



A comparative assessment of neem derivatives for repelling the stored grain pest *Tribolium castaneum* Herbst in a sustainable manner

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Abstract

Tribolium castaneum (Herbst) is a highly detrimental insect pest of wheat, causing critical damage to a diverse variety of precious food products during storage. It is a globally distributed insect pest with remarkable adaptability to survive in diverse atmospheric conditions. Synthetic insecticides and fumigation have been the major choices for insect pest management on a global scale. However, the utilization of chemicals results in adverse consequences for both environmental ecosystems and human well-being. Consequently, the exploration of sustainable options has become a critical need in recent times. This study aims to promote insect pest management using biological approaches. To accomplish this objective, laboratory experiments were undertaken to assess the efficacy of neem (*Azadirachta indica*) and its derivatives, viz., bark, seed, leaf and flower against *Tribolium castaneum* (Herbst). The assessments were made by measuring the percentages of adult mortality and adult emergence. The findings of this study revealed that each treatment efficiently induced adult mortality and significantly reduced the percentage of adult emergence in comparison to the control. Subsequently, neem seed powder was found to be superior among treatments, exhibiting the highest adult mortality and the lowest percentage of adult emergence, followed by neem leaf, neem bark, and neem flower. The present investigation demonstrated that neem and its derivatives exhibit insecticidal activities, thereby emerging as a potential alternative for synthetic pest management techniques.

Keywords: Red flour beetle, neem, sustainable, insecticides

Introduction

Neem, scientifically termed *Azadirachta indica*, is a versatile tree of critical significance in multiple aspects of life. Neem has been admired over the centuries for its immense medicinal, ecological as well as agricultural properties. It is often referred to as the "Village Pharmacy" due to its wide range of therapeutic purposes. Neem is a key component of traditional Ayurvedic medicine for treating various ailments, including skin disorders, digestive issues and infections. The twigs of neem trees are even used as natural toothbrushes due to their oral health benefits. Neem also plays a crucial role in soil improvement, its deep roots help prevent soil erosion, making it valuable to conserve soil health and productivity. Furthermore, neem cake, a byproduct of neem oil extraction, is an efficient organic fertilizer that intensifies the soil with vital nutrients and raises its water-holding capacity. In the field of agriculture, insect pests remain a major concern for farmers and researchers as they are responsible for causing devastating impacts on crop yields and post-harvest storage. Tropical countries involving India endure severe losses due to the more favorable climatic conditions for the survival of insect pests; sometimes these losses surpass the threshold of 20% (Ahmad and Ahmad, 2002^[3]; Rahman et al., 2009)^[13]. Numerous insect species, including ticks, thrips, mites, weevils, beetles and aphids have been identified as major pests in the field of agriculture, leading to infestations on either pre-harvest or post-harvest crops (Chitra and Subramanian, 2016^[7]; Murtaza et al., 2019)^[10]. Among diverse species, *Tribolium castaneum* is a highly destructive insect pest that infests stored grain products, causing severe economic losses worldwide. It is a cosmopolitan pest that

inflicts damage upon stored grains of cereals and dry fruits, including rice, wheat, maize, pulses, almonds and cashew nuts (Rajput et al., 2016)^[12]. It is known for its rapid population growth and ability to survive under adverse conditions (Abdelsamad et al., 1988)^[2]. Their larval and adult stages were known for destroying the quality and quantity of food products, which were further contaminated by the presence of their feces, adhesive secretions and excrement, making them inappropriate for human consumption. Conventional pesticides have been widely employed for pest management since antiquity. However, the versatility of *Tribolium castaneum* in developing resistance to traditional pesticides has rendered it an enormous challenge for pest control. Consequently, the determination of alternative strategies for combating insect pests is of greater significance. In recent years, growing concerns about the adverse environmental and health impacts of synthetic insecticides have also stimulated the search for safer alternatives. Various indigenous plant products have been frequently utilized in the realm of biological pest management techniques, among which neem and its derivatives have achieved considerable appreciation for their effective insecticidal properties. Its leaves, bark, and seeds contain a broad range of bioactive compounds, including azadirachtin, nimbin, nimbidin and salannin, that contribute to its insecticidal activity (Brahmachari G., 2004)^[6]; Mondal and Khalequzzaman, 2009)^[9]. Neem seed oil is extensively applied in organic farming practices to protect crops against pests. Additionally, neem leaves are typically employed as a natural mosquito repellent (Dua et al., 2009)^[8]. Therefore, the insecticidal properties of neem and its derivatives against *Tribolium castaneum* become the subject

of a major investigation. Several studies have explored the efficiency of neem components, along with their extracts, oils and pulverized dust, in mitigating the infestation of insect pests affecting both crops and stored products. This research paper focused on neem and its derivatives to evaluate their efficacy against the population and development of *Tribolium castaneum* in stored wheat and also intends to shed light on their potential as sustainable alternatives to synthetic insecticides.

Material and Methods

The laboratory experiments were carried out in the Department of Zoology, Dayanand Girls P. G. College, Kanpur, Uttar Pradesh, spanning from July to October 2023. The experiments were performed using completely randomized design (CRD) with three replications.

Culture of *Tribolium castaneum*

Adults of *Tribolium castaneum* were procured from a stock of infested wheat grains from the local market in Kanpur. The collected beetles were identified according to their morphological features (Sreeramoju et al., 2016) [15]. The beetles were cultured in a plastic jar containing cleaned and sterilized wheat grains as food. The opening of the jar was covered with muslin cloth, using rubber bands to inhibit the escape of beetles, and kept at room temperature. The beetles were released freely into the jar for the purpose of mating and egg-laying. After a week of egg-laying, the adult beetles were taken away from the jar and freshly emerged beetles were selected for subsequent investigations.

Formulation of botanical powders

The fresh neem tree parts, viz., leaves, bark, seeds and flowers were collected, washed thoroughly, and then shed-dried at room temperature for one week. Subsequently, the dried materials were ground using a grinding machine, passed through a sieve to attain a fine powder and then placed in glass containers for experimental purposes.

Experimental procedure

The experiment was set up in plastic jars containing cleaned and sterilized wheat grains. Botanical powders were then mixed separately at a dose of 2 gm/100 gm grains. The treatments were replicated three times along with an untreated control. The data were recorded on adult mortality and the percentage of adult emergence across different treatments.

Adult mortality

The experiment for determining adult mortality was performed within separate plastic jars, each containing 100 grams of treated grains at a dosage of 2 gm/100 gm, along with untreated control. Ten pairs of freshly emerged adults were introduced into each jar, and the apertures of the jars were secured with muslin cloth using rubber bands. The experiment was replicated three times and jars were kept under laboratory conditions. Insects were regularly monitored and dead adults were counted and taken away from jars to ensure appropriate assessments. The data on adult mortality were recorded for each treatment at intervals of 24, 48, 72 and 96 hours of release, employing the following formula (Abbott, 1925) [1].

Corrected mortality (%) = $(1 - \text{Number of live adults in treatment} / \text{Number of live adults in control}) \times 100$

Adult emergence

The impact of different treatments on adult emergence was studied under a separate set of experiments where ten pairs of adults were introduced into jars with 100 gm of treated grains, including untreated control. All the jars were placed undisturbed under laboratory conditions for a duration of one week. Following this period, the adults were removed and eggs were counted and allowed to remain in the jars until the emergence of the new adult population. The newly emerged beetles were counted and extracted from the jar to prevent egg-laying. Finally, the total number of newly emerged adults was counted until the emergence was stopped. The calculation of the percentage of adult emergence was conducted using the formula outlined by (Ahmed et al., 2016) [4].

Percent adult emergence = $(\text{Number of adults emerged} / \text{Total number of eggs laid}) \times 100$

Data Analysis

Statistical analyses were applied to the data obtained from laboratory experiments following a one-factor Completely Randomized Design (CRD). The analysis of variance (ANOVA) was calculated for proper interpretation of the data. Percentage data undergo transformation to arc-sine values and critical differences (C.D.) were computed at a 5% level of significance. The data was presented in tables and graphs using Microsoft Excel.

Results and Discussion

The data obtained with respect to adult mortality of *Tribolium castaneum* due to neem and its derivatives are depicted in Table 1. It reveals that each of the treatments was effective in causing adult mortality compared to the control. The mortality percentage was observed to increase with the duration of exposure. After 24 hours, grains treated with neem seed powder showed the highest mean adult mortality (21.67%). It was followed by neem leaf powder (18.33%), neem bark powder (15.00%) and neem flower powder (6.67%). Whereas untreated control shows (0.00%) of adult mortality.

The mortality percentage varied between 16.67 and 43.33 after 48 hours, with neem seed powder demonstrating the highest adult mortality (43.33%), followed by neem leaf (40.00%), neem bark (35.00%), and neem flower (16.67%). The untreated control exhibited results consistent with the above exposure duration. After 72 hours, the maximum adult mortality was recorded in grains treated with neem seed powder (55.93%), followed by neem leaf, neem bark and neem flower powder with 52.54, 45.76 and 27.11 percent mortality rates, respectively. The untreated control indicated a mortality rate of 1.67%. The highest mortality percentage of 72.88% was observed after 96 hours of exposure, with neem seed powder demonstrating superior efficiency compared to other treatments. The second highly effective treatment was neem leaf powder, with (69.49%) mortality, followed by neem bark powder (62.71%) and neem flower powder (40.67%). The lowest mortality was recorded in the untreated control (1.67%). The current observations are consistent with the studies of (Tariq et al., 2013) [16]; Patil et al., 2015) [11], who revealed that the neem seed powder exhibits significant repellent activities against *Tribolium castaneum* (Herbst).

Table 1: The impact of neem and its derivatives on the adult mortality of *Tribolium castaneum* (Herbst).

Treatment (Symbols)	Mortality in Percent (%)			
	24 h	48 h	72 h	96 h
Neem Bark (T1)	15.00 (22.76)	35.00 (36.22)	45.76 (42.53)	62.71 (52.27)
Neem Seed (T2)	21.67 (27.71)	43.33 (41.14)	55.93 (48.33)	72.88 (58.53)
Neem Flower (T3)	6.67 (14.95)	16.67 (24.07)	27.11 (31.33)	40.67 (39.56)
Neem Leaf (T4)	18.33 (25.34)	40.00 (39.19)	52.54 (46.38)	69.49 (56.40)
Control (T5)	0.00 (0.00)	0.00 (0.00)	1.67 (7.41)	1.67 (7.41)
SE(m)±	0.47	0.62	1.09	1.16
CD at 5%	1.04	1.39	2.44	2.58

*The data illustrated in the table represents the mean values of three replications

**Figures in parentheses are arc-sine transformed values

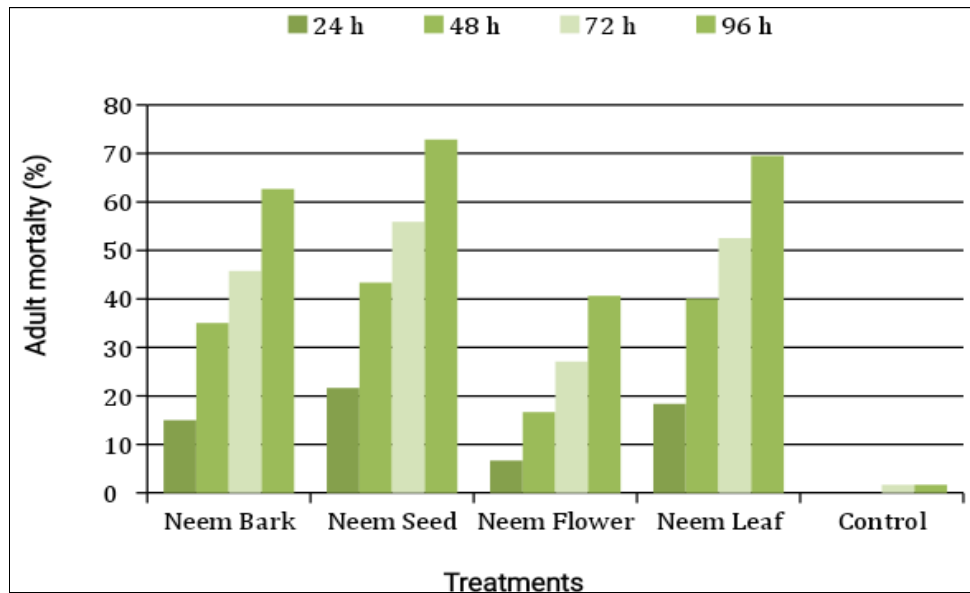


Fig 1: Mortality in adult *Tribolium castaneum* (Herbst) Induced by various neem derivatives.

Similarly, the data collected with respect to the adult emergence of *Tribolium castaneum* under different treatments is presented in Table 2. Considerable variations were observed in the percentage of adult emergence among the different treatments. The lowest adult emergence was obtained in the treatment of neem seed powder (30.95%), which was followed by neem leaf powder (36.73%), neem bark powder (39.28%) and neem flower powder (45.20%). Whereas, the untreated control exhibited the highest percentage of adult emergence (68.74%). Similar outcomes have been obtained by (Rehman and Khan, 2014 [14]; Aweke et al., 2020) [5], who reported that neem seed powder effectively mitigates the adult emergence of various stored grain insect pests.

Table 2: The impact of neem and its derivatives on the adult emergence of *Tribolium castaneum* (Herbst).

Treatment	Symbols	Adult emergence (%)
Neem Bark	T1	39.28 (38.75)
Neem Seed	T2	30.95 (33.77)
Neem Flower	T3	45.20 (42.22)
Neem Leaf	T4	36.73 (37.30)
Control	T5	68.74 (55.99)
SE(m)±	-	1.88
CD at 5%	-	4.19

*The data illustrated in the table represents the mean values of three replications

**Figures in parentheses are arc-sine transformed values

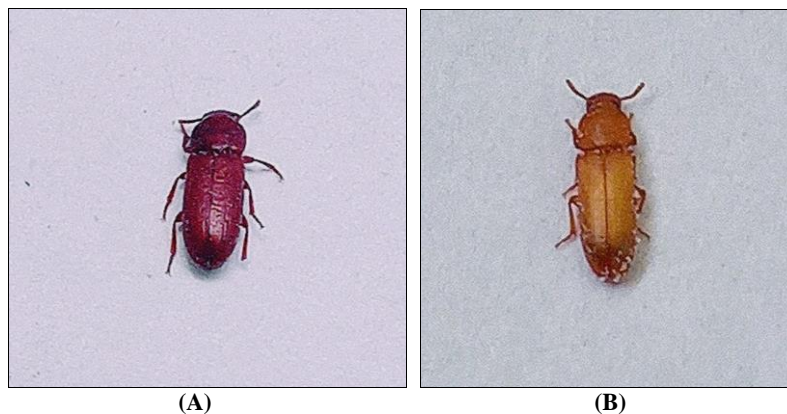


Image: (A) Fully matured adult of *Tribolium castaneum* (Herbst) (B) Freshly emerged adult of *Tribolium castaneum* (Herbst)

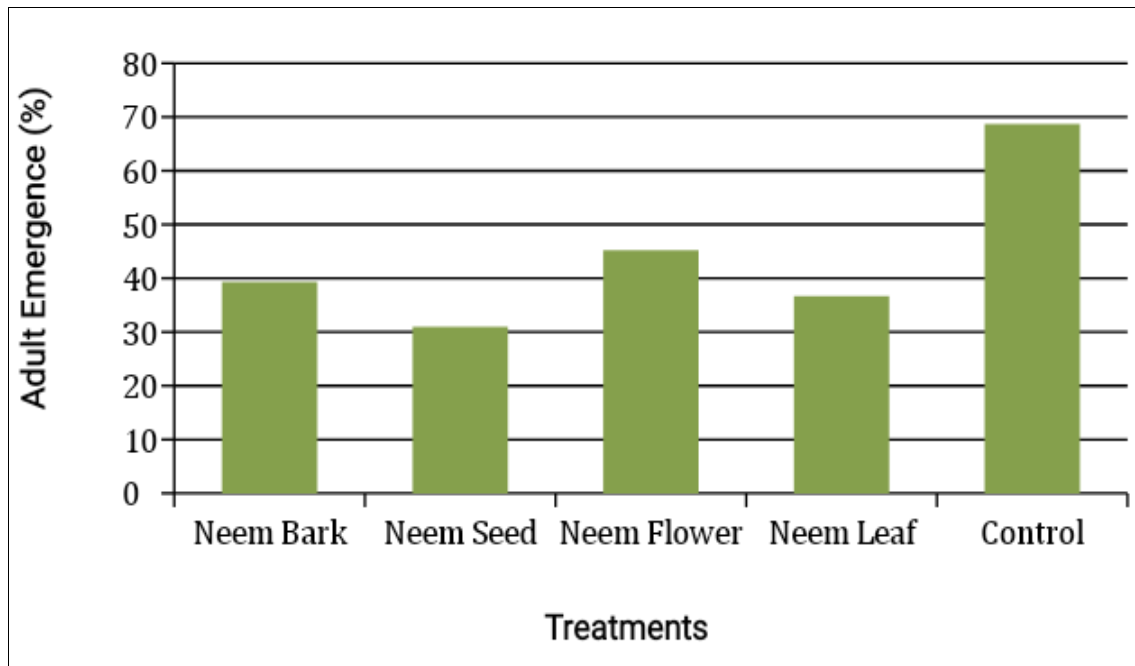


Fig 2: Influence of various neem derivatives on the adult emergence of *Tribolium castaneum* (Herbst).

Conclusion

Tribolium castaneum (Herbst) poses a major threat to stored wheat, leading to the deterioration of nutritious food grains due to their feeding activities and contamination. However, synthetic insecticides prove efficient in addressing such issues, their environmental impact raises serious concerns. On account of the above findings, it was concluded that neem and its derivatives could offer a promising alternative to synthetic insecticides, providing ecological approaches to protecting stored wheat from *Tribolium castaneum*. This study promotes the implementation of biological pest management strategies to assure the protection of food materials during storage.

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