Phytochemical analysis and fabrication of silver nanoparticles using *Acacia catechu*: An efficacious and ecofriendly control tool against selected polyphagous insect pests

Mathalaimuthu Baranitharan\textsuperscript{a}, Saud Ali\textsuperscript{b}, Saad Alkahtani\textsuperscript{b}, Daoud Ali\textsuperscript{b}, Kuppusamy Elumalai\textsuperscript{a}, Jeganathan Pandiyanc, Kaliyamoorthy Krishnappac, Mohan Rajeswaryd, Marimuthu Govindarajande

\textsuperscript{a}Department of Advanced Zoology & Biotechnology, Government Arts College for Men (Autonomous), Chennai 600035, Tamil Nadu, India
\textsuperscript{b}Department of Zoology, College of Science, King Saud University, Riyadh 11451, Saudi Arabia
\textsuperscript{c}Unit of Vector Control, Phytochemistry and Nanotechnology, Department of Zoology, Annamalai University, Annamalainagar 608 002, Tamil Nadu, India
\textsuperscript{d}Unit of Natural Products and Nanotechnology, Department of Zoology, Government College for Women (Autonomous), Kumbakonam 612 001, Tamil Nadu, India

A R T I C L E   I N F O

Keywords:
Nanotechnology
Green synthesis
Pest
*Spodoptera litura*
*Helicoverpa armigera*
Scanning electron microscope

A B S T R A C T

Globally, the farmers are struggling with polyphagous insect pest, and it is the number one enemy of agricultural products, which made plenty of economic deterioration. *Spodoptera litura* and *Helicoverpa armigera* are the agronomically important polyphagous pests. Most of the farmers are predominately dependent on synthetic chemical insecticides (SCIs) for battle against polyphagous pests. As a result, the broad spectrum usage of SCIs led a lot of detrimental outcomes only inconsequently the researchers search the former-friendly phyto-pesticidal approach. In the present investigation, leaf ethanol extract (LEE) and silver nanoparticles (AgNPs) of *A. catechu* (Ac) were subjected to various spectral (TLC, CC, UV, FTIR, XRD, and SEM) analyses. Larval and pupal toxicity of *A. catechu* Ac-LEE and Ac-AgNPs were tested against selected polyphagous insect pests. The significant larval and pupal toxicity were experimentally proven, and the highest toxicity noticed in AgNPs than Ac-LEE. The larval and pupal toxicity of Ac-AgNPs tested against *S. litura* and *H. armigera* LC\textsubscript{50}/LC\textsubscript{90} values were 71.04/74.78, 85.33/88.91 \textmu g/mL and 92.57/96.21 and 124.43/129.95 \textmu g/mL respectively. Ac-AgNPs could be potential phyto-pesticidal effectiveness against selected polyphagous insect pests. In globally, it is significantly sufficient ratification giving towards the prevention of many unauthorised SCPs.

© 2020 The Author(s). Published by Elsevier B.V. on behalf of King Saud University. This is an open access article under the CC BY-NC-ND license (http://creativecommons.org/licenses/by-nc-nd/4.0/).

1. Introduction

Most of the quality and quantity of the agricultural product is directly/ indirectly deteriorated by insect pests in many countries (Elumalai et al., 2010; Kamaraj et al., 2008; Krishnappa et al., 2010; Krishnappa and Elumalai, 2012; Misra, 2014). *Spodoptera litura* is a predominant polyphagous pest occupied a wide range of hosting around 200 floral species globally, in which 74 floral host species noticed from India (Elumalai et al., 2014; Paulraj et al., 2017). *S. litura* larvae consumed the different parts of host flora, including rhizome and causing severe damage, which gives above 60% of revenue loss in India (Elumalai et al., 2014; Krishnappa et al., 2010a, 2010b). India is a tropical country, polyphagous pest (*S. litura*) surviving and high abundance in that particular climate; therefore, recently, agriculture is facing severe economic losses (Paulraj et al., 2017). *Helicoverpa armigera* is a multivoltine, agronomically predominant polyphagous pest and it consumed a wide range of hosts estimated above 300 florae communities globally (Bakkiyajav et al., 2014; Namin et al., 2014). The initial larval stage feeds only soft floral structures then turned to later stages feed on every part of flora (Gokulakrishnan et al., 2014).

Globally, most of the farmers are predominately depending on synthetic chemical insecticides (SCIs) for battle against polyphagous insect fauna (Elumalai et al., 2010; Krishnappa and Elumalai, 2012). As the results of broad-spectrum usage of SCIs
led a lot of detrimental outcomes: a drastic conflict between environment and living organisms, insect pest develops resistance against among the SCIs, the broad eradication of non-target fauna and flora, the direct/ indirect toxicity to formers, SCIs has lesser bio-degradable and drastic conventional effects on the natural ecosystem, unpredictable collapse in food chain/ food web, etc., (Govindarajan et al., 2005; Abinaya et al., 2018; Baranitharan et al., 2016, 2020; Benelli and Govindarajan, 2017; Govindarajan et al., 2011; Govindarajan et al., 2013, 2015, 2016a, 2016b, 2016c, 2016d, 2016e, 2016f, Govindarajan and Benelli, 2016a, 2016b, 2016c, 2016d, 2016e; Govindarajan and Karuppapannan, 2011; Govindarajan and Sivakumar, 2012; Krishnappa et al., 2012, 2013; Krishnappa and Elumalai, 2013). Interestingly, the most of the scientists/researchers search for newer alternative SCIs approach usually it belong from naturally available phytoconstituents (PCs) (Govindarajan and Rajeswary, 2015; Govindarajan et al., 2016g,h; Benelli et al., 2019; Benelli, 2016; Elumalai et al., 2013, 2014; Govindarajan et al., 2016; Govindarajan and Benelli, 2017; Krishnappa and Elumalai, 2013, 2014). Because PCs have less/ zero toxic effects to the ecosystem and other related non-targets fauna and flora (Baranitharan et al., 2017; Benelli et al., 2017a, 2017b, 2017c; Divya et al., 2018; Karthika et al., 2017; Mathivanan et al., 2010; Muthukumaran et al., 2015; Veerakumar et al., 2014; Zahid et al., 2016). The PCs have multispecial derivatives it has been using in many countries (El-Wakeil, 2013; Sola et al., 2014). Acacia catechu (Leguminoseae) is a highly medicinal value flora, and it distributed in entire Asian and African continents. This plant has a lot of vital PCs; therefore, it has been used as different medicinal properties, and it could cure different human/animal infections. The floral parts like a leaf, branches, bark, fruits, seeds, and rhizomes were used as dental care mouthwash, buccal and alimentary canal infections, gastric ulcers, diarrhea, control of hypertension, dysentery, common cold, cough, asthma, leprosy, antimicrobial, antioxidant activities etc., (Patel et al., 2009; Negi and Dave, 2010; Stohs and Bagchi, 2015; Rahman et al., 2016). Since it is firsthand documentation, existing about the pesticidal activity of A. catechu leaf ethanol extract (Ac-LEE) and green-synthesized nanoparticles (Ac-AgNPs) against selected polyphagous insect pests S. litura and H. armigera. Ac-LEE and Ac-AgNPs of A. catechu were subjected to various spectral and microscopic analyses.

## 2. Material and methods

### 2.1. Floral collection and extract preparation

A fresh and cleaned Acacia catechu (Leguminoseae) leaf (Fig. 1A) was collected from parent flora at Namakkal District (11.2189° N, 78.1674° E), Tamilnadu, Southern India. The collected leaves were carefully washed with dechlorinated H2O and immediately kept in the sunshine for 10–15 min. The partially dried and H2O evaporated leaves were carried to the laboratory, which allowed to shade dried on Whatman filter paper (27 ± 2 °C). The dried floral parts were ground as a fine powder (Fig. 1B), which extracted by using the Soxhlet apparatus. Excess of solvent residue in that extract was evaporated naturally, which maintains room temperature on the Petri plate (Fig. 1C) and complete evaporated semi-dried extract weighed, stored in an aseptic glass vial at 0–4 °C in the refrigerator.

### 2.2. TLC, CC, and Phyto-chemical analysis

The Ac-LEE was subjected to find potential PCs accountable for different bioassay activities. The Ac-LEE was run on a pre-coated TLC sheet and CC packed with a silica gel column with a height 50 cm and capacity 50 ml. The Ac-LEE diluted with various solvent systems with the composition of ethanol and diethyl ether (Table 1). The phytochemical analysis using for the quality of various PCs found in the competent Ac-LEE described by Nweze et al. (2004) and Senthilkumar and Reetha (2009).

### 2.3. Silver nanoparticle (AgNP) synthesis

The Ac-AgNO3 90 ml Mm added with Ac-LEE 10 ml was prepared in 200 ml Erlenmeyer flasks for reduction into Ag + ions. AgNO3 + Ac-LEE mixture was retained 1 h at 27 ± 3 °C for complete bio-reduction. The preliminary finding of Ac-AgNPs found the colour change in the AgNO3 + Ac-LEE mixture. The whole reactions allowed in darkness to avoid photoactivation. For the purification process, obtained Ac-AgNPs subjected to ultra-centrifugation above 5,000 rpm for 25 min. After the centrifugation, supernatant discarded and pellet carefully diluted with distilled H2O (Satyavani et al., 2011), the blend was stored in a glass vial, labeled and stored for further analysis.

### 2.4. Characterization of AgNPs

The bio-reduction of Ag + ions solution was keenly monitored by using UV–vis spectroscopy (Rajesh et al., 2009). FTIR spectroscopy evaluated the bio-molecules present in purified Ac-AgNPs (Ashokkumar and Ramaswamy 2014). Ac-AgNPs were allowed to dry at 60° C, and the dried powder was subjected to XRD spectroscopy to identify their exact structure and material.

### 2.5. Polyphagous insect pests rearing

The polyphagous insect pests of S. litura and H. armigera its eggs/ egg masses (Fig. 2A and Fig. 3A), larvae, pupae, and adults were collected from castor and legume field in Mayiladuthurai Dis-
strict (Latitude: 11° 06' 12.74" N; Longitude: 79° 39' 18.00" E), Tamilnadu. Before hatching, the collected eggs were sterilized with 0.02% NaClO and neonate larvae were separately kept in the rearing chamber. S. litura larvae allowed on fresh tender castor leaves and bendi fruits for H. armigera. Heat sterilized soil was provided for pupation at maintained 27 ± 2°C with light 12 h : dark 12 h photoperiod and 70 ± 5% relative humidity in insectariums. Pupae were collected from soil and placed inside the oviposition chamber here cotton soaked with 10–20% (w/v) cane sugar with 1 (or) 2 drops of multivitamins and natural honey was provided for gravid moths to increase the fecundity.

2.6. Insect toxicity

Larval and pupal toxicity of Ac-LEE and Ac-AgNPs were evaluated by the method of Abbott, (1925), and mortality was calculated by probit analysis (Finney, 1971). Five batches of 0–6 h old, 25 number, well active, uniform size, hale and healthy 2nd instar larvae of S. litura and H. armigera were separately introduced in 100 x15 mm petri dish. Larval toxicity of Ac-LEE and Ac-AgNPs of different concentrations (20–150 ppm) Ac-LEE and Ac-AgNPs sprayed on respective host leaves. All phytochemicals (LEE and AgNPs) treated and control larvae were separately allowed to pupate to evaluate the pupal toxicity in which 15 numbers of pupae for S. litura as well as 12 numbers of pupae for H. armigera. Single experiment setup of pupal toxicity maintained five batches in which a total of 75 and 60 pupae tested against S. litura and for H. armigera, respectively (Fig. 2C and 3C). The appropriate concentration of Ac-LEE/ Ac-AgNPs was mixed with dechlorinated H2O applied on the respective host plant of selected pests. The larval and pupal toxicity were assessed on both narrow and broad range test.

\[
\text{Mortality(\%)} = \frac{\%\text{LMT} - \%\text{LMC}}{100 - \%\text{LMC}} \times 100
\]

where

\%LMT = % larval mortality in the treatment
\%LMC = % larval mortality in the control

The same methodology has been applied to pupal toxicity; the hale and healthy of even-sized fifth instars larvae of the selected polyphagous pests were allowed to feed with different concentrations (20–150 ppm) Ac-LEE and Ac-AgNPs sprayed on respective host leaves. All phytochemicals (LEE and AgNPs) treated and control larvae were separately allowed to pupate to evaluate the pupal toxicity in which 15 numbers of pupae for S. litura as well as 12 numbers of pupae for H. armigera. Single experiment setup of pupal toxicity maintained five batches in which a total of 75 and 60 pupae tested against S. litura and for H. armigera, respectively (Fig. 2C and 3C). The appropriate concentration of Ac-LEE/ Ac-AgNPs was mixed with dechlorinated H2O applied on the respective host plant of selected pests. The larval and pupal toxicity were assessed on both narrow and broad range test.

\[
\text{Mortality(\%)} = \frac{\%\text{PMT} - \%\text{PMC}}{100 - \%\text{PMC}} \times 100
\]

where

\%PMT = % pupal mortality in the treatment
\%PMC = % pupal mortality in the control

Table 1

| Sl. No. | Various solvent systems Number of fractions obtained |
|---------|-----------------------------------------------------|
| 1.      | Ethanol:Diethyl ether – 7.5:2.5 2                   |
| 2.      | Ethanol:Diethyl ether – 8.0:2.0 3                   |
| 3.      | Ethanol:Diethyl ether – 8.5:1.5 4                   |
| 4.      | Ethanol:Diethyl ether – 9.0:1.0 5                   |
| 5.      | Ethanol:Diethyl ether – 9.5:0.5 3                   |

Fig. 2. Bioassay experimental setup of A. catechu LEE and AgNPs against S. litura. (A) S. litura eggs collected from castor plant leaf, (B) Larvicidal activity setup, (C) Pupicidal activity setup.

Fig. 3. Bioassay experimental setup of A. catechu LEE and AgNPs against H. armigera. (A) H. armigera eggs collected from legume plant leaf, (B) Larvicidal activity setup, (C) Pupicidal activity setup.
2.7. Statistical analysis

The % mortality data of polyphagous insect pests *S. litura* and *H. armigera* its larvae and pupae were subjected to different statistical tools, LC50/LC90, LCL, UCL, regression, chi-square, etc. All the values were calculated by (IBM) SPSS statistics new version 25.0 version.

3. Results

3.1. TLC, CC analysis and phytochemical screening

The Ac-LEE was subjected to the TLC plate to identify the bioefficiency of PCs were examined. From TLC experiment provided 5 fractions which get in the solvent system ratio of ethanol 9: diethyl ether 1 (Fig. 4A). The same principle was applied on CC; the Ac-LEE capable PCs were assessed by CC tightly packed with silica gel, which runs with the 50 ml solvent ratio of ethanol 9: diethyl ether 1. From the experiment totally we achieved 5 fractions (Fig. 4B). From the *A. catechu* extracts evaluated to phytochemical screening, the maximum phytochemicals (Alkaloids, flavonoids, saponins, tannins, triterpenes, coumarins, anthraquiones and phenolics) gathered from higher polarity solvent like Ac-LEE and it has been listed in Table 2.

3.2. Ac-AgNPs synthesis

The Ac-LEE of Ac-AgNPs (AgNO3 + LEE) composite mixture was clearly indicated and confirming through the colour change (dark brown colour) by adding AgNO3 with Ac-LEE. It is evidently examined in the Fig. 5.

3.3. UV, FTIR, and XRD analysis

Colour change is the basic observation of Ac-AgNPs synthesis which subjected into UV and FTIR spectral analysis of Ac-LEE of Ac-AgNPs are clearly explained in Fig. 6 and Fig. 7 and FTIR analysis supports our hypothesis that the bioreduction of Ag+ ions to Ag0 carried out by *C. a. catechu* leaf borne metabolite. Indeed, the FTIR spectrum showed major peaks at 3422.49, 2922.44, 2853.81, 1608.95, 1588.38, 1489.26, 1444.39, 1383.51, 1268.82, 1237.65, 1110.98, 1036.97, 888.44, 749.31, 724.33, 608.00, 539.81, 487.41, 429.37 cm⁻¹. Above the peak value is strong and broad, they corre-

![Fig. 4. Various fractionation units. (A) Air shield TLC unit, (B) CC unit.](image)

| Sl. No. | Phytochemical screening     | A. catechu, various leaf extracts |
|--------|----------------------------|----------------------------------|
|        | HNE | DER | DME | EAE | ETL |
| 1.     | Carbohydrates | – | + | – | – | – |
| 2.     | Alkaloids | – | – | – | – | + |
| 3.     | Flavonoids | + | * | – | + | + |
| 4.     | Saponins | – | + | – | – | – |
| 5.     | Tannins | * | + | – | – | – |
| 6.     | Triterpenes | + | + | – | – | – |
| 7.     | Resins | + | * | – | – | – |
| 8.     | Coumarins | * | * | – | – | – |
| 9.     | Anthraquinones | + | * | – | + | + |
| 10.    | Phenolics | + | – | – | + | + |

HNE: Hexane; DER: Diethyl ether; DME: Dichloromethane; EAE: Ethyl acetate; ETL: Ethanol.
*+ = noted for the presence of a phytochemical group.
*– = noted for the absence of phytochemical group.
sponded to functional group like alcohols, phenols (O–H stretch, H-bonded, 3422.49 cm\(^{-1}\)), alkanes (C–H stretch, 2922.44, 2853.81 cm\(^{-1}\)), 1\(^{st}\) amine is medium (N–H bend, 1608.95 cm\(^{-1}\)), aromatics are medium (C=C stretch (in-ring), 1588.38, 1489.26, 1444.39 cm\(^{-1}\)), alcohols, carboxylic acids, esters, ethers are strong (C=O stretch, 1268.82, 1237.65, 1110.98, 1036.97 cm\(^{-1}\)), alkenes are strong (C=C–H bend stretch, 888.44, 749.31, 724.33 cm\(^{-1}\)), alkynes is broad and strong (C=C–H: C=H bend stretch, 608.00 cm\(^{-1}\)), and alkyl halides is medium (C–Br stretch, 539.81 cm\(^{-1}\)). The XRD analysis of Ac-LEE of Ac-AgNPs is obviously indicated in (Fig. 8), the appeared peaks were likely matched, and their data were confirming with NIST chemical library.

3.4. SEM analysis

Green synthesized Ac-LEE of Ac-AgNPs evaluated by SEM analysis and its image has been displayed in Fig. 9. From the image obviously declared, the Ac-AgNPs adhered with the Ac-LEE, and Ac-AgNPs confirmed the particle size range from 23.5 nm and 53.4 nm. SEM image has been magnified into different range, and Ac-AgNPs particles appeared like beads shaped it was indicated the category of NPs.

3.5. Insect toxicity

Polyphagous insect pests, S. litura and H. armigera larval and pupal toxicity values of Ac-LEE and Ac-AgNPs expressed in Tables 3 and 4. The predominant larval and pupal toxicity were experimentally demonstrated, and the highest toxicity was noticed in Ac-AgNPs than Ac-LEE. The larval toxicity of Ac-LEE and Ac-AgNPs tested against S. litura and H. armigera LC\(_{50}\)/LC\(_{90}\) values were

![Fig. 5. Colour change observation in A. catechu LEE AgNPs.](image)

![Fig. 6. Spectrum observation of A. catechu LEE of AgNPs through UV-Vis.](image)

![Fig. 7. FTIR spectrum of A. catechu LEE AgNPs.](image)

![Fig. 8. XRD spectrum of A. catechu LEE AgNPs.](image)
The pupal toxicity of Ac-LEE and AgNPs tested against S. litura and H. armigera LC50/LC90 values were 122.31/127.25, 85.33/88.91 μg/mL and 208.49/212.48 and 124.43/129.95 μg/mL respectively. The other statistical values were apparently demonstrated in Tables 3 and 4.

### Table 3
Larval toxicity induced by A. catechu LLE and AgNPs on the larvae of selected polyphagous insect pests.

| Species tested | LC50 ($\mu$g/mL) | 95% Fiducial limit ($\mu$g/mL) | LC90 ($\mu$g/mL) | 95% Fiducial limit ($\mu$g/mL) | R-value | $\chi^2$ |
|----------------|------------------|--------------------------------|------------------|--------------------------------|---------|---------|
| LEE of A. catechu |                  |                                 |                  |                                |         |         |
| S. litura      | 65.47            | 41.73                          | 82.45            | 129.27                         | 107.66  | 178.04  |
| H. armigera    | 77.35            | 70.00                          | 84.20            | 149.43                         | 137.84  | 165.17  |
| AgNPs          |                  |                                |                  |                                |         |         |
| S. litura      | 22.32            | 14.33                          | 28.11            | 43.51                          | 36.16   | 60.47   |
| H. armigera    | 26.17            | 23.93                          | 28.30            | 48.16                          | 44.87   | 52.79   |

LC50 = Lethal Concentration brings out 50% mortality; LC90 = Lethal Concentration brings out 90% mortality; LCL = Lower Confidence Limit; UCL = Upper Confidence Limit; R-value = Regression value; $\chi^2$ = Chi-square.

### Table 4
Pupal toxicity induced by A. catechu LLE and AgNPs on the fresh pupae of selected polyphagous insect pests.

| Species tested | LC50 ($\mu$g/mL) | 95% Fiducial limit ($\mu$g/mL) | LC90 ($\mu$g/mL) | 95% Fiducial limit ($\mu$g/mL) | R-value | $\chi^2$ |
|----------------|------------------|--------------------------------|------------------|--------------------------------|---------|---------|
| LEE of A. catechu |                  |                                 |                  |                                |         |         |
| S. litura      | 91.28            | 59.247                         | 115.01           | 173.15                         | 143.62  | 243.33  |
| H. armigera    | 107.84           | 98.03                          | 117.16           | 206.63                         | 190.27  | 229.05  |
| AgNPs          |                  |                                |                  |                                |         |         |
| S. litura      | 35.90            | 21.07                          | 46.67            | 68.24                          | 55.22   | 105.15  |
| H. armigera    | 41.14            | 37.78                          | 44.38            | 74.85                          | 69.38   | 82.18   |

LC50 = Lethal Concentration brings out 50% mortality; LC90 = Lethal Concentration brings out 90% mortality; LCL = Lower Confidence Limit; UCL = Upper Confidence Limit; R-value = Regression value; $\chi^2$ = Chi-square.

112.48/114.20, 71.04/74.78 μg/mL and 176.53/185.60 and 92.57/96.21 μg/mL respectively. The pupal toxicity of Ac-LEE and Ac-AgNPs tested against S. litura and H. armigera LC50/LC90 values were 122.31/127.25, 85.33/88.91 μg/mL and 208.49/212.48 and 124.43/129.95 μg/mL respectively. The other statistical values were apparently demonstrated in Tables 3 and 4.

### 4. Discussion

#### 4.1. Preliminary phytochemical screening

A. catechu different leaf extracts were evaluated for identifying the qualitative abundance of phytochemical screening, and that
results were verified in higher number of PCs groups were noticed in high polarity organic solvent like Ac-LEE. In previously, numerous PCs investigations have been reported in various floral sources, and it has efficiently controlled in various stages of insect pests. The PCs could be extracted from various parts of flora as well as species. It is incredibly efficient bio-recourse phyto-insecticidal agents, zero effectiveness on non-target fauna/ flora and PCs are best and supreme alternative recourse against SCPs. (Mkindi et al., 2019; Mungenge et al., 2014; Riaz et al., 2018; Ahmed et al., 2020).

4.2. Ag NPs synthesis

The several previous reports obviously synthesized AgNPs have murky brown/ reddish in colour. A similar propensity has been noticed in the present observation of selected flora Ac-LEE of Ac-AgNPs. Many reports strongly empathize with our present investigation (Pirtanghat et al., 2018; Morejón et al., 2018; Roy et al., 2019; Suthanan et al., 2019).

4.3. Ag NPs characterization

**UV–Vis spectral analysis:** The confirmation of Ac-LEE green synthesized AgNPs have been proven by colour change from yellow to brown it can be experimentally observed by UV–vis spectral analysis. In earlier, many kinds of research have been supported to our present investigation. (Ndikau et al., 2017; Elamawi et al., 2018; Femi–Adepaju et al., 2019; Pilaquinga et al., 2019). FTIR spectral analysis: The floral community has several functional groups such as alkaloids, anthraquinones, flavonoids, triterpenes, polyphenols etc., and it could be confirmed and observing through FTIR spectral analysis (Asmathunisha et al., 2010). Therefore, Ac-LEE found various essential function groups and it confirmed their phyto-pesticidal effects while involving with Ac-AgNPs synthesis. Many similar types of works have been observed in previously published experiments (Devaraj et al., 2013; Ajitha et al., 2014; Iyoti et al., 2016; Suresh et al., 2016; Zia et al., 2016). XRD analysis: The periodic steps of lyophilization and acquisition Ac-LEE of AgNPs dried sample subjected to XRD spectral analysis. Results of XRD spectral investigation of Ac-AgNPs crystal structure strongly agreement with earlier reported values (Ramesh et al., 2016; Kumar et al., 2017; Vizuete et al., 2017; Oves et al., 2018; Shanmuganathan et al., 2018). SEM analysis: SEM reflected image has been magnified into various range it was produced the exact size and shape (morphology) of NPs. Similar propensity were recorded in many earlier outcome (Rautela et al., 2019; Pilaquinga et al., 2019; Erdogan et al., 2019).

4.4. Insect toxicity

Larval and pupal toxicity of Ac-LEE and Ac-AgNPs were tested against polyphagous insect pests S. littura and H. armigera, the predominant toxicity was noticed in Ac-AgNPs than Ac-LEE. The similar examinations were noticed in several previously reported insecticidal activities of different insect pests (agricultural/medicinal pests). The naturally available photoproteins like F. religiosa and F. benghalensis leaf AgNPs are significantly reduced gut protease activity of H.armigera (Kantrao et al., 2017). The environmental safety and predominant C. cephalonica larval toxicity was noticed on O. sanctum leaf AgNPs (Gogate et al., 2018). The green products of E. hirta leaf AgNPs against fourth instar larvae and pupae of H. armigera, the selected floral AgNPs provided statistically proven significant insecticidal activity (Durga Devi et al., 2014). The Ag NPs synthesized from different flora of O.euroeapa, F. carica, E. japonica, C. limon, P. vera and M. nigra prepared different concentrations against various life stages of D. melanogaster and their results were given predominant toxicity were recorded from Ag NPs (Araj et al., 2015). The original novel larvicalid agent prepared from C. zedoaria AgNPs, which tested against the larvae of Cx. quinquefasciatus and it produced a prime effect as well as a significant an eco-friendly approach (Suthanan et al., 2019). S. mamossum AgNPs showed remarkable larval toxicity discovered against vector mosquitoes and it could be acted as a potential alternative tool against disease-spreading human vectors (Pilaquinga et al., 2019). The exploration of leaf extracts of C. aromaticus and W. tinctoria AgNPs against Cx. quinquefasciatus and it could be produced maximum toxicity to selected medical pest (Dass and Mariappan, 2018).

5. Conclusion

Ac-LEE green synthesized AgNPs could be potential phyto-pesticidal effectiveness against selected polyphagous insect pests. Around the world above 2000, the floral community has been used as medicinal/ pesticidal properties. In globally, it is significantly sufficient ratification giving towards the prevention of many unauthorized SCPs. Based on the present research, A. catechu could be a potential multidirectional bioactive agent to combat the polyphagous insect pests.

**Acknowledgments**

This research work was funded by Researchers Supporting Project number (RSP-2020/27), King Saud University, Riyadh, Saudi Arabia.

**References**

Abbott, W.S., 1925. A method of computing the effectiveness of an insecticide. J. Econ. Entomol. 18, 265–266.

Abinaya, M., Vaseeharan, B., Divya, M., Sharmili, A., Govindarajan, M., Alharbi, N.S., Kadaikunnan, S., Khaled, J.M., Benelli, G., 2018. Bacterial exopolysaccharide (EPS)-coated ZnO nanoparticles showed high antimicrobial activity and larvicidal toxicity against malaria and Zika virus vectors. J. Trace Elem. Med. Biol. 45, 93–103.

Ahmed, M., Peiven, Q., Gu, Z., Liu, Y., Sikandar, A., Hussain, D., Javeed, A., Shaf, J., Iqbal, M.F., An, R., Guo, H., Du, Y., Wang, W., Zhang, Y., Ji, M., 2020. Insecticidal activity and biochemical composition of Cirtullus colocynthis, Cannabis indica and Artemisia argyri extracts against cabbage aphid (Brevicoryne brassicae L.). Sci. Rep. 10 (1). https://doi.org/10.1038/s41598-019-57092-5.

Ajitha, B., Reddy, Y.A.K., Reddy, P.S., 2014. Biogenic nano-scale silver particles by Tephrosia purpurea leaf extract and their inborn antimicrobial activity. Spectro. Acta Part A 121, 164–172.

Arad, S.E.A., Salem, N.M., Ghabesh, I.H., Awad, A.M., 2015. Toxicity of Nanoparticles against Drosophila melanogaster (Diptera: Drosophilidae). J. Nano. 2015, 1–9.

Ashokkumar, R., Ramaswamy, M., 2014. Phytochemical screening by FTIR spectrophotometric analysis of leaf extracts of selected Indian medicinal plants. Int. J. Curr. Microbiol. App. Sci. 3, 395–406.

Asmathunisha, N., Kathiresan, K., Anburaj, Nabeel, M.A., 2010. Synthesis of antimicrobial silver nanoparticles by callus extracts from saltmarsh plant Sesuvium portulacastrum L. Colloids. Surf. B. Biointerfaces. 79, 488–493.

Backiyaraj, M., Elumalai, A., Kasinathan, D., Mathivanan, T., Krishnappa, K., Elumalai, K., 2014. Bioefficacy of Ciaspinia hondurensis extracts against Tobacco cutworm, Helicoverpa armigera (Hub.) (Lepidoptera: Noctuidae). J. Coast. Life Med. 2, 685–692.

Baranitharan, M., Dhanasekaran, S., Murugan, K., Kovendan, K., Gokulakrishnan, J., Benelli, G., 2017. Coleus aromatics leaf extract fractions: A source of novel ovicides, larvicides and repellents against Anopheles, Aedes and Culex mosquito vectors? Pro. Saf. Environ. Prot. 106, 23–33.

Baranitharan, M., Krishnappa, K., Elumalai, K., Pandiyar, J., Gokulakrishnan, J., Kovendan, K., Tamizhazhagan, V., 2020. Cx. quinquesexta (Riso) - borne compound as novel mosquitoicides: Effectiveness against medical pest and acute toxicity on non-target fauna. South African J. Bot. 128, 218–224.

Baranitharan, M., Sawicki, B., Gokulakrishnan, J., 2019. Phytochemical profiling and larval control of Erythrina variegata methanol fraction against malarial and filarial vector. Adv. Prev. Med. 2019, 1–9.

Baranitharan, M., Dhanasekaran, S., Murugan, K., Kovendan, K., Gokulakrishnan, J., 2016. Chemical composition and laboratory investigation of Melissa officinalis essential oil against human malarial vector mosquito, Anopheles stephensi L. (Diptera: Culicidae). J. Coast. Life Med. 4, 969–973.
Krishnapa, K., Elumalai, K., 2012b. Larvicidal and ovicidal activities of silver nanoparticles synthesized using Andean blackberry fruit extract. Saudi J. Biol. Sci. 24, 45–50.

Rajesh, W.K., Jaya, R.L., Niranjan, S.K., Vijay, D.M., Sahelebrao, B.K., 2009. Phyto synthesis of silver nanoparticles using Cilicridia sepium (Jau)._curr. Nanosci. 9, 117–122.

Ramesh, S., Grijalva, M., Debaut, A., De la Torre, B., Albericio, F., Cumbal, L., 2016. Peptides conjugated to silver nanoparticles in biomedicine—a “value-added” phenomenon. Biomater. Sci. 4, 1713–1725.

Rautela, A., Rani, J., Deb Nath, (Das), M., 2019. Green synthesis of silver nanoparticles from Tectona grandis seed extracts: characterization and mechanism of antimicrobial action on different microorganisms. J. Anal. Sci. Technol. 10, 1–10.

Rajesh, W.K., Smita, K., Cumbal, L., Debut, A., 2017. Green synthesis of silver nanoparticles using the plant extract of Salvia spissa grown in vitro and their antibacterial activity assessment. J. Nano. Chem. https://doi.org/10.1007/s40097-018-0291-4.

Rahman, M.A., Sultana, P., Islam, M.S., Mahmud, M.T., Rashid, M.M.O., Hossen, F., 2016. Comparative antimicrobial activity of Arecia catechu nut extracts using different extracting solvents. Bangladesh J. Microbiol. 31, 19–23.

Krishnappa, K., Elumalai, K., Anandan, A., Govindarajan, M., Mathivanan, T., 2010a. Comparative antimicrobial activity of Arecia catechu against reference to pest - predator population in groundnut ecosystem (Lepidoptera: Noctidae). Int. J. Ana. Chem. 2017, 1–9.