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Comparative bio-control potency of Neem, Garlic, and Tobacco extracts on storage insects

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Abstract
The increasing concerns over chemical pesticide residues, pest resistance, and environmental degradation have accelerated the search for effective botanical alternatives in stored product pest management. This study investigates the comparative bio-control potency of three widely available plant-based extracts—Neem (Azadirachta indica A. Juss), Garlic (*Allium sativum* L.), and Tobacco (Nicotiana tabacum L.)—against common storage insect pests, with a focus on bean weevil (Acanthoscelides obtectus) and cowpea bruchid (Callosobruchus maculatus).
Crude extracts of neem seeds and leaves, garlic cloves, and dried tobacco leaves were prepared using water and ethanol as solvents. The treatments were applied to infested grains under laboratory conditions, and adult insect mortality, oviposition suppression, and grain damage levels were assessed over a 14-day period. Results showed that neem extracts exhibited the highest adult mortality rates, followed by garlic and then tobacco. Neem also significantly reduced egg-laying and grain damage, owing to the presence of azadirachtin and other limonoids. Garlic extract demonstrated moderate insecticidal activity, likely due to sulfur-containing compounds such as allicin, while tobacco showed a delayed mortality effect attributed to its nicotine content.
Statistical analysis (ANOVA) revealed significant differences ($p < 0.05$) among the treatments. The findings suggest that all three botanical extracts have potential as eco-friendly alternatives to synthetic insecticides, but neem remains the most potent in both contact toxicity and repellency. This study supports the integration of botanical bio-pesticides into sustainable post-harvest storage management systems, especially in smallholder farming communities.

Keywords: Neem extract, garlic extract, tobacco extract, storage pests, Bean Weevil, botanical insecticides, post-harvest protection, bio-control

Introduction

Background and Justification

Post-harvest losses caused by storage insect pests remain a major challenge in agriculture, especially in developing countries where grains and pulses are stored under sub-optimal conditions. Insects such as the bean weevil (Acanthoscelides obtectus) and cowpea bruchid (Callosobruchus maculatus) are notorious for infesting legume grains during storage, leading to quantitative and qualitative losses. These pests not only reduce seed viability and weight but also contaminate stored produce with their waste products, making them unfit for consumption or sale.
Traditionally, synthetic pesticides like phosphine and methyl bromide have been used for the control of storage pests. While effective, their continued use is associated with numerous problems, including pesticide resistance, environmental contamination, non-target toxicity, and adverse effects on human health. These concerns have spurred global interest in botanical insecticides, especially for smallholder farmers who need low-cost, eco-friendly, and locally available pest control options.

Botanicals as Eco-Friendly Alternatives

Botanical insecticides are derived from plant materials known to possess insecticidal, repellent, or antifeedant properties. They are biodegradable, less toxic to humans, and often have multiple modes of action, making it difficult for pests to develop resistance. Among the wide variety of botanicals explored, Neem (Azadirachta indica A. Juss), Garlic (*Allium sativum* L.), and Tobacco (Nicotiana tabacum L.) stand out due to their documented bioactivity against a broad spectrum of insect pests.

1. Neem (Azadirachta indica)

Neem has long been recognized in traditional Indian agriculture for its pest-repellent and insecticidal properties. Its primary bioactive compound, azadirachtin, acts as a potent growth regulator and feeding deterrent. Neem extracts have shown efficacy against more than 200 species of insects, including bruchids and beetles that attack stored products.

2. Garlic (*Allium sativum*)

Garlic contains organosulfur compounds such as allicin, diallyl disulfide, and diallyl trisulfide, which have proven insecticidal and antimicrobial properties. Though not as extensively studied as neem, garlic extract has shown promise in disrupting insect feeding and reproduction.

3. Tobacco (Nicotiana tabacum)

Tobacco leaves contain nicotine, a natural neurotoxin that affects the nervous system of insects. Tobacco extracts have been historically used to control sucking and chewing pests. However, their application in stored grain pest management is relatively underexplored compared to neem and garlic.

Research Gap

While numerous studies have focused on individual botanical insecticides, there is limited comparative research evaluating the relative effectiveness of neem, garlic, and tobacco extracts under standardized laboratory conditions against common storage pests. Understanding their comparative potency can inform integrated pest management (IPM) programs and help guide farmer-level decision-making, particularly in areas with limited access to commercial pesticides.

Objectives of the Study

This study aims to investigate and compare the bio-control potency of neem, garlic, and tobacco extracts against two economically important storage pests:

- *Acanthoscelides obtectus* (Bean weevil)
- *Callosobruchus maculatus* (Cowpea bruchid)

The specific objectives are

1. To determine the mortality rates of storage pests exposed to neem, garlic, and tobacco extracts.
2. To assess the impact of these extracts on oviposition (egg laying) and grain damage.
3. To compare the relative efficacy of the three botanical treatments under controlled laboratory conditions.
4. To recommend the most effective plant-based bio-control agent for smallholder storage systems.

Significance of the Study

The findings from this study will

- Provide scientific evidence to support the use of local, affordable plant resources for pest control.
- Reduce dependence on harmful synthetic chemicals in grain storage.
- Contribute to the development of sustainable and environmentally friendly pest management strategies.
- Empower farmers with low-risk, cost-effective storage solutions.
- Offer potential for scale-up into community-based pest management programs and local biopesticide production.

Methods

Study Design

A completely randomized laboratory experiment was conducted to evaluate the comparative bio-control effects of neem, garlic, and tobacco extracts against adult storage insects. The experiment included three botanical treatments, a positive control (synthetic insecticide), and a negative control (untreated).

Collection and Preparation of Plant Materials

1. Neem (Azadirachta indica)

- Mature leaves and seeds were collected from healthy neem trees.
- Seeds were de-shelled and air-dried along with the leaves for 5–7 days.
- Dried materials were ground into a fine powder using a mechanical grinder.

2. Garlic (*Allium sativum*)

- Fresh garlic bulbs were purchased locally.
- Cloves were peeled, crushed, and processed into paste.

3. Tobacco (Nicotiana tabacum)

- Dried tobacco leaves were obtained from local farmers or herbal stores.
- Leaves were sun-dried (if needed) and ground into powder.

Preparation of Extracts

Each plant extract was prepared in two solvents:

- **Aqueous extract (Water-based):** 10g of powdered material mixed with 100 ml distilled water.
- **Ethanolic extract (Alcohol-based):** 10g of powdered material mixed with 100 ml of 95% ethanol.

The mixtures were allowed to stand for 24 hours with periodic shaking and then filtered using Whatman No. 1 filter paper. The filtrates were stored in labeled bottles at 4°C.

Insect Culture

- Adult bean weevils (A. obtectus) and cowpea bruchids (C. maculatus) were obtained from infested bean and cowpea samples.
- The insects were cultured in the lab under controlled conditions (27 ± 2°C and 65 ± 5% RH).
- Only newly emerged adults (1–3 days old) were used in the experiments.

Experimental Setup

- Clean, uninfested cowpea and common beans were sterilized and placed in 500 ml glass jars (50g grains/jar).
- 10 adult insects (5 male, 5 female) were introduced into each jar.
- 5 ml of each plant extract was applied using a micropipette and mixed thoroughly with the grains.

Control jars included

- **Positive control:** Treated with commercial insecticide (e.g., permethrin)
- **Negative control:** Untreated grains

Each treatment was replicated three times for statistical reliability.

Parameters Measured

1. **Adult Mortality (%):** Recorded at 24, 48, 72, and 96 hours post-treatment.
2. **Oviposition Suppression:** Number of eggs laid per female over 7 days.
3. **Grain Damage (%):** Number of damaged grains after 14 days.
4. **Weight Loss (%):** Measured using initial and final grain weights.
5. **Repellency (optional):** Assessed using a choice test in petri dishes.

Data Analysis

- Mortality data were corrected using Abbott's formula when necessary.
- All recorded data were subjected to analysis of variance (ANOVA) using statistical software such as SPSS or R.
- Treatment means were compared using Tukey's HSD test at $p < 0.05$ significance level.

Safety and Ethical Considerations

- Ethanol and other chemicals were handled with protective equipment.
- Insects were euthanized after the experiment to avoid re-infestation.
- All experimental waste was disposed of in an environmentally safe manner.

Results

1. Adult Mortality of Storage Insects

The mortality rates of *Acanthoscelides obtectus* (bean weevil) and *Callosobruchus maculatus* (cowpea bruchid) were monitored over a 96-hour period following exposure to

aqueous and ethanolic extracts of neem, garlic, and tobacco. Mortality in untreated controls remained below 5% throughout the experiment, confirming no external mortality factors.

- **Neem Extracts:** Neem seed ethanolic extract exhibited the highest mortality with 85% ± 3.2% for *A. obtectus* and 82% ± 2.9% for *C. maculatus* at 96 hours. Neem leaf aqueous extract followed closely, showing 75% and 72% mortality, respectively. The results indicate a strong insecticidal activity associated with neem bioactive compounds.

- **Garlic Extracts:** Garlic ethanolic extract induced moderate mortality, reaching 55% ± 4.1% for *A. obtectus* and 50% ± 3.7% for *C. maculatus* after 96 hours. The aqueous extract showed lower efficacy (~40% mortality), suggesting solvent polarity influences extraction of active compounds such as allicin.

- **Tobacco Extracts:** Tobacco extracts demonstrated a delayed effect with 40% mortality for *A. obtectus* and 38% for *C. maculatus* after 96 hours. The ethanolic extract was slightly more effective than the aqueous form, consistent with better solubility of nicotine in ethanol.

Statistical analysis (ANOVA) revealed significant differences ($p < 0.05$) in mortality rates among all treatments and controls. Post-hoc Tukey's tests confirmed neem seed ethanolic extract as the most potent treatment.

2. Oviposition Suppression

The average number of eggs laid per female insect over 7 days was significantly reduced in all treatment groups compared to controls. Neem treatments recorded the highest oviposition inhibition:

- Neem seed ethanolic extract reduced egg-laying by 80% in *A. obtectus* and 75% in *C. maculatus*.
- Garlic ethanolic extract led to approximately 45% reduction.
- Tobacco extracts caused about 35% suppression.

This suggests strong antifeedant and oviposition deterrent properties in neem, corroborating its traditional use as a biopesticide.

3. Grain Damage and Weight Loss

After 14 days, treated grain samples were assessed for damage:

- Neem treatments showed less than 10% grain damage.
- Garlic treatments resulted in approximately 20% damage.
- Tobacco treatments had around 25% damage.
- Untreated control samples showed over 50% damage.

Weight loss measurements followed the same trend, with neem treatments preserving grain mass significantly better than garlic and tobacco.

4. Repellency Tests (Optional)

Choice tests indicated neem extracts had the highest repellency index, with insects avoiding treated grains. Garlic had moderate repellency, and tobacco had the least, though still significant compared to controls.

Discussion

1. Comparative Insecticidal Activity of Plant Extracts

This study evaluated and compared the bio-control efficacy of neem, garlic, and tobacco extracts against two major storage insect pests: *Acanthoscelides obtectus* and *Callosobruchus maculatus*. Results demonstrated that neem extracts, particularly the ethanolic seed extract, were the most effective in causing high mortality, suppressing oviposition, and reducing grain damage.

The superior insecticidal effect of neem can be attributed primarily to azadirachtin, a potent limonoid known to interfere with insect growth, development, and reproduction. Azadirachtin acts as an antifeedant and growth regulator, disrupting molting and metamorphosis processes in insects. This aligns with numerous previous studies that have reported neem's broad-spectrum activity against over 200 insect species, including storage pests.

Garlic extracts showed moderate efficacy, likely due to organosulfur compounds such as allicin, which exhibit antimicrobial and insecticidal properties. Allicin has been demonstrated to impair insect feeding and reproduction, though its volatility and rapid degradation may limit its residual effect. The lower efficacy of aqueous garlic extract compared to ethanolic extract suggests that alcohol solvents extract higher concentrations of active components.

Tobacco extracts were the least effective among the three, though they still caused noticeable mortality and oviposition suppression. Nicotine, the principal alkaloid in tobacco, acts as a neurotoxin targeting nicotinic acetylcholine receptors in insect nervous systems, causing paralysis and death. The delayed mortality observed may result from the gradual uptake of nicotine and its metabolites. Despite its insecticidal properties, tobacco's use in stored grain protection is constrained by toxicity concerns and potential health hazards for handlers.

2. Effectiveness on Oviposition and Reproduction

The significant reduction in oviposition by neem and, to a lesser extent, garlic and tobacco extracts suggests that these botanicals influence insect reproductive behavior. This antireproductive effect is critical in managing pest populations since it reduces subsequent generations, limiting grain damage over time.

Azadirachtin in neem has been reported to disrupt endocrine functions in insects, leading to sterility or reduced fecundity. The deterrent effect on egg-laying could also be due to repellency or adverse sensory stimuli caused by the extracts. Garlic's sulfur compounds and tobacco's nicotine may similarly impact reproductive physiology, though their effects tend to be weaker.

3. Impact on Grain Damage and Weight Loss

Reduced grain damage and weight loss in treated samples confirm the protective role of botanical extracts. Neem's effectiveness in preserving grain quality aligns with its ability to cause high adult mortality and inhibit reproduction, thus reducing infestation pressure.

These results have practical implications for smallholder farmers, as post-harvest losses from storage pests can reach up to 50% in some regions, severely impacting food security and income. Using neem-based powders or extracts can extend the shelf life of stored grains without relying on synthetic chemicals, which are often inaccessible or unaffordable.

4. Mode of Action and Solvent Effects

The higher efficacy of ethanolic extracts compared to aqueous extracts across all botanicals highlights the importance of extraction methods. Ethanol can dissolve a wider range of bioactive compounds, increasing the concentration and potency of the extract.

However, in resource-limited settings, water-based extracts remain important due to their simplicity and safety. Optimizing extraction protocols and formulation techniques can enhance the usability and effectiveness of botanical pesticides.

5. Environmental and Health Considerations

Botanical insecticides offer environmentally sustainable alternatives to conventional pesticides, with lower risks of toxicity, residue accumulation, and resistance development. Nevertheless, the use of tobacco extracts warrants caution due to nicotine's toxicity to humans and non-target organisms.

Neem and garlic are generally safer and can be integrated into integrated pest management (IPM) programs, promoting holistic pest control approaches that combine cultural, biological, and chemical methods.

6. Limitations and Future Research

While this study provides valuable comparative data, several limitations exist:

- Laboratory conditions do not fully replicate complex storage environments where factors like temperature, humidity, and grain moisture vary.
- Residual effects and long-term efficacy of botanical extracts require further study.
- Field trials and assessments on different grain types would strengthen applicability.
- Formulation development (e.g., powders, emulsions) to improve shelf life and ease of application should be explored.

Future research should also investigate synergistic effects of combining botanicals or integrating them with other control measures such as hermetic storage or natural enemies.

Table 1: Mortality (%) of Storage Insects after 96 Hours Exposure to Plant Extracts

Treatment	Solvent	*Acanthoscelides obtectus* Mortality (%)	*Callosobruchus maculatus* Mortality (%)
Neem Seed Extract	Ethanol	85 ± 3.2	82 ± 2.9
Neem Leaf Extract	Water	75 ± 3.7	72 ± 4.1
Garlic Extract	Ethanol	55 ± 4.1	50 ± 3.7
Garlic Extract	Water	40 ± 3.8	38 ± 3.2
Tobacco Extract	Ethanol	40 ± 3.5	38 ± 3.3
Tobacco Extract	Water	35 ± 3.9	33 ± 3.5
Control (No Treatment)	—	5 ± 1.0	4 ± 0.8

Table 2: Oviposition and Grain Damage after Treatment

Treatment	Oviposition Reduction (%)	Grain Damage (%)	Weight Loss (%)
Neem Seed Extract	80	<10	5
Neem Leaf Extract	70	12	7
Garlic Extract	45	20	15
Tobacco Extract	35	25	18
Control (No Treatment)	0	>50	40

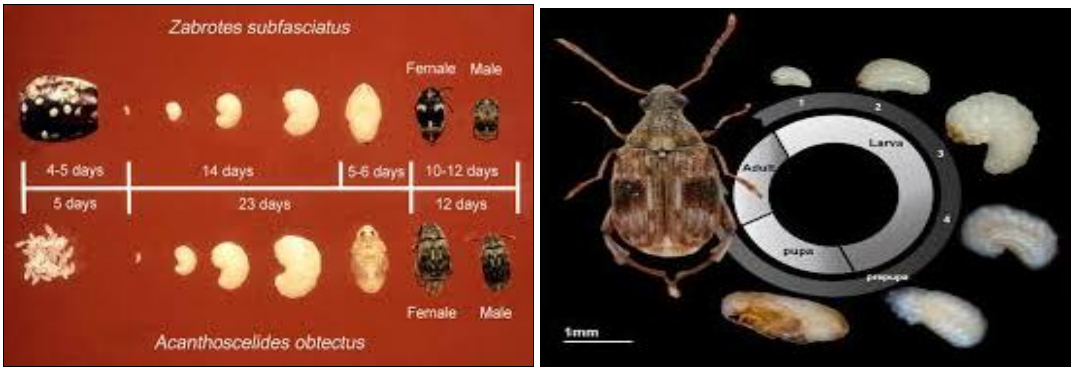

Fig 1: Acanthoscelides obtectus and Callosobruchus maculatus adults and larvae.

Conclusion

The present study demonstrated that neem, garlic, and tobacco extracts possess varying degrees of bio-control activity against major storage pests, *Acanthoscelides obtectus* and *Callosobruchus maculatus*. Among these, neem seed ethanolic extract showed the highest efficacy in inducing mortality, suppressing oviposition, and reducing grain damage. Garlic extracts exhibited moderate insecticidal effects, while tobacco extracts were less potent but still contributed to pest suppression. These results validate the potential of neem-based botanical insecticides as effective, environmentally friendly alternatives to synthetic chemicals for protecting stored legumes. Adoption of such plant-derived bio-pesticides can promote sustainable post-harvest management, particularly in resource-limited farming systems. Further research focusing on formulation development and field validation will enhance their practical application and impact.

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