by sieving, and the eggs laid were allowed to develop into F_1 progeny. This procedure ensured the availability of newly emerged adults of uniform age for the experiment.

Infestation Procedure

Treatments comprising 3.0 g, 5.0 g, and 7.0 g of powders derived from *Azadirachta indica* powder, *Allium sativum* powder, *Afrostyrax lepidophyllus* powder and Cypermethrin, were prepared. A control treatment without insecticide or botanical powders were replicated four times. All treatments were set up in fifty-two (52) glass jars (200 ml capacity), each containing 100 g of the maize cultivar. Twenty five (25) newly emerged (1-3 days old) adult *Sitophilus zeamais* were introduced into each jar. The jars were then left undisturbed on a laboratory workbench under ambient conditions.

Mortality Evaluation

The contents of each jar were gently transferred onto a transparent plastic tray for examination at 3, 5, and 7 days after treatment. The adult insects were then counted, distinguishing between live and dead individuals. Percentage mortality was corrected using Abbott's (1925) formula thus: Pc = $\frac{Po-Pe}{100-Pe} \times 100$

Where:

is the **corrected mortality** percentage.

Po is the **observed mortality** percentage in the treated group.

Pe is the **observed mortality** percentage in the control group (natural mortality).

Progeny Emergence

According to Walgenbach and Burkholder (1987), at 7 days after treatment, both live and dead insects were removed and discarded, and the maize grains were returned to their respective jars and left undisturbed to allow for F_1 progeny development. Adult weevils emerging from each treatment were counted five weeks after the removal of the initial insects to assess the effect of the treatments on reproduction (adult emergence test). Subsequently, newly emerged insects were sieved out daily to prevent mating and further oviposition, since mating in *Sitophilus zeamais* does not occur until approximately three days after emergence. The effects of the treatments on insect reproduction were evaluated using the reproductive potential deterrence formula:

Reduction in progeny = $\frac{Progeny\ control - Progeny\ treated}{Progeny\ control} \times 100$

Assessment of Grain Damage

At the end of the experiment, when no further progeny emergence was recorded, grain damage was evaluated for both treated and untreated samples. Grains were carefully examined and sorted into damaged (those with visible insect emergence holes) and undamaged categories. The total number and weight of grains in each category were then recorded for every treatment. Percentage infestation was finally determined using the formula below:

Percentage infestation = $\frac{\textbf{Number of damaged grains}}{\textbf{Total number of grains (Damaged+undamaged)}} \times 100$

% Weight loss = $\frac{Initial\ weight\ of\ grain - Final\ weight\ of\ grain}{initial\ weight\ of\ grain} \times 100$ (Lale and Ehisianya, 2001).

Statistical Analysis

The data collected on *Sitophilus zeamais* mortality, progeny emergence, weight loss, percentage damage, and seed viability were analyzed using one-way and two-way analysis of variance (ANOVA) in SPSS to determine if there were significant differences among treatments.

Results and Discussion

Mean Percentage Cumulative Mortality of *Sitophilus zeamais* in Maize Treated with Selected Plant Powders and Cypermethrin

The results show how cypermethrin and the three botanical extracts influenced insect mortality across different dosages and exposure periods, with clear differences that were statistically tested at $P \leq 0.05$. At 3 days after treatment (3 DAT), cypermethrin already recorded significantly higher mortality values of 75.88% (3 g), 77.23% (5 g), and 79.42% (7 g) compared to all botanical treatments ($P \leq 0.05$). In contrast, *Azadirachta indica* ranged from 29.25-38.75%, *Allium sativum* from 26.06–35.28%, while *Afrostyrax lepidophyllus* recorded the lowest values of 20.69-23.41%. The different superscript letters indicate that cypermethrin was significantly different from all plant extracts at this stage. By 5 DAT, cypermethrin achieved 100% mortality across all dosages (3, 5, and 7 g) and remained significantly higher ($P \leq 0.05$) than all other treatments. *Azadirachta indica* improved to 44.54-61.51%, *Allium sativum* ranged from 37.64-40.36%, while *Afrostyrax lepidophyllus* remained low at 25.32–28.31%. At this stage, the differences among the botanicals were also significant, as shown by the varying superscripts. At 7 DAT, cypermethrin maintained 100% mortality across all dosages, confirming its consistently superior performance ($P \leq 0.05$). *Azadirachta indica* recorded further increases to 75.62-82.45%, making it significantly more effective than the other plant extracts. *Allium sativum* showed moderate activity at 43.54-52.87%, while *Afrostyrax lepidophyllus* remained the least effective, with 30.36-34.96% mortality, significantly lower than the others in most cases.

Table 1: Mean Percentage Cumulative Mortality of *Sitophilus zeamais* in Maize Treated with Selected Plant Powders and Cypermethrin

DAYS AFTER TREATEMENT	DOSAGE(g)	CONTROL	CYPERMETRIN	*Azadirachta indica*	*Allium sativum*	*Afrostyrax lepidophyllus*
3	3	0.00(±0.00)	75.88(±0.67)^{a}	29.25(±0.40)^{b}	26.06(±3.62)^{bc}	20.69(±0.10)^{c}
	5		77.23(±2.47)^{a}	32.47(±2.51)^{b}	29.36(±0.62)^{b}	22.26(±1.32)^{c}
	7		79.42(±4.52)^{a}	38.75(±4.34)^{b}	35.28(±4.62)^{bc}	23.41(±3.34)^{c}
5	3	0.00(±0.00)	100.00(±0.00)^{a}	44.54(±1.23)^{b}	37.64(±7.45)^{bc}	25.32(±2.21)^{c}
	5		100.00(±0.00)^{a}	51.54(±7.45)^{b}	39.87(±4.51)^{c}	27.01(±3.47)^{c}
	7		100.00(±0.00)^{a}	61.51(±4.96)^{b}	40.36(±3.32)^{c}	28.31(±3.22)^{c}
7	3	0.00(±0.00)	100.00(±0.00)^{a}	75.62(±6.41)^{b}	43.54(±6.21)^{c}	30.36(±0.41)^{c}
	5		100.00(±0.00)^{a}	78.32(±2.25)^{b}	48.23(±0.42)^{c}	32.33(±3.25)^{d}
	7		100.00(±0.00)^{a}	82.45(±3.37)^{b}	52.87(±2.25)^{c}	34.96(±3.41)^{d}

Values are presented as mean ± standard deviation. Means followed by the same superscript letter(s) within the same row are not significantly different at $p \leq 0.05$ (post hoc test such as Tukey or Duncan).

Comparative Evaluation of Plant Powders and Cypermethrin on Progeny Emergence of *Sitophilus zeamais* in Stored Maize Grains

The results show that all the treatments had a significant effect on the progeny emergence of *Sitophilus zeamais* at $p \leq 0.05$, meaning the differences observed were not due to chance. At the 3 g dosage, the untreated maize (control) had the highest number of emerging insects with 55.34 ± 2.72, showing that the grains were highly susceptible to infestation when no treatment was applied. In contrast, cypermethrin completely suppressed emergence, recording 0.00 ± 0.00, and was significantly different from all other treatments. Among the plant powders, *Azadirachta indica* performed best with 6.56 ± 1.40, followed by *Allium sativum* (7.26 ± 3.62), while *Afrostyrax lepidophyllus* was least effective, recording 12.19 ± 2.10. At the 5 g dosage, the same pattern was observed. Cypermethrin again recorded no emergence (0.00 ± 0.00), showing strong effectiveness. *Azadirachta indica* showed improved control with 4.21 ± 3.23, followed by *Allium sativum* (6.64 ± 4.31), while *Afrostyrax lepidophyllus* had the highest value among botanicals (9.41 ± 4.23), indicating weaker protection. At the 7 g dosage, insect emergence dropped even further across treatments. Cypermethrin remainned completely effective (0.00 ± 0.00). *Azadirachta indica* recorded the lowest botanical value (1.54 ± 0.41^{b}), followed by *Allium sativum* (3.54 ± 2.33) and *Afrostyrax lepidophyllus* (6.23 ± 0.56).

Table 2: Comparative Evaluation of Plant Powders and Cypermethrin on Progeny Emergence of *Sitophilus zeamais* in Stored Maize Grains

DOSAGE(g)	CONTROL	CYPERMETRIN	*Azadirachta indica*	*Allium sativum*	*Afrostyrax lepidophyllus*
3	55.34(±2.72)^{e}	0.00(±0.00)^{d}	6.56(±1.40)^{c}	7.26(±3.62)^{a}	12.19(±2.10)^{b}
5		0.00(±0.00)^{c}	4.21(±3.23)^{b}	6.64(±4.31)^{b}	9.41(±4.23)^{a}
7		0.00(±0.00)^{c}	1.54(±0.41)^{b}	3.54(±2.33)^{b}	6.23(±0.56)^{a}

Values are expressed as mean ± standard deviation. Means followed by the same superscript letter(s) within the same row are not significantly different at p ≤ 0.05.

Percentage Damage of *Sitophilus zeamais* in Maize Treated with Plant Powders and Cypermethrin

The results show that the treatments had a significant effect on the percentage damage of maize grains by *Sitophilus zeamais* at p ≤ 0.05, meaning the differences observed among treatments are statistically meaningful. At the 3 g dosage, the control recorded the highest damage of 56.45 ± 4.32, indicating severe grain damage in the absence of treatment. Cypermethrin recorded a very low damage level of 1.00 ± 0.00, showing strong protection and was significantly different from all other treatments. Among the botanicals, *Azadirachta indica* had the lowest damage (13.43 ± 0.90), followed by *Allium sativum* (17.33 ± 1.12), while *Afrostyrax lepidophyllus* recorded the highest damage among the plant powders (25.59 ± 1.30). At the 5 g dosage, a similar trend was observed. Cypermethrin maintained low damage at 1.00 ± 0.12. *Azadirachta indica* again performed best among the botanicals with 12.49 ± 1.28, followed by *Allium sativum* (15.72 ± 2.54), while *Afrostyrax lepidophyllus* showed higher damage (22.43 ± 2.03). At the 7 g dosage, damage levels reduced further across treatments. Cypermethrin recorded 0.00 ± 0.00, indicating complete protection. *Azadirachta indica* showed improved performance with 11.64 ± 1.26, followed by *Allium sativum* (14.54 ± 2.36) and *Afrostyrax lepidophyllus* (19.23 ± 0.26).

Table 3: Percentage Damage of *Sitophilus zeamais* in Maize Treated with Plant Powders and Cypermethrin

DOSAGE(g)	CONTROL	CYPERMETRIN	*Azadirachta indica*	*Allium sativum*	*Afrostyrax lepidophyllus*
3	56.45(±4.32)^{e}	1.00(±0.00)^{a}	13.43(±0.90)^{b}	17.33(±1.12)^{c}	25.59(±1.30)^{d}
5		1.00(±0.12)^{a}	12.49(±1.28)^{b}	15.72(±2.54)^{c}	22.43(±2.03)^{d}
7		0.00(±0.00)^{a}	11.64(±1.26)^{b}	14.54(±2.36)^{c}	19.23(±0.26)^{d}

Values are mean ± SD. Means followed by different superscript letters within rows and columns are significantly different at $p \leq 0.05$

Comparative Evaluation of Weight Loss in Maize Grains Treated with Botanicals and Cypermethrin

The results show that the treatments had a significant effect on weight loss of maize grains caused by *Sitophilus zeamais* at p ≤ 0.05, indicating that the observed differences among treatments are statistically significant. At the 3 g dosage, the control recorded the highest weight loss of 33.42 ± 3.52, showing severe grain deterioration in the absence of treatment. Cypermethrin recorded a negligible weight loss of 0.01 ± 0.30, indicating excellent protection and was significantly different from all other treatments. Among the botanicals, *Azadirachta indica* recorded the lowest weight loss (1.70 ± 0.20), followed by *Allium sativum* (2.13 ± 0.11), while *Afrostyrax lepidophyllus* recorded the highest weight loss among the plant powders (6.21 ± 2.23). At the 5 g dosage, the trend remained similar. Cypermethrin recorded 0.00 ± 0.00, showing complete protection against weight loss. *Azadirachta indica* again performed best among the botanicals with 1.41 ± 0.31, followed by *Allium sativum* (1.32 ± 0.51), while *Afrostyrax lepidophyllus* recorded a higher weight loss of 4.13 ± 0.23. At the 7 g dosage, weight loss further decreased across treatments. Cypermethrin maintained complete effectiveness with 0.00 ± 0.00. *Azadirachta indica* recorded 1.02 ± 1.43, followed by *Allium sativum* (1.22 ± 1.07[c]), while *Afrostyrax lepidophyllus* remained the least effective botanical with 3.23 ± 0.44.

Table 4:Comparative Evaluation of Weight Loss in Maize Grains Treated with Botanicals and Cypermethrin

DOSAGE(g)	CONTROL	CYPERMETRIN	*Azadirachta indica*	*Allium sativum*	*Afrostyrax lepidophyllus*
3	33.42(±3.52)^e	0.01(±0.30)^a	1.70(±0.20)^b	2.13(±0.11)^c	6.21(±2.23)^d
5		0.00(±0.00)^a	1.41(±0.31)^b	1.32(±0.51)^c	4.13(±0.23)^d
7		0.00(±0.00)^a	1.02(±1.43)^b	1.22(±1.07)^c	3.23(±0.44)^d

Values are expressed as mean ± standard deviation. Means within the same row followed by different superscript letters are significantly different at $p \leq 0.05$.

The results demonstrate a clear hierarchy of insecticidal efficacy against the maize weevil (*Sitophilus zeamais*). From the onset at 3 days after treatment (DAT), cypermethrin exhibited rapid neurotoxic effects, achieving mortality rates between 75.88% and 79.42%, which were statistically superior to all plant-based treatments. In comparison, the botanicals showed much slower initial activity, with *Azadirachta indica* (29.25-38.75%) and *Allium sativum* (26.06-35.28%) providing only moderate control, while *Afrostyrax lepidophyllus* remained the least effective. These findings are consistent with recent evaluations by Emeasor *et al.,* (2024), who noted that synthetic insecticides like permethrin consistently achieve 100% mortality within the first week of application, whereas botanical powders often require extended exposure to reach comparable levels. By 5 DAT, the efficacy of the botanicals began to diverge more sharply; *Azadirachta indica* improved significantly (up to 61.51%). Recent studies by Kadi *et al.,* (2025) confirm that neem-based powders, even at lower dosages, can achieve high mortality over time, though they often lag behind synthetics in the initial 72-hour window. By the final observation at 7 DAT, while cypermethrin remained at 100%, *A. indica* reached a peak of 82.45% at the 7 g dosage, confirming its status as the most potent botanical tested. Conversely, *Allium sativum* and *Afrostyrax lepidophyllus* failed to achieve high mortality, with the latter peaking at only 34.96%. The statistically significant differences recorded throughout the trial highlight a clear dosage-dependent relationship, supporting the conclusions of Abba and Yusuf (2026), who found that the insecticidal potency of tropical plant powders against *S. zeamais* is highly dependent on both the concentration used and the duration of exposure.

The results regarding F1 progeny emergence demonstrate that both the synthetic insecticide and the selected botanical powders significantly reduced the reproductive success of *Sitophilus zeamais* compared to the untreated control $p \leq 0.05$. The untreated maize, which recorded the highest emergence (55.34±2.72 at 3g baseline) serves as a clear indicator of the high susceptibility of stored grains to weevil infestation in the absence of intervention. In stark contrast, cypermethrin achieved absolute suppression (0.00±0.00)) across all dosages (3 g, 5 g, and 7 g). This result corroborates the finding of Marilei *et al.* (2010) who showed that 40 g of maize treated with 6 g of leaves and seeds extracts from neem are viable alternatives for controlling the *S. zeamais* in stored maize. A similar work by Shiberu and Negeri (2017) had shown that Pyrethrum flower, neem leaf and seed powder can replace chemical insecticides for the control of *S. zeamais* due to their high mortality, lower grain damage and lower maize weight losses recorded as compared to untreated and synthetic insecticides. Among the plant-based treatments, a clear dosage-dependent efficacy was observed, with higher concentrations leading to lower emergence counts. *Azadirachta indica* (Neem) was the most effective botanical, particularly at the 7 g dosage where it reduced emergence to a mere (1.54±0.41). This efficacy is likely due to the presence of azadirachtin, which acts as a potent insect growth regulator (IGR), interfering with the hormonal balance required for larval molting and adult eclosion (Kadi *et al.,* 2025).

The statistical analysis confirms that all treatments significantly reduced the percentage of grain damage caused by *Sitophilus zeamais* ($p \leq 0.05$). The untreated control group suffered severe degradation, reaching a damage level of 56.45%, which underscores the high voracity of maize weevils and the vulnerability of stored grains in the absence of chemical or botanical barriers. In contrast, cypermethrin provided near-total protection, culminating in 0.00% damage at the 7 g dosage. This high level of grain preservation is attributed to the rapid "knockdown" effect of pyrethroids, which eliminates the pest population before significant boring or oviposition can occur. Recent evaluations by Mahenge *et al,*. (2026) confirm that synthetic standards consistently outperform organic powders in preventing physical damage due to their immediate lethal action on adult weevils.

The botanical powders demonstrated a clear, dosage-dependent ability to mitigate damage, though they did not match the absolute protection of the synthetic insecticide. *Azadirachta indica* (Neem) was the most effective plant-based treatment, limiting damage to 11.64% at the highest dosage. The efficacy of Neem in reducing grain damage is largely due to the presence of azadirachtin, which acts as a potent antifeedant. Recent research by Kadi *et al.,* (2025) highlights that neem-based powders significantly reduce feeding punctures and weight loss by making the kernels unpalatable to the weevil.

Allium sativum (Garlic) and *Afrostyrax lepidophyllus* also reduced damage compared to the control, though *A. lepidophyllus* remained the least effective botanical, with damage levels reaching up to 25.59%. The limited efficacy of *A. lepidophyllus* suggests a lower concentration of the bioactive compounds required to deter the intensive boring behavior of *S. zeamais*. According to Emeasor *et al.*, (2024), the degree of grain protection offered by botanical flora is highly variable and directly linked to the specific phytochemical profile of the plant parts used.

The results demonstrate that all treatments significantly minimized the weight loss of maize grains compared to the untreated control $p \leq 0.05$ highlighting a direct correlation between insect mortality and biomass preservation. The control group suffered a substantial weight loss of 33.42%, illustrating the high metabolic demand and feeding efficiency of *Sitophilus zeamais* when left unchecked. In contrast, cypermethrin provided near-absolute protection, reducing weight loss to 0.00% at higher dosages. This effectiveness is attributed to its rapid knockdown effect, which halts insect feeding almost immediately upon contact. Research by Emeasor *et al.* (2024) supports this, noting that synthetic pyrethroids are superior in maintaining grain weight because they terminate the pest life cycle before the larvae can consume the internal endosperm.

Among the botanical powders, *Azadirachta indica* (Neem) and *Allium sativum* (Garlic) were the most effective, both keeping weight loss below 2% at the 7 g dosage. Neem's performance is particularly notable; its bioactive compounds act as potent antifeedants that discourage boring and internal feeding. This is consistent with findings by Kadi *et al.* (2025), who observed that neem-treated grains remain largely intact due to the deterrent effect of azadirachtin on the weevil's sensory receptors. While *Afrostyrax lepidophyllus* was the least effective botanical (recording up to 6.21% weight loss), it still provided a significant buffer compared to the untreated maize. According to Mahenge et al. (2026), the efficacy of such organic powders in preventing weight loss is dosage-dependent, as higher concentrations ensure better grain coverage and a stronger chemical barrier against larval development.

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