Journal of Science and Technology

ISSN: 2456-5660 Volume 10, Issue 09 (Sep -2025)

www.jst.org.in

DOI: https://doi.org/10.46243/jst.2025.v10.i09.pp06-19

Study on the Effect of Herbal Fumigation in Leaf mealybug and Overall Plant Growth

1*Ananya K Jinesh and 2Dr. Jinesh K S

1Student, DPS Monarch International School, Al Wukair, Qatar

2Primary Health Care Corporation (PHCC), Doha, Qatar

1ananyakjinesh@gmail.com and 2drjineshks@gmail.com

Abstract

Empowering eco-friendly agricultural methods is a global necessity for sustainable living. The long-term consequences of excessive dependence on chemical pesticides pose significant, multifaceted risks to both environmental and human health. In light of these drawbacks, there is a growing international push towards integrated pest management and safer alternatives. This study presents an opportunity to explore the potential of herbal fumes in pest control as a viable substitute for chemical pesticides. The findings indicate that herbal fumigation is an effective measure against leaf mealybug infestations and significantly reduces their spread to neighboring plants. Additionally, the associated study on Green gram plant (*Vigna radiata*) and Tomato plant (*Solanum lycopersicum*) subjected to controlled herbal fumigation demonstrates enhanced growth in smoke-exposed specimens compared to non-exposed plants.

Keywords: Eco-friendly Pest Management, Herbal Fumigation, Leaf Mealybug Control, Sustainable agriculture.

Background

Mealybugs are one of the most destructive high spreading pests affecting a wide range of horticultural and ornamental crops. Their feeding nature leads to chlorosis, stunted growth, premature leaf drop, and the development of sooty mold due to its honeydew secretion. These effects not only reduce crop yield but also the continuity of the effective market chain. Conventional pest management strategies rely heavily on synthetic chemicals and insecticides. Though effective in the short term, these chemicals lead to significant risks to environmental health which is directly and indirectly affecting to safe living in the planet. Moreover, repeated use has created a situation of the emergence of pesticide-resistant pest populations, diminishing long-term efficacy and sustainability.

In response to these challenges, there is growing interest in the development of botanical alternatives for eco-friendly agriculture such as fumigants derived from medicinal and aromatic plants. The plant parts contain bioactive compounds with insecticidal, repellent properties can be the natural agents offer a promising alternative for integrated pest management (IPM), aligning with global efforts to reduce chemical inputs and promote sustainable ecological resilience.

Introduction

Pesticides are substances, either chemical or biological in nature, designed to suppress, mitigate, or eradicate organisms considered harmful to plants or animals. Chemical pesticides have a central role in modern agricultural practices minimizing crop losses due to insect pests, weeds, and pathogens. Though it has contributed to agricultural productivity, the growing dependence on synthetic pesticides has raised serious concerns regarding environmental stability, human health and the long-term resilience of agroecosystems [1,2]. The most critical concern associated with chemical pesticide use is their impact on non-target organisms. Broad-spectrum pesticides adversely affect natural pests such as pollinators, soil microorganisms, and natural pest predators, thereby disrupting ecological balance and triggering secondary pest outbreaks [3]. A thorough meta-analysis encompassing more than 20,000 effect sizes has validated

ISSN: 2456-5660 Volume 10, Issue 09 (Sep -2025)
www.jst.org.in
DOI: https://doi.org/10.46243/jst.2025.v10.i09.pp06-19

persistent negative effects on growth, reproduction, and behavior across various insects, amphibians, and microorganisms. [4]. Pesticides spread through leaching affect nearby environments, polluting soils and waters; it endangers aquatic life and supports ecosystem functions [5]. Pesticides left over from farming can make food unsafe for long-term use, causing problems like hormones getting out of balance, brain damage, and cancer. [6]. Over sixty percent of global farmland covers approximately 24%. Five million square kilometers are vulnerable to pesticide contamination, with over three-quarters identified as high-risk areas that frequently intersect with biodiversity reserves. [7].

Insects face significant threats because about 41% of their species are endangered by pesticides. This jeopardizes crucial ecological processes, especially pollination, which supports over 75% of the world's food crops. Birds have suffered major decreases in numbers because of pesticides that reduce the insects they eat. For human exposure to pesticides over long periods can lead to significant negative impacts on overall well-being. An annual estimate of 385 million accidental pesticide poisoning incidents happens mostly in poor and developing nations, causing about 11,000 fatalities. The WHO predicts that over three million agricultural workers die annually due to severe pesticide poisoning, according to data [11]. Long-term contact with certain substances can lead to conditions affecting the brain and fertility issues, memory loss, and several types of cancer including leukemia, non-Hodgkin's lymphoma, prostate cancer, and breast cancer [12].

A leaf mealybug is a soft-bodied insect that appears as a white, waxy, cotton-like substance inward on the plants. These pests damage plants by weakening them and hindering their growth, which results in yellowing leaves, wilting, and defoliation. Leaf mealybugs cause problems in many types of plants grown for food in Kerala, India. Phloem-feeding insects settle on young stems, foliage, and flowers. Their feeding disrupts plant health by causing chlorosis, leaf deformation, early shedding of leaves, and decreased photosynthesis efficiency. Prolonged infestation leads to stunted growth, low fruit production, and significant crop reductions [13]. Mealybugs secrete a honeydew-like substance that attracts sooty mold, coating leaves and interfering with stomata, disrupting plant physiology. [14]. Their waxy, cotton-like covering provides protection against natural enemies and conventional chemical sprays, complicating management efforts. Outbreaks are exacerbated by warm climates, dense planting, and excessive nitrogen fertilization. Mealybugs exhibit a polyphagous nature, with infestations documented on over 95 host plant species across 39 families, including papaya, cassava, hibiscus, mulberry, and various ornamentals. Dissemination is facilitated by wind, infested seedlings, and human agricultural activities. Kerala’s dense cropping systems, humid climate, and year-round crop availability further promote pest establishment and expansion.

Objectives

The primary objective of this study is to investigate the potential of polyherbal fumes as an eco-friendly alternative for pest management and plant growth promotion. Specifically, the research aims to evaluate the effectiveness of herbal fumigation in the control of leaf mealybug infestation, both in terms of treating infected plants and preventing the spread of pests to neighboring specimens. Leaf mealybugs, being destructive phloem feeders, pose a significant challenge to sustainable agriculture, and the study seeks to establish whether controlled fumigation with selected herbs can provide a practical and environmentally safe solution. In addition, the study aims to assess the influence of polyherbal fumes on plant growth by conducting comparative experiments between fumigated and non-fumigated plants under controlled conditions. Through this dual focus, the research intends to highlight the dual role of polyherbal fumes in pest suppression and plant growth enhancement, thereby contributing to sustainable agricultural practices.

Literature review

ISSN: 2456-5660 Volume 10, Issue 09 (Sep -2025)

DOI: https://doi.org/10.46243/jst.2025.v10.i09.pp06-19

www.jst.org.in

The growing concern over the ecological and health hazards of synthetic pesticides has encouraged research into eco-friendly alternatives. Herbal fumigation, widely practiced in Ayurveda [15] is now gaining modern scientific validation for its antimicrobial and pest-control properties.

Neem (*Azadirachta indica*) – Neem smoke contains bioactive compounds such as azadirachtin and nimbin, which disrupt insect feeding and microbial metabolism. Studies confirm its effectiveness in reducing microbial load and repelling mosquitoes and crop pests [16,17].

Turmeric (*Curcuma longa*) – Fumes of turmeric rhizomes release curcuminoids and turmerones with strong antimicrobial and insect-repellent activity. Experimental studies demonstrated a reduction in airborne microbes and validated its insect deterrent properties [18].

Calotropis (*Calotropis gigantea*) – Burning of Calotropis leaves produces smoke rich in glycosides and flavonoids with insecticidal potential. Research confirmed its mosquito-repellent activity and antimicrobial effects [19].

Frankincense (*Boswellia serrata*) – Frankincense resin releases α- and β-pinene and boswellic acids, contributing to antimicrobial and insect-repellent activity. Studies report reduced airborne bacterial load and therapeutic potential [20].

Vetiver (*Vetiveria zizanoides*) – Vetiver root smoke contains sesquiterpenes such as vetiverol and khusimol, responsible for antimicrobial and insect-repellent action. Laboratory tests confirm its antimicrobial properties and mosquito deterrent potential [21].

In addition to pest control, smoke-derived compounds such as karrikins act as plant growth regulators, enhancing seed germination and vigor [22,23].

These findings highlight the dual role of herbal fumes in pest suppression and growth promotion, offering a sustainable alternative to chemical pesticides.

Methodology

The current study focuses on two objectives, the first one is to understand the polyherbal fumes in the management of Leaf mealybug infection, including treatment to the affected plant and prevention to the neighboring plants. The second one is to understand the effect of herbal fumes in the general plant growth. To evaluate these two objectives, 4 different experiments will be conducted.

Method and Data Collection for the first objective

The study for the first objective was conducted using a longitudinal (time-series) observational method, where data were recorded periodically at regular intervals. A naturally Leaf mealybug-infested ornamental plant growing in a prone Leaf mealybug infection location was identified as the specimen for the first objective. The frequency of the fume will exposure for 15 minutes in a 24-hour cycle for 10 continuous days. Pest density, spread to neighboring plants, and recovery were documented on day 1, day 10, and day 30 using visual scoring and photographic evidence.

Method and Data Collection for the second objective

The study for the second objective was analyzed through the pre-post comparison method. Freshly budded green gram plants under artificial grow light with conventional drip irrigation was divided into control and treatment groups, with the controlled exposure to herbal fumigation for 5 minutes in 24-hours cycle over 14 continuous days. Morphometric parameters, including plant height, leaf length, leaf width, leaf count, and root branching, were recorded on day 7, and day 14. To observe the growth in a different environment, a study was conducted where two freshly budged tomato plants growing under natural sunlight and conventional irrigation. Morphometric parameters, including plant height, leaf length, leaf width, leaf count, and root branching, were recorded on day 14. In both studies, the common factor was the fume exposure and the fume application pattern.

The results of experiments 1 and 2 will be numerically converted by the following formula.

Journal of Science and Technology
ISSN: 2456-5660 Volume 10, Issue 09 (Sep -2025)
www.jst.org.in
DOI: https://doi.org/10.46243/jst.2025.v10.i09.pp06-19

$$\text{Change is growth of the variable in \% (green gram)} = \frac{\text{The difference of total variable measurement of P1 and P2*100}}{\text{Total variable measurement of P2}}$$

$$\text{Change is growth of the variable in \% (Tomato)} = \frac{\text{The difference of total variable measurement of P3 and P4 *10}}{\text{Total variable measurement of P4}}$$

Identification of test Material for herbal for fumigation

The anti-microbial property and pest-repellent property will be prime criteria in the selection of herbs to prepare the polyherbal combination, hence considered as a property-based selection method.

Materials

Specimen

An ornamental plant naturally growing in a location prone to leaf mealybug infestation will be selected as the primary specimen to evaluate the efficacy of polyherbal fumigation. This plant will serve as a model for assessing both the mitigating effects on infected plants and the preventive potential of the treatment in limiting the spread to adjacent vegetation.

In addition, freshly budded green gram and tomato plants will be utilized to investigate the influence of polyherbal fumes on overall plant growth and vigor under controlled conditions.

Test Material: herbal for fumigation

Ingredients of the polyherbal formula (Table 1&2): A polyherbal formula will be developed with the herbs having anti-microbial and pest repellent properties. The selected herbs are Neem, Turmeric, Giant Milkweed, Indian Frankincense, and Vetiver.

#	Local name	Scientific name	Part used
1	Neem	Azadirachta indica	Bark and seed
2	Turmeric	Curcuma longa	Rhizomes
3	Giant Milkweed	Calotropis gigantea	Whole plant
4	Indian Frankincense	Boswellia serrata	Resin
5	Vetiver	Vetiveria zizanoides	Root

Table 1, Ingredients of the polyherbal formula

Neem (*Azadirachta indica*)

Burning of neem leaves, bark, or seed oil cakes produces dense, aromatic fumes that have been traditionally used in India and Southeast Asia for environmental purification, pest control, and medicinal purposes. The smoke contains bioactive compounds such as azadirachtin, nimbin, nimbidin, and quercetin, which exhibit antimicrobial, antifungal, and insect-repellent activities. Several studies have demonstrated that neem smoke reduces airborne bacterial and fungal load and acts as a natural mosquito deterrent, making it effective in vector control and grain preservation. In addition, azadirachtin and other terpenoids act as natural insect deterrents by disrupting insect feeding, reproduction, and sensory perception, making neem effective in repelling mosquitoes, flies, and other pests The volatilization of these bioactive compounds during burning releases aromatic fumes that combine both antimicrobial and insect-repellent effects, forming the basis for the traditional fumigation practices observed in South Asia.

Turmeric (*Curcuma longa*)

Burning turmeric rhizome powder or dried pieces has traditionally been used in Ayurvedic fumigation for disinfection, respiratory relief, and insect control. The aromatic smoke released during combustion contains bioactive volatile compounds such as curcuminoids, turmerones, and zingiberene, which exhibit strong antimicrobial properties by disrupting microbial membranes and inhibiting enzymatic activity—effectively reducing airborne bacterial and fungal load. Additionally, compounds like ar-turmerone and zingiberene serve as natural insect repellents, deterring pests such as mosquitoes through olfactory irritation and masking of host cues. While turmeric fumigation offers promising benefits for sanitation and pest deterrence, controlled exposure is recommended to avoid potential respiratory irritation from dense smoke.

Calotropis gigantea (*Giant Milkweed*)

Calotropis gigantea, known as arka in Ayurveda, has long been used in traditional fumigation practices for wound care, household disinfection, and pest control. When its dried leaves, latex, or roots are

Journal of Science and Technology
ISSN: 2456-5660 Volume 10, Issue 09 (Sep -2025)
www.jst.org.in
DOI: https://doi.org/10.46243/jst.2025.v10.i09.pp06-19

burned, the resulting acrid smoke releases volatile compounds such as cardiac glycosides (calotropin, uscharin, calotoxin), flavonoids, triterpenoids, and proteolytic enzymes. These constituents exhibit antimicrobial activity by disrupting microbial membranes and inhibiting bacterial and fungal growth, making the fumes effective for environmental sanitation. Additionally, the smoke acts as a natural insect repellent, deterring mosquitoes and flies through olfactory irritation and masking of host cues. Ethnobotanical applications include its use in malaria control and grain protection, while Ayurvedic formulations like Aparajitha dhoopana choornam incorporate Calotropis for its biofumigant properties. However, due to the presence of potent cardenolides, excessive exposure to the smoke may cause respiratory and ocular irritation, necessitating careful regulation during use.

Indian Frankincense (*Boswellia serrata*)

Boswellia serrata resin, or Indian frankincense, has been traditionally burned for fumigation in medicinal and ritual contexts due to its aromatic and bioactive smoke. The combustion releases volatile compounds such as α- and β-pinene, limonene, sesquiterpenes, and incensole acetate, which exhibit antimicrobial properties by disrupting microbial membranes and inhibiting metabolism—effectively reducing airborne bacterial and fungal load. Additionally, the smoke serves as a natural insect repellent, deterring pests through olfactory irritation and masking of host cues. Incensole acetate also contributes to calming and anxiolytic effects, supporting its use in respiratory and inflammatory conditions. While Boswellia fumigation offers benefits for environmental sanitation and vector control, controlled exposure is advised to prevent respiratory irritation from dense smoke.

Giant Milkweed (*Calotropis gigantea*)

Calotropis gigantea, known as arka in Ayurveda, has long been used in traditional fumigation practices for wound care, household disinfection, and pest control. When its dried leaves, latex, or roots are burned, the resulting acrid smoke releases volatile compounds such as cardiac glycosides (calotropin, uscharin, calotoxin), flavonoids, triterpenoids, and proteolytic enzymes. These constituents exhibit antimicrobial activity by disrupting microbial membranes and inhibiting bacterial and fungal growth, making the fumes effective for environmental sanitation. Additionally, the smoke acts as a natural insect repellent, deterring mosquitoes and flies through olfactory irritation and masking of host cues. Ethnobotanical applications include its use in malaria control and grain protection, while Ayurvedic formulations like Aparajitha dhoopana choornam incorporate Calotropis for its biofumigant properties. However, due to the presence of potent cardenolides, excessive exposure to the smoke may cause respiratory and ocular irritation, necessitating careful regulation during use.

Vetiver (*Vetiveria zizanoides*)

Burning the roots of Vetiveria zizanoides, commonly known as Ramacham or khus, produces aromatic fumes traditionally used in South India for indoor air purification, pest control, and grain protection. The smoke contains volatile sesquiterpenes such as vetiverol, vetivone, khusimol, and isovalencenol, which exhibit antimicrobial activity by disrupting microbial membranes and inhibiting bacterial and fungal growth. These compounds also act as natural insect repellents, deterring mosquitoes and flies through olfactory irritation and masking of host cues. Ethnobotanical practices and modern studies support vetiver fumigation as an effective method for environmental sanitation and vector management, though exposure should be moderated to avoid respiratory discomfort.

Method of preparation application of fumigation powder

Ingredients and composition of polyherbal fumigation powder

#	**Name of the herm**	**Formula**
1	Neem bark	20%
2	Neem seed	20%
3	Giant Milk weed	25%
4	Turmeric	25%
5	Indian Frankincense	5%
6	Vetiver	5%

ISSN: 2456-5660 Volume 10, Issue 09 (Sep -2025)
DOI: https://doi.org/10.46243/jst.2025.v10.i09.pp06-19
www.jst.org.in

Table 2, Combination of the polyherbal formula

All the above-mentioned ingredients are taken in dried form. The mixture is then prepared into a coarse powder form with the help of a polarizer.

20 grams of the mixture has been taken for each session to get the reachability of 6-10 feet height and 6-8 diameter surrounding.

Method of fumigation

The polyherbal mixture to be gently sprinkled over the burning Coconut fiber in a mud pot kept under the plant so that the fumes are spread to entire plant including the affected area and neighboring plants.

Experiments and results discussion

To evaluate objectives, four targeted experiments were conducted. The first involved green gram plants grown under controlled conditions with artificial lighting and drip irrigation, comparing fumigated and non-fumigated specimens to assess growth parameters. The second extended this comparison to tomato plants in a natural environment, validating the growth-promoting effects of smoke exposure in a different environment which is under sunlight and conventional irrigation. The third experiment focused on a heavily mealybug-infested Indian hog plum plant, subjected to daily herbal fumigation to evaluate its impact of poly herbal fumes for pest control. and post-treatment recovery. Finally, the fourth experiment monitored surrounding healthy plants during the fumigation of the infected specimen to determine the preventive potential of herbal fumes in halting pest transmission. Together, these trials provided a comprehensive framework to assess the effect of polyherbal fumes as a pesticide and a growth promoter.

Experiment 1

Observation on the growth pattern on newly budded green gram plant under artificial grow light with the conventional drip irrigation method. Plant 1 (P1) was exposed to the controlled poly herb fumigation for 5 minutes at an interval of 24 hours. Plant 2 (P2) was kept as the control group for the comparison.

Observation After 7 days

P1-Height 7 CM P2- Height 6.5CM

Figure 1

Plants exposed to smoke exhibited an increase of 0.5 cm height compared to the control group, Figure 1

Observation After 14 days

Green gram plant	Plant Height in cm	Leaf length in cm	Leaf width in cm
Under grow light with drip irrigation and smoke exposure (P1)	13.5	3	1.5
Under grow light with drip irrigation without smoke exposure (P2)	12.5	2.7	1

Table 3

ISSN: 2456-5660 Volume 10, Issue 09 (Sep -2025)

DOI: https://doi.org/10.46243/jst.2025.v10.i09.pp06-19

www.jst.org.in

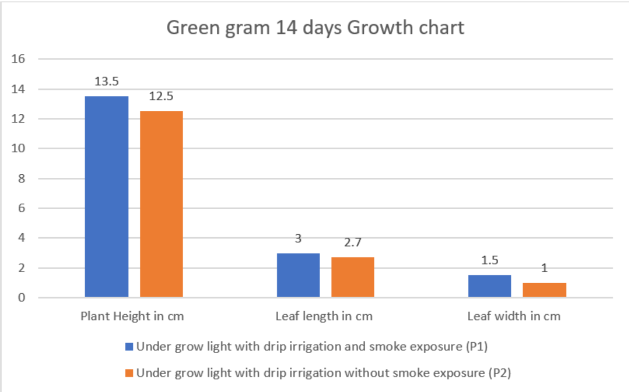

Figure2

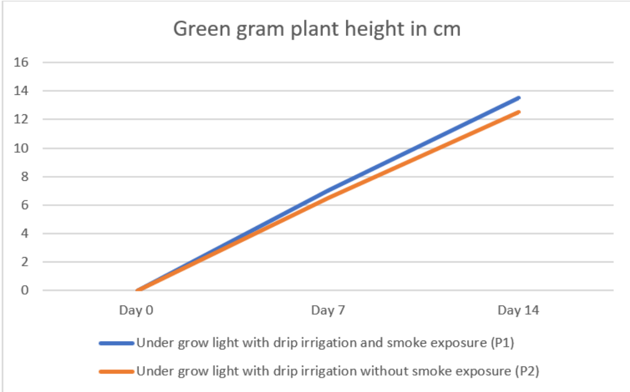

Figure3

In Experiment 1, green gram plants exposed to polyherbal fumigation under controlled grow light and drip irrigation conditions showed notable improvements in growth compared to the control group. After 14 days, the fumigated plant exhibited an 8% increase in height, along with enhanced leaf length (11%) and leaf width (50%). Additionally, more pronounced root branching was observed, indicating improved nutrient uptake and overall vigor. These results suggest that herbal fumes may positively influence plant physiology, promoting healthier and more robust growth even in early developmental stages.

Observation After 14 days

 P1- Height 13.5 CM P2- Height 12.5 CM Figure 4	Plants exposed to smoke exhibited an increase of 1 cm height compared to the control group, Figure 4
 P1 – Leaf length 3 cm P2 – Leaf length 2.7 cm Figure 5	Plants exposed to smoke exhibited an increase of .3 cm leaf length compared to the control group, Figure 5

Journal of Science and Technology
ISSN: 2456-5660 Volume 10, Issue 09 (Sep -2025)
DOI: https://doi.org/10.46243/jst.2025.v10.i09.pp06-19
www.jst.org.in

 Figure 6	Plants exposed to smoke exhibited an increase of .5 cm leaf length compared to the control group, Figure 6
 Figure 7	Plants exposed to smoke exhibited an increase in root branches compared to the control group, Figure 7

Experiment 2
Observation on the growth pattern on newly budded tomato plant under sunlight with the conventional irrigation method. Plant 3 (P3) was exposed to the controlled poly herb fumigation for 5 minutes at an interval of 24 hours. Plant 4 (P4) was kept as the control group for the comparison.

Observation After 14 days

Tomato Plant	**Plant Height in cm**	**Leaf length in cm**	**Leaf width in cm**
Under sunlight with conventional irrigation method with smoke exposure (P3)	5.5	3.2	1.9
Under sunlight with conventional irrigation method without smoke exposure (P4)	5	2.5	1

Table 4

ISSN: 2456-5660 Volume 10, Issue 09 (Sep -2025)

DOI: https://doi.org/10.46243/jst.2025.v10.i09.pp06-19

www.jst.org.in

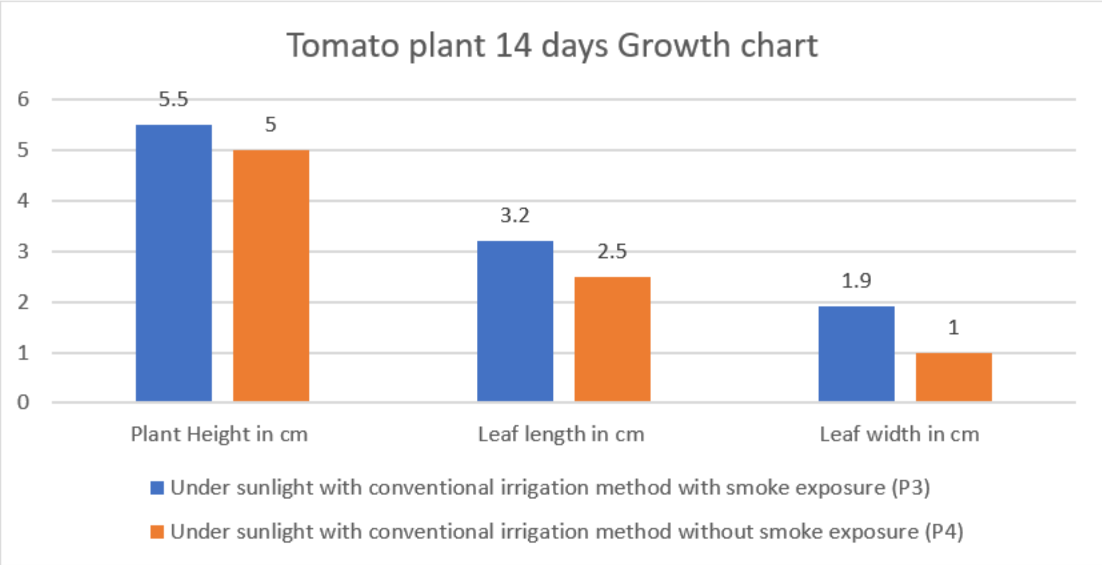

Figure 8

In Experiment 2, tomato plants grown under natural sunlight and conventional irrigation showed clear growth enhancement when exposed to polyherbal fumigation. After 14 days, the fumigated plant exhibited a 10% increase in height, a 28% improvement in leaf length, and a striking 90% increase in leaf width compared to the control. Additionally, the fumigated specimen developed more leaves and showed enhanced root branching, indicating improved vitality and nutrient absorption. These findings reinforce the potential of herbal fumes as stimulants for healthier plant development in open-field conditions.

Figure 9

Plants exposed to smoke exhibited more leaf growth compared to the control group Figure 9

Journal of Science and Technology

ISSN: 2456-5660 Volume 10, Issue 09 (Sep -2025)

www.jst.org.in

DOI: https://doi.org/10.46243/jst.2025.v10.i09.pp06-19

 P4- Height 5.5 CM P4- Height 5 CM Figure10	Plants exposed to smoke exhibited an increase of 0.5 cm height compared to the control group, Figure 10
 P3 P4 Figure 11	Plants exposed to smoke exhibited an increase in root branches compared to the control group

Experiment 3

Experiment 3 is to observe the effectiveness of poly herbal fumes in leaf mealybug. A severely leaf mealybug–infested Indian hog plum plant was subjected to daily polyherbal fumigation for 15 minutes over a 10-day period. The treatment led to a remarkable reduction in pest infestation, with visible signs of recovery by the end of the exposure cycle. Notably, 30 days after fumigation ceased, the plant exhibited healthy regrowth with no recurrence of infection, indicating both curative and sustained protective effects. These results highlight the therapeutic potential of herbal fumes in restoring plant vitality and suppressing persistent mealybug infestations without chemical intervention.

Day 1 Before fumigation. Figure 12	 Figure 12

ISSN: 2456-5660 Volume 10, Issue 09 (Sep -2025)
DOI: https://doi.org/10.46243/jst.2025.v10.i09.pp06-19
www.jst.org.in

Fumigation Process. Figure 13	 Figure 13
Observation after 10 days exposure of the fumes. Figure 14	 Figure 14
Observation 30 days after stopping the fumigation. Figure 15 Observed healthy growth with no recurrence of the infection	 Figure 15

Remarkable reduction of leaf mealybug infection after 10 days 0f exposure to polyherbal fumes

Before the exposure of fumes	10 After the exposure of fumes
	

Figure 16
Experiment 4

Journal of Science and Technology
ISSN: 2456-5660 Volume 10, Issue 09 (Sep -2025)
www.jst.org.in
DOI: https://doi.org/10.46243/jst.2025.v10.i09.pp06-19

In Experiment 4, the preventive potential of polyherbal fumigation was assessed by monitoring healthy plants surrounding a mealybug-infected specimen during a 10-day fumigation period. Remarkably, no signs of infestation were observed in the neighboring plants throughout the exposure cycle, as confirmed by visual inspections on Day 1 and Day 10. This suggests that the herbal fumes created a protective barrier, effectively deterring pest transmission. The outcome underscores the role of botanical fumigation not only in treatment but also in proactive pest management, offering a promising, eco-friendly strategy for safeguarding plant health in vulnerable agroecosystems.

Day 1, No infection in the neighboring plants, Figure 18	 Figure 18
After 10 days, the infection didn't transfer to the neighboring plants, Figure 19	 Figure 19

Result analysis

The experimental outcomes clearly demonstrate the dual efficacy of polyherbal fumigation in promoting plant growth and managing leaf mealybug infestation. In Experiment 1, green gram plants exposed to herbal fumes showed an 8% increase in height, with leaf length and width improving by 11% and 50%, respectively, alongside enhanced root branching. Experiment 2 reinforced these findings under natural conditions, where tomato plants exhibited a 10% increase in height, 28% longer leaves, and a striking 90% increase in leaf width, with greater leaf count and root development. In experiment 3, polyherbal fumigation of a heavily infested Indian hog plum plant resulted in a marked reduction of mealybug infestation within 10 days. Notably, the plant showed sustained recovery and vigorous regrowth over the following 30 days, with no recurrence of infection. Experiment 4 further validated the preventive potential of herbal fumes, as neighboring plants remained pest-free throughout the fumigation cycle, indicating a protective barrier effect.

Conclusion

This study supports the development of integrated pest management in the field of agriculture by adapting alternative measures in the management of pests without harming the plants and the ecosystem. The controlled polyherbal fumes of the herbs having antimicrobial and pest control properties showed promising observation in the management of Leaf mealybug, a pest affecting the plants. The continuous controlled fume exposure of the polyherbal mixture remarkably reduces the Leaf mealybug infection in 10 days. A highlighted observation is that the plant gained healthy growth after the fume treatment. Also, noticed that the mealybug spread didn't happen to the neighboring plants which is enlightening the possibilities of adapting preventive measures in pest management. Experiments during this study reveal the observation of enhanced growth of the plants when exposed to fumes. This is leading to the opportunity to grow healthier plants with comparatively faster growth. This study recommends a further detailed study to evaluate the opportunities of herbal fumes the agriculture.

Acknowledgment

The authors gratefully acknowledge the guidance of their mentors, the unwavering support of their families, and the valuable insights shared by peers throughout the course of this study. Their collective contributions were instrumental in the successful completion of this research.

Ethics Statement

All experimental procedures were conducted in accordance with institutional guidelines for ethical research in agricultural sciences. The study did not involve endangered or protected species, and no genetically modified organisms were used. Plant materials were handled responsibly, and pest management interventions were designed to minimize ecological disruption. The research adhered to principles of scientific integrity, transparency, and reproducibility. No human or animal subjects were involved, and therefore, no additional ethical approvals were required.

Conflict of Interest

The author declares that there are no financial, personal, or professional conflicts of interest that could have influenced the research presented in this study. All findings and interpretations are based solely on scientific evidence and objective analysis. No external funding or sponsorship was received for this work.

References

1. National Institute of Environmental Health Sciences. https://www.niehs.nih.gov/health/topics/agents/pesticides
2. European Environment Agency (2023). How Pesticides Impact Human Health and Ecosystems in Europe. https://www.eea.europa.eu/en/analysis/publications/how-pesticides-impact-human-health
3. Nehul, J.N. (2025). Environmental Impact of Pesticides: Toxicity, Bioaccumulation and Alternatives. Environmental Reports. DOI: 10.51470/ER.2025.7.2.14
4. Wan, N.-F. et al. (2025). Pesticides Have Negative Effects on Non-Target Organisms. Nature Communications. DOI: 10.1038/s41467-025-56732-x
5. US EPA (2024). Human Health Issues Related to Pesticides. https://www.epa.gov/pesticide-science-and-assessing-pesticide-risks/human-health-issues-related-pesticides
6. Furio Franco Bernardes, M.F. et al. (2015). Toxicology Studies – Cells, Drugs and Environment. IntechOpen. DOI: 10.5772/59710
7. The Pesticide Collaboration (2023). Pesticide Pollution Risk Mapping. https://share.google/FCLg8FIZB6EnOpz1P
8. Sánchez-Bayo, F. & Wyckhuys, K.A.G. (2019). Worldwide Decline of the Entomofauna: A Review of Its Drivers. Biological Conservation, 232, 8–27. https://doi.org/10.1016/j.biocon.2019.01.020
9. Hallmann, C.A. et al. (2014). Declines in Insectivorous Birds Are Associated with High Neonicotinoid Concentrations. Nature, 511, 341–343. DOI: 10.1038/nature13531
10. Boedeker, W. et al. (2020). The Global Distribution of Acute Unintentional Pesticide Poisoning. BMC Public Health, 20, 1875. 20:1875. https://doi.org/10.1186/s12889-020-09939-0
11. World Health Organization (2022). Pesticide Poisoning: Global Burden and Prevention Strategies. WHO Technical Report Series. https://www.who.int/teams/environm

ent-climate-change-and-health/chemical-safety-and-health/health-impacts/chemicals/pesticides

12. Mostafalou, S. & Abdollahi, M. (2017). Pesticides and Human Chronic Diseases: Evidences, Mechanisms, and Perspectives. Toxicology and Applied Pharmacology, 268(2), 157–177. DOI: 10.1016/j.taap.2013.01.025
13. Dixit, V.K. et al. (2022). Sustainable Control and Management of Mealy Bugs Infestation. JETIR. https://www.jetir.org/papers/JETIR2201355.pdf
14. Diwan, G. et al. (2020). Management Strategies of Mealy Bug: A Big Threat to Agriculture. AGRIALLIS. https://agriallis.com/wp-content/uploads/2020/11/MANAGEMENT-STRATEGIES-OF-MEALY-BUG-A-BIG-THREAD-TO-AGRICULTURE.pdf
15. Bhatt, R., Negalur, V. B., & Dhanya, S. (2022). An Experimental Study on Anti-Bacterial and Anti-Fungal Effect of Dhoopana Karma with Aparajitha Dhoopa Choorna. International Journal of Research in Ayurveda and Pharmacy. https://ijrap.net/admin/php/uploads/2302_pdf.pdf . DOI: 10.7897/2277-4343.1006123
16. Biswas, K., Chattopadhyay, I., Banerjee, R. K., & Bandyopadhyay, U. (2002). Biological activities and medicinal properties of neem (Azadirachta indica). Current Science, 82(11), 1336–1345. https://www.jstor.org/stable/24106000
17. Schmutterer, H. (1995). The Neem Tree: Azadirachta indica A. Juss and Other Meliaceous Plants: Sources of Unique Natural Products for Integrated Pest Management, Medicine, Industry and Other Purposes. Neem Foundation, Mumbai. DOI:10.1002/3527603980
18. Kumar, S., Singh, K., & Dwivedi, K. N. (2017). Potential of Indian traditional medicinal plant turmeric as insecticide: Antifeedant and insect repellent against household, museum and library insect pests. International Journal of Entomology Research, 2(3), 42–46. https://www.researchgate.net/publication/330900929_Potential_of_Indian_traditional_medicinal_plant_turmeric_as_insecticide_Antifeedant_and_insect_repellent_against_household_museum_and_library_insect_pests
19. Kumar, D., Ranjan, A., Chauhan, A., Prakash, D., & Jindal, T. (2021). Insecticidal Activities of Different Extracts of Calotropis procera. In New Frontiers in Environmental Toxicology (pp. 91–102). Springer. https://www.springerprofessional.de/en/insecticidal-activities-of-different-extracts-of-calotropis-proc/19683582
20. Antimicrobial Effect of Boswellia serrata Resin's Methanolic Extracts Against Skin Infection Pathogens. https://doi.org/10.3390/pr13030850
21. Pawar, S. H., Patil, A. B., & Namewar, P. D. (2023). Development and Analysis of Vetiveria zizanioides for Effectiveness as a Herbal Mosquito Repellent. Bharati Vidyapeeth College of Ayurved, Pune. https://www.ijfans.org/issue-content/development-and-analysis-of-vetiveria-zizanioides-for-effectiveness-as-a-herbal-mosquito-repellent-2451
22. Ahmad, B., Qadir, S. U., Dar, T. A., Alam, P., Yousuf, P. Y., & Ahmad, P. (2023). Karrikins: Smoke-Derived Phytohormones from Stress Alleviation to Signaling. Journal of Plant Growth Regulation, 42, 4784–4796. https://doi.org/10.1007/s00344-022-10703-4
23. Potential of Karrikins as Novel Plant Growth Regulators in Agriculture https://www.mdpi.com/2223-7747/9/1/43