EVALUATION OF POTENTIAL BOTANICAL PESTICIDES AGAINST TOBACCO CUTWORM, *Spodoptera litura* (Fab.)

By

S. SURESH

THESIS

Submitted in partial fulfilment of the requirement for the degree of

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DEPARTMENT OF ENTOMOLOGY

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DECLARATION

I hereby declare that this thesis entitled **"Evaluation of potential botanical pesticides against tobacco cutworm, *Spodoptera litura* (Fab.)"** is a bonafide record of research work done by me during the course of research and that this thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title of any other University or Society.

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CERTIFICATE

Certified that this thesis, entitled **"Evaluation of potential botanical pesticides against tobacco cutworm, *Spodoptera litura* (Fab.)"** is a record of research work done independently by **Sri.S.Suresh** under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to him.

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We, the undersigned members of the Advisory Committee of **Sri. S. Suresh**, a candidate for the degree of **Master of Science in Agriculture** with major in **Agricultural Entomology,** agree that this thesis entitled **"Evaluation of potential botanical pesticides against tobacco cutworm, *Spodoptera litura* (Fab.)"** may be submitted by **Sri. S.Suresh,** in partial fulfilment of the requirement for the degree.

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To my

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CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

Introduction

1. INTRODUCTION

The importance of botanical extracts and other natural preparations in routine Integrated Pest Management (IPM) and Integrated Resistant Management (IRM) programmes are relevant and all the more quite warranting now-a-days. A number of botanical resources are remaining under-exploited which can be suitably extracted and applied in different crop-pest systems to achieve varying results depending on the type of the material, method of extraction, dosage, stage/type of the insect pest species and the level of management. Eventhough there are a number of polyphagous pests, a few like *Spodoptera litura* (Fab.), *Helicoverpa* spp., hairy caterpillars, fruit flies, etc. are quite enigmatic and therefore they require appropriate IPM/IRM strategies. Hence botanicals pesticides can be made more applicable for this ecological management.

The order Lepidoptera includes some of the most destructive and polyphagous insect pest species in agriculture. *S. litura* is one of the polyphagous and enigmatic pest which had a host range of more than 112 plant species including cotton, tobacco, chilli, castor, pulses, groundnut, tomato, sunflower, cabbage, banana, vegetables and various spice crops, causing heavy economic loss every year. The insect is identified by the pale greenish larva with dark markings and the adult moth with wavy white markings on the brownish black forewings and brown border along the margin of its white hindwings. It has an egg period of three days, larval period of 15 days with six instars, pupal period of nine days, pre-oviposition period of two days and a total life cycle of 29 days (Mani and Rao, 1998).

The general population level of this pest species is found to be rapidly increasing during the last few decades because of the green revolution adopting High Yielding Varieties (HYV's) and palatable plant types. Intensification and extensification of agriculture through expanded irrigation facilities, adoption of

high yielding plant types and high energy inputs led to a further narrowing down of the genetic base and consequent susceptibility of the crops to polyphagous pest species. To get quick relief from these pests synthetic organic insecticides were being used extensively. Efficacy, rapid curative action, adaptability to most situations, flexibility to changing agronomic and ecological conditions and above all, economic viability prompts the farmers to go for synthetic pesticides in controlling the enigmatic pest species.

Despite these credentials, the use of synthetic pesticides is ecologically unsound, induces pest resistance, causes outbreaks of secondary pests, imparts adverse effects on non-target organisms and environment, causes hazards to the end users, etc. These features restrict their use in emergent situations, necessitating the adoption of IPM/IRM strategies.

S. litura has developed resistance to DDT, endosulfan, fenitrothion, HCH, lindane, malathion, methyl parathion and monocrotophos (Mehrotra and Phokela, 2000). Armes *et al.* (1997) working on 22 strains of *S. litura* collected from groundnut crop from eight locations in Andhra Pradesh between 1991 and 1996, reported its resistance levels ranging from 0.2 to 197 folds to cypermethrin, 8 to 121 folds to fenvalerate, 1 to 13 folds to endosulfan, 1 to 29 folds to quinalphos, 2 to 362 folds to monocrotophos and 0.7 to 19 folds to methomyl. The area under cotton varieties and hybrids derived from *Gossypium barbadense* Linn had increased in Tamilnadu during 1970s which gave room for resistance build up and outbreak of *S. litura* in the 1970's and early 80s (Dhaliwal and Arora, 2001).

In the search for better IPM/IRM tools, herbal product preparations is the prime choice due to their co-evolutionary adaptation with insects and due to their phenological relationship in the agro-ecosystem. India is very rich in its flora and fauna, providing ample opportunity for studying the insect-plant relationship and exploiting the potential botanicals for insect pest management. Grainage *et al.* (1985) in their report on plant species possessing pest controlling properties,

enlisted 1005 species with pest repellency, 27 species with phagostimulant effects and 31 species with growth inhibition properties. There are more than 2400 plant species reported to possess pesticidal properties distributed in 189 plant families (Singh, 2000). This clearly indicates that the plant kingdom is a vast store of phytochemical weaponry that can be utilized against insect pest invasion on human interests. Active principles present in the plant resources *viz.*, gallic, vanillic and salicylic acids, besides resorcinol, phloroglucinol and gossypol in cotton cultivars have been known to impart resistance against *Helicoverpa armigera* (Hub.) and *S. litura* (Ananthakrishnan, 1992).

Jacobson (1989) reviewed the promising bioactive botanicals and found that they were coming under seven families namely Meliaceae, Rutaceae, Asteraceae, Annonaceae, Malvaceae, Labiatae and Canellaceae. A summary of the important plant species in each family along with their active principles and its pest management values are reported by Parmar (1992).

These botanicals are relatively safer to many natural enemies of the pest species which bring about the natural control in the sustainable systems. The safety of botanicals to the natural enemies of crop pests are well documented (Saxena *et al.*, 1984; Lim and Bottrell, 1994 and Dhaliwal and Arora, 2001). At the same time, it was also found that there was no sign of the insects developing any resistance against botanicals (Vollinger, 1987), probably because, it contains a number of complex phytochemicals instead of a single active principle as in the case of synthetic pesticides. Botanicals are, in general, more compatible with environmental components than the synthetic pesticides assuring sustainability in the production system, because of their low environmental persistence, selectivity, specificity and more over ecological validity.

In the context of the present importance of botanicals/phytochemicals in IPM/IRM strategies, an evaluation on the locally available herbal flora and their preparations were carried out in this programme. The following aspects of selected

botanicals were evaluated in the laboratory on the polyphagous crop pest, *S. litura* as the test insect to determine their bioefficacy and usefulness in crop protection and management programmes.

i) Ovipositional deterrency
ii) Ovicidal action
iii) Antifeedancy
iv) Morphogenic effects and
v) Toxicological parameter of Median Lethal Concentration (LC_{50})

Review of Literature

2. REVIEW OF LITERATURE

A comprehensive review of the work done on the botanical pesticides by virtue of their antifeedancy, repellency, ovipositional deterrency, ovicidal, insecticidal, hormonal and other effects are summarized below.

2.1 ANTIFEEDANT AND REPELLENT ACTIONS

2.1.1 *Azadirachta indica* A. Juss (Neem)

In 1976, Ketkar listed 95 publications on insect repellent and antifeedant effects of neem derivatives. Lepidopterans, in general, were reported to be highly sensitive to neem derivatives particularly in laboratory condition (Schmutterer, 1990). Singh(2000) also reported about 103 insect pest species in different orders which were sensitive to neem in India.

2.1.1.1 Neem leaf extract and neem seed kernel suspension

In India, first detailed experiment employing neem leaf extract was conducted on the desert locust, *Schistocerca gregaria* Forsk., by Chopra (1928). Pradhan *et al.* (1962) observed that 0.05 per cent aqueous suspension of neem seed kernel gave absolute deterrence to *Locusta migratoria* (Linn.) and even at 0.01 per cent the feeding of *S. gregaria* was completely inhibited. The repellent action of neem seed suspension against *Euproctis lunata* Walk., *Prodenia litura* F., *Utetheisa pulchella* L., *Acrida exaltata* L. and *Aulacophora foveicollis* L. was reported by Mane as early as in 1968. Patel *et al.* (1968) found about the deterrency of neem seed paste suspension against the hairy caterpillar *Amsacta moorie* Butl. Pradhan and Jotwani (1971) reported the superiority of crude extracts of neem over refined products. Meisner *et al.* (1980) reported that the neem seed kernel suspension at 0.4 to 1.0 per cent showed significant feeding inhibition of *Spodoptera littoralis* (Boi.) on lucerne.

Significant protection of sugarbeet against *S. littoralis* (Meisner *et al.*, 1981), citrus against *Papilio demoleus* L. (Redknap, 1980), tobacco nurseries against *S. litura* (Ramprasad *et al.*, 1987) were reported with neem seed kernel suspension.

The antifeedant effect of neem leaf powder against *S. litura* was quoted by Kareem (1980). Neem leaf extract at 15 per cent gave 75.5 per cent protection against *S. litura* (Koshiya and Ghelani, 1993). Antifeedant effect against *Pericallia ricini* F. and *Selepa docilis* Butl. at five per cent was found out by Jacob and Sheila (1994). Ninety nine per cent protection of castor leaves against *Spilosoma obliqua* Walker was also obtained at five per cent leaf extract (Tripathi and Singh, 1994). Kumar *et al.* (1997) reported about the antifeedant effects of the neem leaves terminal reddish flush extracts on *S. litura* .

2.1.1.2 Extracts of neem seed kernel (NSKE)

Antifeedant activity of crude ethanol/methanol extracts of neem seeds were observed on different pest species by different authors *viz.*, *Diaphoria hyalinata* L. (@1.0%), second instar larvae of *Heliothis virescens* (F.) (@0.001%) and *Helicoverpa zea* (Bod.) (@ 0.2%), larval and adult *Leptinotarsa decemlineata* (Say.) (@ 0.2%), larvae of *Liriomyza sativa* Meig. and *L. trifolii* (Brug.) (@ 0.2%), larvae of *Manduca sexta* (Joh.) (@ 0.02%), adults of *Sitophilus granarius* (Linn.) (@1.0%) and adults of *Tribolium castaneum* (Herbst.) (@1.0%) (Jacobson *et al.*, 1983). Fagoonee (1981) investigated the behavioural response of *Crocidolomia binotalis* Z. to neem extracts and found that the extract masked the inherent phagostimulatory property of cabbage towards the insect pest. Aqueous emulsion of alcoholic extract of neem seed protected sessafras and soyabean from *Popillia japonica* New., while, the two favourite host plants of the beetle, the rose (*Rosa* sp.) and grapes (*Vitis labrusca*) could not be protected by the same treatment and it was due to the volatile attractants produced by these plants which include geraniol, ugenol and phenethyl butyrate probably overcome the deterrent qualities of neem

extracts (Ladd, 1981). The efficacy of ethanolic extracts in field trials against *Melanagromyza obtusa* (M.), *Heliothis armigera* Hub. and *Maruca testulalis* (G.) were reported by Singh *et al.* (1985).

Mishra (1983) found that the chloroform fraction of the alcoholic extract showed the highest antifeedant activity followed by the methanol and hexane fractions. Schmutterer (1990) proved that the seed kernel extract was the most active one followed by hard shell and fallen leave's extracts against *S. gregaria*. He also reported that reduction in feeding was observed after topical application or injection of neem derivatives including azadirachtin and alcoholic neem seed kernel extract.

Ayyangar and Rao (1989) reported that the methanol extract was superior to hexane extract as it elicited greater repellency to different larval stages at a lower concentration (0.02%) than hexane extract (0.046%) and the percentage of repellency also increased with successive instars at the same concentration on *S. litura*. Methanolic extract of neem seed kernels provided cent per cent protection against *S. litura* followed by ethanol (98.39 %) and aqueous extract (93.01%) (Mohapatra *et al.*, 1995). Methanol extract of neem seed at 0.3 and 0.5 per cent inhibited feeding of *S. litura* as reported by Kulkarni (1999).

Murugan *et al.* (1999) found that the crude ethanolic extracts of neem seed had a higher antifeedant and a lower toxic effect on *S. litura*.

2.1.1.3 Neem oil and neem cakes

Siddique (1942) isolated three neutral and water soluble bitter principles from neem oil, but they were quite ineffective as antifeedants. Neem oil emulsion was more toxic than the extracts from neem seed against *Aphis gossypii* G., *Urentius echnius* D. and *Saissetia nigra* N. (Cherian and Menon, 1944). Crude

neem oil at 12 per cent controlled *Nilaparvata lugens* (Stal.) and rice leaf roller *Cnaphalocrocis medinalis* (Guen.) (Saxena *et al.*, 1981).

Meisner *et al.* (1980) found that neem oil was only slightly active against *S. littoralis* at one per cent in the laboratory and completely inactive at two per cent in the field. Field trials conducted by Singh *et al.* (1985) observed that neem oil was effective against *M. obtusa* but ineffective against *Helicoverpa armigera* and *M. testulalis.* In potato, neem oil at 10 per cent concentration did not reduce the feeding of *Phthorimaea operculella* (Zell.) (Shelke *et al.*, 1987).

Ramachandran *et al.* (1962) reported that the water extracts of neem cake reduced the incidence of *Phyllocnistis citrella* S. Alcoholic extracts of neem cake was effective against *Rhopalosiphum nymphae* (Linn.) and *S. gregaria* (Goyal *et al.*, 1971) and against *L. migratoria* (L.) and *S. gregaria* (Sinha and Gulati, 1963).

2.1.2 *Acorus calamus* Linn.

Calamus oil at 2.5 and 5 per cent concentrations gave 95 and 100 per cent protection respectively, against *S. litura* (Sharma *et al.*, 1990). Rhizome extracts had antifeedant and repellent action against stored grain pests of rice (Baskaran and Narayanasamy, 1995).

2.1.3 *Adathoda vasica* Nees.

Adathoda vasica extracts caused 52.57 per cent larval starvation (Saradamma, 1989). Methanol extract offered 89.91 per cent leaf protection (Tripathi and Singh, 1994) and 86.0 per cent antifeedant effect (Mani and Prabhu, 1999) against *S. litura.* Chloroform, methanol and petroleum ether extracts of *A. vasica* showed pronounced antifeedant action on *S. litura* (Deka *et al.*, 1999).

2.1.4 *Ailanthus excelsa* Roxb.

Acetone extracts of *A. excelsa* had registered 89.67 per cent protection (Tripathi and Rizvi, 1985) and methanolic bark extract had 90.8 per cent protection (Tripathi and Singh, 1994) against *Diacrisia obliqua* (Walker).

2.1.5 *Andrographis paniculata* Wall

Andrographis paniculata extracts had higher antifeedant activities on the pest species *viz.,* against third instar larvae of *S. litura* (Gunasekaran and Chelliah, 1985a), first and fourth stadium larvae of the *Plutella xylostella* (Hermawan *et al.*, 1994 and 1998) and *S. obliqua* (Tripathi *et al.*, 1999). Crude extracts of *A. paniculata* reduced the feeding activity of *Nephotettix cincticeps* (Uhler.) at concentrations as low as one ppm (Widiarta *et al.*, 1997).

2.1.6 *Annona squamosa* Linn.

Kumar and Thakur (1988) found that the petroleum ether extracts of annona seed oils had antifeedant activity on fourth instar larvae of *S. litura.* Ether and water extracts of *A. squamosa* had 90 and 88 per cent antifeedancy respectively against sixth instar larvae of *S. litura* (Mani and Prabhu, 1999).

2.1.7 *Artemisia nilagarica* (C.B.Clarke)

Chowdhury *et al.* (2000) reported that the oils of *A. nilagarica* caused 80.21 per cent feeding inhibition on third instar larvae of *S. obliqua* at 0.4 per cent concentration and 83.76 per cent at 0.3 per cent concentration against *S. litura.*

2.1.8 *Clerodendron* sp.

Tripathi and Rizvi (1985) reported about the antifeedancy of *C. inerme* (Linn.) extract against D. *obliqua.* Saradamma (1989) observed that the water and

acetone extracts of *C. infortunatum* Linn. showed 54.17 per cent and 98.88 per cent leaf protection respectively against *S. litura*.

2.1.9 *Chromolaena odorata* Linn.

Leaf extracts of *C. odorata* possessed antifeedancy against *Henosepilachna vigintioctopunctata* (Fab.) and *S. litura* (Saradamma, 1989). Aqueous extracts of the same at three and five per cent levels had medium antifeedant activity against *P. ricini* (Jacob and Sheila, 1994), while, water and ether extracts had 81 and 88 per cent antifeedancy respectively, against *S. litura* (Mani and Prabhu, 1999).

2.1.10 *Gliricidia sepium* (Jacq.)

Strong antifeedant activity of methanol leaf extract of *G. sepium* was reported against *Achaea janata* Lin. and *S. litura* (Parvathi *et al.*, 1999).

2.1.11 *Lantana camara* Linn.

Lantana camara leaf extracts had antifeedancy and repellency against *Athalia proxima* (Klug.)(Pandey *et al.*, 1977). Chloroform extract of the same possessed strong antifeedant and repellent properties at five per cent level on *Helopeltis theivora* W. (Deka *et al.*, 1998).

2.1.12 *Melia azedarach* Linn.

Chauvin (1946) found that the chloroform extract of the leaves of *M. azedarach* possessed antifeedant action against locust species. Petroleum ether extract of *M. azedarach* at six per cent showed strong antifeedant effect on *N. lugens*. While, methanol extract on fifth instar larvae *S. litura* (Chiu, 1985). Antifeedancy of chloroform, methanol and petroleum ether extracts of the same against *H. theivora* (Deka *et al.*, 1999) were worth investigating.

2.1.13 *Momordica charantia* Linn.

An emulsion of bittergourd seed oil deterred the feeding of *A. proxima* (Arunkumar *et al.*, 1979). The same activity was also observed with the methanol extract of leaves on *S. litura* and *Mythimna separata* (Walk.) (Yasui *et al.*, 1998).

2.1.14 *Ocimum sanctum* Linn.

Mallick and Banerji (1989) reported that the methanolic extract of *O. sanctum* (stem and leaf extracts at 5 and 10 per cent concentrations) exhibited antifeedancy against *Anomis sabulifera* (Guen.) for 72 hours along with repellency at the same level.

2.1.15 *Pongamia* spp.

Koshiya and Ghelani (1993) observed that the seed extracts of *P. glabra* Vent. protected 65.4 per cent treated surface from *S. litura* at 15 per cent concentration. Antifeedancy and repellency of *P. pinnata* Pierre. against *H. theivora* (Deka *et al.*, 1998) was also reported.

2.1.16 *Thevetia nerifolia* Juss.

Antifeedancy of leaf extracts of *T. nerifolia* to *H. vigintioctopunctata* and *S. litura* (Saradamma, 1989) and to *A. proxima* (Pandey *et al.*, 1977) were reported. Crude extract out of its seed and leaves protected 80.1 and 96.67 per cent of treated foliage against *H. vigintioctopunctata* respectively (Bai and Koshy, 1999).

2.1.17 *Vitex negundo* Linn.

Saradamma (1989) reported that the benzene extract of *V. negundo* gave 86 per cent feeding inhibition to *S. litura*. Acetone extract of the same against

Earias vittella (Fab.), *Diaphania indica* (Sau.) and *Epilachna septima* (Kalavathi *et al.*, 1991) were also quoted elsewhere.

2.1.18 Miscellaneous botanicals with promising antifeedancy and repellency properties

Crude leaf extracts of *Euphorbia royleana* Boiss. were reported to be having antifeedancy against *A. proxima* (Pandey *et al.*, 1977) and that of aqueous and alcoholic extracts against *S. litura* (More *et al.*, 1989). Plumbagin from *Plumbago capensis* Thunb. acted as an effective antifeedant for *Spodoptera exempta* (Walk.) (Kubo *et al.*, 1980). The antifeedancy and repellency of essential oils were also reported by Singh and Upadhyay (1993). Tripathi and Singh (1994) found that the *Saraca indica* Auct. extracts had 99.57 per cent antifeedancy against *S. obliqua*. Deterrency of *Citrus sinensis* (Linn.) extracts on last instar larvae of *S. litura* was reported by Sahayaraj (1998). There was 86 per cent antifeedancy with ether extract of *Hyptis saveolens* Poit. against *S. litura* (Mani and Prabhu, 1999). Dichloromethane and methanol extracts of *Melia dubia* Hiern. extracts possessed deterrency to *S. litura* and *H. armigera* (Hub.) larvae (Opender-Koul *et al.*, 2000).

2.2 OVIPOSITIONAL DETERRENCY

2.2.1 *Azadirachta indica* A. Juss.

Fagoonee (1981) reported that the crude alcoholic extracts of dried neem leaves repelled females of *C. binotalis* even from a distance of about 25 cm to avoid oviposition and neem treated substrate was completely inhibited by egg laying of *P. operculella* (Sharma *et al.*, 1984). Saxena and Rembold (1984) found that the neem seed kernel volatiles act as repellents but not as contact ovipositional deterrents, while, and it was *vice versa* with neem seed distillate against *H. armigera*. Neem seed petroleum extracts showed strong ovipositional deterrency on *Orseolia oryzae* (Wood-Mason) (Chiu, 1985).

Methanol extract at 0.01 per cent and hexane extract at 0.02 per cent prevented the treated surface from egg laying by *S. litura* for five and four days respectively (Ayyangar and Rao, 1989). Schmutterer (1990) reported that the neem products repelled females of *C. binotalis, H. armigera, Spodoptera frugiperda* (J.E. Smith), *Lucilla serricator* (Mg.) and *Callosobruchus* spp. from oviposition on the host plants.

Extracts of neem leaf and seed kernel at two and four per cent protected the treated surfaces from egg laying by *S. litura* (Patel and Patel, 1998). Oil free neem seed extracts had no ovipositional deterrency against the females of *Trichoplusia ni* (Hub.), *Peridroma saucia* (Hub.) and *S. litura* on treated cabbage plants, but one per cent crude oil emulsion of neem seed prevented egg laying of *S. litura* (Naumann and Isman, 1995).

2.2.2 *Adathoda vasica* Nees.

Deka *et al.* (1999) reported that the *H. theivora* laid very few eggs on the treated surface with chloroform, methanol and petroleum ether extracts of *A. vasica*.

2.2.3 *Ailanthus excelsa* Roxb.

Leaf extracts at two and four per cent deterred oviposition of *S. litura* on the treated surface (Patel and Patel, 1998).

2.2.4 *Andrographis paniculata* Wall.

Crude extracts of *A. paniculata* prevented egg laying of *P. xylostella* as reported by Hermawan *et al.* (1994). Ethyl acetate fraction was found to be possessing highest ovipositional deterrency against *S. obliqua* as per Tripathi *et al.* (1999).

2.2.5 *Melia azedarach* Linn.

Melia azedarach and *M. toosendan* were repelling females of *S. litura* (Chiu, 1985) and *P. xylostella* (Chen *et al.*, 1996). Very few eggs were only laid by *H. theivora* on the treated substrates with *Melia* leaf extracts as noticed by Deka *et al.* (1999).

2.2.6 *Nerium indicum* Mill.

Leaf extracts of *N. indicum* at two and four per cent levels deterred the oviposition of *S. litura* on treated surface (Patel and Patel, 1998).

2.2.7 Miscellaneous botanicals with ovipositional deterrency

Gallic acid, a common allelochemical in woody plants had significant ovipositional deterrency against *S. litura* (Mukherjee and Sharma, 1993). Ploomi and Luik (1999) could identify the ovipositional deterrency with respect to *Matricaria inodora, Artemisia absinthium, Allium sativum, Sambucus racemosa, Rheum rhaponticum, Ledum palustre* and *Lycopersicon esculentum* against *P. brassicae* at 20 per cent concentration each. Tare (2000) found that the medicinal plant oils (*A. calamus, A. indica, Eucalyptus* sp., *P. glabra*, etc.) showed cent per cent ovipositional deterrency against *P. operculella, S. litura* and *A. janata.*

2.3 OVICIDAL ACTION

2.3.1 *Azadirachta indica*

Aqueous or alcoholic neem seed kernel extract (NSKE) at 5000 and 10,000 ppm per litre of water gave moderate reduction in the rate of emergence of *P. xylostella* eggs (Tan and Sudderuddin, 1978). Dipping of *C. medinalis* eggs in neem oil prevented the emergence of first instar larvae (Saxena *et al.*, 1981). Yadav (1985) found that neem oil had a strong ovicidal action against three species

of *Callosobruchus*. Margoside @ 0.1 per cent and neem seed kernel suspension at five per cent had equal ovicidal action (Mehta *et al.*, 1994).

Petroleum ether and methanol extracts of neem seeds (1.5%) showed cent per cent ovicidal action against *S. obliqua* eggs (Ghatak and Bhusan, 1995). Neem seed kernel suspension and neem leaf extract at three per cent strength showed just 20 and 15 per cent mortality of *H. armigera* eggs respectively whereas neem oil at 0.3 per cent caused 28 per cent egg mortality (Patel and Patel, 1997).

2.3.2 *Adathoda vasica* Nees.

Stem extracts of *A. vasica* caused 25 to 80 per cent inhibition of egg hatching [with an inhibition dose (ID_{50}) of 3.2 µg] while, leaf extracts produced 20 to 70 per cent inhibition of hatching (with an ID_{50} = 1.8 µg) on *S. litura* eggs (Suryakala *et al.*, 1995).

2.3.3 *Ageratum conyzoides* Linn.

The extracts of *A. conyzoides* inhibited the egg hatching of *Oncopeltus fasciatus* (Dall.) (Bowers *et al.*, 1976). Bhathal *et al.* (1991) observed that the *A. conyzoides* extracts showed more pronounced ovicidal action than that of neem oil preparation.

2.3.4 *Annona squamosa* Linn.

Methanol extract of *A. squamosa* had ovicidal action on the eggs of *S. obliqua* at two per cent concentration (Ghatak and Bhusan, 1995).

2.3.5 *Cassia fistula* Linn.

Leaf extract of *C. fistula* resulted in about 60 to 99 per cent (ID_{50} = 2 µg) and 30 to 80 per cent (ID_{50} = 19 µg) hatching inhibition of the eggs of *S. litura* and *Dysdercus koenigii* (Fab.) respectively (Suryakala *et al.*, 1995).

2.3.6 *Eucalyptus globulus* Labill.

Suryakala *et al.* (1995) had again reported that the stem extracts of *E. globulus* inhibited 55 to 90 per cent (ID_{50} = 4 µg) and 30 to 99 per cent (ID_{50} = 14 µg) of egg hatching of *S. litura* and *D. koenigii* respectively. However, the leaf extract had been reported to produce only 20 to 80 per cent hatching inhibition of *S. litura* eggs.

2.3.7 *Piper nigrum* Linn.

Ghatak and Bhusan (1995) observed that the methanol and petroleum ether extracts at one per cent inhibited *S. obliqua* eggs from hatching.

2.3.8 *Vetivera zizanioides* (Linn.)

Root extract of *V. zizanioides* was reported to be inhibiting 75 to 90 per cent (ID_{50} = 1 µg) and 50 to 80 per cent (ID_{50} = 5 µg) egg hatching of *S. litura* and *D. koenigii* respectively (Suryakala *et al.*, 1995).

2.3.9 *Vitex negundo* (Linn.)

Volatile oils from *V. negundo* caused upto 83 per cent mortality of *P. xylostella* eggs (Dayrit *et al.*, 1995).

2.4 INSECTICIDAL ACTION

Chopra *et al.* as early as in 1949 listed about 700 spp. of plants having poisonous effects on man, livestock and insects, out of which, 74 plants showed insecticidal and insect repellent properties. Ganeshan *et al.* (1995) reported that other than neem, there are about 2400 plant species have pest control properties.

2.4.1 *Azadirachta indica*

Neem based products acted as medium to broad spectrum pesticides against phytophagous insects, consisting of insect orders belonging to Orthoptera,

Heteroptera, Homoptera, Thysanoptera (to a limited extent), Hymenoptera, Coleoptera, Lepidoptera and Diptera (Schmutterer and Hellpap, 1989).

2.4.1.1 Neem leaf extracts

Insecticidal property of neem leaves was first explored by Chopra in 1928 on the larvae of *Hypera postica* (Gyll.). Neem leaf extracts at two and five per cent levels killed the larvae of *Epilachna varivestis* (Mul.) in beans and *P. xylostella* in cabbage respectively (Steets, 1975).

Neem leaf extract caused 80 per cent mortality of *S. litura* larvae, 76 hours after treatment (Sahayaraj and Sekar, 1996). Reddish terminal neem leave's exudates caused larval mortality against *S. litura* (Kumar *et al.*, 1997) and water extract of leaves had moderate toxic effects against the same insect (Sahayaraj and Paulraj, 1998).

2.4.1.2 Neem seed kernel extracts (NSKE)

First report about the insecticidal property of neem seed kernel was given by Cherian and Menon in 1944 against *A. gossypii, U. echinus* and S. *nigra.* Meisner *et al.* (1981) observed that 90 per cent larval mortality of *Earias insulana* (Bois.) when treated with water extract of neem seed kernel at one per cent concentration.

NSKE caused cent per cent mortality of *S. litura* 10 days after treatment (Behera and Satapathy, 1996). Freshly prepared NSKE at four per cent was recommended for the management of *P. xylostella* in cabbage and other crucifer pests (IIHR, 1991 and Krishnamoorthy *et al.*, 1998). Field trials conducted by Verkerk and Wright (1993) showed that the water extract of neem seed kernels was more effective than its methanolic NSKE against *P. xylostella*. Methanolic extracts of neem seed and stem caused 80 and 85 per cent mortality of *N. lugens* respectively (Hiremath *et al.*, 1997). Neem extracts caused more than 30 per cent

mortality against *S. litura* and *Lipaphis erysimi* (Kal.) (Desai and Desai, 2000). Neem seed kernel powder extract at four per cent was reported to be effective against *P. xylostella* and *C. binotalis* (Krishnamoorthy and Krishnakumar, 2000).

2.4.1.3 Neem oil and cake preparations

Cherian and Menon as early as in 1944 recorded that neem oil emulsion had a higher toxicity than the seed extract against *A. gossypii, U. echinus* and *S. nigra*. Azam (1991) found that the neem oil at 1 and 1.25 per cent caused more than 80 per cent mortality of *L. trifolii* larvae and pupae in cucumber. Neem oil at three per cent concentration caused 93 per cent larval mortality of *L. trifolii* but ineffective at two per cent level (Jeyakumar and Uthamasamy, 1997). Neem oil minimized the infestation of *Antigastra catalaunalis* Dup at one per cent concentration as observed by Singh and Singh (1997).

Sachan and Pal (1976) reported about the effectiveness of neem cake for the control of *Holotrichia insularis*. Soil incorporation of neem cake with urea reduced the first instar nymphs of *N. lugens* reaching upto the adult stage on the treated plants owing to the systemic action of active principles in neem cake (Saxena *et al.*, 1984). It was reported that neem cake applied in the field gave 39 per cent mortality of the third instar grubs of *Leucopholis burmeisteri* (Bren.) (Padmanaban *et al.*, 1997) in arecanut palm.

2.4.2 *Acorus calamus* Linn.

Rhizome extract of *A. calamus,* caused 57.77 and 72.22 per cent larval mortality of *S. litura* and *H. armigera* respectively (Venkadasubramanian and David, 1999). On *S. litura* and *L. erysimi*, calamus extracts caused more than 30 per cent mortality (Desai and Desai, 2000).

2.4.3 *Annona squamosa* Linn.

Annona squamosa aqueous extracts caused 50 per cent larval mortality against *S. litura* (Behera and Satapathy, 1996) and cent per cent mortality against *N. lugens* at 0.25 µg per female (Hiremath *et al.*, 1997). Ether extracts of *A. squamosa* caused up to cent per cent mortality against *Dysdercus cingulatus* (Fab.) (Mani and Prabhu, 1999). Murugan *et al.* (1999) reported that the seed extract was highly toxic to *S. litura*. Methanolic seed extracts caused 44,89 and 100 per cent larval mortality against *S. litura, H. armigera* and *E. vitella* respectively (Vyas *et al.*, 1999).

2.4.4 *Clerodendron* spp.

Rajamma (1982) recommended that the application of chopped leaves of *C. infortunatum* @ 5000 kg ha^{-1} by soil incorporation one week prior to planting reduced the *Cylas formicarius* Fab. infestation. *C. inerme* caused 90 per cent mortality against *N. lugens* (Hiremath *et al.*, 1997) and *C. siphonanthus* leaf extract at 2.5 per cent reduced 88.4 per cent reproduction of *Callosobruchus chinensis* (Linn.) (Pandey and Khan, 2000).

2.4.5 *Cymbopogon citratus* Stapf.

Rajapakse and Jayasena (1991) observed that the mortality of *S. litura* on exposure to lemongrass oil was increased when the larvae were fed on pods from resistant rather than non-resistant cultivars of peanut and field tests conducted by the same authors in Sri Lanka revealed that treatment with *C. citratus* oil, reduced damage caused by *S. litura in* all cultivars.

2.4.6 *Cymbopogon martinii* (Roxb.)

Venkadasubramanian and David (1999) reported that the palmarosa oil at one per cent caused 91 and 100 per cent larval mortality of H. *armigera* and *S. litura* respectively, under laboratory trials.

2.4.7 *Lantana camara* Linn.

Leaf extract of *L. camara* was less effective against *H. armigera* as observed by Pandey *et al.* (1983). At the same time, it was reported that the water extract gave more than 30 per cent mortality against *S. litura* and *L. erysimi* (Desai and Desai, 2000).

2.4.8 *Mentha spicata* Linn.

Dry leaf powder of *M. spicata* was effective against *P. operculella* in potato under storage (Kashyap *et al.*, 1992). Leaf extract at five per cent caused 28 and 27 per cent mortality only, in *H. armigera* and *S. litura* respectively (Venkadasubramanian and David, 1999).

2.4.9 *Ocimum* spp.

Mature seed extract of *O. basilicum* Linn. caused larval mortality of *H. armigera* at 0.1, 0.5 and 1 per cent concentrations (Pandey *et al.*, 1983) whereas, methanol extract of *O. sanctum* Linn. had no insecticidal activity against *A. sablifera* (Mallick and Banerji, 1989).

2.4.10 *Pongamia glabra* Vent.

Aqueous extract of the *P. glabra* caused 50 per cent mortality in *S. litura* (Behera and Satapathy, 1996). Murugan *et al.* (1999) found that the seed extract was highly toxic to *S. litura.*

2.4.11 *Thevetia* spp.

The effectiveness as well as ineffectiveness of *Thevetia* powder and extracts against various insects were reported (Mc Indoo, 1945 and Deshmukh and Borle, 1975). *T. peruviana* (Pers.) extract caused 50 per cent mortality against *S. litura* as reported by Behera and Satapathy (1996).

2.4.12 *Vitex negundo*

More *et al.* (1989) found that the aqueous and alcohol extracts of *V. negundo* was effective against *S. litura* at higher concentrations only. Acetone extract was toxic to *E. vittella* as found by Kalavathi (1991). Even at higher concentration of 10 per cent, leaf extract was not effective against *Sitotroga cerealella* Oliv. in the field conditions (Ramamurthy and Venugopal, 1997).

Volatile oils of *V. negundo* by topical application caused 91 per cent mortality in third instar larvae of *P. xylostella* (Dayrit *et al.*, 1995) and leaf extract caused 83 per cent mortality in *S. litura* (Sahayaraj and Sekar, 1996).

2.4.13 Miscellaneous botanicals with promising insecticidal action

Leaf extract of ginger caused 70 per cent larval mortality in *S. litura,* 96 hours after treatment (Sahayaraj and Paulraj, 1998). Leaf extract of *Citrus sinensis* also caused 90 per cent larval mortality of *S. litura*, nine hours after treatment (Sahayaraj and Sekar, 1996). Stem extracts of *Aloe vera* Mill. was highly toxic to *S. litura* as reported by Murugan *et al.* (1999), whereas, leaf extracts at one per cent level caused 51 and 54 per cent larval mortality against *S. litura* and *H. armigera* respectively (Venkadasubramanian and David, 1999).

2.5 BOTANICAL PESTICIDES WITH HORMONAL EFFECTS

The possibility of using plant material with insect juvenile hormone activity as pesticide was first reported by Slama and Williams (1966) who observed the inability of European linden bug, *Pyrrhocoris apterus* Lin. to reproduce when they were reared in jars lined with paper towels made of balsam fir wood pulp (*Abies balsamea* Mill.) which was later known as the paper factor effect. Essential oil of *Tagetes minuta* L. was found to have juvenile hormone like activity on *D. koenigii* as reported by Saxena and Srivastava (1973).

Juvenomimetic activity in 12 South Indian plants were also reported by Gopakumar *et al.* (1977).

2.5.1 Growth regulating activity

Growth regulating activity of neem products were reported on many species viz. *C. medinalis* and *N. lugens in* rice (Saxena *et al.*, 1980), *Heliothis zea, Spodoptera gragipuda, Pectinophora gossypiella* (Sau.) and *H. virescens* in cotton (Kubo and Klocke, 1982) and *M. separata* (Chiu, 1985) and *Spodoptera exigua (Hub.)* and *T. ni* (Prabhakar *et al.*, 1986) in vegetables.

Petroleum ether extract of *Tribulus terrestris* Linn. also had the same juvenile effects against *S. litura* and *H. armigera* (Gunasekaran and Chelliah, 1985b). Reddish terminal neem leaf exudates reduced the consumption, growth and nutritional efficiency as well as longer larval and pupal durations and reduced longevity and fecundity of *S. litura* (Kumar *et al.*, 1997).

Tripathi *et al.* (1999) reported about the methanol fraction of *A. paniculata* extracts which had the highest growth inhibitory activity on larval and adult stages of the *S. obliqua.* At higher concentrations, ether extracts of *A. squamosa* treated *S. litura* larvae showed larval-pupal and pupal-adult intermediary forms (Mani and Prabhu, 1999).

2.5.2 Morphogenic effects

Crude extracts of *C. odorata, A. indica, C. infortunatum, L. camara, N. oleander and O. sanctum* when treated on *D. cingulatus* nymphs developed into malformed adults (Saradamma, 1989). Behera and Satapathy (1996) observed that the *A. calamus* extract induced the highest percentage of abnormalities due to morphogenic effects both by leaf dip (38.6%) and topical (37.3%) applications, followed by neem applied as leaf dip; Indian laurel and karanj both when applied topically produced 33.3 per cent abnormalities in the treated *S. litura.* Plant

extracts of *A. indica, C. sinensis, V. negundo* and *Z. officinale* treated on *S. litura*, produced deformed pupae as well as adult stages (Sahayaraj, 1998).

Topical application of 100-300 µg of methanol extracts of *G. sepium* at different stages of *D. koenigii, A. janata* and *S. litura* resulted in larval-pupal intermediates and deformed adults in a dose dependent manner (Parvathi *et al.*, 1999). Crude leaf extract of *Tridax procumbens* when treated on fourth instar *S. litura* larvae developed into deformed pupae and adults (Sahayaraj and Paulraj, 2000).

2.5.3 Moulting inhibition

Chockalingam *et al.* (1986) observed that the duration of fifth instar larvae of *S. litura* was prolonged by two days when fed on treated castor leaves with *Eucalyptus* spp. at 300 and 400 ppm. Pupal duration of *S. litura* was prolonged by acetone extracts of *A. indica, A. conyzoides* and *C. odorata and* normal adult emergence was also reported to be inhibited by *A. indica* and *T. nerifolia* extracts (Saradamma, 1989).

Kalavathi *et al.* (1991) reported that the acetone extract of *V. negundo* could inhibit the emergence of *Epilachna septima* adults if pupae were treated with the same. Benzene extracts of *A. indica* and *C. odorata* completely inhibited the normal adult emergence as found by Saradamma *et al.*, 1993. Indian laurel (*Laurelia* sp.) and *A. indica* extracts prolonged larval duration of *S. litura* (Behera and Satapathy, 1996). Dichloromethane and methanol extracts of *M. dubia* inhibited the larval growth in a dose dependent manner in *S. litura* and *H. armigera* (Opender-Koul *et al.*, 2000).

2.5.4 Fecundity

Pandey *et al.* (1987) found that the 0.5 per cent petroleum ether extracts of *L. camara, A. conyzoides, Ipomea carnea* Jacq., *A. indica* reduced the fecundity

of *L. erysimi,* whereas, *C. fistula* and *T. nerifolia* extracts were ineffective. The fecundity of neem product treated line of the *P. xylostella* was always at a much lower level than that of an untreated control line for about 40 generations (Vollinger, 1987). Various neem products exert a dose dependent influence on the fecundity of female insects (Schmutterer, 1990).

Water and acetone extracts of *A. indica, T. nerifolia, V. negundo* and *N. oleander* when treated on *S. litura* and *H. vigintioctopunctata,* they were completely suppressed from egg laying and also were causing cent per cent sterility (Saradamma, 1989). *C. siphonanthus* leaf extract at 2.5 per cent dose achieved 88.4 per cent reproductive control in *C. chinensis* (Pandey and Khan, 2000).

2.6 ACTIVE PRINCIPLES OF BOTANICALS UPON INSECTS

2.6.1 Neem principles

Azadirachtin (Az) was considered as the most important active principle in neem seed kernels. However, the quantity of the compound present in kernels vary due to environmental factors and genetic nature. The highest yield of Az was 10 g/kg of the seed kernels. Az is a tetranortriterpenoid (limonoid) which has deterrent, antiovipositional, antifeedant, growth distrupting, fecundity and fitness reducing properties in insects (Schmutterer, 1990).

Az was identified and isolated from neem seed by Butterworth and Morgan (1968). Az was found to be formed by a group of closely related isomers called Az A to Az I. Az A was more in quantity in neem seed kernels. However, Az E was regarded as the most effective insect growth regulator (Rembold *et al.*1987;Rembold, 1989 and Ley *et al.*1993).

Oligophagous species were more sensitive to Az than to the polyphagous species (Simmonds and Blaney, 1984). Other active compounds of

neem seed kernels are salannin, salannol, salannolacetate, 3-deacetylsalannin, azadiradion, 14-epoxy azardion, gedunin, nimbinen and deacetylnimbinen (Jones *et al.*, 1989).

Az was reported to be reducing the food intake and approximate digestibility and the volume of *Corpora allata* was also lowered as observed in *S. litura* (Rao *et al.*, 1993). Li-xiaodong *et al.* (1996) reported that the main mode of action of Az was disruption of endocrine activities in insect. Antifeedant activity of Az did not increase in a dose-dependent manner as reflected by the decline in antifeedant effect at higher dosages of 30 and 50 ppm against *S. litura* (Mukherjee and Sharma, 1996). Gujar (1997) found that the sublethal dose of one µg of Az per insect (*H. armigera*) led to drastic growth inhibition for a considerable period of time and eventual death.

Pure Az showed neither repellency nor contact effect on egg laying (Saxena and Rembold, 1984). Crude suspension of the *A. indica* seeds had stronger combined larval mortality and antioviposition properties against noctuid moths than the pure Az (Naumann and Isman, 1995). Verkerk and Wright (1993) observed that the synthetic Az was less toxic against *P. xylostella* larvae as compared to the larvae of *S. littoralis*.

2.6.2 Miscellaneous botanical principles

Wada and Munakata (1968) isolated and identified five antifeedant compounds, active against *S. litura* from three plant species such as 'isoboldine' from *Cocculus trilobus* DC, 'Shiromodiol-diacetate' and 'Shiromodiol-mono-acetate' from *Parabenzoin trilobum* Nakai and 'Clerodendrin' A and B from *C. tricotomum* Thumb.

From the leaves of *Orixa japonica* Thumb., Yojima *et al.* (1977) isolated and identified six feeding deterrent principles namely isopimpenellin,

beryapectin, xantheloxin, kokusogin, evoxine and japonine against *S. litura*. Koul (1983) isolated two limonoids from *Cedrolla toona* R. and grape fruits (cedrelone and limonin) which induced feeding deterrent activity in the larvae of *S. litura*. The alkaloids like vasicine, vasicinol, deoxyvasicine, vasicinone and deoxyvasicinone were extracted from *A. vasica* which deterred the feeding of *Epilachna* and *Aulocophora* beetles at 0.05 to 0.1 per cent concentrations in vegetable crops (Saxena *et al.*, 1986).

Srimannarayana and Rao (1985) found that the 'Karanjin' from *P. glabra*, 'maxima substance'-c from *Tephrosia purpurea* Pers. and 'lonchocarpic acid' from *Derris scadens* (Roxb.) were effective against *S. litura*. 'Amorphone' was isolated and identified from the leguminous plant *Tephrosia candida* DC. by Kole *et al.* (1992).

'Neriifolin' from *Thevetia thevetionides* acted as stomach poison against *O. nubilalis* (Mc Laughlin *et al.*, 1980). Jacobson (1990) reported about the biologically active compounds like 'annonin, annonacin and annonidines' from custard apple. 'Plumbagin' from *Plumbago* sp. possessed antifeedancy, chitin synthesis inhibition and ecdysteroid inhibition against a number of lepidopterous and hemipterous insect pests (Chockalingam *et al.*, 1990 and Krishnayya and Rao, 1995). Plumbagin showed a dose dependent effect on the larval mortality and pupation of *H. armigera* (Gujar, 1997).

The main constituent of *A. paniculata* has been isolated and established as andrographolide (Moktadar and Guha-Sincar 1939 and Charkavarti and Charkravarti, 1952). The compound identified from *A. paniculata* viz.,14-deoxyandrographolide' was less potent than crude extract of the hexane layer (Hermawan *et al.*, 1997). Andrographolide at 1000 ppm reduced the number of eggs laid by the *P. xylostella* by about 50 per cent (Hermawan *et al.*, 1998) and its antifeedant property against *N. cincticeps* was reported by Widiarta *et al.* (1997).

Bowers *et al.* (1966) isolated and identified the active component from *A. balsamea* as 'juvabione' which was a sesquiterpenoid of todomatic acid.

Bowers *et al.* (1976) again isolated and identified two natural antijuvenile hormones viz., 'Precocene' I and II from the extract of *A. haustoniahum* which induced precocious moulting in the nymphs of *O. fasciatus* and *D. cingulatus*.

Active principle responsible for the sterilizing activity of *A. calamus* has been determined to be β-asarone as reported by Schmidt (1986).

Every day, fresh reports on newer botanicals, their active principles and their effects upon the insect growth and development are being piled up especially in the light of the increased awareness and consequent investigations upon the naturally occurring eco-friendly IPM approaches with botanical pesticides.

Materials and Methods

3. MATERIALS AND METHODS

The present study was undertaken in the Department of Entomology, College of Horticulture, Vellanikkara, Thrissur during 2000-2001. The details of the material and methods for the present investigation are elaborated here under.

3.1 A SEARCH ON THE AVAILABILITY OF THE BOTANICAL RESOURCES WITH PEST MANAGEMENT PROPERTIES

Literature and field surveys were undertaken on the important species of plants possessing insecticidal activity, nature of active principles, distribution of these compounds in different plant parts, physiological and behavioural effects of these principles on insects, their market availability and price structure in and around Thrissur town.

3.2 SELECTION OF BOTANICALS FOR INSECTICIDAL/ INSECTISTATIC PROPERTIES

Locally available plants and plant material which were known to possess biocidal activities/medicinal properties/poisonous effects on higher animals and/or those which genuinely harbour low levels of insect populations were evaluated based on the available literature/information. Accordingly, extracts from the selected parts of the plant species and the essential oils were tested for their biological responses such as antifeedancy, repellency, ovipositional deterrency, ovicidal, insecticidal and other effects. The fifteen plant species and six essential oils were selected for preliminary observations (Table 1).

Table 1. List of plant species selected for preliminary observations

Sl. No.	Scientific name	Common name	Part used
1	*Acorus calamus* L.	Sweet flag	Rhizomes
2	*Adathoda vasica* Nees.	Adalodakam	Leaves
3	*Allium sativum* L.	Garlic	Bulbs
4	*Andrographis paniculata* Wall.	Kiriyath	Leaves
5	*Annona squamosa* L.	Custard apple	Seeds
6	*Azadirachta indica* A. Juss	Neem	Kernels
7	*Chromolaena odorata* L.	Communist pacha	Leaves
8	*Clerodendron infortunatum* L.	Vellilavu	Leaves
9	*Eucalyptus grandis* Labille	Yookkali maram	Leaves
10	*Hyptis sauveolens* Poit.	Thiruchada/ Nattapoochedy	Leaves
11	*Lantana camara* L.	Arippu/Kongini chedi	Leaves
12	*Momordica charantia* L.	Paval/Bittergourd	Leaves
13	*Strychnos nux-vomica* L.	Kanjiram	Roots
14	*Thevetia nerifolia* J.	Yellow oleander, Manja arali	Leaves
15	*Vitex negundo* L.	Vellanocchi	Leaves
	Essential oils		
1	*Cinnamomum zeylanicum* Breyn.	Karuvapatta or Cinnamon	Oils
2	*Citronella winterianus*	Theruvapullu or Citronella	Oils
3	*Cymbopogon flexuosus* (Steud.)	Inchipullu or Lemongrass	Oils
4	*Cymbopogon martinii* (Roxb.)	Palmarosa	Oils
5	*Kaempferia galanga* L.	Kacholam	Oils
6	*Mentha piperita* L.	Menthachedy or Peppermint	Oils

3.3 TEST INSECT

S. litura, a polyphagous and enigmatic insect pest on a number of commercial crops such as fruits, vegetables and cotton was selected as the test insect. Moths of the tobacco cutworm, *S. litura* were collected from the field and multiplied in the laboratory as the strater culture. The adult moths were confined to a mating cage and were fed with 10 per cent honey solution and a few drops of vitamin E (per 25 ml solution). Castor leaves were provided inside the cages for egg laying. Eggs laid daily were collected separately and kept in buckets provided with castor or banana leaves as food material for the emerging first and second instar larvae. Third instar larvae onwards were transferred on to the semi-synthetic diet (Mani and Rao, 1998) in test tubes. Two larvae were confined in each tube and plugged with clean, non-absorbent cotton. Pupae were collected from the tube and kept separately for adult emergence. Third instar larvae of uniform size were used for different experiments.

3.3.1 Semi-synthetic diet

Composition of the semi-synthetic diet used is given in Table 2.

3.4 METHOD OF EXTRACTION OF PLANT MATERIALS

3.4.1 Water extraction

Fresh plant materials (~40 g) were collected from the field every time when required, chopped into small pieces and macerated with 100 ml water in a mechanical blender. The macerated slurry was strained through muslin cloth and filtered through Whatman No.1 filter paper. The volume was made up to 100 ml to form the primary stock extract. Secondary stocks for the different experiments were prepared by suitably diluting the primary stock with distilled water.

Table 2. Composition of semi-synthetic diet for rearing *S. litura*

Ingredient	Quantity
Kidney bean	65.0 g
Wheat bran	65.0 g
Yeast extract powder	25.0 g
Agar powder	12.0 g
Casein	3.0 g
L-Ascorbic acid	4.0 g
Sorbic acid	0.9 g
Methyl para hydroxybenzoate	0.4 g
Cholesterol	0.3 g
Streptomycin sulfate	0.1 g
Multi-vitamin capsule	One number
Formaldehyde (35%)	2.0 ml
Vegetable oil	1.0 ml
Distilled water	600.0 ml

(Mani and Rao, 1998)

3.4.2 Solvent extraction

Freshly chopped plant material (~40 g) were macerated separately with 100 ml each of the different solvents *Viz.*, acetone, chloroform, dichloromethane and methanol using a mechanical blender and allowed to stand at room temperature in reagent bottles. After 48 hours these solutions were strained through muslin cloth and filtered through Whatman No.1 filter paper (Saradamma, 1989). The volume was made up to 100 ml with the solvent which served as the stock solution for subsequent dilutions used in different experiments.

3.5 BIOEFFICACY OF PLANT EXTRACTS

3.5.1 Ovipositional deterrency

Ovipositional deterrency was conducted as multiple choice test (using different plant extracts) with castor leaf as substrate for oviposition by drawing lines along the margin of the lobes. Botanical extracts with wetting agent (0.5%) were painted on both sides of the leaves with camel hair brush and it was air dried. Such treated leaf was kept with its stalk dipped in conical flask with water to maintain its freshness and turgor. Mated adult female moths were released (@ 10/cage) for oviposition for three days. Relative number and the size range of the deposited egg masses on each treated and sectored leaf lobes were recorded. The same procedure was repeated with different extracts at different concentrations (aqueous extract at 1, 5 and 10% and essential oils at 0.1, 0.5 and 1.0%).

Range of egg numbers per egg mass	Score value	Frequency	Aggregate score value
Very small egg mass (1-50)	1	n_1	$1xn_1$
Small egg mass (51-100)	3	n_2	$3xn_2$
Medium egg mass (101-150)	5	n_3	$5xn_3$
Large egg mass (>151)	7	n_4	$7xn_4$

$$\text{Average score} = \frac{\text{Sum of score value in respective concentrations}}{3}$$

$$\text{Percentage of ovipositional preference over control} = \frac{\text{Total score in treatments}}{\text{Total score in control}} \times 100$$

3.5.2 Ovicidal action

One day old eggs were subjected to determination of the ovicidal action of botanicals. Scales on the eggs were removed by camel hair brush to make it easier for counting and treatment exposures. Pre-counted egg masses along with its leaf substrate were dipped in the extracts, air dried and kept on moist blotting paper. Each treatment was replicated thrice. Plant extracts were tested at one, five and ten per cent concentrations and essential oils at 0.1, 0.5 and 1 per cent levels. Eggs dipped in water and acetone served as control treatments respectively. After two days of treatment, unhatched eggs were counted and hatching percentage worked out as follows.

$$\text{Hatching percentage} = \frac{\text{No. of eggs hatched}}{\text{Total no. of eggs}} \times 100$$

3.5.3 Antifeedancy

3.5.3.1 Antifeedant effects of plant extracts

Pre-weighed banana leaf discs (50 mm diameter)were dipped in plant extracts and air dried. Ten pre-weighed and pre-starved(1 hr) third instar S. *litura* larvae were released on the treated leaf discs. The extracts with one to five per cent range of concentrations were tested. Three replications were also maintained for each treatment. Leaf discs treated with water and respective solvents were also maintained to serve as control. Observations were recorded after 24 hours of feeding. The left over portion of leaf discs uneaten and the faecal pellets were

weighed to determine the percentage of leaf protection, larval starvations, approximate digestibility and efficiency of conversion of food to body matter.

3.5.3.2 Antifeedant effects of essential oils

Antifeedancy of six selected essential oils on the third instar larvae of *S. litura* were evaluated. High purity oils, obtained from Aromatic and Medicinal Plants Research Station (AMPRS), Odakkali were used in the present studies. Acetone was used to dilute the essential oils to the desired concentration. Pre weighed banana leaf discs dipped in essential oils at different concentrations (1 to 5%) and air dried before releasing the starved and pre-weighed test larvae for observation as in 3.5.3.1.

3.5.3.3 Percentage of leaf protection by the botanical preparations

The percentage of leaf area/weight protected by the botanicals from the larval defoliation were estimated as per Saradamma (1989) and Bai and Koshy (1999).

Percentage of leaf weight protection = (A-B)/A x 100

where,

A = weight of the leaf consumed in the control and

B = weight of the leaf consumed in the treatment

3.5.3.4 Percentage of the larval starvation induced by the botanical preparation

Percentage of larval starvation due to treatment was calculated as per Saradamma (1989) and Bai and Koshy (1999).

Percentage of larval starvation = (C-E)/(C-S) x 100

where,

C = mean weight gain of control larvae in 24 hours,

E = mean weight gain of the treatment larvae in 24 hours and

S = mean weight gain of starved control larvae in 24 hours (the figure is negative)

C-S = Cent per cent starvation

3.5.3.5 Grading of extracts for their antifeedant properties

Based on the percentage of leaf protection and percentage of larval starvation the plant extracts were graded for their feeding inhibition or antifeedancy potential (Saradamma, 1989).

Percentage protection	Degree of activity
81-100	Very high
61-80	High
41-60	Low
21-40	Very low
less than 20	No activity

3.5.3.6 Correction for evaporation loss of leaves by weight

Leaves lose water on excision from the plants. This led to erroneous weight difference on expiry of 24 hours. Waldbauer (1968) has given a formula for the correction of this water loss to be applied to the observed weights.

$$\text{Corrected weight of food eaten} = \left[1-\frac{a}{2}\right] \left[w-(L+bL)\right]$$

where,

W = weight of food introduced

L = weight of uneaten food

Here, the correction was applied both as the ratio of loss of the initial weight of the aliquot (a) and as the ratio of loss to the final weight of the aliquot (b).

3.5.4 Insect food consumption and utilization indices

The digestion and food conversion efficiency indices of the larvae were calculated according to Waldbauer (1968) as follows

Approximate Digestibility (AD)

$$= \frac{\text{Weight of food ingested - Weight of faeces}}{\text{Weight of food ingested}} \times 100$$

Efficiency of Conversion of Ingested food to body substance (ECI)

$$= \frac{\text{Weight gained}}{\text{Weight of food ingested}} \times 100$$

Efficiency of Conversion of Digested food to body tissue (ECD)

$$= \frac{\text{Weight gained}}{\text{Weight of food ingested - Weight of faeces}} \times 100$$

All the above indices were calculated on fresh weight basis.

3.5.5 Assessment of morphogenic malformations and developmental setbacks

Third instar larvae (@ 2/treatment) and five replications were maintained for the studies. Larvae were allowed to feed on the treated leaves for 24 hours (at 1, 3 and 5% levels). After the expiry of the feeding time, it was transferred to semi-synthetic diet. These larvae were reared up to adult emergence. Observations on mortality, pupation, adult emergence, pupal malformations and adult malformations were recorded and percentage values were calculated as followed.

1. Percentage of successful pupation $= \frac{\text{Total no. of pupae in treatment}}{\text{Total no. of pupae in control}} \times 100$

2. Percentage of malformed pupae $= \frac{\text{No. of malformed pupae}}{\text{Total no. of pupae}} \times 100$

3. Percentage of adult emergence $= \frac{\text{No. of adults emerged}}{\text{Total no. of pupae}} \times 100$

4. Percentage of malformed adults $= \frac{\text{No. of malformed adults}}{\text{Total no. of adults emerged}} \times 100$

5. Percentage of normal eclosion $= \frac{\text{No. of normal adults emerged in all concentrations}}{\text{Total no. of normal pupae in all concentrations}} \times 100$

ion $= \frac{\text{No. of malformed pupae in all concentrations}}{\text{Total pupae in all concentrations}} \times 100$

7. Percentage of adult malformation $= \frac{\text{No. of malformed adults in all concentrations}}{\text{Total no. of adults emerged in all concentrations}} \times 100$

8. Percentage of total malformation $= \frac{\text{Total no. of malformed pupae and malformed adults in all concentrations}}{\text{Total no. of pupae and adults in all concentrations}} \times 100$

Ratios

1. Ratio of malformed pupae to normal pupae (Mp/Np)

$$\text{Mp/Np} = \frac{\text{Total no. of malformed pupae}}{\text{Total no. of normal pupae}}$$

2. Ratio of malformed adults to normal adults (Ma/Na)

$$\text{Ma/Na} = \frac{\text{Total no. of malformed adults}}{\text{Total no. of normal adults}}$$

3. Ratio of total malformed ones to total normal ones (Mp+Ma/Np+Na)

$$\frac{Mp + Ma}{Np + Na} = \frac{\text{Total no. of malformed pupae and adults}}{\text{Total no. of normal pupae and adults}}$$

3.5.6 Determination of LC_{50} values of selected botanicals

The acetone extracts of plant parts and essential oil dilutions were prepared at one to ten per cent concentrations. Two microlitres of the same were topically applied on the thoracic tergal plate of the freshly moulted third instar caterpillar of *S. litura* using a micropipette. Five, III instar larvae were maintained per treatment and each treatment was replicated four times; with acetone treatment as control. The treated larvae were then reared on semi-synthetic diet and the percentage of mortality recorded at daily intervals.

3.6 STATISTICAL ANALYSIS

Observations under each experiment (except morphogenic malformation and LC_{50} value) were tabulated and analysed statistically in a completely randomized design (CRD) as proposed by Panse and Sukhatme (1976). The treatments were ranked according to Duncan's Multiple Range Test (DMRT). LC_{50} value was calculated by probit analysis (Finney, 1952).

Results

4. RESULTS

The results of the work carried out during the investigation are detailed below.

4.1 SURVEY ON THE BOTANICAL RESOURCES WITH PEST MANAGEMENT PROPERTIES

A survey was conducted in and around Thrissur town in the wholesale and retail shops dealing with herbal plants, hill produces and ayurvedic drugs. Information was collected and collated from the available secondary and tertiary sources of literature as well to supplement the details on the botanicals with pesticidal properties (Appendix I).

Seasonal availability of the raw botanicals was reported to be more during the two monsoon periods. Most of the root material were imported from hilly tracts of Kerala and Tamil Nadu. Some of the botanical produces especially Kiriyath, Karuvapatta, etc. obtained from these tracts fetched low price, whereas, high value produces were cart loaded from far away places like China, Nepal, Assam, West Bengal and Kolkata regions (Appendix I).

Storage life of many of the botanicals were about one year if properly dried and stocked. It was found that, there was little processing other than drying for majority of the produces before transportation, storage and sale. Fresh materials like Thulasi, *Vitex* etc. could be stored up to maximum one week only and were usually sold as fresh material itself. In Thrissur town, a few wholesale merchants, who exclusively dealing with the medicinal plants and hill produces are

i) C.L.Kurien and Brothers

ii) Anjeri Drugs shop

iii) C.D.Joseph and Company and

iv) Immathy and Sons

However, there are a number of retail shops dealing with the sale of ayurvedic drugs and herbal plant produces in the town.

4.2 LABORATORY REARING OF *S. litura*

Moths of *S. litura*, initially collected from the field, were confined in rearing cages (45 x 30 cm), provisioned with honey solution (10%) plus vitamin E drops as adult feed for oviposition. Fresh castor leaves with its petiole tip dipped in water in conical flask was placed inside each cage for oviposition. Emerged larvae were reared on castor/banana leaves up to the late second instar. Batches of hundred third instar larvae each were then transferred into plastic buckets (20 l capacity) and provided with fresh banana leaves. From late fourth instar onwards; 50 larvae per bucket were only retained and fed with banana leaves. Nuclear Polyhedrosis Virus (NPV) infection were frequently observed on the fourth and fifth instar larval stages leading to massive death of the larvae. Some larvae were found to pupate resulting in undersized pupae not fit for further culturing. The adults emerging from pupae of larvae fed on banana leaves were also smaller in size. These insects laid only a few viable eggs when compared to those reared on semi synthetic diet.

Hence, the test insect was mass cultured on a semi-synthetic diet (as per 3.3) standardized by Mani and Rao (1998) under ambient weather conditions. Early third instar larvae from natural diet (castor leaves) were transferred into glass test tubes (10 x 2 cm) provisioned with 10 g of semi-synthetic diet (cube) at the rate of two larvae per test tube and plugged with clean non-absorbent cotton. Tubes with infected larvae and those with mould growth over the diet cubes were discarded regularly. Larvae reared on semi-synthetic diet were having a larval period ranging from 14 to 20 days. They were allowed to pupate inside the test tube itself. After pupation they were collected from the tubes and kept in emergence cages. The total pupal period recorded was 8 to 10 days. Adult emergence usually started at 7.30 p.m. Ten pairs of emerged adults of both sexes

were then released in rearing cages for mating. Cotton wads soaked in a mixture of honey solution (10%) and vitamin E drops were kept inside the cage as adult feed. Two to three days after emergence and mating, they started egg laying on the castor leaves kept inside the cages. Further rearing was continued to maintain the culture as per the requirement of the experiment.

4.3 BIOEFFICACY OF THE SELECTED BOTANICALS

4.3.1 Ovipositional deterrency

4.3.1.1 Plant extracts

Data in Table 3 shows that the one per cent concentration, *Hyptis sauveolens* aqueous extract showed higher ovipositional deterrency with the lowest score of nine followed by *Strychnos nux-vomica* (score 10). Extracts of *Azadirachta indica* and *Clerodendron infortunatum* ranked third with a score of 14 each. *Thevetia nerifolia* extract showed no ovipositional deterrency with its highest score of 44 (Egg layings was more in *T. nerifolia* treatment as compared to even control).

However, *A. indica* ranked first followed by *H. sauveolens* extracts which gave higher ovipositional deterrency with a score of three and six respectively at five per cent level. *Adathoda vasica* and *Andrographis paniculata* extracts got a score of nine each and they were next to the above extracts in giving higher ovipositional deterrency(Table 3).

All the tested extracts had a score of less than 12 (@ 10% level). The highest ovipositional deterrency was recorded in *A. indica* and *H. sauveolens* extracts with the lowest scores of two and three respectively, followed by *A. vasica* and *A. paniculata* extracts (score of 6 each) at the higher concentration of 10 per cent.

Table 3. Egg laying of *S. litura* on surfaces treated with aqueous plant extracts

Sl. No.	Treatments	1%					5%					10%					Average score	Total score/ control score* 100
		VS	S	M	L	Score	VS	S	M	L	Score	VS	S	M	L	Score		
1	*A. vasica*	4			2	18		3			9		2			6	11.0	33.00
2	*A. paniculata*			5		25		3			9		2			6	13.3	40.00
3	*A. indica*		3	1		14	3				3	2				2	6.3	19.00
4	*C. infortunatum*	2		1	1	14		2		1	13			2		10	12.3	37.00
5	*H. sauveolens*		3			9		2			6		1			3	6.0	18.00
6	*S. nux-vomica*		1		1	10			2		10		1	1		8	9.3	28.00
7	*T. nerifolia*		3		5	44				2	14			1	1	12	23.3	70.00
8	*V. negundo*	1		4		21	10				10		1	1		8	13.0	39.00
9	Control			2	2	24			1	4	33			3	4	43	33.3	100

Range of egg numbers/egg mass	Score value
VS= Very small sized egg mass (1-50)	1
S = Small sized egg mass (51-100)	3
M = Medium sized egg mass (101-200)	5
L = Large sized egg mass (>201)	7

A. vasica - Adathoda vasica

A. paniculata - Andrographis paniculata

A. indica - Azadirachta indica

C. infortunatum-clerodendron infortunatum

H. sauveolens-Hyptis sauveolens

S. nux-vomica - Strychnos nux-vomica

T. nerifolia - Thevetia nerifolia

V. negundo - Vitex negundo

Average score at different concentrations tested (viz., 1, 5 and 10%) revealed that the *H. sauveolens* extract, topped in its oviposition deterrency with the lowest score (6) followed by *A. indica* (6.3) and *S. nux-vomica* (9.3). *A. vasica* and *C. infortunatum* extracts had the scores of 11 and 12.3 respectively. Among the remaining extracts, *T. nerifolia* had the highest score of 23.3 showing the least oviposition deterrency.

As compared to cent per cent oviposition in the untreated control (as per 3.5.1), *H. sauveolens* extracts allowed only 18.00 per cent combined oviposition followed by *A. indica* (19.00%). The highest percentages of oviposition was recorded in *Thevetia nerifolia* extracts (70.00%).

4.3.1.2 Essential oils

Data in Table 4 shows that at 0.1 per cent concentration, *Cinnamomum zeylanicum* oil had the highest ovipositional deterrency with the lowest score of 12 followed by *Cymbopogon flexuosus* and *Citronella winterianus* oils with a score of 17 each. *Mentha piperita* and *Kaempferia galanga* oils had no ovipositional deterrency as inferred from its scores of 22 and 24 respectively which was on par

compared to controls with cent per cent oviposition, *C. zeylanicum* and respectively with scores of 10.3

Table 4. Egg laying of *S. litura* on surfaces treated with essential oils

Sl. No.	Treatments	0.1%					0.5%					1.0%					Average score	Total score/ control score*100
		VS	S	M	L	Score	VS	S	M	L	Score	VS	S	M	L	Score		
1	*C. zeylanicum*			1	1	12			2		10					0	7.3	25.00
2	*C. winterianus*		1		2	17			2	1	17					0	11.3	38.64
3	*C. flexuosus*		1		2	17			3		15					0	10.7	36.36
4	*C. martinii*			1	2	19			1	1	12					0	10.3	35.23
5	*K. galanga*		1		3	24			2	2	24					0	16.0	54.55
6	*M. piperita*		1	1	2	22			1	2	19					0	13.6	46.59
7	Control			2	2	24			2	3	31			1	4	33	29.3	100

1

Range of egg numbers/egg mass	Score value	
VS= Very small sized egg mass (1-50)	1	*C zeylanicum-Cinnamomum zeylanicum*
S = Small sized egg mass (51-100)	3	*C.winterianus-Citronella winterianus*
M = Medium sized egg mass (101-200)	5	*C. flexuosus-Cymbopogon flexuosus*
L = Large sized egg mass (>201)	7	*C. martinii-Cymbopogon martinii*
		K. galanga - Kaempferia galanga
		M. piperita - Mentha piperita

C. martinii oils had lower ovipositional rate (25.0 and 35.2% respectively). Highest percentage of 54.55 per cent oviposition was recorded on *K. galanga* oil treated surface. Other treatments (*viz.*, *C. martinii*, *C. winterianus* and *M. piperita* oils) had less than 50 per cent oviposition.

4.3.2 Ovicidal action

4.3.2.1 Plant extracts

The hatching percentage of *S. litura* eggs treated with plant extracts are presented in Table 5. Aqueous extract of A. *indica* gave the least hatching percentages of 66.73, 38.57 and 11.61 per cent at one, five and ten per cent concentrations respectively. The leaf extract of *V. negundo* allowed 73.10, 62.94 and 33.50 per cent of egg hatching at the same above concentrations respectively. Leaf extract of *A. vasica* applied on eggs gave 72.24 per cent of hatching (@ 10%). *S. nux-vomica*, *T. nerifolia*, *H. sauveolens*, *A. paniculata* and *C. infortunatum* resulted in higher hatching percentage ranging from 83.62 to 96.63 per cent at all concentrations indicating their lesser ovicidal action.

The eggs treated with *C. infortunatum* and *A. paniculata* extracts showed higher hatching percentage of more than 90 at one and five per cent levels while, at 10 per cent concentration it was 88.07 per cent.

A. indica and *V. negundo* extracts treated eggs had relatively lower hatching percentages (73.10 to 11.16%) at all concentrations.

4.3.2.2 Essential oils

Results relating to these studies are presented in Table 6. All the six essential oils dissolved in acetone solvent gave zero per cent hatching at the higher concentration of one per cent. At 0.1 per cent level, the lowest value of 33.59 per cent hatching was observed with *C. martinii* oil. At the same concentration, eggs treated with *K. galanga* and *C. flexuosus* oils had 56.68 and 69.22 per cent of

Table 5. Effect of aqueous plant extracts on the hatching percentage of *S. litura* eggs

Sl. No.	Treatments	Percentage of hatching		
		1%	5%	10%
1	*Adathoda vasica*	83.36 [b] (9.16)	82.54 [b] (9.11)	72.24 [c] (8.51)
2	*Andrographis paniculata*	91.60 [ab] (9.60)	90.46 [ab] (9.54)	88.07 [b] (9.41)
3	*Azadirachta indica*	66.73 [c] (8.19)	38.57 [d] (6.23)	11.61 [e] (3.47)
4	*Clerodendron infortunatum*	96.63 [a] (9.85)	91.70 [ab] (9.60)	89.49 [b] (9.48)
5	*Hyptis sauveolens*	90.75 [ab] (9.55)	86.71 [ab] (9.33)	88.77 [b] (9.45)
6	*Strychnos nux-vomica*	86.01 [b] (9.3)	88.33 [ab] (9.42)	83.62 [b] (9.77)
7	*Thevetia nerifolia*	85.91 [b] (9.29)	84.76 [b] (9.23)	83.93 [b] (9.19)
8	*Vitex negundo*	73.10 [c] (8.57)	62.94 [c] (7.95)	33.50 [d] (5.81)
9	Control	97.74 [a] (9.91)	97.90 [a] (9.92)	99.32 [a] (9.99)

The figures with same alphabets in superscript do not differ significantly at CD 0.05 per cent and figures in parenthesis are transformed value $\sqrt{x+0.5}$

Table 6. Effect of essential oils on the hatching percentage of *S. litura* e

Sl. No.	Treatments	Percentage of hatching		
		0.1%	0.5%	1%
1	*Cinnamomum zeylanicum*	89.72 [b] (9.50)	0.00 [d] (0.71)	0.00
2	*Citronella winterianus*	91.20 [b] (9.58)	40.54 [b] (6.40)	0.00
3	*Cymbopogon flexuosus*	69.22 [c] (8.35)	43.26 [b] (6.61)	0.00
4	*Cymbopogon martinii*	33.59 [e] (5.84)	0.00 [d] (0.71)	0.00
5	*Kaempferia galanga*	56.68 [d] (7.56)	20.40 [d] (4.51)	0.00
6	*Mentha piperita*	87.63 [b] (9.39)	21.65 [c] (4.66)	0.00
7	Control	97.96 [a] (9.39)	100.00 [a] (10.03)	100.00

The figures with same alphabets in superscript do not differ significantly at CD 0.05 per cent and figures in parenthesis are transformed value $\sqrt{x+0.5}$

hatching respectively. Others *viz.*, *C. zeylanicum*, *C. winterianus* and *M. piperita* oils permitted more than 87 per cent hatching (@ 0.1% concentration). All treatments at 0.5 per cent concentration gave more than 50 per cent ovicidal action. Whereas, *C. martinii* and *C. zeylanicum* oils (@ 0.5%) caused zero per cent hatching or cent per cent ovicidal action, *K. galanga*, *M. piperita*, *C. winterianus* and *C. flexuosus* oils showed a range of 20.40 to 43.26 per cent of egg hatching at 0.5 per cent strength.

4.3.3 Antifeedant action

4.3.3.1 Effect of aqueous plant extracts and essential oils on the percentage of leaf protection against *S. litura*

Data relating to the percentage of leaf protection are given in Table 7. Highest feeding inhibition/leaf protection of 51.51 per cent was obtained in treatment with *A. indica* aqueous extracts at one per cent concentration, followed by *M. piperita* oil with 42.23 per cent, as measured by the difference in weight of leaf unfed both in treatment and control. At the same concentration, the lowest feeding inhibition of -6.62 and -1.78 per cent (negative value was due to higher consumption in the treatment as compared to control) was noticed in *C. flexuosus* oil and *V. negundo* aqueous extract respectively. But, the *S. nux-vomica* and *A. vasica* aqueous extracts also gave very low feeding inhibition (2.39 and 3.08% respectively) which were on par with that of *V. negundo* extract. The percentage of feeding inhibition by other aqueous extract and essential oils ranged from 6.97 to 28.99 per cent (Table 7).

K. galanga and *C. winterianus* oils had higher feeding inhibition of 77.00 and 65.37 per cent of respectively at three per cent concentration and were on par. *C. winterianus* was on par with *A. indica* (62.73%) in its feeding inhibition. *A. paniculata* aqueous extract, *M. piperita* and *C. zeylanicum* oils had a moderate effect of 45.12, 44.10 and 40.53 per cent leaf protection respectively. The lowest

Table 7. Effect of aqueous plants extracts and essential oils on the percentage of leaf protection against *S. litura*

Sl. No.	Treatments	Percentage of leaf protection		
		1%	3%	5%
1	*Adathoda vasica*	3.00 ^{fg}	8.99 ^{ef}	26.03 ^{g}
2	*Andrographis paniculata*	26.49 ^{c}	45.12 ^{c}	56.08 ^{de}
3	*Azadirachta indica*	51.51 ^{a}	62.73 ^{b}	71.80 ^{bc}
4	*Cinnamomum zeylanicum*	28.99 ^{c}	40.53 ^{c}	62.68 ^{cd}
5	*Citronella winterianus*	8.01 ^{ef}	65.37 ^{ab}	88.05 ^{a}
6	*Clerodendron infortunatum*	17.50 ^{d}	23.33 ^{d}	37.50 ^{fg}
7	*Cymbopogon flexuosus*	-6.62 ^{h}	-0.51 ^{f}	55.45 ^{de}
8	*Cymbopogon martinii*	14.23 ^{de}	24.10 ^{d}	45.66 ^{ef}
9	*Hyptis sauveolens*	6.97 ^{f}	19.71 ^{de}	33.12 ^{fg}
10	*Kaempferia galanga*	25.01 ^{c}	77.00 ^{a}	84.33 ^{ab}
11	*Mentha piperita*	42.23 ^{b}	44.10 ^{c}	66.68 ^{cd}
12	*Stychnos nux-vomica*	2.39 ^{fg}	19.74 ^{de}	31.92 ^{fg}
13	*Thevetia nerifolia*	9.22 ^{ef}	15.40 ^{de}	26.72 ^{g}
14	*Vitex negundo*	-1.78 ^{gh}	15.49 ^{de}	31.48 ^{g}

The figures with same alphabets in superscript do not differ significantly at CD 0.05 per cent

protection of -0.51 per cent was recorded in *C. flexuosus* oil treated leaf which indicated its phagostimulatory effect at three per cent concentration also.

At five per cent concentration, *C. winterianus* and *K. galanga* oil treatments were on par with 88.05 and 84.33 per cent feeding inhibition respectively. *A. indica* aqueous extracts with 71.80 per cent leaf protection was also on par with *K. galanga* oil treatment. *M. piperita* oil, *C. zeylanicum* oil, *A. paniculata* aqueous extract and *C. flexuosus* oil treatments gave 66.68, 62.68, 56.08 and 55.45 per cent leaf protection respectively and all of them were on par with each other. The lower percentage of leaf protection were noticed in *A. vasica* (26.03%), *T. nerifolia* (26.72%) and *S. nux-vomica* (31.48%) extracts.

K. galanga, *C. winterianus* and *A. indica* treatments gave higher feeding inhibition at three and five per cent concentrations.

4.3.3.3 Effect of aqueous plant extracts and essential oils on the percentage of larval starvation against *S. litura*

Table 8 depicts the results of larval starvation as indicated by the differential weights of larvae at different concentrations in comparison with control larvae.

At one per cent concentration, the highest larval starvation of 45.43 per cent was recorded in *A. indica* extract, whereas, *C.flexuosus* oil, *A. vasica, C. infortunatum* and *T. nerifolia* extracts recorded only -7.83, -5.42, -3.33 and -2.57 per cent respectively (negative value is due to more larval weight gain in the treatments as compared to control weight gain). In other treatments, larval starvation values ranged from 0.16 to 21.31 per cent.

K. galanga oil, *C. martinii* oil, *A. indica* aqueous extract and *C. winterianus* oil treatments induced 70.98, 62.30, 56.75 and 45.76 per cent larval starvations respectively at three per cent level. The lowest value of -0.73 per cent

Table 8. Effect of aqueous plants extracts and essential oils on the percentage of larval starvation of *S. litura*

Sl. No.	Treatments	Percentage of larval starvation		
		1%	3%	5%
1	*Adathoda vasica*	-5.42 ^{h}	9.79 ^{f}	32.39 ^{efg}
2	*Andrographis paniculata*	16.05 ^{c}	21.61 ^{de}	42.71 ^{d}
3	*Azadirachta indica*	45.43 ^{a}	56.75 ^{b}	65.48 ^{c}
4	*Cinnamomum zeylanicum*	6.83 ^{de}	14.49 ^{ef}	41.41 ^{de}
5	*Citronella winterianus*	16.38 ^{c}	45.76 ^{c}	70.06 ^{bc}
6	*Clerodendron infortunatum*	-3.33 ^{gh}	17.53 ^{def}	30.86 ^{fg}
7	*Cymbopogon flexuosus*	-7.83 ^{h}	-0.73 ^{g}	24.96 ^{g}
8	*Cymbopogon martinii*	21.31 ^{b}	62.30 ^{ab}	82.88 ^{a}
9	*Hyptis sauveolens*	0.16 ^{fg}	23.51 ^{de}	37.68 ^{def}
10	*Kaempferia galanga*	11.84 ^{cd}	70.98 ^{a}	76.78 ^{ab}
11	*Mentha piperita*	9.25 ^{de}	25.24 ^{d}	42.20 ^{de}
12	*Stychnos nux-vomica*	6.39 ^{e}	27.55 ^{d}	29.07 ^{fg}
13	*Thevetia nerifolia*	-2.57 ^{gh}	13.54 ^{ef}	28.47 ^{fg}
14	*Vitex negundo*	4.43 ^{ef}	13.47 ^{ef}	30.14 ^{fg}

The figures with same alphabets in superscript do not differ significantly at CD 0.05 per cent

larval starvation was produced by *C. flexuosus* oil treatment. Other treatments (@ 3% level) resulted in larval starvations ranged from 9.79 to 27.55 per cent only (Table 8).

C. martinii oil (82.08%), *K. galanga* oil (76.78%), *C. winterianus* oil (70.06%) and *A. indica* aqueous extract (65.48%) treatments effected higher larval starvations at their five per cent concentrations. Extracts of *V. negundo, C. infortunatum, S. nux-vomica* and *T. nerifolia* were on par and they were in the range of 28.47 to 30.86 per cent larval starvation which were, however, significantly inferior to the above treatments at five per cent level. *A. paniculata* (42.71%), *M. piperita* oil (42.20%) and *C. zeylanicum* oil (41.41%) were on par with each other but were superior to the just above mentioned treatments at five per cent concentration.

C. martinii, C. winterianus and *A. indica* induced higher larval starvations at their higher concentrations of three and five per cent.

4.3.3.3 Solvent extracts of botanicals on leaf protection and larval starvation of *S. litura*

4.3.3.3.1 Solvent extracts of *A. paniculata*

Tables 9 and 10 represents the results of leaf protection and larval starvation.

Acetone extract of *A. paniculta* exhibited 22.74 to 77.74 per cent leaf protection at levels ranging from one to five per cent. Chloroform extract caused lower feeding inhibition (< 52.82%) in all levels. But, dichloromethane extract at three, four and five per cent levels caused 63.60, 78.55 and 84.28 per cent leaf protection/feeding inhibition respectively. However, in the case of methanol extracts none of the concentrations gave reasonable leaf protection(Table9).

Table 9. Effect of *Andrographis paniculata* solvent extracts on the percentage of leaf protection against *S. litura.*

Concentration (%)	Acetone	Chloroform	Dichloromethane	Methanol
1	22.74^{gh}	9.52^{i}	7.96^{i}	3.73^{i}
2	34.52^{ef}	22.63^{gh}	19.90^{h}	8.55^{i}
3	47.32^{d}	29.52^{fgh}	63.60^{c}	24.53^{fgh}
4	71.88^{be}	30.90^{fg}	78.55^{ab}	28.23^{fgh}
5	77.74^{ab}	52.82^{d}	84.28^{a}	43.19^{de}

The figures with same alphabets in superscript do not differ significantly at CD 0.05 per cent

Table 10. Effect of *A. paniculata* solvent extracts on the percentage of larval starvation of *S. litura*

Concentration (%)	Acetone	Chloroform	Dichloromethane	Methanol
1	9.98^{k}	-12.02^{l}	22.09^{ij}	16.83^{jk}
2	63.01^{def}	10.36^{k}	49.71^{gh}	43.04^{h}
3	75.46^{bc}	17.14^{jk}	56.76^{cdf}	64.70^{cde}
4	78.90^{b}	30.83^{i}	66.78^{cde}	72.81^{bcd}
5	97.58^{a}	53.81^{fg}	68.97^{fg}	98.43^{a}

The figures with same alphabets in superscript do not differ significantly at CD 0.05 per cent

In case of the larval starvation, acetone extracts at levels between two and five per cent concentrations gave high larval starvation values ranging from 63.01 to 97.58 per cent(Table 10). Chloroform extracts induced 30.83 and 53.81 per cent larval starvations at four and five per cent concentrations respectively. High larval starvation of 66.78 (@ 4%) and 68.97 per cent(@ 5%) were recorded in dichloromethane extract, whereas, methanol extract gave 65.70, 72.81 and 98.43 per cent larval starvations at three, four and five per cent concentrations respectively. Methanol and acetone extracts at five per cent were superior to all others.

Acetone extracts of *A. paniculata* gave high leaf protection as well as larval starvation.

4.3.3.3.2 Solvent extracts of *V. negundo*

The results of this studies are given in Tables 11 and 12.

Acetone extract (in a range of 1 to 5%) were having 6.55 to 36.23 per cent feeding inhibition only. Lowest leaf protection of –8.64 per cent (higher consumption in the treatment than the control) was noticed in chloroform extract at one per cent concentration. At other levels it was giving only 9.69 to 28.46 per cent feeding inhibition against the test insect(Table 11). Dichloromethane extract gave 53.77 and 67.47 per cent feeding inhibition respectively at four and five per cent levels. Leaf protection induced by methanol extract ranged from 4.76 to 64.31 per cent. It recorded 40.86, 56.06 and 64.31 per cent feeding inhibition at three, four and five per cent strengths respectively.

As far as acetone extract was concerned, even at its highest concentration of five per cent caused 38.54 per cent larval starvation only. Chloroform extract also caused lower larval starvations and it ranged from –8.15 to 27.32 per cent at levels ranging from one to five per cent. More larval weight gain

Table 11. Effect of *Vitex negundo* solvent extracts on the percentage of leaf protection against *S. litura*

Concentration (%)	Acetone	Chloroform	Dichloromethane	Methanol
1	6.55^{gh}	-8.64^{i}	8.80^{fgh}	4.76^{h}
2	20.56^{e}	9.69^{fgh}	22.48^{e}	17.77^{efg}
3	29.36^{de}	24.78^{e}	48.54^{c}	40.86^{c}
4	29.41^{de}	24.26^{de}	53.77^{bc}	56.06^{abc}
5	36.23^{d}	28.46^{de}	67.47^{a}	64.31^{ab}

The figures with same alphabets in superscript do not differ significantly at CD 0.05 per cent

Table 12. Effect of *V. negundo* solvent extracts on the percentage of larval starvation of *S. litura*

Concentration (%)	Acetone	Chloroform	Dichloromethane	Methanol
1	0.30^{kl}	-8.15^{l}	-20.83^{m}	10.38^{ij}
2	6.30^{jk}	7.01^{jk}	-0.49^{kl}	24.12^{fgh}
3	16.89^{hi}	22.03^{efg}	12.25^{ij}	34.35^{de}
4	28.85^{efg}	23.18^{gh}	32.60^{def}	44.44^{bc}
5	38.54^{cd}	27.32^{gh}	48.04^{ab}	55.99^{a}

The figures with same alphabets in superscript do not differ significantly at CD 0.05 per cent

than the control was obtained in dichloromethane extract treatment at one and two per cent concentrations as indicated by its negative values of –20.83 and –0.49 per cent larval starvation(Table 12). A range of 10.38 to 55.99 per cent in larval starvation was noticed in methanol extract treatments ranging from one to five per cent strengths. Methanol extract at five per cent level with 55.99 per cent larval starvation was superior to all other solvents, at any of the tested concentrations.

4.3.3.3.3 Solvent extracts of *A. indica*

Tables 13 and 14 depicts the results of these studies.

Acetone extract of *A. indica* at one per cent level caused –6.82 per cent leaf protection (negative value indicates more leaf weight consumed by test insect in treatment as compared to control). It gave 53.88, 66.42 and 87.21 per cent leaf protection at higher strength (@ 3, 4 and 5%) respectively. Chloroform extract at one to five per cent doses gave a leaf protection ranging from 20.78 to 77.81 per cent. At four and five per cent levels, it recorded 70.63 and 77.81 per cent leaf protection respectively. Dichloromethane extract also gave a leaf protection value of –2.02 per cent at one per cent(Table 13). Higher leaf protection of 63.77 and 72.46 per cent were recorded in dichloromethane extract (@ 4 and 5% levels receptively). Acetone extract at five per cent level gave 87.21 per cent leaf protection and it was superior to all others.

Acetone extract at one per cent concentration gave –8.20 per cent larval starvation (weight gain was more in treatment than the control), whereas, at four and five per cent levels it caused 53.65 and 67.74 per cent larval starvation respectively. Chloroform extract gave a larval starvation of more than 50 per cent at two per cent and above concentrations as evidenced from Table 14. Dichloromethane extract caused larval starvation ranging from –7.28 to 75.09 per cent from one to five per cent levels of the same. Higher larval starvation of 67.05 and 75.09 per cent were noticed at four and five per cent levels respectively in the

Table 13. Effect of *Azadirachta indica* solvent extracts on the percentage of leaf protection against *S. litura*

Concentration (%)	Acetone	Chloroform	Dichloromethane
1	-6.82 ^{g}	20.78 ^{f}	-2.02 ^{g}
2	26.39 ^{f}	44.20 ^{e}	19.19 ^{f}
3	53.88 ^{de}	49.87 ^{e}	45.70 ^{e}
4	66.42 ^{bc}	70.63 ^{bc}	63.77 ^{cd}
5	87.21 ^{a}	77.81 ^{ab}	72.46 ^{bc}

The figures with same alphabets in superscript do not differ significantly at CD 0.05 per cent

Table 14. Effect of *A. indica* solvent extracts on the percentage of larval starvation of *S. litura*

Concentration (%)	Acetone	Chloroform	Dichloromethane
1	-8.20 ^{h}	12.43 ^{fg}	-7.28 ^{h}
2	17.29 ^{f}	50.89 ^{d}	13.41 ^{fg}
3	37.97 ^{e}	59.37 ^{cd}	33.33 ^{e}
4	53.65 ^{d}	73.77 ^{ab}	67.05 ^{bc}
5	67.74 ^{bc}	77.51 ^{a}	75.09 ^{ab}

The figures with same alphabets in superscript do not differ significantly at CD 0.05 per cent

same dichloromethane extract. Larval starvation of chloroform extract at four and five per cent and dichloromethane extract at five per cent levels were superior to all others and were on par.

4.3.4 Effect of botanical in reducing the food consumption and utilization by *S. litura larvae*

4.3.4.1 Effect of aqueous plant extracts and essential oils on the Approximate Digestibility (AD) of *S. litura*

The Approximate Digestibility (AD) was calculated on fresh weight basis of the digestible portion of food and weight of ingested food by the test larvae as per 3.5.4 and the results are presented in Table 15.

At one per cent concentration of *C. flexuosus* and *M. piperita* oils, the AD was higher with 58.67 and 55.30 per cent respectively. Both were on par with that of the control (51.77% AD). The lower AD values were recorded in *T. nerifolia, A. paniculata, C. infortunatum* and *S. nux-vomica* aqueous extracts (22.39, 23.89, 28.43 and 31.93% respectively), however the differences were statistically insignificant. *V. negundo* and *C. zeylanicum* extracts recorded moderate AD values of 34.95 and 46.58 per cent respectively.

Higher AD values of 66.75 and 64.60 per cent were recorded at three per cent concentration of *C. flexuosus* and *M. piperita* respectively. The treatments *viz., C. martinii, K. galanga, H. sauveolens, C. winterianus* and *C. zeylanicum* had 55.61, 49.11, 48.32, 48.28 and 46.76 per cent AD values which were on par with control (51.77%). The lower percentage of 25.38, 27.82, 33.67 and 35.46, AD were registered respectively in *A. paniculata, V. negundo, C. infortunatum* and *S. nux-vomica* aqueous extracts.

Extracts of *A. paniculata, C. infortunatum* and *S. nux-vomica* aqueous extracts and *C. winterianus* oil had lower AD values of 28.13, 34.32, 43.19 and 43.24 per cent respectively. Most of the treatments *viz., M. piperita* (56.65%),

Table 15. Effect of aqueous plants extracts and essential oils on Approximate Digestibility (AD) of *S. litura*

Sl. No.	Treatments	Percentage of AD		
		1%	3%	5%
1	*Adathoda vasica*	40.47 ^{cde}	41.68 ^{cde}	65.18 ^{b}
2	*Andrographis paniculata*	23.89 ^{g}	25.38 ^{g}	28.13 ^{g}
3	*Azadirachta indica*	37.67 ^{cdef}	39.08 ^{de}	55.55 ^{cd}
4	*Cinnamomum zeylanicum*	46.48 ^{bc}	46.76 ^{bcd}	50.46 ^{de}
5	*Citronella winterianus*	36.25 ^{cdef}	48.28 ^{bcd}	43.24 ^{f}
6	*Clerodendron infortunatum*	28.43 ^{fg}	33.67 ^{efg}	34.32 ^{g}
7	*Cymbopogon flexuosus*	58.67 ^{a}	66.75 ^{a}	59.46 ^{bc}
8	*Cymbopogon martinii*	46.11 ^{bc}	55.61 ^{b}	72.13 ^{a}
9	*Hyptis sauveolens*	39.61 ^{cde}	48.32 ^{bcd}	47.43 ^{ef}
10	*Kaempferia galanga*	45.41 ^{bcd}	49.11 ^{bc}	46.74 ^{ef}
11	*Mentha piperita*	55.30 ^{ab}	64.60 ^{a}	56.65 ^{cd}
12	*Strychnos nux-vomica*	31.93 ^{g}	35.46 ^{ef}	43.19 ^{f}
13	*Thevetia nerifolia*	22.39 ^{g}	38.58 ^{de}	48.40 ^{ef}
14	*Vitex negundo*	34.95 ^{def}	27.82 ^{fg}	56.65 ^{cd}
15	Control	51.77 ^{a}	51.77 ^{b}	51.77 ^{de}

The figures with same alphabets in superscript do not differ significantly at CD 0.05 per cent

V. negundo (56.65%), *A. indica* (55.55%), *C. zeylanicum* (50.46%), *T. nerifolia* (48.40%), *H. sauveolens* (47.43%) and *K. galanga* (46.74%) were on par with the control (51.77%) (Table 15). The AD values recorded in *C. martinii, A. vasica* and *C. flexuosus* were higher than and superior to control with 72.13, 65.18 and 59.46 per cent respectively.

A. paniculata and *C. infortunatum* extracts gave lower AD values at all tested concentrations.

4.3.4.2 Effect of botanicals on the Efficiency of Conversion of Ingested food to body tissue (ECI)

ECI was calculated on the basis of weight gained by *S. litura* larvae to the weight of the food ingested as per 3.5.4 and Table 16 depicts the results of it.

At one per cent strength, the highest ECI percentage of 43.85 was recorded in *M. piperita* treatment, followed by *C. infortunatum* (28.43%). In control, 23.48 per cent ECI was obtained which was on par with *A. indica* (23.75%). Lower ECI values of 13.59, 15.62, 17.49 and 17.91 per cent were observed in *C. winterianus, C. flexuosus, A. vasica* and *V. negundo* treatments respectively (Table 16).

C. martinii (@ 3.0%) had the lowest ECI of 5.93 per cent, followed by *K. galanga* (8.29%), *C. flexuosus* (14.58%) and *A. vasica* (15.84%) treatments. Higher percentages of 34.55 and 29.27. ECI were recorded in *M. piperita* and *A. paniculata* respectively. The ECI of *C. infortunatum* (23.70%), *A. indica* (22.51%) and *C. zeylanicum* (21.29%) treatments were on par with control (23.48%) at three per cent concentration.

M. piperita had the highest ECI of 41.98 per cent at five per cent level, followed by 26.69 per cent in *C. zeylanicum.* The ECI of *C. flexuosus* (21.98%), *C. infortunatum* (21.73%) and *A. indica* (21.42%) were on par with control

Table 17. Effect of aqueous plants extracts and essential oils Efficiency of Conversion of Digested food to body matter (ECD) of *S. litura*

Sl. No.	Treatments	Percentage of ECD		
		1%	3%	5%
1	*Adathoda vasica*	43.32 ^{fh}	41.11 ^{gh}	20.79 ^{f}
2	*Andrographis paniculata*	92.80 ^{a}	85.02 ^{a}	68.63 ^{a}
3	*Azadirachta indica*	65.82 ^{cd}	59.00 ^{de}	49.08 ^{c}
4	*Cinnamomum zeylanicum*	35.14 ^{i}	39.01 ^{h}	38.49 ^{de}
5	*Citronella winterianus*	38.47 ^{ij}	34.67 ^{h}	-9.22 ^{i}
6	*Clerodendron infortunatum*	93.58 ^{a}	70.80 ^{b}	70.78 ^{a}
7	*Cymbopogon flexuosus*	27.57 ^{k}	22.77 ^{i}	36.91 ^{de}
8	*Cymbopogon martinii*	48.69 ^{gh}	12.02 ^{j}	-1.98 ^{h}
9	*Hyptis sauveolens*	51.80 ^{fg}	39.78 ^{h}	35.66 ^{e}
10	*Kaempferia galanga*	57.41 ^{ef}	20.47 ^{i}	5.72 ^{g}
11	*Mentha piperita*	79.38 ^{b}	53.84 ^{ef}	60.31 ^{b}
12	*Stychnos nux-vomica*	60.61 ^{de}	49.02 ^{f}	41.89 ^{d}
13	*Thevetia nerifolia*	93.65 ^{a}	48.21 ^{fg}	34.84 ^{c}
14	*Vitex negundo*	51.00 ^{fg}	62.05 ^{cd}	37.00 ^{de}
15	Control	68.91 ^{c}	68.91 ^{bc}	68.91 ^{a}

The figures with same alphabets in superscript do not differ significantly at CD 0.05 per cent

V. negundo (56.65%), *A. indica* (55.55%), *C. zeylanicum* (50.46%), *T. nerifolia* (48.40%), *H. sauveolens* (47.43%) and *K. galanga* (46.74%) were on par with the control (51.77%) (Table 15). The AD values recorded in *C. martinii, A. vasica* and *C. flexuosus* were higher than and superior to control with 72.13, 65.18 and 59.46 per cent respectively.

A. paniculata and *C. infortunatum* extracts gave lower AD values at all tested concentrations.

4.3.4.2 Effect of botanicals on the Efficiency of Conversion of Ingested food to body tissue (ECI)

ECI was calculated on the basis of weight gained by *S. litura* larvae to the weight of the food ingested as per 3.5.4 and Table 16 depicts the results of it.

At one per cent strength, the highest ECI percentage of 43.85 was recorded in *M. piperita* treatment, followed by *C. infortunatum* (28.43%). In control, 23.48 per cent ECI was obtained which was on par with *A. indica* (23.75%). Lower ECI values of 13.59, 15.62, 17.49 and 17.91 per cent were observed in *C. winterianus, C. flexuosus, A. vasica* and *V. negundo* treatments respectively (Table 16).

C. martinii (@ 3.0%) had the lowest ECI of 5.93 per cent, followed by *K. galanga* (8.29%), *C. flexuosus* (14.58%) and *A. vasica* (15.84%) treatments. Higher percentages of 34.55 and 29.27. ECI were recorded in *M. piperita* and *A. paniculata* respectively. The ECI of *C. infortunatum* (23.70%), *A. indica* (22.51%) and *C. zeylanicum* (21.29%) treatments were on par with control (23.48%) at three per cent concentration.

M. piperita had the highest ECI of 41.98 per cent at five per cent level, followed by 26.69 per cent in *C. zeylanicum*. The ECI of *C. flexuosus* (21.98%), *C. infortunatum* (21.73%) and *A. indica* (21.42%) were on par with control

Table 16. Effect of aqueous plants extracts and essential oils on Efficiency of Conversion of Ingested food to body tissues (ECI) of *S. litura*

Sl. No.	Treatments	Percentage of ECI		
		1%	3%	5%
1	*Adathoda vasica*	17.49 ^{g}	15.84 ^{e}	13.51 ^{g}
2	*Andrographis paniculata*	21.64 ^{d}	29.27 ^{b}	19.98 ^{de}
3	*Azadirachta indica*	23.75 ^{c}	22.51 ^{c}	21.42 ^{cd}
4	*Cinnamomum zeylanicum*	20.01 ^{de}	21.29 ^{cd}	26.69 ^{b}
5	*Citronella winterianus*	13.59 ^{i}	16.91 ^{de}	-6.99 ^{j}
6	*Clerodendron infortunatum*	28.43 ^{b}	23.70 ^{c}	21.73 ^{cd}
7	*Cymbopogon flexuosus*	15.62 ^{h}	14.58 ^{e}	21.98 ^{cd}
8	*Cymbopogon martinii*	21.13 ^{d}	5.93 ^{f}	-1.66 ^{i}
9	*Hyptis sauveolens*	20.29 ^{de}	16.86 ^{de}	15.51 ^{fg}
10	*Kaempferia galanga*	21.65 ^{d}	8.29 ^{f}	2.96 ^{h}
11	*Mentha piperita*	43.85 ^{a}	34.55 ^{a}	41.98 ^{a}
12	*Stychnos nux-vomica*	19.32 ^{ef}	17.51 ^{de}	19.91 ^{de}
13	*Thevetia nerifolia*	20.80 ^{de}	18.16 ^{de}	16.22 ^{fg}
14	*Vitex negundo*	17.91 ^{fg}	17.69 ^{de}	17.48 ^{ef}
15	Control	23.48 ^{c}	23.48 ^{c}	23.48 ^{c}

The figur0es with same alphabets in superscript do not differ significantly at CD 0.05 per cent

(23.48%). *C. winterianus* and *C. martinii* oils had much lower ECI of -6.99 and -1.66 per cent respectively (here the negative value was due to loss of weight instead of gain) followed by *K. galanga* (2.96%).

All the three concentrations of *M. piperita* showed higher food conversion than the other treatments resulting in higher weight gain or biomass accumulation of the larvae.

4.3.4.3 Effect of botanicals on the Efficiency of Conversion of Digested food to body matter (ECD)

ECD was calculated on the basis of fresh weight of the larvae as per 3.5.4 and the results are shown in Table 17.

At one per cent concentration, the ECD values were higher in *T. nerifolia, C. infortunatum, A. paniculata* and *M. piperita* with 93.65, 93.58, 92.80 and 79.38 per cent respectively. Control treatment registered an ECD value of 68.91 per cent and was on par with *A. indica* (65.82%). Thereafter, lower ECD values were observed in *C. flexuosus* (27.57%), *C. zeylanicum* (35.14%), *C. winterianus* (38.47%) and *A. vasica* (43.32%) treatments.

C. martinii, K. galanga, C. flexuosus, C. winterianus, C. zeylanicum and *H. sauveolens* treatments had still lower ECD values of 12.02, 20.47, 22.77, 34.67, 39.01 and 39.78 per cent respectively at the three per cent strength. The ECD of *V. negundo* extract (62.05%) was on par with control (68.91%) as shown in Table 17). The highest value of ECD (@ 85.02%) was recorded in *A. paniculata* extract. In other treatments ECD values ranged from 41.11 to 59.00 per cent.

C. winterianus and *Cm* and *A. paniculata* treatments recorded higher ECD values of 70.78 and 68.73 per cent respectively and these were on par with

Table 17. Effect of aqueous plants extracts and essential oils Efficiency of Conversion of Digested food to body matter (ECD) of *S. litura*

Sl. No.	Treatments	Percentage of ECD		
		1%	3%	5%
1	*Adathoda vasica*	43.32 ^{hi}	41.11 ^{gh}	20.79 ^{f}
2	*Andrographis paniculata*	92.80 ^{a}	85.02 ^{a}	68.63 ^{a}
3	*Azadirachta indica*	65.82 ^{cd}	59.00 ^{de}	49.08 ^{c}
4	*Cinnamomum zeylanicum*	35.14 ^{i}	39.01 ^{h}	38.49 ^{de}
5	*Citronella winterianus*	38.47 ^{ij}	34.67 ^{h}	-9.22 ^{i}
6	*Clerodendron infortunatum*	93.58 ^{a}	70.80 ^{b}	70.78 ^{a}
7	*Cymbopogon flexuosus*	27.57 ^{k}	22.77 ^{i}	36.91 ^{de}
8	*Cymbopogon martinii*	48.69 ^{gh}	12.02 ^{j}	-1.98 ^{h}
9	*Hyptis sauveolens*	51.80 ^{fg}	39.78 ^{h}	35.66 ^{e}
10	*Kaempferia galanga*	57.41 ^{ef}	20.47 ^{i}	5.72 ^{g}
11	*Mentha piperita*	79.38 ^{b}	53.84 ^{ef}	60.31 ^{b}
12	*Stychnos nux-vomica*	60.61 ^{de}	49.02 ^{f}	41.89 ^{d}
13	*Thevetia nerifolia*	93.65 ^{a}	48.21 ^{fg}	34.84 ^{e}
14	*Vitex negundo*	51.00 ^{fg}	62.05 ^{cd}	37.00 ^{de}
15	Control	68.91 ^{c}	68.91 ^{bc}	68.91 ^{a}

The figures with same alphabets in superscript do not differ significantly at CD 0.05 per cent

control (68.97%) followed by *M. piperita* (60.31%) at the same concentration of five per cent. *K. galanga* oil treatment also had a lower ECD value of 5.72 per cent followed by 20.79 per cent recorded in *A. vasica* treatment.

C. winterianus, *C. martinii* and *K. galanga* oils had relatively lower ECD values in all concentrations (Table 16).

4.3.5 Influence of botanicals on morphogenic malformation and developmental setbacks in *S. litura* during pupation and eclosion

4.3.5.1 Aqueous extracts and essential oils

Results of this experiments are shown in Table 18. Aqueous extracts of *A. indica*, *C. infortunatum* and *A. calamus* (@ 1.0%) when treated on the third instar larvae, resulted in 75.0, 77.8 and 87.5 per cent pupation respectively, while, *C. zeylanicum*, *C. winterianus* and *C. martinii* oils allowing 57.1, 71.4 and 75.0 per cent pupation respectively at the same level. All other treatments allowed cent per cent pupation (Table 18). *S. nux-vomica* was the only botanical at one per cent concentration resulting in pupal malformations (16.7%). The lowest adult emergence of 28.5 per cent (in *C. zeylanicum* oil) followed by 50 per cent (in *A. squamosa* extract) were recorded during the experiment. *H. sauveolens* treatment resulted in cent per cent successful adult emergence. In other treatments the adult emergence values ranged from 57.1 to 85.7 per cent (Table 18). However, *C. flexuosus* oil and *A. sativum* at one per cent level brought about 42.9 and 12.5 per cent adult malformations respectively out of the totally emerged adults.

At three per cent strength, the lowest pupation rate (28.6%) was recorded in *C. zeylanicum* oil followed by *A. indica* (37.5%). Whereas, *A. paniculata*, *E. grandis* and *H. sauveolens* treatments recorded cent per cent pupation the other treatments recorded pupation rates of 50 to 85.7 per cent. Pupal malformations were recorded in *C. infortunatum* (14.3%), *V. negundo* (14.3%), *C. winterianus* oil (14.3%), *S. nux-vomica* (16.7%), *C. zeylanicum* oil (28.6%) and

Table 18. Malformations and developmental setbacks in *S. litura* caused by aqueous plant extracts and essential oils during pupation and eclosion

Sl. No.	Treatments	1%				3%				5%			
		Tp	Mp	Tae	Ma	Tp	Mp	Tae	Ma	Tp	Mp	Tae	Ma
1	*Acorus calamus*	87.5	0.0	62.5	0.0	87.5	0.0	50.0	0.0	62.5	0.0	37.5	0.0
2	*Allium sativum*	100	0.0	75.0	12.5	75.0	0.0	50.0	12.5	37.5	0.0	12.5	0.0
3	*Annona squamosa*	100	0.0	50.0	0.0	87.5	0.0	42.9	0.0	25.0	0.0	25.0	0.0
4	*Azadirachta indica*	75.0	0.0	62.5	0.0	37.5	0.0	37.5	0.0	37.5	12.5	25.0	12.5
5	*Andrographis paniculata*	100	0.0	75.0	0.0	100	0.0	66.7	33.3	75.0	0.0	25.0	0.0
6	*Cinnamomum zeylanicum*	57.1	0.0	28.6	0.0	42.9	28.6	0.0	0.0	42.7	0.0	14.3	0.0
7	*Citronella winterianus*	71.4	0.0	71.4	0.0	57.1	14.3	14.3	0.0	14.3	0.0	0.0	0.0
8	*Clerodendron infortunatum*	77.8	0.0	66.6	0.0	87.5	14.3	71.4	14.3	87.5	0.0	71.4	14.3
9	*Cymbopogon flexuosus*	100	0.0	57.1	42.9	57.1	28.6	28.6	14.3	28.6	0.0	28.6	14.3
10	*Cymbopogon martinii*	75.0	0.0	75.0	0.0	50.0	0.0	25.0	0.0	25.0	0.0	25.0	12.5
11	*Eucalyptus grandis*	100	0.0	85.7	0.0	100	0.0	85.7	14.3	85.7	0.0	57.1	14.3
12	*Hyptis sauveolens*	100	0.0	100	0.0	100	0.0	85.7	14.3	71.4	0.0	71.4	14.3
13	*Kaempferia galanga*	100	0.0	71.4	0.0	85.7	0.0	42.9	0.0	85.7	0.0	42.9	28.6
14	*Mentha piperita*	100	0.0	57.1	0.0	85.7	0.0	42.9	14.3	28.6	0.0	14.3	0.0
15	*Momordica charantia*	100	0.0	75	0.0	87.5	0.0	71.3	0.0	87.5	0.0	71.3	0.0
16	*Strychnos nux-vomica*	100	16.7	66.7	0.0	66.7	16.7	66.7	16.7	66.7	33.3	33.3	0.0
17	*Vitex negundo*	100	0.0	57.4	0.0	85.7	14.3	28.6	28.6	71.4	42.9	28.6	14.3

Tp - Total pupation
Mp - Malformed pupae
Tae - Total adult emergence
Ma - Malformed adults

Table 18. Continued

Sl. No.	Treatments	Tae/Tp x 100	Mp/Tp x 100	Ma/Ta x 100	Mp+Ma / Tp+Ta	Mp/Np ratio	Ma/Na ratio	Mp+Ma / Np+Na ratio
1.	*A. calamus*	63.1	0.00	0.00	0.00	0.00	0.00	0.00
2.	*A. sativum*	64.71	0.00	18.18	7.14	0.00	0.22	0.08
3.	*A. squamosa*	55.46	0.00	0.00	0.00	0.00	0.00	0.00
4.	*A. indica*	83.30	8.33	10.00	9.09	0.09	0.11	0.10
5.	*A. paniculata*	60.62	0.00	19.98	7.53	0.00	0.25	0.09
6.	*C. zeylanicum*	30.00	20.04	0.00	15.41	0.25	0.00	0.18
7.	*C. winterianus*	60.00	10.01	0.00	6.26	0.11	0.00	0.07
8.	*C. infortunatum*	82.80	5.66	13.65	9.28	0.06	0.16	0.02
9.	*C. flexuosus*	61.6	15.40	62.55	33.37	0.18	0.67	0.50
10.	*C. martinii*	83.30	0.00	10.00	5.20	0.00	0.11	0.05
11.	*E. grandis*	79.90	0.00	12.52	5.56	0.00	0.14	0.06
12.	*H. sauveolens*	94.70	0.00	11.12	5.41	0.00	0.13	0.06
13.	*K. galanga*	57.90	0.00	18.19	6.67	0.00	0.22	0.01
14.	*M. piperita*	53.30	0.00	12.51	4.35	0.00	0.14	0.05
15.	*M. charantia*	79.13	0.00	0.00	0.00	0.00	0.00	0.00
16.	*S. nux-vomica*	71.40	28.58	10.02	16.67	0.40	0.11	0.26
17.	*V. negundo*	44.50	22.25	37.43	26.93	0.29	0.60	0.37

Tp - Total pupation
Mp - Malformed pupae
Tae - Total adult emergence
Ma - Malformed adults

C. martinii oil (28.6%) treatments. No adult emergence was realized in *C. zeylanicum* oil treatment at three per cent concentration. *C. winterianus* oil(14.3%), *C. martinii oil* (25.0%), *C. flexuosus* oil(28.6%) *V. negundo extract* (28.6%) and *A. indica* extract(37.5%) recorded lower rate of adult emergence at the same level. Out of the 17 treatments, nine produced malformed adults at the three per cent level. Highest percentage of malformation was observed in *A. paniculata* (33.3%) followed by *V. negundo* (28.6%) (Table 18).

The highest rate of pupation of 87.5 per cent each was noticed in *C. infortunatum* and *M. charantia* extracts and *K. galanga* oil treatments at five per cent concentrations. Others recorded pupation in the range of 14.3 to 85.7 per cent. *V. negundo, S. nux-vomica* and *A. indica* extracts gave 42.9, 33.3 and 12.5 per cent pupal malformations respectively. No adult emergence was realized in *C. winterianus* oil treatment. In other treatments adult emergence were observed in a range of 12.5 to 71.4 per cent. Out of 17 extracts, only five allowed more than 40 per cent adult emergence at five per cent level. Malformation rate of 28.6 per cent was noticed in *K. galanga* oil followed by 14.3 per cent in *C. infortunatum, E. grandis, H. sauveolens* and *V. negundo* extracts and *C. flexuosus* oil. *A. indica* extract and *C. martinii* oil treatments produced 12.5 per cent adult malformations each.

The average percentage (from all three levels) of combined normal eclosion upon the normal pupation's (as per 3.5.5)representing the normal turn out of adult formation were lower in *C. flexuosus* oil (27.24%), *V. negundo* extract (34.15%) and *C. zeylanicum* oil (37.6%) treatments. Higher percentage of normal eclosion was noticed in extracts of *S. nux-vomica, H. sauveolens, A. indica* and *C. infortunatum* with 90.03, 84.19, 81.81 and 81.18 per cent respectively. The average percentage of total pupal malformations were in *S. nux-vomica* extract (28.58%), *V. negundo* extract(22.25%), *C. zeylanicum* oil (20.04%), *C. flexuosus* oil (15.5%), *C. winterianus* oil (10.01%), *A. indica* extract (8.33%) and

C. infortunatum extract (5.66%) (Table 17). The ratio of malformed pupae upon the normal pupae (of all concentrations as per 3.5.5) was higher in *S. nux-vomica* extract (0.4:1.0), followed by *V. negundo* (0.29:1.0) and *C. zeylanicum* oil (0.25:1.0).

Out of seventeen botanicals tested, five botanical preparations *viz.*, aqueous extracts of *A. calamus, A. squamosa* and *M. charantia* and oils of *C. winterianus* and *C. zeylanicum* induced no adult malformations. Higher percentage of 62.55 per cent adult malformation was observed in *C. flexuosus* oil treatment and it also had a higher ratio of 0.67:1.0 malformed adults to the normal adults. Other treatments *viz., V. negundo, A. paniculata* and *A. sativum* extracts and *K. galanga* oil caused 37.43 (0.60:1.0), 19.98 (0.24:1.0), 18.18 (0.22:1.0) and 18.19 per cent (0.22:1.0) adult malformations and ratio of malformed adults to normal adults (in parenthesis) respectively.

Total malformations (pupal plus adult malformations at all concentrations as per 3.5.5)of 33.37, 26.93, 16.67 and 15.41 per cent were observed in *C. flexuosus* oil, *V. negundo, S. nux-vomica* and *C. zeylanicum* oil treatments respectively. The ratio between the total malformations (of pupae and adults) to the total number of normal ones (pupae and adults) were 0.5:1.0, 0.37:1.0 and 0.26:1.0 respectively in *C. flexuosus* oil, *V. negundo* and *S. nux-vomica* extracts (Table 18). Extracts of *A. calamus, A. squamosa* and *M. charantia* treatments produced no malformations both in pupal and adult stages of development.

4.3.5.2 Solvent extracts of selected botanicals

Table 19 depicts the results of morphogenic malformation and developmental setbacks in *S. litura* treated with solvent extracts of botanicals during pupation and eclosion

Table 19. Malformations and developmental setbacks in *S. litura* caused by solvent extracts of selected botanicals during pupation and eclosion

Sl. No.	Treatments	1%				3%				5%			
		Tp	Mp	Tae	Ma	Tp	Mp	Tae	Ma	Tp	Mp	Tae	Ma
1.	*Azadirachta indica*												
	Acetone	100	0.0	85.7	0.0	71.4	28.6	42.9	14.3	28.6	0.0	28.6	14.3
	Chloroform	85.7	14.3	85.7	14.3	85.7	28.6	42.9	0.0	57.1	28.6	28.6	0.0
	Dichloromethane	100	33.3	50.0	0.0	83.3	33.3	33.3	16.7	50.0	16.7	16.7	0.0
2.	*Andrographis paniculata*												
	Acetone	100	0.0	100	12.5	87.5	0.0	75	25	50.0	0.0	37.5	12.5
	Chloroform	100	0.0	88.9	11.1	66.7	11.1	44.4	0.0	44.4	0.0	22.2	0.0
	Dichloromethane	100	0.0	71.4	0.0	71.4	0.0	51.1	0.0	57.1	14.3	14.3	14.3
	Methanol	87.5	0.0	87.5	25.0	75.0	0.0	50.0	12.5	25.0	0.0	25.0	0.0
3.	*Vitex negundo*												
	Acetone	85.7	14.3	71.4	14.3	85.7	28.6	14.3	0.0	71.4	28.6	42.9	28.6
	Chloroform	100	0.0	50.0	0.0	71.4	12.5	50.0	12.5	37.5	25.0	12.5	0.0
	Dichloromethane	100	0.0	100	14.3	87.5	0.0	71.4	28.6	71.4	28.6	28.6	0.0
	Methanol	100	0.0	87.5	0.0	87.5	12.5	75.0	12.5	75	25.0	37.5	0.0

Table 19. Continued

Sl. No.	Treatments	Tae/Tp x 100	Mp/Tp x 100	Ma/Ta x 100	Mp+Ma / Tp+Ta	Mp/Np ratio	Ma/Na ratio	Mp+Ma / Np+Na ratio
1.	*A. indica*							
	Acetone	75.02	14.3	18.19	16.01	0.17	0.22	0.19
	Chloroform	91.02	32.86	9.09	22.25	0.46	0.10	0.32
	Dichloromethane	55.31	35.71	16.7	30.0	0.56	0.20	0.43
2.	*A. paniculata*							
	Acetone	68.42	0.0	23.53	12.11	0.00	0.31	0.13
	Chloroform	72.20	5.26	7.14	6.06	0.06	0.08	0.07
	Dichloromethane	53.31	6.26	10.45	7.83	0.07	0.12	0.09
	Methanol	66.67	0.00	23.36	10.71	0.00	0.31	0.13
3.	*V. negundo*							
	Acetone	50.03	29.45	33.36	30.8	0.42	0.50	0.45
	Chloroform	58.34	17.95	11.1	15.56	0.22	0.13	0.18
	Dichloromethane	69.39	11.05	14.3	15.58	0.12	0.27	0.19
	Methanol	83.33	14.29	6.25	10.81	0.17	0.07	0.12

4.3.5.2.1 Solvent extract of *A. indica*

Chloroform extracts of *A. indica* (@ 1.0%) gave the lowest pupation rate of 85.7 per cent (Table 19), whereas, the dichloromethane and chloroform extracts at the same level induced 33.3 and 14.3 per cent pupal malformations respectively. Acetone and chloroform extracts allowed 85.7 per cent adult emergence each followed by dichloromethane extract (50%) at one percent level. Chloroform extract at the same concentration of one per cent induced 14.3 per cent malformed adults, out of the 85.7 per cent adults found in the treatments. At three per cent strength the minimum pupation rate of 71.4 per cent was noticed in acetone extract and the maximum pupal malformation of 33.3 per cent in dichloromethane extract. Dichloromethane and acetone extracts at three per cent levels induced 14.3 and 16.7 per cent adult malformations respectively. At the higher concentration of five per cent, acetone extract gave the lowest pupation of 28.6 per cent, whereas, the chloroform extract caused 28.6 per cent pupal malformations out of the total 57.1 per cent pupation. Minimum adult emergence of 16.7 per cent was recorded in dichloromethane extract, while, the acetone extract caused 14.3 per cent malformed adults.

Treatment with dichloromethane extract of *A. indica* produced the lowest percentage of 55.31 combined normal eclosion (average value of all three concentrations), followed by acetone (75.02%) and chloroform (91.02%) extracts. Highest ratio of 0.56:1 malformed pupae to normal pupae (as per 3.5.5) was recorded in dichloromethane extract with 35.71 per cent malformed pupation followed by chloroform extract (a ratio of 0.46:1 and 32.86%) of pupal malformation. The ratio of malformed adult to the normal adults were 0.2:1 and 0.22:1 for dichloromethane and acetone extracts respectively. It also resulted in 18.19 and 16.7 per cent of adult malformations respectively (Table 19). The ratio of total malformations (in pupal + adult stage malformations in all concentrations as per 3.5.5) to the total turn out of normal pupae and adults was higher in

dichloromethane extract (0.43:1) followed by chloroform extract (0.32:1) which caused 30.0 and 22.25 per cent total malformations respectively.

4.3.5.2.2 Solvent extracts of *A. paniculata*

All the solvent extracts of *A. paniculata* (@ 1.0%) recorded cent per cent pupation except methanol extract which gave only 87.5 per cent pupation. At the same concentration the lowest percentage (71.4%) of adult emergence was recorded in dichloromethane extract. But it had no adult malformation, whereas, methanol, acetone and chloroform extract treatments resulted in 25.0, 12.5 and 11.0 per cent of adult malformations respectively (Table 19).

Highest and lowest percentage of 87.5 and 66.7 pupation was noticed in acetone and chloroform extracts respectively at three per cent concentration. Chloroform extract alone caused pupal malformation of 11.1 per cent at the same strength (pupal malformation was nil in other solvent extracts as shown in Table 19). Adult emergence of 44.4, 50.0, 51.1 and 75 per cent were observed in chloroform, methanol, dichloromethane and acetone extracts respectively. Methanol and acetone extracts (@ 3.0%) resulted in 12.5 and 25.0 per cent adult malformations respectively.

The lowest rate of 25.0 per cent pupation was recorded in methanol extract at five per cent level. Pupal malformation to the tune of 14.3 per cent was recorded in dichloromethane extract. Adult emergence (of 37.5%) recorded in acetone extract was the highest among all solvent extracts at their five per cent concentrations. Only 14.3 per cent adult emergence was recorded in dichloromethane extract and all of them were malformed.(Table 19). Acetone extract also caused 12.5 per cent adult malformations.

The lowest percentage of combined normal eclosion (53.31%) was observed in dichloromethane extract followed by methanol (66.67%).

Dichloromethane (0.07:1) and chloroform (0.06:1) extracts had lesser ratio of pupal malformation to normal pupation with 6.26 and 5.26 per cent respectively. And in other solvents (acetone and methanol) had no pupal malformations at all. In case of adult malformations, acetone and methanol extract caused 23.53 and 23.36 per cent malformations respectively with a ratio of 0.31:1 each (of malformed adult upon the normal adults). The same acetone and methanol extracts realized 11.11 and 10.71 per cent total malformations respectively and both had a ratio 0.13:1 total malformations upon the total pupae and adults put together in all concentrations.

4.3.5.2.3 Solvent extracts of *V. negundo*

Acetone extracts (@ 1%) gave 14.3 per cent malformed pupae out of 85.7 per cent pupation. Other solvents resulted in cent per cent pupation. At the same one per cent concentration, chloroform extract allowed the lowest adult emergence of 50.0 per cent followed by in acetone extract (71.4%). Acetone and dichloromethane extracts experienced 14.3 per cent each of malformed adults.

At three per cent strength, 71.4 and 85.7 per cent pupation was recorded in chloroform and acetone extracts. Rest of the two solvent extracts *viz.*, dichloromethane and methanol caused 87.5 per cent pupation each. Acetone, chloroform and methanol extracts caused 28.6, 12.5 and 12.5 per cent pupal malformations respectively at three per cent concentration. Higher percentage of 75.0 per cent adult emergence was recorded in methanol extract followed by dichloromethane extract (71.4%), whereas, acetone extract allowed only 14.3 per cent adult emergence at the same level. Dichloromethane extract produced 28.6 per cent malformed adults, while chloroform and methanol extracts produced 12.5 per cent malformed adults.

The lowest pupation of 37.5 per cent was recorded in chloroform extract (@ 5%) as evidenced from Table 19. Acetone and dichloromethane extract had

28.6 per cent pupal malformations each, whereas, methanol and chloroform extracts resulted in 25.0 per cent each. In the case of adult emergence, while, chloroform extract permitted only 12.5 per cent emergence, other treatments *viz.* dichloromethane, methanol and acetone extracts gave 28.6, 37.5 and 42.9 per cent emergence respectively at their five per cent level. Acetone extract was the only treatment which caused adult malformation of 28.6 per cent at five per cent level.

The maximum and minimum of 83.33 and 50.03 per cent combined normal eclosion was observed in methanol and acetone extracts respectively. The highest percentage of 29.45 per cent pupal malformation was recorded in acetone extract with a ratio of 0.42:1 malformed pupae to the normal pupae. Adult malformation was also higher in acetone extract (33.36%) with a ratio of 0.5:1 malformed adults to the normal adults. Total combined malformations (pupal + adult stages) of 30.8, 15.58, 15.56 and 10.81 per cent were obtained in acetone, dichloromethane, chloroform and methanol extracts respectively. The ratio of total malformation to total normal pupae and adults was 0.45:1 in acetone extract followed by chloroform and dichloromethane with 0.16:1 each.

4.3.6 Median Lethal Concentration (LC_{50}) of botanicals on *S. litura* larvae

These results are elucidated in Table 20. Preliminary experiments on the topical toxicity of the botanicals on the test insect revealed that only essential oils resulted in larval mortality by topical application on the third instar larval stage. Hence, only essential oils *viz.*, *C. winterianus*, *C. flexuosus*, *M. piperita* and *C. martinii* oils only were selected and subjected to experimentation and probit analysis to determine their LC_{50} values.

Acetone extracts of *A. indica, A. paniculata* and *V. negundo* were tested for its topical toxicity by micropipette application technique (as per 3.5.6). None of the acetone preparations of the above botanicals produced any mortality on the test

Table 20. LC_{50} value of essential oils for *S. litura*

Sl No.	Treatment	Heterog-enity χ^2	Regression equation	LC_{50} value in ppm	Relative toxicity to *C. martinii*
1	*Citronella winterianus*	6.79	y = 14.92 + 6.93x	370	2.08
2	*Cymbopogon flexuosus*	5.61	y = 12.99 + 5.31x	311	1.75
3	*Cymbopogon martinii*	9.69	y = 9.35 + 2.48x	178	1.00
4	*Mentha piperita*	7.55	y = 10.84 + 3.74x	273	1.53

insects even after 72 hours, whereas, out of the six essential oils, four oils *viz.*, *C. winterianus*, *C. flexuosus*, *M. piperita* and *C. martinii* produced larval mortality under the laboratory conditions. LC_{50} values were calculated for this essential oils by probit analysis. Among these four oils, *C. martinii* oil treatment produced 50 per cent mortality at 178 ppm, whereas, *C. winterianus* oil gave the same at 370 ppm. LC_{50} values determined for *C. flexuosus* and *M. piperita* oils were 311 and 273 ppm respectively.

Discussion

5. DISCUSSION

The experimental results obtained in the study are briefly discussed here under drawing the various inferences.

5.1 SURVEY ON THE BOTANICAL RESOURCES

Seasonal availability of the raw botanicals were more in rainy season especially during the two monsoon periods. It was worthwhile to note that, in the different medicinal plant material/produces, there were quality grades depending upon the place of cultivation and accordingly there was wide variation in the cost structure. Plant material marketed in Thrissur included those from countries/states as far away as China, Nepal, Assam, West Bengal and Kolkata. Storage life of many of the botanicals were about one year if they were properly dried/processed and stocked. Fresh plant material like Thulasi, *Vitex* etc. could be stored up to one week only and in such cases there was demand for fresh material only (Appendix I).

5.2 LABORATORY REARING OF *S. litura*

It was found that the rearing of *S. litura* from early third instar larvae was more efficient in terms of vigour of the stages, escape from NPV infection and ease of mass culturing, on semi-synthetic diet than on natural diet.

5.3 BIOEFFICACY OF THE SELECTED BOTANICALS

5.3.1 Ovipositional deterrency

5.3.1.1 Aqueous extracts

Hyptis sauveolens aqueous extract was found to be highly deterrent to oviposition by the adult moths of *S. litura* at one per cent concentration (as per 3.5.1and Table 3). However, *Thevetia nerifolia* extract allowed maximum number

of egg layings and therefore, it was inferred that it had no ovipositional deterrency at all at the same concentration. But at the same time it was having good antifeedant action as reported by Bai and Koshy (1999) against *Henosepilachna vigintioctopunctata.*

All the botanical extracts tested were showing considerable deterrency to oviposition by *S.litura* at five per cent concentration. Patel and Patel (1998) had found that the neem seed kernel suspension at two and four per cent levels showed ovipositional deterrency against the test insect *S. litura* adults. In this experiment also it was found that *Azadirachta indica* extract had a higher ovipositional deterrency than the others as evidenced by very small egg masses on the treated surface. At the same concentration (*viz.*, 5%), *H. sauveolens* extract also showed good repellency against oviposition which was next to *A. indica* extract in the efficiency order.

At still higher concentration of 10 per cent, *A. indica* and *H. sauveolens* extracts were highly deterrent to adult oviposition. *Andrographis paniculata* and *Adathoda vasica* extracts were also showing deterrency at 10 per cent level equal to that of *H. sauveolens* extract at five per cent. The ovipositional deterrency of *A. paniculata* against *P. xylostella* had been reported by Hermawan *et al.* (1998). The deterrency of *M. azedarach* and *A. vasica* extracts were also proved by Deka *et al.* (1999) against *S. litura.*

At all the three concentrations (*viz.*, 1, 5 and 10%) tested, both *H. sauveolens* and *A. indica* extracts proved efficient in ovipositional deterrency as compared to others.

5.3.1.2 Essential oils

From the experiment, it was found that at the lowest concentration of 0.1 per cent, none of the treatments had any significant ovipositional deterrency

except *Cinnamomum zeylanicum*, whose ovipositional deterrency was moderate as compared to others. *Kaempferia galanga* oil had no ovipositional deterrency as inferred from its score of 24 which was equal to the control score. At 0.5 per cent concentration, *Cinnamomum zeylanicum, Cymbopogon martinii* and *Cymbopogon flexuosus* oils showed high ovipositional deterrency as shown by the lower number of egg masses on the treated surface. At the highest concentration (of 1%) all the treatments prevented egg laying as observed from Table 4. This corroborates the results of Tare (2000) who also reported that the medicinal plant oils had cent per cent ovipositional deterrency against *P. operculella, S. litura* and *A. janata*. However, scorching of the treated leaves were noticed at this concentration (1%) possibly due to oil phytotoxaemia.

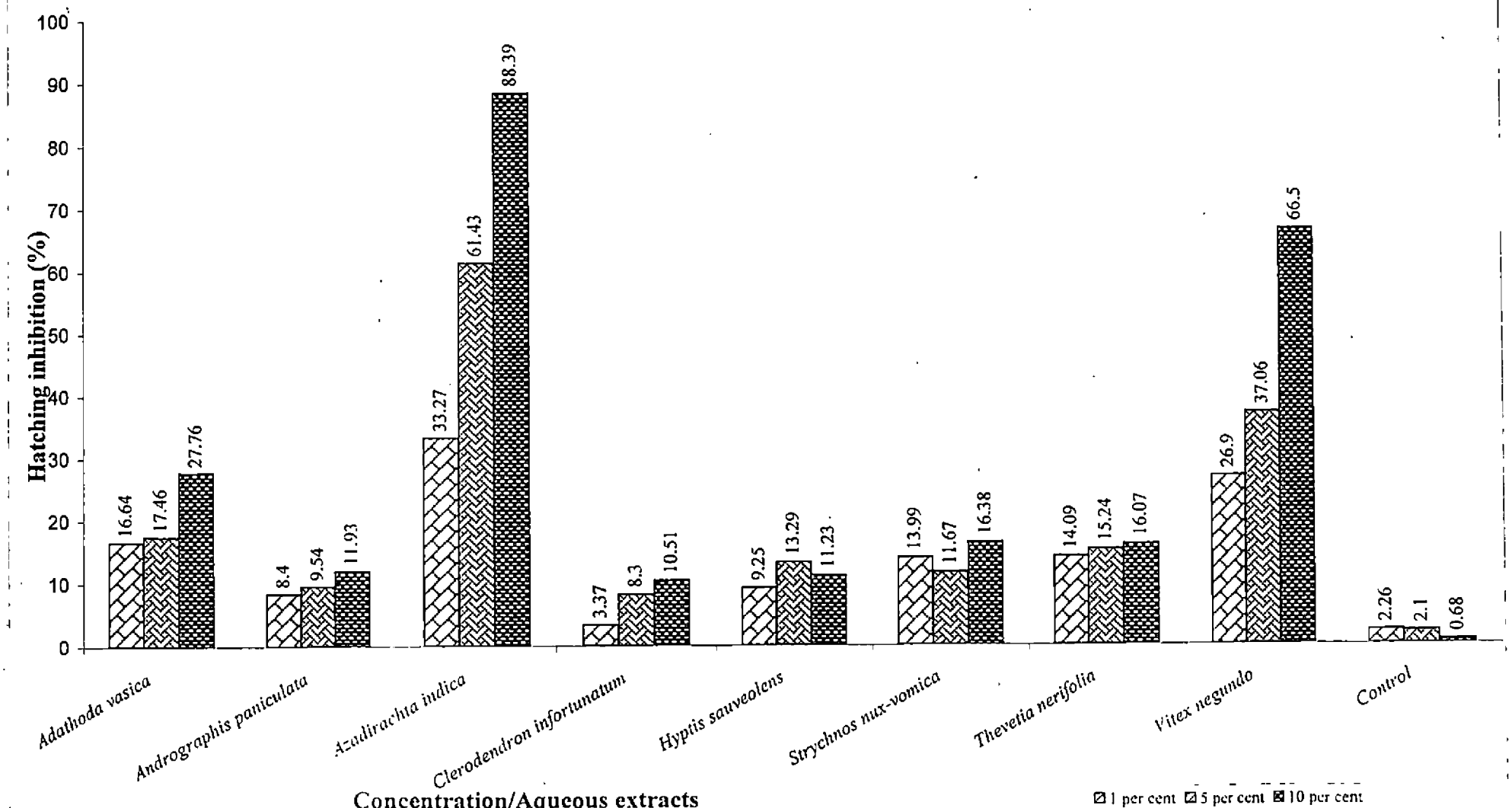
Similarly, Chiu (1985) also observed that neem seed oil (6%) exhibited strong oviposition - deterring effects to *Orseolia oryzae* in rice. The highest percentage of 54.55 oviposition was observed in *K. galanga* treated surface and the lowest in *C. zeylanicum* treatment (25.0%). Therefore, it may be suggested that the *C. zeylanicum* oil can be effectively utilized in deterring the *S. litura* adults from oviposition at 0.5 per cent level but its persistence as to be studied.

5.3.2 Ovicidal action

5.3.2.1 Plant extracts

A perusal of the data (Table 5 and Fig.1) on the hatching percentage of treated eggs of *S. litura* reveals the general aspects of plant extracts and their ovicidal properties which was calculated as per 3.5.2. *A. indica* aqueous extracts gave lowest hatching percentage at all the levels (1, 5 and 10%) indicating its efficacy as supported by Ghatak and Bhusan,(1995). These workers also found that the petroleum ether and methanol extracts of neem seeds (@ 1.5%) caused cent per cent ovicidal action to *S. obliqua* eggs. contrary to this Patel and Patel (1997) found that the neem seed kernel suspension and neem leaf extract suspension in water at three per cent strength showed only 20 and 15 per cent mortality of the

Fig. 1.Effect of aqueous plant extracts on hatching inhibition (%) of *S.litura* eggs.



treated eggs of *H. armigera*. Next to *Azadirachta indica, Vitex negundo* aqueous extract gave the lower hatching percentages of 73.10, 62.94 and 33.50 per cent at one, five and ten per cent strengths respectively indicating its ovicidal value (Table 5 and Fig.1). More or less similar results of 45 to 90 per cent inhibition of hatching was reported with *Vitex leucoxylon* stem extract with an inhibition dose (ID_{50}) of 8.5 µg against *S. litura* eggs (Suryakala *et al.*, 1995). The *V. negundo* extract was also found to cause upto 83 per cent egg mortality of *P. xylostella* (Dayrit *et al.*, 1995).

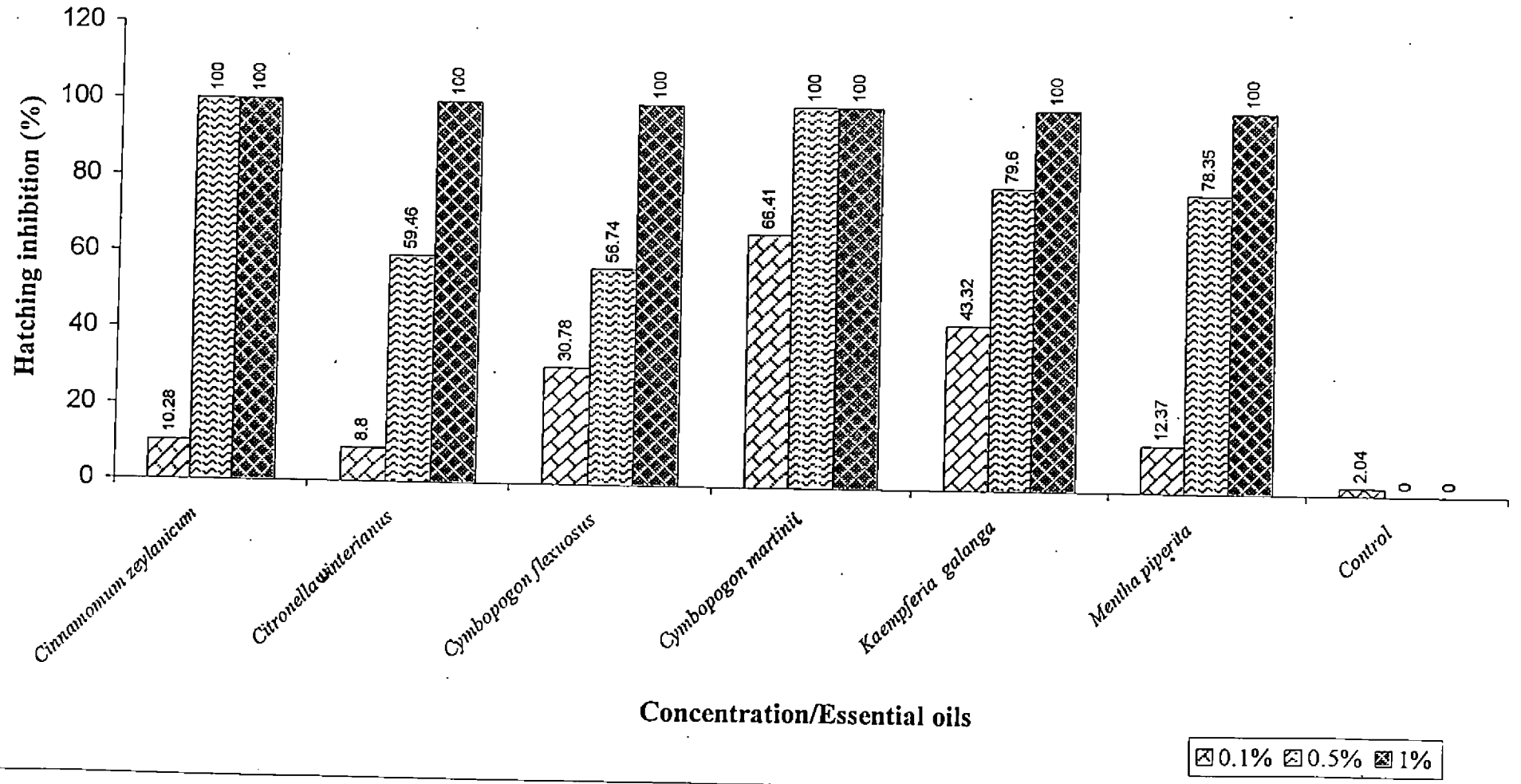
Even at the highest concentration (10%) *A. vasica* had a lower ovicidal action of 28 per cent. Suryakala *et al.* (1995) also reported almost the same effect with *A. vasica* leaf extract giving a range of 20 to 70 per cent inhibition of egg hatching with an higher ID_{50} of 61 µg against *S. litura*. Extracts of *A. paniculata, C. infortunatum* and *H. sauveolens* did not differ significantly as compared to the control, at their one and five per cent concentrations showing less ovicidal action on the test insect. From this experiment it could be found that *A. indica* and *H. sauveolens* extracts at five or ten per cent level can be used against *S. litura* eggs.

5.3.2.2 Essential oils

In all the six essential oil preparations (@ 1%) tested, there was cent per cent egg mortality (Table 6 and Fig.2). At the lower concentration of 0.1 per cent, *C. martini* oil was effective (50%) followed by *K. galanga* (40%) ovicidal effect on *S. litura* eggs. At 0.5 per cent strength, *C. zeylanicum* and *C. martini* oil preparations produced cent per cent ovicidal action. At all tested concentrations, all the essential oil preparations were significantly better in offering ovicidal action as compared to control.

Similar ovicidal actions are reported elsewhere also. *C. zeylanicum* stem extracts caused 30 to 80 per cent hatching inhibition with an ID_{50} value of 17 µg

Fig. 2. Effect of essential oils on hatching inhibition (%) of *S. litura* eggs



against *S. litura* eggs (Suryakala *et al.*, 1995). Saxena *et al.* (1981) reported that the dip treatment of eggs of *C. medinalis* in neem oil prevented the emergence of first instar larvae. Similarly, Bhathal *et al.* (1991) also found that neem oil at 5000 ppm was found to completely prevent the hatching of treated eggs of *D. koenigii* (0-12 hours old). The results suggest that the oil preparations of *C. martini* and *C. zeylanicum* (0.5% level) could be used as an ovicidal spray for controlling *S. litura* at the egg/egg laying stage which may be biologically and economically more efficient.

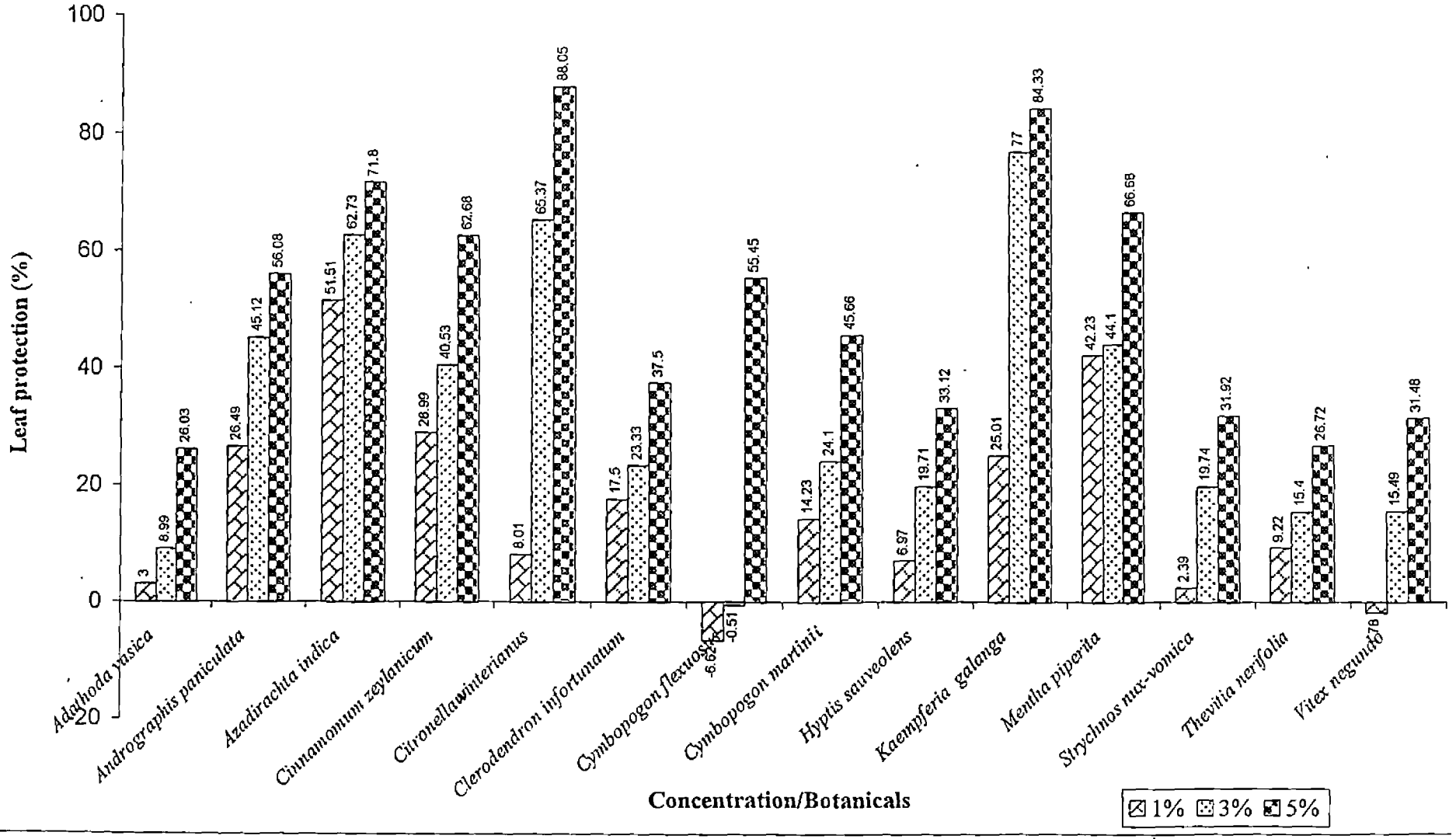
5.3.3 Antifeedant action

5.3.3.1 Effect of aqueous plant extracts and essential oils on the percentage of leaf protection against *S. litura*

Data relating to the percentage of leaf protection as per 3.5.3.3 are represented in the Table 7 and Fig.3 throws light on antifeedant aspects of botanical preparation against *S. litura.*

Azadirachta indica aqueous extract offered consistent feeding inhibition of 51.15, 62.73 and 71.80 per cent at one, five and ten per cent levels respectively in a dose dependent manner (Table 7 and Fig.3). Kumar *et al.* (1997) also got similar results in fifth instar larvae of *S. litura.* At three per cent concentration, high feeding inhibition range of 62 to 77 per cent were obtained with *A. indica* aqueous extract, *K. galanga* and *Citronella winternianus* oils. At still higher concentration of five per cent, very high feeding inhibition of above 80 per cent was noticed in *C. zeylanicum* and *C. winterianus* oils. These experimental results agree with the findings of Sharma *et al.* (1990). They reported that essential oils of *Angelica glauca* (root) and *Acorus calamus* (rhizome) exhibited significant antifeedancy to the level of cent per cent protection at five per cent each against *S. litura.* A range of 50 to 70 per cent feeding inhibition was also observed in case of *A. indica, M. piperita, A. paniculata* and *C. flexuosus* preparations (@ 5% level) in this experiment.

Fig. 3. Effects of botaniclas on leaf protection (%) against *S.litura*



Essential oils performed better than the aqueous plant extracts in affording leaf protection against *S. litura*. *C. winterianus* and *K. galanga* oils and *A. indica* aqueous extract were almost on par with their higher rate of leaf protection at the moderate, non-phytotoxic level of three per cent. Still at higher level of five per cent, *C. zeylanicum, C. winterianus, K. galanga* and *M. piperita* oils as well as *A. indica* aqueous extract were equally good in offering efficient feeding deterrency.

The antifeedancy of *A. paniculata* was reported against *P. xylostella* by Hermawan *et al.* (1993). In the present experiment also, *A. paniculata* extract caused more than 50 per cent feeding inhibition. Venkadasubramanian and David (1999) recorded that the *C. martinii* oil at one per cent level caused cent per cent mortality of *S. litura* third instar larvae. However, the results obtained from the experiment here, it was disagreeable with the above authors. This may be due to the variation if any in the biotype of the test insect as well as the environmental conditions prevailing over here.

Therefore, it can be concluded that essential oils *viz.*, *C. winterianus, K. galanga, M. piperita, C. zeylanicum* etc. as well as neem seed extracts are better antifeedants in affording leaf protection against *S. litura* feeding when the insects were allowed to fed immediately after treatment on the treated surfaces.

5.3.3.2 Effect of aqueous plant extracts and essential oils on the percentage of larval starvation against *S. litura*

At one per cent concentration, none of the treatments elicited any larval starvation except *A. indica* aqueous extract (with 45.43%). Oils of *K. galanga* (70.98%) and *C. martinii* (62.30%) followed by extract of *A. indica* (56.75%) induced better larval starvation at three per cent level. At five per cent level, the percentage of larval starvation was very high with *C. martinii, K. galanga* and

C. winterianus oils and *A. indica* aqueous extract which had a range of 65 to 82 per cent starvation.

Therefore, it was inferred that *K. galanga* and *C. martinii* oils and *A. indica* aqueous extract were consistently better in inducing higher larval starvation of more than 55 per cent at the three and five per cent levels of preparations as evidenced from Table 8 and Fig.4.

Saradamma (1989) also reported the larval starvation of 78.25, 59.21, 34.14 and 25.08 per cent in *A. indica. C. infortunatum, T. nerifolia* and *V. negundo* aqueous extracts respectively against *S. litura.* In this experiment too, the larval starvations for the above mentioned treatments were almost in conformity except that of *C. infortunatum* (Table 8 and Fig.4). Bai and Koshy (1999) reported that the *T. nerifolia* aqueous extract caused 84.5 per cent larval starvation of *H. vigintioctopunctata* at four per cent level, whereas, in this experiment the same extract at five per cent level caused only 28.47 per cent larval starvation. The reason may possibly be the difference between the coleopteran and lepidopteran selectivity/sensitivity. This type of selectivity between coleopteran and lepidopteran insects were also reported by Bowers (1980) with differential less feeding deterrency or sensitivity with respect to botanicals.

5.3.3.3 Solvent extracts of botanicals on leaf protection and larval starvation of *S. litura*

5.3.3.3.1 Solvent extracts of *A. paniculata*

The percentage of leaf protection afforded by the acetone extract of *A. paniculata* was 71 to 77 per cent respectively at four and five per cent concentrations, whereas, dichloromethane extract gave 78 to 84 per cent feeding inhibition at the same levels (Table 9 and Fig.5). However, chloroform and methanol extracts had comparatively lower feeding inhibition even at the higher concentration of five per cent of either. The antifeedancy of *A. paniculata* extract

Fig. 4. Effect of botanicals on larval starvation (%) of *S. litura*

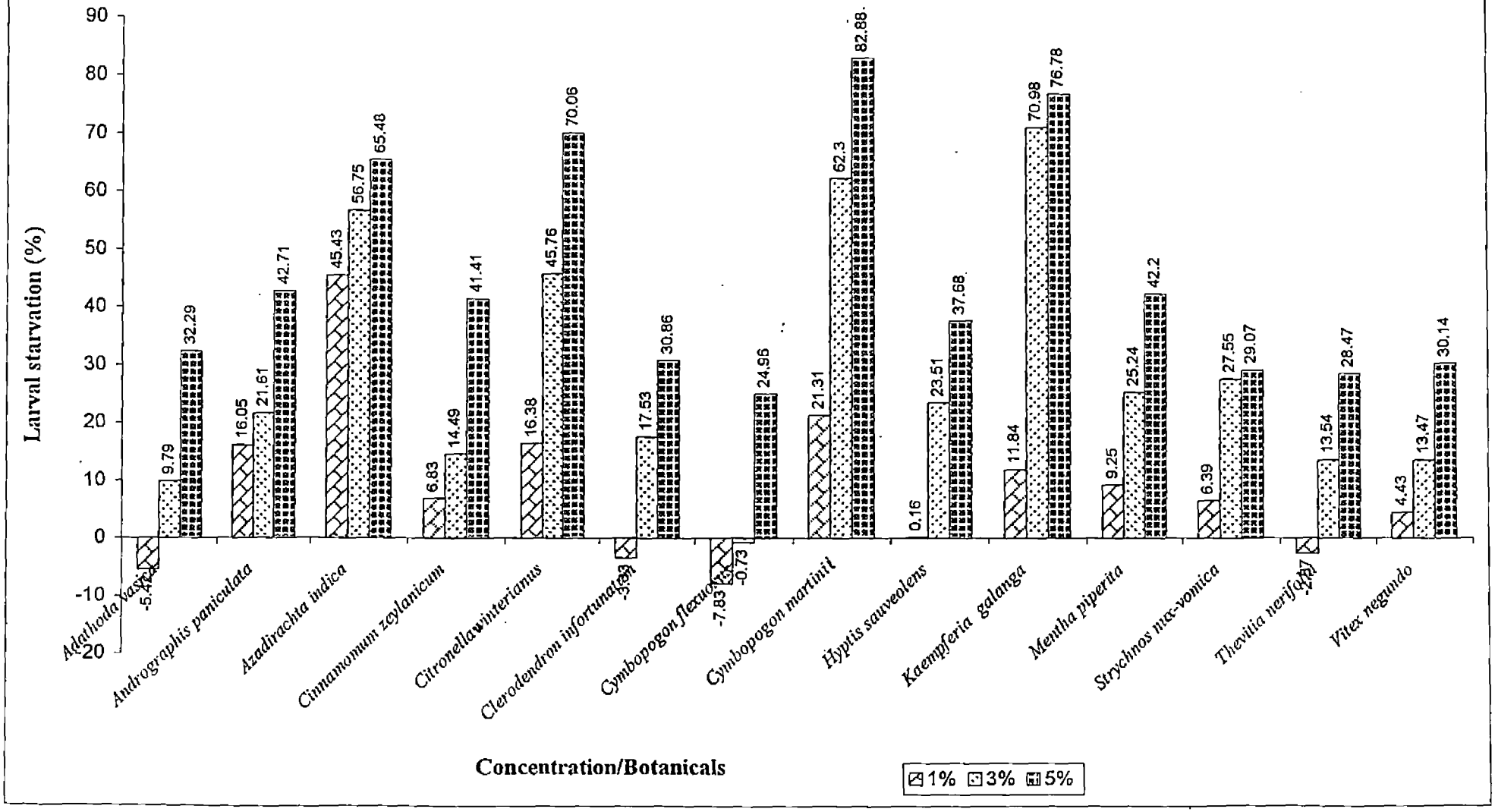


Fig.5. Effect of *Andrographis paniculata* solvent extracts on leaf protection (%) against *S.litura*

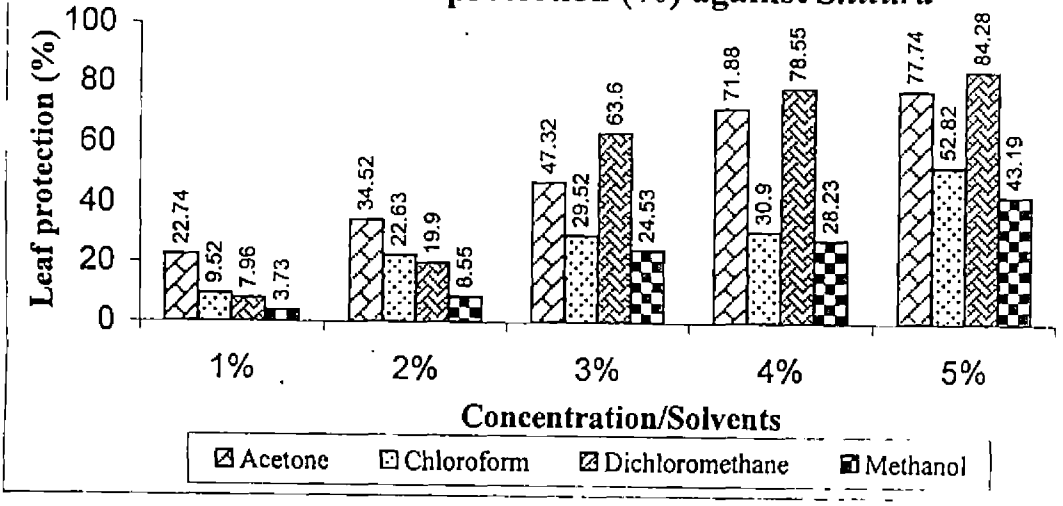
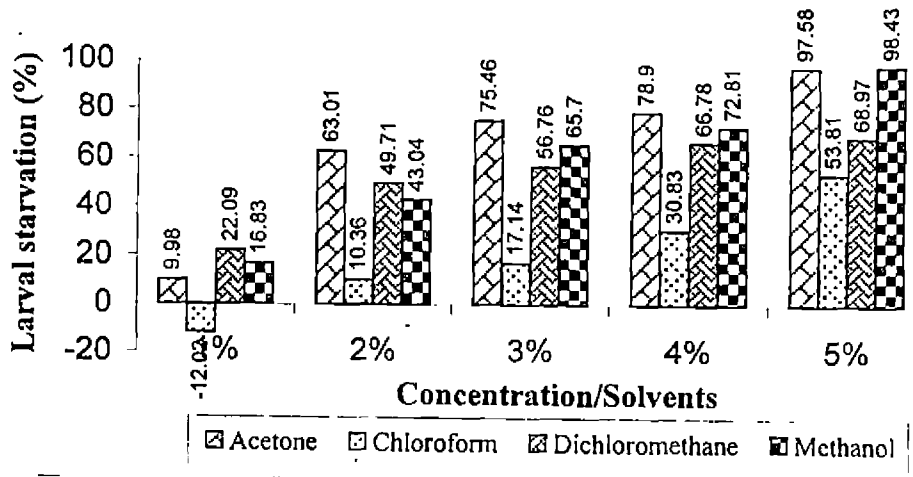


Fig.6. Effect of *A . paniculata* solvent extracts on larval starvation (%) of *S.litura*



was already reported by Hermawan *et al.*(1993) against *P. xylostella* and by Widiarta *et al.* (1997) against *N. cincticeps.* The present results agree with the above reports. Hermawan *et al.* (1997) found that the antifeedant action was due to presence of a major component "andrographolide", a diterpenoid.

A very high activity of larval starvation was noticed in acetone and methanol extracts of *A. paniculata* which gave 65 to 95 per cent range of larval starvation at three to five per cent strength. Eventhough dichloromethane extract gave high feeding inhibition, the larval starvation elicited was lower when compared to its acetone extract and *vice versa* with methanol extract as indicated in Table 10 and Fig.6. Methanol fraction of *A. paniculata* possessed high antifeedant properties with its FD_{50} (Feeding deterrency) value of 159.7 µg/g diet against *S. obliqua* (Tripathi *et al.*, 1999). Gunasekaran and Chelliah (1985a) observed that the acetone extract of *A. paniculata* had a higher antifeedant activity against *S. litura* larvae than its aqueous extract. Those results are almost in conformity with the present studies. Therefore, it may be inferred that, acetone extract was effective in offering higher leaf protection as well as eliciting higher larval starvation against *S. litura* larvae.

5.3.3.3.2 Solvent extracts of *V. negundo*

Dichloromethane extract of *V. negundo* offered 48 to 67 per cent leaf protection at three to five per cent levels, whereas, methanol extract gave protection of 40 to 64 per cent at the same levels. However, acetone and chloroform extracts of the same had a low feeding inhibition even at its higher concentrations as inferred from Table 11 and Fig.7. This corroborates with the results of Saradamma (1989) who also reported that the acetone extract of *V. negundo* gave a low level of leaf protection and lower larval starvation.

Dichloromethane and methanol extracts (@ 5%) induced 48.0 and 55.0 per cent larval starvation respectively. These were found to be superior to the other

Fig.7. Effect of *Vitex negundo* solvent extracts on leaf protection (%) against *S.litura*

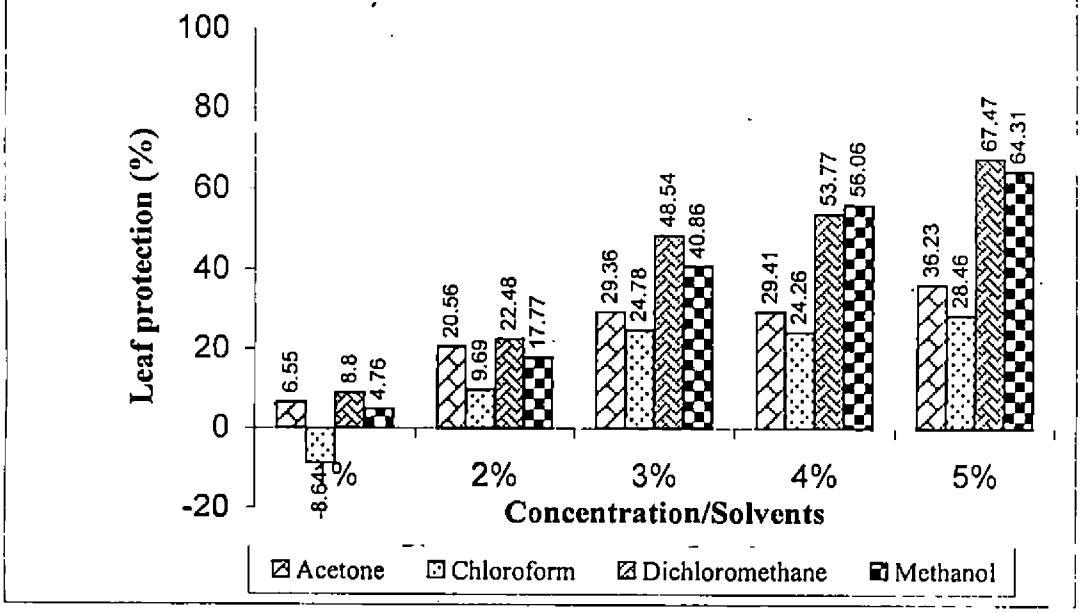
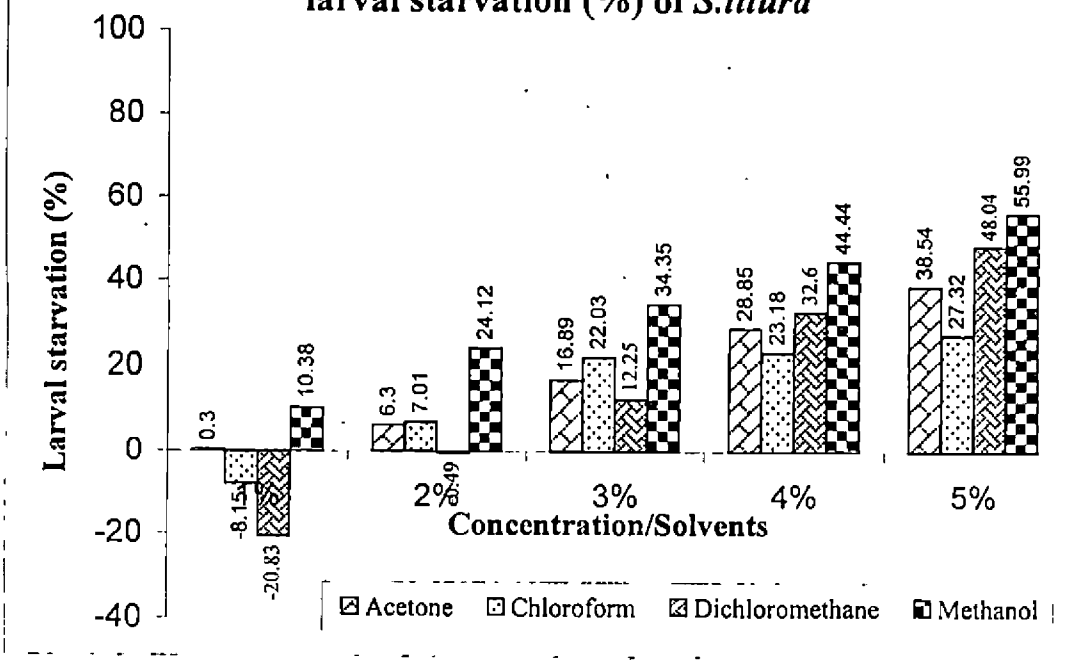


Fig.8. Effect of *V. negundo* solvent extracts on larval starvation (%) of *S.litura*



solvent extracts (Table 12 and Fig.8). Similar to the lower leaf protection obtained in acetone and chloroform extracts, larval starvation elicited by the same solvent extracts of *V. negundo* were also low. Sahayaraj (1998) also reported that was the highest antifeedancy was shown by *V. negundo* aqueous extract against *S. litura* as against other solvent extracts. At the same time, it was found that acetone extract of the same showed good antifeedancy against *E. vitella, D. indica* and *E. septima* (Kalavathi *et al.*, 1991) which meant to conflicting effects of the same botanical with different solvents on different test insects. Therefore, the selection of botanical, method of extraction, target insect, etc. have to be taken care of when they are recommended for IPM programmes.

5.3.3.3.3 Solvent extracts of *A. indica*

Both acetone and chloroform extracts showed high feeding inhibition of more than 77 per cent at five per cent concentration. All the three solvent extracts including dichloromethane extract gave more than 60 per cent feeding inhibition (@ 4% and above). However, in one per cent acetone and dichloromethane extracts of *A. indica* the consumption of treated leaves was more than that in the untreated control as indicated in Table 13 and Fig.9. This observation indicates that botanicals at lower levels can be phagostimulatory to *S. litura* larvae and hence dosage should be taken care of. All the larvae treated with four and five per cent methanol extract were killed and the percentage of leaf protection and larval starvation could not be calculated for this extract as a result of its insecticidal effects and hence, this treatment afforded cent per cent leaf protection. Mohapatra *et al.* (1995) also reported that there was cent per cent protection of treated leaves against *S. litura* by the neem seed kernel methanol extract applied as encapsulated forms.

In case of larval starvation, chloroform extract was better than the other two solvent extracts (*viz.*, acetone and dichloromethane) with 50.89 and 59.37 per cent starvation respectively at two and three per cent concentrations and more than

Fig. 9. Effect of *Azadirachta indica* solvent extracts on leaf protection (%) against *S.litura*

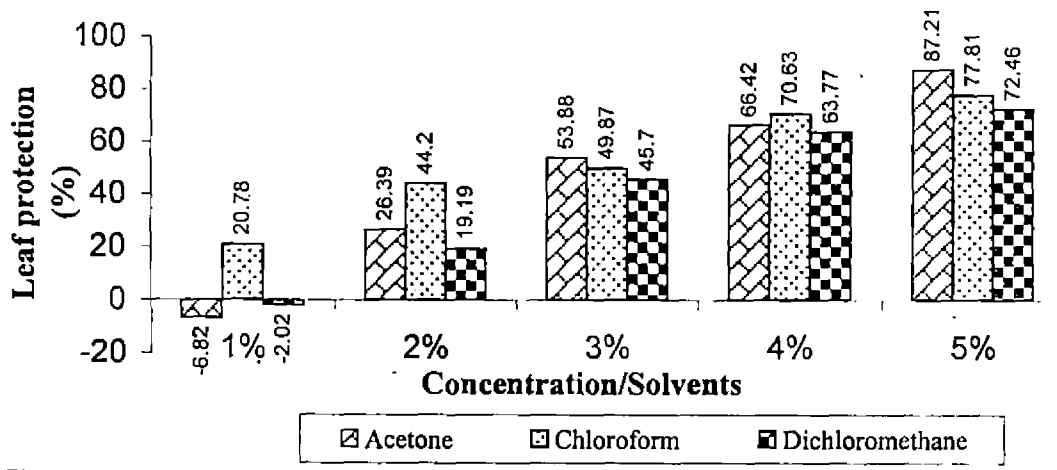
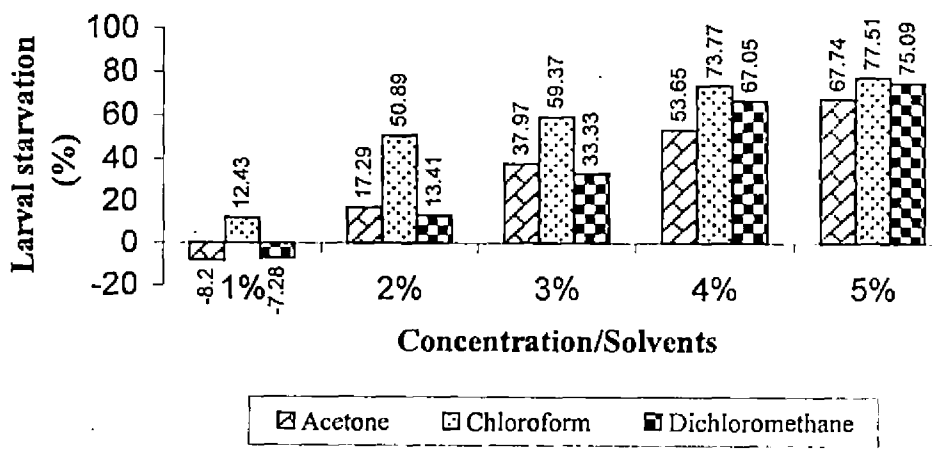


Fig. 10. Effect of *A . indica* solvent extracts on the larval starvation (%) of *S.litura*



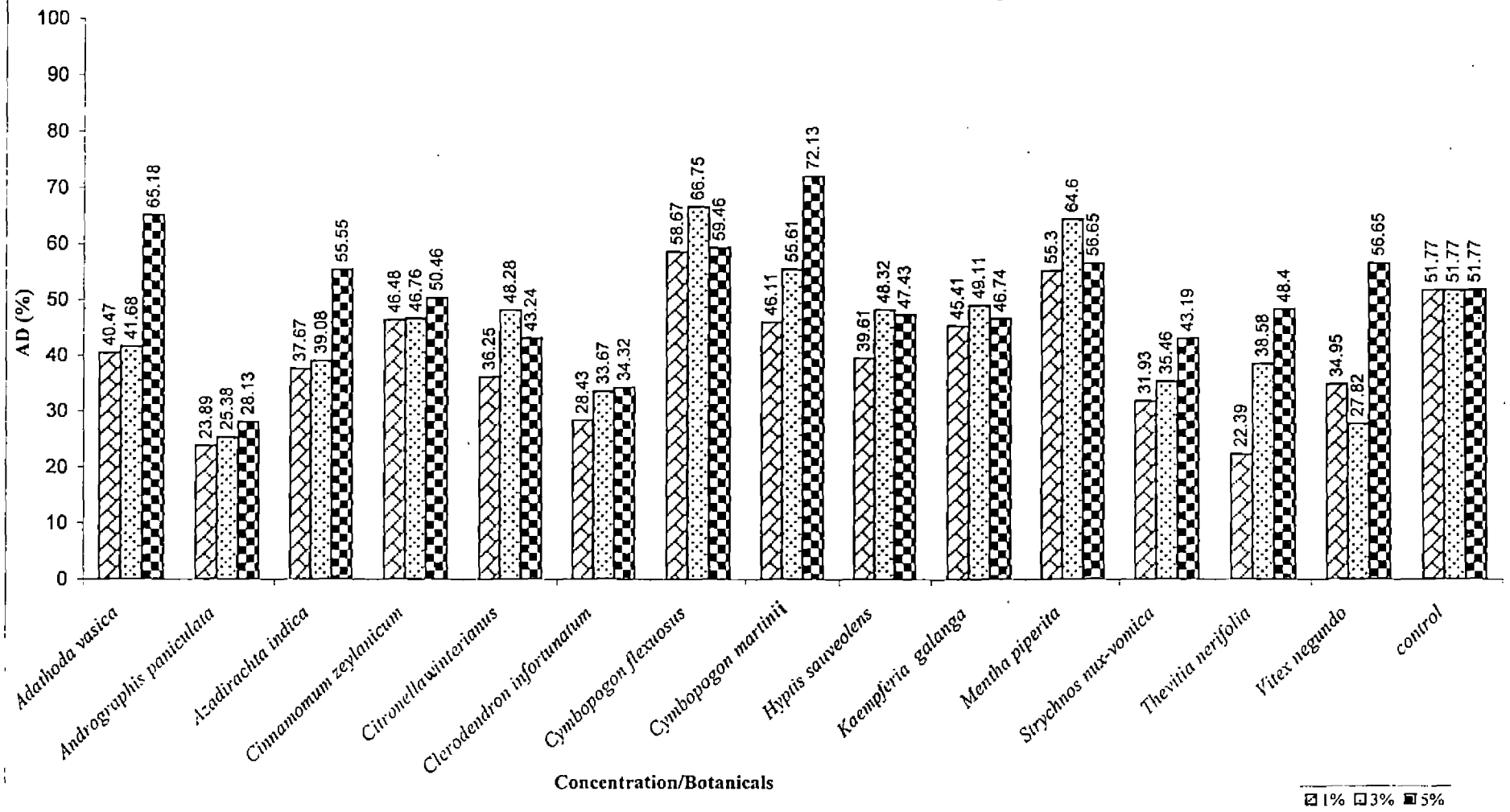
70 per cent starvation at other higher concentrations. Dichloromethane extract also gave more than 67 per cent larval starvation at the same level and it was at par with the chloroform extract as shown in the Table 14 and Fig.10. Saradamma (1989) also reported the leaf protection and larval starvation of *S. litura* as induced by acetone extract of *A. indica* against *S. litura*. In this experiment, the effect of feeding inhibition was similar to the above report with the same acetone extract.

5.3.4 Effect of botanicals in reducing the food consumption and utilization of *S. litura* larvae

5.3.4.1 Effect of aqueous plant extracts and essential oils on the Approximate Digestibility (AD) of *S. litura*

At one per cent concentration, AD value(calculated as per 3.5.4) of most of the botanical treatments was less than that of control indicating their negative influence upon the digestion process of the larvae. *A. paniculata, T. nerifolia* and *C. infortunatum* extracts (@ 1% level) had very low AD value indicating their high digestive inhibition level. AD value at three per cent concentration was also lower in most of the treatments (*viz.*, *A. paniculata, V. negundo, C. infortunatum, S. nux-vomica, T. nerifolia,* etc.) as compared to control indicating their digestive inhibition at this level also. However, at the higher concentration of five per cent, out of the 14 botanicals, seven botanicals (*viz.*, *A. vasica, A. indica, C. zeylanicum, C. flexuosus, C. martinii, M. piperita* and *V. negundo*) had a higher AD value as compared to control (Table 15 and Fig.11). At all the three concentrations (*viz.*, 1, 3 and 5% level) *C. flexuosus* and *M. piperita* oil preparations had higher AD value than control, which prove that these botanicals have no digestive toxicity. However, with most of the extracts, percentage of AD was found to be increasing with increasing levels of concentration. The same trend was also reported by Chitra and Rao (1996) in *S. litura* with *N. odorum, A. mexicana* and *A. indica*. The results indicated that they are not digestive inhibitors at higher levels and their mode of action may be behaviouristic, by bringing about repellency or antifeedancy. Sahayaraj (1998) observed that at much higher concentration of 10 per cent,

Fig. 11. Effect of botanicals on Approximate Digestibility (AD %) of *S.litura*



A. indica, Z. officinale, C. sinensis and *V. negundo* had a lower AD value as compared to control.

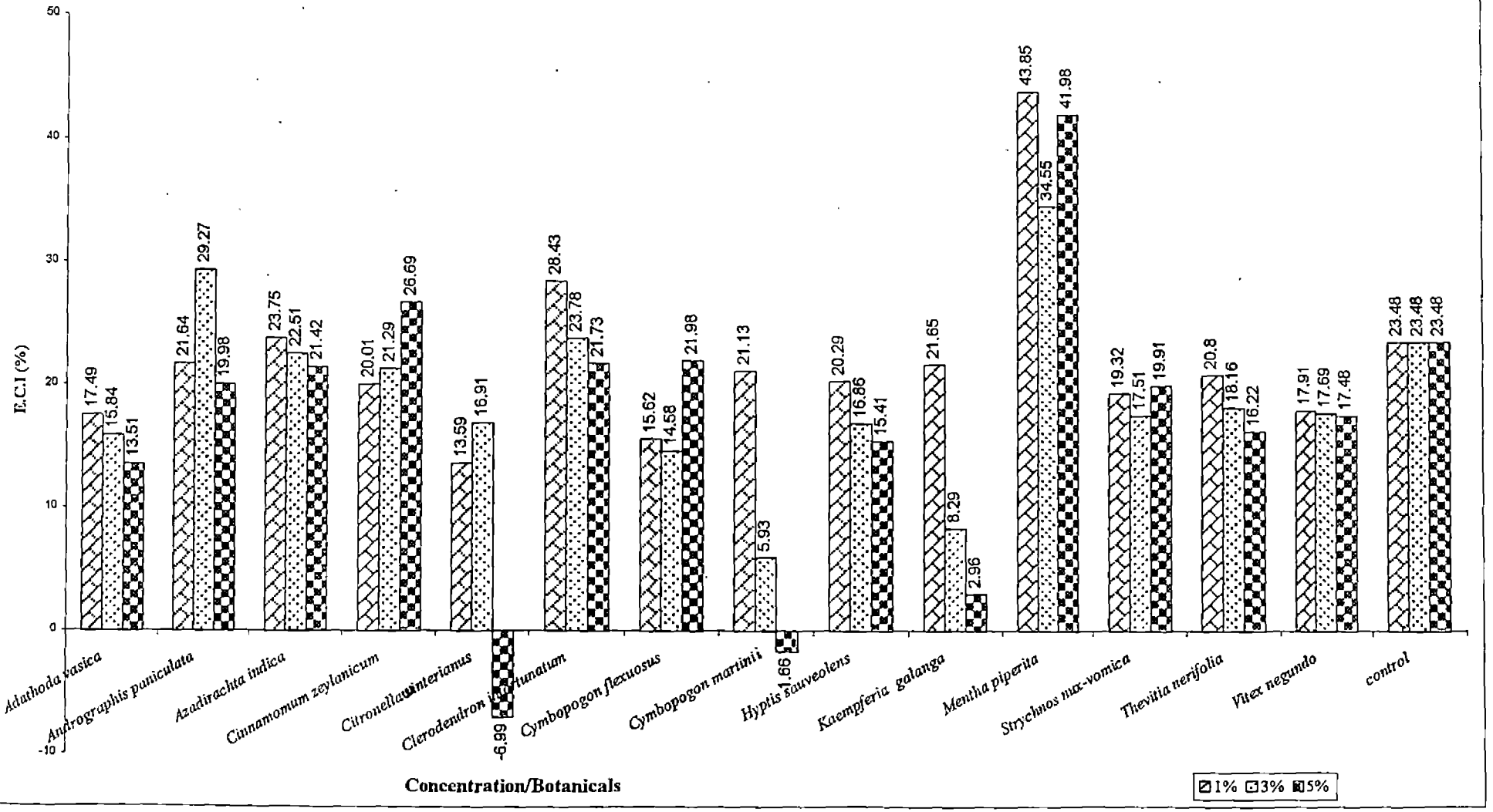
5.3.4.2 Effect of botanicals on the Efficiency of Conversion of Ingested food to body tissues (ECI)

In eight treatments out of 14, the assimilation of ingested food to body tissues (as per 3.5.4) decreased with increasing concentration of the extracts. In rest of the treatments, the response was erratic as evidenced from Table 16 and Fig.12. Chitra and Rao (1996) also found that ECI was inversely proportional to concentrations in *S. litura* treated with *N. odorum, A. mexicana* and *A. indica* extracts. *C. winterianus* and *C. flexuosus* oils and *A. vasica* and *V. negundo* aqueous extracts had low ECI values showing their assimilatory inhibition even at one per cent concentration. At three and five per cent concentrations in addition to the above treatments, oils of *C. martinii* and *K. galanga* and the extract of *H. sauveolens* produced lower ECI values which again proved their effect against the *S. litura* by inhibiting assimilation of food. Oil preparation of *C. winterianus* and *C. martinii* at five per cent level resulted in negative ECI values which indicate that they can be potential growth inhibitors preventing normal weight gain and consequently growth of the insect. Similar observation was made by Sahayaraj (1998) in *S. litura* with *A. indica, Z. officinale, C. sinensis* and *V. negundo* extracts at 10 per cent level. The ECI value in *M. piperita* (@ 1, 3 and 5% levels), *A. paniculata* (@ 3%) and *C. zeylanicum* (@ 5%) were much higher than control ECI (Table 16 and Fig.12), proving that they may not be growth inhibitors but can be growth promoters as far as insect feeding, digestion and assimilation processes are concerned.

5.3.4.3 Effect of botanicals on the efficiency of Conversion of Digested food to body matter (ECD)

The ECD values (as per 3.5.4) were also found to decrease with the increase in concentrations of botanicals which indicated that the treatments were

Fig. 12. Effect of botanicals on E.C.I. (%) of *S.litura*



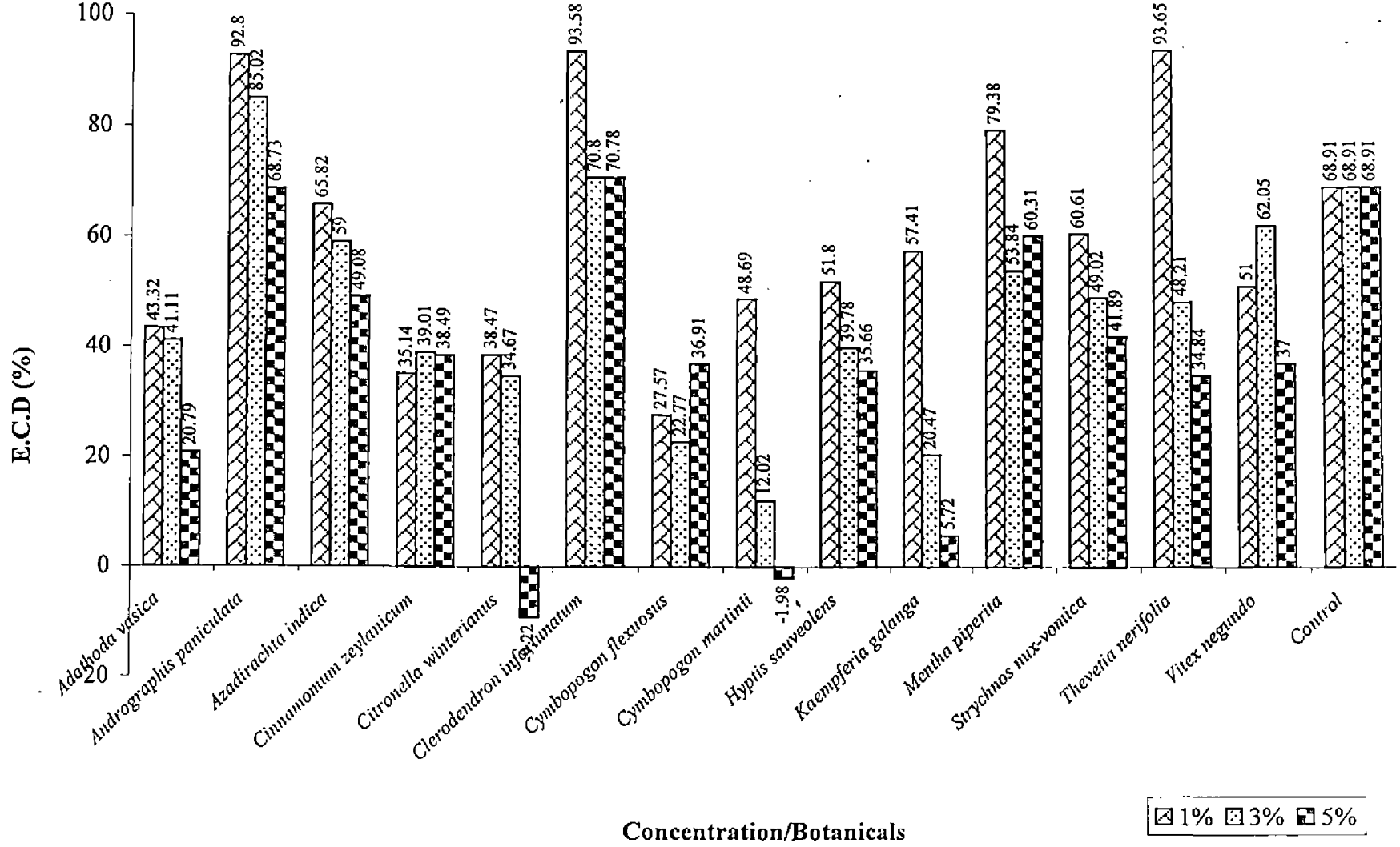
more effective at higher concentrations in preventing nutrient assimilation of food by *S. litura* larvae. This was also supported by the observation of Chitra and Rao (1996). The ECD value of *A. paniculata* and *C. infortunatum* extracts were higher than control at three to five per cent strengths indicating that these botanicals may be partially insect growth promoters. However, the effect was contrary to approximate digestibility values. At one per cent level in addition to the above two extracts, *M. piperita* oil and *T. nerifolia* aqueous extract also had relatively higher ECD values as compared to control, proving that their bio-efficacy vary significantly with dosages (Table 17 and Fig.13). At five per cent level, *A. vasica, H. sauveolens* and *T. nerifolia* aqueous extracts and *K. galanga, C. winterianus* and *C. martinii* oils had less than 35 per cent ECD values only indicating their possible interference in the metabolic conversion processes in insect nutrition.

5.3.5 The influence of botanicals on morphogenic malformations and developmental setbacks in *S. litura* during pupation and eclosion

5.3.5.1 Aqueous extracts and essential oils

One per cent concentration each of *C. zeylanicum, V. negundo, C. flexuosus* and *M. piperita* preparations when fed to the third instar larvae, resulted in lower rate of adult emergence (28 to 37%) indicating their pre-eclosion mortality (as per 3.5.5). *S. nux-vomica* and *C. flexuosus* produced pupal and adult malformations respectively after being fed to larvae at the same concentration of one per cent. At three per cent strength, *A. indica* extract gave the lowest pupation rate of 37.50 per cent and also lower rate of adult emergence as seen from Table 17. Sahayaraj (1998) also found that *A. indica* gave lower rate of pupation when fed to in the *S. litura* larvae. *A. paniculata* and *V. negundo* extracts at the same level induced more than 28 per cent adult malformations. Five per cent concentration of *A. sativum, A. squamosa, A. indica, C. winterianus, C. flexuosus, M. piperita* and *C. martinii* resulted in a lower range of 14 to 37 per cent pupation only and the remaining larvae died before pupation. However, the same treatments

Fig. 13. Efficiency of botanicals on ECD (%) of *S. litura*



could not result in any malformations except *A. indica.* At the same time *S. nux-vomica* and *V. negundo* at five per cent level produced more than 30 per cent malformed pupae (Plate 1). Adult emergence in majority of the extracts at five per cent level was negligible due to higher pupal mortality and out of the 17 botanicals tested, eight *viz., K. galanga, C. flexuosus, C. infortunatum, E. grandis, H. sauveolens, V. negundo, A. indica* and *C. martinii* produced malformed adults. Therefore, it can be considered that in the order of increasing adult deformity, *K. galanga, C. flexuosus, C. infortunatum,* etc. have a potential value in IPM when administered as a bait or spray at five per cent concentration.

The percentage of total combined malformations (pupal plus adult) from all the three levels (1, 3 and 5%) put together ranged from 15 to 33 per cent in the increasing order of *C. zeylanicum* > *S. nux-vomica* > *V. negundo* > *C. flexuosus* as shown in Table 18. Pupal malformation was higher in *S. nux-vomica, V. negundo* and *C. zeylanicum* as per the combined rating and therefore, these botanicals may be considered as pupal growth disruptants. Pupal stage malformation may be due to the inhibition of chitin synthesis by active principles of the botanicals. Sahayaraj (1998) also reported the pupal deformity in treated *S. litura* with *A. indica* and *V. negundo* extracts which is in conformity with these observations. Adult malformations was in the range of 18 to 62 per cent in *C. flexuosus, V. negundo, A. paniculata* and *K. galanga* extracts when fed on treated leaves after starvation (Plate 2).

Therefore, it can be concluded that spraying on the leaf surface with *C. flexuosus* and *K. galanga* oils or *S. nux-vomica, V. negundo, A. indica* and *A. paniculata* aqueous extracts (@ 1-5% level) may produce ill formed pupae and adults of *s. litura* when the treated leaf is fed by third instar larvae but the persistence of these experiments has to be studied.

Plate 1. Pupal malformations on exposure to aqueous plant extract treatments

Plate 1a. *Strychnos nux-vomica* (5%)

Plate 1b. *Vitex negundo* (5%)

Plate 1

Plate 1a

Plate 1b

Plate 2. Adult malformations on exposure to aqueous plant extract treatments

Plate 2a. Andrographis paniculata (3%)

Plate 2b. Cymbopogon flexuosus (1%)

Plate 2c. Kaempferia galanga (5%)

Plate 2d. Vitex negundo (3%)

Plate 2

Plate 2a

Plate 2b

Plate 2c

Plate 2d

5.3.5.2 Solvent extracts of selected botanicals

5.3.5.2.1 Solvent extracts of *A. indica*

Chloroform and dichloromethane extracts of *A. indica* at all the three concentrations (*viz.*, 1, 3 and 5%) produced malformed pupae ranging from 14 to 33 per cent and at the same time, in three per cent level, acetone extract also resulted in 28 per cent pupal malformation (Plate 3). Higher adult malformations were also recorded in the same extract at three and five per cent levels. Malformations caused by acetone and benzene extracts of *A. indica* in *S. litura* were already been reported by Saradamma (1989) and Saradamma *et al.* (1993). The combined total malformations of pupal and adult stages ranged from 22 to 35 per cent in case of chloroform and dichloromethane extracts of *A. indica*. Therefore, the extracts of *A. indica* in chloroform and dichloromethane may be more powerful in inducing morphogenic disruption as evidenced by the results (Table 19).

5.3.5.2.2 Solvent extract of *A. paniculata*

The malformations induced by the solvent extracts of *A. paniculata* was very low as compared to that of *A. indica* and *V. negundo* solvent extracts. The percentage of adult malformation was higher than the pupal malformation in all the solvent extracts of *A. paniculata.* About 25 per cent adult malformation each was observed in methanol and acetone extracts, at one and three per cent levels respectively (Table 19). The percentage of adult emergence at higher concentration of five per cent was also lower indicating their inverse relationship. However, it may be due to pre-eclosion mortality induced by the active principles of *A. paniculata* pro-active in the latent pupal stage eventhough fed on the larval stages.

Referring to the Table 18 and 19, there is a difference in performance between the aqueous and solvent extracts of *A. paniculata* on the adult

Plate 3. Pupal malformation on exposure to *Azadirachta indica* solvent extract treatments

Plate 3a. Acetone extract (3%)

Plate 3b. Chloroform extract (5%)

Plate 3c. Dichloromethane extract (1%)

Plate 3d. Dichloromethane extract (3%)

Plate 3

Plate 3a

Plate 3b

Plate 3c

Plate 3d

malformation. At three per cent concentration, aqueous extract gave 33.3 per cent adult malformations, whereas, its acetone extract at the same level resulted 25.0 per cent malformation only. This shows that the difference between the two solvents in extracting the principles responsible for inducing malformations.

5.3.5.2.3 Solvent extracts of *V. negundo*

Both pupal and adult malformations were more in acetone extract of *V. negundo* as compared to other solvent extracts in all the three concentrations (*viz.*, 1, 3 and 5%). Dichloromethane and acetone extracts at its three and five per cent concentrations induced 28.6 per cent adult malformations each (Table 19 and Plate 4). Total malformation caused by acetone extract was nearly 30 per cent, while those caused by chloroform and dichloromethane extracts was only 15 per cent of the total malformations. Saradamma *et al.* (1993) had also reported about the juvenomimetic activity of *V. negundo* (benzene) extracts on the penultimate instars of *D. cingulatus* leading to such abnormal physiological setbacks. However, the percentage of adult emergence in these two solvent extracts were less at five per cent level, in comparison to *A. paniculata* with the same physiological effect of pre-eclosion mortality.

5.3.6 Median Lethal Concentration (LC_{50}) of botanicals on *S. litura* larvae

Out of the four essential oils which gave topical toxicity on third instar larvae of *S. litura*, *C. martinii* (Palmarosa oil) was the most effective and toxic one (LC_{50} = 178 ppm) followed by *M. piperita* (Peppermint oil) (LC_{50} = 273 ppm). The topical toxicity of *C. winterianus* (Citronella oil) and *C. flexuosus* (Lemongrass oil) were relatively low. When the oils were evaluated based on their comparative toxicity upon Palmarosa oil (the most toxic one), citronella, lemongrass and peppermint oils were only 0.5, 0.6 and 0.7 times toxic respectively against *S. litura* larvae as depicted in Table 20.

Plate 4. Adult malformations on exposure to *Vitex negundo* solvent extract treatments

Plate 4a. Dichloromethane extract (3%)

Plate 4b. Acetone extract (5%)

Plate 4

Plate 4a

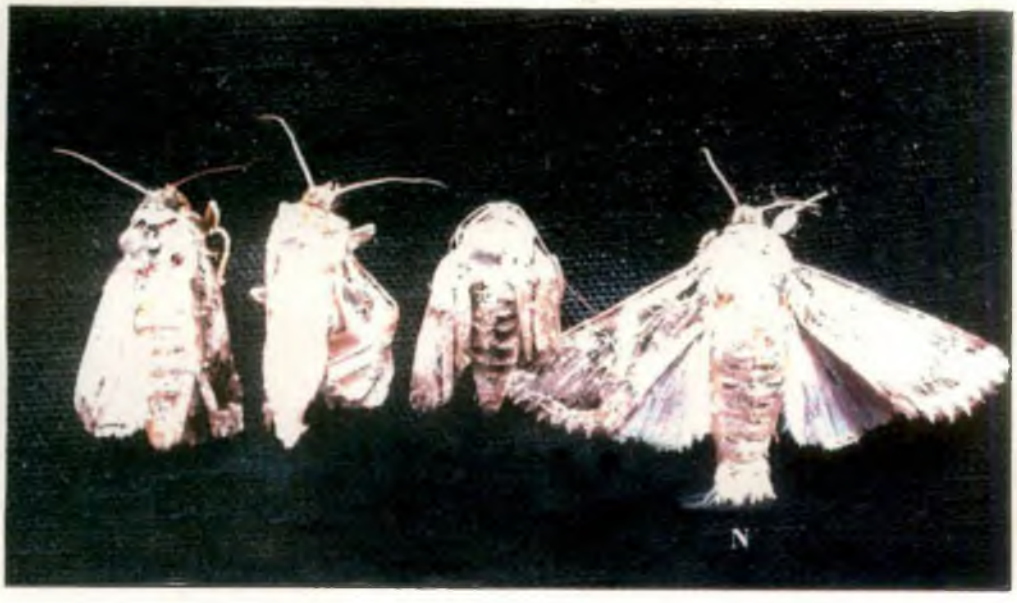


Plate 4b

5.4 BIORESPONSES OF SELECTED BOTANICALS UPON *S. litura*

A summary of the bioresponses of the tested botanicals are given below.

5.4.1 Plant extracts

5.4.1.1 *Azadirachta indica*

Aqueous extract of neem seed kernels exhibited ovipositional deterrency and ovicidal action (61.43 and 88.39% egg mortality) at five and ten per cent concentrations, while, at three and five per cent concentrations it had high feeding inhibition (62.73 and 71.80%). Among the solvent extracts tested, chloroform extract showed very high leaf protection and larval starvation (50 to 77%) at and above three per cent levels. Larvae treated with dichloromethane extract of *A. indica* resulted in higher malformations (30.0%) during pupation and eclosion at three and five per cent levels.

5.4.1.2 *Andrographis paniculata*

Aqueous extract had no pronounced effects of ovipositional deterrency, ovicidal action and antifeedancy at the tested concentrations. But solvent extracts (especially in acetone) afforded higher leaf protection (78 to 97%) and larval starvation (71 to 77%) at four and five per cent levels. Insects treated with aqueous extract had lower AD value (28.13%) at five per cent concentration. Both aqueous and solvent extracts of *A. paniculata* caused a lower malformed pupae and adults (6 to 15% total malformations only).

5.4.1.3 *Vitex negundo*

The aqueous extract had no ovipositional deterrency and antifeedancy with respect to *V. indica*. But, it had better ovicidal action (66.50%) at 10 per cent level. Solvent as well as aqueous extracts had lower feeding inhibition (36% only even at 5% level), however, both caused higher rate of pupal and adult malformations (up to 30% total malformations).

5.4.1.4 *Hyptis sauveolens*

H. sauveolens aqueous extracts showed pronounced ovipositional deterrency (with lower score values of 6 and 3%) at five and ten per cent strengths respectively. However, it had no other effects on the treated insects.

5.4.1.5 Other plant extracts

Aqueous extracts of *Clerodendron infortunatum, Strychnos nux-vomica* and *Thevetia nerifolia* had no had no effects of ovipositional deterrency, ovicidal action and antifeedancy. Except *C. infortunatum*, other extracts of above mentioned plants, had significant effects on the efficiency of conversion and utilisation on the food consumption (ECI and ECD). At the same time, *S. nux-vomica* extract induced higher rate of adult malformations (28.58%).

5.4.2 Essential oils

5.4.2.1 *Cinnamomum zeylanicum*

There was ovipositional deterrency (with lower score value of 10) even at 0.5 per cent level with respect to *C. zeylanicum* oil preparation, while, at the same level it caused cent per cent egg mortality. It had no influence upon the AD and ECI values. But the efficiency of conversion of digested food to body matter (ECD) was less (38.49%) at five per cent level, and it also had moderate leaf protection (40.53 and 62.68%) at three and five per cent levels respectively against the test insect.

5.4.2.2 *Citronella winterianus*

C. winterianus oil at 0.5 per cent strength exhibited moderate ovipositional deterrency and ovicidal action (59.46% egg mortality). At three and five per cent strengths it had higher leaf protection (65.37 and 88.05%). It also adversely affected the efficiency of consumption and utilisation of the food at the

above concentrations as inferred from lower ECI and ECD values. It had an LC_{50} value of 370 ppm on the third instar larvae.

5.4.2.3 *Cymbopogon flexuosus*

It also exhibited ovipositional deterrency and ovicidal action (56.74% egg mortality) at 0.5 per cent strength. Instead of antifeedancy, it had phagostimulatory effect at three per cent strength. Higher adult malformation (42.9%) was also noticed at one per cent level itself and it had an LC_{50} value of 311 ppm as determined in the laboratory.

5.4.2.4 *Cymbopogon martinii*

At 0.5 per cent concentration, it caused cent per cent egg mortality and moderate of ovipositional deterrency (with lowest score value of 12). At three per cent level, it induced higher larval starvation (62.30%). The consumption and utilisation of the food by the test insect was adversely affected at three and five per cent strengths. It had a lower LC_{50} value of 178 ppm showing its higher topical toxicity.

5.4.2.5 *Kaempferia galanga*

It had no ovipositional deterrency at 0.5 per cent level. While at 0.1 and 0.5 per cent strengths, it had ovicidal action (43.32 and 79.60% respectively). It also induced very high larval starvation (62 to 82%) at three and five per cent concentrations. At the above concentrations, it greatly affected the assimilation of ingested and digested food.

5.4.2.6 *Mentha piperita*

It recorded 80 per cent ovicidal action at 0.5 per cent concentration against that of *C. zeylanicum* and *C. martinii* which registered cent per cent

ovicidal action and it had no ovipositional deterrency. It had an LC_{50} value of 273 ppm on the third instar larvae. And no other significant effects were further observed against the test insect.

All the above essential oils tested were showing cent per cent ovipositional deterrency and ovicidal action at their one per cent strength when administered on the eggs and as well as on host plant surface.

Summary

6. SUMMARY

An evaluation of potential botanical pesticides against tobacco cut worm, *Spodoptera litura* (Fab.) was undertaken in the Department of Entomology, College of Horticulture, Vellanikkara, Thrissur during 2000-2001. The salient findings of the experiments covering ovipositional deterrency, ovicidal action, antifeedancy, morphogenic and lethal effects are summarized here under.

1. *H. sauveolens* and *A. indica* extracts gave better ovipositional deterrency at higher concentrations of five and ten per cent.

2. Essential oils viz., *C. zeylanicum* and *C. martinii* exhibited moderate ovipositional deterrency against *S. litura* when applied as 0.5 per cent acetone solution. Whereas, all six tested essential oils gave cent per cent deterrency at one per cent level.

3. Aqueous extracts of *A. indica* and *V. negundo* exhibited 33.27 and 26.9 per cent ovicidal action respectively at one per cent and 61.43 and 37.06 per cent at five per cent concentration on the one day old eggs of *S. litura.*

4. All the six tested essential oil preparations *viz., C. winterianus, C. zeylanicum, C. flexuosus, C. martinii, K. galanga* and *M. piperita* brought about cent per cent ovicidal action at one per cent level. *C. zeylanicum* and *C. martinii* oil preparations gave the same extent of ovicidal effect even at 0.5 per cent concentration.

5. Preparations out of *C. winterianus* oil, *K. galanga* oil and *A. indica* aqueous extract afforded leaf protection/feeding inhibition ranging from 62 to 77 per cent at three per cent concentration against third instar larvae of *S. litura.*

6. Preparations out of *K. galanga* oil, *C. martinii* oil and *A. indica* aqueous extract were inducing larval starvation of 70.98, 62.30 and 56.75 per cent respectively at three per cent concentration.

7. Among the four different solvent extracts of botanicals tested, the following species of plants were showing efficient leaf protection and larval starvation.

   i) *A. paniculata* extract in acetone at two per cent level, showed pronounced larval starvation and in dichloromethane at three per cent level afforded 63 per cent leaf protection.

   ii) *V. negundo* extracts in both dichloromethane and methanol at five per cent concentration each gave more than 60 per cent leaf protection and around 50 per cent larval starvation in *S. litura*, which again showed lesser antifeedant action against *S. litura*.

   iii) Acetone and chloroform extracts of *A. indica* at four per cent concentration gave more than 65 per cent leaf protection, while, chloroform extract of the same at four per cent level induced more than 70 per cent larval starvation reaffirming their efficiency with respect to their feeding inhibition potential.

8. In terms of physiological indices expressed by the botanicals upon *S. litura* it could be inferred that

   i) Approximate Digestibility (AD) in *A. paniculata, T. nerifolia, C. infortunatum* and *S. nux-vomica* were found to be giving low digestibility values ranging from 22 to 48 per cent highlighting their importance as digestive inhibitors.

   ii) The essential oils of *C. winterianus, C. martinii* and *K. galanga* are potential disrupters of digestion and assimilation in insect systems leading to the development of weak individuals of *S. litura* larvae

with low rate of growth and survivability aspects as proved by their lower ECI and ECD values.

9. *C. flexuosus* and *K. galanga* oil preparations and aqueous extracts of *S. nux-vomica, V. negundo, A. indica* and *A. paniculata* at their concentrations ranging from one to five per cent were inducing pupal and adult malformations when applied on the third instar larvae of *S. litura*.

10. Among the solvent extracts, chloroform extract of *A. indica* and acetone extract of *V. negundo* also induced higher level of morphogenic deformation on the treated *S. litura* larvae.

11. The toxicological parameters based on topical toxicity in terms of LC_{50} values proved that only *C. martinii* oil was with high insecticidal toxicity with its lowest LC_{50} value of 178 ppm when compared to all other tested botanicals.

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* Originals not seen

Appendix

APPENDIX- I

Survey report on the botanical resources with pest management properties

Sl. No.	Scientific name	Common name(s)	Part(s) with insecticidal property	Active principles	Pest(s) controlled	Nature of action	Availability	Market price (Rs./kg)	Storage life
1	2	3	4	5	6	7	8	9	10
1	*Acorus calamus* Linn.	Sweet flag (E) Vayambu (M) Vasambu (T)	Rhizomes	ß-asarone, Calamenol, Calamene	Fleas, Bed bugs, Fruit fly, Stored grain pests	Antifeedant, Repellent, Ovicidal, Sterilant, Contact inhibitor,	Throughout India up to 2200 ft above MSL	27.5/kg	1 year (dried)
2	*Adathoda vasica* Nees.	Malabar nut (E) Adalodakam (M) Adathoda (T)	Leaves, Roots	Vasicicine, Vasicinol, Vasicinone	Stored grain pest, Red spider mites of tea	Antifeedant, Repellent	Throughout India up to 1300 ft above MSL	14.50/kg	1 year (dried leaves)
3	*Agave americana* Linn.	Century plant (E) Panam-kattarvazha (M) Aanai-kathalai (T)	Leaves	Agavasa-ponins - A,B,Z	Paddy leaf folder Fish poison	Contact & stomach poison	Railway embankments, waste land weeds	NI	Prolonged (Whole plant in raft)
4	*Ageratum conyzoides* Linn.	Goat weed	Leaves	Precocenes - I & II, Anacylin	*Drosophila*, Red cotton bug	Ovicidal, Sterilant Growth inhibitors AJH activity	Waste land weeds	NI	NA
5	*Allium cepa* Linn.	Onion (E) Ulli (M) Vengayam (T)	Bulbs, leaves, oil	Diallyl sulphides	General disinfectant, Fruit flies, Rice pests, Fruit tree pests	Repellent	Northern temperate regions	15/kg	2-3 months
6	*A.. sativum* Linn.	Garlic (E) Vellulli (M) Vellaipoondu (T)	Bulbs	Diallyl sulphides, Diallyl trisulfides	Diamondback moth, Rice BPH, GLH, Thrips, Coconut mite, Rats	Antifeedant, Repellent	Northern temperate regions	50/kg	5-6 months
7	*Amorphophallus campanulatus* Blume.	Elephant foot yam (E) Chena (M) Karunaikizhangu (T)	Rhizomes	Calcium oxalate	Rats	Repellent and skin irritant	Upper gangetic-plains and peninsular India	8-10/kg	6 months

Contd.

Continued

1	2	3	4	5	6	7	8	9	10
8	*Andrographis paniculata* Wall.	Kiriyath (M)	Whole plant	14-deoxy-andrographolide, Andrographolide	Diamondback moth, GLH	Antifeedant, Ovipositional deterrent	High quality from Nepal, Assam and Kolkata. Low quality from Tamil Nadu hills	350/kg 25/kg	1 year
9	*Annona squamosa* Linn.	Custard apple	Leaves, seeds	Annonine, Annonacin, Annonidines	Gall fly, Tobacco cutworm, Defoliating caterpillars	Antifeedant	All over India mainly in Andhra Pradesh	10-15/kg (fruits)	1 year
10	*Aristolochia bracteata* Retz.	Aduthinnappalai (M & T)	Leaves	Aristolochic acid	All insects	Repellent, Insecticidal/anti dots for insect/ animal poisoning	Weeds in black soils	NI	NA
11	*Azadirachta indica* A. Juss	Neem (E) Veppu (M) Vembu (T)	Leaves, seeds	Triterpenoids (Azadirachtin)	All Insects	Antifeedent, Repellent, Ovicidal, Ovipositional deterrent, Growth inhibition etc.	All over India	15/kg	1 year
12	*Butea monosperma* (Lam.)	Flame of the forest (E) Plas (M) Poovarasu (T)	Flowers	Butin, Butein, Butrin	Crab, Tobacco cutworm	Ovicidal, JH activity	Drier parts of Kerala	NA	NA
14	*Calotropis gigantea* Ait.	Milk weed (E) Erukku (M & T)	Leaves	O-pyrocate chuic acid	Lepidopteran caterpillars, Larvae of mosquitoes	Stomach poison, Growth inhibitor	Throughout India	NA	NA
15	*Cassia fistula* Linn.	Golden shower (E) Kanikonna (M) Sarakonnai (T)	Flowers, Barks	Kaempiferal, Leucopelargonidin tetramer	*Callosobruchus* sp	NI	In deciduous forests	10/kg	1 year (dried)

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Continued

1	2	3	4	5	6	7	8	9	10
15	*Catharanthus roseus* G. Don	Red periwinkle (E) Nithyakalyani (M & T)	Leaves , Roots	Vinblastine, Vincristine, Leurosidine	Red cotton bug, Larvae of mosquitoes	Sterilant	Ornamental plant	10/kg	1 year
16	*Chromolaena odorata* Linn.	Communist pacha	Leaves, Young shoots	-	Defoliators of vegetables, Stored grain pest	Repellent, Nematicidal	Common weed	NA	NA
17	*Chrysanthemum coronarium* (Linn.)	Pyrethrum (E) Jamanthi (M) Samanthi (T)	Flowers, Buds, Shoots	Pyrethrins	Ectoparasites of livestock, Aphids and other soft bodied insects	Repellent, Insecticidal, AJH mimetic	Foot hills of upper India, Eastern and Western Ghats	60/kg	NI
18	*Cinnamomum camphora* (Linn.)	Camphor (E) Karpuram (M&T)	Wood oils	Safrole, Linalool, Cary ophyllene	Stored grain pest, Moths	Repellent, Insecticidal	Evergreen ornamental	90/kg	Prolonged as oil
19	*C. zeylanicum Breyn.*	Cinnamon (E) Karuvapatta (M) Ilayangam (T)	Leaves, Barks	Eugenol, Cinnamalde hyde	Screw worms, Other fly maggots	Attractants	Evergreen forests of Western Ghats	80/kg (China) 40/kg (local varieties)	1-2 year
20	*Citrus sinensis* (Linn.)	Sweet orange (E) Maduranarangai (M) Sathugudi (T)	Peels	Nomolin, Harrisonin	Tobacco cutworm, Bittergourd semilooper	Antifeedant, Insecticidal	Subtropical region of N. India, Tropical humid regions of S. India	10-15/kg	15 days
21	*Clerodendron infortunatum* Linn.	Peringalam (M)	Leaves	Trans-decalin, Clerodendri n A & B	Cabbage butterfly caterpillar, Red cotton bug, *Epilachna* beetle, Tobacco cutworm	Antifeedant, Ovicidal	Common waste land weed in Kerala	NA	NA
22	*Cymbopogan flexuosus* (Steud.)	Lemongrass (E) Theruvapullu (M)	Leaves	Citral	Mosquitoes House flies, Other fly spp.	Repellent	Upland terraces and bunds of western ghats	450/kg (oil)	Prolonged as oil
23	*C. martinii* var. *motia* (Roxb.)	Palmarosa (E)	Leaves	Geraniol	-do-	Repellent	-do-	450/kg (oil)	Prolonged as oil

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Continued

1	2	3	4	5	6	7	8	9	10
24	*Eucalyptus grandis*	Eucalyptus (E) Yookali maram (M)	Leaves	1,8-cineole	Stored grain pests	Repellent	Common tree species in India	NA	NA
25	*Hyptis sauveolens* Poit.	Thiruchada Nattapoochédy (M)	Leaves, Shoots, Flower buds	l-sabinene d-limonene	Vegetable pests, Parasites of domestic animals	Antifeedent, Repellent, AJH activity	Common weed	50/kg	NA
26	*Kaempferia galanga* Linn.	Kacholam (M)	Rhizomes	P-methoxy cinnamate, Benzyl benzoate, Kaempferide	Parasitic helminths	Antihelminthic, Insecticidal	Cultivated herbal plant	130/kg	5-6 months
27	*Lantana camara* Linn.	Wild sage (E) Puchedi (M) Unnichedi (T)	Leaves, Stems	Lantadene	General	Fish poison, Insect repellent	Hilly weed up to 1800 ft above MSL	NA	NA
28	*Melia azedarach* Linn.	Persian lilac (E) Shimaveppu (M) Malaivembu (T)	Barks, Leaves, Fruits	Tetranortripe noids, Azadaracol, Meliantriol	Screw worms, Tobacco cutworm, Grass hoppers, Locust, Carpet beetle	Antifeedent, Repellent, Ovicidal, Insecticidal, Growth inhibition	Tropical tree	6-10/kg bark	1 year
29	*Mentha piperita* Linn.	Peppermint (E) Mentha chedy (M)	Leaves	Carvone, Pulegone, Menthol	Cotton bollworms, Termites, Rice weevil	Antifeedant	Humid and temperate region	500/kg (oil)	Prolonged as oil
30	*Nerium indicum* Mill.	Oleander (E) Kanaviram (M) Arali (T)	Fruits, seeds	Neriodorin, Karabin, Neriodorein	Rice weevil, Rhinoceros beetle, Black carpet beetle	Stomach poison	In ornamental, gardens and avenue shrubs	NA	NA
31	*Ocimum sanctum* *O. basalicum* Linn.	Basil (E) Trittavu or Thulasi (M) Thulasi (T)	Leaves, Oils	Citral, Geraniol, Methyl eugenol	Fruit flies, Rice pests, Fruit tree beetles, Mosquitoes	Attractant, Antifeedant, Repellent, JH activity	In gardens	10/kg	5-6 months dried (mostly raw in use)

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Continued

1	2	3	4	5	6	7	8	9	10
32	*Piper nigrum* Linn.	Black pepper (E) Kurumulaku (M) Milagu (T)	Berries	N-isobutyla-mides	Adult corn cutworms, Bean weevil, Rice weevil, Diamondback moth, Adult bark weevils, American bollworm	Stomach poison, Antifeedant	Plantations or homesteads in S. India	40-60/kg	1 year
34	*Plumbago zeylanica* Linn.	Tumbakoduveli (M) Cithramulam (T)	Roots	Plumbagin	Red cotton bug, *Helicoverpa caterpillar*, Pink bollworm	Growth inhibitor	Herbal gardens and forests	60/kg (raw) 240/kg (dried)	1 year
35	*Pongamia pinnata* (Linn.)	Karanj (E) Pungu, Punnu (M) Pongum (T)	Leaves, Fruits, Seeds	Karanjin, Pongamol	*Spodoptera* larvae, *Epilachna* beetles, Lemon butterflies, Stored grain pests	Antifeedant, Repellent, Insecticidal	In gardens upto 1200 ft above MSL	NA	NA
36	*Parthenium hysterophorus*	Parthenium (E)	Leaves		*Heliothis zea*	Antifeedant	Common weeds	NA	NA
37	*Strychnos nux-vomica* Linn.	Snake wood (E) Kanjiram (M) Ettikottai (T)	Seeds, Roots	Strychnine, Brucine	Rats, Mites	Pesticidal	In western ghats up to 360 ft above MSL	12/kg	2 years
38	*Tagetes erecta* Linn.	African marigold (E) Chendumalli (M) Tulukka-samanthi (T)	Leaves	Tagetone, Limonene, Ocimene	GLH, Flies	Repellent	All over India	-	-
39	*Vitex negundo* Linn.	Indian privet (E) Vellanocchi (M) Vellai-nochi (T)	Leaves	-	Castor semilooper, Stored grain pests	Insecticidal, Contact poison, Growth inhibitor,	Throughout India, up to 1500 ft MSL	15/kg	Only raw available

Sources: CSIR (1976)
Baskaran and Narayanaswamy (1995)
Dhaliwal and Arora (2001)
C.L. Kuriens and Brothers, Thrissur (Ayurvedic products dealer)

(E) - English
(M) - Malayalam
(T) - Tamil
NI - No information
NA - Not available

EVALUATION OF POTENTIAL BOTANICAL PESTICIDES AGAINST TOBACCO CUTWORM, *Spodoptera litura* (Fab.)

By

S. SURESH

ABSTRACT OF THE THESIS

Submitted in partial fulfilment of the requirement for the degree of

Master of Science in Agriculture

Faculty of Agriculture

Kerala Agricultural University

DEPARTMENT OF ENTOMOLOGY

COLLEGE OF HORTICULTURE

VELLANIKKARA, THRISSUR-680 656

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ABSTRACT

Investigations were carried out on the "Evaluation of potential botanical pesticides against tobacco cutworm, *Spodoptera litura* (Fab.)" in the Department of Entomology, College of Horticulture, Vellanikkara during 2000-2001. The objectives of this study were to screen the botanicals with biological resources such as ovipositional deterrency, ovicidal action, antifeedancy, morphogenic disruptions, insecticidal properties, etc. on the enigmatic and polyphagous caterpillar pests such as *S. litura.*

Ovipositional deterrency test was conducted with aqueous plant extracts and essential oils. *Azadirachta indica* and *Hyptis sauveolens* aqueous extracts allowed lower rate of oviposition (as evidenced by their lower average score values of 3 to 6) on the treated surface at five and ten per cent strengths. Similarly, the essential oils *viz.*, *Cinnamomum zeylanicum* and *Cymbopogon martinii* showed pronounced ovipositional deterrency even at 0.5 per cent level. Aqueous extract of *Azadirachta indica* gave higher ovicidal action as high as 61.43 and 88.39 per cent hatching inhibitions at five and ten per cent concentrations respectively. Among the six tested essential oils, *Cinnamomum zeylanicum* and *Cymbopogon martinii* exhibited cent per cent egg mortality at 0.5 per cent strength each.

Citronella winterianus oil, *Kaempferia galanga* oil and *A. indica* aqueous extract exhibited higher leaf protection of 62 to 77 per cent at three per cent concentration each. Oils of *Kaempferia galanga* and *Cymbopogon martinii* and aqueous extract of *Azadirachta indica* induced larval starvation of 56 to 70 per cent at the same concentration of three per cent each. Among the solvent extracts of the botanicals tested, acetone extract of *Andrographis paniculata* exhibited larval starvation of 63 per cent at its two per cent concentration, while, dichloromethane extract of the same produced 63 per cent leaf protection at the same strength. *Vitex negundo* extract in methanol afforded leaf protection to the level of 64.31 per cent and larval starvation of 55.99 per cent at its five per cent

level. Chloroform extract of *Azadirachta indica* at four per cent level produced more than 70 per cent leaf protection as well as larval starvation.

The Approximate Digestibility (AD) was lower in aqueous extracts of *Andrographis paniculata, Thevetia nerifolia, Clerodendron infortunatum* and *Strychnos nux-vomica* at one and three per cent strengths on the treated insects, highlighting their inhibitory action during digestion process, whereas, the essential oils *viz., Citronella winterianus, Cymbopogon martinii* and *Kaempferia galanga* treatments at three and five per cent inhibited the assimilation of ingested and digested food into body matter as indicated by their lower ECI and ECD values.

The third instar larvae when fed on host leaves treated with oils of *Cymbopogon flexuosus* and *Kaempferia galanga* and aqueous extracts of *Strychnos nux-vomica, Vitex negundo, Azadirachta indica* and *Andrographis paniculata* (@ 1, 3 and 5% levels each) were found to be inducing pupal and adult malformations (7.53 to 16.67% total malformations). The chloroform extract of *Azadirachta indica* and acetone extract of *Vitex negundo* on exposure on host plants, induced higher rate of deformities at the time of pupation and eclosion to the extent of up to 30.8 per cent. *Cymbopogon martinii* oil had the lowest LC_{50} value of 178 ppm as compared to other oils *viz., Mentha piperita, Cymbopogon flexuosus* and *Citronella winterianus* (with their respective LC_{50} values of 273, 311 and 370 ppm) indicating its significant insecticidal and insectistatic properties and offer their scope for IPM strategies.