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EFFECT OF PLANT DERIVED NANOPARTICLES ON *SPODOPTERA FRUGIPERDA* (LEPIDOPTERA: NOCTUIDAE)

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ABSTRACT

The fall army worm (*Spodoptera frugiperda*), a major pest of maize, is responsible for substantial crop losses worldwide. Conventional chemical insecticides are increasingly limited by issues such as pest resistanceand concerns about human health. The present study investigates the potential of green-synthesized silver nanoparticles (AgNPs) derived from six different plant extracts as an eco-friendly alternative for managing the *Spodoptera frugiperda*. Larvae were collected from infested maize fields in Nashik district, Maharashtra, India, and subsequently reared under laboratory conditions. Fall armyworms were placed in jars and reared in cages with chickpea, rice and maize flour. Rearing conditions: 27 ± 3°C temperature and 60 ± 5% relative humidity. Plant extracts from six plants (datura, neem, ginger, onion, tobacco and mint) were dried, ground, and filtered. 100 grams of powder were dissolved in 500 ml of distilled water, shaken daily for a week, and then filtered. The solution was heated to 78°C to obtain crude extracts. Silver nanoparticles were synthesized by the reduction of silver nitrate using aqueous extracts from six medicinal plants: *Datura stramonium*, *Azadirachta indica* (Neem), *Zingiber officinale* (Ginger), *Allium cepa* (Onion), *Nicotiana tabacum* (Tobacco), and *Mentha arvensis* (Mint). UV-Visible spectroscopy confirmed the formation of polydisperse AgNPs with an average absorbance peak of around 400 nm. Toxicity was assessed through a leaf-dip bioassay method across concentrations ranging from 1 to 60 ppm, with larval mortality recorded at 24 and 48 hours post-treatment. AgNPs synthesized from *Datura* and *Neem* exhibited the highest insecticidal activity, resulting in 96% and 85% mortality at 20 ppm, respectively. AgNPs derived from *Mentha* achieved 88% mortality at 60 ppm, whereas *Zingiber*-based nanoparticles were the least effective, with 73% mortality at the same concentration. The median lethal concentration (LC_{50}) values were lowest for *Datura* (1.88 ppm) and *Neem* (2.61 ppm), indicating superior efficacy, while the highest LC_{50} was observed for *Zingiber* (14.91 ppm). Although one-way ANOVA revealed no statistically significant differences in mortality among treatments ($p > 0.05$), the observed variation in LC_{50} values suggests practical differences in effectiveness. These findings highlight the potential of plant-mediated silver nanoparticles, particularly those synthesized from *Datura stramonium* and *Azadirachta indica*, as promising, sustainable alternatives for managing *Spodoptera frugiperda*.

Keywords: *Datura,*Fall armyworm (FAW),Silver nano particles, *Spodoptera frugiperda*

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INTRODUCTION

The fall armyworm (*Spodoptera frugiperda* J.E. Smith) (Lepidoptera: Noctuidae) is a globally significant agricultural pest known for its extensive host range and high adaptability. Native to the subtropical and tropical regions of the Americas, this pest has emerged as a major threat to global food security (Goergen *et al*., 2016; Naharki *et al*., 2020).

This highly migratory and polyphagous insect can feed on more than 350 plant species across 76 plant families, exhibiting a remarkable ability to adapt to diverse agro-ecosystems. Its primary hosts include economically critical crops such as maize, cotton, sorghum, millet, sugarcane, wheat, rice, groundnut, cowpea, potato, and soybean. Maize, however, remains the most vulnerable crop, with yield losses attributed to *Spodoptera frugiperda* infestation estimated to range between 10 and 22 million tons, corresponding to financial losses of approximately USD 6 billion annually. This pest can damage up to 65% of maize crops, severely impacting both smallholder and commercial farming systems (Naharki *et al*., 2020).

The main food source of *Spodoptera-frugiperda* larvae is the foliage of their host plants, which causes serious tissue damage. Later instar-larvae often eat complete leaf portions, leaving only the midribs intact, whereas early instar larvae usually feed on the outer layers of leaves, producing distinctive "window pane" patterns. The color of larvae changes from greenish to dark as they mature, and they have noticeable longitudinal stripes that help them blend into the plant canopy.

The fall armyworm exhibits remarkable adaptability and proliferation in novel environments, contributing to its designation as an invasive species. The host Maize (*Zea mays L.*), a globally significant diploid annual cereal crop, serves as a critical food source in many countries. The maize kernel, a nutritious and edible component of the plant, is rich in vitamins, carbohydrates, proteins, fiber, and riboflavin (Kumar and Jhariya, 2013). *Spodoptera frugiperda*is a significant pest affecting maize cultivation in tropical and subtropical regions of the Americas. It poses a substantial threat to maize production in all major maize-growing regions, resulting in significant economic losses and food security challenges.

Recent advances in nanotechnology have further expanded the potential of pest management tools. Nanotechnology, which focuses on the manipulation of materials at the nanoscale, has demonstrated promising applications in pest control, including the development of more efficient pheromone delivery systems, targeted pesticide formulations and innovative monitoring devices. These nanomaterials can enhance the stability, dispersion and controlled release of active compounds, potentially revolutionizing pest management practices in the coming years.The characterization of nanoparticles has been employed to assess their size (Deshmukh, 2019). Nanoparticles (NPs) possess unique physicochemical properties, including high surface area, enhanced reactivity, and specific particle morphology, making them highly effective for a wide range of agricultural applications. Numerous studies have demonstrated the efficacy of different nanoparticles in managing various insect pests and plant diseases (Jabbar *et al*., 2022; Khan *et al*., 2021; Nazir *et al*., 2019; Shahbaz *et al*., 2022).

One promising alternative is the use of green-synthesized nanoparticles, which have gained attention for their potential to reduce the ecological footprint of pest control while maintaining efficacy. Such nanoparticles, derived from natural plant extracts, offer several advantages, including lower toxicity to non-target organisms, reduced environmental persistence, and enhanced biodegradability. In this study, we evaluated the toxicological effects of artificially produced, plant-derived silver nanoparticles against fall armyworms (FAWs), assessing their potential as an eco-friendly alternative for pest management.

MATERIAL AND METHODS

Fall armyworm collection and mass-rearing.

Larvae of *Spodoptera frugiperda* were collected from maize plants displaying characteristic infestation symptoms in various villages across the Nashik District, Maharashtra, India. To ensure proper ventilation and containment during transportation, the collected larvae were initially placed in jars covered with fine muslin cloth.Upon arrival at the laboratory, the larvae were transferred to rearing cages measuring 60 × 60 cm. These cages were provisioned with a nutritionally balanced artificial diet composed of chickpea flour, rice flour, and maize flour, formulated to support the optimal growth and development of *Spodoptera frugiperda*.Mass-rearing was conducted at the Laboratory of the P.G. Department of Zoology and Research Centre, K.R.T. Arts, B.H. Commerce, and A.M. Science College, Nashik (K.T.H.M. College, Nashik), affiliated with Savitribai Phule Pune University, Pune. Rearing conditions were meticulously maintained at a temperature of 27 ± 3°C and a relative humidity of 60 ± 5%, replicating the natural climate conditions favorable for *Spodoptera frugiperda* development. Following pupation, the pupae were carefully sexed and segregated into separate cages to prevent premature mating and ensure accurate monitoring of adult emergence. Upon enclosure, the adult moths were provided with a 10% (v/v) honey or sugar solution as a carbohydrate source, administered every alternate day to support mating activity and reproductive output.Mating

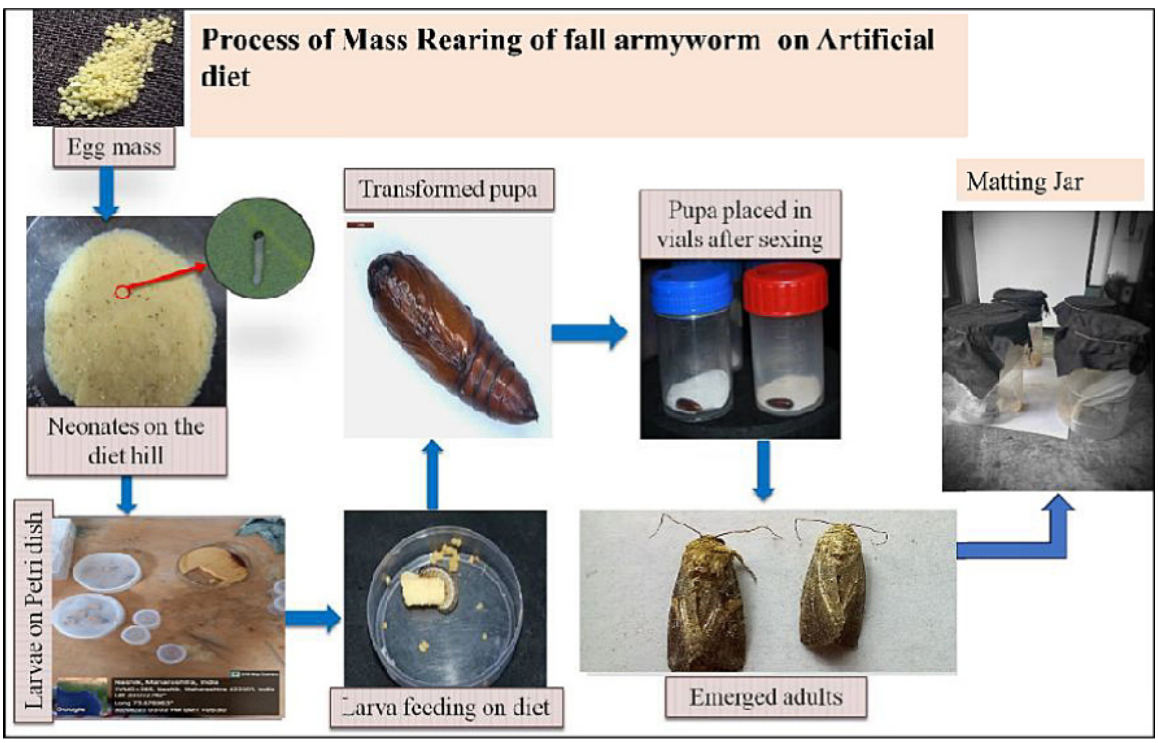

Fig. 1. Mass rearing process of *Spodoptera frugiperda.*

pairs were subsequently introduced into specialized mating cages, designed to promote copulation and oviposition, thereby ensuring a continuous and reliable supply of eggs for ongoing experimental studies.

Preparation of plant extracts

The plant extracts were prepared following the method described by Sarda *et al*., 1986. Fresh materials from six different plant species were carefully collected, thoroughly cleaned to remove any surface impurities, and then spread on a plastic sheet for shade drying over three weeks to preserve their active phytochemicals. After complete drying, the plant materials were finely ground using an electric grinder and sieved through a 20 µm mesh to ensure a uniform particle size is 20 µm, promoting consistency in subsequent analyses.For extraction, 100 g of the powdered plant material was added to 500 mL of distilled water in a conical flask. The flask was tightly covered with aluminum foil and manually agitated daily for one week to enhance the solubilization of bioactive compounds. After this period, the mixture was filtered to remove residual plant material, and the resulting filtrate was transferred to a fresh conical flask. The filtrate was then concentrated at 78°C to evaporate the solvent (ethanol), yielding the crude plant extract, which served as the final product for subsequent bioassays.

Green synthesis of nanoparticles

Six different botanical extracts, including *Datura stramonium, Azadirachta indica, Zingiber officinale, Allium cepa, Nicotiana tabacum* and *Mentha arvensis*, were utilized to synthesize silver nanoparticles (AgNPs) for effective management of fall armyworm infestations. These nanoparticles had an average particle size of 20 nm, providing a high surface area and enhanced bioactivity.The synthesis commenced by gently heating 300 ml of distilled water in a pan for 15 to 20 minutes, just until the formation of small bubbles indicated the onset of boiling. The finely powdered plant extracts were then introduced into the heated water, producing a light green mixture. After cooling and filtering to remove residual plant material, a silver nitrate ($AgNO_3$) solution was prepared by dissolving a 1mM $AgNO_3$ (0.085 gm) in 500ml of distilled water.The reduction of the silver nitrate was achieved by gradually adding 15 ml of the prepared plant extract to the boiling $AgNO_3$ solution, followed by continuous stirring for an additional 10 minutes. This step facilitated the rapid formation of AgNPs, typically indicated by a color change from light green to yellowish-brown, confirming successful nanoparticle synthesis. The final $AgNO_3$ stock solution had a concentration of 200 ppm, making it suitable for subsequent bioassays and application against fall armyworms.

UV Vis spectral analysis.

The UV Vis absorption spectrum indicated a size of approximately 400 nm. This feature of the silver nanoparticles suggested that the synthesized nanoparticles exhibited polydispersity.

Pesticidal effect of silver nanoparticles

Stock solutions of silver nanoparticles (AgNPs) synthesized from various botanical sources were serially diluted with deionized water to achieve specific concentration ranges tailored to each plant extract: *Azadirachta indica* and *Datura stramonium* at 1, 2, 3, 5, 10, and 20 ppm; *Nicotiana tabacum* and *Allium cepa* at 3, 6, 12, 25, and 50 ppm; and *Mentha arvensis* and *Zingiber officinale* at 4, 8, 15, 30, and 60 ppm. The pesticidal efficacy of these silver nanoparticles (AgNPs) solutions was assessed using a leaf-dip bioassay. Uniform leaf discs (4–5 cm in diameter) were excised from host plants and immersed in the silver nanoparticles (AgNPs) solutions for 30 seconds. The discs were then air-dried under sterile conditions to remove excess solution. Each treated leaf disc was placed in a sterile petri dish containing moistened filter paper to maintain humidity. To prevent cannibalism, a single 2nd or 3rd instar fall armyworm (*Spodoptera frugiperda*) larva was introduced into each petridish. Each treatment group included three replicates, with ten larvae per replicate. A negative control group was included, consisting of leaf discs treated with deionized water only.Larval mortality was recorded at 24 and 48 hours post-treatment. Larvae were deemed dead if they showed no response to gentle stimulation with a fine brush. Mortality percentages were calculated for each treatment group, and Abbott's formula was applied to correct for any mortality observed in the control group.

RESULTS AND DISCUSSION

After the silver nanoparticles were applied, mortality was recorded at 24 hour and 48 hour intervals. The data presented in the table highlights the mortality rates of various plant extracts (Neem, Datura, Tobacco, Onion, Mint, and Ginger) at different concentration levels, ranging from control to the highest tested concentration of 60 ppm. Neem extract silver nanoparticles exhibited a significant dose-dependent increase in mortality, starting from 40 percent at 1 ppm and peaking at 85% at 20 ppm. This consistent rise indicates strong

Table 1. Combined mortality of fall armyworms with Abbott's correction.

S.No	Concentration (ppm)	Silver nanoparticle's mortality percentage					
		Neem (%)	Datura (%)	Tobacco (%)	Onion (%)	Mint (%)	Ginger (%)
1	Control	5	7	5	7	6	5
2	1 ppm	40	35	0	0	0	0
3	3 ppm	50	50	30	37	0	0
4	5 ppm	60	70	0	0	0	0
5	10 ppm	70	88	0	0	0	0
6	20 ppm	85	96	0	0	0	0
7	Control	0	0	5	7	0	0
8	3 ppm	0	0	30	37	0	0
9	6 ppm	0	0	35	50	0	0
10	12 ppm	0	0	50	55	0	0
11	25 ppm	0	0	68	60	0	0
12	50 ppm	0	0	75	65	0	0
13	Control	0	0	0	0	6	5
14	4 ppm	0	0	0	0	35	25
15	8 ppm	0	0	0	0	42	38
16	15 ppm	0	0	0	0	68	48
17	30 ppm	0	0	0	0	80	65
18	60 ppm	0	0	0	0	88	73

bioactivity even at lower concentrations, making Neem a promising candidate for nanoparticle-based biopesticide formulations. Datura extract silver nanoparticles showed the highest mortality among all the tested plant extracts, achieving 35% at 1 ppm and reaching a maximum of 96% at 20 ppm. Tobacco and Onion extracts silver nanoparticles exhibited moderate effectiveness, with mortality rates starting at 5% in the control and reaching up to 75% and 65% respectively at 50 ppm. This gradual increase suggests that these extracts may require higher doses to achieve comparable efficacy to Neem and Datura.Mint and Ginger extract silver nanoparticles displayed unique response patterns. Mint showed a significant increase in mortality from 6% (control) to 88% at 60 ppm, reflecting potent insecticidal activity at higher concentrations. Ginger, while effective, demonstrated a slightly lower range, starting at 5% (control) and peaking at 73% at 60 ppm.

Statistical Analysis

The ANOVA analysis yielded an F-statistic of 0.61 with/ a corresponding p-value of 0.6934, indicating that there is no statistically significant difference in the corrected mortality rates among the six plant extracts (Neem, Datura, Tobacco, Onion, Mint, and Ginger) at a 95% confidence level ($p > 0.05$). This result suggests that the observed variations in mortality are likely due to random experimental variation rather than a true difference in the efficacy of the tested plant extracts.

The LC_{50} (Lethal concentration for 50% mortality) values presented in Table. 2 indicate the relative toxicity of various plant extracts used for pest control. Lower LC_{50} values correspond to higher toxicity, reflecting the potency of each extract against the target organism. With an LC_{50} value of 1.88 ppm, Datura showed the highest toxicity and the lowest concentration needed to reach 50% mortality. With LC_{50} of 2.61 ppm, Neem came up second, demonstrating its well-established insecticidal qualities. With an LC_{50} of 6.63 ppm, Mint demonstrated moderate toxicity and took third place. With LC_{50} levels of 9.43 ppm and 10.55 ppm, respectively, Tobacco and Onion came next. Despite their effectiveness, these extracts probably need larger concentrations to achieve deadly doses, perhaps because they contain less bioactive chemicals than Datura and Neem.Ginger exhibited the lowest toxicity, with an LC_{50} of 14.91 ppm, suggesting a comparatively milder impact on the target organism.

In Fig.2,Datura and Neem silver nanoparticles exhibit the highest insecticidal efficacy at lower concentrations, indicating strong potency. Tobacco and Onion silver nanoparticles demonstrate moderate activity, requiring higher doses for effectiveness. Mint and Ginger silver nanoparticles are less toxic

Table 2. LC_{50} Values of plant extract-synthesized silver nanoparticles against fall armyworm.

Sr.No.	Silver Nanoparticles	LC_{50} (ppm)	Toxicity Rank
1	Datura	1.88	1st (Highest toxicity)
2	Neem	2.61	2nd
3	Mint	6.63	3rd
4	Onion	9.43	4th
5	Tobacco	10.55	5th
6	Ginger	14.91	6th (Lowest toxicity)

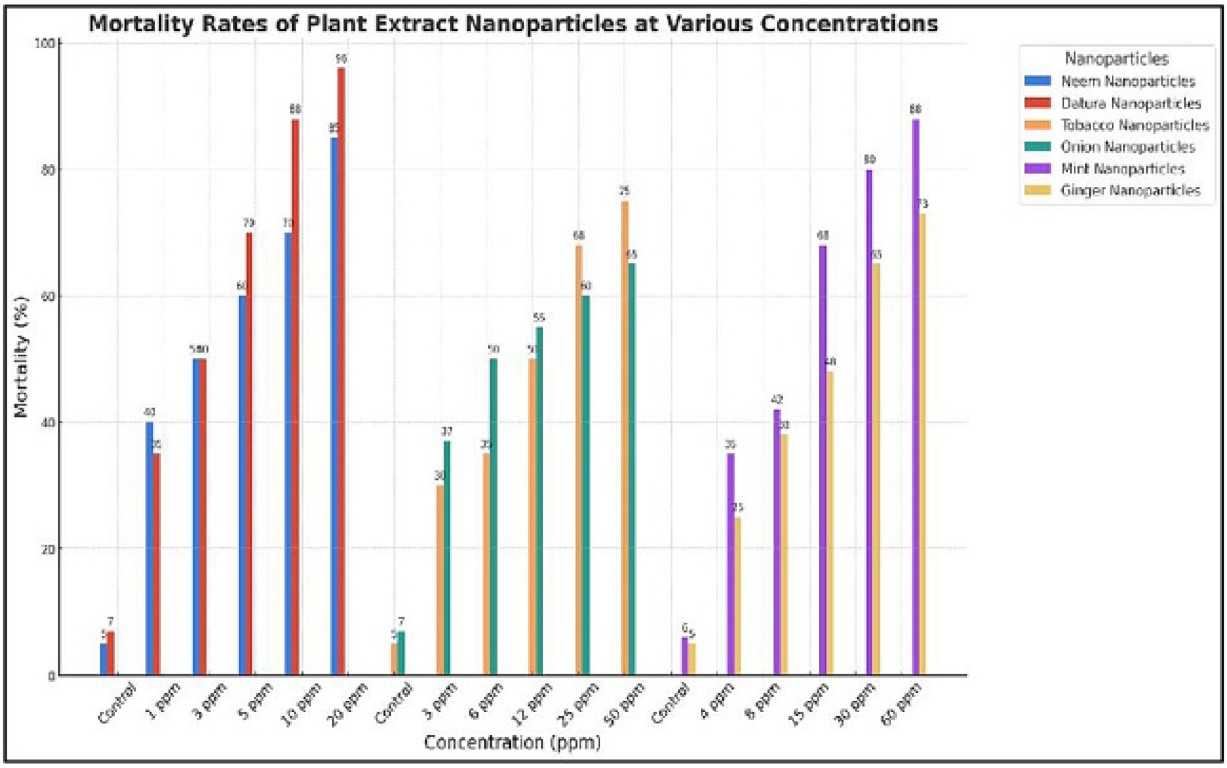

Fig. 2. The mortality rates of six different plant extract nanoparticles (Neem, Datura, Tobacco, Onion, Mint, and Ginger) at various concentrations against the fall armyworm

but remain effective at higher concentrations, making them suitable for use in high-dose biopesticide applications.

Overall, the results indicate that Datura silver nanoparticles possess the most potent insecticidal activity among the tested extracts, closely followed by Neem and Mint silver nanoparticles. The relatively high mortality rates at lower concentrations (e.g., 1 ppm for Neem and Datura) suggest that these silver nanoparticles may be effective even at reduced doses, potentially reducing environmental impact and production costs. In contrast, Ginger and Onion silver nanoparticles, while effective, may require higher doses to achieve comparable mortality rates, potentially limiting their cost-effectiveness in large-scale applications.

These results align with the findings of Sanchis and Bourguet (2008), Pascoli *et al*., (2020), and Reed *et al*., (2001), who reported an 84% mortality rate in Lepidoptera and cotton pests when utilizing Neem silver nanoparticles. Additionally, Gulzar *et al*., (2020) and Umair *et al*., (2020) applied Datura plant extracts and silver nanoparticles to *Trogoderma granarium* and observed a mortality rate of 67% within 72 hours. The differences in mortality rates may be linked to the various types of insect species utilized in the studies related to silver nanoparticles.

CONCLUSION

Among the plant-based silver nanoparticles tested, *Datura* and *Neem* exhibited the highest insecticidal potency against the target pest, achieving substantial mortality even at low concentrations (1–20 ppm), with the lowest LC_{50} values of 1.88 ppm and 2.61 ppm, respectively. This indicates strong bioefficacy and high potential for the development of cost-effective biopesticides. Mint nanoparticles ranked third, demonstrating 88% mortality at 60 ppm and a moderate LC_{50} of 6.63 ppm. In contrast, the silver nanoparticles of Tobacco, Onion, and Ginger displayed comparatively lower toxicity, requiring higher concentrations to elicit similar effects, with LC_{50} values of 9.43 ppm, 10.55 ppm, and 14.91 ppm, respectively. Notably, Ginger was the least potent. Although one-way ANOVA ($p = 0.6934$) did not reveal statistically significant differences in overall mortality across treatments at the 95% confidence level, the consistent trend in LC_{50} values and concentration-dependent mortality supports differential toxic efficacy.The findings of the present study indicated that both the *Datura* and *Neem* silver nanoparticles exhibited notable biocidal effects on the fall armyworm. Additionally, it is advisable to incorporate these nanoparticles in combination with environmentally sustainable methods for the effective management of fall armyworms.

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