1. Introduction

The overuse of synthetic pesticides for controlling insect pests in the agricultural fields has polluted not only agro-ecosystem but also the water we drink, the soil that we use and all natural resources that we use for our livelihood. This dreadful situation demands the human community to find an alternative and safe practices to control insect pests without causing ill-effects to non-target organisms, environment and so on. Now there is a tremendous effort taken by the modern humanity to practice methods that are eco-friendly, economically viable, and easily available. As a result, there is an increasing interest in developing phytotoxic agents for controlling insect pests due to their effectiveness at low concentrations and low impacts on non-target organisms[1–3]. The biomolecules present in phytotoxic agents act as feeding deterrent, bioinsecticide, ovicide, oviposition deterrent and growth inhibition against field insect pests[4–9]. Klun c(7) reported that mosquitoes were differently repelled by isomers of piperidines. Pongam and neem oils or neem based commercial pesticides showed antioviposition effects on the adults of greenhouse whitefly[8], *H. armigera*(9) and *S. litura*(Lepidoptera : Noctuidae) are major insect pests[10,11]. They attack a wide range of industrial, ornamental cereal, legume and vegetable crops throughout the world[12] especially in Asia, Africa, Australia. *S. litura* alone damages more than 180 crops causing 69 per cent reduction in yield[13,14]. Field insect pests like *H. armigera* and *S. litura* cause great damage to the agricultural crops and reduce their productivity[15]. By keeping this background we focussed our research to formulate a novel phytotoxic formulation[16] known as PONNEEM at Entomology Research Institute (ERI) to find oviposition deterrent effect of PONNEEM, a newly formulated phytotoxic agent against *H. armigera* and *S. litura*. Due to its high efficacy in controlling field insect pests, PONNEEM was patented in India (Indian Patent No. 204381 by the Entomology Research Institute, Loyola College, Chennai, Tamil Nadu, India).
2. Materials and methods

2.1. Formulation of Phytopesticide

Five phytopesticidal formulations were prepared using pungam, neem oils at different combinations. These oils were taken at specified ratio in a stainless steel vessel with a stirrer and were stirred at 120 r/min for 10 min. Then 8% emulsifier and 1% stabilizer were added to the oils and again it was stirred at 120 r/min for 10 min. At last 0.123% Azadirachtin and 2% isopropyl alcohol were added and again it was mixed thoroughly by using a stirrer at 120 r/min for 10 min. Then the final formulations were obtained[11,16].

2.2. Insect culture

2.2.1. H. armigera

H. armigera larvae were collected from bhendi field at Mangadu, Kancheepuram district. The collected larvae were reared individually in a plastic container (vials) and regularly fed with bhendi till the larvae attained the pupal stage under laboratory conditions (28 ± 2°C and 80 ± 5% RH). Sterilized soil was provided for pupation. After pupation, the pupae were collected from the soil and placed inside the cage. Cotton swabs soaked with 10% honey solution mixed with few drops of multivitamin were provided for adult feeding to increase the rate of fecundity. The newly hatched adults were used for the present investigation.

2.2.2. S. litura

Egg masses of S. litura were collected from groundnut field at Vellavedu village near Poonamallee, Chennai. The eggs were surface sterilized with 0.02% sodium hypochlorite solution, dried and allowed to hatch. After hatching the neonate larvae were reared on castor leaves till pre pupal stage and sterilized soil was provided for pupation. The pupae were collected from the soil and kept in oviposition chambers (40 cm × 25 cm × 25 cm). After adult emergence, cotton soaked with 10% (w/v) sugar solution with multivitamin drops was provided for adult feeding to increase the rate of fecundity. The newly hatched adults were used for this study.

2.3. Deterrence of Oviposition against S. litura and H. armigera

Oviposition deterrent activities of different phytopesticidal formulations were studied at different concentrations (5, 10, 15 and 20 μL/L). The concentrations of different oil formulations were sprayed on fresh castor leaves for S. litura and cotton leaves for H. armigera along with selected controls nimbicide and emulsifier with water and placed inside the cage (60 cm × 45 cm × 45 cm) covered with mosquito net. Ten pairs of S. litura moths and ten pairs H. armigera were introduced in separate cages and 10% (w/v) sucrose solution with multivitamin drops was provided for adult feeding. Five replicates were maintained for control and treatments. After 48 h the number of egg masses laid on treated and control leaves were recorded and the percentage of oviposition deterrence was calculated using the formula of Williams et al.[17].

\[
\text{Oviposition deterrence } (\%) = \frac{\text{No. of egg masses on control} - \text{No. of egg masses on treated}}{\text{No. of egg masses on control}} \times 100
\]

3. Results

PONNEEM has showed good results against insect pests due to the presence of bioactive molecules like azadirachtin (Fig.1) and karanjin (Fig.2)[28,29]. The combination of these two oils at 1:1 ratio gives synergistic effect in controlling lepidopteran pests.

![Figure 1. Structure of Azadirachtin.](image)

The castor leaves treated with different concentrations (5, 10, 15 and 20 μL/L) of phytopesticidal formulations were provided for oviposition of gravid female moths of S. litura. The numbers of eggs laid by a female moth on treated and control leaves were recorded and the percentage of oviposition deterrence was calculated using the formula of Williams et al.[17].

The deterrence of oviposition activity was evaluated using one way ANOVA. Significant differences between treatments were determined using Duncan’s multiple range (DMRT) (P<0.05).

Table 1.

| Treatments                      | Concentration tested | 5 μL/L     | 10 μL/L     | 15 μL/L     | 20 μL/L     |
|---------------------------------|----------------------|------------|------------|------------|------------|
| Formulation A (Pungam oil + Neem oil – 3:7) |                       | 34.94±8.15a | 39.25±8.05a | 41.99±5.98b | 49.23±8.13c |
| Formulation B (Pungam oil + Neem oil – 7:3) |                       | 33.77±7.63a | 33.92±8.04a | 31.34±10.25a | 32.36±8.45ab |
| Formulation C (PONNEEM)(Pungam oil + Neem oil – 1:1) |                       | 63.65±4.08b | 71.55±4.44b | 75.77±2.90c | 77.48±4.15d |
| Formulation D (Pungam oil) |                       | 30.29±8.43a | 28.73±7.90a | 34.64±8.33ab | 30.36±8.84a |
| Formulation E (Neem oil)          |                       | 29.13±7.22a | 35.08±8.22a | 34.56±6.77ab | 33.96±7.73ab |
| Formulation F (Nimbicide)          |                       | 27.78±9.12a | 34.52±8.55a | 38.38±6.96ab | 42.71±7.92bc |
| Formulation G (Emulsifier control) |                       | 2.66±1.98a  | 2.66±1.98a  | 2.66±1.98a  | 2.66±1.98a  |

Values are mean of five replications. Means ± SD followed by same letter(s) in a column are not significantly different (P=0.05) by DMRT.
Table 2. Per cent oviposition deterrent activity of phytopesticidal formulations against H. armigera

| Treatments                        | Concentration tested | 5 mL/L | 10 mL/L | 15 mL/L | 20 mL/L |
|-----------------------------------|----------------------|--------|---------|---------|---------|
| Formulation A (Pungam oil + Neem oil - 3:7) |                      | 28.81±5.78a | 35.29±2.88a | 36.90±3.81a | 40.26±3.11a |
| Formulation B (Pungam oil + Neem oil - 7:3) |                      | 29.98±6.03a | 34.21±4.70a | 36.53±3.31a | 46.29±5.11b |
| Formulation C (PONNEEM)(Pungam oil + Neem oil - 1:1) | 45.59±3.39b | 45.14±2.22b | 57.54±1.99b | 68.12±1.24c |
| Formulation D (Pungam oil) |                      | 27.40±3.58a | 34.70±4.40a | 35.78±3.62a | 41.39±5.37a |
| Formulation E (Neem oil) |                      | 30.53±5.71a | 37.11±3.83a | 38.64±5.51a | 49.51±2.93b |
| Formulation F (Nimbicidine) |                      | 30.26±6.66a | 36.18±3.64a | 38.11±6.92a | 49.52±2.07b |
| Formulation G (Emulsifier control) | 1.06±0.14a  | 1.06±0.14a | 1.06±0.14a | 1.06±0.14a |

Values are mean of five replications. Means ± SD followed by same letter(s) in a column are not significantly different (P=0.05) by DMRT.

control leaves of castor are presented in Table 1. The per cent oviposition was greatly decreased with increasing concentrations of the treatments. The maximum oviposition deterrent activity against S. litura was seen in formulation C PONNEEM treated leaves followed by formulation A at 20 mL/L compared to all other formulations (Figure 3).

4. Discussion

4.1. Deterrence of Oviposition activity against S. litura and H. armigera

In this present investigation, different phytopesticidal formulations exhibited deterrence of oviposition activity against H. armigera and S. litura depending on the concentrations. This finding coincides with finding of Dethier[18] who noticed that plant characteristics, such as chemicals, color, trichomes, and architecture, in concert with the insect’s internal milieu, form the basis for discrimination between acceptable and unacceptable plants for feeding or oviposition by various species of phytophagous insects. Feeding and oviposition were deterred by exposing insects to substrates treated with compounds that are bitter tasting[19]. Female moths could have sensory receptors sensitive to host plant biochemical compositions in which contact chemoreceptors on their tarsi and ovipositor would be useful in assessing the suitability of host for oviposition[20,21]. The per cent oviposition of S. litura and H. armigera was greatly decreased with increasing concentrations of PONNEEM. Similary Packiam and Ignacimuthu[11] observed that PONNEEM treated larvae of S. litura became malformed pupa and reduced the laid egg hatchability of the emerged adult. PONNEEM was found to be effective in controlling mosquitoes vector[22] and ovicidal activity[16]. PONNEEM has shown good results against insect pests due to the presence of bioactive molecules like azadirachtin and karanjin (1:1,V/V). The bioactive molecules present in the plant based pesticides have a significant role in regulating the growth of insect pests. As a result the larvae are unable to continue to prolong the larval duration due to biomolecules of plants[23].

Pavunraj et al.[24] reported that effective fraction from Melochia corchorifolia with 1:1 ratio of neem and pongam showed antifeedant activity against four lepidopteran pests. Earlier Srinivasan and Sundarababu[25] reported that neem seed kernel extract deterred the egg laying capacity of Leucinodes orbonalis. Several investigators reported the reduction in the egg laying capacity of S. litura due to the treatment with the plant extracts[26]. Elumalai et al.[27] reported that fraction from diethyl ether extract of Hyptis...
suaveolens and Melochia chorchorifolia showed significant oviposition deterrent activity against *H. armigera*.

The novel phytopesticide PONNEEM exhibited statistically significant deterrent of oviposition activity against *H. armigera* and *S. litura* at all the concentrations when compared to all other treatments. At 20 μL/L concentration of PONNEEM, the maximum oviposition deterrent activity was observed against these two lepidopteran insect pests. Due to its high level efficacy, PONNEEM which was patented under the government of India could be used as a good phytopesticide for insect pest management. The efficacy of PONNEEM is the first report on deterrence of oviposition against lepidopteran pests.

**Conflict of interest statement**

We declare that we have no conflict of interest.

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