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Evaluation of Insecticidal and Repellent Potential of Botanicals Against the Red Flour Beetle, *Tribolium castaneum* (Herbst)

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ABSTRACT :

The current study was evaluated the insecticidal and repellent efficacy of four botanical leaf powders neem, bkain, eucalyptus and knear against *Tribolium castaneum* under controlled conditions. Percentage Mortality was assessed at 24, 48, 72, 96, 120, and 144 hours, while repellency was assessed using a filter paper disc method at 24, 48, and 72 hours. Results depicted significant differences among treatments across all time intervals ($p < 0.05$). Neem exhibited the highest insecticidal activity (76.22%) mortality after 144 hours, followed by bkain (63.63%), eucalyptus (56.02%), and knear (48.52%). Repellency data showed a similar trend, with neem demonstrating the strongest deterrent effect (57.33–63.43%), while knear remained the least effective. Mortality increased progressively with exposure time, indicating cumulative toxic effects of botanicals. Overall, neem leaf powder proved to be the most potent botanical, exhibiting both rapid and sustained activity against *T. castaneum*. These findings highlight the potential of plant-derived materials as eco-friendly alternatives to synthetic insecticides for sustainable stored-grain pest management.

Keywords: Botanicals; mortality; Repellencey; red flor beetle; ecofriendly; dtored grain insects

Introduction:

Wheat (*T. aestivum* L.) is a main cereal crop and a key component of daily diets across many regions of the world (Hussain et al., 2025). Ensuring the safe storage of wheat and other grains is essential for maintaining quality and preventing deterioration caused by insect pests (Aslam et al., 2018; Afzal et al., 2025). According to the IGMRI (2019), insect damage alone accounts for an annual post-harvest loss ranging from 2% to 4.2% (Ali et al., 2016; Hasan et al., 2017).

The most devastating insect pests associated with stored products is the red flour beetle (*T. castaneum*) (Coleoptera: Tenebrionidae). This species is a highly adaptable secondary pest that infests a variety of stored commodities, including cereals, pulses, oilseeds, and processed food materials. Adult beetles can survive for up to 12–18 months, and females have the capacity to lay nearly 1,000 eggs during their lifetime (Malik et al., 2023). The feeding activity of both larvae and adults on broken grains and flour-based products leads to significant qualitative and quantitative losses, imparting an undesirable odour and reducing the market value of the infested grain. Prolonged consumption of contaminated products may also have adverse consequences for the environment and human health (Alsudani et al., 2021).

Chemical fumigants and comercially available synthetic insecticides have traditionally been used to suppress *T. castaneum* populations (Attia et al., 2020). Methyl bromide and phosphine gass tablets are used as fumigation pupose among the most commonly applied fumigants worldwide. however, the continued reliance on these chemicals has contributed to the emergence of resistant pest strains (Malik et al., 2021). In addition, synthetic pesticides are often associated with ecological risks, negative impacts on non-target organisms, and contamination of soil, air, and water resources (Nicolopoulou-Stamati et al., 2016; Hamel et al., 2020; Sonu Kumar et al., 2022; Ali et al., 2021).

Given these limitations, growing attention is being directed toward natural, eco-friendly pest management options derived from plant-based sources such as botanical extracts, biopesticides (Hussain et al., 2017), essential oils, and spices (Shehzad et al., 2021)

Many plant products contain secondary metabolite such as terpenoids, phenolics, flavonoids, and alkaloid that exhibit insecticidal, repellent, and growth-inhibiting effects (Rakha and Mousa, 2017; Kanwal et al., 2021). Botanical pesticides offer several advantages, including being biodegradable, affordable, and safer for humans and the environment, while also lowering the chances of resistance development in insect pests (Jaleel et al., 2020). In this context, the present study was designed to investigate the insecticidal and repellent activities of four plant specie neem, bkain, eucalyptus, and kanee against adult red flour beetles (*Tribolium castaneum*).

MATERIALS AND METHODS

Study Area

The study was carried out in the Stored Grain Laboratory of the Entomological Research Institute, Ayub Agricultural Research Institute (AARI), Faisalabad.

Rearing of Insects

Adult red flour beetles (*Tribolium castaneum*) of mixed age groups were collected from the grain market in Faisalabad. The insects were transferred into sterilized 500-mL plastic jars containing 200 g of a standard diet composed of wheat flour and brewer's yeast in a 95:5 ratio. The jars were covered with muslin cloth secured with rubber bands to allow ventilation while preventing escape. Cultures were maintained at 27 ± 2°C and 70 ± 5% RH following Perez-Mendoza et al. (2011). Adults used in experiments were obtained from the laboratory stock colony maintained according to the procedure of Rehman et al. (2020).

Preparation of Botanical Powders and Extracts

Fresh leaves of neem, bkain, eucalyptus, and kaneer were collected from the field area of the Entomological Research Institute, Faisalabad. Leaves were washed thoroughly, shade-dried for 48 hours, and ground into fine powders using an electric grinder.

Aqueous extracts were prepared following the method of Odey et al. (2012) with minor modifications. Ten grams of each leaf powder was mixed with 100 mL of distilled water and heated at 65°C for 20 minutes. The mixture was filtered through Whatman No. 1 filter paper and centrifuged at 1200 rpm for 10 minutes. The supernatant obtained was stored under refrigeration until use.

Insecticidal Bioassay

For the mortality assay, 20 g of sterilized wheat grains were placed in 20-mL plastic jars and coated uniformly with each botanical powder. Twenty newly emerged *T. castaneum* adults were introduced into each jar. Mortality was recorded at 24, 48, 72, 96, 120, and 144 hours after treatment. Each treatment was replicated three times. The protocol followed Ahmad et al. (2019).

Repellency Bioassay

Repellency was evaluated using a filter-paper disc method following Ramsha et al. (2019) and Iqbal et al. (2010). Circular Whatman filter papers (9 cm diameter) were cut into two equal halves. One half was treated with plant extract, while the other was treated with distilled water as a control. The halves were rejoined using adhesive tape without obstructing insect movement.

Each paper disc was placed in a Petri dish, and twenty adult beetles were released at the center. After exposure, beetles present on the treated and untreated halves were counted to determine repellency.

Data Analysis

The experiment was arranged in a Completely Randomized Design (CRD) comprising four treatments with three replications. Data were analyzed using Statistics 8.1, and treatment means were compared at the 5% significance level.

Results

Insecticidal Bioassay

The insecticidal potential of four plant leaf powders against adults of *Tribolium castaneum* was evaluated. The results revealed notable differences among the treatments, with mortality progressively increasing with time for all botanicals (Table 3). Statistical analysis indicated significant variations among treatments at each observation interval.

At 24 hours of exposure, neem and bkain caused the highest initial mortality (3.70% and 3.33%, respectively), while knear and eucalyptus recorded no mortality. By 48 hours, significant separation among treatments became evident (LSD = 9.1449), with neem causing the highest mortality (17.04%), closely followed by bkain (13.33%). Knear and eucalyptus showed substantially lower mortality at this stage (6.67% and 3.33%, respectively).

The differences among treatments became more pronounced as the exposure period increased. At 72 hours, neem maintained the highest toxicity (41.11%), statistically similar to bkain (35.93%). Meanwhile, knear and eucalyptus produced identical mortality values (20.74%), forming a separate and significantly lower group.

A similar trend continued through the subsequent intervals. At 96 and 120 hours, neem and bkain consistently recorded higher mortality, forming the top statistical group, whereas knear and eucalyptus remained moderate in their toxicity, with mortality values ranging between 28.15–41.11% at 96 hours and 36.22–41.11% at 120 hours. By 144 hours, neem exhibited the maximum mortality of 76.22%, significantly outperforming all other treatments. Bkain showed the second-highest mortality (63.63%), followed by eucalyptus (56.02%) and knear (48.52%).

Table.1 Effects of plant leaves powder on Mortality (%) of Red flour beetle adults

Sr.No.	Treatments	Mortality (%)					
		24 Hours	48 Hours	72 Hours	96 Hours	120 Hours	144 Hours
1.	NEEM	3.7037 A	17.037A	41.111 A	52.481 A	60.004 A	76.221 A
2.	KNEAR	0.0000 A	6.6667 BC	20.741 B	28.148 B	36.222 B	48.519 C
3.	BKAIN	3.3333 A	13.333 AB	35.926 A	49.222 A	54.778 A	63.630 AB

4.	**EUCLYPTUS**	0.0000 A	3.3333 C	20.741 B	31.852 B	41.111 B	56.019 BC
5.	**LSD at 5%**	7.0218	9.1449	12.428	12.740	12.991	13.886

Repellency Bioassay

The repellency effects of different plant leaf powders against adults of *Tribolium castaneum* were evaluated at 24, 48, and 72 hours of exposure (Table 4). Significant differences among treatments were observed at all time intervals.

At 24 hours, neem exhibited the highest repellency (57.33%), followed closely by bkain (54.55%) and eucalyptus (50.39%). Knear showed the lowest repellency of 41.45% and was significantly inferior to all other treatments. Repellency increased slightly at 48 hours for all treatments. Neem maintained the highest repellency (63.43%), significantly higher than all other botanicals. Bkain (57.89%) and eucalyptus (55.41%) formed the next group, while knear again recorded the lowest repellency (51.03%).

By 72 hours, repellency began to decline slightly across treatments. However, the overall trend remained consistent, with neem showing maximum repellency (37.32%), followed by bkain (34.74%) and eucalyptus (31.85%). Knear exhibited the lowest repellency (29.89%), continuing its trend of reduced effectiveness. Despite the slight decrease in repellency over time, neem consistently outperformed all other treatments.

Table.2 Effects of plant extracts on repellency (%) of Red flour beetle adults

Sr.No.	**Treatments**	**Repellent (%)**		
		24 Hours	**48 Hours**	**72 Hours**
1.	**NEEM**	57.33 A	63.427 A	37.32 A
2.	**KNEAR**	41.45 D	51.033 D	29.89 D
3.	**BKAIN**	54.55 B	57.89 B	34.74 B
4.	**EUCLYPTUS**	50.39 C	55.41 C	31.85 C
5.	**LSD at 5%**	1.812	1.493	1.149

Disccssion:

The present study demonstrated that botanical leaf powders vary significantly in their insecticidal and repellent effects against adults of *Tribolium castaneum*. Among the evaluated botanicals, neem leaf powder consistently produced the highest mortality and repellency across all exposure intervals, followed by bkain, whereas eucalyptus and knear exhibited comparatively moderate activity. These results reaffirm the strong potential of botanicals, particularly neem, in the management of stored-grain pests.

The superior performance of neem observed in this experiment aligns closely with the findings of Sekar et al. (2021), who reported neem leaf powder as the most effective botanical for reducing adult mortality, grain weight loss, and F_1 emergence of *T. castaneum*. Neem's efficacy is generally attributed to azadirachtin and other limonoids, which possess strong antifeedant, growth-disrupting, and contact-toxic properties. Supporting this, Xie et al. (1995) demonstrated that azadirachtin and neem-based extracts caused significant toxicity and repellency to multiple stored-product beetles, confirming the broad-spectrum activity of neem components.

The present study also showed that bkain leaf powder produced mortality levels statistically comparable to neem during earlier exposure periods. Although research on bkain is limited, the results suggest the presence of bioactive constituents with insecticidal potential, warranting further chemical investigation. In contrast, knear and eucalyptus displayed moderate mortality and repellency, indicating weaker or slower modes of action. Similar moderate effects of eucalyptus have been reported previously, where essential oils showed repellency but comparatively lower toxicity to stored-product pests.

Across the exposure intervals, mortality increased progressively for all botanicals, suggesting that continuous contact or ingestion enhances the cumulative impact of plant powders. This trend supports earlier observations by Athanassiou et al. (2005), who found that mortality in *Rhyzopertha dominica*, *Sitophilus oryzae* and *Tribolium confusum* increased with exposure duration when treated with NeemAzal. The present findings further corroborate Rahila (2006), who emphasized that neem oil's toxicity and growth inhibition in *T. castaneum* are both dose- and time-dependent.

The repellent activity recorded in this study followed a similar pattern to the insecticidal effect, with neem demonstrating the highest repellency, followed by bkain and eucalyptus. Knear consistently showed the lowest repellency throughout the experiment. These results are consistent with Chander et al. (1992), who reported that plant-derived materials, including turmeric and mustard oil, caused significant suppression of *T. castaneum* progeny, indicating the value of botanicals as deterrents and reproductive inhibitors. Likewise, Jabilou et al. (2006) observed strong insecticidal and repellent effects of *Peganum harmala* and *Ajuga iva* extracts against *T. castaneum*, further supporting the use of botanicals as effective pest management tools.

The consistency of neem as the top-performing treatment across all studies underscores its reliability as an eco-friendly alternative to synthetic insecticides. Krishna et al. (2023) similarly concluded that various plant extracts provide safe, cost-effective, and easily accessible options for managing *T. castaneum*, making botanicals highly suitable for integration into storage pest management programs. Furthermore, Malik et al. (2023) demonstrated that insect growth regulators (IGRs) can achieve substantial progeny suppression, suggesting that a combined approach using botanicals and IGRs may further enhance control efficacy.

Overall, the findings of the present study, supported by existing literature, clearly indicate that botanical particularly neem possess strong potential for managing *T. castaneum* in stored grains. Their effectiveness, affordability, and safety profile make them valuable components of integrated pest management (IPM) strategies. Future research may focus on biochemical profiling of less-studied botanicals such as bkain, formulation development for improved efficacy, and evaluation under field or warehouse conditions to promote practical, large-scale adoption.

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