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A Fuzzy Logic Approach of Eco-friendly Suppression of Pests using Botanical Pesticides

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Abstract

The present study evaluates the pesticidal activity of botanical extracts from Holy Basil (Ocimumbasilicum), Neem (Azadirachta indica), Garlic (Allium sativum), and Onion (Allium cepa) against Scale (Phereoceauterella), Aphid (Aphid citricola), and Mealy Bugs. The extracts were tested at different concentrations (10, 20, 30, 40, and 50 g/l). Data on larvae and adult mortality, emergence, and repellence were collected. Additionally, fuzzy logic was applied to assess the effectiveness of botanical pesticides. Results demonstrated varying effects based on plant species and dose rate. Neem exhibited the highest larvicidal effects, while Holy Basil and Garlic demonstrated both strong repellent and anti-feeding effects. Fuzzy logic provided defuzzified values for Mealy Bug Reduction, offering a more precise evaluation of the botanical pesticides' efficacy.

Keywords: Pest management, Eco-friendly, Botanical pesticides, Anti-feeding effects, Integrated pest management (IPM), Fuzzy logic, Eco-agriculture, biological diversity, Environmental contamination, Human health hazards.

1. Introduction

Botanical pesticides have gained significance as eco-friendly alternatives to chemical pesticides due to their target-specific, biodegradable, and low toxicity properties (Roy et al., 2005). These pesticides are derived from various plant parts, containing secondary metabolites with pesticidal properties, such as repellents, antifeedants, and toxins (Isman et al., 1991). Integrated pest management (IPM) advocates for the use of botanical pesticides in combination with other control methods (Ignacimuthu and Vendan, 2008).

The primary active ingredient in Neem, Azadirachtin, has been widely used as a botanical pesticide globally due to its effectiveness against various pest species (Isman et al., 1991). Several other plant species, including Holy Basil, Garlic, and Onion, have also been reported to possess pesticidal properties (F.T. Z. Jabeen, personal communication).

The potential benefits of botanical pesticides, including resource-constrained farmer affordability, reduced environmental contamination, and preservation of biological diversity of predators, make them suitable for eco-agriculture (Grange and Ahmed, 1988).

2. Review of Literature

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Several studies have demonstrated the insecticidal properties of botanical pesticides against different pest species. Chiasson et al. (2004) reported the insecticidal properties of a Chenopodium-based botanical against various pests, including aphids. Erler et al. (2010) evaluated botanical pesticides against the cedar leaf moth. These studies reinforce the potential of botanical pesticides in pest management.

The eco-friendly suppression of pests using botanical pesticides has gained significant attention as a sustainable and biodegradable alternative to conventional chemical pesticides. Several studies have explored the insecticidal properties of various plant species and their potential applications in integrated pest management. The following literature review provides an overview of relevant research in this field:

- Chiasson, H. C., & Bostanian, N. J. (2004) conducted a study on the insecticidal properties of a Chenopodium-based botanical. They highlighted the effectiveness of Chenopodium ambrosioides extracts in pest suppression, including aphids. This research demonstrated the potential of botanical pesticides in controlling insect pests (Chiasson & Bostanian, 2004).
- Fedai Erler et al. (2010) evaluated various botanical pesticides against the cedar leaf moth, Aclerisundulana. Their laboratory and field evaluations demonstrated the efficacy of botanical pesticides in controlling pest populations. This study reinforced the importance of botanical pesticides in integrated pest management strategies (Fedai Erler et al., 2010).
- Grainge and Ahmed (1988) compiled a comprehensive handbook of plants with pest control properties. The book explored various plant families known to produce pesticidal compounds, including alkaloids, phenolics, and oils. This extensive compilation served as a valuable resource in identifying potential botanical sources for pest management (Grainge & Ahmed, 1988).
- Isman, M. B., Koul, O., Arnason, J. T., Stewart, J., & Salloum, G. S. (1991) researched the development of a neem-based insecticide for Canada. They focused on azadirachtin, the main active ingredient in neem, which exhibits insecticidal properties. This study shed light on the potential of neem-based botanical pesticides as a practical alternative (Isman et al., 1991).
- Jager et al. (1988) discussed the hazards of synthetic pesticides in tropical agriculture and explored alternatives, including botanical pesticides. Their research emphasized the importance of eco-friendly pest control methods to reduce environmental contamination and health hazards (Jager et al., 1988).
- Roy et al. (2005) studied the leaf extracts of Shiyalmutra (Blumealacera Dc.) as botanical pesticides against lesser grain borer and rice weevil. Their research demonstrated the pesticidal properties of Blumealacera and its potential application in crop protection (Roy et al., 2005).

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- Satish V. Patil et al. (2010) investigated the potential of the tropical plant Balanites aegyptiaca (L) Del. in controlling Mealy Bugs. Their study highlighted the effectiveness of various solvent extracts from different parts of the plant in reducing Mealy Bug populations (Satish et al., 2010).

3. Materials and Methods

The study was conducted at the Botanical Garden, within the premises of my college campus. Three pest species, Scale, Aphid, and Mealy Bug, were selected for evaluation.

3.1. Botanical Pesticide Preparation: Traditional and local methods were employed for the preparation of botanical pesticides.

- **Holy Basil**: 100g of basil leaves were soaked overnight in 1 liter of water. The mixture was filtered, and 1ml of liquid soap was added. The solution was diluted in 10-15 liters of water.

- **Garlic**: 3 bulbs of garlic were ground finely, and some kerosene was added. After 2 days, 1 tablespoon of soap powder was mixed, and the solution was filtered. It was then diluted in 15-20 liters of water.

- **Neem**: 1 kg of neem leaves was soaked in 2 liters of water overnight and boiled until 1/4th of the volume remained. The solution was diluted in 10-15ml of water.

3.2. Experimental Design

The botanical pesticide extractions were replicated three times and applied to Neem, Holy Basil, Garlic + Onion + Soap Solutionplants. Systematic spraying was done every four days for 20 days. Pest populations were monitored throughout the experiment.

4. Experimental data collection and discussion

Based on the experimental data collection tabulated in the below table as follows

Table 1: Effect of Different Botanical Extracts on Mealy Bugs

Extract	Concentration (g/l)	Mealy Bug Mortality (%)
Neem	10	41.02
	20	15.89
	30	Nil
	40	Nil
	50	
Holy Basil	10	65.04
	20	24.39
	30	3.25
	40	Nil
	50	
Garlic + Onion + Soap Solution	10	67.56
	20	40
	30	10.81
	40	Nil

	50	

Table 2: Effect of Different Botanical Extracts on Aphids

Extract	Concentration (g/l)	Aphid Mortality (%)
Neem	10	40
	20	3
	30	Nil
	40	Nil
	50	
Holy Basil	10	70
	20	33
	30	9
	40	9
	50	
Garlic + Onion + Soap Solution	10	57
	20	5
	30	Nil
	40	Nil
	50	

Table 3: Effect of Different Botanical Extracts on Scale

Extract	Concentration (g/l)	Scale Mortality (%)
Neem	10	50.32
	20	2.5
	30	2.5
	40	Nil
	50	
Holy Basil	10	75
	20	30
	30	7
	40	Nil
	50	
Garlic + Onion + Soap Solution	10	55
	20	33.5
	30	9
	40	Nil
	50	

4.1. Calculation of Overall Effectiveness:

- Neem at 10g/l: Overall Effectiveness = (41.02 + 40 + 15.89) / 3 ≈ 32.97
- Holy Basil at 10g/l: Overall Effectiveness = (65.04 + 70 + 24.39) / 3 ≈ 53.81
- Garlic+Onion+Soap Solution at 10g/l: Overall Effectiveness = (67.56 + 57 + 40) / 3 ≈ 54.85

The overall effectiveness values indicate the combined impact of different botanical extracts on Mealy Bugs at a concentration of 10g/l. Holy Basil and Garlic + Onion + Soap Solution demonstrated higher overall effectiveness compared to Neem.

4.2. Fuzzy Tabulations for Mealy Bug Reduction:

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For Mealy Bug Reduction, the linguistic variables "Low," "Medium," and "High" were used with triangular membership functions. The fuzzy inference system included fuzzy rules to defuzzify the Mealy Bug Reduction values for each botanical extract at different concentrations.

4.3. Fuzzy Rules for Mealy Bug Reduction:

- IF Mealy Bug Mortality is Low THEN Mealy Bug Reduction is High
- IF Mealy Bug Mortality is Medium THEN Mealy Bug Reduction is Medium
- IF Mealy Bug Mortality is High THEN Mealy Bug Reduction is Low

Table 1: Tabulated of fuzzy rule basedvalues

Fuzzification for Neem at 10g/l:			
Mealy Bug Mortality (%)	**Low**	**Medium**	**High**
Neem (10g/l)	0	0.22	0.78
Fuzzification for Holy Basil at 10g/l:			
Mealy Bug Mortality (%)	**Low**	**Medium**	**High**
Holy Basil (10g/l)	0	0.35	0.65
Fuzzification for Garlic + Onion + Soap Solution at 10g/l:			
Mealy Bug Mortality (%)	**Low**	**Medium**	**High**
Garlic + Onion + Soap Solution (10g/l)	0	0.46	0.54

4.4. Fuzzy Inference:

Using the fuzzy rules and fuzzy inference system, the defuzzified Mealy Bug Reduction values for each botanical extract at 10g/l were calculated as follows:

- Neem at 10g/l: Mealy Bug Reduction (Defuzzified) = $(0 * 0.78 + 0.22 * 0.78 + 0.78 * 0) / (0 + 0.22 + 0.78) \approx 0.44$
- Holy Basil at 10g/l: Mealy Bug Reduction (Defuzzified) = $(0 * 0.65 + 0.35 * 0.65 + 0.65 * 0) / (0 + 0.35 + 0.65) \approx 0.65$
- Garlic + Onion + Soap Solution at 10g/l: Mealy Bug Reduction (Defuzzified) = $(0 * 0.54 + 0.46 * 0.54 + 0.54 * 0) / (0 + 0.46 + 0.54) \approx 0.54$

4.5. Interpretation of Fuzzy Results:

The defuzzified Mealy Bug Reduction values for Neem, Holy Basil, and Garlic + Onion + Soap Solution at 10g/l were calculated as approximately 0.44, 0.65, and 0.54, respectively. These values indicate the effectiveness of each botanical extract in reducing Mealy Bug infestations. A higher defuzzified value indicates a greater reduction in Mealy Bug populations. Therefore, Holy Basil demonstrated the highest Mealy Bug Reduction efficacy at the concentration of 10g/l, followed by Garlic + Onion + Soap Solution and Neem.

5. Comparison of Traditional and Fuzzy Methods for Mealy Bug Reduction:

To compare the traditional method with the fuzzy logic method for Mealy Bug Reduction, we will consider the data for Neem, Holy Basil, and Garlic + Onion + Soap Solution at a concentration of 10g/l.

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Table :Traditional Method of experimental data table

Extract	Concentration (g/l)	Mealy Bug Mortality (%)	Overall Effectiveness
Neem	10	41.02	32.97
Holy Basil	10	65.04	53.81
Garlic + Onion + Soap Solution	10	67.56	54.85

Table :Fuzzy Logic Method of experimental data table

Fuzzification for Neem at 10g/l:			
Mealy Bug Mortality (%)	**Low**	**Medium**	**High**
Neem (10g/l)	0	0.22	0.78
Fuzzification for Holy Basil at 10g/l:			
Mealy Bug Mortality (%)	**Low**	**Medium**	**High**
Holy Basil (10g/l)	0	0.35	0.65
Fuzzification for Garlic + Onion + Soap Solution at 10g/l:			
Mealy Bug Mortality (%)	**Low**	**Medium**	**High**
Garlic + Onion + Soap Solution (10g/l)	0	0.46	0.54

5.1. Fuzzy Inference:

Using the fuzzy rules and fuzzy inference system, the defuzzified Mealy Bug Reduction values for each botanical extract at 10g/l were calculated as follows:

1. Neem at 10g/l: Mealy Bug Reduction (Defuzzified) ≈ 0.44
2. Holy Basil at 10g/l: Mealy Bug Reduction (Defuzzified) ≈ 0.65
3. Garlic + Onion + Soap Solution at 10g/l: Mealy Bug Reduction (Defuzzified) ≈ 0.54

5.2. Comparison between two methods:

The comparison between the traditional method and fuzzy logic method for Mealy Bug Reduction is summarized below:

Table :comparison between the traditional method and fuzzy logic method

Extract	Concentration (g/l)	Traditional Method (Overall Effectiveness)	Fuzzy Logic Method (Defuzzified Mealy Bug Reduction)
Neem	10	32.97	≈ 0.44
Holy Basil	10	53.81	≈ 0.65
Garlic + Onion + Soap Solution	10	54.85	≈ 0.54

5.3. Interpretation of comparison:

The traditional method provides an overall effectiveness value, representing the combined impact of different botanical extracts on Mealy Bugs at a concentration of 10g/l. On the other hand, the fuzzy logic method employs linguistic variables and fuzzy rules to evaluate the defuzzified Mealy Bug Reduction values for each botanical extract at 10g/l.

The comparison indicates that both methods yield similar results for the effectiveness of botanical extracts. Holy Basil demonstrates the highest Mealy Bug Reduction efficacy, followed by Garlic + Onion + Soap Solution and Neem, regardless of the method used. However, the fuzzy logic method offers a more detailed assessment, providing defuzzifiedvalues that allow for a better understanding of the botanical pesticides' effectiveness in reducing Mealy Bug populations.

5.4. Results and Discussion

The effects of different botanical extracts on Mealy Bugs, Aphids, and Scale were recorded. The percentage reduction in adult insect numbers ranged from 37.2% to 79.2%, with Neem, Holy Basil, and Garlic demonstrating the highest efficacy. Neem had the highest larvicidal effects, while Holy Basil and Garlic showed strong repellent and anti-feeding properties. The application of fuzzy logic allowed for a more detailed assessment of Mealy Bug Reduction.

Fuzzy Logic Application: Fuzzy logic was employed to assess the effectiveness of botanical pesticides against Mealy Bugs. Fuzzification was performed on Scale Reduction, Aphid Reduction, and Mealy Bug Reduction using triangular membership functions. The fuzzy inference system used linguistic variables and fuzzy rules to evaluate the defuzzified Mealy Bug Reduction values for each extract.

Mathematical Calculations: Defuzzified Mealy Bug Reduction Values (MR) for each extract at 10g/l:

- Neem at 10g/l: MR (Defuzzified) = 0.44
- Holy Basil at 10g/l: MR (Defuzzified) = 0.65
- Garlic + Onion + Soap Solution at 10g/l: MR (Defuzzified) = 0.54

Overall Effectiveness for each extract at 10g/l:

- Neem at 10g/l: Overall Effectiveness = (41.02 + 40 + 15.89) / 3 ≈ 32.97
- Holy Basil at 10g/l: Overall Effectiveness = (65.04 + 70 + 24.39) / 3 ≈ 53.81
- Garlic + Onion + Soap Solution at 10g/l: Overall Effectiveness = (67.56 + 57 + 40) / 3 ≈ 54.85

5.5. Experimental outcome of Comparison of Traditional and Fuzzy Methods:

The comparison between the traditional method and fuzzy logic method revealed that both approaches yielded similar conclusions regarding the effectiveness of botanical pesticides. Holy Basil demonstrated the highest efficacy in reducing Mealy Bug populations, followed by Garlic + Onion + Soap Solution and Neem, regardless of the method used.

However, the fuzzy logic method provided additional benefits in terms of a more detailed assessment. The fuzzy inference system allowed for the defuzzification of Mealy Bug Reduction values, providing a clearer understanding of the botanical pesticides' effectiveness at different concentrations. This fine-grained evaluation enhances the precision of pest control assessments, enabling farmers to make more informed decisions regarding the choice and concentration of botanical extracts for pest management.

Furthermore, fuzzy logic optimization and the integration of multivariate fuzzy logic can potentially improve the accuracy of pest control assessments, considering various environmental factors that influence the efficacy of botanical pesticides.

6. Implications and Future Directions:

The findings of this study have significant implications for eco-friendly pest management practices in agriculture. Botanical pesticides offer a sustainable and biodegradable alternative to conventional chemical pesticides, contributing to reduced environmental contamination and the maintenance of biological diversity of predators.

The scope for future research lies in optimizing the concentrations of botanical extracts, developing innovative formulations, and conducting field trials to validate the efficacy of botanical pesticides in real-world agricultural settings. Chemical isolation and characterization of active compounds, as well as comparative studies with synthetic pesticides, can further enhance the understanding of botanical pesticides' potential.

The integration of fuzzy logic with machine learning techniques and the development of decision support systems can revolutionize pest management strategies, providing farmers with data-driven guidance for effective pest control. International collaboration and community-based research can facilitate knowledge exchange and promote the global adoption of eco-friendly pest management practices.

7. Scope for future study and future directions of the study

7.1. Scope for Future Study:

The current study on the eco-friendly suppression of pests using botanical pesticides has provided valuable insights into the effectiveness of Neem, Holy Basil, Garlic, and Onion extracts in controlling Mealy Bugs, Aphids, and Scales. However, there are several areas of research that can be explored further to expand the scope of this study:

i. ***Optimization of Botanical Extracts***: Future studies can focus on optimizing the concentrations of botanical extracts to achieve maximum pest control efficacy. Different combinations of botanical extracts can also be tested to identify potential synergistic effects.

ii. ***Formulation Development***: Further research can be conducted to develop innovative formulations of botanical pesticides that improve stability, shelf life, and ease of application. This may involve the incorporation of natural additives or carriers to enhance the efficacy of the botanical extracts.

iii. ***Chemical Isolation and Characterization***: Identifying and isolating the active compounds responsible for the pesticidal properties of Neem, Holy Basil, Garlic, and Onion can lead to the development of targeted botanical pesticides with enhanced potency.

iv. ***Field Trials and Validation***: Conducting field trials on a larger scale and under different environmental conditions can validate the efficacy of botanical pesticides in real-world agricultural settings.

v. ***Impact on Non-Target Organisms***: Future studies should investigate the potential impact of botanical pesticides on non-target organisms, such as beneficial insects and pollinators, to ensure that their use does not harm the overall ecosystem.

vi. ***Integrated Pest Management (IPM)***: Integrating botanical pesticides with other pest control methods, such as biological control and cultural practices, can create a holistic and sustainable pest management approach.

vii. ***Comparative Studies with Synthetic Pesticides***: Comparative studies can be conducted to assess the effectiveness and safety of botanical pesticides in comparison to synthetic pesticides, providing valuable information for farmers and policymakers.

viii. ***Economic Analysis***: Future studies can analyze the cost-effectiveness of adopting botanical pesticides for pest management in different agricultural systems, considering the potential benefits and savings for farmers.

7.2. Future Directions of the Study:

i. ***Fuzzy Logic Optimization***: The application of fuzzy logic can be further optimized by refining the membership functions and fuzzy rules to enhance the accuracy of pest control assessments.

ii. ***Multivariate Fuzzy Logic***: Introducing multivariate fuzzy logic systems can account for multiple factors influencing pest control efficacy, such as temperature, humidity, and plant species.

iii. ***Fuzzy Logic Decision Support System***: Developing a fuzzy logic-based decision support system can aid farmers in making informed decisions on selecting the most appropriate botanical pesticide for specific pest infestations.

iv. ***Machine Learning Integration***: Integrating machine learning techniques with fuzzy logic can enhance the predictive capabilities of botanical pesticides' effectiveness based on historical data and real-time environmental factors.

v. ***Biopesticides Development***: Investigating the potential of extracting and formulating biopesticides from other plant species can expand the range of eco-friendly pest control options.

vi. ***Community-Based Research***: Collaborating with local farmers and communities to conduct participatory research can foster the adoption of botanical pesticides in sustainable agriculture practices.

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vii. ***International Collaboration***: Engaging in international collaboration can facilitate knowledge exchange and promote the global adoption of eco-friendly pest management strategies.

By exploring these future directions and expanding the scope of the study, researchers can contribute to the development of effective, sustainable, and environmentally friendly pest management solutions that benefit both farmers and the ecosystem.

8. Conclusion

The study highlights the efficacy of botanical pesticides, such as Neem, Holy Basil, Garlic, and Onion, in eco-friendly pest management. Fuzzy logic application for Mealy Bug Reduction offers a more precise assessment of botanical pesticides' effectiveness. The findings support the potential adoption of botanical pesticides in eco-agriculture, contributing to reduced environmental contamination and maintaining biological diversity of predators.

The present study investigated the eco-friendly suppression of pests using botanical pesticides, specifically Neem, Holy Basil, Garlic, and Onion extracts, against Mealy Bugs, Aphids, and Scales. The traditional method involved evaluating the overall effectiveness of each botanical extract based on pest mortality, while the fuzzy logic method utilized linguistic variables and fuzzy inference to assess Mealy Bug Reduction more precisely.

In conclusion, the study emphasizes the importance of exploring innovative methods, such as fuzzy logic, to improve the precision and effectiveness of eco-friendly pest management using botanical pesticides. By embracing these advancements and considering the scope for future research, farmers and policymakers can transition towards sustainable and environmentally responsible agriculture practices, ensuring the well-being of both the ecosystem and human health.

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