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Evaluating the Efficacy of Cashew (*Anacardium occidentale* L.) Leaf Green Nanoparticle Insecticide against *Mesopsis laticornis* (Orthoptera: Caelifera), *Schistocerca americana* (Orthoptera: Acrididae), and *Lilioceris lilii* (Coleoptera: Polyphaga) of Soybeans

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Abstract

The use of green nanoparticles has gained attention in recent years due to their potential as a safer and more environmentally friendly alternative to traditional synthetic insecticides. This study was conducted to evaluate the effectiveness of green nanoparticles from cashew (*Anacardium occidentale)* leaf in controlling the infestation of pre-flowering insect pests of soybeans. Silver nitrate was used in the biosynthesis of *A. occidentale* leaf (AoL-AgNPs), *A. occidentale* leaf extracts (botanical), cypermethrin as an insecticide, and untreated plants (control) as treatments for evaluation in this study. The experiment was arranged in a randomized complete block design with three replicates of each treatment. Data collected were analyzed using analysis of variance (ANOVA). The results showed that the applied treatments significantly reduced the infestation level of *Mesopsis laticornis*, *Schistocerca americana*, and *Lilioceris lilii;* however, the plants treated with AoL-AgNPs enhanced the soybean plants' growth parameters, including plant height and number of leaves, while also competing favorably in control of *Mesopsis laticornis, Schistocerca americana,* and *Lilioceris lilii* with the plants treated with cypermethrin. It is thus recommended that green-synthesized silver nanoparticles derived from *A. occidentale* leaves (AoL-AgNPs) be further developed and promoted as an alternative in insect pests' management for soybean production. The dual role exhibited by AoL-AgNPs by effectively reducing major insect pests' infestation and enhancing plant growth makes it a promising factor of a sustainable and eco-friendly pest management option for farmers.

Keywords: *Anacardium occidentale* L., silver nitrate (AgNPs) *Lilioceris lilii, Schistocerca americana*, soybeans.

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INTRODUCTION

Soybean (*Glycine max* L.) is a leguminous crop originally domesticated in

East Asia, primarily China, several thousand years ago. According to Giller and Dashiell (2025), soybeans were introduced to Africa in the 19th century by Chinese traders through East Africa. Soybeans are highly valued both nutritionally and economically. It is a major source of vegetable protein, oil, and fiber, used for human consumption, animal feed, and industrial materials, including biodiesel (Nzossié and Bring, 2020). It plays a major role in food security and income generation for smallholder farmers. Soybean-derived products such as soy milk, tofu, and textured vegetable protein are important food items; it also improve soil fertility through biological nitrogen fixation. Despite its importance, soybean production in Nigeria is affected by different challenges, from diseases that affect yield and seed quality to insect pests' infestation. According to Sastawa *et al*. (2004), insect pests are the major biotic constraints on soybean production in Nigeria and West Africa, especially during the developmental stage. The pre-flowering stage of soybeans is a foundational period where the yield potential is established. While the crop exhibits remarkable resilience to defoliation during its developmental stage, the emergence of invasive species like *Melanagromyza sojae* and the increasing prevalence of viral vectors like thrips and whiteflies necessitate taking precautionary measures in its management. Most research focuses on the management of reproductive-stage pests (e.g., pod-sucking bugs) of soybeans; the pre-flowering or vegetative stage (VE to V6) is a critical period for plant establishment and canopy development. Damage during this phase can result in stunted growth, delayed maturity, and predispose the plant to secondary infections.

Traditionally, farmers relied heavily on the use of synthetic insecticides in the control of these insect pests; though effective, they pose several challenges, including environmental contamination, non-target organism harm, human health risks, and the development of pest resistance (Boff *et al*. 2022). In recent years, there has been growing attention to sustainable alternatives that can match or approach the bioefficacy of synthetic insecticides while reducing negative impacts. Amongst all this approach is the use of botanicals and the introduction of nanotechnology as insecticides. Nanotechnology insecticides, also known as nano-insecticides, are modern agricultural pest management products that use nanotechnology. It involves nanomaterial particles (e.g., silver and zinc oxide) at an extremely small size (between 1 and 100 nanometers) to act as active agents against insect pests. At this scale, materials show unique physical and chemical properties that can improve how insecticides work. According to Yuan Wei et *al. (2025),* nanotechnology insecticides are designed either by reducing insecticidal substances to nanosize or by loading them into nanocarriers to improve delivery and performance. Nanotechnology-based insecticides (nano-insecticides) offer many advantages, but they also have important limitations and challenges that currently restrict their widespread and safe use in insect pest control (Grillo *et al.* 2019).

Botanical insecticides are naturally occurring substances extracted from various plant parts, including seeds, leaves, bark, and roots. They consist of complex mixtures of bioactive compounds such as alkaloids, terpenoids, phenolics, and essential oils that plants have evolved as defense mechanisms against herbivores (Ngegba *et al*., 2022). The major advantage of botanical insecticides is their rapid biodegradability (Damalas and Koutroubas, 2020). Also, insect pests are less likely to develop resistance to their control when compared to synthetic insecticides

(Ngegba *et al*., 2022). Cashew (*Anacardium occidentale* L.) leaves contain phytochemical compounds such as tannins, flavonoids, saponins, and phenolic compounds that contribute to their insecticidal effects (Ajileye *et al*., 2015). These compounds act as feeding deterrents, oviposition inhibitors, and toxicants against several insect pests (Agedah *et al*., 2010). The potential of cashew leaves as natural insecticides is increasingly recognized due to growing concerns over synthetic pesticide residues, environmental pollution, and pest resistance (Ajileye *et al*., 2015). However, the application of botanical insecticides is limited due to their slow mode of action and rapid degradation. (Isman, 2020). Also, with the limitations and challenges that currently restrict the widespread and safe use of nano insecticides in insect pest control (Grillo *et al*. 2019), there is a need to investigate the efficacy of plant-synthesized nanomaterials against insect pests. Therefore, this study tends to investigate the efficacy of biosynthesized *A. occidentale* nano-AgNPs and crude extract of *A. occidentale* against pre-flowering insect pests of soybeans and their effect as growth enhancement.

MATERIALS AND METHODS

Experimental Site

The experiment was conducted at the Oyo State College of Agriculture and Technology (OYSCATECH) Teaching and Research Farm in Igboora, Oyo State, Nigeria, during the 2024 to 2025 planting season. The location lies within the derived savannah agroecological zone of Southwestern Nigeria, which is along longitude 30°18.089'E to 30°17.752'E and latitude 7°24.875'N to 7°24.572'N and is characterized by a bimodal rainfall pattern with an annual mean of about 1,200–1,500 mm and a temperature range of 25–32°C. The soil type of the site is sandy loam with moderate organic matter content, suitable for the cultivation of soybean and other leguminous crops. The choice of this site was based on its representativeness of local soybean production zones in Oyo State.

Treatments and Experimental Design

There were four treatments, namely, AgNPs by *A. occidentale* leaves (AoL-AgNPs), crude *A. occidentale* (leaves), cypermethrin, and control. The experimental land was ploughed and harrowed once. Twelve plots were arranged and demarcated in a Randomized Complete Block Design (RCBD) with three replicates. The plot size was 2 m x 2 m with a planting space of 0.5 m between and within the plant rows, respectively. Each plot had four (4) plant rows. Two to three seeds of the soybean variety (Tax 1448-2E) obtained from IR&T Ibadan were planted per hole, which was later thinned to one plant per stand after two weeks of planting. Manual weeding was done four weeks after planting.

Preparation of leaf extracts

The fresh leaves of cashew (*A. occidentale*) were collected from the local area of Igboora. The leaves were washed and air-dried under laboratory conditions for 14 days to avoid photodegradation of the chemically active compounds of the plants. The dried leaves were blended using a grinding machine (Sliver Crest 50 watts) and sieved into fine particles, which were kept in a dry, clean, covered jar.

Preparation of crude aqueous extracts of *A. occidentale*

700 g of the powdered cashew leaf was soaked in 3000 mL of distilled water in 10 L containers. To optimize the efficacy of the botanical insecticide, two additives were incorporated: Black Soap (20 g): Utilized as a surfactant to enhance leaf adhesion and cuticular penetration and sodium chloride (20

g): Added as a preservative to inhibit microbial decomposition and extend the formulation's shelf life. The mixture was stirred vigorously and allowed to infuse for 24 hours at room temperature. The resulting suspensions were filtered through a muslin cloth, and the filtrates were decanted into 5 L plastic containers for storage as stock solutions for further use (Alao *et al.* 2018). These crude extracts of cashew leaf products were used as botanical insecticides for this study.

Preparation of nano-synthesized insecticide

Five grams (5 g) of cashew leaf powder were dissolved in one hundred milliliters (100 mL) of distilled water and heated at 60°C in a water bath for two hours. The suspension was then filtered using No. 1 Whatman filter paper and centrifuged at 4,000 rpm (revolutions per minute) for 25 minutes. The filtrate was decanted, and the supernatant was reacted with forty milliliters (40 mL) of the leaf extracts with one millimole mass (1 mM) of silver nitrate ($AgNO_3$) solution and mixed vigorously. It was then placed under sunlight for photoactivation and was observed for color change till the color became stabilized. (Lateef *et al.*, 2016).

Characterization of silver nanoparticles

To confirm the successful synthesis and properties of the AgNPs, the following analytical techniques were employed, in line with the procedure described by Lateef *et al.* (2016).

- UV-Vis Spectroscopy: Absorbance spectra were measured (Cecil, Cambridge, UK) to confirm the peak resonance of the nanoparticles, which was done at the Ladoke Akintola University of Technology Ogbomoso.
- FTIR Spectroscopy: Fourier Transform Infrared analysis (Shimadzu, UK) was performed to identify the functional groups (biomolecules) responsible for the reduction, capping, and kinetic stabilization of the particles and was done at the University of Ibadan.
- Transmission Electron Microscopy (TEM): Morphological assessment and size distribution were determined using a JEM-1400 TEM (JEOL, USA) and were done at Afe Babalola University.

Application of treatments

From each stock solution of crude cashew leaf extract (used as a botanical insecticide) and biosynthesized AgNPs by cashew leaf (used as a nano-insecticide), 1000 ml was measured, where 20% of this volume (200 ml) was determined and diluted with 800 ml of water to make 1000 ml of spray solution. The synthetic insecticide (cypermethrin) was applied at the manufacturer's recommended rate, i.e., 1 ml diluted with 1000 ml of water. Treatment application commenced four weeks after planting, which was done early in the morning (to avoid photodecomposition of the extracts, as noted by Alao *et al*., 2020) using a hand-held sprayer to prevent drifting. Foliar applications were carried out at 7-day intervals, and observations were recorded weekly for five weeks.

Data collection

Three plants were selected randomly on each plot and were tagged with a ribbon for data collection. All data were collected from the tagged plants on each plot. The data collected were on numbers of leaves, which were done through manual counting; also, numbers of defoliated leaves were counted manually, plant heights were determined with the use of a ruler, and insect infestation was done through visual counting. Data was collected a day after the application of treatments.

Data analysis

Data collected were analyzed using Analysis of Variance (ANOVA) with SAS software version 9.00 (2002), and significant means were separated with Duncan's multiple range test at a 5% probability level with statistical software analysis.

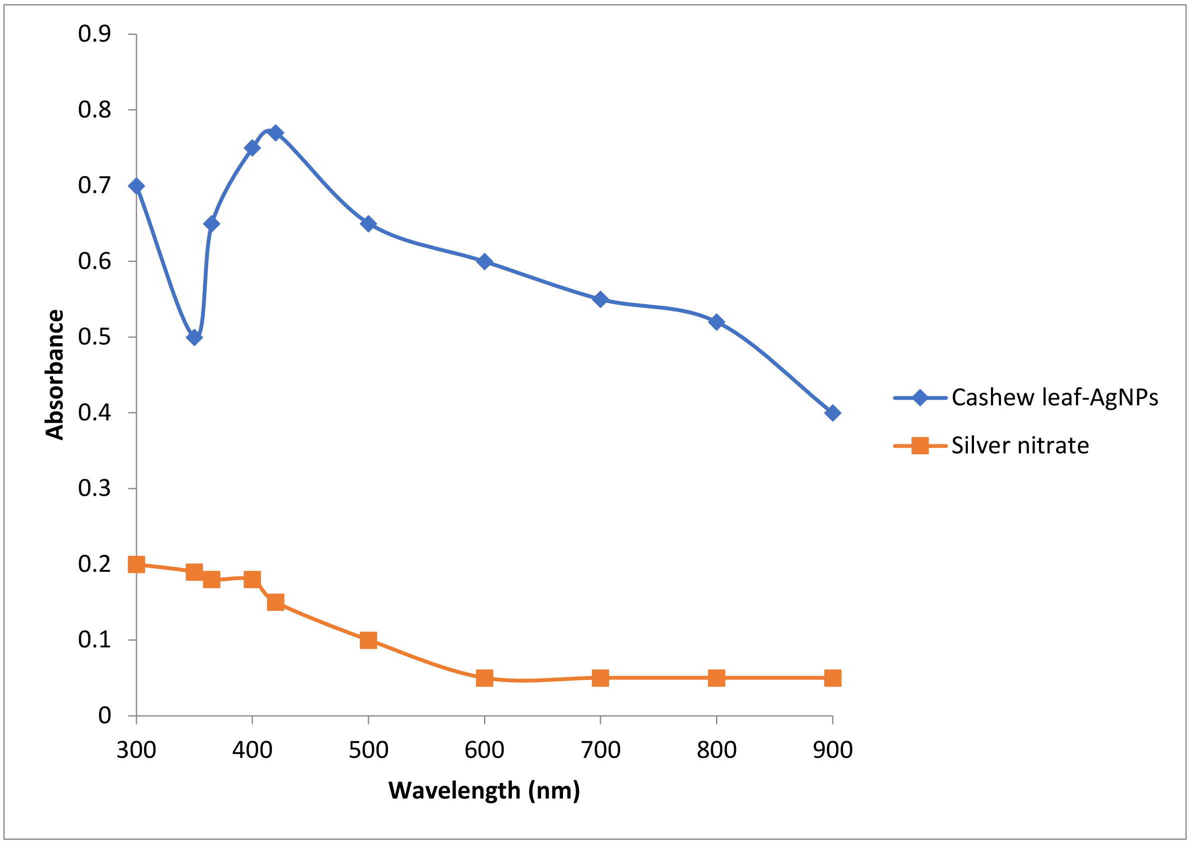

Fig. 1. UV-Vis spectrum of *A. occidentale* leaf-mediated AgNPs

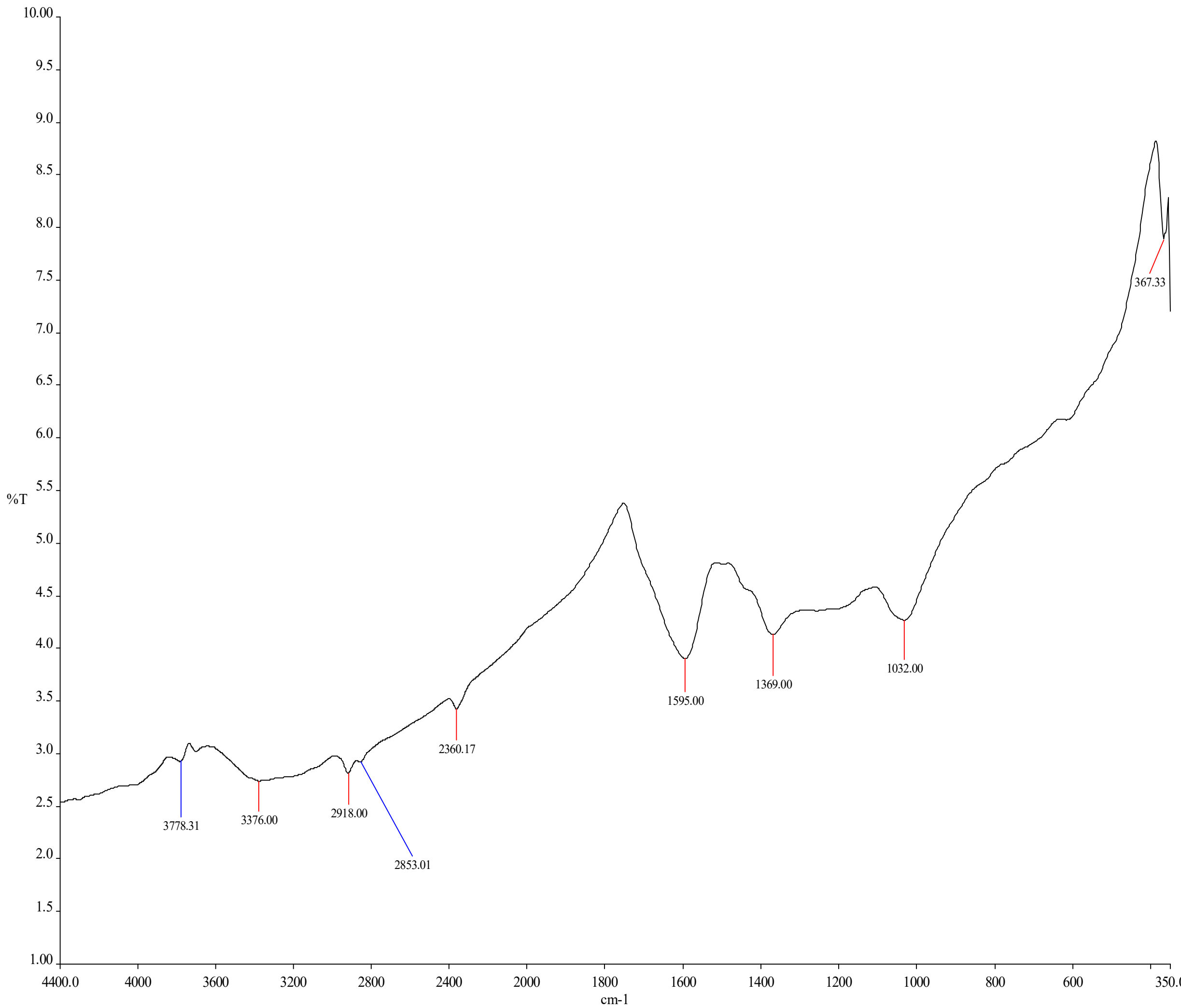

Fig. 2. FTIR spectrum of biosynthesized *A. occidentale leaf*-mediated AgNPs

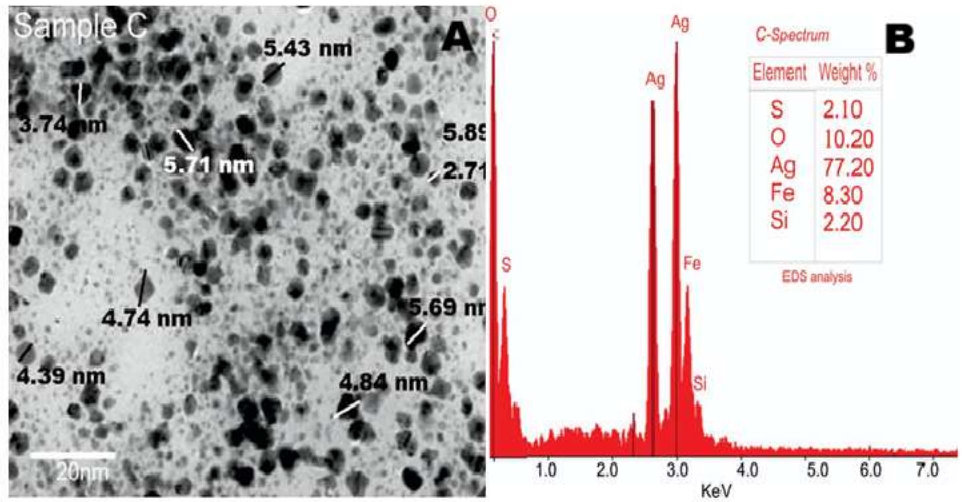

Fig 3: TEM micrograph (A) and EDX spectrum (B) of biosynthesized *A. occidentale* leaf-mediated AgNPs

Table 1: Phytochemical analysis of cashew (*A. occidentale*) leaf

Phytochemical	Content (mg/100 g)
Alkaloids(mg/100g)	16.59
Flavonoids(mg/100g)	16.15
Tannins(mg/100g)	18.01
Saponins(mg/100g)	26.11
Phenol(mg/100g)	19.88
Glycosides(mg/100g)	13.77
Terpenoids(mg/100g)	11.61

RESULTS

Phytochemical analysis of cashew (*A. occidentale*) leaf

The phytochemical analysis of cashew leaf reveals the presence of several bioactive compounds in appreciable quantities, indicating its insecticidal potential.

Saponins (26.11 mg/100 g) were the most abundant phytochemicals in the cashew leaves. Saponins are known to disrupt cell membranes of insects, leading to mortality or developmental disruption. (Kazemi, 2024). Phenols (19.88 mg/100 g) and tannins (18.01 mg/100 g) were also present in high concentrations. These compounds are strong antioxidants, which deter feeding and impair digestive enzymes in herbivorous insects. They can also repel insects and reduce nutrient assimilation, slowing growth or causing death (Kazemi, 2024). Alkaloids (16.59 mg/100 g), flavonoids (16.15 mg/100 g), glycosides (13.77 mg/100 g), and terpenoids (11.61 mg/100 g) also influence insect behavior by repelling insects and reducing nutrient assimilation, slowing growth, or causing death.

Characterization of AgNPs

The result of the UV-Vis spectrum of *A. occidentale* leaf mediated by AgNPs indicated that the biosynthesized AgNPs absorbed maximally at 420 nm, which is typical of AgNPs and within the range of 391-460 nm established for AgNPs.

The FTIR spectrum revealed peaks at 3778, 3376, 2918, 2853, 2360, 1595, 1369, and 1032 cm^{-1}, indicating the presence of N-H stretch of primary and secondary amines, O-H stretch of carboxylic acids, C-H stretch of alkanes, N-H bends of primary amines, C-H rock of alkanes, and C-O stretch of alcohols as functional groups involved in the biosynthesis and stabilization of the nanoparticles.

The TEM micrograph revealed that the *A. occidentale* leaf-mediated AgNPs were spherical, oval, cylindrical, and rectangular-shaped with particle sizes that ranged from 2.71 to 5.89 nm (Fig. 3A), while the EDX spectrum revealed silver as the most prominent element (77.20%), thus confirming the presence of silver nanoparticles (Fig. 3B).

Table 2: Effect of insecticides on numbers of leaves of soybeans

	Weeks After Treatment				
Treatments	**1**	**2**	**3**	**4**	**5**
AoL-AgNPs	32.62^{a}	50.00^{a}	105.32^{a}	150.24^{a}	207.01^{a}
Cypermethrin	31.33^{a}	46.21^{ab}	87.01^{b}	119.03^{b}	165.12^{b}
***A. occidentale* leaf**	30.33^{a}	44.34^{ab}	86.22^{b}	120.32^{b}	162.67^{b}
Control	32.00^{a}	39.41^{b}	76.10^{c}	103.00^{c}	148.00^{c}

Means with the same superscripts along the column are not significantly different at $P \leq 0.05$.

Keys: AoL-AgNPs – Nano *A. occidentale.*

Effect of insecticides on numbers of leaves of soybeans

The result in Table 2 shows the effects of different insecticides on the number of leaves of soybean. In the first week after treatment (1 WAT), no significant difference was detected in the number of leaves across all the plants treated (AoL-AgNPs, cypermethrin, and A. occidentale leaves) and untreated (control). At 2 WAT, there were no significant differences among the plants treated with AoL-AgNPs, cypermethrin, and A. occidentale; however, plants treated with AoL-AgNPs had the highest number of leaves (50.00), followed closely by the plants treated with cypermethrin (46.21) and A. occidentale leaf (44.34), while the least number of leaves was detected in the untreated plants (39.41).

At 3WAT, the plants treated with AoL-AgNPs had the highest number of leaves (105.32), which was significantly higher than the plants treated with cypermethrin and *A.*

occidentale leaves. There was no significant difference between the numbers of leaves on the plants treated with cypermethrin (87.01) and A. occidentale leaf (86.22), while the untreated plants had the least number of leaves (76.10). A similar observation was detected at 4WAT, where the plants treated with AoL-AgNPs had the highest numbers of leaves (150.24), while the untreated plants had the least number of leaves (103.00).

The highest number of leaves was observed on the plants treated with AoL-AgNPs (207.01) at 5 WAT, which was followed by the plants treated with cypermethrin (165.12) and the plants treated with *A. occidentale* leaf (162.67), although there was no significant difference detected between these two treatments, but it was observed that they also improved the numbers of leaves when compared with the untreated plants, which had the least number of leaves (148.00).

Table 3: Effect of insecticides on numbers of defoliated leaves of soybeans

	Weeks After Treatment				
Treatments	**1**	**2**	**3**	**4**	**5**
AoL-AgNPs	13.90^{a}	13.00^{a}	9.03^{b}	7.10^{c}	6.40^{c}
Cypermethrin	15.10^{a}	12.33^{a}	7.03^{c}	5.23^{d}	4.70^{d}
***A. occidentale* leaf**	14.00^{a}	14.00^{a}	11.33^{ab}	9.67^{b}	9.00^{b}
Control	11.03^{a}	15.07^{a}	14.27^{a}	14.47^{a}	15.10^{a}

Means with the same superscripts along the column are not significantly different at $P \leq 0.05$

Keys: AoL-AgNPs – Nano *A. occidentale.*

Effect of insecticides on numbers of defoliated leaves of soybeans

As presented in Table 3, there were no significant differences between the treated and the untreated plants at 1 and 2 WAT, although the untreated plants had the highest numbers of defoliated leaves (15.07). At 3 WAT, the untreated plants had the highest number of defoliated leaves (14.27), which was significantly higher when compared with the plants treated with AoL-AgNPs and cypermethrin, although the plants treated with cypermethrin had the least number of defoliated leaves (7.03).

At 4 WAT, the untreated plants had the highest number of defoliated leaves (14.47). The number of defoliated leaves for plants treated with *A. occidentale* leaf (9.67) was significantly lower than the control but higher than those treated with AoL-AgNPs (7.10). The least number of defoliated leaves was observed in plants treated with cypermethrin (5.23).

At 5 WAT, the untreated plants had the highest number of defoliated leaves (15.10). This was followed by plants treated with *A. occidentale* leaves (9.00), while plants treated with AoL-AgNPs (6.40) and cypermethrin (4.70) had less defoliation when compared to the control and the plants treated with *A. occidentale* leaves. However, the plants treated with cypermethrin had the least number of defoliated leaves during the period of observation. The application of AoL-AgNPs and cypermethrin significantly improved the development of the soybean plants by reducing the numbers of defoliation when compared with the untreated plants.

Table 4: Effect of insecticides on plant height of soybeans

	Weeks After Treatment				
Treatments	**1**	**2**	**3**	**4**	**5**
AoL-AgNPs	36.33^{a}	52.67^{a}	88.00^{a}	111.00^{a}	147.42^{a}
Cypermethrin	39.33^{a}	50.33^{a}	77.67^{ab}	103.33^{ab}	128.04^{b}
***A. occidentale* leaf**	36.00^{a}	52.33^{a}	75.00^{b}	93.24^{b}	124.20^{b}
Control	37.00^{a}	54.00^{a}	61.00^{c}	86.01^{c}	10.33^{c}

Means with the same superscripts along the column are not significantly different at $P \leq 0.05$.

Keys: AoL-AgNPs – Nano *A. occidentale.*

Effect of insecticides on plant height of soybeans

Table 4 shows the effects of insecticides on the plant height of soybeans. At 1 and 2 WAT, there was no significant difference observed in the plant height of the treated and untreated plants.

The plants treated with AoL-AgNPs had the highest plant height (88.00 cm) at 3 WAT, although there was no significant difference when compared with the plants treated with cypermethrin (77.67 cm) and *A. occidentale* leaf (75.00 cm). Meanwhile, the least plant height was detected in the untreated plants (61.00 cm).

The plants treated with AoL-AgNPs continued to have the highest plant height (111.00 cm), which was significantly higher than the heights detected on the plants treated with *A. occidentale* leaf and the control at 4 WAT. While a significant difference was not detected between the plant heights of the plants treated with AoL-AgNPs and cypermethrin (103.33 cm). However, the untreated plants had the least plant height (86.01 cm).

At 5WAT, the plants treated with AoL-AgNPs had the highest plant height (147.42 cm), followed by the plants treated with cypermethrin (128.04 cm) and *A. occidentale* leaf (124.20 cm). There was no significant difference between the plant heights of the plants treated with cypermethrin and *A. occidentale* leaf; the least plant height was detected on the untreated plants (10.33 cm). However, the plants treated with AoL-AgNPs proved to be the most effective treatment for promoting and maintaining plant height in soybeans.

Table 5: Effect of insecticides on *Mesopsis laticornis* infestation

	Weeks After Treatment				
Treatments	**1**	**2**	**3**	**4**	**5**
AoL-AgNPs	0.88^{a}	0.88^{a}	1.05^{ab}	1.05a	1.05^{a}
Cypermethrin	0.71^{a}	0.71^{a}	0.71^{a}	0.71^{b}	0.88^{b}
***A. occidentale* leaf**	1.05^{a}	1.05^{a}	1.22^{a}	1.05^{a}	1.22^{a}
Control	1.05^{a}	1.05^{a}	1.05^{a}	1.46^{a}	1.46^{a}

Means with the same superscripts along the column are not significantly different at $P \leq 0.05$.

Keys: AoL-AgNPs – Nano *A. occidentale.*

Effect of insecticides on *Mesopsis laticornis* infestation

Table 5 shows the effects of insecticides on slant-faced grasshopper *Mesopsis laticornis* infestations. It was observed during the study that there were significant differences in the control of *M. laticornis* infestation on the treated and untreated plants at 1 and 2 WAT.

At 3 WAT, the plants treated with A. occidentale leaf had the highest infestation level of *M. laticornis* (1.22), though it was not significantly different from the infestation levels in the plants treated with AoL-AgNPs (1.05) and untreated plants (1.05). The plants treated with cypermethrin had the least *M. laticornis* infestation (0.71).

At 4 WAT, the plants treated with cypermethrin had the least *M. laticornis* infestation (0.71), which is significantly different when compared with the other treated plants, AoL-AgNPs (1.05), *A. occidentale* leaf (1.05), and the untreated plants (1.46).

The untreated plants had the highest level of *M. laticornis* infestation (1.46) at 5 WAT, which was significantly higher than the plants treated with cypermethrin (0.88). There was no significant difference in the levels of *M. laticornis* infestation between the plants treated with AoL-AgNPs (1.05) and *A. occidentale* leaf (1.22). However, both AoL-AgNPs and cypermethrin-treated plants had lower *M. laticornis* infestation when compared to the untreated plants. The application of cypermethrin had the least infestation (0.88) during the period of observation, proving to be the most consistent treatment for controlling *M. laticornis* infestation.

Table 6: Effect of insecticides on *Schistocerca americana* infestation

	Weeks After Treatment				
Treatments	**1**	**2**	**3**	**4**	**5**
AoL-AgNPs	1.05^{a}	0.88^{a}	0.88^{ab}	0.71^{b}	0.71^{b}
Cypermethrin	1.17^{a}	0.88^{a}	0.71^{b}	0.71^{b}	0.71^{b}
***A. occidentale* leaf**	1.05^{a}	1.22a	0.88^{ab}	0.71^{b}	1.05^{ab}
Control	1.22^{a}	1.34^{a}	1.34^{a}	1.46^{a}	1.34^{a}

Means with the same superscripts along the column are not significantly different at $P \leq 0.05$.
Keys: AoL-AgNPs – Nano *A. occidentale.*

Effect of insecticides on *Schistocerca americana* infestation

As presented in Table 5, there were no significant differences among the applied insecticides on the plants of soybean and the untreated plants at 1 and 2 WAT, although the untreated plants had the highest *S. americana* infestation (1.34) at 2 WAT. However, there were significant differences among the treatments at 3 WAT; the highest-level *S. americana* infestation was detected in the untreated plants (1.34), while the plants treated with cypermethrin had the least *S. americana* infestation (0.71), which was significantly lower than the control. No significant difference was observed between the plants treated with AoL-AgNPs (0.88) and plants treated with the *A. occidentale* leaf (0.88), which are similar to the plants treated with cypermethrin in the control of *S. americana* infestations. At 4 WAT, all applied treatments (AoL-AgNPs, cypermethrin, and *A. occidentale* leaf) effectively reduced the level of *S. americana* infestation (0.71), respectively. These treatments were significantly more effective than the untreated plants, which had the highest *S. americana* infestation (1.46). The plants treated with AoL-AgNPs and cypermethrin had the least *S. americana* infestation (0.71) at WAT, although it was not significantly different when compared with the plants treated with *A. occidentale* (1.05). However, both the plants treated with AoL-AgNPs and cypermethrin significantly reduced the level of *S. americana* infestation on soybean plants when compared to the untreated plants, which had a higher *S. americana* infestation level of 1.34.

Table 7: Effect of insecticides on *Lilioceris lilii* infestation

	Weeks After Treatment				
Treatments	**1**	**2**	**3**	**4**	**5**
AoL-AgNPs	1.22^{a}	1.05^{a}	0.71^{b}	0.71^{b}	0.88^{b}
Cypermethrin	0.88^{a}	0.88^{a}	0.71^{b}	0.71^{b}	0.71^{b}
***A. occidentale* leaf**	1.34^{a}	1.05^{a}	0.88^{ab}	0.88^{ab}	0.88^{b}
Control	1.22^{a}	1.46^{a}	1.34^{a}	1.34^{a}	1.58^{a}

Means with the same superscripts along the column are not significantly different at $P \leq 0.05$.

Keys: AoL-AgNPs – Nano *A. occidentale.*

Effect of insecticides on *Lilioceris lilii* infestation

Table 7 shows the effects of insecticides on the infestation of *L. lilii* (red lily beetle). At 1 and 2 WAT, no significant difference was detected in the level of *L. lilii* infestation among the plants treated with insecticides and the untreated plants, although the plants treated with cypermethrin had the least *L. lilii* infestation level of 0.88, while the untreated plants had the highest *L. lilii* infestation level (1.46).

Significant differences were detected among the treatments at 3 WAT. The untreated plants had the highest *L. lilii* infestation (1.34), while plants treated with AoL-AgNPs and cypermethrin had the least *L. lilii* infestation (0.71); the plants treated with *A. occidentale* leaf extract had 0.88 *L. lilii*. Infestation but not significantly different from other treated plants. All the applied treatments effectively reduced the *L. lilii* infestation level when compared to the untreated plants.

At 4WAT, the highest *L. lilii* infestation level (1.34) was observed in the untreated plants, while the plants treated with AoL-AgNPs (0.71) and cypermethrin (0.71) had the least infestation level of *L. lilii* infestation.

The untreated plants had the highest *L. lilii* infestation level (1.58), which was significantly higher when compared with all the treated plants. There was no significant difference among the insecticidal potential of AoL-AgNPs (0.88), cypermethrin (0.71), and *A. occidentale* leaf extract (0.88), as all three insecticides significantly reduced *L. lilii* infestation level. It was observed during the period of observation that the plant treated with AoL-AgNPs and cypermethrin effectively reduced *L. lilii* infestation of soybean plants.

DISCUSSION

This study was carried out to evaluate the efficacy of green nanoparticles from cashew (*A. occidentale)* leaf against the field insect pests of soybeans. Soybeans were planted during the 2024 planting season in Igboora, Oyo State, Nigeria. The plants were naturally infested by three major pre-flowering insects in the field: *M. laticornis*, *S. americana*, and *L. lilii,* which are used as index insects in this study. It was observed during this study that the applied insecticides significantly reduced and impaired the activities of these insects. There were varying degrees of efficacy between green-synthesized silver nanoparticles (AoL-AgNPs), synthetic insecticides (cypermethrin), and botanical extracts (*A. occidentale* leaf) in enhancing the growth and protecting soybean plants.

On the growth parameters (plant height and numbers of leaves), there was a significant increase in the number of leaves and plant height observed in plants treated with AoL-AgNPs, which implies that silver nanoparticles may play a dual role as both a protective agent and a growth stimulant. The plants treated with AoL-AgNPs reached a height of 147.42 cm, significantly outperforming both the synthetic and botanical treatments. This aligns with the findings by Lateef e*t al*. (2016), who noted that green-synthesized nanoparticles can enhance vegetative growth by improving nutrient uptake and reducing the physiological stress caused by pest herbivory. Furthermore, Raliya *et al*. (2015) observed that certain metal nanoparticles can interact with plant metabolic pathways to increase chlorophyll content and biomass, which explains the high numbers of leaves detected on the plants treated with AoL-AgNPs in this study.

The reduction in defoliated leaves and the control of *M. laticornis*, *S. americana*, and *L. lilii* indicate the potent insecticidal properties of AoL-AgNPs and cypermethrin. While Cypermethrin often showed the lowest infestation levels (e.g., 0.71 for *S. americana*), AoL-AgNPs competed effectively, showing no significant difference in many instances during the study.

This efficacy can be attributed to the high surface-area-to-volume ratio of nanoparticles, which allows for better penetration of the insect cuticle. Benelli (2016) argued that AgNPs serve as effective "next generation" pesticides because they disrupt the enzymatic activities and digestive tracts of insects. The fact that the *A. occidentale* leaf extract also reduced infestation compared to the control, though often less effectively than AoL-AgNPs, supports the work of Pavela and Benelli (2016), who emphasized that botanical biopesticides provide a safer, albeit sometimes slower-acting, alternative to synthetic chemicals.

It was also observed during this study that the untreated plants had declined in growth by the fifth week. This decline is likely a result of cumulative "pest pressure," where the high infestation of grasshoppers and beetles led to severe defoliation and stunted growth. He *et al*. (2019) demonstrated that silver nanoparticles provide a sustained release of ions that offer longer-lasting protection compared to some volatile botanical extracts. This explains why the plants treated with AoL-AgNPs maintained a high growth ratio and low infestation through the final week of the study, whereas the efficacy of *A. occidentale* leaf extracts showed more fluctuations.

CONCLUSION

Based on the results of this study, it can be concluded that green-synthesized silver nanoparticles derived from *A. occidentale* leaves (AoL-AgNPs) are highly effective in the control of pre-flowering insect pests of soybean under field conditions. AoL-AgNPs significantly reduced the infestation levels of *M. laticornis*, *S. americana*, and *L.*

lilii, performing comparably to the synthetic insecticide (cypermethrin) and more effectively than crude botanical leaf (*A. occidentale* leaves) extracts. The strong insecticidal activity of AoL-AgNPs can be attributed to their nanoscale properties, particularly their high surface-area-to-volume ratio and ability to disrupt insect physiological and enzymatic processes.

Beyond pest control, AoL-AgNPs enhanced the soybean plants' growth parameters, including plant height and number of leaves, indicating a dual role as both a protective agent and a growth stimulant. The superior vegetative performance of AoL-AgNP-treated plants suggests improved nutrient uptake, reduced pest-induced stress, and possible stimulation of key metabolic pathways. In contrast, the untreated plants exhibited progressive growth decline due to sustained insect infestation and severe defoliation, underscoring the importance of effective pest management in soybean production.

Although the plants treated with cypermethrin often produced the lowest numbers of insect infestations, its performance was not superior to the plants treated with AoL-AgNPs, which highlights the potential of green nanoparticles as a viable and eco-friendly alternative to synthetic insecticides. While *A. occidentale* leaf extracts also reduced pest infestation, their fluctuating efficacy suggests a shorter residual effect compared to the sustained protection offered by AoL-AgNPs.

Overall, the findings support the potential integration of green-synthesized silver nanoparticles into sustainable pest management strategies for soybean cultivation. AOL-AgNPs offer an environmentally safer approach with added agronomic benefits, making them a better alternative to the conventional synthetic insecticides

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REFERENCES

Agedah, C., Bawo, D., and Nyananyo, B. (2010). Identification of antimicrobial properties of cashew, *Anacardium occidentale* L. (Family *Anacardiaceae*). *Journal of Applied Sciences and Environmental Management,* 14(3), 25–27.

Ajileye, O., Obuotor, E., Akinkunmi, E., and Aderogba, M. (2015). Isolation and characterization of antioxidant and antimicrobial compounds from *Anacardium occidentale* L. (*Anacardiaceae*) leaf extract. *Journal of King Saud University-Science*, 27 (3), 244–252.

Alao, F.O., Adebayo, T.A., and Olaniran, O.A. (2020). Bioactivity and effects of spraying interval of selected plant extracts for control of pre-flowering insect pests of watermelon (*Citrulus lanatus* [Thunb.]

Matsum and Nakai). *Acta Agric. Slov*. 116 (1), 107–114. https://doi.org/10.14720/aas.2020.116.1.1583.

Alao, F.O., Adebayo, T.A., Olaniran, A.O., (2018). Bioefficacy of *Moringa oleifera* and *Anacardium occidentale* against insect pests of watermelon (*Citrullus lanatus* Thumb) and their effects on watermelon fatty acid profiles. *Acta fytotechn Zootech*. 21 (3), 84–92. https://doi.org/10.15414/afz.2018.21.03.84-92.

Benelli, G. (2016). Plant-mediated biosynthesis of silver and gold nanoparticles via *Helianthus annuus*: Toxicity against mosquito vectors and *Drosophila melanogaster*. *Journal of Trace Elements in Medicine and Biology*, *33*, 110–118. https://doi.org/10.1016/j.jtemb.2015.09.006

Boff, J. S., Reis, A. C., and Gross, R. B. (2022). Development and biological evaluation of nanoencapsulated-based pyrethroids with synergists for resistance management of two soybean pests: insights for new insecticide formulations. *Pest Management Science*. Volume 79, issue 3, pp. 73 - 84. https://doi.org/10.1002/ps.7295
PDF: https://scijournals.onlinelibrary.wiley.com/doi/pdf/10.1002/ps7295

Damalas, C. A., and Koutroubas, S. D. (2020). Botanical pesticides for eco-friendly pest management: Drawbacks and limitations. *Pesticides in Crop Production: Physiological and Biochemical Action*, 181–193. https://doi.org/10.1002/9781119432241.ch10

Giller, K. E., and Dashiell, K. (2025). Development of the Soybean Industry in Africa. *Engineering Journal*. Volume 49, June 2025, Pages 272-278

Grillo, R., Abhilash, P. C., Fraceto, L. F., and de Melo, N. F. S. (2019). Nanotechnology-applied bio-based pesticides for sustainable agriculture. *Journal of Nanobiotechnology, 17*, 1–16. https://doi.org/10.1186/s12951-019-0533-8.

He, X., Deng, J., and She, P. (2019). Silver nanoparticles: Synthesis, characterization, and their insecticidal activity against agricultural pests. *Applied Nanoscience*, *9*(5), 1145–1152. https://doi.org/10.1007/s13204-018-0921-2

Isman, M. B. (2020). Botanical insecticides in the twenty-first century—fulfilling their promise? *Annual Review of Entomology*, *65*, 233–249. https://doi.org/10.1146/annurev-ento-011019-025010

Kazemi, A. (2024). *Phytochemical screening and insecticidal activities of some medicinal plants against the maize weevil* (*Sitophilus zeamais*) (Coleoptera: Curculionidae). *Scientific Reports*. (Nature)

Lateef, A., Ojo, S. A., Azeez, M. A., Asafa, T. B., Yekeen, T. A., Akinboro, A., and Oladipo, I. C. (2016). Green synthesis of silver nanoparticles using *Cola nitida* seed extract and its carbon dots: A nano-biotechnological approach. *Applied Nanoscience*, *6*(6), 811–823. https://doi.org/10.1007/s13204-015-0492-4

Ngegba, P. M., Cui, G., Khalid, M. Z., and Zhong, G. (2022). Use of botanical pesticides in agriculture as an alternative to synthetic pesticides. *Agriculture*, *12*(5), 600. https://doi.org/10.3390/agriculture12050600

Nzossié, E., and Bring, C. (2020). Soybean (*Glycine max* (L.) *Merr.*) production in the Cameroun cotton basin between the dynamics of the agricultural value chain and sustainability issues. Soybean for Human Consumption and Animal Feed, Aleksandra Sudaric, IntechOpen. Doi: 10.5772/intechopen.93981.

Pavela, R., and Benelli, G. (2016). Essential oils as eco-friendly biopesticides: Challenges and constraints. *Trends in Plant Science*, *21*(12), 1000–1007. https://doi.org/10.1016/j.tplants.2016.10.001.

Raliya, R., Nair, R., Chavalmane, S., Tarafdar, J. C., and Biswas, P. (2015). Mechanistic evaluation of translocation and physiological impact of titanium dioxide and zinc oxide nanoparticles on the tomato (*Solanum lycopersicum* L.) plant. *Metallomics*, *7*(12), 1584–1594. https://doi.org/10.1039/C5MT00168D

Sastawa, B.M., Lawan, M.A., and Maina, Y.T. (2004). Management of insect pests of soybean: effects of sowing date and intercropping on damage and grain yield in the Nigerian Sudan savanna, Crop Protection, Volume 23, Issue 2, Pages 155-161, ISSN 0261-2194, https://doi.org/10.1016/j.cropro.2003.07.007.

Yuan Wei, Jianhua Chen, Ming Dong, Min Yin, Jun Shen, Lei Gao, and Sheng Yan (2025). Nano-enabled insecticides for efficient pest management: Definition, classification, synergistic mechanism, and safety assessment. *Nanomaterials, 15*(13), 1050. https://doi.org/10.3390/nano15131050

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