Evaluating the Efficacy of Boric Acid and Natural Ingredients against *Sitophilus granarius*: A Sustainable Approach to Wheat Protection

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***Abstract*—** *The economy and employment in India are significantly impacted by agriculture, with Wheat (Triticum aestivum) serving as a crucial staple crop. However, Sitophilus granarius infestations result in yearly significant agricultural losses. This study compares natural insect prevention techniques employing Azadirachta indica, Piper nigrum, Syzygium aromaticum, and Laurus nobilis and the efficacy of boric acid, a common pesticide, against the Triticum aestivum pest. The experimental design examined 50g of Triticum aestivum, 10 Sitophilus granarius, and different amounts of boric acid (1g, 2g, and 5g) during 24 hours, 48 hours, and 72 hours. The LD_{50} value of boric acid was observed to be best at 5g in 48 hours. Similarly, for the natural method, the LD_{50} value was best observed in Laurus nobilis in 48 hours. By this, we can state that Boric acid (Chemical method) remains more effective than the natural method, as it has immediate results. Natural methods can be considered as an alternative to an environmentally friendly approach.*

Keywords*— *Azadirachta indica (Neem), Boric acid, Piper nigrum (Black pepper), Laurus nobilis (Bay leaf), Sitophilus granarius, Syzygium aromaticum (Cloves), Triticum aestivum (Wheat).

I. INTRODUCTION

Agriculture is a vital sector in the Indian economy, employing 56% of the workforce and contributing to economic growth and poverty alleviation. It also enhances earnings in the non-agricultural sector by expanding commercial crops and promoting exports (*Dev, S.M. & Indira Gandhi Institute of Development Research. (2012)*). Pest and insect infestations cause agrarian losses, wasting natural resources, harming the economy and ecology, and reducing global food availability. These losses disrupt production, reduce crop quality, and negatively impact financial outcomes as consumers demand higher-quality products (Junaid and Gokce, 2024)

Triticum aestivum, an ancient crop essential for the human diet, is experiencing increased demand due to its affordable finished goods. India loses 10% of its food grains after harvest due to improper storage, insects, rodents, and microbes. Infested grains cause significant economic losses, including food contamination and waste, rendering them unfit for human consumption. Around 500 insect species infest stored grain products, with nearly 100 causing financial losses. Almost 100 pest species that damage stored goods result in substantial financial losses (Kumar, 2017). It has been shown that pests harm 20% of crops post-harvest; in developing countries, the percentage of losses can sometimes exceed 80%. Stored insects inflict considerable quantitative and qualitative economic damage to agricultural produce. In addition to the issues surrounding the harmful effects of pesticides on humans and animals, as well as environmental contamination, pesticides are used to protect crops and stored commodities from dangerous insects (*USE OF SILICA BORIC ACID MIXTURE TO CONTROL THE KHAPRA BEETLE (TROGODERMA GRANARIUM, DERMESTIDAE: COLEOPTERA) ON STORED WHEAT SEEDS. PLANT ARCHIVES. (N.d.). (No date)*, no date).

In both industrialized and developing countries, insect pests account for a significant portion of crop losses. More than 10,000 insect species, 30,000 weed species, and 100,000 diseases (caused by fungi, viruses, bacteria, and other microbes) are believed to affect food plants worldwide (Dhaliwal, Jindal and Mohindru, 2015).

Sources in the agricultural industry include wastewater, livestock dung, insecticides, and fertilizer. Toxicants such as heavy metals (cadmium (Cd), lead (Pb), copper (Cu), and zinc (Zn) and pesticides (insecticides, herbicides, and fungicides), which can penetrate and accumulate through the food chain, are causing harmful health issues like lung cancer, renal failure, osteoporosis, and heart failure, leading to acute and chronic illnesses (Alengebawy *et al.*, 2021).

Four insect species, including the granary weevil, can grow inside *Triticum aestivum* kernels on endosperm and live on the grain while stored. The granary weevil, a damaging insect, prefers moderate climates and can grow up to three-sixteenths of an inch in length. Its head has a long, thin snout with mouthparts at the end, and bigger oval punctures characterize its pronotum. Adult granary weevils typically take over four weeks to complete their life cycle and can survive for seven to eight months. They are one of the most damaging insects for stored grains (Alanazi, 2023). The granary weevil, *Sitophilus granarius* L., is a pest of *Triticum aestivum* and attacks dried grain and bean products. Adult weevils range in colour from black to chestnut-brown and have elbowed antennae distally. The head, stretched into a thin rostrum, contains sensory organs and receptors for smell, taste, and vision. The antennae are often carried in extended positions during travel (El-Ghany and El-Aziz, 2017).

Boric acid (H_3BO_3) has a long history of use in pest management, including controlling ants, cockroaches, and grain weevils. Registered in 1983, it has been used in stomach poison, dry powder, and bait formulations. Insects are drawn to boric acid, which attaches to their legs. However, due to its acute effects, including mutagenicity, eye and skin irritation, and oral and dermal toxicity, the Environmental Protection Agency (EPA) classifies boric acid as moderately acutely hazardous (*Evaluating the effectiveness of different concentrations of boric acid on the pink and spiny bollworms under laboratory conditions: Vol. Vol 6.; 2019:485-497. (N.d.).*, no date). Boron is a non-volatile, low-toxicity mineral found in soils, aquatic habitats, and human diets. It is a necessary nutrient for humans and plants and is often used as a low-toxicity insecticide to manage pests like insects, mites, fungi, algae, and certain vascular plants. Boric acid is a safer alternative to synthetic pesticides and can be used in bait compositions (Alanazi, 2023).

Novel pesticides are abundant in higher plants. Botanical insecticides may be more environmentally friendly than synthetic ones. Farmers and small businesses can also utilize these insecticides because they are less expensive and simple to process (Abubaker, 2021).

Laurus nobilis: India's higher cereal consumption necessitates non-insecticide management methods, such as essential oils and dried bay leaf, for pest control and post-harvest crop protection, as even a small pesticide residue can significantly impact grain intake (Chahal, Bansal and Kaur, 2016)) . *Laurus nobilis* is a natural pesticide that can reduce environmental and human health risks, replacing synthetic pesticides. Botanical pesticides are increasingly popular, with some plant components used as green insecticides worldwide (*Use of aromatic plant extracts as bio-insecticides for the control of stored-product insect, Sitophilus Granarius. (n.d.).*, no date).

Piper nigrum: Black pepper, a widely accessible herb in Nigeria and West Africa, offers new ways to combat insects, reduce cross-resistance, and provide ideas for creating target-specific compounds (Emeribe, Ohazurike and Okorie, 2016). Numerous plant compounds, particularly essential oils, have had their poisonous qualities against various stored grain pests assessed. Numerous studies on black pepper fruits have demonstrated their high effectiveness as a pesticide against various pests. In addition, their valuable culinary spicy flavour has made them economically significant). (*Toxicity of three chemical extracts of black pepper fruits against two stored grain insect pests. Toxicity of three chemical extracts of black pepper fruits against two stored grain insect pests: Vol. Vol 6. www.ijpsi.org; 2017:20-29. (n.d.).*, no date).

Azadirachta indica: Synthetic chemical pesticides are the primary method for controlling pest infestations in stored grains. However, plant materials with insecticidal qualities remain a viable, biodegradable, and affordable solution. Azadirachtin, an environmentally friendly, short-lived, selective, and mildly toxic insecticide, has gained global interest due to its potential (Danga et al., 2015). Plants like neem have poisonous, repellent, and antifeedant properties against various insect pests. These plants are simple and inexpensive to prepare, with bioactive metabolites activating insect receptors. Pest control or repelling organic extracts from plants protects with minimal ecological effects, keeping pests away from treated *(Use of neem and garlic dried plant powders for controlling some stored grains pests. Use of neem and garlic dried plant powders for controlling some stored grains pests Egyptian Journal of Biological Pest Control: Vol. 2015;25(2):507-512. (N.d.)., no date).*

Syzygium aromaticum: One of the insects that can cause significant financial losses to stored grains globally is the granary weevil, *Sitophilus granarius* (L.) (Coleoptera: Curculionidae). In insects, essential oils and their components have lethal and sub-lethal effects like phagoinhibition, irritability, repellence, and biocide activity (Plata-Rueda *et al.*, 2018). Plant oils have strong insecticidal properties against various insects found in preserved goods. The study aimed to assess clove plant oils' toxicity to pests and their insecticidal activity (Makarem *et al.*, 2017).

II. MATERIALS AND METHODS

The weevils that were used for the experiment were isolated from the *Triticum aestivum* kernels for a very long duration of time. The grains were collected from household storage that was stored in the woven polypropylene bags, at a temperature of 28℃ and 52% humidity to provide the ideal conditions. These conditions were observed using a Hygrometer. The species that was taken for the experiment is *Sitophilus granarius*.

Boric acid is a commercially viable pesticide that inhibits the growth of *Sitophilus granarius* in *Triticum aestivum* kernels. It is predominantly considered a chemical method for preventing *Sitophilus granarius* in *Triticum aestivum*. Similarly, three natural alternatives were considered for the testing, which were Neem leaves (*Azadirachta indica*), Black pepper (*Piper nigrum*), Bay leaves (*Laurus nobilis*), and Cloves (*Syzygium aromaticum*), to check their effectiveness and compare the growth rate of *S. granarius* in *Triticum aestivum*.

The experiment was carried out in a borosilicate glass container with a capacity of 100 g.

Muslin cloth was used to cover the containers to prevent the movement of *S. granarius* outside the container. A digital weighing balance (range 0.01g to 200g) was used to weigh the Boric acid and *Triticum aestivum*.

2.1 Chemical Method:

Four containers were set up to experiment with the chemical method, in which 50 g of wheat (*Triticum aestivum*) and 10 *S. granarius* with different concentrations of boric acid were kept standard as follows:

i. Control- Wheat (*Triticum aestivum*) grains, 10 *S. granarius*
ii. Test 1- 2g Boric acid.
iii. Test 2- 4g Boric acid.
iv. Test 3- 10g Boric acid.

In the above-given setup, the *S. granaries* were tested for different concentrations for 24 hours, 48 hours, and 72 hours to check the LD_{50} (Lethal Dose 50) value and the Acute toxicity of Boric acid on *S. granarius.*

2.2 Natural Method:

Five containers were set up to experiment with the natural method, in which 50 g of wheat (*Triticum aestivum*) and 10 *S. granarius* having different natural remedies were kept standard as follows:

i. Control- Wheat (*Triticum aestivum*) grains, 10 *S. granarius*
ii. Test 1- 10 units of dried neem leaves (*Azadirachta indica)*.
iii. Test 2- 2 units of Bay leaves *(Laurus nobilis*).
iv. Test 3- 10 units of Peppers (*Piper nigrum).*
v. Test 4- 10 units of Cloves *(Syzygium aromaticum)*.

III. RESULT AND DISCUSSION

In the above-given setup, the *S. granarius* were tested with different remedies for 24 hours, 48 hours, and 72 hours to check the LD_{50} (Lethal Dose 50) value and the Acute toxicity of these natural remedies on *S. granarius.*

The rising concentration of Boric acid resulted in a gradual decline in the movement speed of *Sitophilus granarius*. Additionally, it was observed that the number of *Sitophilus granarius* increased in the Control setup.

TABLE 1
EVALUATION OF THE EFFICACY OF BORIC ACID AGAINST *SITOPHILUS GRANARIES*

Time (hours)	Boric acid concentration(g)			
	Control	Test 1	Test 2	Test 3
24 hours	10.33±0.47	9.33±0.47	9.33±0.47	9±0.82
48 hours	10.33±0.94	8±0.82	7.33±1.7	5.33±1.25
72 hours	10±0.82	2.33±1.25	2.67±0.47	1.67±0.47

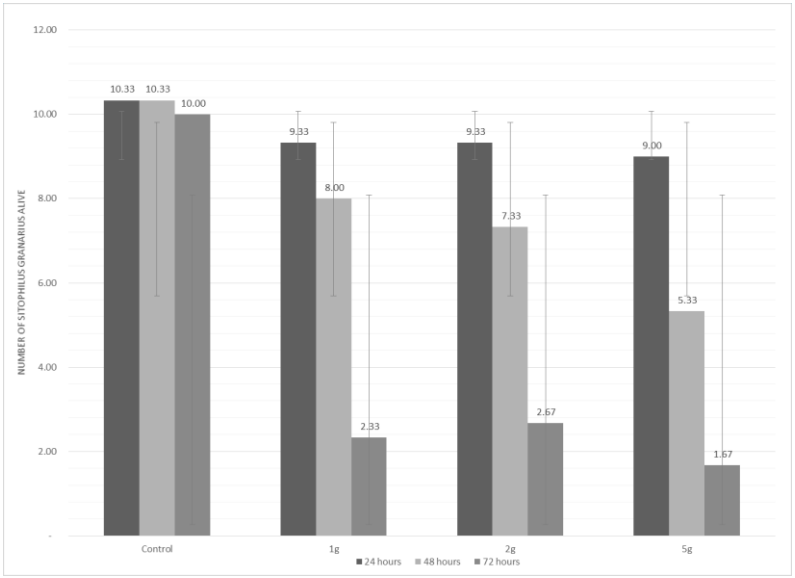

FIGURE 1: Evaluation of the Efficacy of Boric Acid against *Sitophilus granarius*

TABLE 2
EVALUATION OF THE EFFICACY OF NATURAL INGREDIENTS AGAINST *SITOPHILUS GRANARIES*

Time(hours)	Control	Neem leaves	Bay leaf	Pepper	Cloves
24 hours	10.33±0.47	10±0	8±0.82	7.5±1.7	9.5±0.47
48 hours	10.33±0.94	10±0	5±0.82	7±1.25	9±0.94
72 hours	10±0.82	10±0	4.5±0.82	5±0.82	5.5±0.47

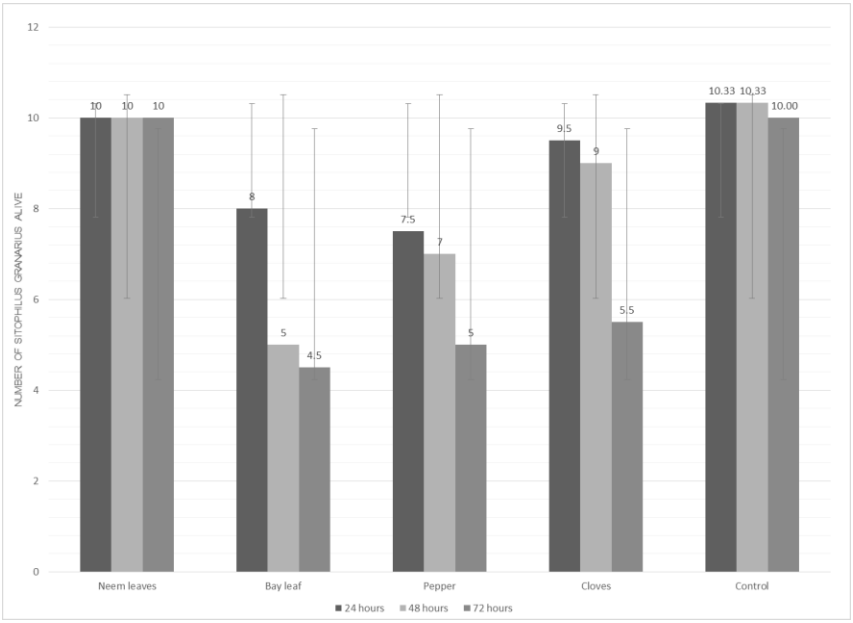

FIGURE 2: Evaluation of the Efficacy of Natural Ingredients against *Sitophilus granaries*

The efficacy of several boron compounds as insecticides against *Sitophilus granarius* and *Rhyzopertha dominica*, two common grain pests, was evaluated. While calcium metaborate (CMB) was nearly as effective but required higher doses, disodium octaborate tetrahydrate (Etidot-67) demonstrated total mortality at certain doses and time frames. The impact of these treatments on the pests' body weight and reproductive capacity was examined as well. At larger dosages, Etidot-67 completely killed both species, while CMB caused a considerable amount of death. SMT and ATFB did not exhibit any noteworthy activity. Both substances showed significant progeny suppression and insecticidal effectiveness (Ertürk *et al.*, 2024). Similarly, in our study, the experiment was conducted concerning Boric acid (Boron Compound). The results observed by (Ertürk *et al.*, 2024), which stated the complete mortality of *Sitophilus granarius*, aligns with the results observed in our experiment, where it showed the LD50 value in 5g of Boric Acid in 48 hours.

The use of synthetic insecticides for storage has sparked worries about their potential drawbacks. By 2030, there is a drive to cut the usage of chemical pesticides by half. There is a push for integrated pest control as a practical substitute for using fewer pesticides (Hamel, Rozman and Liška, 2021) Therefore, in this experiment, the use of natural ingredients plays a pivotal role as to study the effect of different natural ingredients on *Sitophilus granarius*. By the natural testing, significant results in mortality were observed. Natural ingredients like *Azadirachta indica, Piper nigrum, Syzygium aromaticum*, and *Laurus nobilis* can be considered as a sustainable and environmentally friendly approach for grain protection, as chemical pesticides have chronic effects on human health.

In line with a study, the neem-based pesticide *Azadirachtin* effectively repels and toxicity-induces the granary weevil, *Sitophilus granarius*. According to the study, biochemical studies revealed a decrease in the nutrition depletion index, while fumigant and contact toxicity grew with concentration and exposure duration. According to the study, azadirachtin may be used as a natural bioinsecticide to control the number of granary weevils (*Guettal S, Tine SSB, Tine-Djebbar F, Soltani N. Repellency and toxicity of Azadirachtin against Granary Weevil Sitophilus granarius L. (n.d.).*, no date).

The results found in the above study match with our results, as it was observed that the dried Neem leaves act as a preventive measure and repel the growth of *Sitophilus granarius* in stored *Triticum aestivum* grains.

The effect of clove bud powder against granary weevils, both alone and in combination with abamectin and spinosad insecticides, was studied. The results showed that clove powder significantly reduced weevil mortality, with 100% mortality at 1% concentration after 7 days (Abubaker, 2021) Comparable results were observed as the mortality of weevils was seen in the presence of cloves, but a major drawback in the usage of clove was that it released a strong aroma of Cloves in the grains, which can cause changes in the odor in the *Triticum aestivum* and the processed flour.

The study was also conducted in the presence of *Piper nigrum*, where no significant mortality of *Sitophilus granarius* was observed.

This study investigates how well bay leaf essential oil and its constituents may kill the grain pest *Tribolium castaneum*. The two main components of the oil, which were obtained by hydrodistillation, are 7,7-dimethyl-3-methylene bicyclo [2.2.1] heptan-4-ol and eugenol. It has been found that eugenol is more harmful than other substances. Mortality was seen at 33 and 35 days, indicating that the oil and its polar portion were very toxic to the insect. Effectiveness rose with longer exposure times and higher concentrations.[4] The above results align with the findings of our experiment. We found out that amongst all the natural ingredients tested, *Laurus nobilis* showed high mortality on *Sitophilus granarius. Laurus nobilis* can be concluded as the most effective natural approach towards grain protection, as it has no severe impact on human health and is readily available in households for sustainable grain protection.

IV. CONCLUSION

Wheat weevils (*Sitophilus granarius*) are a common invasive species that causes crop losses in India every year. Due to this crop wastage, major economic losses are faced annually. We concluded that 5g of Boric acid in 48 hours of exposure gave the best results, *whereas Laurus nobilis* (Bay leaf) was most effective in 48 hours for natural ingredients. By this, we can say that natural ingredients can be sustainable and are less detrimental to human health. We also observed that *Azadirachta indica* (Neem leaves) restricts the growth of *Sitophilus granarius* and can be used as a preventive measure. Whereas Boric acid remains the most effective in a shorter period continued exposure may have chronic effects on human health. However, we believe that further studies can be carried out to determine the effect of Boric acid and its impact on human health and find the LC_{50} (lethal concentration) of Boric acid on various invasive crop species.

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CONFLICT OF INTEREST

There is no conflict of interest.

AUTHOR'S CONTRIBUTION

Ms. Bakul Dhawane and Ms. Srushti Sawant contributed equally to the completion of the research paper. Both authors conceptualized the idea, performed the experiment, and analysed the results.

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