Insecticidal activity of bio-silver and gold nanoparticles against *Pericallia ricini* Fab. (Lepidaptera: Archidae)

K. Sahayaraj, M. Madasamy and S. Anbu Radhika

ABSTRACT

A laboratory experiment was conducted to evaluate the impact of silver aqueous solution, gold aqueous solution, pungamoil, pungamoil-based silver nanoparticles (PO-AgNPs) and pungamoil-based gold nanoparticles (PO-AuNPs), vijayneem against *Pericallia ricini* larval mortality, development and fecundity and gravimetric analyses. The results showed that Ag^+ aqueous solution as well as pungamoil-based gold nanoparticles caused more mortality than commercial neem insecticide (vijayneem). Aqueous solutions of Ag^+ and Au^+ drastically reduced the body weight of *P. ricini* larvae. PO-AgNPs and PO-AuNPs treatment drastically enhanced the food consumption, assimilation but reduced the conversion, subsequently affecting growth. Distinct difference was noticed between PO-AgNPs and PO-AuNPs treatments in larval, pupal and adult developmental periods, fecundity and hatchability. It is recommended to integrate PO-AgNPs and PO-AuNPs in pest management; however, field evaluations and bio-safety assessments were imperative before the utilization of these bio-nanoparticles were recommended.

Key words: Bionanoparticles, castor, pestiferous insects, mortality, development, reproduction

MS History: 28.03.2016 (Received)-11.05.2016 (Revised)- 19.05.2016 (Accepted)

Citation: K. Sahayaraj, M. Madasamy and S. Anbu Radhika. 2016. Insecticidal activity of bio-silver and gold nanoparticles against *Pericallia ricini* Fab. (Lepidaptera: Archidae). *Journal of Biopesticides*, 9 (1): 63-72.

INTRODUCTION

Castor *Ricinus communis* (Linn) (Euphorbiaceae) is oil seed crop infested by more than 107 species of insects and 6 species of mites, among them, *Pericalia ricini* Fab. (Lepidaptera: Archidae) commonly called as hairy caterpillar or woolly bear. It is the major pest of castor, gingelly, cotton, country bean, brinjal, drumstick, coccina, banana, calotropis, sunflower (Ayyanna *et al.,* 1978), oleander, tea, sweet potato, pumpkin (David and Ananthakrishnan, 2004) elephant foot, coccina, cow pea, yam, arum (Colocasia) (Nair, 1970; Butani and Jotwani, 1984; David, 2001), groundnut, maize (Singh and Sharma, 2014), etc.

Neem oil at various concentrations was recommended for the management of *Nilaparvata lugens, Bemisia tabaci, Helicoverpa armigera,* *Maruca testulalis, Melanagromyza obtuse, Clavigralla gibbesa,* *Spodoptera litura, Callosobruchus chinensi, Callosobruchus maculates* etc. (http://agritech.tnau.ac.in/org_farm/orgfarm_agripest.html). Similarly, Pungam oil of *Pongamia glabra* possesses toxic components such as glabrin, karajin, karanjae and pongaglabrone, effective against insect pests of field and plantation crops (Gibbs, 1974; Sahrawat 1982; Adiroubane and Raghuraman, 2008; Koshiya and Ghelani, 1993, Pavela and Herda, 2007; Mathur *et al.,* 2012; Yadav *et al.*, 2015). Various mechanical, chemical (Tasida and Gobena, 2010), mycoinsecticides (Sahayaraj and Borgio, 2012), neem oil (Mala and Muthalagi, 2008), botanical insecticides in general (Sundararaj, 2014; Gahukar, 2015) and specifically *Datura stramonium* L. (Prakash and Rao, 1997), *Tragia involucrate* (Jeyasankar *et al.,* 2014) were recommended for *P. ricini* control.

Nanoparticles have been suggested for crop pest and disease managements. Accordingly essential oil-loaded solid lipid nanoparticles (Liu *et al.*, 2006); nano-silica (Barik *et al.,* 2008), silver nanoparticles (SNP), aluminium oxide (ANP), zinc oxide and titanium dioxide (Goswami *et al.*, 2010); nanostructured alumina (Teodoro *et al.*, 2010); imidacloprid encapsulated chitosan and sodium alginate (Guan *et al.*, 2010), nano alumina (Stadler *et al*. 2010), amino-functionalized nano-composite material (NCM) using tetraethylenepentamine (TEPA) (Zhao *et al.*, 2011); sodium dodecyl sulfate (SDS) modified photocatalytic TiO2 /Ag nanomaterial conjugated with clay-based nanolayers (Khot *et al.*, 2012); CabO-Sil-750 and Cab-O-Sil-500-Nano particles (Sabbour, 2013a), Zinc oxide ZnO (Sabbour, 2013b), *Avivennia marina*-based silver and lead nanoparticles (Sankar and Abideen, 2015), nano-imidacloprid (Sabbour, 2015), nanoencapsulated essential oils from *Zanthoxylum rhoifolium* (Christofoli *et al.*, 2015), nano-destruxin (Sabbour, 2015), *Aristolochia indica*- AgNPs (Yasur and Rani, 2015) were suggested for pest management. However, no one has used essential oil-based nanoparticles for any pest management. Considering the lacuna we proposed to study the 1) insecticidal activity of vijayneem, pungam oil or its Ag or Au nanomaterials against *P. ricini* third instars larvae under laboratory conditions, 2) observe the energy budget and 3) observe the developmental days, reproduction and hatchability, adult longevity of *P. ricini.*

MATERIALS AND METHODS

Collection and rearing of pest

Life stages of *P. ricini* were collected from castor plantation at St. Xavier's College campus, Palamkottai, reared on castor leaves under laboratory conditions at 29 ± 2^{0}C, 70-80% relative humidity and 11Land 13D hrs photoperiod up to pupation. Healthy pupae were transferred on to the Petri dishes (9.5 cm x 1.5 cm) for adult emergence. Five pairs of healthy adults were transferred and maintained in an oviposition chamber (height 43.7 cm × diameter 35.0 cm) where fresh castor leaves to maintain humidity and substrate for oviposition. Adults were fed with 10% sucrose fortified with vitamin mixture (Supradyn Multi vitamin tablet). Eggs were collected from castor leaves using camel hairbrush, surface sterilized with 0.01% formaldehyde solution for five minutes, then washed in running water for 20 min, air-dried at room temperature and maintained in Petri dishes (height 1.5 cm × diameter 9.5 cm) for hatching. The neonate larvae were placed on clean castor leaves with its petiole immersed in 100 mL conical flask. Fresh leaves were provided and maintained at room temperature, when larvae reach the second instar; ten larvae were retained in each plastic container (7.5 cm x. 6.5 cm). When the larvae reached the third instar, they were used for the experiment.

Preparation of oil emulsion

Pungam oil purchased from the local market was first filtered through a clean, sterilized muslin cloth and then through filter paper. From this fresh stock, solutions of 0.03 per cent concentration [100 ml water + 30 µL oil] was prepared, and then add 50 µL 0.05% Twin 80 immediately. The mixture was subjected in rotary shaker at 40 rpm for 30 minutes for through mixing and used for experiments.

Preparation of Vijayneem

Neem-based commercial product vijayneem (Maras Fertilizers Ltd., Chennai) was purchased from local pesticide company. Field recommended application concentration of 0.03% was prepared by mixing with water and used for the experiments.

Preparation of bionano particles

Silver nitrate purchased from Hi-Media (RM409-25G) with 99.9% purity was used for the preparation. 17 mg silver nitrate was taken and dissolved in the 100 mL of distilled water (10^{-3}M AgNo3). To induce the synthesis of silver nanoparticles, 25 ml of pungam oil was mixed with 75 mL of aqueous silver nitrate solution. This mixture was slowly and gently mixed for 10-15 minutes at room temperature and the solution turned pale yellow to brown. Gold chloride trihydrate purchased from Hi-Media (RM4291-1) with 99.0% purity was used for the preparation. 17 mg of gold chloride was taken and dissolved in 100 mL of distilled water (10^{-3}M $HAuCl_4$). To induce the synthesis of silver nanoparticles, 25 mL of pungam oil was mixed with 75 mLof aqueous silver nitrate solution. This mixture was slowly and gently mixed for 10-15 minutes at room temperature and the solution turned yellow to violet in colour.

Insecticidal bioassay

Castor leaf discs of 3 g were weighed and dipped in various concentrations of vijayneem (0.03%) or pungam oil (0.03 %) or gold chloride trihydrate aqueous extracts (10^{-3} M) and its bio-nanoparticles (10^{-3}M), silver nitrate (10^{-3} M) and its bio-nano liquid (10^{-3} M) or castor leaf treated with water for 5-minutes, shade dried for 10 minutes and placed over a moist filter paper in the Petri dishes. Twelve hours pre-starved third instar larvae (420-460 mg) were weighed and released in each transparent plastic container (7.5 cm x. 6.5 cm) for feeding. The experiment was replicated five times. After 24-hrs, the number of dead or live larvae, weight of the unconsumed leaf, fecal pellets and larval weight in each treatment were recorded. All live larvae of both experimental and control categories were fed with fresh healthy castor leaves. After 24-hrs, again numbers of dead or live larvae, weight of the unconsumed leaf, fecal pellets and larval weight in each treatment were recorded. Then all live larvae were provided with castor leaf discs dipped in various concentrations of the vijayneem (0.03 %) or pungam oil (0.03 %) or gold chloride trihydrate aqueous extracts (10^{-3} M) and its bionano liquid (10^{-3} M), aqueous silver nitrate solution (10^{-3} M) and its bionano liquid (10^{-3}M) or water or without water or their combinations. Same observations and procedures were followed still the larvae were transformed in to pupae.

Gravimetric analyses

The leaves remaining at the end of each day were weighed again. The quantity of food ingested was estimated by subtracting the diet) remaining at the end of each experiment from the total weight of the diet provided. Feces were collected daily and weighed. The experiment was continued for 10-days and observations recorded every 24-hrs. Consumption, growth rates, and post-ingestive food utilization efficiencies were calculated in the traditional manner (Walbauer, 1968), such as:

Growth rate = Growth (mg) / Initial weight × duration × 100

Food consume rate (FCR) = Dry food consume (mg) / wet weight gain (mg)

Species growth rate (SGR) = InI_2- InI_1 / Experiment duration × 100

Consumption (C) = P+ R (F+U)

Assimilation (A) = C- (F+U)

Conversion efficiency (%) = Dry animal weight / Wet animal weight (mg) × 100

Where,

P= Growth

R= Growth rate

F+U= Faecal weight

Observations of biological parameters

During the life time (larvae to adults), larval period, pupal period and adult longevity, pupation rate (number of normal pupae emerged from a particular category / total number of larvae maintained x 100), adult emergence (number of normal adult emerged from a particular category / total number of pupae maintained x 100), sex ratio (male: female = number of female emerged from a category / total number of adults emerged) were recorded. Furthermore, deformed larvae, pupae and adults were observed, preserved at 70% alcohol. Healthy adults emerged from each category were released into cage (43.7 cm height × 35.0 cm diameter) for oviposition where fresh castor leaves with petiole immersed in 100ml conical flasks to maintain turgidity of leaves were provided in the cage as ovipositional substrate. Adult feed consisting of 10% sucrose fortified with vitamin mixture (Supradyn Multi vitamin tablet) was provided to enhance the oviposition. Oviposition and hatching of eggs were observed as mentioned previously.

Statistical analysis

The median lethal contractions (LC_{50}) were calculated using Probit analysis (SPSS version 11.5) (Finny, 1971) and values were expressed as mean of five replication. Tenth day corrected mortality and animals weight data

Table 1. Corrected mortality (%) of seven days old *Pericallia ricini* treated with pungam oil (0.03%), silver nitrate (10^{-3}M), $AuCl_3$ (10^{-3}M), pungam oil + $AuCl_3$ (10^{-3}M), pungam oil + $AuCl_3$ (10^{-3}M) and untreated castor leaf

Treatments	Days after exposure									
	1	2	3	4	5	6	7	8	9	10
Pungam oil	-	6.66 ±0.66	19.98 ±1.15	19.98 ±1.15	19.98 ±1.15	26.64 ±1.66	33.30 ±1.00	33.30 ±1.00	46.62 ±1.15	53.28 ±1.15de
Ag^+ solution	6.66 ±0.66	6.66 ±0.66	19.98 ±1.15	19.98 ±1.15	19.98 ±1.15	39.96 ±1.24	46.62 ±2.15	53.30 ±1.33	59.96 ±1.24	73.30 ±2.22a
Au^+ solution	-	-	16.65 ±0.61	19.98 ±1.33	33.30 ±1.48	46.62 ±1.33	46.62 ±1.33	46.62 ±1.33	53.28 ±1.15	66.60 ±0.09b
Pungam oil-AgNPs	-	-	6.66 ±0.66	6.66 ±0.66	19.98 ±1.15	26.64 ±1.66	33.30 ±1.00	33.30 ±1.00	46.62 ±2.15	46.62 ±2.15f
Pungam oil-AuNPs	-	-	13.32 ±1.33	13.32 .±1.33	13.32 ±1.33	13.32 ±1.33	13.32 ±1.33	13.32 ±1.33	53.28 ±1.15	59.94 ±2.66c
Vijayneem	13.20 ±0.15	13.20 ±0.15	39.60 ±1.66	39.60 ±1.66	39.60 ±1.66	46.62 ±1.15	53.28 ±2.10	53.28 ±2.10	53.28 ±0.95	53.28 ±0.95d

10^{th} day observation was subjected to Tukeys test ($\alpha = 0.05$). Same alphabets in a column is not statistically insignificant

and also larval development, pupal period, adult period, fecundity, hatchability were subjected to One-way Analysis of variance (ANOVA) and the mean values were separated using Tukey test (SPSS 20.0 version). All significances were expressed from 0.01 to 0.0005 levels.

RESULTS AND DISCUSSION

Biogenesis of nanoparticles

Biogenesis of silver (PO-AgNPs) and gold (PO-AuNPs) nanoparticles were confirmed by V-visible spectrophotometer.

Insecticidal activity

Commercial insecticide vijayneem (df=2,2; F=18.022; p<0.05) and pungam oil caused (df=1,3; F=71.576; P<0.005) almost same mortality at 10-days after exposure. This commercial pesticide was safer to common natural enemy like *Trichogramma chilonis* Ishii. (Lingathurai *et al.*, 2015) and can be used as an integrated pest management component for *P. ricini* too. Though pungam oil showed insecticidal activity against many insect pests like brinjal (*Solanum melongena* L.) shoot and fruit borer, *Leucinodes orbonalis* (Guenee) (Yadav *et al.*, 2015), we recorded only 67% (df=1,3F=9.276;p<0.009) mortality against *Pericallia ricini* on 21^{st} day of its larval life time. Further, *P. glabra* was considered as an ideal botanical pesticidal plant for rice plant pest management (Venkatesan *et al.*, 2016). Pungam oil based silver (PO-AgNPs) and gold (PO-AuNPs) nanoparticles caused 47 and 60% mortality against *P. ricini* (Table 1). However, PO-AgNPs (df1,3;F=9.276;p<0.009) or PO-AuNPs (df=1,3;F7.800;p<0.015) caused only 73% and 67% mortality, respectively suggested that addition of pungam oil with either Ag+ or Au+ reduced the mortality, suggested to utilize the bio-nanoparticles in pest management as suggested previously by many authors (Sahayaraj, 2012, 2014a, 2014b, 2016; Sahayaraj *et al.*, 2015; Parisi *et al.*, 2015; Grillo *et al.*, 2016).

Gravimetric analyses

For the first time, Krishnan (1984) studied the bioenergetics of *P. ricini*. Invariably body weight gradually increased while the larvae grew older (Table 2) indicates in order to sustain the life whether it was treated with botanical pesticides or bionanomaterials or metal ion solutions. Ramdev and Rao (1979) reported that food intake increased with age of *Achaea janata* L. (Noctuidae) on castor, due to increased consumption of food (Ranjith, 1981) by *P. ricini* larvae. This was possible by converted all consumed food into body mass (Table 3). Among all treatments at 10^{th} day, *P. ricini* larval body weight was high when the larvae consumed normal castor leaves (df 8, 72; F= 6.10; p < 0.005). The weight was significantly reduced when the castor leaf was dipped with water + teepol (df 8, 72; F= 3.001; p < 0.05). It was further reduced in PO-

Table 2. *Pericallia ricini* total body weight (mg) when fed with pungam oil (0.03%), $AgNO_3$, $AuCl_3$, pungam oil + silver nitrate solution, pungam oil + $AuCl_3$ solution, water treated and untreated castor leaf fed larvae.

Treatments	Days after exposure								
	2	3	4	5	6	7	8	9	10
Vijayneem	73.82 ±9.47	89.98 ±2.99	107.68 ±2.90	118.90 ±5.10	194.18 ±2.42	196.96 ±1.85	248.26 ±9.36	258.98 ±6.47	343.86 ±1.48d
Pungam oil	31.22 ±3.18	52.76 ±4.69	71.88 ±1.02	92.32 ± 1.35	140.00 ±1.39	255.00 ±0.06	273.00 ±7.13	295.0 ±7.52	294.00 ±3.38e
Ag+ solution	27.76 ±2.76	42.44 ±1.17	45.60 ±9.03	61.42 ±1.9	73.72 ±2.00	98.00 ±1.13	111.00 ±0.42	123.0 ±4.87	165.00 ±7.94h
Au+ solution	33.44 ±5.43	63.26 ±8.59	78.88 ±8.74	93.06 ±7.89	144.7 ±9.54	241.2 ±6.58	256.6 ±5.61	265.6 ±8.41	192.4 ±2.08g
Pungam oil + $AgNO_3$	39.70 ±3.71	59.92 ±7.4	65.62 ±4.52	119.7 ±1.83	160.6 ±9.60	223.3 ±6.29	262.1 ±2.33	269.1 ±8.79	268.2 ±1.16f
Pungam oil + $AuCl_3$	42.64 ±4.10	65.92 ±8.92	88.62 ±4.63	178.7 ±2.93	189.1 ±4.07	240.9 ±9.52	366.8 ±8.49	400.3 ±1.30	411.5 ±1.20c
Castor leaf + water	43.4 ±2.77	80.54 ±7.10	87.56 ±2.04	143.4 ±9.47	168.86 ±2.34	254.66 ±1.30	287.02 ±1.48	348.15 ±1.09	421.6 ±5.11b

10^{th} day observation was subjected to Tukeys test (α = 0.05). Same alphabets in a column is not statistically insignificant

AuNPs treatment followed by vijayneem (df 8, 72; F= 2.988; $p < 0.05$). Leaf powder extracts of *Azadirachta indica* A. Juss. (Meliaceae), *Datura metal* L. (Solanaceae), *Calotropis gigantea* L.R.Br (Asclepiadaceae) and *Vinca rosea* Linn. (Apocynaceae.) reduced animal weight, food consumption and faecal pellet production of *P. ricini* (Mohamed and Kareem, 2010). Similarly, it was also observed that the reduction in food consumption, weight loss during exposure period and reduction in growth rate occurs, when third and fifth instar larvae of *P. ricini* were fed on castor leaves dipped in different concentrations of diamino-furyl-s-triazine (Srivastava and Srivastava, 1990).

In an average *P. ricini* larvae consumed 396.3±6.4 mg castor leaves per day. Food consumption was reduced while the insect was fed with pungam oil (df1,18; F=248.0; $p < 0.05$), Ag^+ solution (df1,18; F=247.25; $p < 0.05$), Au^+ solution (df1,18; F=249.8887; $p < 0.05$) treated leaf fed larvae (Table 3). Findings indicate that secondary plant metabolites exhibiting insecticidal and especially repellent (antifeedant) activities are the most acceptable and without side effects (Knio *et al.*, 2008). The rate of feeding significantly varied depending on the concentration of the secondary metabolites of pungam oil, active ingredient azadirachtin of vijayneem, and Ag+ or Au+ ions and their nanoparticles. Further, these organic and inorganinic ions or compounds inhibit larval feeding behaviour or make the food unpalatable or the substances directly act on the chemosensilla of the larva resulting in feeding deterrence. Therefore, prevention of leaf damage achieved by the application of tested materials could be mainly attributed to their active compounds.

Simmonds *et al.* (1995) reported that azadirachtin and its analogues significantly reduced food intake and insect growth of the Egyptian cotton leafworm, *Spodoptera littoralis* (Boisd). Similar observations were also reported in *Pericallia ricini* by Mohamed and Kareem (2010). However, fortification PO-AgNPs (df1,18; F=249.887; $p < 0.05$) and PO-AuNPs (df1,18; F=249.89; $p < 0.05$) significantly enhanced food consumption of the larvae, which shows physical or chemical stress caused by Ag^+ and Au^+ metals, to compensate the stress animal try to consume, assimilate

Table 3. Gravimetric analyses for *Pericallai ricini* treated with pungam oil based silver and gold nano liquid ions, Pungam oil (0.003%)

Treatments	Consumption	Assimilation	Conversion efficiency (%)	Growth rate (%)	Specific Growth Rate (SGR)
Vijayneem	670.5 ±8.4a	365.4±9.4a	53.3±3.0h	44.8±1.9	8.5±0.2c
Pungam oil	278.2±3.8f	160.8±3.2f	52.9±6.1b	50.1±1.0	7.5±1.0ef
Ag^+ solution	262.3±.6.3g	88.5±4.3h	59.9±2.4a	30.2±9.9	5.3±1.1h
Au^+ solution	252.4±3.6h	159.2±2.9fg	61.7±2.1bc	51.1±1.1	7.5±0.4fg
Pungam oil-AgNPs	340.4±5.3e	197.2±4.7e	66.1±3.2cd	72.2±1.5	7.6±1.2de
Pungam oil-AuNPs	535.5±7.3b	318.9±5.7b	69.0±3.5fg	77.6±1.1	7.8±1.8d
Castor leaf + Water	396.3±6.4d	216.3±3.1d	48.0±2.5ef	70.3±1.5	9.4±1.0a

Individual data was subjected to Tukeys test and significance was expressed (α = 0.05). Same alphabets in a column is not statistically insignificant

and convert more food. The activity of the midgut enzymes (protease, phosphatase, amylase and invertase) was reduced (Ayyangar and Rao, 1989). Hence, such kinds of enzyme studies are imperative to confirm this postulation.

Biology

The biochemical pesticides and the botanicals possess pesticidal, repellent, growth disturbance properties and have come up as better substitutes to synthetics as they are ecofriendly with target specificity and biodegradability and are economically feasible. The part provides information on the different types of the biological product-based pesticide formulations on the biological traits of *P. ricini*. Ghosh and Gonchaudhuri (1996) initially studied the biology and food utilization efficiency of *P. ricini*. Our results show larval, pupal and adult periods were 20.0±1.35, 13.0±8.8 and 13.3±0.90 respectively when castor leaf alone provided as food (Table 4). These periods slightly decreased when castor leaf was dipped in water (19.6±1.59, 12.4±1.00 and 10.6±1.67 days as larval, pupal and adult periods respectively) (Table 4). Neem oil was acts as insecticide against *P. ricini* (Revathi and Kingsley, 2008), similarly, its commercial Further, vijayneem reduced pupal and adult emergence (Fig. 1), fecundity and hatchability and altered male and female sex ratio (Table 4) insecticide also showed insecticidal activity by reducing larval, pupal and adult periods.

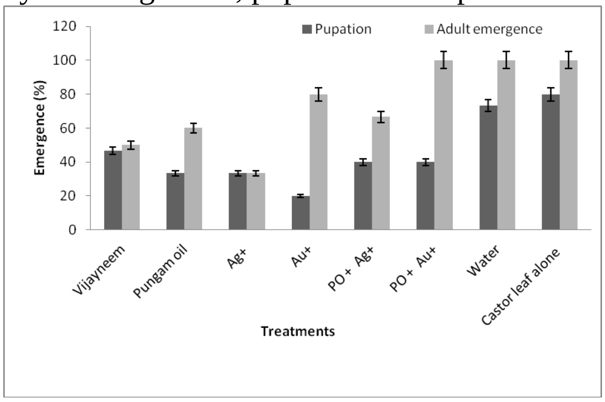

Fig.1. *Pericallia ricini* pupal and adult emergence (%) fed with pungam oil (0.03%), $AgNO_3$, $AuCl_3$, pungam oil + silver nitrate solution, pungam oil + $AuCl_3$ solution, water treated and untreated castor leaf fed larvae.

Nanoparticles or quantum dots are easily ingested by insects, moved insect gut lumen into haemolymph and also visualised in the frass (Al-Salim *et al.*, 2011). It was also suggested to utilize nanoparticles for pest management (De *et al.*, 2014; Chandrashekharaiah *et al.*, 2015; Dziewięcka *et al.*, 2016). Results also reveal that PO-AgNPs (df1,18; $F=249.987$; $p < 0.05$) and PO-AuNPs significantly reduced the fecundity of

Table 4. Feeding of pungam oil (0.03%) (PO), silver ion solution, auric ion solution, PO-AgNPs, PO-AuNPs, water and untreated caster leaf on the biological parameters of *Pericallia ricini*

Life traits	Castor leaf treated with						
	Vijayneem	Pungam oil	Ag+	Au+	PO + Ag+	PO + Au+	Castor leaf
Larval period (days)	16.4 ±1.5g	20.5 ±1.7c	22.0 ±1.5a	21.1 ±1.4b	20.1 ±1.7cd	19.5 ±1.6ef	19.6 ±1.6e
Pulpal period (days)	9.4 ±0.84g	13.1 ±1.8c	15.0 ±1.01b	11.43 ±0.7	13.1 ±1.1de	16.5 ±0.5a	12.4 ±1.00f
Adult longevity (days)	17.0 ±0.8	19.5 ±0.4	16.0 ±0.8	16.6 ±1.1	11.0 ±0.8	19.0 ±0.4	10.6 ±1.7
Sex ratio (Male:Female)	1.0:0.2	1.0:0.2	1.0:0.4	1.0:0.2	1.0:04	1.0:0.2	1.0:0.4
Fecundity	581.3 ±7.7b	566.5 ±9.1c	321.2 ±7.1d	288.0 ±10.2e	223 .9 ±11.2f	172.7 ±15.1g	603.5 ±10.7a
Hatchability (%)	53±2.1b	48±3.0c	40±1.5d	33±0.9e	23±2.9f	20±1.0g	89±10.7a

P. ricini. rice weevil, *Sitophilus oryzae*, lesser grain borer, *Rhyzopertha dominica* and cowpea beetle, *Callosobruchus maculates* reproduction was reduced by Aerosil 200 Nano Particles (Doaa and Nilly, 2015) as observed in the present research. Among all tested materials PO-AuNPs showed higher ovipositional deterrence (df1,18; F=249.00; $p < 0.05$) than vijayneem, pungam oil, Ag^+ solution, Au^+ solution and PO-AgNPs. From this study we recommend to utilize PO-AuNPs and PO-AgNPs for pest management particularly the defoliators.

Acknowledgements

Senior author KSR thanks St. Xavier's College, Palayamkottai management for the laboratory assistance and encouragements.

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