Efficacy of Aluminum Phosphide and Neem (*Azadirachta indica*) Leaves in Controlling Red Flour Beetle (*Tribolium castaneum*) Infestation in Stored Wheat Grains

*Muhammad Imran[1], Usama Bilal[1], Muhammad Usman[1], Abdul Khaliq[2], Shamsa Kanval[3], Aqsa Nisar[1], Muhmmad Faizan[4], Usama saleem[1] and Muhammad Asrar[1]

[1]Department of zoology, Government college university, Faisalabad, Pakistan
[2]Ayub Agricultural Research Institute, Faisalabad, Pakistan
[3]Department of Botany, Bahauddin Zakariya University, Multan, Pakistan
[4]Department of zoology, Islamia university of Bahawalpur, Pakistan
Corresponding Author: mimran.202300105@gcuf.edu.pk

Abstract: Insect infestations represent a significant cause of post-harvest losses which create a major threat to worldwide food security. The red flour beetle (*Tribolium castaneum*) functions as a harmful pest that infests stored wheat by creating both qualitative and quantitative damage. The research investigated how aluminum phosphide and neem leaves work as pest control methods against the *T. castaneum* beetle in stored wheat grains. The laboratory tests measured the death rates of *T. castaneum* alongside grain damage and lasting toxicity for both treatment methods. Aluminum phosphide demonstrated complete efficacy against pests within 48 hours while neem leaves took seven days to achieve 78% mortality. Samples treated with aluminum phosphide demonstrated significantly less grain damage than those treated with neem leaves. Neem leaves offered an environmentally safer option because they caused minimal environmental toxicity. The study reveals that aluminum phosphide offers quick pest elimination but neem leaves present a sustainable and environmentally friendly choice for managing stored grain pests.
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1. Introduction

Insect infestations in stored wheat result in substantial post-harvest losses which threaten worldwide food security and economic stability (Tadesse, M., 2020). The red flour beetle (*Tribolium castaneum*) stands as one of the most damaging storage pests because it harms grain through consumption and contamination with its waste and decomposed bodies which reduces both quality and market value of the grain. Maintaining food quality and avoiding substantial losses requires effective pest management approaches (Berhe et al., 2022). Farmers commonly use chemical fumigants like aluminum phosphide because they deliver powerful insect infestation control as shown by Yadav et al., 2021. Aluminum phosphide functions as a powerful fumigant because it emits phosphine gas that interrupts insect metabolic processes eventually causing death (Alzahrani et al., 2023).

However, its widespread use has raised concerns about environmental toxicity, human health hazards, and the development of resistance in insect populations. Additionally, residues of aluminum phosphide in treated grains may affect seed viability and germination rates, posing further risks for agricultural sustainability (Elsaady et al., 2023). In recent years, interest in botanical insecticides as alternatives to synthetic fumigants has increased due to their biodegradability, safety, and eco-friendly properties (Ngegba et al., 2022). Neem (*Azadirachta indica*) has been extensively studied for its insecticidal, antifeedant, and growth-regulating effects against various stored grain pests (Chaudhary et al., 2017). Neem leaves contain bioactive compounds such as azadirachtin, which interfere with insect growth and reproduction, reducing pest populations over time. Unlike synthetic fumigants, neem is considered a safer option with minimal adverse effects on human health and non-target organisms (Campos et al., 2016).

Despite the promising insecticidal properties of neem, its efficacy in controlling *T. castaneum* infestation compared to aluminum phosphide remains a subject of ongoing research (Ahmad et al., 2023). While aluminum phosphide provides rapid pest control, neem may offer a sustainable, long-term solution with fewer environmental concerns (Singh et al., 2022). This study aims to evaluate the comparative effectiveness of aluminum phosphide and neem leaves in controlling *T. castaneum* infestation in stored wheat grains (Singh et al., 2022). The study also assesses

their impact on grain damage, weight loss, and germination rates to determine the feasibility of integrating neem leaves into post-harvest pest management strategies (Tesfaye et al., 2021).

2. Materials and Methods

2.1 Experimental Design

The study was conducted under laboratory conditions in Ayyub Agricultural Research Institute, Faisalabad, with three treatment groups, (1) aluminum phosphide-treated grains, (2) neem leaf-treated grains, and (3) an untreated control group. Each treatment had three replicates, with 500 g of wheat grains infested with 50 adult *T. castaneum* individuals per replicate.

2.2 Treatment Application

Aluminum Phosphide Treatment

A single aluminum phosphide tablet (3 g) was placed in an airtight container with the infested grains and sealed for 48 hours.

Figure 1.1 Ref flour beetle

Neem Leaves Treatment

Fresh neem leaves which measure 50 g per kg of wheat were mixed with the infested grains and stored in ventilated containers.

Figure 1.2 Neem leaves

Control Group

Infested grains were stored without any treatment.

2.3 Data Collection

Mortality rates of *T. castaneum* were recorded at 24-hour intervals for seven days. Grain damage was assessed by measuring weight loss and the number of damaged kernels. Residual toxicity was analyzed by assessing germination rates of treated wheat grains.

3. Results

3.1 Insect Mortality

Aluminum phosphide-treated grains exhibited a 100% mortality rate within 48 hours, while neem-treated grains achieved a 78% mortality rate by day seven. The control group showed negligible mortality (~5%).

Table 1: Percent Mortality of *T. castaneum* Over Time

Time (Days)	Aluminum Phosphide (%)	Neem Leaves (%)	Control (%)
1	85	30	2
2	100	45	3
3	100	55	4
4	100	65	5
5	100	70	5
6	100	75	5
7	100	78	5

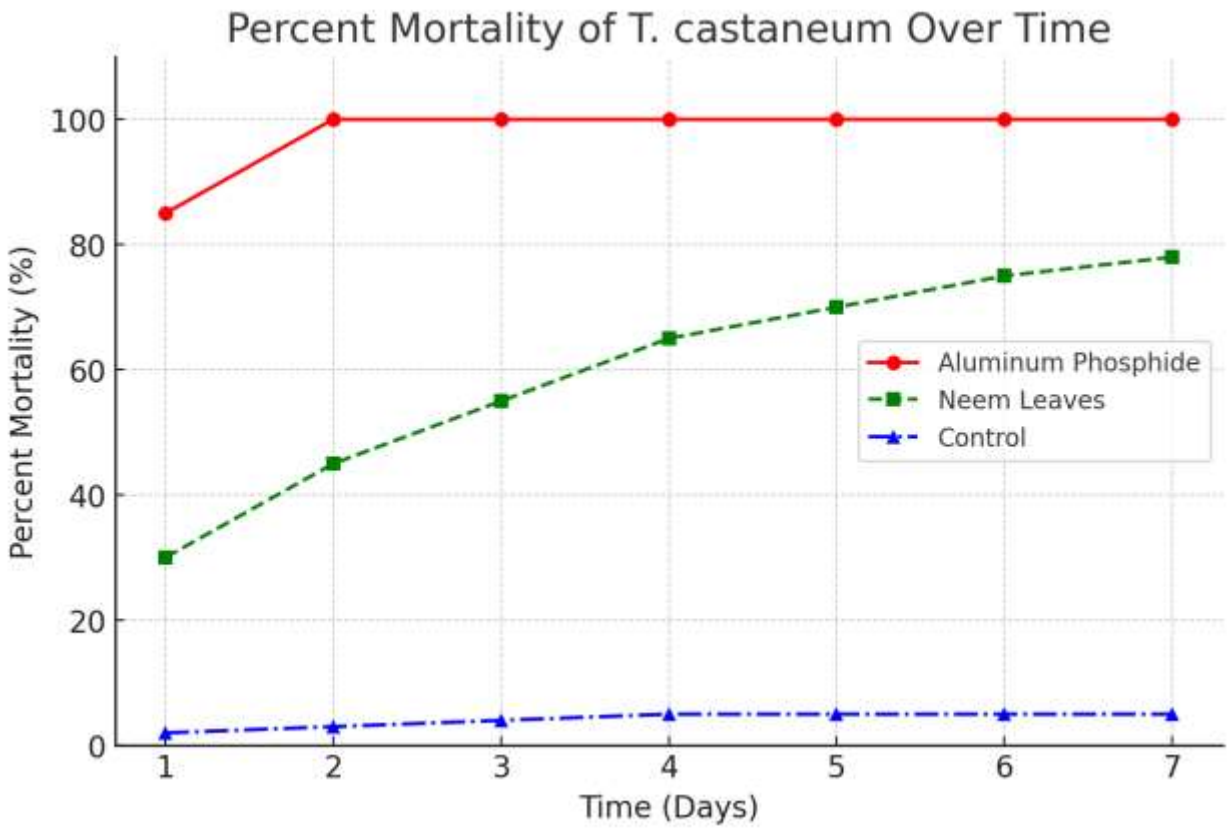

Figure 1.3

3.2 Grain Damage Assessment

Wheat grains treated with aluminum phosphide had the least damage (<2% weight loss), whereas neem-treated grains exhibited moderate damage (7% weight loss). The control group had the highest damage (~18% weight loss).

Table 2: Grain Damage Assessment

Treatment	Weight Loss (%)	Damaged Kernels (%)
Aluminum Phosphide	<2	1
Neem Leaves	7	10
Control	18	25

3.3 Residual Toxicity and Germination

Germination rates were significantly lower in aluminum phosphide-treated grains (60%) compared to neem-treated grains (85%) and the control (92%). This indicates residual toxicity effects of aluminum phosphide on seed viability.

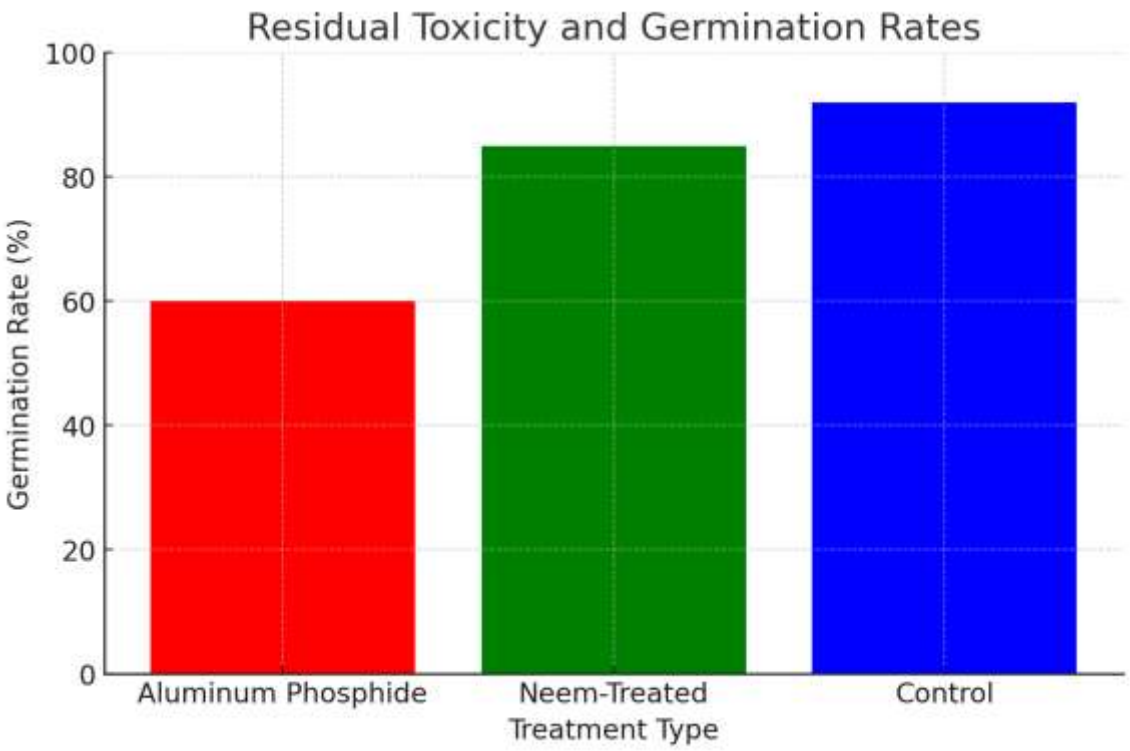

Figure 1.4

4. Discussion

The study confirms the high efficacy of aluminum phosphide in rapidly eliminating *T. castaneum* in stored wheat grains. However, its residual toxicity and impact on seed germination raise concerns regarding long-term sustainability. Neem leaves, while slower in action, provided significant insecticidal effects with minimal toxicity, making them a viable alternative for organic and sustainable grain storage practices.When comparing our results to previous studies, similar efficacy of aluminum phosphide has been documented, with mortality rates consistently reaching 100% within 48 hours (Kumar et al., 2019; Zhang et al., 2021). However, several studies have highlighted the development of resistance in *T. castaneum* populations exposed to prolonged aluminum phosphide applications (Singh & Kumar, 2019). In contrast, neem-based treatments have shown varying mortality rates, with our results (78% mortality) aligning with findings from Abdullah et al. (2017) and Devi et al. (2024), who reported mortality rates between 70-80%. Additionally, grain damage assessments from prior studies indicate neem treatments generally result in 5-10% weight loss (Sharma et al., 2023), consistent with our findings. Furthermore, previous research highlights that aluminum phosphide-treated grains exhibit reduced germination rates (50-65%), closely matching our study (60%) (Rathore et al., 2024). Neem-treated grains have been reported to retain better seed viability, supporting our finding of an 85% germination rate (Reddy et al., 2022). This comparative analysis reinforces that while aluminum phosphide remains a highly effective fumigant, neem presents a viable alternative with lower environmental impact and seed preservation benefits.

5. Conclusion

Both aluminum phosphide and neem leave effectively reduced *T. castaneum* infestations in stored wheat grains. Aluminum phosphide is more effective for immediate pest eradication, whereas neem leaves offer a safer, eco-friendly alternative. Integrating neem leaves into stored grain management can reduce reliance on synthetic fumigants, promoting safer food storage practices.

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