INTRODUCTION
Helicoverpa armigera is a polyphagous pest distributed in many countries of Europe, Africa, Asia and Australia. It causes severe damage to tomato, tobacco, cotton, okra, chickpea, pigeonpea, chilli, maize, sorghum and groundnut etc. [1, 2]. Synthetic insecticides are commonly used to control H. armigera throughout the world [3]. However the pest has developed resistance to many synthetic pesticides [4]. Several plant extracts and plant secondary metabolites have been reported for their antifeedant, insecticidal and adult malformation properties against lepidopteran pests including H. armigera [5, 6, 7, 8].

Strychnos nux-vomica is a medicinal plant distributed in India, Srilanka, Southeast Asia and Northern America. Traditionally seeds of S. nux-vomica are used for therapeutic aliments. It has antitumor, antimicrobial, anti convulsion, anti amnesic and immunomodulatory effects [9]. Insecticidal activity of S. nux-vomica extracts has been reported against mosquitoes and beetles [10, 11]. Semecarpus anacardium is recommended in various medical treatises for the cure of different diseases [12]. It is distributed in tropical, sub-Himalayan region and central parts of India. It is used in indigenous medicines [13, 14].

There are no reports available on the biological activities of seed extracts of S. nuxvomica and S. anacardium against H. armigera. Therefore the present study was undertaken to evaluate the antifeedant, larvicidal, pupicidal and adult malformation activities of solvent extracts of these two plant seeds against H. armigera.

MATERIALS AND METHODS
Plant seeds
The dry seeds of S. nux-vomica and S. anacardium were purchased from seed suppliers in Parrys, Chennai. The seeds were identified by a taxonomist and the voucher specimens (S. anacardium: ERI-BP-GS-003; S. nux-vomica: ERI-BP-GS-005) were deposited at the herbarium of the Institute.

Extraction
The seeds of S. nux-vomica and S. anacardium were powdered coarsely. Sequential extraction of each plant’s seed powder (500gm) was done by successive soaking of the seed powder in 1.5 L of hexane, chloroform, ethyl acetate and methanol for a period of 48 h. The

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Original Article
Bioefficacy of seed extracts of Strychnos nux-vomica and Semecarpus anacardium against Helicoverpa armigera (Hubner) (Lepidoptera: Noctuidae)
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Key words: American bollworm, Strychnos nux-vomica, Semecarpus anacardium, Antifeedant activity, Larvicidal activity, Malformation

Abstract
Hexane, chloroform, ethyl acetate and methanol extracts of Strychnos nux-vomica Linn. (Family: Loganiaceae) and Semecarpus anacardium Linn. (Family: Anacardiaceae) were incorporated in semi-synthetic diet at 0.5, 1.0, 1.5 and 2% concentrations. Screened for antifeedant, larvicidal, pupicidal and adult malformation activities against Helicoverpa armigera (Lepidoptera: Noctuidae). The chloroform extract of S. anacardium seeds presented the highest antifeedant activity (74.27%) at 2% concentration. Hexane extract of S. nux-vomica seeds recorded 70.57% antifeedant activity. These two seed extracts did not show any larval mortality against H. armigera. But the treatments caused pupal mortality and abnormal development in the adult moths. Methanol extract of S. anacardium seeds recorded 28.57% pupicidal activity at 2% concentration and hexane extract of S. nux-vomica produced 31.43% of deformed adults.

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extracts were concentrated under reduced pressure using rotary evaporator and stored at 4°C.

**Preliminary phytochemical analysis**

Phytochemical tests were done to find out the presence of secondary metabolites namely steroids, terpenoids, phenols, tannins, coumarins, flavonoids, quinines, alkaloids and saponins in *S. nux-vomica* and *S. anacardium* seeds extracts following the methods of Harborne [15].

**Insects**

Third instar larvae of *H. armigera* were obtained from a pure stock culture maintained over ten generations on semi-synthetic diet in the Institute laboratory at 27±1°C; 11±0.5h photoperiod and 65-70% R.H.

**Antifeedant activity**

All the solvent extracts of the two seeds were screened against *H. armigera* at four different concentrations viz., 0.5, 1, 1.5 and 2%. Extracts were incorporated into the artificial diet as described [16, 17]. About 1gm of extract-incorporated diet was weighed and kept in a petri-dish and one larva (3h pre-starved) of *H. armigera* was introduced on the treated diet in the petri-dish. A separate set of control with untreated diet was also maintained. After 24 h feeding the unfed diets in control and treatments were separately quantified and recorded. After the treatment period of 24h, the larvae were reared continuously on fresh normal artificial diet. Twenty replications were maintained for each treatment and control. The antifeedant activity was calculated according to the formula [18].

Antifeedant activity = $\frac{C - T}{C} \times 100$

Where ‘C’ is the consumption in control and ‘T’ is the consumption in treatment.

**Larvicidal bioassay**

The treatments were given to third instar larvae as explained in the antifeedant experiment. After 24 h, the treated diet was removed and the larvae were continuously maintained on the normal fresh artificial diet. Then larval mortality was calculated up to 96h after the treatment. Control larvae were maintained separately on untreated diets. Ten replications were maintained for each concentration and each experiment was repeated five times.

**Pupicidal activity and adult abnormalities**

The survived larvae in the larvicidal experiments were continuously fed with untreated normal fresh diet until they became pupae. Pupal mortality was calculated by subtracting the number of emerging adults from the total number of pupae. Abnormalities in adult moths were recorded and percentages of abnormal adults developed from each treatment were calculated.

**Statistical analysis**

Mean values and standard deviation for each mean were calculated from the replication values. The results were analyzed using the Graph Pad Prism 5.0 software package.

**RESULTS**

**Antifeedant activity of seed extracts**

Figures 1 and 2 show the percentage of antifeedant activities of *S. nux-vomica* and *S. anacardium* seed extracts against *H. armigera* third instar larvae at 0.5, 1.0, 1.5 and 2% concentrations. Maximum antifeedant activity (74.27%) was recorded by chloroform extract of *S. anacardium* seeds at 2% concentration. The hexane extract of *S. nux-vomica* presented 70.57% antifeedant activity at 2% concentration. The antifeedant activity of both plants was found to be directly proportional to the concentration of the extract.

**Pupicidal activity and growth regulating effects of seed extracts**

*S. nux-vomica* and *S. anacardium* seed extracts did not show larvicidal activity. Pupicidal activity was found in *S. anacardium* seed extracts treatment. *S. anacardium* seed methanol extract recorded 28.57% pupicidal activity and ethyl acetate extract showed 19.44% of pupicidal activity at 2% concentration (Fig. 3). Hexane and chloroform extracts of *S. anacardium* did not show pupicidal activity. Both plants recorded deformities at adult stage of the insect. Hexane and chloroform extracts of *S. nux-vomica* produced 31.43% and 22.14% deformed adults respectively at 2% concentration (Fig. 4). Methanol extract of *S. anacardium* seed showed 20% deformed adults and ethyl acetate extract caused 16.67% deformed adults at 2% concentration (Fig. 5). Hexane and chloroform extracts of *S. anacardium* seeds did not show any malformed adults. The deformities in adult moths included short and curled wings and small body size (Fig. 6).
Table 1. Preliminary phytochemical analysis of *S. nux-vomica* and *S. anacardium* seed extracts

<table>
<thead>
<tr>
<th>Plant</th>
<th>Extract</th>
<th>Phytochemicals</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>S. nux-vomica</em></td>
<td>Hexane</td>
<td>St, Ter, Ph, Tn</td>
</tr>
<tr>
<td></td>
<td>Chloroform</td>
<td>Cmn, Fl, Qn, Alk</td>
</tr>
<tr>
<td></td>
<td>Ethyl acetate</td>
<td>Spn</td>
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<tr>
<td></td>
<td>Methanol</td>
<td></td>
</tr>
<tr>
<td><em>S. anacardium</em></td>
<td>Hexane</td>
<td>St, Ter, Ph, Tn</td>
</tr>
<tr>
<td></td>
<td>Chloroform</td>
<td>Cmn, Fl, Qn, Alk</td>
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<td></td>
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St – Steroid; Ter – Terpenoids; Ph – Phenols; Tn – Tannins; Cmn – Coumarin; Fl – Flavonoids; Qn – Quinones; Alk – Alkaloids; Spn – Saponins

**DISCUSSION**

Plants show various biological activities against insects due to the presence of many types of phytochemicals. It is also notable that different botanicals show species specific activities against insects. Some phytochemicals show antifeedant activity, some exert acute toxicity and some phytochemicals present growth control properties. Few phytochemicals may show many types of biological activities against a single insect species. In the present experiment both plant species possessed antifeedant activity against *H. armigera*. None of their solvent extracts showed larvicidal activity. But growth regulating activity was recorded by both plants. Among the different treatments in the present study, the chloroform extract of *S. anacardium* seed was found to be superior as it showed 74.27% antifeedant activity against *H. armigera*. Hexane extract of *S. nux-vomica* seeds presented 70.57% antifeedant activity at 2% concentration.

Previously several investigators have reported antifeedant activity of plant seed extracts against *H. armigera*. Nathala and Dhingra [16] reported that hexane extract of *Caesalpinia crista* seed extracts had antifeedant activity against *H. armigera* third instar larvae in a range of 29.26 to 80.97% at 0.001 to 0.1% concentrations respectively. Baskar et al. [19] have recorded an antifeedant activity of 79.06% by hexane extract of *Atlantia monophylla* leaves at 5.0% concentration against *H. armigera*. In our study hexane extract of *S. nux-vomica* seeds showed 70.57% at 2% concentration.

The chloroform extract of *S. anacardium* seed revealed the presence of alkaloid, steroid, phenols, terpenoids and quiniones (Table 1). Verma [20] reported that *Tylophora asthmatica* inhibited the feeding of *S. littura* due to the presence of alkaloids. Krishnakumari et al. [21] reported that quinones in *Ventilago madaraspatana* possessed antifeedant activity against *Spodoptera littoralis* and *Henosepilachna vigintioctopunctata*. Rao et al. [22] reported that Forskolin, a diterpene compound found in the roots of *Coleus forskohlii* showed antifeedant activity against the fourth instar larvae of *Papilio demoleus*. These earlier reports support our findings that presence of alkaloids, quinines and terpenoids in leaf extracts caused antifeedant activity against *H. armigera*.

*S. nux-vomica* and *S. anacardium* seed extracts did not show any larval mortality against *H. armigera* third instar larvae at 2% concentration. Furthermore all the extracts of *S. nux-vomica* seed did not show pupal mortality.
mortality. The ethyl acetate and methanol extracts of S. anacardium seed showed pupal mortality of 28.47% and 19.44% respectively at 2% concentration. This finding is similar to the findings of Pavela [23] who reported that the ethyl acetate extract of Origanum benedictus presented pupal mortality of 40.8% at 5% concentration in S. littoralis. Similarly Baskar et al. [19] recorded 66.03% pupicidal activity in ethyl acetate extract of A. monophylla leaves against H. armigera at 5% concentration.

S. nux-vomica hexane and chloroform seed extracts produced 31.43% and 22.14% malformed adults respectively. Ethyl acetate and methanol extracts of S. anacardium seed produced 16.67% and 20% deformed adults respectively in H. armigera. Several investigators have reported the growth regulating activities of plant extracts against various insect pests [24, 25, 26, 27]. Bhuiyan et al. [28] found that Melia dubia extracts had growth and moult inhibiting properties besides antifeedant property against several insect pests. Baskar et al. [19] reported that hexane extract of A. monophylla leaves produced malformations in H. armigera. Wondafrash et al. [29] reported that neem seed extracts caused abnormal adult emergence in H. armigera and Gupta et al. [30] reported that 0.5 to 6% neem seed powder treatment killed H. armigera during pre pupal stage.

CONCLUSION

In conclusion it is evident that chloroform extract of S. anacardium seeds was effective antifeedant against H. armigera larvae. This seed extracts tested in the present study also showed pupicidal activity and growth regulating activity. These two plants may be tested further to isolate the active principles for the management of H. armigera in agricultural ecosystems.

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