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Bio-efficacy of green synthesized silver nitrate and zinc oxide nanoparticles against *Spodoptera litura* (Fabricius)

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Abstract

The development of high resistance in the polyphagous insect pest *Spodoptera litura* to conventional insecticides highlights the pressing need to find alternative environmentally friendly control measures. This study demonstrates the insecticidal potency of green-synthesized silver nitrate ($AgNO_3$ NPs) and zinc oxide nanoparticles (ZnO NPs) against 2nd-instar larvae of *S. litura*. The larval leaf-dip bioassay revealed a significant mortality, depending on concentration and exposure time. The nanoparticles were synthesized by using 6 different plant extracts and tested in distilled water and ethanol (solvent) at three concentrations (3, 5, and 7 ml). Data was noted at 24, 48, and 72 h intervals. The highest mortality of larvae (90.3%) was recorded for $AgNO_3$ NPs synthesized from a *Z. officinale*. Also, ethanol-based suspensions of ZnO NPs showed high efficiency, resulting in 83.3% mortality. In contrast, *O. basilicum* nanoparticles suspended in distilled water established the lowest insecticidal activity for $AgNO_3$ and ZnO nanoparticles, both after 72 h interval. These results demonstrate that green synthesis is a rapid and non-toxic method for generating an effective nanoparticle. The high potency of these green synthesized nanoparticles, particularly nanoparticles derived from *Z. officinale* spots them as a promising and sustainable implement for the integrated management of *S. litura*. Furthermore, these findings provide a foundation for the development of plant-mediated nanoparticle-based bioinsecticides that could reduce reliance on conventional chemical insecticides and contribute to environmentally sustainable pest management. Future studies should evaluate their field performance, long-term stability, and potential effects on non-target organisms before large-scale application.

Keywords: Bio efficacy, Nanoparticles, Plant extracts, Silver nitrate, *Spodoptera litura*, Zinc oxide

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Introduction

Loss of crop yield is a global challenge for the agriculture industry, with all the abiotic and biotic factors playing a big part in this loss, insect pests being one of the big factors (Abebaw, 2025; Qureshi et al., 2025; Shahbazi et al., 2025). Insect pests are considered significant pests if they cause damage of more than 10% and are considered as minor pests if they cause damage ranging between 5% and 10% (Dhaliwal et al., 2010; Ali & Shahid, 2018; Rahman, 2025). The tobacco cutworm, *Spodoptera litura* (Fabricius) (Lepidoptera: Noctuidae), is a highly destructive insect pest known for its rapid reproduction and dispersal capabilities (Holloway, 1989; Hamzah, 2025). This polyphagous insect is ubiquitous across temperate and tropical regions (Monobrullah & Shankar, 2008). *S. litura* attacks over 380 host plants, with considerable agricultural damage reported on cotton, tobacco, tea, lucerne, jute, maize, soybeans, rice, cauliflower, cabbage, capsicum, castor, and potato (Matsuura & Naito, 1997; Sahayara & Gabriel, 1998; Wu et al., 2019). The larval stage is the most damaging, with early instars feeding on leaf epidermis and mesophyll tissues, leaving characteristic white speckled patterns on foliage (Ashraf, 2018; Otuka et al., 2020). The pest can potentially induce yield losses ranging from 35% to 55% during crops' blossom and vegetative stages (Rao et al., 2014; Ahmad & Ahmad, 2018). The feeding behavior of the larvae causes significant economic loss to farmers, and the loss depends on the stage of plant growth, crop species, and the density of the pest. In extreme cases, yield losses of over 50% can occur, causing serious economic losses for the farmers (Sharma et al., 2022).

Several management strategies have been utilized to control this highly destructive pest, though chemical control remains the most widely used method (Ahmad et al., 2022; Yi et al., 2025). However, due to excessive and non-selective use of synthetic insecticides, *S. litura* has developed resistance to multiple classes of insecticides (Saleem et al., 2008; Ahmad et al., 2015). Beyond resistance issues, the extensive application of synthetic pesticides has also brought attention relating to their detrimental effects on the environment and non-target organisms (Zadoks & Waibel, 2000; Ehdaie, 2007). Later the genetically modified Bt crops offered a promising alternative for managing *S. litura*, but over time, resistance to these transgenic plants has also been documented (Wan et al., 2008). Consequently, sustainable pest management alternatives are urgently needed. Biological control offers a more sustainable approach to managing this pest. Numerous microbial agents and natural enemies have been exploited effectively (Sarwar et al., 2021; Li et al., 2023). These agents not only suppress pest populations but also hamper their physiological processes (Su et al., 2012; Wu et al., 2020). Among the several emerging solutions, nanoparticle-based pesticides offer a promising strategy.

The various eco-friendly, biomedical properties of metal nanoparticles have been provoking desirable attention of the research community and establishing new milestones in advancement in engineered technology and research (Kapadia et al. 2021; Sheershwal et al., 2025). The antimicrobial activities of various methods of synthesized ZnO NPs were enhanced, which is attributed to the increased surface area of the ZnO NPs (Thakur et al., 2020; Vijayakumar et al., 2019). It is found that nanoparticles enter the cell wall of microorganism and show anti-pathogenic properties (Schwartz et al., 2012; Kapadia et al., 2021). ZnO NPs possess high insecticidal activity and are thought to cause desiccation in insects by breaking down the protective cuticular wax layer which results in a loss of water from the insects (Arumugam et al. 2016). Pathogenic contaminations are serious health issues across the globe, and multiple antibiotic resistance and insufficient solutions in developing countries are a serious threat to human health (Sirelkhatim et al. 2015).

Nanoparticles show distinct biological interactions in natural ecosystems compared to laboratory-based cell toxicity assays. Their exceptional properties make them potential candidates for developing novel insecticides (Owolade et al., 2008; Duarte et al. 2020). The insecticidal potential of nanoparticles arises from their remarkable strength, great chemical reactivity, and enhanced electrical conductivity (Kimber et al., 2018; Salem & Fouda, 2021). These characteristics stem from their atomic-level structural features, which differ significantly from bulk materials (Auffan et al., 2009). Nanoparticles are synthesized through the precise assembly of individual atoms, allowing controlled manipulation of their size and morphology (Roy, 2009). Their ability to form ordered layers is governed by intermolecular forces, including hydrogen bonding, hydrophobic-hydrophilic effects, dipolar interactions, gravitational forces, and surface tension (Ulrich et al., 2006). Both quantum size effects and high fraction of surface exposed and unsaturated atoms lead to unique behaviors exhibited by nanoparticles. These nanoparticles can be embedded in polymeric films and then give new advanced catalytic, magnetic and optical properties (Seil & Webster, 2011). Plant-based phytochemicals are natural agents for reduction and stabilization of metal nanoparticles. The stabilizing effect of *Acacia catechu* extract is due to its rich phytochemical composition (saponins, alkaloids, anthraquinones, flavonoids, triterpenes, tannins and coumarins) while the cap and stabilization on nanoparticles (NPs) from neem extract can be explained by the presence of terpenoids and flavanones (Ujah et al., 2021; Baranitharan et al., 2021).

The use of nanomaterials in controlling insects has been a subject of recent research. Slow and effective release of these particles can be made onto host plants, to result in specific control of insect pests (Scrinis & Lyons, 2007). Different nanopesticide formulation methods have been elaborated including the incorporation of pesticide active ingredients into nanoemulsions and dispersions, the identification of new nanopesticide active ingredients based on the use of nanomaterials as carriers of insecticidal active ingredients, and the use of nanoparticles as insecticidal active ingredients (Smith et al., 2008; Benelli et al., 2017). The majority of the studies on nanotechnology in entomology have been focused on mosquito control (Benelli, 2016). Thus, it is important to examine the effect of nanoparticles on other insect orders including agricultural pests. One such application of nanoparticles in pest control is silica (SiO_2) nanoparticles which were found to have high mortality rate on *Sitophilus oryzae* (Debnath et al., 2011). Likewise, adults of *S. oryzae* were completely killed by alumina (Al_2O_3) at 1000 ppm (Stadler et al., 2010). The current research on the control of notorious pest *S. litura* was designed to keep in view the above-mentioned economically important nanotechnology. It is environmentally friendly technology for farmers that costs less. The combination of silver nitrate and ethanol has shown 100% control of *S. litura*. However, there will still be more work to be done in the future if it is to be a commercially viable product. These activities could include additional development of application techniques, optimization of formulations and ultimately, larger-scale field trials to assess its feasibility and impact on a larger scale.

Materials and Methods

Insect culture

The larvae of *S. litura* were obtained from the fields of cabbage (*Brassica oleracea*) at Bahauddin Zakariya University, Multan, Pakistan. The insects were reared on fresh leaves of castor bean in the laboratory at 26±2 °C, 70±5% RH and 16: 8 h of light-dark cycle. Individual larvae were kept in separate plastic jars (5×3 inches) to prevent cannibalism. The jars were covered with muslin cloth which was tied securely to allow for sufficient ventilation but to prevent escape of larvae. Castor bean fresh leave was supplied daily to ensure optimum feeding conditions. After two weeks the larvae entered cocoons, and pupated. The pupae were then moved to a larger, clear plastic jar (18" × 15"). After a week, adult moths hatched and were kept on 10% honey solution. Muslin cloth strips inside the rearing containers were suspended for ease of egg laying. Egg masses were removed from the cloth and placed in individual jars and hatched within 2 days. The newly hatched larvae were isolated in plastic jars and were given fresh leaves.

Botanicals extraction

All the plant materials were gathered from the fields of Bahauddin Zakariya University, Multan (Table 1). The dust particles were removed from all the plant materials by washing them 2-3 times with water and then allowed to dry air in the shade of laboratory for about one week. After drying the plant material was ground to a fine powder using an electric grinding machine. The powders obtained were sieved through a mesh to get uniform size particles. For preparing the aqueous plant extracts, 5 g of the powdered plant material was mixed with 50 ml of distilled water. Botanical information was completely labelled on each beaker. These beakers were then covered with aluminum foil and heated at 65°C in a water bath for 2 h. Once cooled the solutions were poured into 50ml falcon tubes and then centrifuged at 13,000 rpm for 15 minutes. The supernatants after centrifugation were filtered. The rest extracts were kept in sterile containers at 4 ℃ until use.

Table 1 List of plant extracts used in the study

Sr. No.	English Name	Scientific name	Family	Plant part used
1.	Basil or Sweet basil	*Ocimum basilicum* L.	Lamiaceae	Leaves
2.	Turmeric	*Curcuma longa* L.	Zingiberaceae	Rhizome
3.	Cloves	*Syzygium aromaticum* L.	Myrtaceae	Leaves
4.	Garlic	*Allium sativum* L.	Liliaceae	Bulb
5.	Black pepper	*Piper nigrum* L.	Piperaceae	Dried fruit
6.	Ginger	*Zingiber officinale* Roscoe	Zingiberaceae	Rhizome

Preparation of nanoparticles

For the synthesis of nanoparticles, 100 mL plastic bottles were used, two of them containing 50mL of distilled water and the other two containing 50mL of ethanol. A solution of zinc oxide (0.406 g) was prepared in 50 mL of each pair of solvents (1 mM). Each bottle was then filled with plant extracts (5 ml each bottle). Immediately after each container, aluminium foil was added to stop the hydrolysis. Exposing the solutions directly to the sunlight for 3 h was used to initiate the synthesis process. The appearance of the solutions was used as evidence of successful formation of nanoparticles: the zinc oxide solutions became whitish and the silver nitrate solutions (made up with 0.849 g $AgNO_3$) became a characteristic dark brown. This was also carried out with all the botanical extracts studied. Finally, the synthesized nanoparticles were kept at 4°C for further experimental uses (Kausar et al., 2016).

Bioassay

Synthesized $AgNO_3$ nanoparticles and ZnO nanoparticles were tested against 2nd instar *S. litura* larvae using leaf-dip bioassay method for their larvicidal activity. Fresh leaves of castor bean were used as feeding substrate and as the medium for the antifeedant and they were washed thoroughly with water and dried in the air. Leaves were then sliced to 5cm diameter discs which fit into a standard plastic Petri dish (9cm diameter). Nanoparticles were stored in 3 test concentrations (3, 5 and 7mL). The leaf discs were dipped in each nanoparticle's suspension for 5-10 minutes and then dried for 2 minutes. All the treated leaves were then taken to the petri dishes, containing 10 third instar larvae per replicate and 4 replications for each concentration along with the control. This experiment was performed in laboratory, and fresh treated leaves were taken every 24 h. Data was taken every 24 h for the 72-h period. All the synthesized nanoparticles in the study were followed by the same standardized protocol.

Data analysis

Data analysis was conducted with Statistix 8.1. The significance of differences among treatment means was determined by ANOVA, followed by Tukey's test. For mortality data, a probit analysis was employed.

Results

Evaluation of green-synthesized $AgNO_3$ and ZnO nanoparticles prepared in distilled water against *S. litura* mortality

The larvicidal efficacy of various, green-synthesized nanoparticles, utilizing an aqueous solvent for preparation, against *S. litura* larvae was evaluated, with key results summarized in Table 1. A dose-dependent increase in larval mortality was observed, resulting in maximum efficacy after 72 h at the 7 ml concentration, where *O. basilicum*-derived ZnO and $AgNO_3$ nanoparticles yielded mortality rates of 60% and 66.67%, respectively. Correspondingly, nanoparticles synthesized from *C. longa* extract induced the highest larval mortality rates 63.3% for ZnO and 70% for $AgNO_3$ at the maximum concentration of 7 ml after a 72-h exposure period. Nanoparticles synthesized from *S. aromaticum* extract resulted in maximum larval mortality rates of 66.66% for ZnO and 76.67% for $AgNO_3$ at the highest concentration (7 ml) after a 72 h. At the highest concentration tested (7 ml), nanoparticles derived from *A. sativum* induced larval mortality rates of 70% (ZnO) and 80% ($AgNO_3$) after 72 h. Correspondingly, *P. nigrum* synthesized nanoparticles resulted in 76.7% and 86.67% mortality for ZnO and $AgNO_3$ formulations, respectively. In contrast, nanoparticles synthesized from *Z. officinale* demonstrated greater larvicidal efficacy, achieving the highest mortality rates of 80% for ZnO and 90% for $AgNO_3$ at the 7 ml concentration after 72 h. This concentration-dependent response was consistent across all evaluated plant-based nanoparticles at the 24 h and 48 h intervals (Table 2).

Table 2 Mortality percentage of *S. litura* after the treatment with plant extracts coated with ZnO and $AgNO_3$ nanoparticles dissolved in distilled water

Mortality percentage							
		ZnO dissolved in distilled water			$AgNO_3$		
Plant extracts	Concentration (ml)	24h	48h	72h	24h	48h	72h
O. basilicum	3	3.33±0.25	6.67±0.25	13±0.25	6.7±0.25	13±0.25	17±0.25
	5	13.33±0.25	16.7±0.25	23.33±0.3	13.33±0.25	23.3±0.25	33.33±0.25
	7	16.67±0.25	43.33±0.25	60±0.44	26.67±0.25	56.7±0.25	66.67±0.25
C. longa	3	6.7±0.25	10±0.44	17±0.26	13±0.68	17±0.25	20±0.89
	5	13.33±0.25	20±0.44	26.65±0.25	16.67±0.68	26.6±0.25	40±1.54
	7	23.3±0.25	46.66±0.25	63.3±0.51	30±0.44	60±0.44	70±0.44
S. aromaticum	3	13±0.25	17±0.51	23±0.23	20±0.44	23±0.25	27±0.68
	5	16.7±0.25	23.3±0.51	30±0.44	23.3±0.51	33.3±0.68	43.33±1.29
	7	26.66±0.25	50±0.44	66.66±0.68	36.67±0.68	66.67±0.91	76.67±0.68
A. sativum	3	20±0.44	23±0.51	30±0.44	33±0.51	37±0.25	43±0.25
	5	26.6±0.25	33.3±0.25	36.66±0.93	36.67±0.51	46.67±0.68	53.3±0.51
	7	33.33±0.51	53.33±0.27	70±0.77	46.67±0.93	73.33±0.68	80±0.46
P. nigrum	3	27±0.25	33±0.93	37±0.25	43±0.68	50±0.44	53±0.25
	5	33.33±0.93	40±0.44	50±0.89	40±0.44	53.33±0.68	66.67±0.51
	7	43.3±0.68	63.3±0.68	76.7±0.68	53.33±0.68	76.67±0.68	86.67±0.25
Z. officinale	3	30±0.44	37±0.68	40±0.44	47±0.51	53±0.25	57±0.51
	5	36.66±0.68	43.3±0.68	53.33±0.68	43.33±0.51	56.67±0.93	70±0.44
	7	46.7±0.51	66.66±0.93	80±0.44	56.67±0.93	80±0.44	90±0.44

Evaluation of green-synthesized $AgNO_3$ and ZnO nanoparticles prepared in ethanol against *S. litura* mortality

The effect of three different concentrations of green synthesized nanoparticles was assessed to larval mortality of *S. litura*, in which ethanol was used as solvent, is given in Table 2. The highest larval mortality for *O. basilicum*-synthesized nanoparticles was observed at the 7 ml concentration after 72 h. The ZnO formulation yielded 56.7% mortality, which was significantly lower than the 70% mortality rate caused by the $AgNO_3$ based nanoparticles. Likewise, the highest concentration (7 ml) of *C. longa* mediated nanoparticles produced mortality rates of 60.3% for ZnO and 73.3% for $AgNO_3$ following a 72-h treatment period. The maximum mortality of *S. litura* larvae treated with *S. aromaticum* synthesized nanoparticles was 66.7% for the ZnO formulation and 80% for the $AgNO_3$ formulation. Similarly, evaluation at 72 h post-treatment revealed that *A. sativum* mediated nanoparticles caused a maximum mortality of 73% (ZnO) and 83.3% ($AgNO_3$) at the 7 ml concentration. The maximum *S. litura* mortality rates with ZnO and $AgNO_3$ were 80% and 90%, respectively, noted after 72 h in *P. nigrum* nanoparticles at 7 ml. The larvicidal efficacy of nanoparticles synthesized from *Z. officinale* was concentration dependent. However, the maximum mortality rate observed for ZnO nanoparticles was 83.3% at the highest concentration of 7 ml. However, this was surpassed by $AgNO_3$ nanoparticles, which exhibited superior efficacy with a 93.3% mortality rate at the same concentration following a 72-h exposure. This pattern of increasing larval mortality with increasing concentration was consistent across all nanoparticle variants and was evident at both the 24 h and 72 h assessments (Table 3).

Discussion

Nanotechnology has found applications in various scientific fields of agricultural research with great application. The investigation of nanoscale materials' interactions with insects has been stimulated by the fact that at the nanoscale, they display unique physicochemical properties. The goal of such studies is to investigate their utility as new pest control tools and to consider any ecological impact that may be caused (Yasur & Rani, 2015). Silver nanoparticles (AgNPs) especially are reported to have insecticidal effects, and the morphological and structural features are reported to cause adverse physiological changes in insects (Nel et al., 2006). Previous studies had reported on the effect of different types of nanoparticles on the development of Lepidopteran species; however, it is required that re-study is carried out to clearly understand the effect of some of the parameters which are still not explored (Yasur & Pathpati, 2015). The bioactivity and toxicity of the nanoparticles depend on the size, shape and composition of the nanoparticles. For example, nano alumina has proven to be effective against pests such as *Rhyzopertha dominica* (F.) and *S. oryzae* (Stadler et al., 2010); and gold nanoparticles have been evaluated against *S. litura* (Chakravarthy et al., 2012). The present work examines the entomotoxic effect of six different kinds of green synthesized nanoparticles (AgNO3 and ZnO) on *S. litura*.

The present study demonstrates that *Z. officinale* nanoparticles extract in combination with silver nitrate had a higher larvicidal potency against *S. litura*, than nanoparticles of *P. nigrum*. This concentration dependent mortality is in line with other studies conducted on the green nanoparticles against insect pest control. Wazid et al. (2018) reported that best results were obtained at 1500 ppm for the mortality of the adults of *Callosobruchus analis* when the contact time with the ZnO NPs was longer. The adult mortality of *Callosobruchus maculatus* was also 100% by ZnO NPs documented by Lakshmi et al. (2020). However, Gul et al. (2016) have also reported that the green synthesized nanoparticles using melon extract were found to be feeding deterrent and growth inhibitory activity against *Musca domestica*. Govindarajan et al. (2016) also found biosynthesized AgNPs using *Anisomeles indica* leaf extract were also highly effective for the larvae of *Culex quinquefasciatus* and *Aedes aegypti*, with 95-100% mortality. Alyahya et al. (2018) reported that the AgNPs synthesized with the leaf extract of the *Holostemma adakodien* killed all larvae of *A. aegypti*, *Cx. quinquefasciatus*, and *An. stephensi* after 48 h exposure at 1500 µg/ml. Similarly, Ag nanoparticles treated with the leaf extract of *Camelina sativa* (L.) were found to be the most effective against *Oryzaephilus surinamensis* (L.) and *Sitophilus granarius* (L.) in the range of concentrations tested (500 ppm) (Rehman et al., 2021).

The plant derived nanoparticles like silver, zinc, iron and gold were proved to be effective against the agricultural pest and are a sustainable and successful method in integrated pest management (Rasheed et al., 2017). In addition, Kumar et al. (2014); Sarwar et al. (2009) described that the efficacy of the biocides was enhanced by its nano size and malleable surface which facilitated interaction with target pests.

Our results agree with previous investigations with different insect pests. Rani et al. (2016) successfully synthesized silver nanoparticles from the extract of leaf of *Hibiscus tiliaceus* against the third instar larvae of *S. litura* which exhibited 94% feeding deterrent action. Also, the 3^{rd} instar larvae of *S. litura* were treated with ZnO nanoparticles prepared from *Z. officinale* and the mortality rate of 100% was documented by Thakur et al. (2022). Moreover, Hosamani et al. (2019) reported that the larvae of *S. litura* were completely killed by the silver nanoparticles prepared from soyabean. The mortality observed against larvae was 91% for the concentration of 5% ZnO nanoparticles by Rameshbabu et al. (2022). The same reports mentioned by Ghramh et al. (2018) who found that Chrysanthemum-derived silver nanoparticles exhibited high antifeedant activity of 96% against the 4^{th} instar larvae of *A. aegypti*. In addition, Devi et al. (2014) showed an effective correlation between the mortality of *Helicoverpa armigera* and the concentration of ZnO nanoparticles; their results were also correlated with results from studies on other species treated with ZnO nanoparticles that resulted in 90% mortality (Khooshe-Bast et al., 2016).

Table 3 Mortality percentage of *S. litura* after the treatment with plant extracts coated with ZnO and $AgNO_3$ nanoparticles dissolved in ethanol

Mortality percentage							
		ZnO dissolved in ethanol			$AgNO_3$		
Plant extracts	Concentrations (ml)	24h	48h	72h	24h	48h	72h
O. basilicum	3	6.67±0.26	13.3±0.26	20±0.45	16.7±0.26	20±0.89	26.7±0.51
	5	10± 0.45	23.3±0.26	26.7±0.52	23.3±0.93	30±0.45	40±0.45
	7	23.± 0.6	46.± 0.26	56.7±0.52	33.3±0.6	60±0.45	70±0.45
C. longa	3	13.3±0.52	16.7±0.68	23.3±0.26	16.7±0.52	20±0.45	26.7±0.52
	5	20±0.45	26.7±0.52	30±0.45	20±0.89	33.3±0.52	43.3±1.29
	7	30±0.77	53.3±0.26	63.3±0.25	36.7±0.68	63.3±0.26	73.3±0.26
S. aromaticum	3	20±0.45	26.7±0.68	30±0.45	20±0.45	26.7±0.52	30±0.45
	5	23.3±0.68	30±0.89	33.3±0.26	26.7±0.68	33.3±0.68	50±0.77
	7	33.3±0.6	56.7±0.26	66.7±0.68	40±0.8	70±0.77	80±0.45
A. sativum	3	23.3±0.26	30±0.45	36.7±0.93	33.3±0.26	36.7±0.68	43.3±0.26
	5	30±0.44	40±0.7	43.3±0.68	40±0.45	43.±0.52	56.7±0.26
	7	36.7±0.68	567±0.51	73.±0.9	50±1.1	76.7±0.68	83.3±0.26
P. nigrum	3	33.3±0.6	40±0.4	43.±0.51	46.7±0.9	53.3±0.6	60±0.4
	5	36.7±1.0	46.7±0.26	53.3±0.68	46.7±0.6	567±0.68	70±0.32
	7	43.3±0.68	66.7±0.6	80±0.44	56.7±0.6	80±0.44	90±0.44
Z. officinale	3	36.7±0.93	46.7±0.25	50±0.7	50±0.4	56.7±0.25	60±0.44
	5	40±0.89	50±0.89	60±0.45	46.±0.26	60±0.89	73.3±0.5
	7	50±0.77	70±0.89	83.3±0.2	60±1.18	76.7±0.6	93.3±0.26

Conclusion

This study proved that green-synthesized nanoparticles are an eco-friendly alternative to synthetic pesticides and have a negligible effect on the environment. Positive correlations between the concentrations of nanoparticles and mortality of *S. litura* were found. These results are helpful to manage pests in an environmentally responsible manner. In addition, they promote the development of safer formulations of biocidal products. These alternatives are in line with the ecological safe goals. So, green nanotechnology is promising in the field of sustainable agriculture.

Conflict of Interest: The authors declare that they have no conflict of interest.

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