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MANAGEMENT OF FALL ARMY WORM OF MAIZE, *SPODOPTERA FRUGIPERDA*, WITH GREEN SYNTHESIS SILVER NANOPARTICLES

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ABSTRACT

The fall armyworm (FAW), *Spodoptera frugiperda* is a polyphagous and economically important insect pest originated from tropical and sub-tropical parts of America. Being a strong flier, climatic adaptation and large host range makes it a serious threat to food security. It is responsible for high economic losses in many cash crops, vegetables and cereals. The overreliance and overuse of pesticides for the management of FAW posed many problems including insecticide resistance, resurgence of insect pests, biotype development and environmental hazards. To combat these problems, the most important alternative is the use of green synthesis nanoparticles and biocontrol agents which have been proven as eco-friendly technology for pest control. The current study was, therefore, planned to evaluate the toxicity of different plant based synthetic nanoparticles and biocontrol agent (*Trichogramma* spp.) against fall armyworm. Silver nanoparticles of neem resulted in the highest (83%) and the lowest (40%) mortality of 2nd instar larvae of FAW. However, the highest mortality due to silver nanoparticles of tobacco, onion, mint, ginger and datura was observed as 86%, 63%, 76%, 63% and 73% while the lowest mortality was 30%, 33%, 30%, 23% and 16% respectively. In view of the current findings nanoparticles of datura and neem could be recommended as potential bio-based chemicals for the control of *S. frugiperda*.

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INTRODUCTION

Spodoptera frugiperda (J.E. Smith) (Lepidoptera: Noctuidae), also known as fall armyworm (FAW), is an economically important cosmopolitan and polyphagous insect pest that originated from subtropical and tropical regions of America (Goergen et al., 2016; Naharki et al., 2020). FAW appeared as an invasive pest in West Africa in 2016 and recently has been reported in 47 countries of Africa and 18 countries of Asia including Pakistan. It is an invasive and migratory polyphagous insect pest and can feed on more than 350 plant species belonging to 76 plant families (Naharki et al., 2020). It is a prime pest of maize in North and South American continents where it was confined to maize crop.

FAW is a voracious foliage feeder having large host range; the preferred ones are maize, cotton, sorghum, millet, sugarcane, wheat, rice, groundnut, cowpea, potato and soybean. *S. frugiperda* has been reported to cause up to 65% damage in maize crops. The yield losses ranging from 10 to 22 million tons resulting in monetary losses of approximately US$ 6 billion have been reported by this pest which affected more than 300 million Africans who rely on crops for food and well-being (Day et al., 2017).

A female of FAW lays around 100 to 200 eggs which are naturally laid in clusters. The female lays eggs on the upper and lower sides of the leaves. FAW incubation period takes 2-3 days in summer and 7-9 days in winter (Tahir et al., 2020). Larvae have an inverted "Y" on the head capsule (Oliver and Chapin, 1981) which feed on foliage and cause plant damage. The larvae become greenish dark in color after feeding on plant foliage. Young ones consume the epidermal tissue of the leaves making holes in the leaves. Caterpillars also feed on young plants causing dead heart which is a common symptom of FAW. Invasive pests are extrinsic or non-endemic pests that live somewhere other than their natural habitat. FAW has the potential to establish itself in new environments and increases its population. It is classified as an invasive pest because of this trait. Maize (*Zea mays L.*) is an influential diploid annual cereal crop of world which is considered as an essential food in lots of country of the world. It is also the 3rd leading crop after wheat and rice. Its fruit is an edible and nutritive part of the plant which contains vitamins, carbohydrates, proteins, fiber and riboflavin (Kumar and Jhariya, 2013). *S. frugiperda* is considered as a major pest of maize crop in all the maize growing areas and broadly distributed throughout the tropical and subtropical parts of America.

FAW management includes integrated pest management (IPM), which is based on combinations of control methods which are more cheap, effective and less hazardous to the environment and human health. Insecticides cause different human health issues like presumed carcinogens, heritable mutation, ozone depletion substance and irreversible adverse effect. FAW has the ability to develop insecticide resistance very quickly in many countries. FAW already has developed resistance against many insecticides and is difficult to manage with chemical insecticides and pesticides (Day et al., 2017). Effective monitoring activity is required for the successful IPM implementation. FAW is monitored by using light and pheromone traps. Aggregation pheromone and sex pheromone are two commonly used pheromones. Nanotechnology deals with manipulation of materials at nano-scale and has already shown promising results to manage insect pests. Richard Feynman, a Nobel Prize winner, first suggested the idea of "nanotechnology" in 1959. The size of nanoparticles was evaluated by characterization (Deshmukh, 2019). Nanoparticles (NPs) have special physiochemical properties such as high reactivity, particle morphology, and high surface area. Different nanoparticles have been proved to manage various insect pests and diseases (Jabbar et al., 2022; Khan et al., 2021; Nazir et al., 2019; Shahbaz et al., 2022).

The overreliance and overuse of pesticides for FAW control posed many problems including insecticide resistance, resurgence of insect pests, biotype development and environmental hazards. To combat these problems, the most important alternative strategy is the use of green synthesis nanoparticles which have proven environmental remediation technology for pest control. So, the current study was planned to evaluate toxicity of different plants based synthetic nanoparticles against fall armyworm.

MATERIALS AND METHODS

Rearing of fall armyworm

Immatures of fall armyworm were collected from infested plants of maize. Collected larvae from field were kept in jars covered with a muslin cloth. The collected insect population was reared in rearing cages (60 × 60 cm). Larvae were fed on different diets e.g. maize or cabbage leaves. After pupation, male and female pupae were separated in new cages until emergence. The emerged adults were fed 10% (v/v) honey or sugar solution every second day. The pairing of emerged adults was done and allowed for mating and oviposition in mating cages. Rearing conditions were maintained at 27 ± 3°C and 60 ± 5% relative humidity.

Preparation of plant extractions

Plant extracts were prepared according to the method described by Sarda et al. (1986). The six plants' fresh materials were collected, properly washed for removal of dust and pathogen. After that, they were placed on a plastic sheet and left to dry in the shade. It took three weeks for the materials to be ready to be crushed in an electric grinder. A fine mesh of size 20 µm was used to filter the ground powder to produce a fine powder with the required particle size. Each specimen received 100 g of powder which was dissolved in 500 mL of distilled water. The flask was filled with the solution and aluminum foil was placed over the top. The solution was shaken vigorously by hand every day for the following week. The solution was then re-poured into the conical flask after filtering through Whatman No.1 filter paper. With an operating temperature of 78°C, the solution was transformed into crude extract. The desired crude extract was aimed by evaporating the ethanol used to make the extract.

Preparation of plant extracts and green synthesis of nanoparticle

Six botanical extracts (*Azadirachta indica, Zingiber officinale, Allium cepa*, *Nicotiana tabacum, Mentha arvensis*, and *Datura stramonium*) were prepared and used in the management of FAW. Silver nanoparticles were prepared by the biological degradation of silver nitrate. Plant extract was taken; 300 ml of distilled water was placed in the pan and boiled under medium heat for 15-20 minutes. After observing the formation of bubbles, plant extract was put into the water until the solution color turned light green. The solution was then cooled and strained, at the end, the silver nitrate (AgNO3) solution was formulated by dissolving (depending on plant) of silver nitrate in 500 ml of distilled water and the solution was boiled for 20 minutes on the hot plate and steered continuously. Step-by-step reduction of silver nitrate solution was done by the addition of 15 ml plant extract, boiled for 10 minutes and retained under light until the color of the solution changed. Finally, the stock solution of $AgNO_3$ having a concentration of 200 ppm was prepared and used for application.

UV-Vis spectra analysis

The UV-Vis absorption spectrum showed that the size is around about 400 nm. This characteristic of silver nanoparticles indicated that the synthesized nanoparticles were polydispersed.

RESULTS AND DISCUSSION

After applying the concentration of silver nanoparticles, mortality was observed with time interval of 24 h and 48 h. The Figure 1 shows total mortality caused by silver nanoparticles neem and datura.

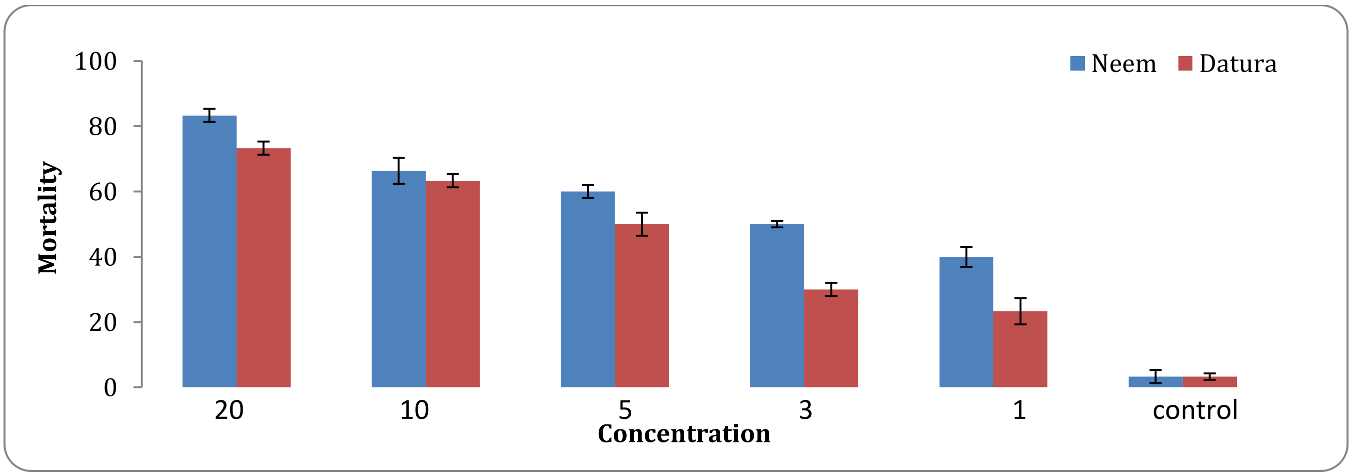

Figure 1: Mean mortalities of FAW by the treatment of silver nanoparticles of neem and datura at 20%.

It is clear from Figure 1 that the mortality was dose dependent and the highest concentration of 20 ml/80 ml of water caused significantly higher mortalities of 83% and 73.3% by the silver nanoparticles of neem and datura as compared to other doses. The minimum mortality was recorded when only water (control) treated leaves were exposed to fall armyworm. Only 3.3% mortality was observed in controlled treatment. These findings are according to the results of Reed et al. (2001), Sanchis and Bourguet (2008) and Pascoli et al. (2020). They found 84% mortality in Lepidoptera and cotton pest by using neem silver nanoparticles. Gulzar et al. (2020) and Umair et al. (2020) applied datura plant extracts and silver nanoparticles on *Trogoderma granarium* and observed 67% mortality in 72 h. The minor change occurred due to different insects which are used in the silver nanoparticles experiment.

Figure 2 expresses the highest mortality at 50 ml/50 ml of water which caused significantly highest mortalities of 86.6% and 63.3% as compared to other doses of onion and tobacco silver nanoparticles and the lowest mortalities of 30% and 33% respectively. Only 6.6% mortality was observed in controlled treatment. Ibrahim et al. (2020) and Devi et al. (2014) observed 70% mortality by using silver nanoparticles of onion and also observed antimicrobial activity (Jafir et al., 2021). Gupta et al. (2018) conducted an experiment on silver nanoparticles against *S. litura* in the tobacco field and their results were in line with our current findings.

Figure 3 showed that the mortality was dose dependent and at 60 ml/40 ml water resulted in significantly higher mortality (76.6% and 63.3%) as compared to other doses of ginger and mint whereas the lowest doses caused mortalities of 33% and 16.6% respectively. However, the minimum (6%) mortality was recorded when only water (control) treated leaves fed to fall armyworm. Ginger nanoparticles are mostly used for their antimicrobial, antifungal, and antibacterial activities (El-Refai et al., 2018) while the plant extracts are used as mosquitoes repellent (Khan et al., 2021), but they cause low mortality in different insects (Thakur et al., 2022). This is the reason that their insecticidal activity was not clearly reported and is used as antimicrobial and mosquito repellent.

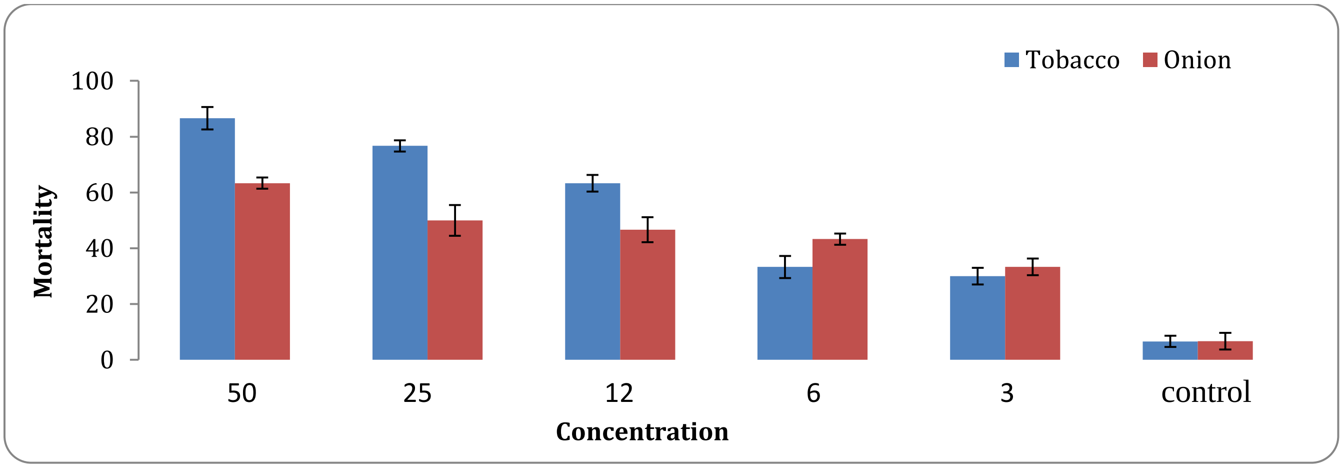

Figure 2: Mean mortalities of FAW caused by the silver nanoparticles of onion and tobacco.

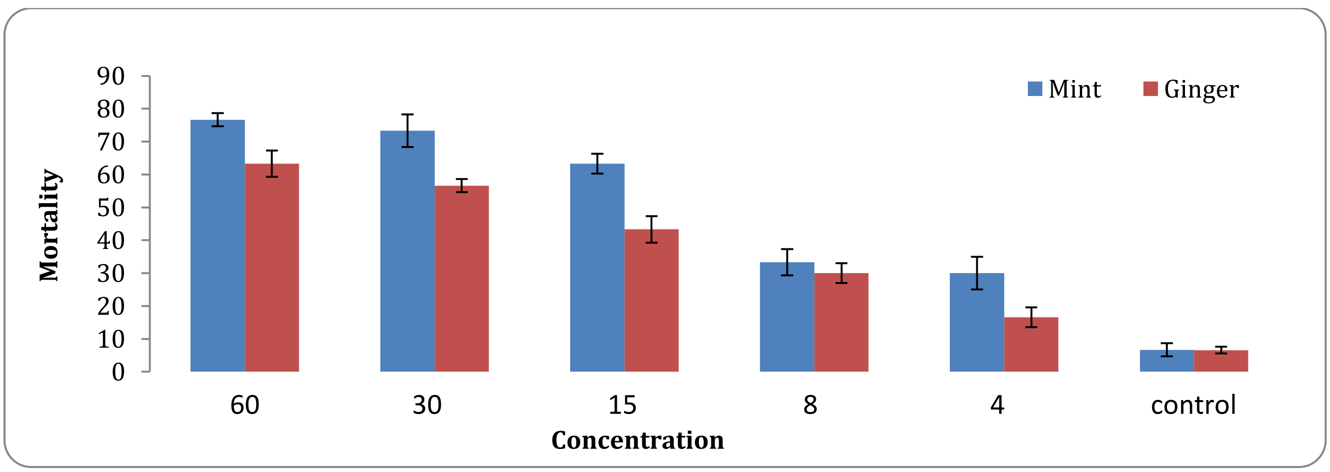

Figure 3: Mean mortalities of FAW by the application of mint and ginger silver nanoparticles.

CONCLUSION

Fall armyworm is a serious pest of maize, causing substantial economic loss. It showed resistance against insecticides, so the current study evaluated the effectiveness of different plant based nanoparticles against the insect pest. The present study highlighted that datura and neem had significant biocidal effect on fall armyworm. Furthermore, it can be recommended that these nanoparticles could be integrated with eco-friendly techniques for the management of fall armyworm.

AUTHORS' CONTRIBUTION

AHT and MT designed the study; AHT made the nanoparticles, performed the experiments, collected the data; MS helped in collecting and analyzing the data, AHT wrote the manuscript; MT supervised the work; All the authors proofread the manuscript.

CONFLICT OF INTEREST

The authors declare no conflict of interest

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