Turkish Journal of Agriculture - Food Science and Technology, 13(2): 321-326, 2025
DOI: https://doi.org/10.24925/turjaf.v13i2.321-326.7143

Turkish Journal of Agriculture - Food Science and Technology

Available online, ISSN: 2148-127X | www.agrifoodscience.com | Turkish Science and Technology Publishing (TURSTEP)

Optimization of Angoumois Grain Moth (*Sitotroga cerealella* Olivier) Infestation in Stored Grains as Influenced by Some Botanical Powders

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ARTICLE INFO

Research Article

Received : 22.09.2024
Accepted : 14.11.2024

Keywords:
Angoumois grain moth
Azadiracta indica
Botanical powders
Persicaria lapathifolia
Sitotroga cerealella

ABSTRACT

The Angoumois grain moth, *Sitotroga cerealella* Olivier is predominantly a devasting infested stored grain pest of cereals, whose development proceeds within a single grain of infested cereals. Investigating greener alternatives to widely used chemical control techniques is crucial because synthetic chemicals pose risks to public health and the environment. This investigation was carried out for developing the ecofriendly control management of the Angoumois grain moth in stored cereals through utilizing four botanical powders and one insecticide, wood ash (1 gm), and a single synthetic insecticide (Carbaryl) (0.25mg), neem (1 gm), Korobi (1 gm), Bishkatali (1 gm) and Datura (1 gm) treatments against untreated control in Completely Randomized Design (CRD). It was revealed that Neem (*Azadiracta indica*) powder at 1 g/100 g seed performed excellently, resulting in minimization of adult mortality percent, adult emergence, grain weight loss, and number of holes per ten seeds. The maximum percent of germination was noted in bishkathali (*Persicaria lapathifolia*) powder at 1 g/100 g seed, and moreover, bishkathali powder functions more effectively for limiting infestation percent. Therefore, the botanical neem and bishkathali powder at 2 g/100 g seed rate is the better alternative of carbaryl at 0.5 g/100 g rate, and it could be suggested for Angoumois grain moth management at storage.

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Introduction

Cereals have been a major source of nutrition for nearly one-third of humanity, with a particular emphasis on developing regions including Sub-Saharan Africa and Southeast Asian countries. Rice, wheat, and maize account for approximately 85% of the global production of cereals (Erenstein et al., 2022). Bangladesh produces 38.09 million metric tons of rice using 26.02 million acres of land, with around 90 percent of people relying on rice for sustenance (BBS, 2023). Over 65% of this rice is stored by farmers for a variety of purposes, such as food, feed, and seed, and the rice is preserved as paddy, brown, or milled rice. Bamboo containers (dole or golas) and earthen jars (motka) are among the standard storage methods for parboiled rice. In addition, grain losses are considerable as a result of improper storage, which is primarily caused through pests such as weevils, beetles, moths, and rodents, despite manufacturing advances. Song et al. (2020) calculated that storage losses in rice can exceed 10% when farm losses are included, and insects alone are to blame for up to 12.61% of the losses (Maziku, 2019).

Along with the most negative pests in stored rice are the grain moth (*Sitotroga cerealella*), rice weevil (*Sitophilus oryzae*), and red flour beetle (*Tribolium castaneum*), via moths and beetles more often attacking raw rice and weevils targeting milled rice (Zote Vaishali & Shukla, 2023a). *Sitotroga cerealella*, also known as the Angoumois grain moth or paddy moth, is one of the most critical parasites in safeguarded rice (Zote Vaishali & Shukhla, 2024). It infests grains in fields and storage conditions, boosting its potential for damage (Sowmya et al., 2023), as well as the moth is especially hazardous in Bangladesh because it is termed "surui" and affects stored wheat, maize, and other agricultural products like joar and bran; therefore, single larvae can cause 13–24% economic losses in grain weight as well as reductions in nutritional value. Furthermore, the larvae bore into the cereal, making it more susceptible to secondary parasites and rendering the rice unsatisfactory for digestion.

Suppression of pests, notably the Angoumois grain moth, has traditionally relied on synthetic pesticides, which, while effective, pose ecological risks and contribute to pest resistance (Zhang et al., 2021). Due to these concerns, there is growing interest in learning alternative, eco-friendly pest control methods. Historically, botanical products have been used as natural insecticides, repellents, and antifeedants (Yesmin et al., 2023). These solutions based on plants are cost-effective, locally available, and less detrimental to the natural world compared to synthetic chemicals; additionally, some of the most effective botanical products include extracts, oils, and granules from leaves like neem (*Azadirachta indica*), karanja (*Millettia pinnata*), and mahogany (*Swietenia macrophylla*). In Bangladesh, the fundamental applications of these botanicals or organic plant materials have proven highly effective against stored insects and pests, as well as increased plant protection mechanisms through improved biochemical synthesis (Karim et al., 2024; Laboni et al., 2024; Howlader et al., 2023). This study aims to investigate the damage caused by the Angoumois grain moth in rice storage and evaluate the effectiveness of various indigenous extracts from plants as a sustainable, eco-friendly pest management solution. The study will assess the extent of grain damage caused by the pest and look at the use of botanicals as an alternative to synthetic insecticides, reducing environmental pollution and minimizing contamination of stored grains. In addition, this technique is intended to provide farmers with a more sustainable solution for pest control while ensuring enhanced storage situations.

Materials and Methods

Experimental Setup

The present research assessed the impact of various botanicals on handling of Angoumois grain moth (*S. cerealella*) under laboratory conditions, as well as the scientific study was carried out in the MS Laboratory-II, Department of Entomology, Bangladesh Agricultural University (BAU), from March 2023 to February 2024. Treatments were put together in a completely randomized design (CRD) with five replications; additionally, ten adult moths were introduced into each container holding disinfected, uninfected rice grains.

In the present experiment, the BR-11 rice variety was used, and an examination presents four types of botanical powders, wood ash, and one chemical pesticide, with each treatment replicated five times. The botanical granule dosage was 1 gram per 50 grams of grain, while the pesticide dosage was 0.25 gram per 50 grams of grain (Figure 1c). There were six treatments used in this experiment compared to the control. Among all treatments, there were three types, such as botanical, wood ash, and chemical. Seeds were acquired in March 2023 to carry out the task at hand. The seeds were scrubbed, dried, and salted out from damaged, unhealthy seeds and stored in a large polythe box in an airtight condition to keep them free from insects and microorganisms.

Statistical Analysis

The research investigations were conducted in a highly randomized manner. The data were analyzed using the SPSS 29 statistics software, version 2022. Mean values are separated by the X-stat test at 5% probability to gauge the significance of individual treatment.

Table 1. Details about the treatments

Type	Treatments Name	Scientific Name	Doses	Form
Botanical	Neem	*Azadiracta indica*	1gm	Powder
	Korobi	*Nerium oleander*	1gm	
	Bishkatali	*Persicaria lapathifolia*	1gm	
	Datura	*Datura metel*	1gm	
	Wood Ash		1gm	
	Control	No uses	No uses	
Insecticide	Name of the insecticide	Group	Doses	Form
	Abin 85 SP	Carbaryl	0.25gm	Powder

a b c

Figure 1. a. Set up of the experiment; b. Mass Rearing of Angoumois Grain Moth Inside of Earthen Pots and c, Preparation of different treatments

Rearing of Angoumois grain moth (S. cerealella) and test insects

Steps	Details
Moth Placement	50-60 moths placed in 10×10-inch earthen pots with rice grains at 26-27°C for 30-35 days.
Identification	Males and females distinguished via microscope; females (5.5 mm) and males (5.0 mm) separated by aspirator based on abdominal characteristics.
Mass Rearing	Thousands of adults collected and reared in a glass cylinder covered with a 32-mesh net for mating and egg-laying.
Egg Collection	Eggs laid on cylinder walls were brushed, sieved, cleaned, and stored in a refrigerator at 4°C for future studies.
Egg Hatching	Collected eggs placed on white paper in a Petri dish for hatching.
Larvae Transfer	Newly hatched larvae transferred to Petri dishes containing grains for further observation and study.

Data Collection

Parameters	Details
Moth Exposure	Ten newly emerged moths were placed in plastic containers with insect-free rice grains treated with various substances, including an untreated control. Moth mortality was monitored every 24 hours for 21 days.
Adult Emergence Observation	After 24–28 days, new adults began emerging from the grains; the numbers of emerged adults were recorded by gently shaking the containers and removing cloth covers.
Mortality Counting	Adult moth mortality was counted at 7, 14, and 21 days after treatment (DAT). The total death count in treated and untreated conditions was compared, and the percentage of adult mortality was calculated using the formula: % Mortality = (Total deaths / Initial population) × 100
Cumulative Mortality	Cumulative mortality was calculated at 5, 10, 15, and 20 DAT as the total number of deaths within the population over time, expressed as a percentage.
Seed Damage Evaluation	After adult emergence, seeds were cleaned, and 10 random seeds were inspected to count holes made by larvae. The percentage infestation was calculated as % Infestation = (Number of infested seeds / Total seeds) × 100.
Adult Emergence Rate	To determine adult emergence rate, larvae or pupae were reared and monitored daily, with emergence rates calculated at 7, 14, 21, and 28 DAT.
Cumulative Adult Emergence	Daily emergence counts were recorded and cumulatively added up to obtain a total. Cumulative emergence was plotted to observe trends, with counts at 7, 14, 21, and 28 DAT.
Seed Hole Count	Ten random seeds were inspected for visible holes, with the total number of holes counted.
Grain Weight Loss Measurement	Initial grain weight and subsequent weights at each recording time were measured. Percentage weight loss was calculated as % Grain Weight Loss = (Initial Weight - Recorded Weight) / Initial Weight × 100.
Seed Viability (Germination Test)	The germination rate was tested by placing 10 seeds on water-soaked blotting paper for 5 days at 27-34°C. After germination, the rate was calculated as % Seed Germination = (Germinated Seeds / Total Tested Seeds) × 100.

Results

The mortality rates of adult Angoumois grain moths are significantly different from one another, and the percentage of adult mortality increases each day following treatment. Among all treatments, insecticide had the highest mortality rate (99%) at 21 DAT, followed by Neem (86%), Bishkatali (62%), Korobi (42%), Dhutora (40%), Ash (36%), and Control (34%), respectively (Table 2).

Among the all treatments, the highest cumulative mortality (10%) was observed in insecticide (Carbaryl) after 5 DAT, while among the botanical treatments, it was observed that Neem had the highest cumulative mortality (9%) after 20 DAT. Control treatment demonstrated the lowest cumulative mortality in different days after treatment (Figure 2).

The mean number of adult moths that emerged from grains varied significantly among the various treatments that were applied (Table 2). In terms of all treatments that were executed, the highest adult emergence was observed at 14 DAT, with a value of 50.45 in control (Table 2). This number of adult emergences was followed by wood ash (32.46), korobi (29.80), and dhutora (26.43).

The mean value of the untreated control was 138.11, which is the maximal cumulative adult emergence that was recorded. The second highest emergence was observed in Ash (74.03), followed by Korobi (72.73) and Dhutora (65.41). Bishkathali's mean value was 56.4. The considerably lowest cumulative number of adult emergences observed was 43.77 in Neem (Table 2).

Table 2. Effect of different treatments on adult mortality (%) and numbers of adult emergence of Angoumois grain moths

Treatment	Adults Mortality (%)			Numbers of adult emergence			
	7 DAT	14 DAT	21 DAT	7 DAT	14 DAT	21 DAT	28 DAT
Neem	56 a	66 b	86 b	9.62 b	16.01 b	14.31 b	3.83 b
Korobi	36 a	38 b	46 d	13.83 d	29.80 d	22.29 d	6.81 d
Dutora	28 d	34 d	40 d	12.81 d	26.43 cd	19.41 cd	6.76 d
Bishkatali	40 c	54 c	62 c	10.26 c	23.89 c	17.63 c	4.62 c
Wood ash	26 d	44 d	36 e	13.81 d	32.46 d	20.49 cd	7.27 d
Insecticide (Carbaryl)	91 a	94 a	99 a	1.40 a	2.60 a	4.00 a	2.01 a
Control	14 e	32 d	34 e	16.44 e	50.45 e	45.00 e	26.22 e
LS	*	*	*	*	**	**	**
CV (%)	16.26	14.76	14.4	14.67	8.94	12.87	18.46
LSD (0.05)	3.23	4.68	2.29	1.15	0.96	1.32	1.67

Here, Means having same letter within a column do not differ significantly at 5% level of probability, LS= level of significance *= Significant at 5% level of probability and **= significant at 1% level of probability

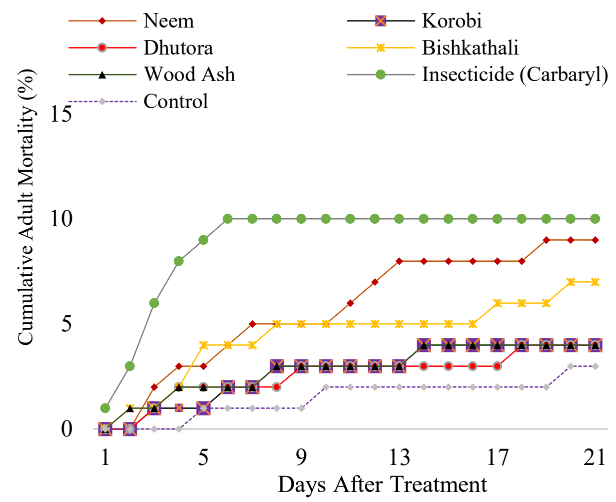

Figure 2. Cumulative mortality of Angoumois grain moth against different Treatments for several days

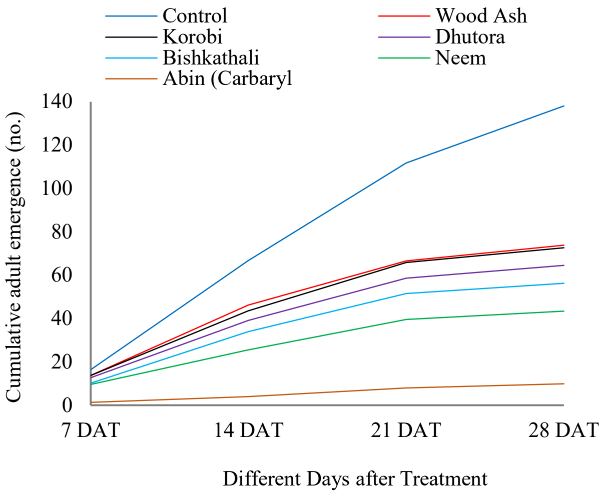

Figure 3. Effects of different treatments on cumulative adult emergence

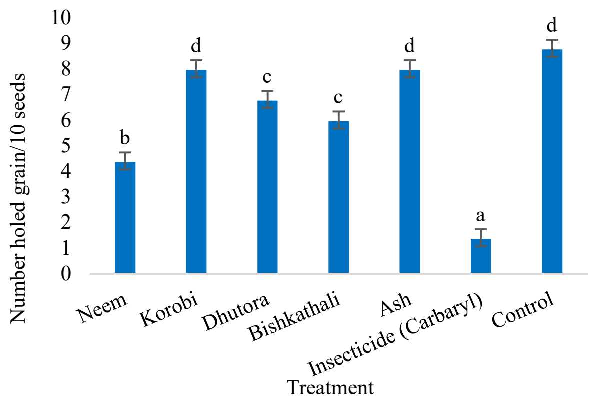

Figure 4. Number of holes grains per 10 seeds for different treatments.

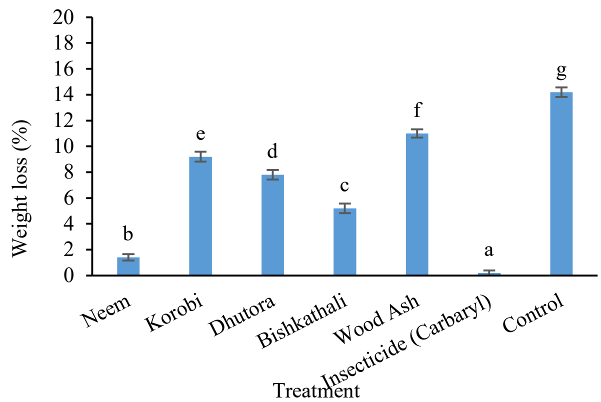

Figure 5. Weight loss of grain (%) for different treatments by AGM.

The number of holes per 10 seeds for different botanicals, ash, and pesticides displays inconsistent results. Neem, pesticide, (dhutora and bishkatali), and (korobi, ash, and control) are substantially distinct from each other, while dhutora and bishkatali do not significantly differ. On the other hand, Korobi, wood ash, and control are considerably dissimilar. It had been observed that the control treatment had the most numbers of hole seeds per ten seeds (8.8), and moreover, it was demonstrated that the wood ash (8) and the korobi both had the exact same numbers of hole seeds per ten seeds (8), followed by Bishkathali (6). The lowest numbers of holes per grain per 10 seeds were exhibited in insecticide (1.4), and additionally, Neem resulted in better performance with a value of 4.4 (Figure 4).

Untreated control treatment had the highest quantity of weight loss (14.2%), followed by wood ash (11%) and korobi (9.2%), respectively, whereas it was the minimal in insecticide (Carbaryl) (0.2 %) (Figure 5).

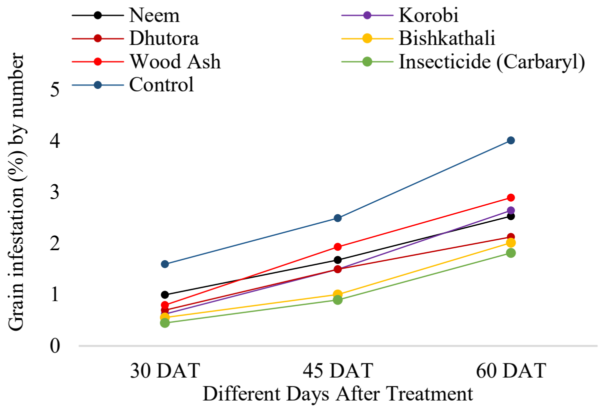

Figure 6. Effect of different treatments on the grain infestation by number of stored grain seeds during the management of AGM

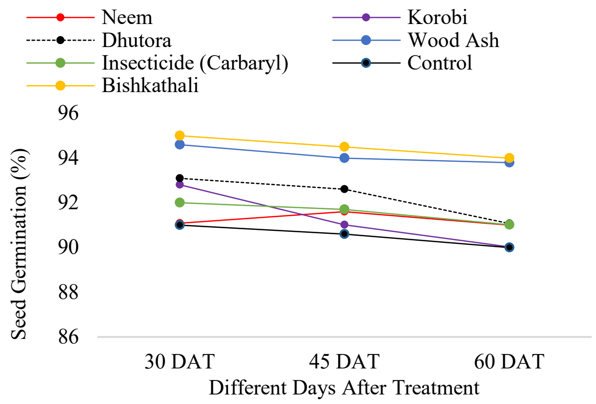

Figure 7. Effect of different treatments on germination of stored seeds during the management of AGM

The diseases infestation was statistically significant at the 1% level of probability, considering the seven promising treatments. Bishkathali demonstrated the minimum percent of infestation to be 0.56, 1.01, and 2.02% among the botanical treatments at 30, 45, and 60 DAT, respectively. The minimum percent of infestation was lowest in insecticide (Carbaryl) at 0.45, 0.905, and 1.82% for 30, 45, and 60 DAT, respectively (Figure 6).

Statistically, percent germination of rice seed was varied significantly at the 1% level of probability among seven promising treatments. At 30, 45, and 60 DAT, the maximum germination percent of the evaluated seven treatments was bishkathali, with values of 95, 94.5, and 94%, respectively. The subsequent maximum germination percent was observed in wood ash, with values of 94.8% at 30 DAT, 94% at 45 DAT, and 93.80% at 60 DAT (Figure 7).

Discussion

Protecting crops from insects is one of the global problems. Continuous uses of synthetic chemicals lead to toxicity, endangering the health of farm operators, bioagents, animals, farmers, and food consumers, and additionally harming the ecology. Application of botanical extracts and dried powders has an enormous effect on biorational or integrated pest management tactics for insects and pests. This strategy is recognized by many as eco-friendly. From the outcomes of this investigation, the highest mortality and cumulative mortality percent recorded in carbaryl were followed by Neem. In spite of the fact that the mortality time of *Sitophilus granarius* and *Rhizopertha dominica* decreased as concentrations of botanical treatments increased (Hassan et al., 2022). *Azadirachta indica* (neem) was more effective at reducing *S. cerealella* by increasing mortality percent; however, different levels of efficacy may be observed. The adult emergence of the insect was substantially reduced or prevented by the botanical powders and extracts.

Akter & Jahan (2013) found that neem plant extracts had the most deleterious effects, such as the number of dead insects at 72 DAT (14.75), insect mortality (100%), adult mortality (0.00), and germination (96%), and additionally, biskatali, dhutora, korobi, and ash showed inferior performance than neem.

The study appears to be similar to Zote Vaishali & Shukla (2023b), and findings mentioned that the neem leaf powder was found most effective due to causing higher mortality. Naseri et al. (2017) found that Corcyra cephalonica (Stainton) in stored rice kernels is used as some selected botanicals, such as neem, tulsi, karanj, and eucalyptus leaf powder. The result revealed the highest mortality (81.67%) after 30 DAT, and it was concluded that the neem leaf powder was most effective. Untreated control treatment had the highest number of adult emmergence and cumulative adult emmergence; similar observations were recorded by Akter & Amin (2017). The least number of adult emergences was observed in Neem, indicating that the minimum number of newly emerged adult Angoumois grain moths was observed. After that, bishkatali, dhutora, korobi, and ash exhibit a lower number of adult emergences than control. The study's findings indicate that atypical development prevents adult emergence. By using botanicals, the average grain weight loss was 13.63%, and a germination percentage of 68.75% was recorded in Sitophilus-infested sorghum. Hossein et al. (2018) observed that bishkatali leaf powder had the effect of minimizing grain infestation (0.58%) at 30 DAT and increasing germination (92.13%) of paddy.

Conclusion

Considering the findings of this study, it was exhibited that the insecticide (Carbaryl) was performed superiorly in the extent of highest mortality and cumulative mortality, weight loss control, but to protect the ecological environment, which is not suggested for controlling Angoumois Grain Moth. Among the botanical treatments, Neem powders performed better at increasing adult mortality, reducing grain weight loss, adult emergence, and reducing grain hole problems in seeds. Additionally, bishkathali powders are suggested for reducing infestations and subsequently increasing the germination rate. The results of this study indicate that Neem and Bishkathali powders were more effective in suppressing the Angoumois grain insect.

Declarations

Acknowledgements

All authors express their gratitude to the laboratory staff of the Department of Entomology at Bangladesh Agricultural University, Mymensingh-2202, for their cooperation during the evaluation period of this investigation.

Conflicts of interest

All authors declared there was no conflict of interest.

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