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Silver Nanoparticles as a New Trend for Controlling Subterranean Termite, *Psammotermes hypostoma* Desneux in Qena Region, Egypt

Allam, R. O. H.[1]; Eman G. Ibrahim[2] and A. M. Fahmy[3*]

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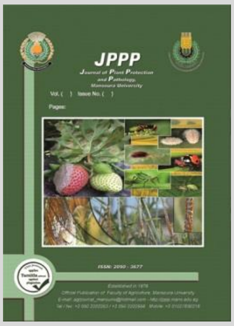
[1] Plant Protection Department, Faculty of Agriculture, South Valley University, Egypt.
[2] Faculty of Technological Industry and Energy, Thebes Technological University, Thebes, Luxor 85863, Egypt
[3] Plant Protection Department, Faculty of Agriculture and Natural Resources, Aswan University, Aswan, 81528, Egypt



ABSTRACT

Psammotermes hypostoma Desneux considered one of the most dangerous pests in Egypt is which can harm any cellulose-containing materials. Pesticide resistance may develop as a result of the extravagance of using pesticides to avoid infection of termites and to avoid the dangers of resistance, it is a must to change the traditional methods and use the featured effective, innovative focusing on countermeasure techniques. Thus, using a combination of green nanoparticles and an aqueous extract of chlorpyrifos insecticide, *Datura stramonium, Nerium oleander, Poinciana regia, Citrullus coloroynthis* and *Calotropis procera* with the appropriate salt (silver nitrate) would be more effective against *P. hypostoma.* The obtained results showed that chlorpyrifos was most hazardous substance, while *C. procera* was the lowest toxic one, however, *D. stramonium, N. oleander, P. regia, C. coloroynthis* came in between. According to these findings, all the compounds and extracts were much more lethal to *P. hypostoma* workers than the pesticide chlorpyrifos, and they can be utilized as a low-cost substitute in future IPM programs to combat *P. hypostoma*. Data showed that 35.86, 29.77, 26.31, 23.82, and 12.94 fold as effective as chlorpyrifos at the LC_{50} level. The results revealed that the toxicity of pesticides for termites in decreasing order as follows: chlorpyrifos insecticide > *D. stramonium* > *N. oleander* > *P. regia* > *C. coloroynthis* > *C. procera*.

***Keywords*: *Psammotermes hypostoma*; extract; nanoparticles; control.**

INTRODUCTION

As a result of the feeding systems, termites are considered the most harmful to the community, not only affecting the structure of buildings but also affect negatively the fields to be wastelands. Controlling the termites by spaying different insecticides only, is considered an environmentally unfriendly method. Subterranean termites are incredibly dangerous polyphagous insect pests that mostly harm building materials found in homes (Hickin, 1971; Lo Pinto and Agrò, 2023). They harmed objects, living things, and agricultural plants like rice, millet, sugarcane, and millet (Manzoor and Mir, 2010). Subterranean termites *Psammotermes hypostoma* (Desn.) has become a major urban blight and also considered of economic importance in Egypt as a result of damage caused by the buildings rural brick mud and timber farmed, as well as furniture (Beal, 1979; Ahmed and El-Sebay, 2008).

Chemicals, particularly synthetic pesticides, have historically been the exclusive means of controlling termites (Nisar *et al*., 2012). One of the obstacles that prevent pesticides from being used widely is their greatest residual effects. Other stumbling blocks include the increase in pesticide resistance in pests being targeted, negative effects on human health, and worries about environmental degradation (Rice and Coats, 1994). IPM is an environmentally sound pest management method that can be considered to solve this issue. With a view to control termites in a safe, affordable, and accessible manner, there is a constant requirement (Logan *et al*., 1990). IPM is a logical environmental strategy for the management of pests that can be used to solve this issue. With a view to control termites in a safe, affordable, and accessible manner, there is a constant requirement (Logan *et al*., 1990; Mohanny *et al*., 2023). Building capacities in terms of biological approaches that don't embrace using harmful chemicals or creating toxic byproducts as a result of the high demand for ecologically safe synthetic procedures for the production of nanoparticles. Accordingly, "green nanotechnology" is becoming more and high desire (Shankar *et al*., 2004 and Daohua *et al*., 2011).

Smarika (2022) reported that the green synthesis of silver nanoparticles is gaining worldwide attention due to their non-toxicity, and eco-friendly nature.

According to Bhattacharyya *et al.* (2010) and Allam *et al.* (2022), nanotechnology is one of the new technologies that utilized for pest control and has evolved into a new method of pest management. Termite control and wood protection are accomplished through the use of nanotechnology. Additionally, employing Nano-ZnO produced termite-repelling wood that protected it from attack. (Clausen *et al*., 2011).

Jenuka (2022) investigated a green synthesis technique for synthesizing zinc oxide nanoparticles and zinc oxide/copper oxide nanocomposites from *Punica granatum* extract by microwave method and their catalytic activities against 4-Nitrophenol.

A massive, mostly untapped store of chemical substances with numerous potential uses is offered by plant

*** Corresponding author.**
E-mail address: dr.abdelnaeem@agr.aswu.edu.eg
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extracts. Agriculture is one of these uses, as it offers a safer alternative to synthetic substances that are toxicologically and environmentally unfavorable for pest management. Experiments employing plant extracts in agriculture, home pest management, and human and animal health protection have all shown encouraging results (Scott *et al.,* 2004; Allam *et al.,* 2023).

Different ways that photochemical agents or unprocessed plant extracts harm insects can be seen, including the complete suppression of screaming behavior (Saxena and Khan, 1986), growth retardation, toxicity, oviposition deterrence, feeding restriction (Wheeler and Isman, 2001) and a decline in fertility and fecundity (Muthukrishnan and Pushpalatha, 2001)

Since green synthesis is less expensive, environmentally friendly, easily scales up for large-scale synthesizing, and doesn't involve the use of hazardous chemicals, excessive pressure, energy, or temperature, it is preferable to physical and chemical procedures. The biological reduction of ions of metal by combinations of biomolecules using bacteria, enzymes, and botanical extracts is an environmentally benign but chemically challenging process. (Rastogi and Arunachalam, 2011; Narayanan and Sakthivel, 2010; Song and Kim, 2008).

Out of all the green synthesis techniques, plant-mediated synthesis seems to be the most advantageous because it produces stable nanoparticles more quickly and allows for steady synthesis. (Iravani, 2011; Allam *et al.,* 2023)

The current study is focused on clarifying the insecticidal potential of fresh *Datura stramonium, Nerium oleander, Poinciana regia, Citrullus coloroynthis* and *Calotropis procera* biosynthesized extracts and their sources Silver ions nano particles comparing with synthesized insecticides (chloropyrofos methyle).

MATERIALS AND METHODS

This experiment was implemented at Plant Protection Lab., Faculty of Agriculture, South Valley University. In this fulfillment, plant extracts in water and their environmentally friendly silver nano-particles were used to control the subterranean termite *P. hypostoma* in alternative way. *Datura stramonium, Nerium oleander, Poinciana regia, Citrullus coloroynthis* and *Calotropis procera* extracts were compared with chlorpyrifos insecticide as suggested dosages by the Egyptian Ministry of Agriculture, (Table 1).

Table 1. The tested compounds against *P. hypostoma*

Chemical Name	Active ingredient	Rate
chlorpyrifos	chlorpyrifos	
Datura stramonium	Atropine and Datorin , muscoplamine	
Nerium oleander	oleandrin and oleandrigenin	1000-500-250-125-63%
Poinciana regia	Crude extract	of the crude compounds
Citrullus coloroynthis	Cucarbetacins and Glucosides, aglycones	
Calotropis procera.	Latex	

The insect collection:

Using an EL-Sebay adapted trap, *P. hypostoma* was removed from the South Valley University campus. After fifteen days, traps from the infected locations were removed and sent to the lab for a bioassay. The workers were removed from the catches to the glass tank and fed wet cardboard for five days as a supply of cellulose and temperature in an incubator set at 27°C to ensure their survival. Healthy insects were employed for the evaluation, and dead or morbid personnel were removed daily.

Pesticides and plant extracts:

The assessment of bioassays utilizing chlorpyrifos pesticides and their alternatives namely *D. stramonium, N. oleander, P. regia, C. coloroynthis* and *C. procera* extracts.

Preparation of Plant Extract:

Fresh *D. stramonium, N. oleander, P. regia, C. coloroynthis* and *C. procera* extracts were collected from wild desert around Qena Governorate, washed, allowed to air dry at room temperature for a week, then using a tissue processor (IKA A10, Germany), pulverized into a fine powder, and stored dry and airtight. 100 g of powder and 1000 ml of sterilized distilled water were shaken for 24 hours at 180 rpm. The resultant extract was then filtered with the filter paper from Whatman No. 1, and its filtrate was gathered in 1000 Erlen-meyer bottles before being chilled at 4° C for later use. (Verástegui *et al*., 1996).

Biosynthesis of nano-scale silver particle:

For reductions of Ag+ ions, the 100 ml of previously kept extracts in water were mixed continuously with 100 ml of freshly made AgNO3 (2 mM) solution. Before usage, the produced solutions were incubated at 37° C in a dark place (Mondal *et al*., 2011).

Characterization of silver nanoparticles at the nanoscale
Analysis of UV-visible spectrum

Using the optical density "UV-2401 PC Shimadzu, Japan" scanning spectrophotometer, UV-visible spectral analysis for AgNPs of aqueous extracts of *D. stramonium, N. oleander, P. regia, C. coloroynthis*, and *C. procera* was conducted. With a 1 nm precision and a three hundred nm/min scan speed, measurements were taken across 200 and 800 nm. The decrease of Ag+ ions was detected by examining the ultraviolet-visible spectrum of 1 ml portions of the material and 2 ml water that was deionized in the quartz cell previously reported (Wiley *et al*., 2006). As a blank and to alter the baseline, a silver nitrate solution (2 mM) was utilized.

TEM-Transmission electron microscopy:

After the reaction was complete, the precipitate had settled to the conical flasks' bottoms, and the suspension that remained above was originally sampled for TEM analysis. The size and shape of extract nanoparticles were examined at 70 kV using a "LEOL-2010, Japanese" transmission electron microscopy, or TEM, equipped with an optical "Kodak Megaplus 1.6i digicam" and picture processing and analysis software (AMT, USA). The sample was pared, as previously described by (Sathishkumar *et al*., 2009), by placing a drop of each solution on a copper grid that had been coated with carbon and letting it dry at room temperature. The size pattern of the resulting nanoparticles was predicted using TEM micrographs.

FTIR)-Fourier Transform Infra-Red spectra:

The FTIR spectra of AgNPs were recorded on a Perkin-Elmer spectroscopy in the 4000-400 cm-1 region at room temperature. Diffused reflectance spectra were recorded using the UV140404B spectrophotometer in the 200–800 nm wavelength range, and numerical data were shown using the "Origin 7" program (Slman *et al*., 2018).

XRD-X-Ray Diffraction:

The fluid containing the created silver nanoparticles was centrifuged at 10,000 rpm for 30 minutes. The solid AgNP residue were first dried at 80 oC and then twice washed with double-distilled water to produce powder AgNPs for the X-ray powder diffraction measurements. The Shimadzu XRD-6000 was utilized to record powdered material XRD (X-ray diffraction) patterns using copper rays (Cu Ka, 1.5406) at a voltage of 40 kV with 30 mA (Slman *et al*., 2018).

Bioassay: Five concentrations of each of the investigated compounds as 100, 80, 60, 40 and 20 ml/L were utilized, purified water serving as the control. To prevent direct contact and from crushing insects, ten workers were aspirated into 120 mm Petri dishes. Then, treated cardboard pieces (2 x 2 cm) with earlier levels were added, and the dishes were subsequently incubated in an incubator at 271°C. In order to determine whether an insect is still alive, a needle was used to poke it every 24 hours to record worker deaths.

Data analysis

All of the mortality data were statistically assessed for toxicity index using (Finney, 1971). The lethal concentration (LC_{50}) and slope amounts were calculated using the computerized probit analysis toxicity line application, Toxicity lines were then painted on probit-log paper (Bakr, 2005).

Toxicity index (T.I.): was calculated for each one according to the equation of Sun (1950) as follow:

T.I. = (LC_{50} of the most toxic insecticide / LC_{50} of other tested insecticide) x 100.

RESULTS AND DISCUSSION

Silver nano particles tests.

The investigation into how silver nanoparticles are biosynthesized, fresh *D. stramonium, N. oleander, P. regia, C. coloroynthis* and *C. procera* was reported in this work. When applied to the evaluated plant extracts, the silver ions in water were transformed into silver nano particles. It was noted that the hue of the *D. stramonium, N. oleander, P. regia, C. coloroynthis* and *C. procera* turned from (yellow to brown), (yellow to dark brown), (yellow to dark brown), (yellow to brown), and (yellow to brown), respectively after the reaction, which showed the creation of silver nanoparticles, had been present for 24 hours. Through UV-vis spectrophotometer examination, the decreased silver nanoparticles' synthesis and stability in the solution of colloidal silver were monitored. The UV spectra's maximum absorbance was observed at 420 nm, and it rose with the length of time that the silver nitrate solution was incubated using the plant extract. (Fig 1, 2, 3, 4 & 5).

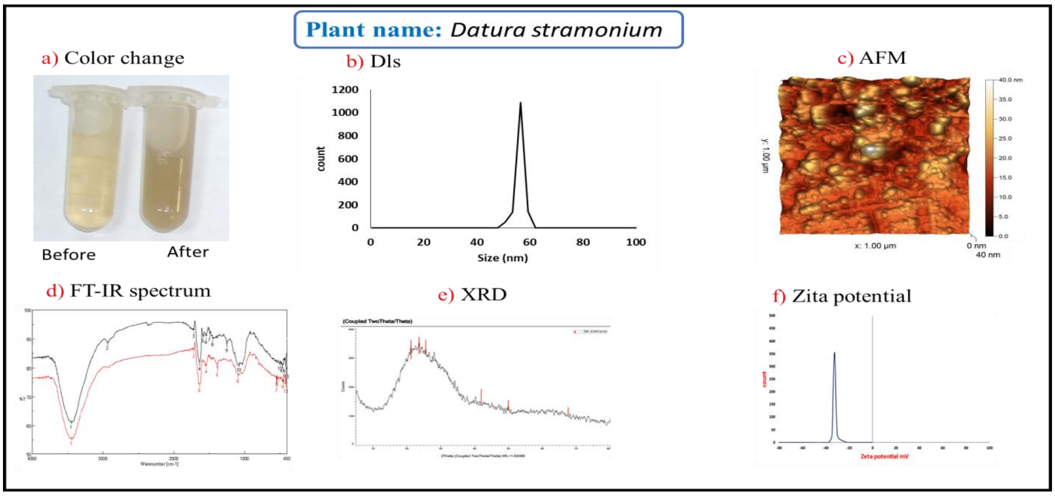

Figure 1. Tests on the production of silver nanoparticles by *Datura stramonium* aqueous extract

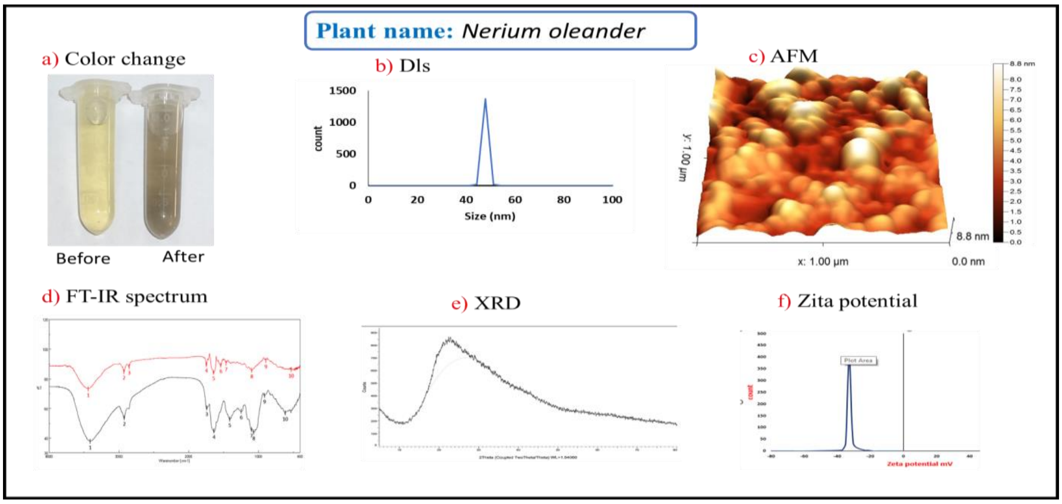

Figure 2. Tests on the production of silver nanoparticles by of *Nerium oleander* aqueous extract

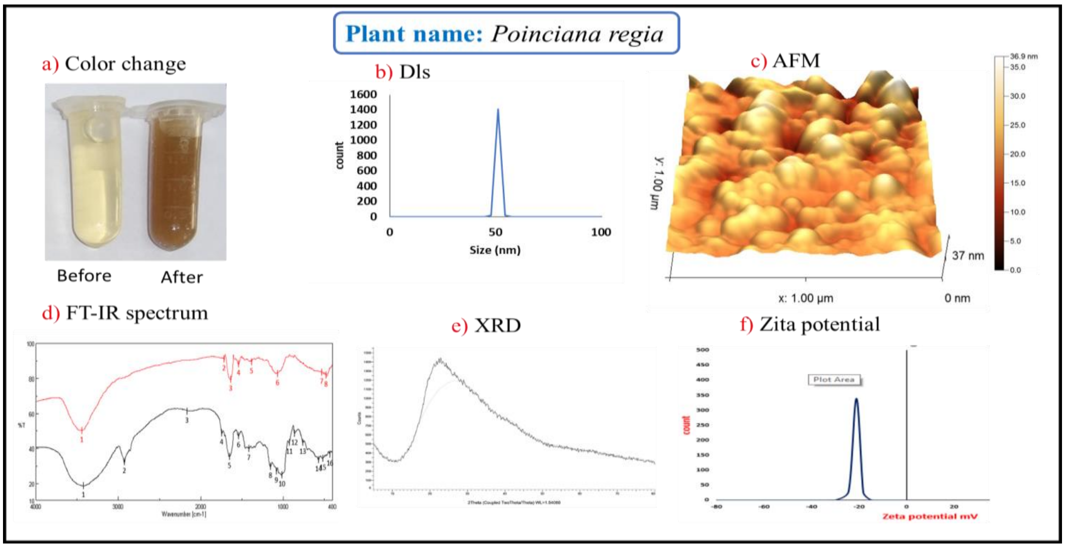

Figure 3. Tests on the production of silver nanoparticles by *Poinciana regia* aqueous extract

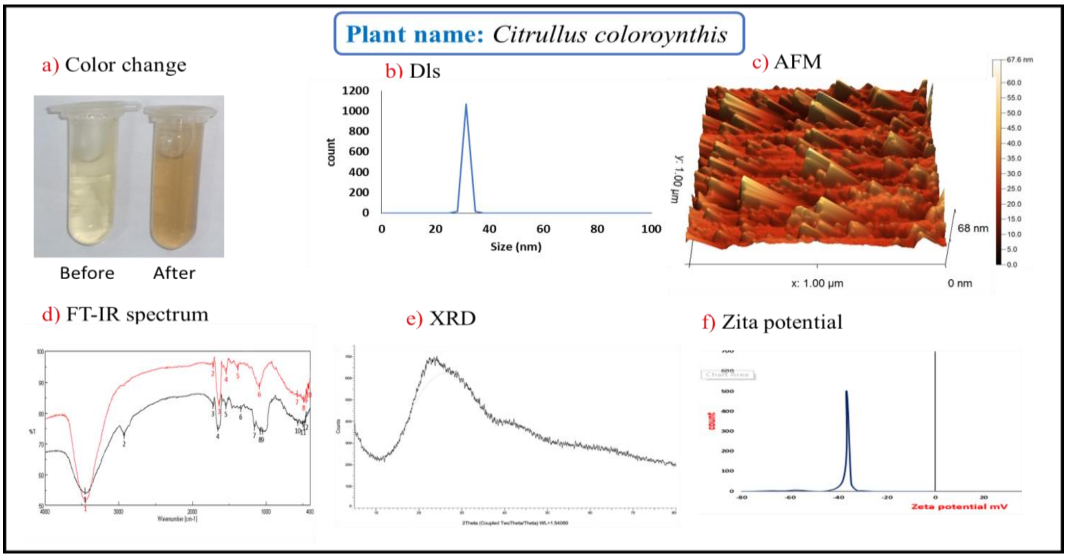

Figure 4. Tests on the production of silver nanoparticles by *Citrullus coloroynthis* aqueous extract

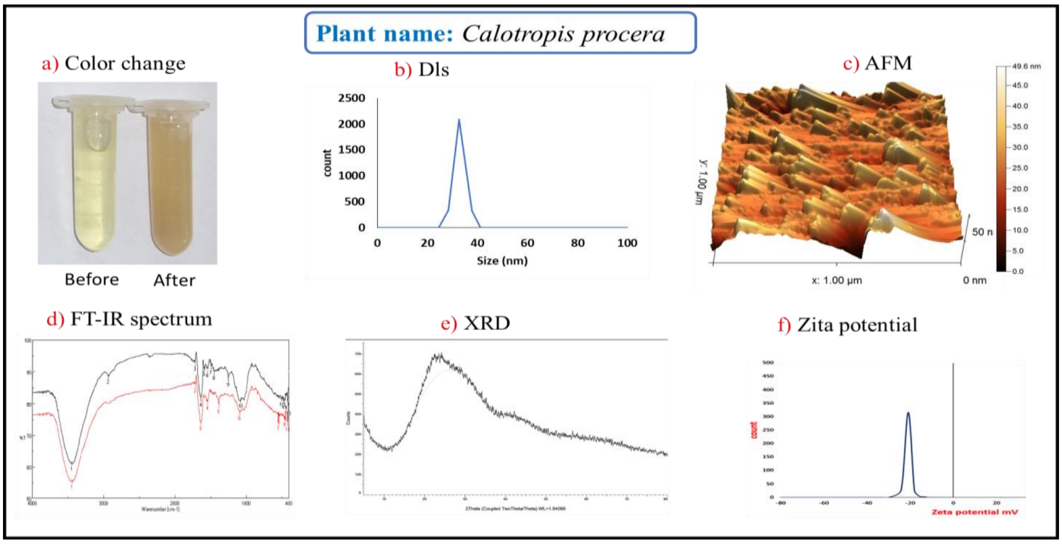

Figure 5. Tests on the production of silver nanoparticles by *Calotropis procera* aqueous extract

The FTIR examination of silver nanoparticles corroborated the presence of multiple functional categories and the plant extract's dual action as a capping and reducing agent (Figs. 1, 2, 3, 4 and 5). The technique of transmission electron microscopy, or TEM, has been used to determine nanoparticle size, shape, and morphology. While the majority of the nanoparticles made of silver were spherical and evenly dispersed, it indicates that some of particles have differently shaped constructions, which can be observed in (Figs. 1, 2, 3, 4 and 5).

Toxicity study:

D. stramonium, N. oleander, P. regia, C. coloroynthis and *C. procera* were assessed to ascertain their impact on *P. hypostoma* at the lab. condition. The comparative toxicity of substances that have been evaluated on *P. hypostoma* was shown in Table (2) and Fig. (6). Data show that the investigated substances' order of efficacy was the same at LC_{50} and LC_{90} levels. Following is a list of the tested pesticides in descending order: *D. stramonium, N. oleander, P. regia, C. coloroynthis* and *C. procera*. The corresponding LC_{50} values were 40.68, 113.44, 136.63, 154.60, 170.80 and 314.44 ppm, whereas the LC_{90} amounts were 596.68, 1472.83, 1164.96, 1293.59, 2459.35 and 1500.05 ppm, respectively. While, slope values were 1.099, 1.15, 1.38, 1.39, 1.06 and 1.89, respectively.

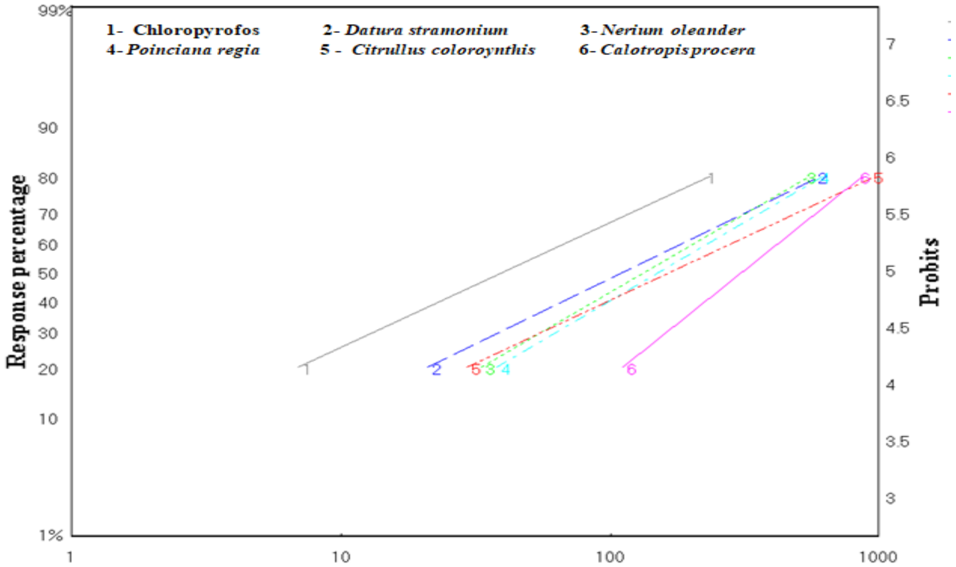

Fig. 6. Toxicity lines of pesticides and their alternatives against subterranean termite.

Table 2. Compounds toxicity against *P. hypostoma*.

Compounds	LC50	LC50-confidence limits		LC90	Slope	Index
		Lower limit	Upper limit			
Chloropyrofos	40.68	8.84	76.80	596.68	1.099	100
Datura stramonium	113.44	55.13	176.43	1472.83	1.15	35.86
Nerium oleander	136.63	82.73	197.03	1164.96	1.38	29.77
Poinciana regia	154.60	97.24	221.67	1293.59	1.39	26.31
Citrullus coloroynthis	170.80	95.82	266.16	2459.35	1.06	23.82
Calotropis procera	314.44	237.22	427.25	1500.05	1.89	12.94

T.I. - Index compared with chlorpyrifos * = ppm based on active ingredients

When examining the overlap between the confidence bounds and other boundaries, the overlap between the confidence bounds was evident with *D. stramonium, N. oleander, P.regia, C. coloroynthis* and *C. procera*, but not overlapped with Chloropyrofos. Therefore, this study can conclude that there is no discernible difference between *D. stramonium, N. oleander, P. regia, C. coloroynthis* and *C. procera*, yet when using chloropyrifos, they differ greatly. Table (2). It is also clear, as appear in Table (2) and Fig. (6) reported that Calotropis procera exhibited the flattest toxicity line and Chloropyrofos had the most pronounced toxicity line, although *D. stramonium, N. oleander, P. regia* and *C. coloroynthis* came in between. This reverses the superiority of Chloropyrofos insecticide and the attenuation of *C. procera*. Chloropyrofos was the most toxic one, whereas *C. procera* was the least toxic compound.

The information in Table (2) clarified that at the LC_{50} level, *C. procera, D. stramonium, N. oleander, P. regia, C. coloroynthis,* and *N. oleander* were 100, 35.86, 29.77, 26.31, 23.82, and 12.94 times as poisonous as Chloropyrofos, respectively. These findings complemented those of Ahmed *et al.* (2016). While, the garlic oil results (3.5 microliter/liter) are completely in agreement with their findings when compared to the Japanese termites *Reticulitermes spertus* Kolb, which has a 100% mortality rate after 24 hours of treatment. Garlic oil has the highest anti-termite acidity of any plant essential oil. (Park and Shin, 2005). Moreover, it was reported by Shi *et al.* (2004); Tuan *et al.* (2014) and Allam *et al.* (2023) that spray a solution of garlic, chile and detergent at a concentration of 0.1% was significantly more efficient than untreated control at reducing insect pests of cauliflower vegetables.

CONCLUSION

Definitely and regarding to the obtained findings, all compounds and extracts were much more lethal to *P. hypostoma* workers than the insecticide chlorpyrifos; they can be used in the future as a low-cost alternative materials for integrated pest management. To combat *P. hypostoma.* Findings clarified that, at the LC_{50} level, the corresponding compounds were 35.86, 29.77, 26.31, 23.82, and 12.94

times as effective as chlorpyrifos. Based on the results, the insecticides were ordered as chlorpyrifos insecticide > *D. stramonium* > *N. oleander* > *P. regia* > *C. coloroynthis* > *C. procera* in decreasing order of termite species toxicity. The results of the current study propose that bio pesticides, in particular *D. stramonium* AgNPs, *N. oleander* AgNPs, *P. regia* AgNPs, *C. coloroynthis* AgNPs and *C. coloroynthis* AgNPs, have the potential to be considered in new methodologies of pest control programs in places where the effectively control *P. hypostoma* was undesirable or prohibited to use synthetic pesticides.

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جسيمات الفضة النانوية كإتجاه جديد لمكافحة النمل الأبيض في منطقة قنا، مصر

رفعت علوى علام [1]، إيمان جمال إبراهيم [2] وعبد النعيم محمد فهمي [3]

[1] قسم وقاية النبات، كلية الزراعة، جامعة جنوب الوادي، مصر.
[2] كلية تكنولوجيا الصناعة والطاقة، جامعة طيبة التكنولوجية، طيبة، الأقصر 85863، مصر.
[3] قسم وقاية النبات، كلية الزراعة والموارد الطبيعية، جامعة أسوان، أسوان، 81528، مصر.

الملخص

يعتبر النمل الأبيض من أهم الآفات الخطيرة في مصر، حيث يتسبب في تلف أي مواد تحتوي على السليلوز. قد يؤدي الاستخدام المكثف لمبيدات الآفات في مكافحة النمل الأبيض إلى ظهور صفة المقاومة لمبيدات الآفات. وبالتالي، من المهم جدًا استخدام إستراتيجية جديدة فعالة للتدابير المضادة لتجنب تطور صفة المقاومة لهذه الآفة. ولذا تم تحويل المركبات المستخدمة فى التجربة الى صورة الجسيمات النانوية وذلك بتغليف هذه الجسيمات بنترات الفضة مع مستخلص مائي من مبيد حشري كلوربيريفوس، داتورا، الدفلة، البونسيانا، الحنظل ونبات العشار. أظهرت النتائج أن المبيد الحشري كلوربيريفوس كان أكثر المركبات سمية، بينما كان نبات العشار أقلها سمية، أما الداتورة، الدفلة، البونسيانا، الحنظل تقع بينهما. بشكل قاطع، بناءً على هذه النتائج، فإن جميع المركبات والمستخلصات المختبرة حققت نسب موت معنوية على حشرات النمل الأبيض. أظهرت النتائج أن المبيدات الحشرية بالترتيب تناقص سميتها على النمل الأبيض فكان المبيد الحشرى كلوربيريفوس > مستخلص الداتورة > مستخلص الدفلة > البونسيانا > الحنظل > العشار