INTEGRATION OF INTERCROPS AND PLANT PRODUCTS ON CHOSEN GROUNDNUT PESTS MANAGEMENT

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Certified that the thesis entitled "**Integration of intercrops and plant products on chosen groundnut pests management**" submitted by **M. Gabriel Paulraj** is a record of research work carried out by him from October 1997 to October 2000 for the degree of **Doctor of Philosophy** under our guidance. This thesis is an original work of the candidate and has not been submitted, in part or in full, for any Diploma, Degree, Associateship, Fellowship or other similar titles in this or any other University. No portion of the thesis is a reproduction from any other sources either published or unpublished, without acknowledgement.

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DECLARATION

I declare that the thesis entitled "**Integration of intercrops and pl[illegible] products on chosen groundnut pests management**" is the result of a original study carried out by me under the guidance and supervision of **Rev. Dr. S. John Britto**, **S. J.** Principal, St. Joseph's College (Autonomous), Tiruchirappalli and **Dr. K. Sahayaraj,** Lecturer, Department of Zoology, St. Xavier's College (Autonomous), Palayamkottai from October 1997 to October 2000. This work has not been submitted earlier, in full or part for any diploma or degree in this or any other universities. I also declare that no part of the thesis is a reproduction from any other sources either published or unpublished, without acknowledgement.

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CONTENTS

PREFACE

Insect pests are often considered as important factors for the loss of production and economy in agriculture. Insects have a remarkable capacity to adapt to chemicals that are used to control them. More than 4000 examples of resistance to insecticides have been documented in populations of about 500 species of insects. Besides this, chemical pesticides pollute the environment, kill natural enemy population and create health problems in human beings and household animals. By the 1970s, research institutions around the world started major programs to develop new or improved alternatives to conventional pesticides. The researchers finally concluded that integrated pest management (IPM) is the best alternative to chemical control, which is eco-friend, cost effective and socially acceptable method. From the view point of IPM, chemical control is an ultimate choice when IPM is less effective in certain circumstances like heavy pest infestation. IPM enables the farmers to follow cultural, mechanical, physical, chemical and biological control methods. IPM method manipulates the agro-ecosystem to make it less favourable to the pests and more favourable to the natural enemies with a view to prohibit, reduce and delay the growth of the pest population. Botanical pest control is a distinct possibility in India, where we have a rich biodiversity of plants having anti-insect properties. Intercropping is one of the important cultural control methods, which prevents the pest attack in the main crop, enhances the natural enemy complex and increases the benefit. Intercropping system is always less likely to fail and is more stable than monocropping. Botanical pest management and intercropping system offer a transition route to IPM.

More than 100 insect pests attack groundnut, a major oil seed crop of India. Studies on IPM in groundnut particularly intercropping and botanical control studies are very rare. Keeping these points in mind, the present study entitled, "**Integration of intercrops and plant products on chosen groundnut pests management**" has been undertaken in which we have tried to findout the efficacy of the water extracts of neem (vembu) (*Azadirachta indica* A. Juss), Karanj (pungai) (*Pongamia pinnata* Pierre.), Lagundi (nochi) (*Vitex negundo* Linn.) and Madar (erukku) (*Calotropis gigantea* Linn.) leaves and four intercrops such as castor (*Ricinus communis*), maize (*Zea mays*) soybean (*Glycine max*) and sunflower (*Helianthus annus*) on the management of *Aproaerema modicella* (Dev.) (Groundnut leaf miner), *Helicoverpa armigera* (Hubner) (gram pod borer), and *Spodoptera litura* (Fab.) (Tobacco army worm) in groundnut.

Besides a common introduction, review of literature and a list of references, this dissertation contains five chapters as follows :

Chapter – 1

Plant extracts on the median lethal dose (LD_{50}) of three pests.

Chapter – 2

The impact of plant products on the biology and juvenometry of chosen groundnut pests.

Chapter – 3

Field efficacy of chosen plant products on three groundnut defoliators management and groundnut production.

Chapter – 4

Influence of intercropping on chosen groundnut defoliators management and groundnut production.

Chapter – 5

Integration of intercrops and plant products on chosen groundnut defoliators' management and groundnut production.

The results are presented in the form of 27 tables and 13 figures.

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

Plate No.	Title

6. Intercropping in groundnut field
   - a. Groundnut + Castor intercropping system
   - b. Groundnut intercropped with maize
   - c. Groundnut + Soybean intercropping system
   - d. Groundnut + Sunflower intercropping system

ABBREVIATIONS USED

AI	*Azadirachta indica* (Neem)
ANOVA	Analysis of Variance
CD	Critical Difference
CG	*Calotropis gigantea* (Madar)
CR	Castor
cv	Cultivars variety
DASE	Days After Seedling Emergence
DMRT	Duncan's Multiple Range Test
Fig.	Figure
GN	Groundnut
ID	Incidence
IF	Infestation
IPM	Integrated Pest Management
JH	Juvenile hormone
L and D	Light and Dark (Photoperiod)
LC_{50}	Median Lethal Concentration
LD_{50}	Median Lethal Dose
MZ	Maize
NPV	Nuclear Polyhedrosis Virus
NS	Not Significant
PP	*Pongamia pinnata* (Karanj)
rh	Relative humidity
SB	Soybean

SE	Standard Error
SE(d)	Standard error for deviation
SF	Sunflower
VN	*Vitex negundo* (Lagundi)

INTRODUCTION

I. INTRODUCTION

Groundnut (*Arachis hypogaea* Linn.) is a major oil seed crop in India, occupying 8.6 million hectares, of which 85 per cent is rainfed and 15 per cent irrigated. It accounts for 38 per cent in oilseeds cultivated area and 48 per cent in oil seed production (9.5 million tons) among the other oilseed crops grown in India. The importance of groundnut was reported by AICORPO (1980, 1983, 1990). Although India ranks first in area of cultivation and groundnut production in the world, the average production is only 945 kg ha^{-1} as compared to the developed countries (2500 to 4000 kg ha^{-1}) (Ghewande *et al.,* 1996; Dharne and Patel, 2000). The major constraints on yield are pests and diseases. In general, insects cause 10 to 20 per cent crop loss. More than 100 insect pests have been reported in groundnut (Ramaraju *et al.,* 1998). Among them, some defoliators such as *Amsacta albistriga* Walker (Red hairy caterpillar), *Aproaerema modicella* Deventer (groundnut leaf miner), *Helicoverpa armigera* Hubner (gram pod borer) and *Spodoptera litura* Fabricius (tobacco army worm) are found to be the most serious pests (Plate 1). The loss due to these pests is high magnitude all over the world, particularly in India (Amin, 1983). *S. litura* and *A. modicella* have assumed greater importance in recent years by inflicting severe damage. The damage is more severe

PLATE 1. SOME MAJOR GROUNDNUT PESTS

(a) Groundnut leaf miner
(*Aproaerema modicella* Deventer)

(b) Gram pod borer
(*Helicoverpa armigera* Hübner)

(c) Tobacco army worm
(*Spodoptera litura* Fabricius)

in the rainfed conditions, which accounts more than sixty per cent of the groundnut cultivating area in Tamil Nadu, India.

A. modicella was reported as a serious pest of groundnut throughout the year (Tejkumar, 1979; Jagtap *et al.,* 1986; Anon, 1986; Veeresh *et al.,* 1989; Logiswaran and Mohanasundaram, 1990; Brar *et al.,* 1995; Nandagopal *et al.,* 1995) in many parts of India. In India, the major groundnut cultivating area coming under rainfed conditions suffers maximum damage by *A. modicella* (Ayyer, 1963; Nair, 1975; Muthiah and Kareem, 2000). The pest initially appears as a leaf miner causing short blister like mines in the leaf but as feeding advances, the larvae fold the leaflets and feed within, as a result the leaflets turn brownish, shrivel and dry up. Severely infested crops give a burnt appearance causing appreciable yield loss, ranging from 15 to 76 per cent (Tejkumar, 1979; Anon, 1986; Veeresh *et al.,* 1989).

S. litura is widely distributed throughout Asia and the Pacifica islands (Wightman and Rao, 1993; Martinez and Van Emden, 1999). It is a polyphagous pest and is reported as a serious pest of groundnut both in irrigated and rainfed conditions (Moussa *et al.,* 1960; Panchabhavi and Nethradhaniraj, 1987; Rao *et al.,* 1991; Dhir *et al.,* 1992; Singh and Jalali, 1997). The larval stages of *S. litura* feed on the leaves and flowers of groundnut and reduce the production. Dhir *et al.* (1992) have reported that one *S. litura* larva per plant at seedling stage reduced the pod yield by 25.8 per cent. *H. armigera* is another significant pest of groundnut crop in Andhra Pradesh, Karnataka and Gujarat (Reddy and Ghewande, 1986; Arora *et al.,* 1996)

To overcome the losses due to these pests, prophylactic pest control measures mostly with chemical pesticides are adopted. However, indiscriminate use of the pesticides in intensively cropped areas led to the destruction of beneficial organisms, accumulation of pesticide residue in food chain, environmental pollution, health hazards, resistance in insect pests against pesticides and resurgence of treated pests. Insecticide resistance in insects has grown over the last four decades into one of the most serious challenges to pest control by chemicals around the world. *H. armigera* developed high degree of resistance towards synthetic pyrethroids and other commonly used insecticides from several states of India (Dhingra *et al.,* 1988; Mehrotra and Phokela, 1992; Armes *et al.,* 1996; Patel and Koshiya, 1999; Tripathy and Singh, 1999).

In order to overcome such adverse effects posed by chemical pesticides, the current thrust in plant protection is on promoting Integrated Pest Management (IPM), which is ecologically sound, economically viable and socially acceptable method. The role of indigenous plant materials in pest control was clearly spell out by Banerjee *et al.* (1985). IPM includes mechanical and physical (hand picking and destruction, exclusion by screens/barriers and trapping/suction devices), cultural (selection of site/crops, ploughing, planting material, planting dates and crop duration, destruction of alternative hosts, thinning and topping, pruning, defoliation and destruction of crop refuse, crop rotation and trap crops), chemical (synthetic pesticides, botanical pesticides, insect growth regulators, pheromones and kairomones) and biological (parasitoids, pathogens and predators) control methods. Ghewande and Misra (1986) proposed that IPM offers scope for eco-friend pest management and increasing production in groundnut.

In recent years, increasing research has focused on plant derived insecticides which are economic, non-pollutant and bio-degradable especially if used as total or enriched extractives and most of the plant products are safe to human beings and household animals. It has already been reported that plant species possessing pest controlling properties included 1005 species with antifeedant property, 297 species with repellent, 27 species with attractant and 31 species with growth inhibition properties (Bhatnagar and Sharma, 1994). Previous investigations of many researchers clearly indicated that many plant products such as *A. indica, V. negundo, C. gigantea* and *P. glabra* exhibited toxic effects on major groundnut pests like *A. modicella* (Prabhakar and Rao, 1994; Sahayaraj and Paulraj, 1998a), *H. armigera* (Sachan and Lal, 1990; Rao and Rao, 1993; Pugalenthi *et al.*, 1994) and *S. litura* (Bai and Kandasamy, 1985; Stevenson *et al.*, 1993; Sahayaraj and Sekar, 1996; Senthilkumar *et al.*, 1997; Sahayaraj, 1998; Sahayaraj and Paulraj, 1998b). Furthermore Koul (1985), Chandramohan and Sivasubramanian (1987) and Gujar (1997) proposed neem based botanical pesticides as suppressible agents of *H. armigera* and *S. litura* populations. Hence the above mentioned botanicals can be used to control these pests in groundnut field. Intercropping is a cultural method of pest control and considered as one of the important components in IPM. Growing two or more crops, simultaneously on the same piece of land is considered inter or mixed cropping. Groundnut is usually intercropped with castor (Senthivel *et al.*, 1989; Muthiah *et al.*, 1991; Davidayal and Reddy, 1991) sunflower (Putnam *et al.*, 1990; Davidayal and Reddy, 1991), blackgram (Senthivel *et al.*, 1989; Muthiah *et al.*, 1991; Lourduraj *et al.*, 1994; Kalai Selvi *et al.*, 1996), soybean (Senthivel *et al.*, 1989; Muthiah *et al.*, 1991) maize (Sharma and Varshney, 1990; Alegbejo, 1997) and cowpea (Senthivel *et al.*, 1989; Kennedy *et al.*, 1990; Lourduraj *et al.*, 1994).

Studies on efficacy of water extracts of *A. indica, C. gigantea, P. glabra* and *V. negundo* leaves and integration of the plant pesticides with intercrops like sunflower, castor, maize and soybean are very rare in groundnut pests management programme. The present study aims to findout the efficacy of chosen plant products such as neem (*Azadirachta indica* A. Juss) (vembu), karanj (*Pongamia pinnata* Pierre.) (pungu), madar (*Calotropis gigantea* Linn.) (erukku) and lagundi (*Vitex negundo* Linn.) (nochi) and intercrops like castor (*Ricinus communis* – cvTMV. 4), maize (*Zea mays*,– cvMDSH), soybean (*Glycine max* – cv Co 1) and sunflower (*Helianthus annus* – cv Co. 3) on *A. modicella, H. armigera* and *S. litura* incidence and their infestation and groundnut production.

REVIEW OF LITERATURE

II. REVIEW OF LITERATURE

The literature on various aspects of pest management in groundnut such as intercropping and use of plant products and impact of Integrated Pest Management (IPM) components on groundnut production and profit analysis is substantial. In the present study, literature relevant to the areas of research presented in this thesis is reviewed under the following headings.

II. 1. Impacts of chemical pesticides

The indiscriminate use of synthetic pesticides in pest management programmes causes unwanted effects of which environmental pollution, pesticide resistance in pests, residues of pesticides in food materials and destruction of beneficial insects in the field are important effects. Many investigators throughout the world have explored these effects of synthetic pesticides. Bachthaler (1985) reviewed the side effects of pesticides on plants under conditions of intensive crop production with particular reference to physiology, morphology and mutation frequency of crop spp. Gunathilagaraj and Babu (1987) concluded that the insecticides such as carbaryl, chlorpyrifos, dichlorvos, endosulfan, ethion, fenitrothion, HCH, Phosalone and quinalphos recommended to control red hairy caterpillars (*Amsacta albistriga* Walker) were highly toxic to larval parasitoids of *A. albistriga*. Funderburk *et al.* (1990) found that granular chlorpyriphos application increased the defoliating pests and reduced the density of araneids, the athropod predators in groundnut field in florida. Bhatnagar and Gupta (1992) found out the presence of chlorpyriphos residues in the soil and groundnut kernels. They reported that the half life values of chlorpyriphos in soil were found to be 11.55 and 16.96 days for a dosage of 800 and 1200 g a i/ha respectively. Pest out break is a serious problem and this is created by synthetic pesticides. Until 1968, just four insects were considered as serious pests of groundnut crop in India (Rai, 1976). Since then, the number of pest species affecting groundnut has increased to more than 120 both in field and storage (Ramaraju *et al.*, 1998).

II. 2. Groundnut pests

A large number of insect pests have been found depredating the yield of groundnut (Amin and Mohammed, 1980). Until 1968, the groundnut farmers in India had to worry about just four serious insect pests such as aphids, groundnut leaf miners, hairy caterpillars and termites (Rai, 1976). Since then, the number of pest species affecting groundnut has increased, as have their geographical ranges. Islam *et al.* (1983) recorded 18 species of insect pests in the groundnut field in Bangladesh of which the arctiid *Spilosoma obliqua* was the most serious one. They also reported that *S. litura* and *Helicoverpa armigera* (Hubner) were abundant in groundnut field during March, April and May. Singh *et al.* (1990) listed 52 insects and 2 mite pests in high yielding variety of groundnut (MH – 2). Jayanthi *et al.* (1993) recorded 18 insect pests of groundnut in Delhi. Recently, Ramaraju *et al.* (1998) reported 120 pests of groundnut both in field and storage.

S. litura is considered as a ployphagous pest (Moussa *et al.*, 1960). The name reflects the fact that this species was once mainly restricted to tobacco crops. It has been reported that *S. litura* feed on 112 cultivated food plants all over the world (Moussa *et al.*, 1960) of which 40 are grown in India (Basu, 1943 and Thobbi, 1961). Many workers have reported *S. litura* as a foliar pest (Patel *et al.*, 1973; Gangrade, 1974; Rathi, 1984). Singh *et al.* (1998) reported *S. litura* as a potential pest on groundnut under irrigated condition. Panchabhavi and Nethradhaniraj (1987) reported that groundnut yield was affected by varying larval density of *S. litura*. ICRISAT (1986) and Dhir *et al.* (1992) assessed the groundnut loss due to *S. litura* infestation.

The groundnut leaf miner, *Aproaerema modicella* is a serious pest of groundnut in many Asian countries including India (Kalyanasundaram, 1985; Marwoto, 1996). Senguttuvan and Sujatha (2000) reported that *A. modicella* is the most important foliage feeding pest of groundnut in India, especially in southern states. Recently, Sherasiya and Butani (1998) and Senguttuvan (1999a) reported that *A. modicella* is one of the major pests attacking groundnut during the kharif and summer seasons in India. Tejkumar (1979), Anon (1986) and Veeresh *et al.* (1989) estimated the yield loss caused by *A. modicella*. Logiswaran and Mohanasundaram (1990) studied the damage potential of *A. modicella*. The gram pod borer, *H. armigera* is also a notable and serious pest in groundnut. Koshiya and Patel (1987) and Mc Caffery *et al.* (1989) have reported the pest status of *H. armigera* in groundnut. The larvae of *H. armigera* prefer to feed on flowers and buds (Wightman and Rao, 1993). Another important pest of groundnut is the red hairy caterpillar, *Amsacta albistriga* Walker. Groundnut leaf miner and red hairy caterpillars are the two serious pests in the kharif rainfed crop and gram pod borer tobacco army worm and jassids in the rabi rainfed and rabi summer irrigated crops in Tamil Nadu State as well as in other states in peninsular India (Jeyaraj – personnel communication). Gunathilagaraj and Babu (1987) reported the severe outbreaks of the red hairy caterpillar in rain fed groundnut in Tamil Nadu.

II. 3. Intercropping

Growing mixed crops or intercropping is an important feature of Indian agriculture, especially under rainfed conditions (Aiyer, 1949). Intercropping has become an important component of small farm agriculture in tropical countries (Lamb, 1978). Since intercropping system reduces the incidence of insect pests (Altieri *et al.*, 1978) and gives higher total income (Sidhu *et al.*, 1997; Bhondave *et al.*, 1994; Baskaran *et al.*, 1993; Gnanamurthy and Balasubramanian, 1996) greater importance is given in India and also at the International level for intercropping system. Intercropping system increased parasitoid and predatory population (Li, 1987; Wu *et al.*, 1991; Godfrey and Fleigh, 1994; Swaminathan *et al.*, 1999), availability of alternate prey, decreased colonization and reproduction in pest, chemical repellency, masking feeding inhibition of odours from non-host plants, prevention of emigration in pest and optimum synchrony in relation between pests and their natural enemies (Bhatnagar and Davies, 1981; Risch, 1981). Gavarra and Raros (1975) found more predatory spiders and predatory coccinellids in groundnut maize cropping system than in sole crop of groundnut. Changes in the microclimate of an inter crop also influence the behaviour of insect pest. Usually temperature and humidity in the intercrop will differ from those of sole crop, thereby affecting pest colonization (Mehto *et al.*, 1988). The identification of a suitable intercrop for a particular main crop is important to reduce pest incidence and also to enhance the production and net return. Intercropping system is always less likely to fail and is more stable than monocropping (Rao and Willey, 1980).

Recent demonstrations of IPM, which included sunflower as a trap crop on the borders of groundnut fields, clearly showed the ovipositional and larval preference of *S. litura* and *H. armigera* on sunflower (Dineshkumar *et al.*, 1992; Sarode *et al.*, 1999). In India, the crops generally used for intercropping with groundnut are sorghum (Shinde and Umrani, 1986; Senthivel *et al.*, 1989; Kennedy *et al.*, 1990; Putnam *et al.*, 1990; Muthiah *et al.*, 1991; Alegbejo, 1997), peas (Senthivel *et al.*, 1989; Kennedy *et al.*, 1990; Muthiah *et al.*, 1991; Lourduraj *et al.*, 1994; Das, 1998), Maize (Karim *et al.*, 1988; Wightman and Amin, 1988; Sharma and Varshney, 1990; Natarajan and Zharare, 1994; Alegbejo, 1997;), castor (Senthivel *et al.*, 1989; DeviDayal and Reddy, 1991; Muthiah *et al.*, 1991) sunflower (Putnam *et al.*, 1990; DeviDayal and Reddy, 1991; Natarajan and Zharare, 1994), millet (Baker, 1980; Gregory and Reddy, 1982; Wightman and Amin, 1988; Kennedy *et al.*, 1990; Muthiah *et al.*, 1991; Alegbejo, 1997), soybean (Senthivel *et al.*, 1989; Muthiah *et al.*, 1991), blackgram (Senthivel *et al.*, 1989; Muthiah *et al.*, 1991; Lourduraj *et al.*, 1994; Kalai Selvi *et al.*, 1996), cotton, pigeonpea, sesame and ragi (Senthivel *et al.*, 1989; Muthiah *et al.*, 1991; Loudruaj *et al.*, 1994; Ghosh *et al.*, 1999a). Kennedy and Raveendran (1989) reported that groundnut intercropped with pearlmillet reduced the incidence of leafminer, leafhopper and thrips substantially. Baskaran and Thangavelu (1990) recommended inter cropping of groundnuts and pearlmillet (*Pennisetum glaucum*) at a ratio of 4:1 respectively to reduce the occurrence of groundnut leafminer *A. modicella* and to increase natural enemy activity and yield. Muthiah *et al.* (1991) observed that intercropping in groundnut with blackgram, cowpea, pearlmillet and castor reduced the pest and disease incidence and gave higher net income. Bhondave *et al.* (1994) intercropped groundnut with castor and soybean. They found that soybean intercropping system gave highest net returns. Groundnut yield increased when groundnut was intercropped with pearl millet and cowpea (Kulkarni and Sojitra, 1986). Chandrasekar *et al.* (1988) made an attempt of intercropping groundnut with different cultivars of *Cajanus cajan*. Shinde *et al.* (1989) reported that the red gram, *Cajanus cajan* intercropped with groundnut enhanced the production.

Intercropping system is advantageous not only to minimize pest population, but also to reduce groundnut rosett virus (GRV) disease (Alegbejo, 1997) and suppress weed growth (Tewari *et al.*, 1989). Intercropping groundnut with *Pennisetum glaucum* gave the highest net return (4.7%) and also enhance the natural enemies of *A. modicella* (Baskaran *et al.*, 1993). Logiswaran and Mohanasundaram (1985) found that groundnut intercropped with cowpea (*Vigna unguiculata*) or black gram (*V. mungo*) was advantageous to get higher cost benefit ratios than pure groundnut cultivation.

II. 4. Plant Products

II. 4. 1. Neem (*Azadirachta indica* A. Juss.)

Efficiency of neem products in insect control in general and particularly with groundnut pests was reviewed by Saxena (1989), Schmutterer (1990) and Ghewande *et al.* (1996). The neem derivatives affect more than 200 insects (Saxena *et al.*, 1980). The bioactive principle of neem is Azadirachtin (Koul, 1982). Azadirachtin was first isolated by Butterworth and Morgan from the seeds of *Melia azadirachta* Linn. and the closely related species *M. azedarach* and they used it in a feeding inhibition test for *Schistocerca gregaria* (desert locust) (Butterworth and Morgan, 1968; Morgan and Thornton, 1973). Leaves and seeds of the neem tree, *Azadirachta indica* showed tremendous insecticidal activity (Schmutterer, 1990; Tanzubil and Mc Caffery, 1990; Sahayaraj and Paulraj, 1998 a,b,c). Kraus *et al.* (1985) reported that neem products are primarily feeding poisons for nymphs, larva and adult of polyphagous insects. Joshi and Ramprasad (1975) and Senthil Kumar *et al.* (1997) demonstrated the antifeedant property of azadirachtin. The impact of neem products on insect growth and development (Jotwani and Srivastava, 1981; Schmutterer, 1981; Schmutterer *et al.,* 1981; Rembold *et al.,* 1982; Gujar and Mehrotra, 1983; Koul, 1984a and b; Mehrotra and Gujar, 1986;Jacobson, 1988; Ayyangar and Rao, 1989a, Saxena and Harshand, 1992; Isman, 1993), ovipositional deterrent (Ayyangar and Rao, 1989b; Gupta and Rao, 1994; Naumann and Isman, 1995), feeding behaviour (Kareem, 1980; Koul, 1982; Ayyangar and Rao, 1989b; Isman, 1993; Prabhakar *et al.,* 1994) and haemolymph constituents, enzymes and endocrine system (Ayyanger and Rao, 1989a, 1990; Gupta and Rao, 1990; Mani *et al.,* 1996) were well documented. Lethal effect of neem products on insect pests was explored by Koul (1985), Tanzubil and Mc Caffery (1990), Prabhakar *et al.* (1994), Sahayaraj (1998) and Sahayaraj and Paulraj (1998a, b and c).

Neem products have been tested against gram pod borer, *H. armigera* by many investigators (Rao and Srivastava, 1985; Singh *et al.,* 1985; Sinha, 1993; Sachan and Lal, 1990; Katti *et al.,* 1992; Simwat and Dhawan, 1992; Solsoloy and Embuido, 1992; Jhansi and Singh, 1993; Pandey and Misra, 1996) in field conditions. Gahukar (1988) reported that neem cake extract gave satisfactory control of groundnut pests including *H. armigera* when compare to chemical pesticides. Joshi and Ramprasad (1975), Rao and Subramanian (1987), Jeyarajan *et al.* (1990), Mohapatra *et al.* (1995) and Koul *et al.* (1996) have reported that neem products can interfere with the feeding behaviour, nutritional physiology and metamorphosis in *S. litura.*

Azadirachtin is a neem based insecticide and used as natural insect control agent, because it possesses both protectant and toxic properties. Nandagopal *et al.* (1990) reported that neem products were the possible insecticides on groundnut jassid. Neem based product like margoside OK (0.1%) and aqueous leaf extract significantly increased the pod yield at Vridhachalam Centre, Tamil Nadu, apart from reducing the leaf miner damage (Anon, 1990). Rabindra and Jeyaraj (1994) observed that neem seed kernel extract can act as activators for the microsporidian, *Vairimorpha* sp., a natural enemy of *H. armigera*. Govindachari and Geetha (1998) reported that azadirachtin is the supermolecule for insect control. Senguttuvan (1999b) stated that, neem formulations were effective against thrips (*Scirtothrips dorsalis* Hood) in groundnut.

II. 4. 2. Madar [*Calotropis gigantea* (Linn.)]

Calotropis gigantea (Linn.) is known for its medicinal importance and it contains cardenolides (C_{22} sterolidic compounds) as the chief active principle (Brower *et al.*, 1982; Seiber *et al.*, 1986; Pugalenthi and David, 1997). Various parts of the plants like leaves, stem, buds, flowers, latex, root, barks, seeds etc., have been known to possess different types of cardenolides in different concentrations (Rajagopalan *et al.*, 1955; Hassal and Reyle, 1959; Bruschweiler *et al.*, 1969; Roeske *et al.*, 1975; Pant and Chaturvedi, 1989). The insecticidal property of calotropis was well documented by Pugalenthi *et al.* (1994), and Pugalenthi (1995). According to Pugalenthi *et al.* (1994), cardenolides caused 100 per cent mortality in *Epilachna viginitioctopunctata, H. armigera, Pericallia ricine* and *Earias vittella* (Fab.) at 70, 900, 1000 and 1000 ppm respectively within 24 hrs. Recent studies of Pugalenthi and David (1997) showed that treatments at 600 g/ha and 720 g/ha reduced the aphids and jassids population. Calotropis leaf extract caused mortality in *S. litura*

(Sahayaraj and Paulraj, 1998b; Murugan *et al.*, 1999) and *A. modicella* (Sahayaraj and Paulraj, 1998a).

II. 4. 3. Karanj (*Pongamia pinnata* Pierre)

Pongamia glabra is a perennial tree found in tropical and sub-tropical zones of India. Since ancient times, various isolated parts of this tree have been used as folk remedies for different maladies and as stored grain protectant against many stored product pests. *P. pinnata* was reported for its insect control property against *H. armigera* (Pandey and Misra, 1996). Sahayaraj and Paulraj (1998a, b) observed that water extracts of *P. pinnata* leaves at different concentrations caused larval mortality in *A. modicella* and *S. litura*. Ghewande (1989) reported that 2 per cent leaf extracts of *P. pinnata* controlled the groundnut foliar diseases and increased the yield. Murugan *et al.* (1999) investigated the toxicity of *P. pinnata* seed extract on *S. litura*.

II. 4. 4. Lagundi (*Vitex negundo* Linn.)

Vitex negundo L., an Indian shrub was evaluated against *S. litura* and found to cause 100 per cent mortality in third instar larvae (Bai and Kandasamy, 1985). Efficacy of vitex extracts on insect pests was explored by Tripathi and Rizvi (1985); Campos and Quilantang (1985); Kandasamy *et al.* (1987); Rabindra *et al.* (1991); Rejesus *et al.* (1993).

V. negundo leaves were found to be the best protectant against many stored product pests (Ahmed *et al.*, 1980; Krishnaraja *et al.*, 1985; Mia *et al.*, 1985; Prakash and Rao, 1989). In last instar larvae of *S. litura*, *V. negundo* leaf extract caused 83 per cent mortality (Sahayaraj and Sekar, 1996) and 66 per cent mortality at 6 per cent concentration (Sahayaraj and Paulraj, 1998b). *Vitex leucoxylon* affected the fecundity and embryonic development of *S. litura* and *Dysdercus koengii* (Suriyakala *et al.*, 1995) and *Sitophilus oryzae* Linn. (Ahmed *et al.*, 1980). The chemical principles of vitex that act on insect behaviour and physiology was studied by Anzaldo (1980), Dayrit and Lagurin (1994) and Suksamrarn *et al.* (1995). Douressamy *et al.* (1990 a) stated that *V. negundo* extract has ovicidal activity against *Pericallia ricini.*

CHAPTER - 1

"Integration of intercrops and plant products on chosen groundnut pests management" - Ph.D thesis submitted by M. Gabriel Paulraj to Bharathidasan University, Trichy, Tamil Nadu, India.

CHAPTER - 1

PLANT EXTRACTS ON THE MEDIAN LETHAL DOSE (LD_{50}) OF THREE PESTS *

1. 1. INTRODUCTION

Plant derived natural pesticides are the best alternatives to synthetic pesticides. The plant products can be used effectively in evolving an ecologically sound, economically viable and socially acceptable pest management system. Recent plant protection researchers, particularly of the last decade revealed the importance of plant products that disrupt the normal insect growth and development (Tripathi, 1998). The insect growth inhibitors of plant origin differ from the classical insecticides by their specificity and environmental acceptability.

Toxic effects of plant products on *Aproaerema modicella* Dev (Prabhakar and Rao, 1994; Sahayaraj and Paulraj, 1998a), *Helicoverpa armigera* Hubner (Sachan and Lal,1990; Rao and Rao, 1993; Pugalenthi *et al.,* 1994) and *Spodoptera litura* Fab.

*Part of this study has been published in two journals (See Publications)

(Bai and Kandasamy, 1985; Rao and Subramanian, 1987; Stevenson *et al.*, 1993; Mohapatra *et al.*, 1995; Koul *et al.*, 1996; Sahayaraj and Sekar, 1996; Senthil Kumar *et al.*, 1997; Sahayaraj, 1998; Sahayaraj and Paulraj, 1998b; Narendran *et al.*, 1999) were explored previously. Neem (*Azadirachta indica* A. Juss.) (Plate 2a) is a well-known plant for its insecticidal, antifeedant and growth inhibition properties (Saxena *et al.*, 1980; Schmutterer *et al.*, 1981; Koul, 1985; Gahukar, 1999; Joseph, 2000), erukku (*Calotropis gigantea* L.), a plant of milk weed family (Plate 2b), karanj (*Pongamia pinnata* Pierre.) and nochi (*Vitex negundo* Linn.) (Plate 2c & d) are commonly available plants throughout India and are used in folk remedies and also as repellants for stored grain and agricultural pests.

There has been limited works on the toxicity studies on the crude water extracts of leaves of *A. indica, C. gigantea, P. pinnata* and *V. negundo* against *A. modicella, H. armigera* and *S. litura* and the preparation of water extracts using the leaves of these plants is a feasible method which could be followed by the farmers. However it is important to test the efficacy of this method. In the present study, effect of water extract of *A. indica, C. gigantea, P. pinnata* and *V. negundo* leaves on the median lethal dose (LD_{50}) to *A. modicella, H. armigera* and *S. litura* was investigated.

1. 2. MATERIALS AND METHODS

1. 2. 1. Insects

Larval stages of *A. modicella, H. armigera* and *S. litura* were collected from the groundnut fields in Trichy District, Tamil Nadu and were used to maintain the laboratory nucleus cultures. All these pests larvae were maintained on groundnut leaves (cvTMV 7) in the laboratory (29 ± 1°C temperature; 65 – 70% r h and 11L and 13D photoperiod) *A. modicella* and *S. litura* larval instars were reared in plastic

PLATE 2. PLANTS USED FOR THE PRESENT STUDY

a. Neem tree (*Azadirachta indica* A. Juss) (Vembu)

b. Madar (*Calotropis gigantea* (Linn.)) (Erukku)

c. Karanj (*Pongamia pinnata* (Pierre)) (Pungai)

d. Lagundi (*Vitex negundo* (Linn.)) (Vellai nochi) troughs (21.0 × 28.0 × 9.0 cm) whereas *H. armigera* larvae were reared individually in small plastic vials (30 ml volume) to avoid cannibalism. Laboratory emerged fourth and fifth instar larvae were used for the experiments.

1. 2. 2. Preparation of plant extracts

Water extracts of *A. indica, C. gigantea, P. pinnata* and *V. negundo* leaves were prepared following the procedures described by Nandagopal (1992) and Sahayaraj (1998). Ten grams each of these leaves were washed thoroughly (2 times) with tap water and once with distilled water, macerated individually in mortar and pestle and extracted with 20 ml of distilled water. The extract was squeezed through fine muslin cloth and the final volume was made upto 100 ml to get 10 per cent stock solution. Different concentrations *viz.,* 0.5, 1.0, 2.0, 4.0 and 6.0 per cent were prepared from the stock solution by adding required quantity of distilled water and used for this study.

1. 2. 3. Treatment

Ten grams groundnut foliage (cvTMV 7) was dipped in the different concentrations of plant extracts separately for 15 minutes. For control, the leaves were dipped in distilled water. After 15 minutes the leaves were taken out and shade dried for 20 minutes on filter paper and supplied to the pest larvae. Ten laboratory reared fourth instar *A. modicella* larvae were released on the treated and non-treated (control) leaves taken in the plastic vials (600 ml) and the vials were covered by muslin cloth. Six replications were made for each concentration and control respectively. The larvae were allowed to feed the treated leaves for a period of 4 days and the mortality was recorded for every 24 hrs starting from first day to the fourth day. Similar procedure was followed for the fifth instar

A. modicella larvae and fourth and fifth instar larvae of remaining two pests tested here.

1. 2. 4. Statistical Analysis

Statistical analysis of experimental data was performed using probit analysis to find out the LD_{50}, regression, chi-square and variance (Finney, 1971). Data was analysed by completely randomized, one-way ANOVA and the means were separated using Duncan's multiple range test (DMRT) (Duncan, 1955), to determine the significant difference if any, among the treatment means of percentage larval mortality.

1. 3. RESULTS

1. 3. 1. *A. modicella*

The effect of plant extracts on the survival of *A. modicella* fourth and fifth instar larvae is presented in the Table 1. The results clearly indicated that *A. indica* was the most toxic plant followed by *V. negundo, C. gigantea* and *P. pinnata* and this order of toxicity was clearly expressed in the LD_{50} studies (Fig. 1). Although neem caused the highest mortality of 20.0, 30.0 and 53.3 per cent at 0.5, 1.0 and 2.0 per cent concentrations respectively, *V. negundo* was the most lethal one at 4.0 and 6.0 per cent concentrations by killing 60.0 and 63.3 per cent fourth instar larvae respectively. Similarly *C. gigantea* was the most toxic plant to fifth instar larva at 6 per cent concentration and this was clearly seen from Table - 1 (5.0, 35.0, 45.0, 60.0 and 75.0 per cent larval mortality at 0.5, 1.0, 2.0, 4.0 and 6.0 per cent concentrations respectively). The mortality values in different concentrations of each treatment were significantly different ($P < 0.05$) by ANOVA.

Table 1. Per cent larval mortality of three groundnut pests following the oral administration of four plant products

Treatments	Concentration (in %)	Pest					
		A. modicella		*H. armigera*		*S. litura*	
		IV instar	V instar	IV instar	V instar	IV instar	V instar
	Control	0.0^{c}	0.0^{e}	0.0^{d}	0.0^{e}	0.0^{d}	0.0^{d}
	0.5	20.0^{b}	42.0^{d}	65.0^{c}	23.3^{d}	0.0^{d}	25.9^{c}
	1.0	30.0^{b}	48.0^{c}	71.0^{b}	36.6^{c}	16.6^{c}	33.3^{bc}
A. indica	2.0	53.3^{a}	52.0^{c}	75.0^{b}	43.3^{c}	30.0^{b}	44.4^{abc}
	4.0	56.6^{a}	60.0^{b}	80.0^{a}	60.0^{b}	53.3^{a}	48.2^{ab}
	6.0	60.0^{a}	72.0^{a}	82.0^{a}	83.3^{a}	56.6^{a}	55.6^{a}
	Control	0.0^{c}	0.0^{e}	0.0^{e}	0.0^{c}	0.00^{e}	0.0^{c}
	0.5	6.6^{c}	5.0^{e}	0.0^{e}	0.0^{c}	36.6^{d}	44.4^{b}
	1.0	26.6^{bc}	35.0^{d}	20.0^{d}	3.3^{c}	60.0^{c}	55.6^{ab}
C. gigantea	2.0	43.3^{ab}	45.0^{c}	26.0^{c}	40.0^{b}	76.6^{b}	63.0^{a}
	4.0	53.3^{a}	60.0^{b}	48.0^{b}	53.3^{a}	93.3^{a}	66.7^{a}
	6.0	56.6^{a}	75.0^{a}	66.0^{a}	60.0^{a}	93.3^{a}	70.4^{a}
	Control	0.0^{c}	0.0^{f}	0.0^{d}	0.0^{c}	0.0^{c}	0.0^{e}
	0.5	3.3^{c}	20.0^{e}	0.0^{d}	0.0^{c}	0.0^{c}	22.2^{d}
	1.0	20.0^{b}	30.0^{d}	20.0^{c}	0.0^{c}	6.6^{c}	29.6^{c}
P. pinnata	2.0	30.0^{b}	46.0^{c}	20.0^{c}	10.0^{c}	26.6^{b}	40.7^{b}
	4.0	53.3^{a}	54.0^{b}	40.0^{b}	33.3^{b}	26.6^{b}	44.6^{b}
	6.0	60.0^{a}	63.0^{a}	50.0^{a}	60.0^{a}	53.3^{a}	53.7^{a}
	Control	0.0^{d}	0.0^{e}	0.0^{d}	0.0^{b}	0.0^{c}	0.0^{d}
	0.5	0.0^{d}	15.0^{d}	0.0^{d}	0.0^{b}	13.3^{c}	37.0^{c}
	1.0	23.3^{c}	32.0^{c}	0.0^{d}	0.0^{b}	30.0^{b}	48.2^{bc}
V. negundo	2.0	43.3^{b}	52.0^{b}	20.0^{c}	43.3^{a}	60.0^{a}	55.6^{ab}
	4.0	60.0^{a}	55.0^{ab}	40.0^{b}	43.3^{a}	66.6^{a}	63.0^{ab}
	6.0	63.3^{a}	58.0^{a}	60.0^{a}	53.3^{a}	63.3^{a}	67.0^{a}

Values carrying same alphabet(s) in each treatment in a column are not significantly different by DMRT at 5% level.

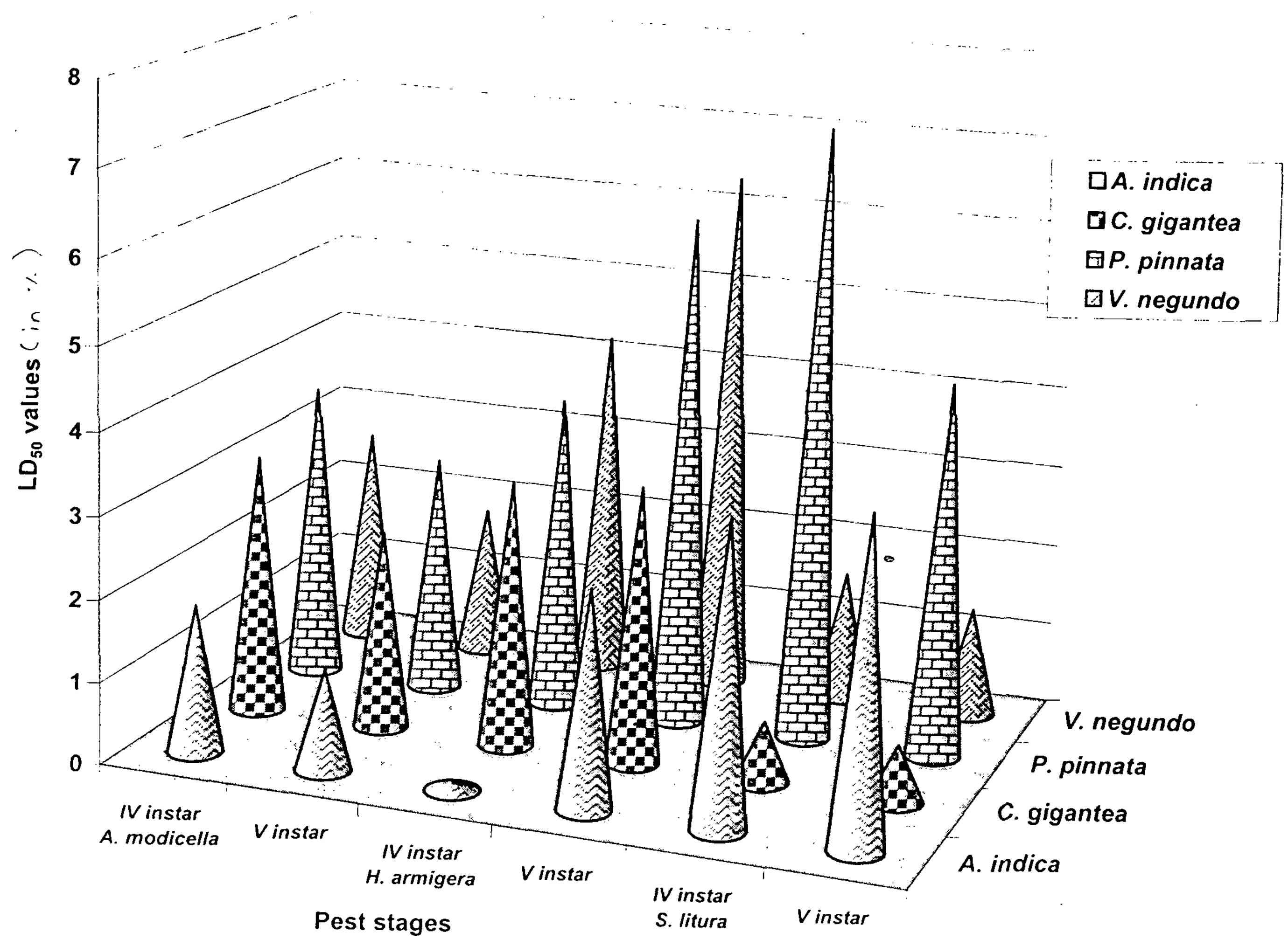


Fig. 1. Impact of plant products on LD_{50} in different life stages of groundnut pests

From the LD_{50} values it was clearly understood that *P. pinnata* was a less toxic plant however caused 60.0 per cent mortality at 6 per cent concentration in the fourth instar larva which was higher than *C. gigantea* (56.66) at the same concentration. The LD_{50} values for fourth instar larvae were 2.71, 3.45, 3.72 and 2.72 for *A. indica, C. gigantea, P. pinnata* and *V. negundo* respectively. In the fifth instar larvae, percentage mortality was found to be high in all the treatments except *V. negundo* when compared with the fourth instar larvae at the same concentrations. The order of toxicity was the same as for the fourth instar larvae. The LD_{50} values for the fifth instar larvae were 1.22, 2.43, 2.94 and 1.82 for *A. indica, C. gigantea, P. pinnata* and *V. negundo* respectively (Fig. 1). The order of toxicity of the plant products to fourth and fifth instar *A. modicella* larvae can be written as *A. indica* > *V. negundo* > *C. gigantea* > *P. pinnata.*

1. 3. 2. *H. armigera*

A. indica was found to be the most toxic plant to *H. armigera* fourth and fifth instar larvae (Table 1). The influence of the neem extract on *H. armigera* was clearly expressed even at the lowest (0.5%) concentration (65.0 per cent mortality in fourth instar larvae) and the highest concentration (6%) caused 82.0 and 83.3 per cent mortality in fourth and fifth instar larvae respectively. Fifth instar larvae were found to be less susceptible than the fourth instars in *A. indica* and *P. pinnata* treatments at all concentrations except at 6 per cent. The percentage mortality of fifth instar larvae were 0, 3.3, 40.0, 53.3 and 60.0 per cent in *C. gigantea*; 0, 0, 10.0, 33.3 and 60.0 per cent in *P. pinnata* and 0.0, 0.0, 43.3, 43.3 and 53.3 in *V. negundo* treatments at 0.5, 1.0, 2.0, 4.0 and 6.0 per cent concentrations respectively. Statistical comparison between the treatments was significantly different ($p < 0.05$) by ANOVA.

From the LD_{50} values it was clearly understood that *V. negundo* was the least toxic plant to *H. armigera*. The LD_{50} of *A. indica, C. gigantea, P. pinnata* and *V. negundo* to the fourth instar larva was 0.08, 3.24, 3.82 and 4.20 per cent and fifth instar was 1.95, 3.49, 4.70 and 3.66 per cent respectively. The order of toxicity was found to be same for both fourth and fifth instar larvae (*A. indica* > *C. gigantea* > *P. pinnata* > *V. negundo*). Unlike *A. modicella*, the dose required to kill 50 per cent larvae of *H. armigera* was higher in the fifth instar larvae than fourth instar. The LD_{50} for fourth instar was lower than the fifth instar for *A. indica, C. gigantea, P. pinnata* and *V. negundo* extract respectively (Fig. 1).

1. 3. 3. *S. litura*

It was observed that unlike *A. modicella* and *H. armigera*, *S. litura* larvae were severely affected by *C. gigantea* extracts and the larval mortality was recorded as 36.6, 60.0, 76.6, 93.3 and 93.3 per cent in the fourth instar and 44.4, 55.5, 62.9, 66.6 and 70.37 per cent in the fifth instar at 0.5, 1.0, 2.0, 4.0 and 6.0 per cent concentrations respectively (Table - 1). *P. pinnata* was the least toxic plant product to *S. litura* followed by *A. indica* and *V. negundo* and the treatment effects were significant ($P < 0.05$) by ANOVA. The LD_{50} results were presented in Fig. 1 and from the figure, it is clear that the LD_{50} value of *P. pinnata* for fourth instar was higher (7.33) than fifth instars (4.55). The order of toxicity is expressed as *C. gigantea* > *V. negundo* > *A. indica* > *P. pinnata*.

1. 4. DISCUSSION

Berenbaum (1986) reported that postingestive effects of plant constituents can be acute or chronic in phytophagous insects. In the case of acute toxicity, the toxic principle in the plant material kills the insect outright due to involvement in intermediary metabolism or cellular functions. Chronic toxicity is exposed through malfunctions and malformations in treated insects. In the present study, the four plants screened exhibited insecticidal properties and the mortality was found to be concentration dependent. Concentration dependent mortality in insect pests due to biorational biopesticides and also synthetic pesticides has been reported by many investigators (Bai and Kandasamy, 1985; Pugalenthi *et al.*, 1994; Gujar, 1997; Jeyakumar and Uthamasamy, 1997; Singh *et al.*, 1997; Murugan *et al.*, 1998; Sahayaraj and Paulraj, 1998 a, b). Desai and Desai (2000) reported that alcoholic extracts of *C. gigantea* and *V. negundo* leaves and *P. pinnata* seed kernels caused 6.89, 17.24 and 34.47 per cent mortalities respectively in *S. litura* larva in 72 hrs observation. Another interesting observation in this study was that the four plant products tested here are species specific and it is supported by Desai and Desai (2000) and Malathi and Sriramulu (2000). Neem was the most toxic plant to *A. modicella* and *H. armigera* and *C. gigantea* was the most toxic plant to *S. litura*. Among the four plants tested, *P. pinnata* was the least toxic to *A. modicella* and *S. litura* where as *V. negundo* was the least toxic plant to *H. armigera*. In general *A. indica* and *C. gigantea* were the most toxic plants among the four botanicals tested.

Feeny (1976) and Berenbaum (1983) reported that the plant toxins such as alkaloids, glucosinolates and furanocoumarins exert their effects on herbivorous insects qualitatively, i. e., cause mortality. Furthermore, tannis and resins exert their effects by reducing the digestive efficiencies (qualitative) in insects (Berenbaum, 1986). Azadirachtin is the active compound present in *A. indica,* which is responsible for antifeedant, repellant and insecticidal properties exerted by *A. indica* (Schmutterer *et al.,* 1981; Koul, 1984a; Koul, 1985). Saxena (1987) and Dureja and Sapna Johnson (2000) pointed out that neem derivatives do not kill the insects directly, rather they eventually succumb to behavioural and physiological stresses and starvation on treated plants and caused mortality. Barnby *et al.* (1989) reported the bio-activity of azadirachtin against the last instar larvae of *Heliothis virescens* by oral injection and found that 2μl of azadirachtin caused 100 per cent mortality. Rembold (1989 a,b); Gupta and Rao (1990) and Mani *et al.* (1996) have reported that azadirachtin interfered with juvenile hormone titers, inhibiting larval moulting into the next instar, thereby causing eventual mortality. Murugan *et al.* (1998) recorded 15, 22, 41, 62 and 91 per cent larval mortalities in *H. armigera* at 0.5, 1.5, 3.0, 5.0 and 7.5 per cent concentrations of neem seed kernal extract. In the present study the larvae treated by *A. indica* and *C. gigantea* showed regurgitation and this may be due to the emetic property of these plants. Martinez and Van Emden (1999) observed that *S. littoralis* larvae consumed less food after feeding on diet treated with azadirachtin for two days. This effect called secondary antifeedant effect which leads to poor growth and finally to death. The secondary antifeedant effect exerted by azadirachtin was also reported by Mordue (Luntz) *et al.* (1985) and Rembold (1989a, b). Azadirachtin was found to be the most effective botanical in inhibiting growth and development of *H. armigera* as compared to plumbagin of *Plumbago* spp. (Gujar, 1997).

Karanjin was identified as the toxic principle present in *P. pinnata* plant (Chakraborty *et al.,* 1976) and this toxic compound exerts toxic effects in insects when orally treated. The toxic principle present in *C. gigantea* is a C_{23} steroidic compound known as cardenolides. Cardenolides are synthesised by plants of milk weed family, *Asclepiadaceae* (Brower *et al.,* 1982; Seiber *et al.,* 1986; Pugalenthi, 1995; Pugalenthi *et al.,* 1994; Pugalenthi and David, 1997). Murugan *et al.* (1999) reported that 2 per cent leaf extract of *C. gigantea* caused 98 per cent larval mortality in *S. litura*. In their study, 2.0 per cent *P. pinnata* and *A. indica* seed extracts caused 90 and 53 per cent larval mortalities respectively. Sahayaraj and Sekar (1996) reported that 10% leaf extracts of *V. negundo* and *A. indica* caused 83 and 80 per cent mortalities respectively in the last instar larvae of *S. litura*.

Among the three pests tested, *S. litura* was found to be the target pest for *C. gigantea*. *A. modicella* and *H. armigera* were severely affected by *A. indica*. *V. negundo* was less effective to *H. armigera* than *A. indica*. This is confirmed from the findings of previous studies carried out by Murugan *et al.* (1998). They recorded 12, 20, 36, 56 and 78 per cent mortality of *H. armigera* larvae at 0.5, 1.5, 3.0, 5.0 and 7.5 per cent concentrations of *V. negundo* leaf extract. Rabindra and Jeyaraj (1994) have reported about the indirect effect of *C. gigantea, V. negundo* and *A. indica* on *H. armigera* larva. They reported that 10 per cent leaf extracts of *C. gigantea, V. negundo* and one per cent seed kernel extract of *A. indica* enhanced the activity of microsporidian in *H. armigera* second instar larvae and caused 57.5, 42.5 and 85.0 per cent mortality respectively. All the four plant products tested in the present study showed stage specificity. Among the two life stages tested in *A. modicella*, the fifth instars were much susceptible to all the plants tested here. *H. armigera* fourth instar was the target stage for *A. indica* and *P. pinnata* and other two plants had more or less same impact on both stages of this polyphagous pest. *C. gigantea* caused high mortality in the fourth instar larvae of *S. litura*. The most enigmatic species in the present study is *S. litura* and confirm the results of Isman (1993). He reported that *S. litura* was the sensitive pest among the six pests he studied.

There are a few studies which permit direct comparison of the efficacy of plant products against different lepidopteran pests (Isman, 1993). The incidence of mortality is generally an acceptable measure of potency expressed either as a percentage relative to a control or as an LC_{50} (lethal concentration) or LD_{50} (lethal dose) value. Matsumura (1976) defined LC_{50} and LD_{50} as the amount required per unit weight to kill 50% of the test population. The LD_{50} of plant products for *A. modicella* and *S. litura* was indirectly proportional to larval age. This trend was supported by Jayachandran *et al.* (1999), who reported that the LD_{50} of NPV for *S. litura* decreased as the larval age increased. However, in *H. armigera* the LD_{50} was age dependent. Schmutterer *et al.* (1983) reported that neem products (purified neem seed extracts) did not affect the survival of *A. modicella* during larval and pupal stages. In contrast, in the present study, neem leaf extract caused high mortalities at all concentrations except at 6% concentration and the LD_{50} value for fifth instar was 2.0 times lower than *C. gigantea* and 2.4 times lower than *P. pinnata*. Blackening of the body colour, breaking of the cuticle and oozing out of the haemolymph from the body were the direct effects observed in the treated *A. modicella* larvae.

1. 5. CONCLUSION

The insecticidal property of *A. indica, C. gigantea, P. pinnata* and *V. negundo* were clearly expressed in this study. Neem and calotropis were found to be the most effective bio-pesticides against *A. modicella, H. armigera* and *S. litura* larval stages. *S. litura* was the target pest for *C. gigantea* whereas *H. armigera* and *A. modicella* were severely affected by *A. indica*. However, the ultimate value of these bio-pesticides for the control of groundnut defoliators can only be determined through actual field trials.

CHAPTER - 2

"Integration of intercrops and plant products on chosen groundnut pests management" - Ph.D thesis submitted by M. Gabriel Paulraj to Bharathidasan University, Trichy, Tamil Nadu, India.

CHAPTER – 2

THE IMPACT OF PLANT PRODUCTS ON THE BIOLOGY AND JUVENOMETRY OF CHOSEN GROUNDNUT PESTS

2. 1. INTRODUCTION

In agriculture the lepidopteran larval stage causes severe damage, by consuming large quantities of plant material. They grow and develop rapidly and moult frequently under the control of endocrine system. Ecdysone and juvenile hormone (JH) are the two main endocrine secretions in insects, which regulate several physiological processes such as growth, metamorphosis and reproduction etc. Upsetting the normal titre of these hormones in the haemolymph by their exogenous application at certain times in the life cycle of insects induces mortality, abnormal moulting, formation of supernumerary instars, adult malformation and infertility etc. (Mulder and Gijswijt, 1973; Mitchell and Smith, 1988; Mathur and Srivastava, 1989). The effect of JH and its analogues on growth and development have hitherto been studied in many insect species (Mathur and Srivastava, 1989; Anita Mane, 1997; Gujar, 1997). Toxins, which interfere with hormone regulation, have therefore, frequently been suggested as potential insecticides, particularly because insect hormones generally do not occur in mammals.

Since Williams and Slama (1966) discovered that certain plant products inhibited metamorphosis in pyrrhocoroid bugs, JH activity has been discovered in various plants all over the world and the substances responsible for JH activity have been isolated and their structure elucidated in certain cases. Ruscoe (1972) first reported the growth disruption in *Heliothis virescens* (Fab.) by azadirachtin. Recent researches, particularly of the last decade, revealed the importance of plant products that disrupt the normal insect growth and development. Further, the intermediates, produced with hormone treatment may differ greatly irrespective of their characters, possessing the pupal and adult characters in varying properties. Bhatnagar and Sharma (1994) listed 31 species out of 1005 plant species for their growth inhibition properties.

The insect growth inhibitors of plant origin differ from the classical insecticides by their specificity and environmental acceptability. The biological activity of plant products was well documented by many investigators. Jotwani and Srivastava (1981), Rembold *et al.* (1982), Koul (1985), Mehrotra and Gujar (1986) Jeyarajan *et al.* (1990), Isman (1993), Narendran *et al.* (1999) and Joseph (2000) reported the growth inhibiting effect of neem compounds and other plant products on insect pests.

In the present study, water extracts of *A. indica, C. gigantea, P. pinnata* and *V. negundo* leaves were tested for their effects on the biology, development and morphology of *A. modicella, H. armigera* and *S. litura* fourth instar larval stages.

2. 2. MATERIALS AND METHODS

Methods of laboratory rearing of the experimental insects, preparation of plant products and plant products treatment procedures were explained in the Materials and Methods section of the Chapter - 1.

The treated *A. modicella* larvae were maintained on the groundnut leaves and allowed to pupate. The pupated insects were placed on moist cotton swabs in petridishes and kept inside wire cages (30 x 30 x 90 cm) and further observed until adult emergence. After emergence of the controls, the old pupal cuticle of the unemerged experimental pupae was carefully removed and the specimens were studied for their morphological characters. Specimens that died prior to the completion of developmental period were disregarded in evaluating the results. Furthermore larval period, pupal period and adult longevity were recorded. Adult moths were supplied with 10 per cent honey solution as feed upto their death. The same procedure was followed for *H. armigera* and *S. litura*.

2. 2. 1. Statistical analysis

From the observed data, the mean values for all the parameters were calculated. Pupal and adult abnormalities and pupal mortality were converted in to percentages. Analysis of variance (ANOVA) was used to test the significance between treatments at 5% level. Duncan's Multiple Range Test (DMRT) was used to determine the significant difference if any, among the treatment means of larval and pupal periods (Duncan, 1955).

2. 3. RESULTS

The results of the present study are given here under the following headings.

2. 3. 1. Biology

2. 3. 1. 1. Larval period

All the four plant products tested here increased the total larval period in all the three pests as compared to the controls (Table 2). For instance, *A. modicella* larval period was 14.9, 14.7, 14.6 and 14.7 days at 6 per cent concentration of *A. indica, C. gigantea, P. pinnata* and *V. negundo* respectively when compared with control (13.9 days). Furthermore the larval period of *H. armigera* and *S. litura* in *A. indica* treatment (at 6% concentration) was nearly 3 and 4 days higher respectively than control. In the control category the larval duration of *H. armigera* and *S. litura* were 16.5 and 15.8 days respectively. At the highest concentration (6%) of *A. indica, C. gigantea, P. pinnata and V. negundo,* the larval period of *H. armigera* was 19.3, 18.6, 18.6 and 17.4 days respectively; *S. litura* was 19.8, 18.0, 15.8 and 17.6 days respectively. The larval period of all pests studied here was directly proportional to the concentrations of the plant extracts tested.

2. 3. 1. 2. Pupal period

As observed in the larval period, all the plant products tested here increased the pupal period also (Fig. 2a, b, c and d). In control categories, the pupal period of *A. modicella, H. armigera* and *S. litura* were 4.6, 8.1 and 7.3 days respectively. *S. litura* pupal period was nearly 2 days longer (9.4 days) than control at 6.0 per cent concentration of *A. indica*. *V. negundo* significantly increased the pupal period for one day in *S. litura* at 4.0 (8.3 days) and 6.0 (8.5 days) per cent concentrations. Similarly, pupal duration of *H. armigera* in *A. indica* treatment was increased for nearly 1.5 to 2.5 days more than in control and this increase was found to be concentration dependent (9.8, 10.5, 10.4, 10.5 and 10.4 days for 0.5, 1.0, 2.0, 4.0 and 6.0 per cent concentrations respectively). In *C. gigantea* treatment, the pupal period of *H. armigera* increased for nearly 1.5 days from the lowest to the

Table 2. Influence of plant products on the mean larval period (in days) of three groundnut Pests (n = 180)

Treatments	Pest	Concentration (%)						Grand Mean
		Control	0.5	1.0	2.0	4.0	6.0	
A. indica	*A. modicella*	13.9^{b}	14.2^{b}	14.7^{a}	14.7^{a}	14.6^{a}	14.9^{a}	14.5
	H. armigera	16.5^{d}	16.8^{d}	17.3^{c}	17.5^{c}	18.4^{b}	19.3^{a}	17.6
	S. litura	15.8^{d}	15.6^{d}	16.3^{c}	16.4^{c}	17.3^{b}	19.8^{a}	16.9
C.gigantea	*A. modicella*	13.9^{c}	14.3^{ab}	14.2^{bc}	14.3^{ab}	14.5^{ab}	14.7^{a}	14.3
	H. armigera	16.5^{c}	17.8^{b}	18.1^{b}	18.3^{ab}	18.7^{a}	18.6^{a}	18.0
	S. litura	15.8^{c}	16.5^{b}	16.7^{b}	16.8^{b}	17.0^{b}	18.0^{a}	16.8
P. pinnata	*A. modicella*	13.9^{c}	14.3^{ab}	14.1^{bc}	14.2^{bc}	14.2^{abc}	14.6^{a}	14.2
	H. armigera	16.5^{d}	17. 8^{c}	18.3^{ab}	18.0^{bc}	18.5^{ab}	18.6^{a}	18.0
	S. litura	15.8^{ab}	15.4^{b}	15.7^{ab}	15.8^{ab}	15.7^{ab}	15.8^{a}	15.7
V. negundo	*A. modicella*	13.9^{b}	13.9^{b}	14.0^{b}	14.6^{a}	14.5^{a}	14.7^{a}	14.3
	H. armigera	16.5^{d}	16.5^{cd}	16.9^{bc}	17.3^{ab}	17.4^{a}	17.4^{a}	17.0
	S. litura	15.8^{d}	16.3^{c}	16. 8^{b}	16.8^{b}	16.9^{b}	17.6^{a}	16.7

Values carrying same alphabet(s) in a row are not significantly different by DMRT at 5% level.

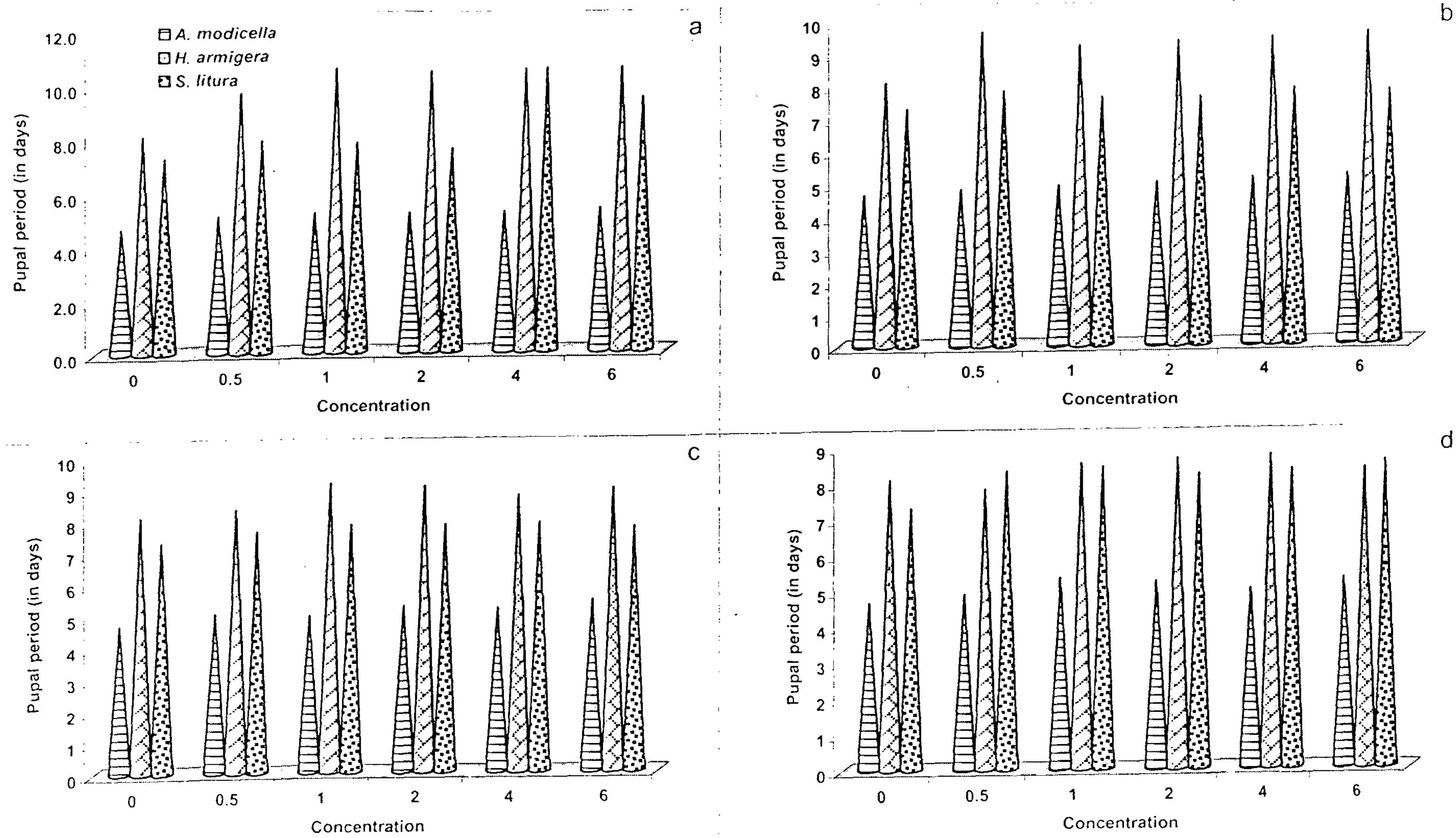


Fig. 2. Impact of (a) *A. indica*, (b) *C. gigandea*, (c) *P. pinnata* and (d) *V. negundo* leaf extracts on pupal period of groundnut pests

highest concentrations and this was depicted as 9.6, 9.2, 9.3, 9.4 and 9.5 days at 0.5, 1.0, 2.0, 4.0 and 6.0 per cent concentrations respectively. Neem was highly significant to increase the pupal duration in *H. armigera* among the four plants tested here. For *S. litura, V. negundo* treatment was significantly more effective than other plant product treatments.

2. 3. 1. 3. Adult longevity

The life span of male and female moths of *A. modicella, H. armigera* and *S. litura* in response to different plant products treatment is given in Table 3. Both in the control and all the treatments, the female moths lived longer than males. In control, the longevity of male moths of *A. modicella, H. armigera* and *S. litura* were 3.9, 5.7 and 5.1 days respectively and of female moths were 4.9, 7.0 and 5.7 days respectively. When *A. modicella* was treated with botanicals, the female longevity was reduced and this reduction was found to be concentration dependent in all treatments (2.4, 2.4, 3.2, 2.2 and 2.0 days in *A. indica*; 3.7, 3.6, 3.7, 2.2 and 2.2 days in *C. gigantea*; 5.8, 3.6, 3.5, 3.7 and 3.0 days in *P. pinnata* and 4.3, 4.4, 4.2, 3.8 and 3.6 days in *V. negundo* treatments at 0.5, 1.0, 2.0, 4.0 and 6.0 per cent concentrations respectively). *C. gigantea* was found to be the most effective to *S. litura* and caused a female life span of 3.8, 3.3, 3.4, 3.1 and 2.6 days and male life span of 2.0, 1.8, 2.0, 1.7 and 2 days at 0.5, 1.0, 2.0, 4.0 and 6.0 per cent concentrations respectively which was nearly 2 to 3 days less than control. *V. negundo* was the most effective botanical to *H. armigera* in relation to adult longevity and it was clearly exhibited from the results (5.5, 5.0, 4.2, 4.2 and 3.6 days and 3.4, 3.0, 3.0, 2.1 and 2.0 days of female and male longevity respectively at 0.5, 1.0, 2.0, 4.0 and 6.0 per cent concentrations respectively).

Table 3. Impact of plant products on the mean adult longevity (in days) of three groundnut pests (n = 180).

(Values in parentheses indicate the male life span).

Treatments	Pest	Concentration (%)					
		Control	**0.5**	**1.0**	**2.0**	**4.0**	**6.0**
A. indica	*A. modicella*	4.9 (3.9)	2.4 (2.0)	2.4 (2.0)	3.2 (2.0)	2.2 (1.9)	2.0 (1.8)
	H. armigera	7.0 (5.7)	6.8 (5.2)	6.8 (5.3)	6.5 (5.0)	6.5 (5.0)	6.3 (4.6)
	S. litura	5.7 (5.1)	5.6 (4.6)	5.6 (3.1)	4.6 (3.4)	4.4 (3.0)	4.3 (3.0)
C.gigantea	*A. modicella*	4.9 (3.9)	3.7 (2.3)	3.6 (2.3)	3.7 (2.0)	2.2 (2.0)	2.2 (2.0)
	H. armigera	7.0 (5.7)	5.8 (5.6)	5.3 (5.0)	5.3 (4.1)	5.0 (3.2)	4.7 (3.0)
	S. litura	5.7 (5.1)	3.8 (2.0)	3.3 (1.8)	3.4 (2.0)	3.1 (1.7)	2.6 (2.0)
P. pinnata	*A. modicella*	4.9 (3.9)	5.8 (2.6)	3.6 (2.4)	3.5 (2.7)	3.7 (2.7)	3.0 (2.3)
	H. armigera	7.0 (5.7)	5.9 (4.3)	5.6 (5.0)	4.8 (4.6)	4.0 (3.0)	4.0 (2.0)
	S. litura	5.7 (5.1)	4.7 (3.2)	4.5 (2.6)	4.6 (2.5)	4.3 (2.0)	4.0 (2.0)
V. negundo	*A. modicella*	4.9 (3.9)	4.3 (2.6)	4.4 (2.5)	4.2 (2.5)	3.8 (2.0)	3.6 (1.8)
	H. armigera	7.0 (5.7)	5.5 (3.4)	5.0 (3.0)	4.2 (3.0)	4.2 (2.1)	3.6 (2.0)
	S. litura	5.7 (5.1)	4.3 (2.0)	4.2 (2.0)	4.3 (1.6)	3.2 (2.2)	3.2 (2.0)

2. 3. 2. Juvenometry

2. 3. 2. 1. Pupal abnormality

The botanicals interfered with the normal pupal development of *A. modicella, H. armigera* and *S. litura* as evident from the results. The development of abnormal structures in the pupa and pupal death were found in the treated insects. More number of abnormal pupae were observed in *S. litura* at 4.0 per cent concentration of *A. indica* (32.5%) and *V. negundo* (22.2%) (Plate 4). In *A. modicella*, deformed pupae were produced by *A. indica, C. gigantea* and *V. negundo* treatments but *P. pinnata* did not produce any pupal abnormality. In *H. armigera*, 12.0 and 12.5 per cent pupal abnormalities were recorded in *A. indica* treatment at 1.0 and 2.0 per cent concentrations (Plate 3). *C. gigantea* produced 3.3 per cent pupal deformities in *A. modicella* at 0.5 per cent, 12.5 per cent in *H. armigera* at 6.0 per cent and 10.0 per cent in *S. litura* at 4.0 per cent concentrations. *P. pinnata* caused 4.2 and 6.7 per cent pupal abnormalities in *H. armigera* and *S. litura* respectively at 0.5 per cent and 8.0 per cent abnormal pupae in *H. armigera* at 1.0 per cent concentration respectively. *V. negundo* produced 7.7 per cent pupal abnormalities at 0.5 per cent concentration in *A. modicella* and 6.7 per cent pupal abnormalities in *H. armigera* at 6.0 per cent concentrations respectively.

Most of the pupae of *H. armigera* and *S. litura* were small in size, had thoracic legs and remnants of larval skin and curved in structure (Plates 3 and 4). In some pupae of *S. litura*, the gap between the abdominal segments was wide. In *A. modicella*, all abnormal pupae had vesicles in the abdominal region.

PLATE 3. MALFORMATIONS IN THE LIFE STAGES OF *H. armigera* CAUSED BY PLANT PRODUCTS

a. Larval – pupal intermediate produced by *C. gigantea* 0.5%

b. Deformed pupa with remnants of thoracic legs and larval skin (*P. pinnata* 1.0%)

c. Abnormal pupa produced by *P. pinnata* 0.5%. Larval head capsule remains in the pupa

d. Incompletely eclosed adult with part of pupal case in the head region, produced by *C. gigantea* 2.0%

e. Normal *H. armigera* pupa

PLATE 4. DEFORMITIES IN THE LIFE STAGES OF *S. litura* PRODUCED BY PLANT PRODUCTS

a. Incomplete moulting in *S. litura* during pupation caused by *A. indica* at 4.0%

b. Deformed *S. litura* pupa produced by 4.0% *C. gigantea*

c. Small size, curved *S. litura* pupa caused by *P. pinnata* 0.5%

d. Larval – pupal intermediate with abdominal vesicle (*V. negundo* 4.0%)

e. Normal *S. litura* pupa

2. 3. 2. 2. Adult abnormality

Adult deformities were formed in *H. armigera* and *S. litura* only. *C. gigantea* caused 4.2 per cent deformed adults in *H. armigera* at 2.0 per cent concentration (Plate 3d). *V. negundo* produced 8.3 per cent deformities at 6.0 per cent concentration in *H. armigera* adults and 5.6 and 5.6 per cent deformities in *S. litura* at 4.0 and 6.0 per cent concentrations, respectively. The deformed adults had curled and under developed wings and head capsules and small in size.

2. 4. DISCUSSION

Williams (1969) described JH as "the status quo" hormone and regarded that the classical status quo effect on the larvae or pupa by treatment with JH is manifested in the form of a supernumerary larval or pupal molt. This would presumably happen when the larval – pupal or pupal - adult transformation is fully arrested by the treatment of plant products before the process of transformation begins and quantity of hormone necessary to bring about the arrest of transformation is available. Any interruption on the hormonal regulation in insects will lead to biological and morphological defects (Mulder and Gijswijt, 1973; Anita Mane, 1997; Gujar, 1997). In the present study, the larval and pupal periods of the tested insects were found to be increased by the plant product treatments. These results agreed with the results reported by Murugan *et al.* (1998). They reported that water extracts of *A. indica* seed kernel and *V. negundo* leaves increased the larval and pupal period of *H. armigera*.

The adult development inside the pupa was slowed down by the treatments and this indicated the inhibitory function of growth hormone, which may be due to the presence of secondary metabolites in the botanicals tested here. Rembold (1989 a) and Gujar (1997) attributed the action of azadirachtin to the interference with the hormonal regulation in insects. Warthen (1989) reported that azadirachtin affect the growth and development of *H. virescens*. Later, studies carried out in *H. armigera* (Barnby *et al.,* 1989; Gujar, 1997) showed that azadirachtin delayed moulting of larvae to pupal stage. The longer persistence of the JH in the final instar *S. litura* larvae delayed the induction of fat body storage proteins, thus disrupting the rhythm for the commitment of larval – pupal metamorphosis (Tojo *et al.,* 1985; Mani and Rao, 1998). In the present study, the larvae of *H. armigera* and *S. litura* were found to be more sensitive to all the plants tested here than *A. modicella*. Among the four plants screened here, *A. indica* was found to be the most effective in extending the larval period in *H. armigera* and *S. litura* followed by *C. gigantea*. This kind of specific action of botanicals on insects has been reported by Desai and Desai (2000) and Malathi and Sriramulu (2000). Kubo and Klocke (1982) reported about the ecdysial inhibitory activity of azadirachtin (EI 2 ppm) against the first instar larvae of *Helicoverpa zea* (Boddie) and *H. virescens*. Barnby *et al.* (1989) have reported on the bioactivity of azadirachtin against *H. virescens* by oral injection and found that 2 μg of azadirachtin caused 100 per cent mortality in the last instar larvae.

The effect of botanicals tested here was found to be concentration dependent. For instance, the total larval and pupal durations were positively and adult longevity negatively correlated with concentration. Senthil Kumar *et al.* (1997) found that acetone extract of neem leaf increased the total larval duration of *S. litura* for nearly 2 to 6 days more than in control and this increase was directly dependent to the concentration. Kimmins *et al.* (1995) have also reported about the dose dependent effects of caffeoylquinic acids from the wild groundnut, *Arachis paraguariensis* on the growth of *H. armigera*. They found that caffeoylquinic acids from *A. paraguariensis* increased the larval period in *H. armigera* when mixed with synthetic diet. Hence, the quantity of compound administered is an important factor in producing morphogenetic effect.

Malformations were observed in the pupae of all the three pests when treated with botanicals. Most common deformities in *H. armigera* and *S. litura* were the reduction in pupal size, curved structure, remnants of thoracic legs and larval skin with head capsule in the pupa. The later two deformities clearly indicated the failure of normal function of the moulting hormone, the ecdysone. The storage proteins in the insect haemolymph (Thomson, 1975; Wyatt and Pan, 1978) appear to be special adaptation to insect moulting, metamorphosis and reproduction. Rao *et al.* (1996) and Padmaja and Rao (2000) observed a reduction of haemolymph protein in azadirachtin treated *S. litura* and plant oils treated *H. armigera* larvae respectively. The interference with haemolymph protein synthesis by plant products may lead to incomplete moulting during pupation and abnormalities in metamorphosis. In *A. modicella*, all the abnormal pupae showed vesicle in the abdomen and other deformities were not observed. All abnormal pupae were found to be dead immediately after the process of pupation. Some pupae looked like normal also died within four days and these results showed that residual toxicity of the plant chemicals. Koul (1985), Isman (1993) and Gujar (1997) reported that azadirachtin, the allelochemical of neem products disrupted the moulting process in some pest larvae. Kandasamy *et al.* (1987) reported that acetone extract of *V. negundo* leaves at 400 ppm caused malformations in *S. litura* larvae.

Irrespective of the plant products treated larvae showed loss of appetite and this condition led to poor growth and hence produced pupal deformities especially small sized pupae. Tanzubil and Mc Caffery (1990) observed abnormalities both in the pupae and adults of *Spodoptera exempta* due to inhibition and/or disruption of moulting when the larvae were treated with azadirachtin and neem seed extracts. Moreover deformities were also observed in *H. armigera* and *S. litura* adults. Defective eclosion, crumpled and poorly developed wings and reduced body size were the adult deformities and the main reason for these deformities may be the inhibitory action of plant products during transformation of the pupa into adult. Saxena and Harshand (1992) reported that the flower extract of *A. indica* possessed JH effect and it produced abnormal adults and also prolonged the larval period of *Dysdercus koenigii*, a pyrrhocorid bug. These findings clearly confirm the presence of JH like chemicals in plant kingdom. The morphological deformities produced in these pests by these plant products resembled the effects induced by synthetic JH analogues in *S. litura* (Mathur and Srivastava, 1989; Anita Mane and Subrahmanyam, 1998).

2. 5. CONCLUSION

Plant products are having growth disrupting properties in insect metamorphosis and previous investigations showed that most of these toxins are safe to non-target natural enemies and mammals due to their narrow range. Since these phytotoxins are target specific and species specific, they could be used against pest insects in the field conditions without causing severe effects on beneficial insect fäuna. In this study, water was used to prepare plant products and in future studies, different solvent extracts of these botanicals could be used for their role on insect biology and physiology. Rabindra and Jeyaraj (1994) have reported that plant products enhanced the activity of bio-pesticides when both are mixed and treated against *H. armigera*. Hence more intensive studies are necessary to explore the possibilities of integration of biopesticides and botanicals against insect pests.

CHAPTER - 3

"Integration of intercrops and plant products on chosen groundnut pests management" - Ph.D thesis submitted by M. Gabriel Paulraj to Bharathidasan University, Trichy, Tamil Nadu, India.

CHAPTER – 3

FIELD EFFICACY OF CHOSEN PLANT PRODUCTS ON THREE GROUNDNUT DEFOLIATORS MANAGEMENT AND GROUNDNUT PRODUCTION

3. 1. INTRODUCTION

Plant products could be used effectively in evolving an ecologically sound, economically viable and socially acceptable pest management system. Replacement of synthetic insecticides by bio-rational insecticide is an universally acceptable and practicable approach world wide. The insecticidal properties and field efficacy of plant products from *A. indica* (Rao and Srivastava, 1985; Saxena, 1987; Sahayaraj and Paulraj, 1998a, b; Gahukar, 1999; Murugan *et al.,* 1999) *P. pinnata* (Ghewande, 1989; Pandey and Misra, 1996; Sahayaraj and Paulraj, 1998 a, b; Ma *et al.,* 1999; Murugan *et al.,* 1999) and *V. negundo* (Bai and Kandasamy, 1985; Rejesus *et al.,* 1993; Sahayaraj, 1998; Sahayaraj and Paulraj, 1998 b) on several pests of agricultural importance were investigated previously.

The present study deals with the field efficacy of chosen plant leaf extracts such as neem (*A. indica*), madar (*C. gigantea*), karanj (*P. pinnata*) and lagundi (*V. negundo*) on *A. modicella, H. armigera* and *S. litura* populations and their infestation levels, groundnut production, per cent avoidable yield loss, cost of cultivation and cost-benefit ratio.

3. 2. MATERIALS AND METHODS

3. 2. 1. Plant products preparation

The procedure of preparing plant leaf extracts was described in the materials and methods section of Chapter 1. For this study, 3 per cent water extract of *A. indica, C. gigantea, P. pinnata* and *V. negundo* were used.

3. 2. 2. Plot description

Field trials were conducted in rabi and kharif seasons from 1998 – 2000 in lands under controlled irrigation conditions at Moolakaraipatti, Tirunelveli District, Tamil Nadu. The total area of the field (735 m^2) was divided into 5 plots, as there were 5 treatments (four experimental and one control). Each plot was separated by 1 m of bare soil from adjacent treatment plots and had an area of 15 × 9 m. Each plot was further divided into three sub plots to maintain three replications for each treatment. The treatments were arranged in a randomized block design. Treatment 1 sprayed with the leaf extracts of *A. indica*; treatment 2– *C. gigantea*; treatment 3 – *P. pinnata*; treatment 4 – *V. negundo* and treatment 5 – untreated control. Groundnut seed variety, TMV 7 was sown in the plots with a spacing of 30 and 15 cm between and within rows respectively and the fertilizer doses and other crop husbandry practices were followed as per the local recommendations.

3. 2. 3. Plant products application

The leaf extracts of *A. indica, C. gigantea, P. pinnata* and *V. negundo* were sprayed at 3 per cent concentrations separately in the respective plots on the 30th day after seedling emergence (DASE) in the late evening hours with the help of a power sprayer (Aspee polo) at a rate of 0.5 litre/minute. The sprayings were conducted thrice at 15 days intervals (i.e. on 30th, 45th and 60th DASE). Pest counting was done before (26th, 41st and 56th) and after 4 days of each spray, (34th, 49th and 64th DASE).

3. 2. 4. Sampling

The symptoms described by Amin (1983) were considered for the pest damage counting (Plate 5). Number of larvae and number of damaged leaves were counted in ten randomly selected groundnut plants from each sub plot. The upper most 30 leaves were considered for pest population and damage counting. The observations were recorded as number of larvae or number of damaged leaves per plant. Pest populations were observed in the early morning hours (between 5.30 a.m. to 7.30 a.m.).

3. 2. 5. Production and per cent avoidable loss estimation

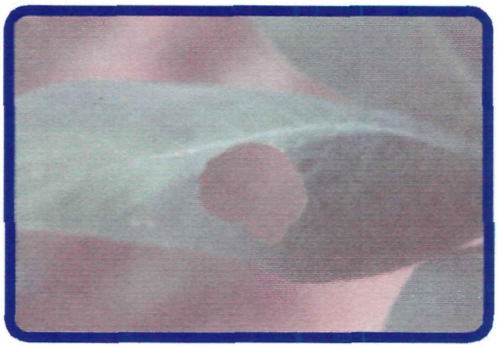
After harvest, the dry groundnut pod yield in each treatment as well as in the untreated control plots was estimated separately and converted into kilograms per hectare (kg ha^{-1}).

The production of each treatment plot was compared with the control and per cent avoidable yield loss in groundnut was calculated using the following formula of Krishnaiah (1977) :

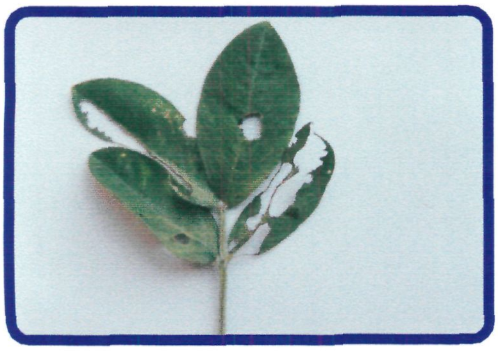
$$\text{Per cent avoidable loss} = \frac{\text{Mean yield from Protected plots} - \text{Mean yield from unprotected plots}}{\text{Mean yield from Protected plots}} \times 100$$

PLATE 5. SYMPTOMS FOR GROUNDNUT PEST INFESTATIONS

a. Groundnut leaf damage caused by *A. modicella*



b. Leaf damage by *H. armigera*



c. *S. litura* infestation in the groundnut leaf

d. Groundnut field severely defoliated by *H. armigera* and *S. litura*

3. 2. 6. Cost-benefit ratio

Cost-benefit ratio was calculated using the formula of Kalyanasundaram *et al.* (1994) as follows :

$$\text{Cost-benefit ratio} = \frac{\text{Total gain}}{\text{Total cost of cultivation}}$$

3. 2. 7. Statistical Analysis

Two-way analysis of variance (ANOVA) was used to test the significance between treatments and between the different periods of countings. Duncan's multiple range test (DMRT) was used to separate the treatment means (Duncan, 1955).

3. 3. RESULTS

3. 3. 1. *A. modicella* incidence

The population level of *A. modicella* both in the rabi (1999) and kharif (1999 – 2000) is presented in Table 4. The mean number of pest was significantly lower in the plant product treatments than control plot in both seasons. When we consider grand mean, neem was the most effective botanical in reducing the *A. modicella* population (3.5 and 1.6 larvae per plant for rabi and kharif seasons respectively) followed by *P. pinnata* (4.2 and 1.7 larvae/plant for rabi and kharif seasons respectively), *V. negundo* (4.5 and 1.8 larvae/plant) and *C. gigantea* (4.7 and 1.9 larvae/plant for rabi and kharif). In the control plot, 5.8 and 3.7 larvae per plant were recorded during rabi and kharif seasons respectively. In *P. pinnata* treated field, pest incidence decreased after first, second and third sprays, whereas in *A. indica* and *C. gigantea* treatments, the pest population slightly increased after second and third sprays (Table 4).

Table 4. Plant products' impact on the incidence of *A. modicella* in two seasons (Mean ± SE) (n = 30).

Treatments	Mean number of larvae/plant						Grand Mean
	26 DASE	34 DASE	41 DASE	49 DASE	56 DASE	64 DASE	
				Rabi 1999			
A. indica	5.6 ± ^{a} 0.8	5.8 ± ^{a} 1.1	3.5 ± ^{b} 0.8	2.4 ± ^{d} 0.5	2.1 ± ^{c} 0.2	1.7 ± ^{c} 0.3	3.5
C. gigantea	6.2 ± ^{a} 0.5	6.5 ± ^{a} 0.5	4.6 ± ^{ab} 0.7	4.0 ± ^{c} 0.1	3.9 ± ^{b} 0.8	3.1 ± ^{b} 0.4	4.7
P. pinnata	6.0 ± ^{a} 0.2	5.4 ± ^{a} 0.4	4.6 ± ^{ab} 0.5	3.3 ± ^{cd} 0.2	3.2 ± ^{b} 0.4	2.4± ^{bc} 0.3	4.2
V. negundo	5.7 ± ^{a} 0.8	5.3 ± ^{a} 1.4	4.9 ± ^{ab} 0.1	5.3 ± ^{b} 0.6	3.1 ± ^{bc} 0.1	2.7 ± ^{b} 0.3	4.5
Control	6.0 ± ^{a} 0.4	5.6 ± ^{a} 0.4	5.7 ± ^{a} 0.6	6.5 ± ^{a} 1.1	5.3 ± ^{a} 1.8	5.7 ± ^{a} 0.8	5.8
				Kharif 1999 – 2000			
A. indica	0.7 ± ^{a} 0.7	2.3 ± ^{a} 0.3	2.7 ± ^{ab} 0.9	1.7 ± ^{b} 0.3	1.3 ± ^{b} 0.3	0.7 ± ^{b} 0.3	1.6
C. gigantea	2.0 ± ^{a} 0.6	2.7 ± ^{a} 0.7	2.7 ± ^{ab} 0.3	1.7 ± ^{b} 0.7	1.7 ± ^{b} 0.3	0.7 ± ^{b} 0.3	1.9
P. pinnata	2.0 ± ^{a} 0.6	2.3 ± ^{a} 0.3	2.7 ± ^{ab} 0.3	0.7 ± ^{b} 0.3	1.7 ± ^{b} 0.7	1.0 ± ^{b} 0.6	1.7
V. negundo	1.7 ± ^{a} 0.9	3.0 ± ^{a} 1.0	2.0 ± ^{b} 0.6	2.3 ± ^{ab} 0.7	1.0 ± ^{b} 0.6	1.0 ± ^{b} 0.0	1.8
Control	2.7 ± ^{a} 0.7	3.3 ± ^{a} 0.3	4.0 ± ^{a} 0.6	4.3 ± ^{a} 1.2	3.7 ± ^{a} 0.3	4.0 ± ^{a} 0.6	3.7

Values carrying same alphabet(s) in a column are not significantly different by DMRT at 5% level.

In rabi, *V. negundo* treatment reduced *A. modicella* incidence after the first (5.3 larvae/plant) and third (2.7 larvae/plant) sprays, but increased pest population was recorded after the second spray (5.3 larvae/plant) in rabi. In the kharif season the number of larvae were the highest (3.7 larvae/plant) in the control plot and all the four plant product treatment reduced the pest incidence significantly. In the rabi season, *A. indica, C. gigantea* and *P. pinnata*, pest incidence increased after the first spray, however pest population was controlled after the second and third sprays.

In *V. negundo* treatment plot, pest incidence increased after the first (3.0 larvae/plant) and second (2.3 larvae/plant) sprays and neither decreased nor increased after the third (1.0 larvae/plant) spray in the kharif. Neem treatment significantly ($p < 0.05$) reduced the larval population on 49, 56 and 64 DASE in rabi, 1999. In kharif, pest population reduction was significant ($p < 0.05$) in *V. negundo* treatment on 41 DASE; *A. indica, C. gigantea* and *P. pinnata* on 49 DASE and all four plant products on 56 and 64 DASE.

3. 3. 2. *A. modicella* infestation

The observations on the leaf damage (Table 5) clearly indicated that more number of damaged leaves (11.0 and 9.3 leaves/plant for rabi and kharif seasons respectively) were recorded in the control plot whereas the plant treatments reduced the leaf infestation in both seasons. In the rabi, among the treatments, *V. negundo* treatment showed lowest infestation (7.4 leaves/plant) followed by *C. gigantea* (7.6 leaves/plant), *P. pinnata* (7.7 leaves/plant) and *A. indica* (8.0 leaves/plant) treatments respectively. Number of damaged leaves increased after the first spray of *A. indica* and *P. pinnata* and after that, gradual decrease in the infestation was observed for instance 8.7, 6.4, 5.5 and 4.6 leaves at 41, 49, 56 and

Table 5. Impact of plant products on the infestation of *A. modicella* in two seasons (Mean ± SE) (n = 30).

Treatments	Mean number of damaged leaves/plant						Grand Mean
	26 DASE	34 DASE	41 DASE	49 DASE	56 DASE	64 DASE	
			Rabi 1999				
A. indica	11.0 ± [a] 1.1	12.1 ± [a] 2.0	8.7 ± [b] 1.1	6.4 ± [b] 1.8	5.5 ± [c] 0.5	4.6 ± [c] 1.1	8.0
C. gigantea	10.4 ± [a] 1.2	7.3 ± [c] 1.2	7.2 ± [b] 0.8	7.6 ± [b] 0.8	7.3 ± [b] 0.5	6.1 ± [bc] 0.2	7.6
P. pinnata	9.2 ± [a] 1.8	9.9 ± [abc] 1.6	8.1 ± [b] 1.0	7.7 ± [ab] 0.6	6.1 ± [bc] 0.2	5.3 ± [bc] 0.2	7.7
V. negundo	9.9 ± [a] 2.3	8.0 ± [bc] 1.4	6.8 ± [b] 1.1	5.8 ± [b] 0.7	6.9 ± [b] 1.0	6.7 ± [b] 1.3	7.4
Control	9.4 ± [a] 0.3	11.3 ± [ab] 2.1	12.5 ± [a] 1.6	10.5 ± [a] 1.5	11.4 ± [a] 2.2	11.1 ± [a] 0.8	11.0
			Kharif 1999 – 2000				
A. indica	7.0 ± [a] 0.6	4.3 ± [b] 0.3	4.3 ± [c] 0.3	5.0 ± [b] 0.6	3.7 ± [b] 0.3	3.3 ± [b] 0.3	4.6
C. gigantea	5.3 ± [a] 0.9	6.3 ± [ab] 1. 5	7.3 ± [ab] 0.3	6.3 ± [ab] 0.9	5.7 ± [b] 0.9	5.7 ± [b] 0.7	6.1
P. pinnata	7.7 ± [a] 0.9	6.7 ± [ab] 0.7	5.3 ± [bc] 0.9	4.7 ± [b] 1.2	4.3 ± [b] 0.3	3.7 ± [b] 0.7	5.4
V. negundo	7.3 ± [a] 0.3	7.7 ± [a] 0.3	6.0 ± [bc] 1.5	5.7 ± [b] 0.7	5.0 ± [b] 1.0	4.7 ± [b] 0.3	6.1
Control	7.7 ± [a] 1.2	8.0 ± [a] 0.6	9.7 ± [a] 0.7	9.0 ± [a] 1.5	11.3 ± [a] 1.2	10.0 ± [a] 1.5	9.3

Values carrying same alphabet(s) in a column are not significantly different by DMRT at 5% level.

64 DASE respectively in *A. indica* plot and 8.1, 7.7, 6.1 and 5.3 leaves at 41, 49, 56 and 64 DASE respectively in *P. pinnata* treated plot. In kharif season, *A. indica* was the most effective (4.6 leaves/plant) followed by *P. pinnata* (5.4 leaves/plant) *V. negundo* (6.1 leaves) and *C. gigantea* (6.1 leaves /plant).

In the control plot, leaf damage increased from 7.7 (on 26 DASE) to 10.0 (on 64 DASE) and maximum number of damaged leaves (11.3 leaves/plant) was recorded on 56 DASE. In neem treatment, infestation decreased after first (4.3 leaves/plant) and third (3.3 leaves/plant) sprays, but an increased infestation was found after the second spray. *V. negundo* decreased the leaf damage after the second (From 6.0 to 5.7 leaves/plant) and third (From 5.0 to 4.7 leaves/plant) sprays. In rabi, *C. gigantea* treatment at the first time reduced the infestation, but the damage increased (7.6 leaves/plant) after the second spray then gradual decrease was recorded on the succeeding counting periods of rabi season. During kharif season, *C. gigantea* treated plots showed an increase in the number of damaged leaves after the first spray and the infestation decreased after the second spray. Similar trend was found in the *V. negundo* treated plots.

3. 3. 3. *S. litura* incidence

S. litura population was affected by all the four plant products tested (Table - 6). The pest incidence was minimum in *P. pinnata* (1.1 larvae/plant) and *C. gigantea* (1.2 larvae/plant) in rabi and in *C. gigantea* (1.4 larvae/plant) in kharif and maximum in the control plots in both seasons (2.0 larvae and 2.9 larvae/plant in rabi and kharif seasons respectively). *A. indica* reduced *S. litura* incidence from 2.4 (26 DASE) to 0.4 (64 DASE) and the mean population was 1.4 larvae/plant in the rabi. *V. negundo* reduced the pest population from 2.3 (26 DASE) to 0.6 (64 DASE) and the mean incidence was 1.3 larvae/plant in the rabi. Except in the

Table 6. Efficacy of plant products on the incidence of *S. litura* in two seasons (Mean ± SE) (n = 30).

Treatments	Mean number of larvae/plant						Grand Mean
	26 DASE	34 DASE	41 DASE	49 DASE	56 DASE	64 DASE	
				Rabi 1999			
A. indica	2.4 ± [a] 0.5	2.2 ± [a] 0.5	1.3 ± [ab] 0.9	0.6 ± [b] 0.1	1.2 ± [b] 0.3	0.4 ± [c] 0.1	1.4
C. gigantea	1.9 ± [ab] 0.1	1.4 ± [a] 0.4	1.2 ± [ab] 0.4	0.7 ± [b] 0.2	0.9 ± [b] 0.3	0.9 ± [b] 0.2	1.2
P. pinnata	1.3 ± [b] 0.3	2.0 ± [a] 0.2	0.8 ± [b] 0.3	0.6 ± [b] 0.1	1.3 ± [ab] 0.2	0.8 ± [bc] 0.3	1.1
V. negundo	2.3 ± [a] 0.5	1.3 ± [a] 0.4	1.6 ± [ab] 0.5	0.6 ± [b] 0.1	1.1 ± [b] 0.1	0.6 ± [bc] 0.1	1.3
Control	2.5 ± [a] 0.4	2.2 ± [a] 0.3	1.9 ± [a] 0.1	1.6 ± [a] 0.7	1.1 ± [a] 0. 7	2.4 ± [a] 0.5	2.0
				Kharif 1999 – 2000			
A. indica	2.0 ± [a] 0.6	2.3 ± [a] 0.9	2.0 ± [a] 0.6	1.0 ± [b] 0.6	1.3 ± [b] 0.3	0.3 ± [b] 0.3	1.5
C. gigantea	2.0 ± [a] 0.6	1.7 ± [a] 0.3	1.7 ± [a] 0.3	1.0 ± [b] 0.6	1.3 ± [b] 0.3	0.7 ± [b] 0.3	1.4
P. pinnata	1.7 ± [a] 0.9	2.0 ± [a] 0.6	2.3 ± [a] 0.9	1.3 ± [ab] 0.3	1.7 ± [b] 0.7	1.0 ± [b] 0.6	1.7
V. negundo	2.3 ± [a] 0.3	1.7 ± [a] 0.3	1.7 ± [a] 0.3	1.0 ± [b] 0.6	1.3 ± [b] 0.3	0.7 ± [b] 0.3	1.5
Control	1.7 ± [a] 0.3	2.3 ± [a] 0.3	3.3 ± [a] 0.3	3.0 ± [a] 0.6	3.8 ± [a] 0.3	3.0 ± [a] 0.6	2.9

Values carrying same alphabet(s) in a column are not significantly different by DMRT at 5% level.

P. pinnata treatment, the pest incidence was reduced after every spray. In *P. pinnata* treatment, pest incidence increased after the first spray, however decreased after the second and third sprays. In kharif every spray of *C. gigantea* reduced the pest incidence and this trend was found in *V. negundo* treatment also. Next to calotropis, *V. negundo* was effective in controlling the incidence (1.5 larvae) and followed by *A. indica* (1.5 larvae) and *P. pinnata* (1.7 larvae). In the control plot, a gradual increase in the pest population (1.7, 2.3, 3.3, 3.0, 3.8 and 3.0 larvae/plant on 26, 34, 41, 49, 56 and 64 DASE respectively) was recorded. In *A. indica* and *P. pinnata* treatment, an increased incidence was observed after the first spray (2.33 and 2.00 larvae in *A. indica* and *P. pinnata* treated plots, respectively) and decreased after the second and third sprays.

3. 3. 4. *S. litura* infestation

Infestation was highest in the control category (9.5 and 7.8 leaves/plant in rabi and kharif respectively) and comparatively lower in the plant products treated plots in both seasons (Table - 7). In rabi, *P. pinnata* was the most effective treatment in reducing the leaf damage and this was significant from control only ($p < 0.05$). The leaf damage in this treatment was recorded as 6.7, 7.6, 5.8, 6.0, 6.2 and 4.5 leaves per plant on 26, 34, 41, 49, 56 and 64 DASE respectively. In kharif, *C. gigantea* application was effective and *A.* indica and *V.* negundo were also had same effect in reducing the leaf damage significantly when compared with control, and the difference was not significant ($p > 0.05$) from other treatments.

After every spray of plant products, the infestation decreased and this trend was commonly observed in both seasons. The statistical analysis showed that all treatments significantly reduced the infestation when compared with control, however among the treatments, the infestation decrease was not significant in both

Table 7. Effect of plant products on the infestation of *S. litura* in two seasons (Mean ± SE) (n = 30).

Treatments	Mean number of damaged leaves/plant						Grand Mean
	26 DASE	34 DASE	41 DASE	49 DASE	56 DASE	64 DASE	
			Rabi 1999				
A. indica	7.3 ± 0.4 [ab]	8.0 ± 1.0 [ab]	5.6 ± 0.6 [c]	6.4 ± 0.3 [bc]	6.6 ± 1.7 [b]	4.7 ± 0.3 [c]	6.4
C. gigantea	7.5 ± 0.4 [ab]	6.7 ± 1.0 [b]	8.4 ± 0.9 [ab]	5.8 ± 0.5 [c]	5.5 ± 0.8 [b]	5.9 ± 0.3 [b]	6.6
P. pinnata	6.7 ± 0.3 [b]	7.6 ± 0.5 [ab]	5.8 ± 0.4 [c]	6.0 ± 1.0 [bc]	6.2 ± 0.5 [b]	4.5 ± 0.6 [c]	6.1
V. negundo	7.0 ± 0.2 [b]	6.9 ± 0.3 [b]	7.4 ± 1.8 [bc]	7.7 ± 0.8 [ab]	6.5 ± 1.2 [b]	6.3 ± 0.5 [b]	7.0
Control	7.8 ± 1.0 [a]	9.3 ± 0.7 [a]	10.8 ± 1.0 [a]	9.3 ± 2.5 [a]	10.2 ± 0.8 [a]	9.5 ± 2.0 [a]	9.5
			Kharif 1999 – 2000				
A. indica	3.7 ± 0.3 [a]	4.3 ± 0.3 [a]	3.0 ± 0.6 [b]	2.0 ± 0.6 [b]	1.7 ± 0.3 [b]	1.7 ± 0.3 [b]	2.7
C. gigantea	2.7 ± 0.9 [a]	3.3 ± 0.3 [a]	3.3 ± 0.7 [b]	2.7 ± 0.7 [b]	2.3 ± 0.7 [b]	1.7 ± 0.3 [b]	2.7
P. pinnata	3.3 ± 0.3 [a]	4.3 ± 1.5 [a]	3.7 ± 0.7 [b]	3.0 ± 1.6 [b]	2.0 ± 0.6 [b]	2.3 ± 0.3 [b]	3.1
V. negundo	3.3 ± 0.9 [a]	3.7 ± 1.2 [a]	3.3 ± 0.3 [b]	2.3 ± 0.9 [b]	2.0 ± 0.6 [b]	1.7 ± 0.7 [b]	2.7
Control	3.7 ± 0.7 [a]	4.7 ± 0.7 [a]	8.7 ± 2.2 [a]	8.3 ± 0.6 [a]	8.0 ± 1.0 [a]	13.3 ± 1.5 [a]	7.8

Values carrying same alphabet(s) in a column are not significantly different by DMRT at 5% level.

seasons. In the *A. indica* and *P. pinnata* treatments, the infestation increased after the first and the second sprays and decreased after the third spray during rabi. In the *C. gigantea* treated plot leaf damage decreased after the first (6.7 leaves) and the second (5.8 leaves) sprays but slightly increased after the third (5.9 leaves) spray. *V. negundo* treatment decreased the damage after the first and the third sprays, but an increased infestation was recorded after the second spray in the *V. negundo* treatment. During kharif, in all the four plant product treated plots, infestation increased after the first spray *C. gigantea* and *V. negundo* treatments reduced the infestation after the second and the third sprays. In *P. pinnata* treatment, infestation decreased after the second spray (3.0 leaves), but increased after the third spray from 2.0 to 2.3 leaves per plant. *A. indica* treatment reduced the infestation from 3.0 to 2.0 leaves/plant after the second spray and neither reduced nor increased after the third spray (1.7 leaves/plant).

3. 3. 5. *H. armigera* population

Neither the incidence nor the infestation of *H. armigera* was recorded during the rabi season of the year 1999 in any treatment plots. *H. armigera* was effectively controlled by *A. indica* and this was clearly exhibited by the incidence (Table - 8) and infestation level. Least number of larvae (0.4 larvae/plant) were recorded in *A. indica* treatment on 34 and 49 DASE and the average number of larvae recorded per plant in *A. indica* treatment were 0.8 larvae. Next to *A. indica, P. pinnata* was the effective (0.9 larvae/plant) plant product followed by *V. negundo* (1.0 larvae/plant) and *C. gigantea* (1.1 larvae/plant) and this order of effectiveness is clearly seen from Table - 9. *A. indica* and *C. gigantea* treatments controlled the pest population significantly after every spray. In *P. pinnata* treated plot, pest incidence increased after first (1.5 larvae/plant) and second (0.7 larvae/plant) spray

Table 8. Role of plant products on *H. armigera* incidence in kharif 1999 - 2000 (Mean ± SE) (n = 30).

Treatments	Mean number of larvae/plant						Grand Mean
	26 DASE	34 DASE	41 DASE	49 DASE	56 DASE	64 DASE	
A. indica	1.3 ± 0.2 [a]	0.4 ± 0.2 [c]	1.4 ± 0.1 [b]	0.4 ± 0.1 [a]	0.9 ± 0.2 [a]	0.5 ± 0.3 [b]	0.8
C. gigantea	1.4 ± 0.1 [a]	1.0 ± 0.1 [bc]	1.3 ± 0.3 [b]	1.0 ± 0.1 [a]	1.1 ± 0.4 [a]	0.9 ± 0.2 [b]	1.1
P. pinnata	1.0 ± 0.4 [a]	1.5 ± 0.3 [b]	0.6 ± 0.2 [c]	0.7 ± 0.2 [a]	1.0 ± 0.2 [a]	0.6 ± 0.2 [b]	0.9
V.negundo	1.4 ± 0.1 [a]	1.2 ± 0.2 [b]	0.9 ± 0.1 [bc]	1.1 ± 0.3 [a]	1.0 ± 0.2 [a]	0.6 ± 0.3 [b]	1.0
Control	1.5 ± 0.5 [a]	2.5 ± 0.2 [a]	2.7 ± 0.3 [a]	1.6 ± 1.0 [a]	1.9 ± 0.9 [a]	2.0 ± 0.5 [a]	2.0

Values carrying same alphabet(s) in a column are not significantly different by DMRT at 5% level.

Table 9. Order of effectiveness of plant pesticides against pest incidence and infestation in groundnut.

Pest	ID/IF	Season	**Order of Effectiveness of plant pesticides** (From the lowest to the highest effect)
A. modicella	ID	Kharif 1999-2000	Control < CG < VN < PP < AI
		Rabi 1999	Control < CG < VN < PP < AI
	IF	Kharif 1999-2000	Control < CG < VN < PP < AI
		Rabi 1999	Control < AI < PP < CG < VN
H. armigera	ID	Kharif 1999-2000	Control < CG < VN < PP < AI
		Rabi 1999	-
	IF	Kharif 1999-2000	Control < VN < PP < CG < AI
		Rabi 1999	-
S. litura	ID	Kharif 1999-2000	Control < PP < AI < VN < CG
		Rabi 1999	Control < AI < VN < CG < PP
	IF	Kharif 1999-2000	Control < PP < AI < VN < CG
		Rabi 1999	Control < VN < CG < AI < PP

(- = Not studied)

and decreased after the third (0.6 larvae/plant) spray. In *V. negundo* treatment, pest incidence increased after the second spray (1.1 larvae/plant) but the first and the third sprays controlled the incidence.

3. 3. 6. *H. armigera* infestation

Infestation was the least in *A. indica* treated plots (5.3 leaves/plant) followed by *C. gigantea* (5.6 leaves/plant), *P. pinnata* (5.8 leaves/plant) and *V. negundo* (5.9 leaves/plant) (Table 10). In control plot, 8.9 leaves were damaged per plant. *A. indica* treatment successfully reduced leaf damage after every spray (5.3, 5.1 and 3.9 leaves/plant after the first, the second and the third sprays respectively). In the *C. gigantea* and *V. negundo* treated plots an uniform trend was found in which, infestation increased after the first two sprays and decreased after the third spray. *P. pinnata* reduced the infestation after the first (5.8 leaves/plant) and the third (5.0 leaves/plant) sprays, but increased after the second spray. From the statistical analysis it was clear that the infestation and incidence in the treatment plots were significantly ($p < 0.05$) lower than the control plot.

3. 3. 7. Production and per cent avoidable loss

Data on the Groundnut production is presented in Fig. 3. In rabi 1999, highest groundnut pod yield (1304 kg ha^{-1}) was obtained from *C. gigantea* treatment followed by *A. indica* (1260 kg ha^{-1}), *V. negundo* (1215 kg ha^{-1}), control (1177 kg ha^{-1}) and *P. pinnata* (1154 kg ha^{-1}). In kharif 1999 – 2000, *A. indica* treatment yielded the highest pod production (1330 kg ha^{-1}) followed by *V. negundo* (1262 kg ha^{-1}), *P. gigantea* (1222 kg ha^{-1}) and *P. pinnata* (1143 kg ha^{-1}) control plot harboured the least amount of production (1023 kg ha^{-1}).

Table 10. Plant products' impact on the infestation of *H. armigera* in kharif 1999-2000 (Mean ± SE) (n = 30).

Treatments	Mean number of damaged leaves/plant						Grand Mean
	26 DASE	34 DASE	41 DASE	49 DASE	56 DASE	64 DASE	
A. indica	6.9 ± 0.9 [ab]	5.3 ± 0.6 [b]	5.9 ± 0.7 [b]	5.1 ± 2.1 [b]	4.5 ± 0.5 [c]	3.9 ± 0.1 [c]	5.3
C. gigantea	5.7 ± 0.7 [b]	6.3 ± 0.6 [ab]	5.0 ± 0.2 [b]	6.1 ± 0.5 [b]	5.4 ± 0.1 [bc]	4.8 ± 0.0 [bc]	5. 6
P. pinnata	6.0 ± 0.2 [b]	5.8 ± 0.5 [ab]	5.3 ± 0.6 [b]	6.2 ± 0.6 [b]	6.7 ± 0.5 [ab]	5.0 ± 0.4 [b]	5.8
V. negundo	5.7 ± 1.0 [b]	6.3 ± 0.8 [ab]	5.5 ± 0.3 [b]	6.4 ± 1.1 [b]	5.8 ± 0.8 [bc]	5.7 ± 0.4 [b]	5. 9
Control	8.0 ± 0.3 [a]	7.4 ± 1.0 [a]	10.0 ± 2.7 [a]	10.2 ± 0.4 [a]	8.3 ± 1.0 [a]	9.6 ± 0.7 [a]	8.9

Values carrying same alphabet(s) in a column are not significantly different by DMRT at 5% level.

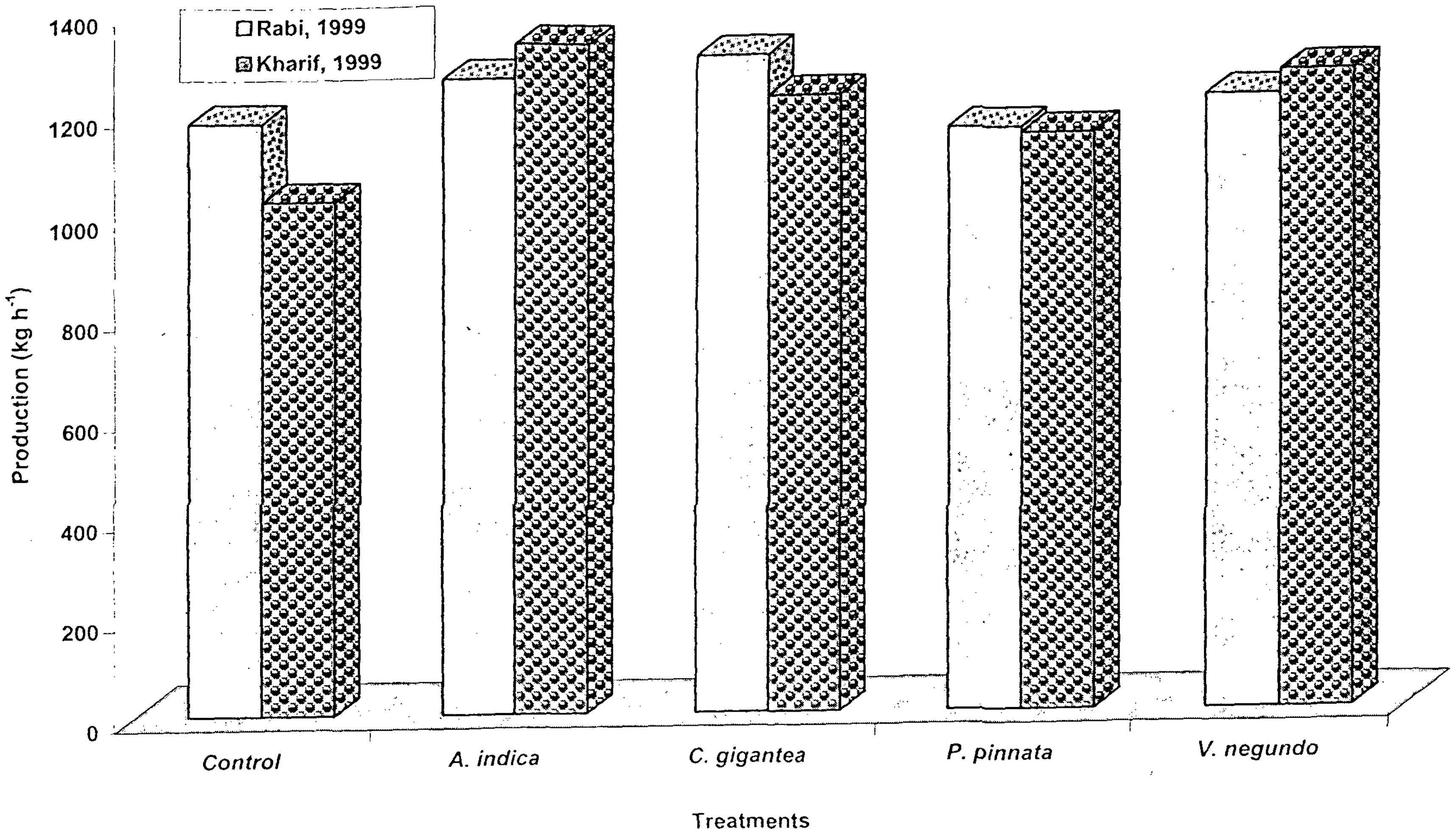


Fig. 3. Impact of application of plant products on yield of groundnut in two seasons

The per cent avoidable loss in rabi 1999 was the highest in *C. gigantea* (9.7 per cent) followed by *A. indica* (6.6%) and *V. negundo* (3.1%) (Fig. 4). In *P. pinnata* treatment, the per cent avoidable loss value was found in negative value (-2.1%) and this indicated the yield loss. In kharif season, in general, per cent avoidable loss in all treatments is higher than that in the rabi season. Highest per cent avoidable loss in kharif season was recorded in *A. indica* treated plot (23.1%) followed by *V. negundo* (19.0%), *C. gigantea* (16.3%) and *P. pinnata* (10.5%).

3. 3. 8. Economics and Cost-benefit ratio

Cost-benefit ratio was the highest in *A. indica* (1:2.2) and *C. gigantea* (1:2.0) treatments in kharif and rabi seasons respectively. The cost of cultivation was less in control both in kharif (Rs.13,325) and rabi (Rs. 14,325) seasons when compared to other treatments, however net gain and cost-benefit ratio (1:1.7)for kharif and 1:1.8 in rabi) were less than plant products treatments (Table - 11). In general, cost of cultivation in the rabi season exceeds in comparison to all plant product treatments.

3. 4. DISCUSSION

In both seasons studied, the performance of the plant extracts used in this study in minimizing pest incidence and their damage was superior when compared to the control. Particular plant product was found to be effective against a particular pest. For instance, *A. indica* treatment was the most effective against *A. modicella* and *H. armigera* whereas *C. gigantea* was the effective botanical against *S. litura*. Another interesting observation in this study was that the order of effectiveness of the plant extracts against *A. modicella* incidence during the two seasons and foliage damage during kharif being same and recorded as *A. indica* > *P. pinnata* > *V. negundo* > *C. gigantea*. However *V. negundo* was the most

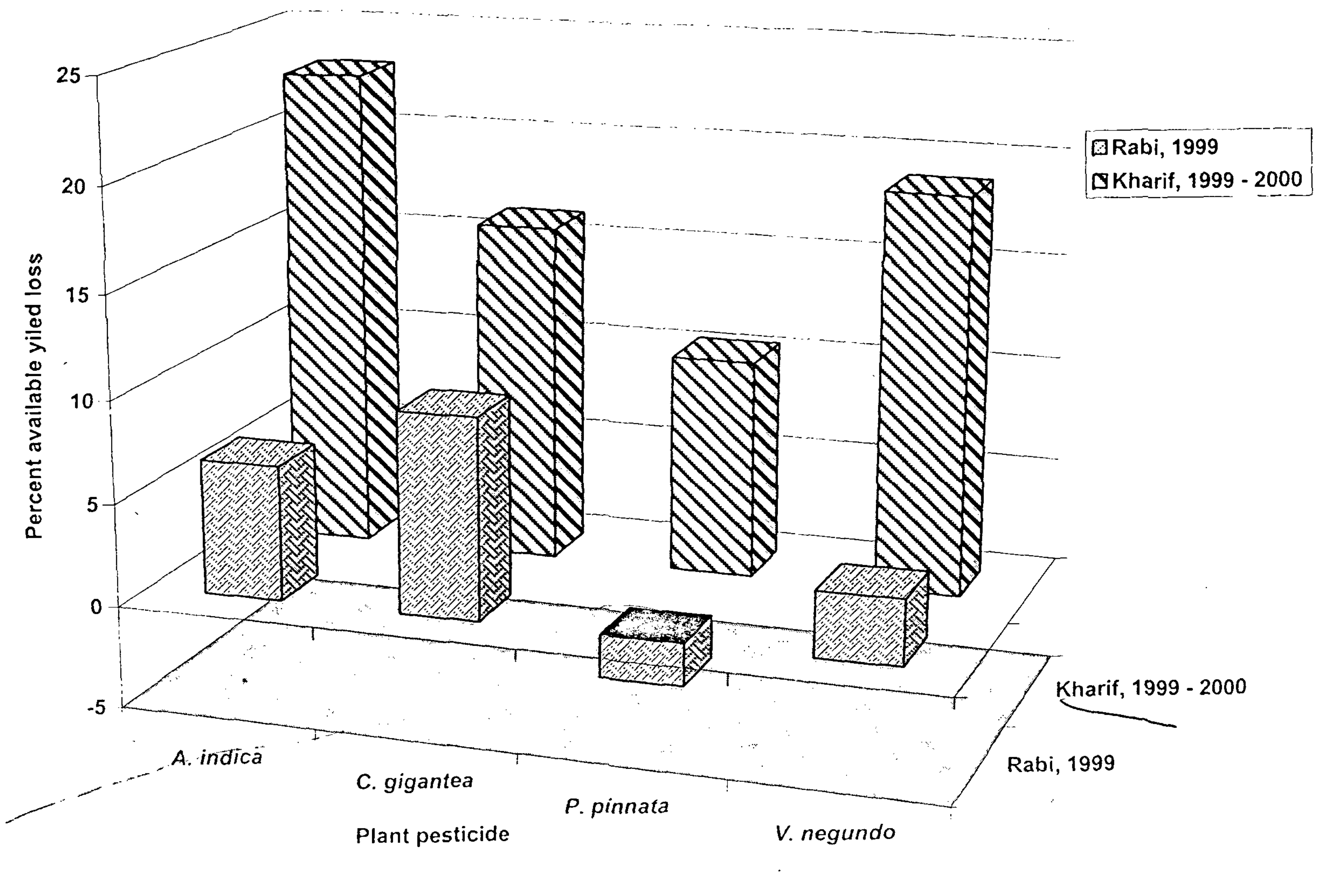


Fig. 4. Influence of plant products on per cent avoidable yield loss in two seasons

Table 11. Impact of plant products on economics and cost-benefit ratio in groundnut cultivation.

Treatments	Rabi 1999				Kharif 1999 - 2000			
	Total gain (Rs./ha)	**Cost of cultivation (Rs./ha)**	**Net gain (Rs./ha)**	**Cost benefit ratio**	**Total gain (Rs./ha)**	**Cost of cultivation (Rs./ha)**	**Net gain (Rs./ha)**	**Cost benefit ratio**
A. indica	27,720	14,475	13,245	1: 1.9	29,260	13,475	15,785	1: 2.2
C. gigantea	28,688	14,475	14,213	1: 2.0	26,884	13,475	13,409	1: 2.0
P. pinnata	25,388	14,475	10,913	1: 1.8	25,146	13,475	11,671	1: 1.9
V. negundo	26,730	14,475	12,255	1: 1.8	27,764	13,475	14,289	1: 2.1
Control	25,894	14,325	11,569	1: 1.8	22,506	13,325	9,181	1: 1.7

effective in the rabi crop in controlling the foliage damage by *A. modicella*. This specificity of plant products against the pests was already observed in the laboratory studies and is explained in the previous two Chapters.

Pandey and Misra (1996) observed that neem seed kernel extract (NSKE) was more effective in controlling *H. armigera* infestation on chickpea than Karanj (*P. pinnata*) oil. But in contrast, Bajpai and Sehgal (2000) found that Karanj oil (2%) was more effective than NSKE in controlling *H. armigera* in chickpea. They further reported that endosulfan was superior over botanicals in reducing pod damage and increasing cost – benefit ratio. Douressamy *et al.* (1990b) found that *A. indica* and *V. negundo* extracts exerted feeding disruption on insects particularly foliage feeders and they suggested that this property could be used in pest management to debilitate the insect from feeding and to cause death by starvation. The efficacy of neem products (neem oil and NSKE) to *A. modicella* infestation in groundnut was satisfactory when compared to the chemical pesticides treatment (Ramaraju *et al.*, 1998).

The field efficacy of neem and other plant products on some important insect pests was already reported by many investigators (Nandagopal, 1992; Pandey and Misra, 1996; Macedo *et al.*, 1997; Pandey and Faruqui, 1998; Senguttuvan, 1999b). Ma *et al.* (1999) have reported that azadirachtin (neem seed extract) treatment protected cotton field from *H. armigera* and *H. puntigera* Wallengren and increased yield of cotton compared with control. They further stated that although the chemical pesticides were superior to bio-pesticides, they were very destructive to predatory insects in cotton field. *A. modicella* and *S. litura* populations were recorded during the study period of rabi and kharif season, however *H. armigera* was observed only during the kharif 1999 – 2000. In Tamil Nadu *H. armigera* incidence observed only in kharif season whereas *A. modicella* and *S. litura* infestation observed both in kharif and rabi seasons (Jeyaraj – Personal Communication). Tripathy and Singh (1999) stated that, *H. armigera* population appears during the rainy (kharif) season. So this may be the reason for the absence of *H. armigera* in the present study during rabi (post – rainy) season.

Another important point to be noted here is that *A. modicella* incidence and infestation were more severe during rabi 1999 than kharif 1999 – 2000. The lower incidence of *A. modicella* in kharif may be due to continuous rain fall observed during this season. Lewin *et al.* (1979) found that temperature was associated positively and rainfall negatively with leaf miner incidence in groundnut. Nair (1975) and Senguttuvan (1999a) also stated that *A. modicella* incidence was maximum during July and August and from February to May. Further they mentioned that the wide spread rainfall inhibited the *A. modicella* incidence.

Groundnut pod yield was maximum in the rabi season, although *A. modicella* attack was higher in this season than kharif. But *S. litura* attack in rabi was more or less same as in kharif. Though the average yield was maximum in rabi, highest yield was recorded in *A. indica* treatment during kharif. Neem treatment effectively controlled *A. modicella* and *H. armigera* and increased the yield. Cobbina and Osei – Owusa (1988) and Jackai *et al.* (1992) stated that aqueous extract of neem has given higher seed yield of cowpea. *P. pinnata* was found effective in controlling pest incidence, however it did not increased the yield. Deka *et al.* (2000) have reported about the field efficacy of *P. pinnata* extracts against tea mosquito bug.

The efficacy of plant products on production was clearly noticed when the yield from plant product treated plots was compared with that of control plot. The relationship between pest incidence or infestation and production was not clearly exhibited in this study. However previous studies carried out by Mohammed (1981), Dhir *et al.* (1992), Brar *et al.* (1995) and Ramaraju *et al.* (1998) showed that yield was affected by increasing pest population. Sepsawardi *et al.* (1987) and Tarimo and Mkesele (1987) reported that groundnut yield was affected by defoliation in the plants. Further studies are necessary to prove the relationship between pest incidence and their infestation.

3. 5. CONCLUSION

The present study clearly indicates the efficacy of botanicals on groundnut pest management and increasing production. Among the four plants tested here, *A. indica* and *C. gigantea* were superior over the other two plants. These two plants are available in all places and the farmers can use these plants to prepare natural pesticides without spending much money. Gahukar (1999) proposed that neem products appear to be environmentally safe and IPM compatible and have the potential to be adopted on a broad scale, together with other measures to provide a low cost management strategy. The preparation and application of botanical pesticides need less labour and cost. To improve the activity of plant products on pest population, different solvents could be used for complete isolation of the active compounds. Isolation of the active ingredients responsible for insecticidal effects could possibly facilitate in new formulations for effective activity at lower concentrations, thereby making them economically viable.

CHAPTER - 4

"Integration of intercrops and plant products on chosen groundnut pests management" - Ph.D thesis submitted by M. Gabriel Paulraj to Bharathidasan University, Trichy, Tamil Nadu, India.

CHAPTER - 4

INFLUENCE OF INTERCROPPING ON CHOSEN GROUNDNUT DEFOLIATORS MANAGEMENT AND GROUNDNUT PRODUCTION

4. 1. INTRODUCTION

UNIAS (1978), Karim *et al.* (1988), Sampet *et al.* (1989) and Gnanamurthy and Balasubramanian (1996) stated that intercropping is advantageous by efficient use of available moisture, solar energy, nutrients and space besides the possibility of increasing total crop population per unit area. In the more humid tropics, intercropping in groundnut is an important cultural practice (Lamb, 1978). Rajat and Singh (1981) considered the intercropping system as an insurance against the risk of crop failure, better utilization of farm resources and labour and also protecting the main crop from insect pests. The advantages of intercropping in groundnut pest management and yield were reported by several investigators (Lamb, 1978; Jeyaraj and Santharam, 1985; Anon, 1987; Kennedy and Raveendran, 1989; Kennedy *et al.*, 1990; Singh and Singh, 1992; Marwoto, 1996; Nath and Singh, 1998). Intercropping, especially under rainfed situations is practiced not only for risk avoidance but also to maximize resource - use efficiency and monetary return (Ghosh *et al.*, 1999b).

The crops often used as intercrops in groundnut are castor (Davi Dayal and Reddy, 1991; Senthivel *et al.*, 1989; Bhondave *et al.*, 1994), Maize (Ikeorgu and Odurukwe, 1990; Sharma and Varshney, 1990; Alegbejo, 1997; Ghosh *et al.*, 1999c) legumes (Senthivel *et al.*, 1989; Muthiah *et al.*, 1991; Shivakumar and Reddy, 1993; Lourduraj *et al.*, 1994; Gnanamurthy and Balasubramanian, 1996), Soybean (Senthivel *et al.*, 1989; Muthiah *et al.*, 1991), Sunflower (Putnam *et al.*, 1990; Devi Dayal and Reddy, 1991) and Millet (Reddy and Willey, 1981; Baskaran *et al.*, 1993; Nath and Singh, 1998).

Growing sunflower as intercrop or mixed crop in post rainy season with groundnut proved its advantage as trap crop. Sunflower plant attracts *Spodoptera litura* moths for oviposition which facilitated easy picking of egg masses and young larvae before they dispersed to other plants (Uthamasamy, 1996). Castor (Jeyaraj and Santharam, 1985) and Soybean (Muthiah *et al.*, 1991) were recommended as border or intercrops to reduce the incidence of *S. litura* and *A. modicella* respectively in groundnut crop.

Considering the importance of intercropping system in pest management, the present study was undertaken to investigate the influence of castor, maize and sunflower on chosen defoliators such as *A. modicella, H. armigera* and *S. litura* management in groundnut based intercropping system. Further more the impact of intercrops on groundnut production and economics were also studied.

4. 2. MATERIALS AND METHODS

4. 2. 1. Plot description

Field experiments were carried out in Kharif 1997 at Palayam, Perambaloor District and in Kharif 1999 at Moolakaraipatti, Tirunelveli District in medium lands under controlled irrigation conditions. In Kharif 1997, two intercrops (Castor and sunflower) and in Kharif 1999, three intercrops (castor, maize and sunflower) were used for this study. Each treatment and control plot had an area of 35 m^2 (7 × 5m) and each plot was separated by 1m of bare soil from the adjacent plots. The treatments were arranged in a randomised block design and replicated three times. Groundnut seeds cv TMV - 7 were sown in the plots with the spacing of 30 and 10 cm between and within rows respectively. Sole groundnut crop was maintained with three replications as control. The fertilizer doses and other crop husbandry practices were followed as per the local recommendations.

4. 2. 2. Intercrops

Castor (*Ricinus communis* cvTMV - 4), maize (*Zea mays* L. cvMDSH) and sunflower (*Helianthus annus* cvCo - 3) were used as intercrops. Inter crop seeds were sown after one week of groundnut seedling emergence. The Groundnut - intercrop row ratios were 10:1 for Groundnut - castor; 4 : 1 for groundnut - maize and 5 : 1 for groundnut - sunflower. The space arrangement within the row of castor, maize and sunflower were 100cm, 60cm and 45cm respectively(Plate - 6)

4. 2. 3. Sampling procedure

Pest and their defoliation counting were done on 26, 34, 41, 49, 56 and 64 DASE. Thirty leaves were collected from ten randomly selected groundnut plants from each treatment sub-plot to record the incidence of *A. modicella, H. armigera* and *S. litura* and defoliation caused by them. Sampling was done on

PLATE 6. INTERCROPPING IN GROUNDNUT FIELD

a. Groundnut + Castor intercropping system

b. Groundnut intercropped with maize

c. Groundnut + Soybean intercropping system

d. Groundnut + Sunflower intercropping system early morning hrs (5.30 to 6.30 a.m). The symptoms described by Amin (1983) were considered for pest damage counting.

4. 2. 4. Production and per cent avoidable loss estimation

During harvest, the yield of groundnut pod, and intercrop from each treatment plot was estimated and the production was converted into kilogram dry weight per hectare. Per cent avoidable loss was calculated using the formula of Krishnaiah (1977) (See Chapter 3 for the formula).

4. 2. 5. Economics and cost-benefit ratio

Efficacy of groundnut-based intercropping system on the economics was found out by cost analysis and cost-benefit ratio was calculated using the formula of Kalyanasundaram *et al.* (1994) (See Chapter 3 for the formula).

4. 2. 6. Statistical Analysis

Mean values and standard error (mean) were calculated from the three replications of each treatment for pest incidence, pest infestation and production. Analysis of variance (ANOVA - Two way) was used to test the significance between treatments and the means were separated by Duncan's multiple range test (DMRT) (Duncan, 1955).

4. 3. RESULTS

4. 3. 1. Pest incidence

Tables 12 and 13 and fig. 5, 6 and 7 showed the impact of intercrops on *A. modicella, H. armigera* and *S. litura* incidences in Kharif 1997 and kharif 1999. In Kharif 1997, Sunflower intercropping was found to be superior over castor in controlling *A. modicella* and *H. armigera* populations (Fig. 5 and 6) and this was significant from sole crop ($p < 0.05$). Among the three intercrops tested in Kharif

Table 12. Efficacy of intercrops on the incidence of *A. modicella* in kharif 1999 (Mean ± SE) (n = 30).

Treatments	Mean number of larvae/plant						Grand Mean
	26 DASE	34 DASE	41 DASE	49 DASE	56 DASE	64 DASE	
Castor	3.6 ± 5.0 [a]	4.7 ± 0.1 [b]	4.7 ± 0.2 [b]	1.9 ± 0.4 [b]	4.8 ± 0.7 [b]	3.2 ± 0.3 [c]	3.8
Maize	3.1 ± 0.6 [a]	5.5 ± 0.1 [a]	6.0 ± 0.5 [ab]	3.0 ± 0.4 [a]	5.4 ± 0.6 [ab]	5.1 ± 0.4 [b]	4.7
Sunflower	2.9 ± 1.2 [a]	5.5 ± 0.1 [a]	5.7 ± 0.3 [b]	3.1 ± 0.5 [a]	4.8 ± 0.3 [b]	4.4 ± 0.3 [d]	4.4
Control	3.1 ± 0.5 [a]	4.5 ± 0.3 [b]	7.1 ± 0.4 [a]	3.5 ± 0.4 [a]	5.9 ± 0.3 [a]	7.4 ± 0.5 [a]	5.3

The values carrying same alphabet(s) in a column are not significantly different by DMRT at 5% level.

Table 13. Influence of intercrops on the incidence of *S. litura* in kharif 1999 (Mean ± SE) (n = 30).

Treatments	Mean number of larvae/plant						Grand Mean
	26 DASE	34 DASE	41 DASE	49 DASE	56 DASE	64 DASE	
Castor	0.1 ± 0.1 [b]	0.0 [c]	0.0 [c]	0.0 [c]	0.1 ± 0.1 [c]	0.0 [c]	0.0
Maize	0.3 ± 0.3 [a]	0.5 ± 0.3 [a]	0.7 ± 0.2 [b]	0.3 ± 0.2 [b]	0.3 ± 0.1 [b]	0.1 ± 0.0 [b]	0.4
Sunflower	0.0 [c]	0.3 ± 0.3 [b]	1.0 ± 0.3 [a]	0.4 ± 0.4 [b]	0.2 ± 0.0 [bc]	0.1 ± 0.0 [b]	0.3
Control	0.0 [c]	0.2 ± 0.2 [b]	0.7 ± 0.4 [b]	1.2 ± 0.2 [a]	0.5 ± 0.1 [a]	0.5 ± 0.1 [a]	0.5

The values carrying same alphabet(s) in a column are not significantly different by DMRT at 5% level.

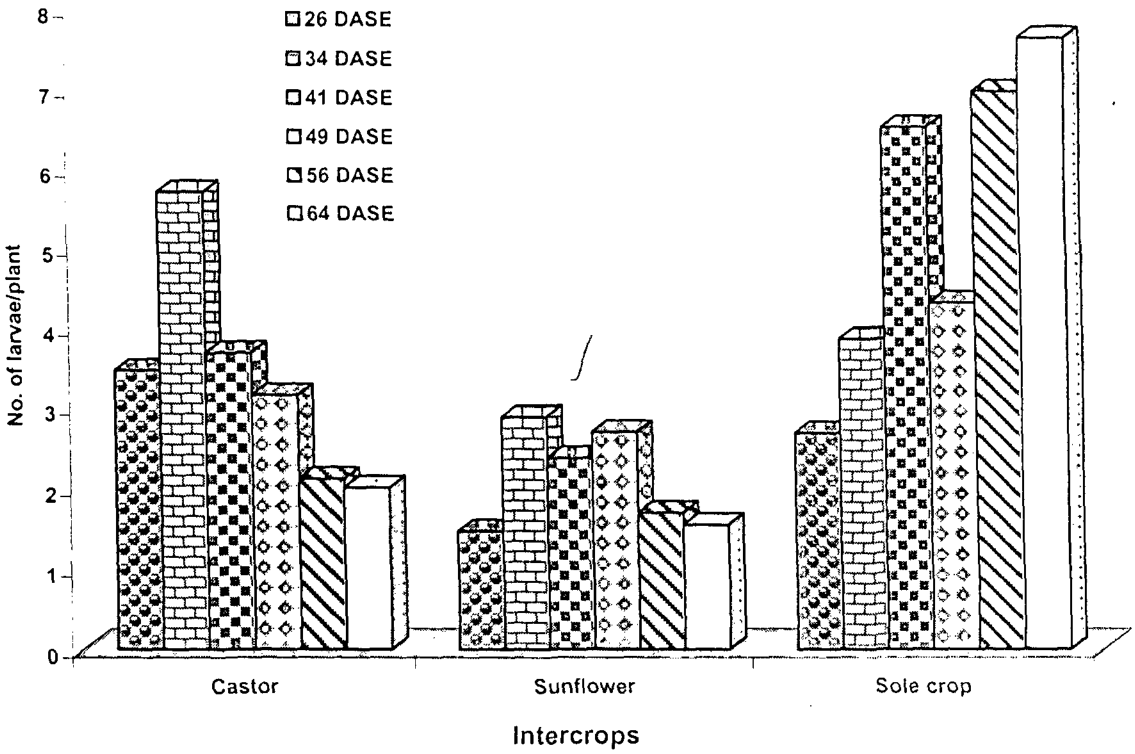


Fig. 5. Effect of intercrops on *A. modicella* incidence in groundnut in kharif 1997

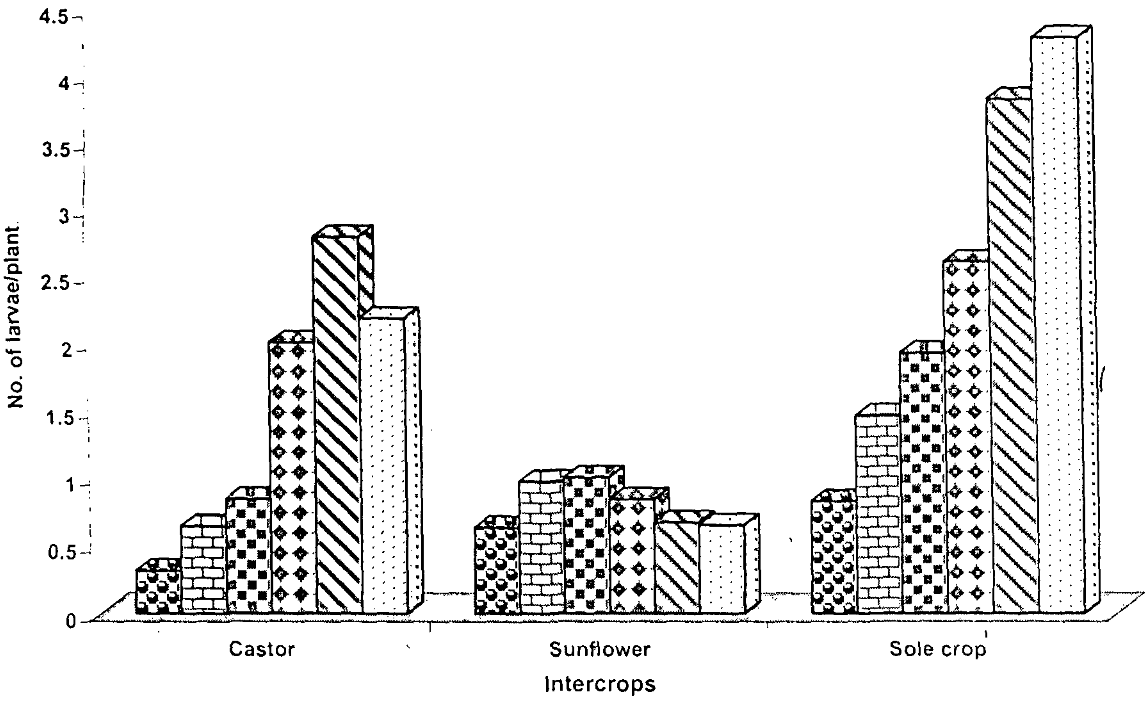


Fig. 6. Efficacy of intercrops on *H. armigera* incidence in kharif 1997

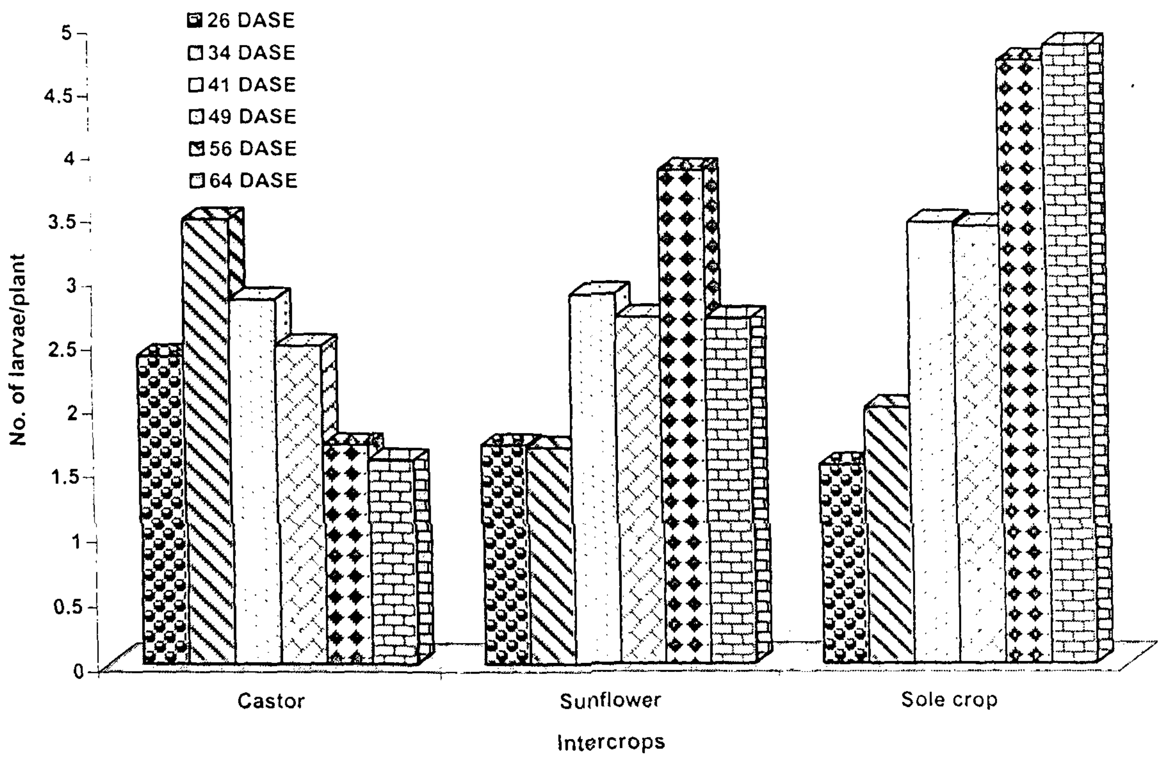


Fig. 7. Efficacy of intercrops on *S. litura* incidence in kharif 1997

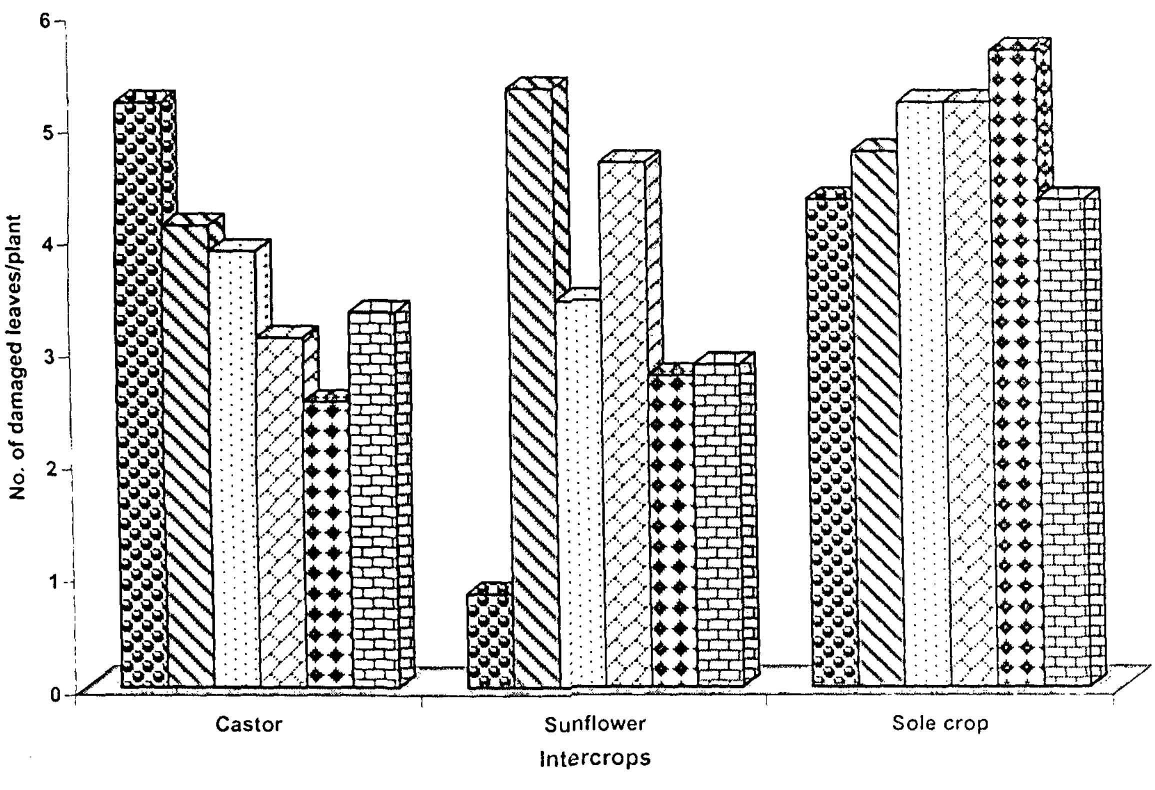


Fig. 8. Impact of intercrops on *A. modicella* infestation in kharif 1997

1999, castor effectively controlled *A. modicella* and *S. litura* populations (Table 12 and 13). In the castor intercropped field, *A. modicella* and *S. litura* incidences were 3.6, 4.7, 4.7, 1.9, 4.8 and 3.2 larvae and 0.1, 0.0, 0.0, 0.0, 0.1 and 0.0 larvae/plant respectively on 26, 34, 41, 49, 56 and 64 DASE respectively. *A. modicella,* and *H. armigera* population in the groundnut crop in sunflower intercropped field were recorded as 1.5, 2.9, 2.4, 2.7, 1.7 and 1.5 larvae and 0.6, 1.0, 1.0, 0.8, 0.7 and 0.7 larvae/plant respectively on 26, 34, 41, 49, 56 and 64 DASE respectively in kharif 1997. *S. litura* incidence was lower in castor intercropped field (2.4, 3.5, 2.8. 2.5. 1.7 and 1.6 larvae/plant on 26, 34, 41, 49, 56 and 64 DASE) than sunflower intercropped field (1.7, 1.7, 2.9, 2.7. 3.8 and 2.7 larvae/plant on 26, 34, 41, 49, 56 and 64 DASE respectively.

In kharif 1997, castor intercropping was less effective to control *A. modicella* (3.5, 5.7, 3.7, 3.1, 2.1 and 2.0 larvae/plant on 26, 34, 41, 49, 56 and 64 DASE respectively) and *H. armigera* (0.3, 0.6, 0.8, 2.0. 2.8 and 2.2 larvae/plant on 26, 34, 41, 49, 56 and 64 DASE respectively) populations than sunflower, however it was better than sole crop, in which the pest populations were found to be increased from the first observation to the last. In the sole crop, populations of *A. modicella, H. armigera* and *S. litura* were recorded as 2.7, 3.9, 6.5, 4.3, 7.0 and 7.7 larvae/plant; 0.8, 1.5, 1.9, 2.6, 3.8 and 4.3 larvae and 1.5, 2.0, 3.4, 3.4, 4.7 and 4.8 larvae/plant respectively on 26, 34, 41, 49, 56 and 64 DASE respectively.

In kharif 1999, sunflower effectively controlled *A. modicella* (2.9, 5.5, 5.7, 3.1, 4.8 and 4.4 larvae per plant on 26, 34, 41, 49, 56 and 64 DASE respectively) and *S. litura* (0.0, 0.3, 1.0, 0.4, 0.2 and 0.1 larvae per plant on 26, 34, 41, 49, 56 and 64 DASE respectively) populations next to castor in the groundnut crop. Maize intercropping was found less effective to control *A. modicella* (3.1, 5.5, 6.0, 3.0, 5.4

and 5.1 larvae on 26, 34, 41, 49, 56 and 64 DASE respectively) and *S. litura* (0.3, 0.5, 0.7, 0.3, 0.3 and 0.1 larvae on 26, 34, 41, 49, 56 and 64 DASE respectively) populations and the difference was less with the sole crop (3.1, 4.5, 7.1, 3.5, 5.9 and 7.4 *A. modicella* larvae and 0.0, 0.2, 0.7, 1.2, 0.5 and 0.5 *S. litura* larvae per plant on 26, 34, 41, 49, 56 and 64 DASE respectively). In kharif 1997, the three pest incidences in treatment plots were significantly lower than control plot ($p < 0.05$) and in kharif 1999, *A. modicella* and *S. litura* incidences were significantly low in castor treatment ($p < 0.05$).

An uniform trend in *A. modicella* incidence was observed in all three intercropping systems tested, i.e. population level increased from the first to third counting. On the fourth count, sudden decrease was observed in all the three intercropping systems and in the sole crop too. An increase was then observed in the fifth count, which declined on the last count. In the sole crop plot, except in the 49 DASE, *A. modicella* incidence was found to be increased from 26 to 64 DASE (3.1, 4.5, 7.1, 3.5, 5.9 and 7.4 larvae per plant on 26, 34, 41, 49, 56 and 64 DASE respectively) in kharif 1999. Maximum number of *S. litura* larva (1.2 larvae/plant) was recorded in the control plot on 49 DASE and the mean *S. litura* population was also maximum (0.5 larvae/plant) in the control plot in 1999. In sunflower and maize treatments, *S. litura* incidence gradually increased from 26 to 41 DASE and gradually declined after wards.

4. 3. 2. Pest infestation

Impact of intercrops on pest infestations on main crop was shown in Tables, 14 and 15 and Fig. 8, 9 and 10. In Kharif, 1997, infestations of *A. modicella, H. armigera* and *S. litura* were observed, where as in Kharif, 1999, only two pests (*A. modicella* and *S. litura*) infestations were recorded. The mean infestation in kharif 1997 showed that sunflower was superior over castor in reducing *A. modicella* (3.3 leaves/plant) and *H. armigera* (1.8 leaves/plant) infestations (Fig. 8 and 9). Control plot showed highest infestations (4.3, 4.8, 5.2, 5.2, 5.7 and 4.3 leaves per plant by *A. modicella;* 1.0, 3.5, 4.0, 3.7, 4.3 and 5.1 leaves per plant by *H. armigera* and 5.3, 6.5, 8.3, 10.1, 12.5 and 13.3 leaves per plant by *S. litura* on 26, 34, 41, 49, 56 and 64 DASE respectively). In castor intercropped field, *A. modicella, H. armigera* and *S. litura* infestations were recorded as 5.2, 4.1, 3.9, 3.1, 2.5 and 3.3 leaves per plant; 0.9, 0.9, 2.7, 1.3, 4.9 and 2.9 leaves per plant and 8.9, 5.9, 7.3, 7.7, 4.3 and 4.2 leaves per plant on 26, 34, 41, 49, 56 and 64 DASE respectively. In sunflower intercropped field, it was observed as 0.8, 5.3, 3.4, 4.7, 2.8 and 2.9 leaves per plant by *A. modicella;* 1.0, 2.0, 1.2, 1.0, 2.9 and 2.7 leaves per plant by *H. armigera* and 6.1, 5.0, 7.8, 6.7, 7.0 and 7.0 leaves per plant by *S. litura* on 26, 34, 41, 49, 56 and 64 DASE respectively.

In Kharif 1999, damaged leaves were significantly higher in the sole crop (4.6, 6.4, 9.9, 10.6, 12.1 and 13.7 leaves/plant by *A. modicella* and 2.8, 4.1, 7.3, 11.6, 12.9 and 13.9 leaves/plant by *S. litura* on 26, 34, 41, 49, 56 and 64 DASE respectively). Among the intercrops, the mean infestation of *A. modicella* (6.0 leaves/plant) and *S. litura* (4.8 leaves/plant) were the least in sunflower and castor intercropped fields respectively. *A. modicella* and *S. litura* infestations were high in castor (6.4 leaves/plant) and maize (6.2 leaves/plant) intercrop treatments respectively. *A. modicella* infestation increased gradually upto 49 DASE in castor and maize treatment and declined on 56 and 64 DASE. This trend was observed in all the three intercrop integrated with groundnut. In the sole crop, *S. litura* and *A. modicella* infestations increased gradually throughout the study period.

Table 14. Effect of intercrops on the infestation of *A. modicella* in kharif 1999 (Mean ± SE) (n = 30).

Treatments	Mean number of damaged leaves/plant						Grand Mean
	26 DASE	34 DASE	41 DASE	49 DASE	56 DASE	64 DASE	
Castor	5.2 ± 1.1 [a]	6.5 ± 0.1 [bc]	7.0 ± 0.1 [b]	7.3 ± 0.1 [bc]	6.9 ± 0.1 [b]	5.5 ± 0.2 [b]	6.4
Maize	4.0 ± 0.9 [ab]	7.2 ± 0.3 [ab]	7.5 ± 0.2 [b]	7.9 ± 0.2 [b]	6.3 ± 0.3 [bc]	5.5 ± 0.3 [b]	6.4
Sunflower	3.6 ± 0.6 [b]	7.4 ± 0.6 [a]	7.5 ± 0.4 [b]	6.7 ± 0.8 [c]	5.7 ± 0.2 [c]	5.2 ± 0.5 [b]	6.0
Control	4.6 ± 0.6 [ab]	6.4 ± 0.5 [c]	9.9 ± 1.2 [a]	10.6 ± 1.4 [a]	12.1 ± 1.0 [a]	13.7 ± 0.3 [a]	9.6

The values carrying same alphabet(s) in a column are not significantly different by DMRT at 5% level.

Table 15. Effect of intercrops on the infestation of *S. litura* in kharif 1999 (Mean ± SE) (n = 30).

Treatments	Mean number of damaged leaves/plant						Grand Mean
	26 DASE	34 DASE	41 DASE	49 DASE	56 DASE	64 DASE	
Castor	3.1 ± 0.4^{a}	3.7 ± 0.2^{b}	5.8 ± 0.3^{b}	7.3 ± 0.5^{c}	6.1 ± 1.0^{c}	2.7 ± 0.6^{c}	4.8
Maize	2.3 ± 0.2^{a}	5.6 ± 0.3^{a}	6.0 ± 0.2^{ab}	8.8 ± 0.2^{b}	8.3 ± 0.5^{b}	6.3 ± 0.5^{b}	6.2
Sunflower	2.9 ± 0.1^{a}	4.8 ± 0.3^{ab}	6.9 ± 0.2^{ab}	8.3 ± 0.5^{bc}	7.0 ± 0.8^{bc}	3.0 ± 0.5^{c}	5.5
Control	2.8 ± 0.9^{a}	4.1 ± 0.2^{b}	7.3 ± 0.5^{a}	11.6 ± 0.4^{a}	12.9 ± 0.7^{a}	13.9 ± 0.4^{a}	8.8

The values carrying same alphabet(s) in a column are not significantly different by DMRT at 5% level.

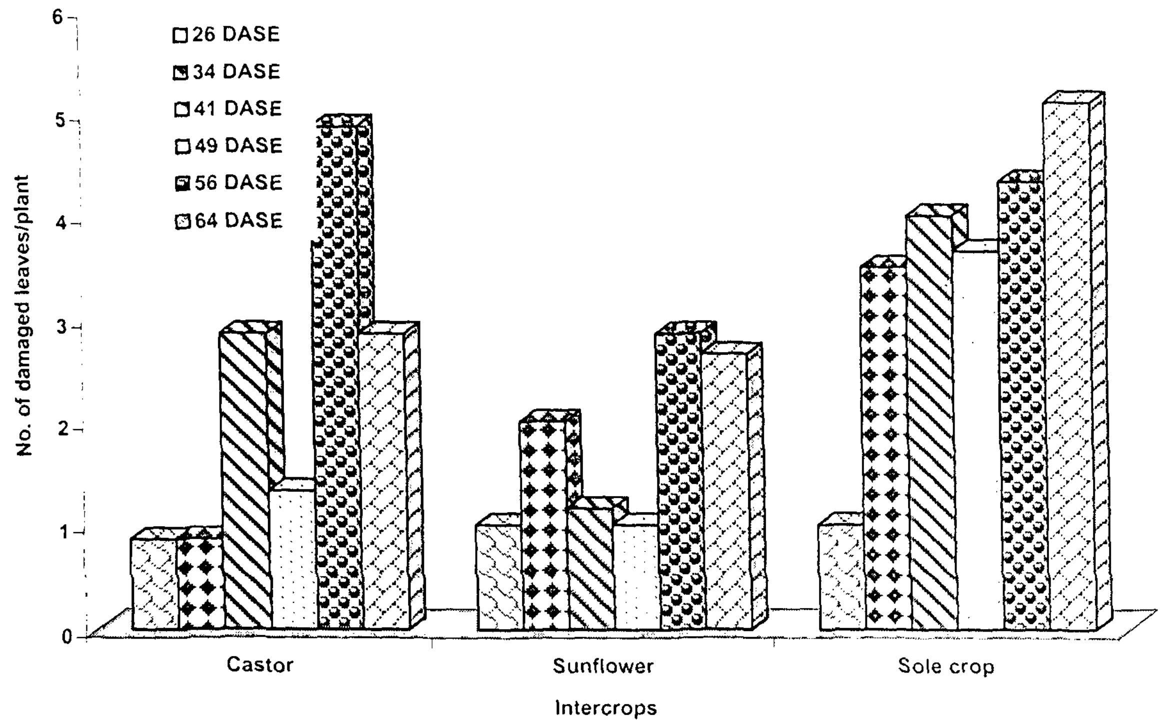


Fig. 9. Effect of intercrops on *H. armigera* infestation in kharif 1997

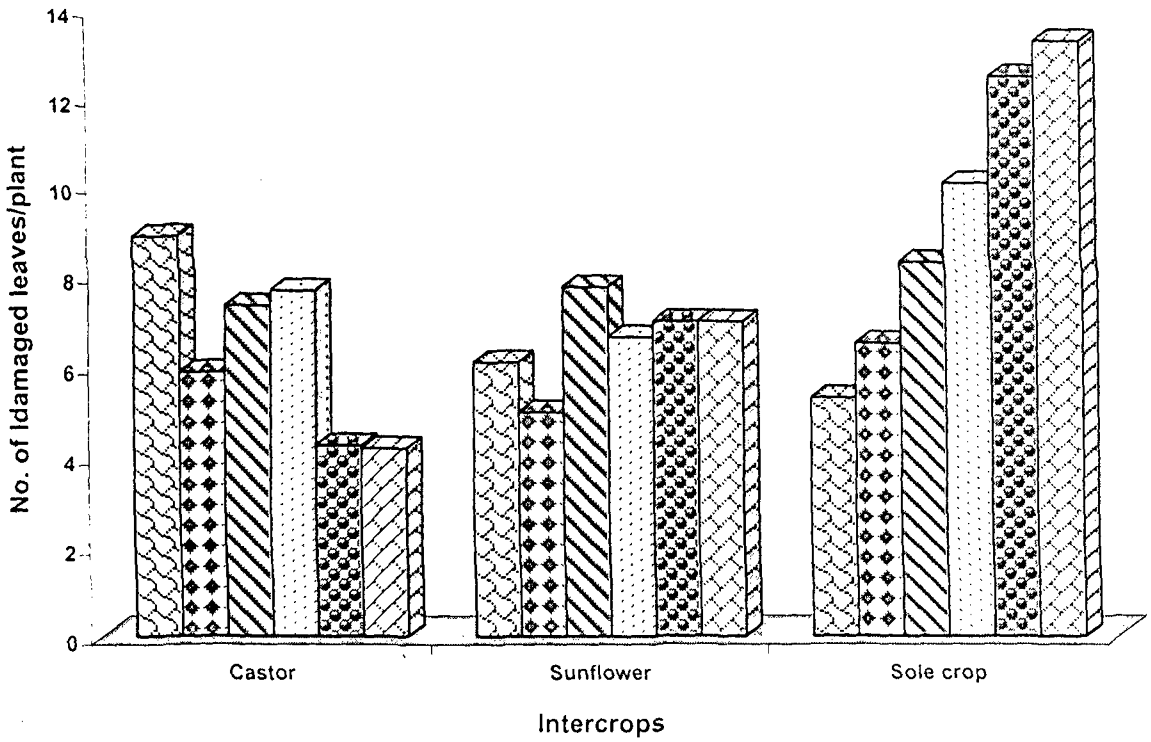


Fig. 10. Efficacy of intercrops on *S. litura* infestation in kharif 1997

In kharif 1999, *A. modicella* infestation was recorded as 5.2, 6.5, 7.0, 7.3, 6.9 and 5.5 leaves per plant in castor; 3.6, 7.4, 7.5, 6.7, 5.7 and 5.2 leaves per plant in sunflower and 4.0, 7.2, 7.5, 7.9, 6.3 and 5.5 leaves per plant in maize intercropped fields on 26, 34, 41, 49, 56 and 64 DASE respectively. *S. litura* infestation was, 3.1, 3.7, 5.8, 7.3, 6.1 and 2.7 leaves per plant in castor; 2.9, 4.8, 6.9, 8.3, 7.0 and 3.0 leaves per plant in sunflower and 2.3, 5.6, 6.0, 8.8, 8.3 and 6.3 leaves per plant in maize intercropped fields on 26, 34, 41, 49, 56 and 64 DASE respectively. In kharif 1999, all the intercrops treatments, were showing more or less same effect on *A. modicella* infestation however when compared to control, the treatment effects were significant ($p < 0.05$)(Table 16).

4. 3. 3. Production and per cent avoidable loss

The results on production indicated clearly that intercropping enhanced groundnut pod yield (Fig. 11a and b). In kharif 1997, sunflower intercropping system harboured higher yield (1475 kg/ha) than castor (1455 kg/ha) and sole crop 1088 kg/ha whereas, in Kharif 1999, castor enhanced the groundnut yield (1044.13 kg/ha) followed by sunflower (980.77 kg/ha), maize (822.69 kg/ha) and sole crop (801.60 kg/ha). The per cent avoidable loss was high in sunflower (26.24%) in 1997 and castor (23.23%) in 1999. Maize intercropping system decreased the groundnut yield and per cent avoidable loss (2.56%). From sunflower and castor, 165 and 380 kilogram seeds were gained respectively per hectare, in 1997. In 1999, sunflower, castor and maize yielded 144, 361 and 833 kg seeds per hectare respectively.

4. 3. 4. Economics and cost – benefit ratio

Among the intercrops, maize gave the highest net return (Rs. 15,229/ha) and cost – benefit ratio (1 : 2.10) during 1999 (Table 17). In 1997, the net gain and cost

Table 16. Order of effectiveness of intercrops in groundnut pests management

Pest	ID/IF	Season	**Order of Effectiveness of Inter crops** (From the lowest to the highest effect)
A. modicella	ID	Kharif 1997	Control < Castor < Sunflower
		Kharif 1999	Control < Maize < Sun flower < Castor
	IF	Kharif 1997	Control < Castor < Sunflower
		Kharif 1999	Control < Castor < Maize < Sunflower
H. armigera	ID	Kharif 1997	Control < Castor < Sunflower
		Kharif 1999	-
	IF	Kharif 1997	Control < Castor < Sunflower
		Kharif 1999	-
S. litura	ID	Kharif 1997	Control < Sunflower < Castor
		Kharif 1999	Control < Maize < Sun flower < Castor
	IF	Kharif 1997	Control < Sunflower < Castor
		Kharif 1999	Control < Maize < Sun flower < Castor

- = not studied.

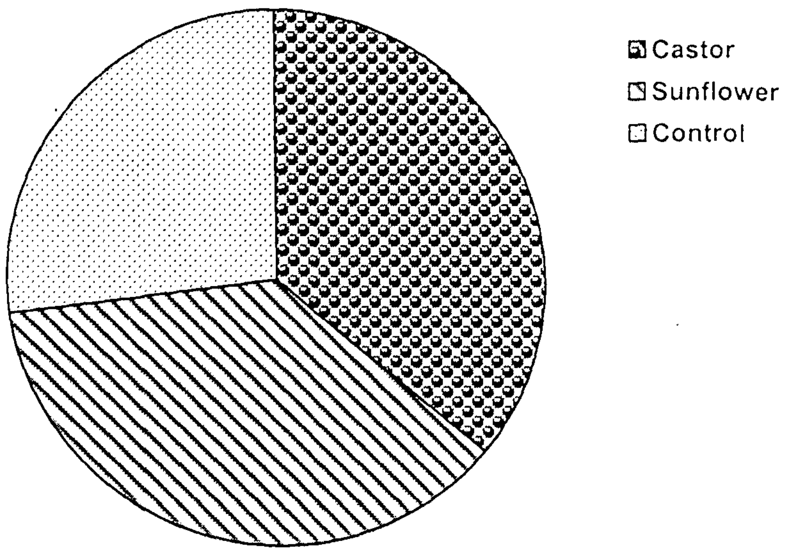


Fig.11a. Influence of intercrops on groundnut production (kg ha^{-1}) in kharif 1997

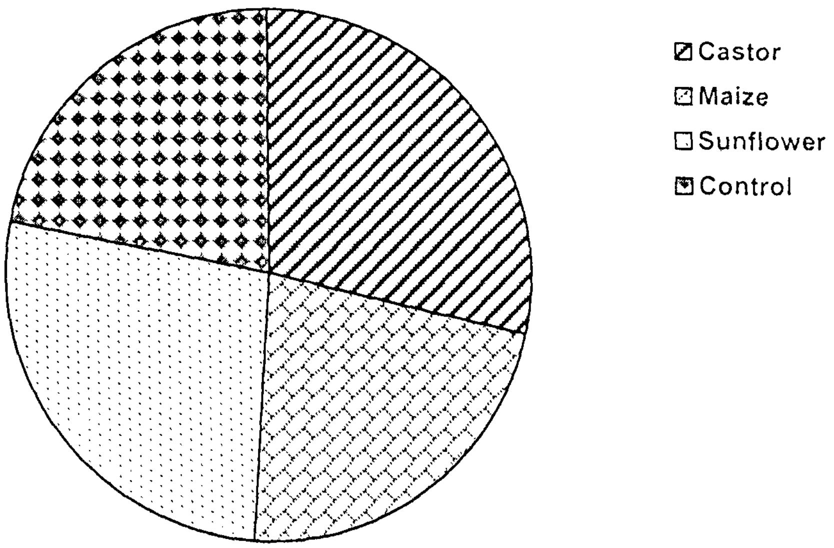


Fig. 11b. Efficacy of intercrops on groundnut pod yield (kg ha^{-1}) in kharif 1999

Table 17. Efficacy of intercrops on economics and cost-benefit ratio in groundnut in two years.

Year	Parameters	Treatment			
		Castor	Maize	Sunflower	Control
Kharif 1997	Total gain (Rs./ha)	23,247	-	22,343	14,144
	Cost of cultivation (Rs./ha)	13,538	-	13,809	13,484
	Net gain (Rs./ha)	9709	-	8,534	660
	Cost benefit ratio	1:1.72	-	1:1.62	1:1.05
Kharif 1999	Total gain (Rs./ha)	17,904	29,025	15,921	10,421
	Cost of cultivation (Rs./ha)	13,538	13,796	13,809	13,484
	Net gain (Rs./ha)	4,366	15,229	2,112	-3,063
	Cost benefit ratio	1:1.32	1:2.1	1:1.15	1:0.77

- = Not studied

– benefit ratio from the control plot were the least and it was calculated as Rs. 660/ha and 1 : 1.05 respectively. In 1999, the loss was recorded from control plot which was equivalent to 22.7 per cent of cost of cultivation and the cost benefit ratio was 1 : 0.77. Next to maize, castor was found to be a suitable intercrop as it increased net gain (Rs. 4,366/ha in 1999 and Rs. 9709/ha in 1997) and cost – benefit ratio (1 : 1.72 in 1997 and 1 : 1.32 in 1999). Sun flower intercropping system gave net gain of Rs. 8,534/ha in 1997 and Rs. 2,112/ha in 1999 and a cost – benefit ratio of 1 : 1.62 and 1 : 1.15 in 1997 and 1999 respectively.

4. 4. DISCUSSION

Among the IPM components, intercropping is one of the important components on the principle of reducing insect pests by increasing the diversity of the ecosystem and natural enemies population. In the present study, influence of intercropping on pest management, groundnut production and profit was clearly exhibited from the results. When compared to the sole crop, intercropped fields showed reduction in pest population and their infestations. Among the intercrops tested, sunflower was found to be the best intercrop in reducing *A. modicella* and *H. armigera* populations and also their infestations in Kharif 1997. However in 1999, sunflower controlled *A. modicella* damage only but not populations. Baskaran *et al.* (1993) have reported that, cumbu comparatively reduced the leafminer population in groundnut when inter cropped with groundnut at a ratio of 4 : 1 among various intercrops such as red gram, cowpea, black gram and gingelly. Castor was the most effective intercrop to reduce *S. litura* population and its infestations. This kind of specific action of intercrops in pest controlling property was due to the preference of the pest towards a particular crop.

Jeyaraj and Santharam (1985) proposed that castor was highly preferred by *S. litura*. Adult moths of *S. litura* preferred castor for oviposition and the larval stages of this pest also prefers castor than groundnut for feeding. This behaviour may be a reason for the lower incidence of *S. litura* in groundnut in castor intercropped field. Another important observation during the study period was that castor provided shelter for a number of natural enemies such as spiders, preying mantids and lady bird beetles which are the predators of *S. litura* and predate on this pest larvae. Anon (1987) reported that *A. modicella* population was less in groundnut when sunflower was intercropped. In the present study, the reduction in the *A. modicella* population in the sunflower intercropped field was may be due to the presence of more natural enemy complex against *A. modicella*. Rajagopal and Hanumanthaswamy (1996) proposed that cultural practices especially intercropping influence the *A. modicella* population and reduce the population in the main crop.

In the sole crop a lack or poor number of natural enemies was observed when compared with intercropped fields. Ananthakrishnan (1992) recommended intercropping system to avoid a lack of synchrony or poor ratio between number of natural enemies and their hosts in the sole crop. Swaminathan *et al.* (1999) reported that intercropping in cotton with sunflower increased natural enemy (*Chrysoperla carnea* (Stephens) activity and decreased *H. armigera* population.

In the maize intercropped field, the activities of lady bird beetles were found to be very high, however this system was less effective than other two intercrop systems in reducing pests population and infestation, however superior over the sole crop. Gavarra and Raros (1975) found more predatory spiders and predatory *Coccinellids* in groundnut - maize cropping system than in sole crop of groundnut.

Marwoto (1996) reported that intercropping in groundnut with maize apparently reduced the population of *A. modicella* and its damage.

The advantages of intercropping system on groundnut yield and cost - benefit ratio were also clearly exhibited in this study. Groundnut yield in 1997 was higher than in 1999. This variation may be due to poor rainfall in 1999. However, the variations in the yield of groundnut between intercropped fields and the sole crop were clearly exposed in this study. Inter crops enhanced the groundnut production. In contrast to this study, Ghosh *et al.* (1999c) have reported that intercropping reduced groundnut yield. However they reported that, the yield loss was nullified by high net return. The economic importance of intercropping system in groundnut was also proved by many investigators (Logiswaran and Mohanasundaram, 1985; Reddy *et al.*, 1987; Mandal *et al.*, 1990; Singh and Singh, 1992). In the present study, maize intercrop system failed to increase production of groundnut in 1999 when compared to other intercropping systems, the net gain and cost - benefit ratio were the highest in maize intercropped systems. The net gain from the sole crop was the least in 1997 and no gain was obtained from the sole crop in 1999. This clearly indicated that yield loss from a monoculture can be corrected by mixed cropping system.

4. 5. CONCLUSION

The present study clearly indicated that castor, maize and sunflower are the suitable crops in groundnut based intercropping system. The efficacy of an intercrop was found to be specific as from the present study to control a particular type of pest in the main crop (groundnut). The intercrops increased the benefit also. In the present study the spacings between groundnut and sunflower and also groundnut and maize were nearly same, which may lead to less yield of main crop when compared to that in castor intercropped field. This is mainly due to competition between the two crops for natural resources such as water, fertilizers and sunlight. This could be corrected by providing optimum space between main crop and intercrop and choosing a less competitive intercrop. However the net gain and cost-benefit ratio were the highest in maize intercropped field. So further studies are necessary to find out the role of space arrangements in groundnut based intercropping system particularly castor, maize and sunflower in production and economics.

CHAPTER - 5

CHAPTER - 5

INTEGRATION OF INTERCROPS AND PLANT PRODUCTS ON CHOSEN GROUNDNUT DEFOLIATORS MANAGEMENT AND GROUNDNUT PRODUCTION

5. 1. INTRODUCTION

The worldwide awareness of safe environment leads to adopt non-chemical pest management strategies. Non-chemical pest management strategies altogether constitute the IPM. In IPM, two or more methods are followed at a time to manage the pest populations. Among the various IPM components, cultural control (tillage, crop rotation, inter/mixed cropping) and bio-rational insecticides constitute the most practical oriented approach. Inter or mixed cropping is an important cultural control method that is advantageous in reducing pest attack in the main crop, enhancing the natural enemies and beneficial insects population and increasing the profit. In the past, several investigators have worked out the advantages of intercrops such as castor (Senthivel *et al.*, 1989; Davi Dayal and Reddy, 1991; Bhondave *et al.*, 1994), legumes (Muthiah *et al.*, 1991; Shivakumar and Reddy, 1993; Lourduraj *et al.*, 1994; Gnanamurthy and Balasubramanian, 1996), maize (Sharma and Varshney, 1990; Alegbejo, 1997; Ghosh *et al.*, 1999c), soybean (Senthivel *et al.*, 1989; Muthiah *et al.,* 1991), and sunflower (Putnam *et al.,* 1990; Davi Dayal and Reddy, 1991) in groundnut.

Similarly the efficacy of plant products, mostly neem derived pesticides have been tested against many field pests (Singh *et al.,* 1985; Saxena, 1987; Nandagopal *et al.,* 1990; Sinha, 1993; Jhansi and Singh, 1993; Pandey and Misra, 1996). But there is a lack of studies on integration of intercrops and plant products, especially crude water extracts of *A. Indica, C. gigantea, P. pinnata* and *V. negundo* leaves in groundnut pests management. So the present study has been undertaken to findout the efficacy of integration of intercrops (castor, maize, soybean and sunflower) and plant leaf extracts (neem, calotropis, pongamia and vitex) in *A. modicella* and *S. litura* management in groundnut. Moreover the impact of these IPM components on groundnut yield and cost – benefit ratio were also studied.

5. 2. MATERIALS AND METHODS

Plot description, preparation and application of botanicals, intercropping method, procedure of pest incidence and infestation counting, yield estimation and per cent avoidable loss estimation are given in Chapter – 4. Soybean (cvCo 1) was also included for the present study. One row of soybean was intercropped after every 10 rows of groundnut. The space between two soybean plants within a row was 30 cm (Plate - 6 c)

5. 2. 1. Statistical analysis

Statistical analysis of experimental data was performed using two-way analysis of variance (ANOVA) and critical difference (CD) was calculated to identify the treatment mean that is significantly different from other treatment means (Rangaswamy, 1995).

5. 3. RESULTS

5. 3. 1. *A. modicella* incidence

The influence of integration of intercrops and plant products on *A. modicella* larval population in Kharif 1998 is presented in Table 18. In sole crop, larval population was very high (1.0, 1.3, 5.0, 7.7, 10.7 and 13.3 larvae/plant on 26, 34, 41, 49, 56 and 64 DASE respectively). During kharif 2000, *A. modicella* population gradually increased from 26 to 41 DASE and declined on 49 DASE and again increased afterwards in the sole crop and this trend is clearly seen from Table 19 (3.7, 4.5, 7.1, 3.5, 6.0 and 7.4 larvae per plant on 26, 34, 41, 49, 56 and 64 DASE respectively).

In kharif 1998, CR + AI integrated field had the highest incidence (0.3, 4.7, 2.0, 1.7, 1.3 and 1.0 larvae/plant on 26, 34, 41, 49, 56 and 64 DASE respectively) next to control. CR + VN treatment also had the same effect as CR + AI combination when seeing on the grand mean (1.8 larvae/plant) (Table 18). In contrast, castor and neem integrated field had the lowest incidence in kharif 2000. Among the various treatments, lowest incidence during kharif 1998 was recorded (Mean = 0.8 larvae/plant) in MZ + CG treatment (0.3, 2.0, 0.7, 0.7, 1.0 and 0.3 larvae/plant on 26, 34, 41, 49, 56 and 64 DASE respectively) followed by soybean + plant products combination. SB + VN (0.3, 1.7, 1.3, 0.3, 1.0 and 0.7 larvae), SB + CG (0.0, 2.7, 1.7, 0.7, 0.3 and 0.3 larvae), SB + PP (1.7, 1.7, 0.7, 0.7, 0.7 and 0.3 larvae) and SB + AI (1.0, 2.0, 1.7, 0.3, 0.7 and 0.3 larvae/plant) combinations had equal effects and considerably reduced the *A. modicella* incidence per plant. During kharif 2000,after the first spray of plant extracts, *A. modicella* population decreased only in SF + VN (5.2, 5.0, 6.2, 2.7, 4.2 and 3.2 larvae per plant) and SF + CG (4.8, 4.5, 5.6, 1.9, 3.5 and 3.5 larvae per plant) combinations and in all other treatments the larval

Table 18. Integrated effect of inter crops and plant products on *A. modicella* incidence in kharif 1998 (Mean ± SE.) (n = 30).

Treatments	Mean number of larvae/plant 26 DASE	34 DASE	41 DASE	49 DASE	56 DASE	64 DASE	Grand Mean
Control	1.0 ± 0.6	1.3 ± 0.3	5.0 ± 0.6	7.7 ± 0.9	10.7 ± 0.9	13.3 ± 3.1	6.5
CR + CG	0.7 ± 0.3	1.3 ± 0.9	3.0 ± 1.5	1.3 ± 0.3	0.7 ± 0.3	0.7 ± 0.3	1.3
CR + AI	0.3 ± 0.3	4.7 ± 0.9	2.0 ± 0.6	1.7 ± 0.3	1.3 ± 0.3	1.0 ± 0.6	1.8
CR + VN	1.0 ± 0.9	3.0 ± 0.6	2.0 ± 0.6	1.7 ± 0.6	2.0 ± 0.6	1.0 ± 0.6	1.8
SB + CG	0.0	2.7 ± 0.3	1.7 ± 0.3	0.7 ± 0.3	0.3 ± 0.3	0.3 ± 0.3	1.0
SB + AI	1.0 ± 0.6	2.0 ± 0.6	1.7 ± 0.3	0.3 ± 0.3	0.7 ± 0.3	0.3 ± 0.3	1.0
SB + PP	1.7 ± 1.2	1.7 ± 0.3	0.7 ± 0.3	0.7 ± 0.3	0.7 ± 0.6	0.3 ± 0.3	1.0
SB + VN	0.3 ± 0.3	1.7 ± 0.7	1.3 ± 0.3	0.3 ± 0.3	1.0 ± 0.6	0.7 ± 0.3	1.0
MZ + CG	0.3 ± 0.3	2.0 ± 0.6	0.7 ± 0.3	0.7 ± 0.6	1.0 ± 0	0.3 ± 0.3	0.8
MZ + AI	0.7 ± 0.3	2.7 ± 0.3	1.3 ± 0.3	1.0 ± 0.6	0.3 ± 0.3	0.0	1.0
MZ + PP	0.0	3.3 ± 0.3	1.7 ± 0.3	1.3 ± 0.9	1.0 ± 0	0.7 ± 0.6	1.3
MZ + VN	0.0	3.3 ± 0.9	1.7 ± 0.6	0.3 ± 0.3	1.3 ± 0.3	0.7 ± 0.3	1.2
SF + CG	0.3 ± 0.3	2.3 ± 0.3	3.0 ± 0.6	2.0 ± 0.6	1.3 ± 0.3	1.0 ± 0.6	1.7
SF + AI	0.0	0.7 ± 0.3	2.7 ± 0.3	1.7 ± 0.3	1.7 ± 0.9	1.3 ± 0.6	1.4
SF + PP	0.7 ± 0.7	2.0 ± 0.6	3.3 ± 0.3	1.7 ± 0.6	1.0 ± 0.6	1.0 ± 0.6	1.6
SE(d) ±		0.80	0.83	0.77	0.71	1.32	
CD at 5% level	NS	1.65	1.68	1.57	1.45	2.7	

NS = Not Significant (p = 0.05)

Table 19. Integrated effect of plant products and intercrops on *A. modicella* population in kharif 2000 (Mean ± SE.) (n = 30).

Treatments	Mean number of larvae/plant						Grand Mean
	26 DASE	34 DASE	41 DASE	49 DASE	56 DASE	64 DASE	
Control	3.7 ± 0.5	4.5 ± 0.3	7.1 ± 0. 4	3.5 ± 0.4	6.0 ± 0.3	7.4 ± 0.5	5.4
CR + AI	2.4 ± 0.4	3.4 ± 0.2	4.4 ± 0.3	1.4 ± 0.4	4.9 ± 0.5	3.3 ± 0.2	3.3
CR + PP	2.1 ± 0.1	4.6 ± 0.6	5.8 ± 0.3	3.2 ± 0.1	6.1 ± 0.5	5.3 ± 0.3	4.5
CR + VN	3.6 ± 0.3	3.9 ± 0.1	5.0 ± 0.4	2.6 ± 0.2	3.1 ± 0.2	2.4 ± 0.2	3.4
CR + CG	2.9 ± 0.6	4.9 ± 0.5	4.5 ± 0.1	1.1 ± 0.1	4.1 ± 0.2	3.0 ± 0.1	3.4
SF + AI	5.2 ± 0.3	5.3 ± 0.1	6.1 ± 0.4	1.7 ± 0.2	5.1 ± 0.1	5.0 ± 0.4	4.7
SF + PP	4.5 ± 0.3	4.7 ± 0.9	6.0 ± 0.2	2.6 ± 0.1	4.5 ± 0.9	4.1 ± 0.5	4.4
SF + VN	5.2 ± 0.5	5.0 ± 0.6	6.2 ± 0.3	2.7 ± 0.3	4.2 ± 0.1	3.2 ± 0.3	4.4
SF + CG	4.8 ± 0.1	4.5 ± 0.1	5.6 ± 0.1	1.9 ± 0.2	3.5 ± 0.3	3.5 ± 0.7	4.0
MZ + AI	3.7 ± 0.2	5.4± 0.1	5.8 ± 0.3	1.8 ± 0.1	5.2 ± 1.0	3.9 ± 0.1	4.3
MZ + PP	3.3 ± 0.2	5.8± 0.3	6.5 ± 0.4	2.8 ± 0.2	6.1 ± 0.3	4.8 ± 0.1	4.9
MZ + VN	3.7 ± 0.7	5.3 ± 0.8	6.0 ± 0.5	2.4 ± 0.2	6.1 ± 0.3	5.6 ± 0.3	4.9
MZ + CG	4.2 ± 0.4	6.1 ± 0.1	5.3 ± 0.6	1.9 ± 0.1	5.4 ± 0. 6	5.2 ± 0.2	4.7
SE(d) ±	0.62	0.64	0.50	0.31	0.68	0.5	
CD at 5% level	1.30	1.32	1.03	0.64	1.41	1.00	

population increased. Larval population declined after the second and third spray in Kharif 1998, however in Kharif 2000, the first spray did not minimise the pest incidence except in SF + VN and SF + CG combinations. Statistical significance among the treatment means ($p < 0.05$) was observed in all the six counts except the first count.

In kharif 2000, castor + plant products combination was the most effective among the various treatments in minimising *A. modicella* incidence (Table 19). *A. modicella* incidence was the lowest in CR + AI treatment (2.4, 3.4, 4.4, 1.4, 4.9 and 3.3 larvae/plant) followed by CR + CG (2.9, 4.9, 4.5, 1.1, 4.1 and 3.0 larvae/plant), CR + VN (3.6, 3.9, 5.0, 2.6, 3.1 and 2.4 larvae/plant) combinations. A sudden decline in larval population was observed in all treatments on 49 DASE (after the second spray) and this trend was recorded in the sole crop (control) also. In the sole crop, the incidence was found to be significantly ($p < 0.05$) high when compared to other treatments.

5. 3. 2. *A. modicella* infestation

A reduction in the leaf damage was recorded in intercrop + plant products treatments in both years of study, when compared to the control (Table 20 & 21). In the sole crop, leaf damage increased as the crop grew older (2.7, 2.7, 10.0, 11.3, 17.0 and 17.0 and 4.6, 6.4, 10.0, 10.6, 12.1 and 13.7 leaves/plant on 26, 34, 41, 49, 56 and 64 DASE respectively in kharif 1998 and 2000 respectively). Among the treatment in 1998, SF + AI combination (0.3, 3.7, 5.3, 3.3, 4.0 and 3.7 leaves/plant on 26, 34, 41, 49, 56 and 64 DASE respectively) and SB + AI (4.0, 2.3, 3.7, 3.3, 3.7 and 3.3 leaves/plant) were the best treatments in reducing *A. modicella* infestation. In kharif 2000, CR + CG (4.9, 6.9, 5.7, 5.8, 5.4 and 4.0 leaves/plant) and CR + VN

Table 20. Effect of inter crops and plant products on *A. modicella* infestation in kharif 1998 (Mean ± SE.) (n = 30).

Treatments	Mean number of larvae/plant						Grand Mean
	26 DASE	34 DASE	41 DASE	49 DASE	56 DASE	64 DASE	
Control	2.7 ± 0.6	2.7 ± 0.1	10.0 ± 0.5	11.3 ± 1.2	17.0 ± 0.5	17.0 ± 0.3	10.1
CR + CG	3.3 ± 0.4	4.7 ± 0.4	8.0 ± 1.2	6.3 ± 0.1	5.0 ± 0.3	5.3 ± 0.4	5.4
CR + AI	2.7 ± 0.4	10.7 ± 0.6	6.7 ± 0.5	7.7 ± 0.4	5.0 ± 0.3	4.7 ± 0.1	6.3
CR + VN	5.3 ± 0.4	7.7 ± 0.4	5.0 ± 0.3	7.3 ± 0.5	6.0 ± 0.3	5.0 ± 0.3	6.1
MZ + CG	2.3 ± 0.1	8.0 ± 0.3	6.3 ± 0.4	8.0 ± 0.3	5.3 ± 0.6	4.7 ± 0.5	5.8
MZ + AI	1.3 ± 0.1	10.0 ± 0.3	6.7 ± 0.6	4.3 ± 0.6	3.7 ± 0.1	3.3 ± 0.4	5.0
MZ + PP	3.3 ± 0.1	11.7 ± 0.9	8.3 ± 0.6	9.3 ± 1.2	4.7 ± 0.1	3.7 ± 0.1	6.8
MZ + VN	0.7 ± 0.3	11.0 ± 0.3	6.7 ± 0.3	6.3 ± 0.6	5.7 ± 0.3	4.7 ± 0.4	6.0
SB + CG	0.0	8.0 ± 0.3	7.7 ± 0.4	6.3 ± 0.6	4.0 ± 0.4	4.0 ± 0.3	5.0
SB + AI	4.0 ± 0.4	2.3 ± 0.1	3.7 ± 0.4	3.3 ± 0.6	3.7 ± 0.4	3.3 ± 0.1	3.4
SB + PP	5.0 ± 0.8	4.7 ± 0.5	6.3 ± 0.1	6.3 ± 0.5	5.0 ± 0.7	3.7 ± 0.3	5.2
SB + VN	0.7 ± 0.3	6.0 ± 0.8	4.7 ± 0.4	4.3 ± 0.8	3.7 ± 0.4	3.3 ± 0.4	3.8
SF + CG	1.7 ± 0.5	6.7 ± 0.6	6.7 ± 0.6	4.3 ± 0.6	3.3 ± 0.1	3.0 ± 0.3	4.3
SF + AI	0.3 ± 0.1	3.7 ± 0.6	5.3 ± 0.4	3.3 ± 0.1	4.0 ± 0.3	3.7 ± 0.1	3.4
SF + PP	1.7 ± 0.4	5.0 ± 1.0	6.0 ± 0.3	4.0 ± 0.3	5.0 ± 0.3	4.3 ± 0.4	4.3
SE(d) ±	1.3	1.7		2.0	1.2	0.9	
CD at 5% level	2.6	3.5	NS	4.2	2.5	2.0	

NS = Not significant (p = 0.05).

Table 21. Integrated effect of intercrops and plant products on *A. modicella* infestation in kharif 2000 (Mean ± S.E.) (n = 30).

Treatments	Mean number of larvae/plant						Grand Mean
	26 DASE	34 DASE	41 DASE	49 DASE	56 DASE	64 DASE	
Control	4.6 ± 0.6	6.4 ± 0.5	10.0 ± 1.2	10.6 ± 1.4	12.1 ± 1.0	13.7 ± 0.3	9.6
CR + AI	5.3 ± 0.3	5.6 ± 0.1	5.9 ± 0.3	6.9 ± 0.3	7.0 ± 0.1	4.7 ± 0.3	6.0
CR + PP	4.6 ± 0.7	6.3 ± 0.3	7.0 ± 0.3	6.5 ± 0.8	7.1 ± 0.1	5.5 ± 0.3	6.2
CR + VN	6.4 ± 0.4	6.1 ± 0.4	5.9 ± 0.2	6.6 ± 0.2	4.5 ± 0.2	3.3 ± 0.2	5.5
CR + CG	4.9 ± 0.4	6.9 ± 0.3	5.7 ± 0.1	5.8 ± 0.3	5.4 ± 0.2	4.0 ± 0.5	5.5
SF + AI	7.6 ± 0.3	6.5 ± 0. 2	8.5 ± 0.3	8.9 ± 0.3	6.6 ± 0.3	5.9 ± 0.1	7.3
SF + PP	6.4 ± 1.0	8.1 ± 0.3	8.1 ± 0.9	8.7 ± 0.8	5.5 ± 0.8	4.8 ± 0.6	7.0
SF + VN	7.5 ± 0.8	8.4 ± 0.7	8.2 ± 0.2	8.4 ± 0.8	6.7 ± 0.3	5.6 ± 0.8	7.5
SF + CG	7.9 ± 0.6	6.9 ± 0.3	6.7 ± 0.7	7.2 ± 0.4	5.8 ± 0.2	5.3 ± 0.4	6.6
MZ + AI	6.0 ± 0.3	6.7 ± 0.1	7.3 ± 0.1	7. 6 ± 0.1	6.4 ± 1.1	5.5 ± 1.0	6.6
MZ + PP	6.6 ± 0.3	8.9 ± 0.1	8.4 ± 0.3	8.1 ± 0.7	7.7 ± 0.3	6.5 ± 0.2	7.7
MZ + VN	6.1 ± 1.5	6.9 ± 0.9	6.9 ± 0.0	7.1 ± 0.7	6.4 ± 0.2	7.1 ± 0.4	6.8
MZ + CG	6.3 ± 0.3	7.9 ± 0.3	7.5 ± 0.9	9.9 ± 0.3	6.7 ± 0.4	5.9 ± 0.1	7.4
SE(d) ±	0.94	0.60	0.77	0.84	0.75	0.67	
CD at 5% level	1.94	1.24	1.60	1.73	1.54	1.40	

(6.4, 6.1, 5.9, 6.6, 4.5 and 3.3 leaves/plant) were the most effective treatments and reduce *A. modicella* infestation significantly to control ($p < 0.05$).

The least effective treatment in 1998 was identified as MZ + PP combination (Mean = 6.8 leaves/plant) and the number of damaged leaves in this treatment on 26, 34, 41,49, 56 and 64 DASE were 3.3, 11.7, 8.3, 9.3, 4.7 and 3.7 leaves/plant respectively. Among the four plant products tested, neem spray was best in maize (1.3, 10.0, 6.7, 4.3, 3.7 and 3.3 leaves/plant) and in the castor intercropped system, calotropis treatment was found to be the best (3.3, 4.7, 8.0, 6.3, 5.0 and 5.3 leaves/plant) in reducing *A. modicella* infestation. In Kharif 2000, neem extract spray was found to be the best in the maize intercropped field, than any other plant extracts tested here, where as in sunflower intercropped field, calotropis spray was the most effective one in controlling *A. modicella* damage. On 34, 49 and 64 DASE, CR + AI (5.6 leaves/plant), CR + CG (5.8 leaves/plant) and CR + VN (3.3 leaves/plant) treatment plots respectively showed significantly low infested leaves among other treatments.

In 1998, the first spray reduced the infestation only in SB + AI (from 4.0 to 2.3 leaves) and SB + PP (from 5.0 to 4.7 leaves) combinations and in all other treatments, the infestation was found to be increased. The second spraying of plant extracts minimised the leaf damage in CR + CG, SF + CG, SF + AI, SF + PP, SB + CG, SB + AI, SB + VN, MZ + AI and MZ + VN combinations. Third spray decreased the infestation in all treatments except CR + CG integrated field, where the damage increased from 5.0 leaves to 5.3 leaves per plant. Plant product with the intercrop combinations were found to be significant ($p < 0.05$) during the study period except on 41 DASE. The CD analyses shows significances among the various treatments except the 41 DASE in 1998. In 2000, castor intercropped field showed significantly less damage (Table 21).

5. 3. 3. *S. litura* incidence

S. litura incidence in Kharif 1998 was given in Table 22. The number of *S. litura* larvae recorded in all treatment plots were ranged from one to three larvae per plant and in the sole crop, the number of larvae per plant was the maximum and recorded as five larvae per plant on 64 DASE. *S. litura* population in the sole crop was 2.0, 3.2, 3.8, 4.0, 4.8 and 5.0 larvae per plant on 26, 34, 41, 49, 56 and 64 DASE respectively. From the grand mean values of larval population, it was understood that SB + CG combination was the most effective treatment (1.9, 1.7, 1.7, 1.5, 1.4 and 0.8 larvae/plant) and SF + CG combination was the least effective treatment (2.6, 2.6, 2.2, 2.0, 1.2 and 1.2 larvae /plant on 26, 34, 41, 49, 56 and 64 DASE respectively) for *S. litura*. Among the four plant products tested, calotropis was the most effective treatment in castor, soybean and maize intercropped fields. However, in the sunflower intercropped field the neem treatment was the best to control *S. litura* population. In all the treatments, pest population gradually decreased from the first to last observation periods and it was highly significant ($p < 0.05$) by CD analysis.

In kharif 2000, *S. litura* population was very low in sole as well as in treatment plots, (Table 23). Maximum number of larvae per plant was recorded as 1.4 larvae per plant in the SF + PP treatment on 41 DASE. Among the various treatments, CR + CG combination was found to be the most effective one in which no larvae were recorded except on 56 DASE on which day 0.1 larva per plant was recorded. Next to this treatment, CR + AI integrated field showed minimum incidence of *S. litura* recorded as 0.3, 0.0, 0.1, 0.0, 0.2 and 0.1 larva per plant on 26,

Table 22. Integrated effect of inter crops and plant products on the incidence of *S. litura* in kharif 1998 (Mean ± SE.) (n = 30).

Treatments	Mean number of larvae/plant						Grand Mean
	26 DASE	34 DASE	41 DASE	49 DASE	56 DASE	64 DASE	
Control	2.0 ± 0.2	3.2 ± 0.4	3.8 ± 0.4	4.0 ± 0.3	4.8 ± 0.2	5.0 ± 0.5	3.8
CR + CG	2.1± 0.2	2.0 ± 0.3	1.7 ± 0.1	1.5 ± 0.0	1.1 ± 0.5	0.9 ± 0.3	1.6
CR + AI	2.1 ± 0.2	2.1 ± 0.1	1.8 ± 0.1	1.6 ± 0.1	1.1 ± 0.1	0.6 ± 0.1	1.6
CR + VN	2.2 ± 0.2	2.0 ± 0.1	1.9 ± 0.2	1.7 ± 0.1	1.4 ± 0.1	1.0 ± 0.1	1.7
MZ + CG	2.0 ± 0.0	2.0 ± 0.3	1.9 ± 0.2	1.8 ± 0.1	1.7 ± 0.1	0.8 ± 0.1	1.7
MZ + AI	2.2 ± 0.2	2.2 ± 0.3	2.1 ± 0.1	1.9 ± 0.1	1.7 ± 0.1	0.9 ± 0.1	1.8
MZ + PP	2.3 ± 0.2	2.2 ± 0.1	2.1 ± 0.1	1.9 ± 0.1	1.7 ± 0.0	1.1 ± 0.1	1.9
MZ + VN	2.0 ± 0.0	1.9 ± 0.1	1.9 ± 0.1	1.9 ± 0.1	1.8 ± 0.0	1.2 ± 0.0	1.8
SB + CG	1.9 ± 0.1	1.7 ± 0.1	1.7 ± 0.1	1.5 ± 0.0	1.4 ± 0.1	0.8 ± 0.1	1.5
SB + AI	2.1 ± 0.1	2.0 ± 0.0	1.9 ± 0.1	1.8 ± 0.0	1.7 ± 0.0	0.8 ± 0.1	1.7
SB + PP	2.1 ± 0.2	1.9 ± 0.1	1.8 ± 0.1	1.5 ± 0.1	1.1 ± 0.2	1.0 ± 0.3	1.6
SB + VN	2.0 ± 0.3	2.0 ± 0.2	1.9 ± 0.2	1.9 ± 0.0	1.7 ± 0.0	1.0 ± 0.0	1.8
SF + CG	2.6 ± 0.5	2.6 ± 0.3	2.2 ± 0.1	2.0 ± 0.5	1.2 ± 0.1	1.2 ± 0.3	2.0
SF + AI	2.7 ± 0.2	2.0 ± 0.4	2.0 ± 0.1	1.9 ± 0.3	1.0 ± 0.4	0.8 ± 0.1	1.7
SF + PP	3.0 ± 0.7	2.1 ± 0.7	2.3 ± 0.5	2.0 ± 0.3	0.9 ± 0.4	0.9 ± 0.1	1.9
SE(d) ±	0.25	0.27	0.26	0.18	0.25	0.25	
CD at 5% level	0.52	0.56	0.53	0.38	0.53	0.53	

Table 23. Efficacy of intercrops and plant products combination in *S. litura* incidence Management in kharif 2000 (Mean ± SE.) (n = 30).

Treatments	Mean number of larvae/plant						Grand Mean
	26 DASE	34 DASE	41 DASE	49 DASE	56 DASE	64 DASE	
Control	0.0	0.2 ± 0.2	0.7 ± 0.4	1.2 ± 0.2	0.5 ± 0.1	0.5 ± 0.1	0.5
CR + AI	0.3 ± 0.2	0.0	0.1 ± 0.1	0.0	0.2 ± 0.1	0.1 ± 0.1	0.1
CR + PP	0.0	0.0	0.2 ± 0.1	0.2 ± 0.1	0.2 ± 0.1	0.2 ± 0.1	0.1
CR + VN	0.3 ± 0.3	0.4 ± 0.2	0.4 ± 0.3	0.2 ± 0.2	0.0	0.0	0.2
CR + CG	0.0	0.0	0.0	0.0	0.1 ± 0.1	0.0	0.0
SF + AI	0.2 ± 0.1	0.2 ± 0.2	0.5 ± 0.1	0.3 ± 0.3	0.0	0.0	0.2
SF + PP	0.0	0.2 ± 0.1	1.4 ± 0.5	0.2 ± 1.1	0.2 ± 0.1	0.1 ± 0.1	0.4
SF + VN	0.0	0.1 ± 0.1	0.7 ± 0.4	0.2 ± 0.1	0.1 ± 0.1	0.1 ± 0.1	0.2
SF + CG	0.0	0.0	0.8 ± 0.2	0.0	0.0	0.0	0.1
MZ + AI	0.6 ± 0.3	0.0	0.5 ± 0.2	0.3 ± 0.3	0.4 ± 0.1	0.1 ± 0.1	0.3
MZ + PP	0.4 ± 0.4	0.3 ± 0.2	0.9 ± 0.6	0.7 ± 0.3	0.2 ± 0.1	0.1 ± 0.1	0.4
MZ + VN	0.2 ± 0.2	0.5 ± 0.3	0.8 ± 0.4	0.3 ± 0.2	0.1 ± 0.1	0.1 ± 0.0	0.3
MZ + CG	0.0	0.3 ± 0.3	0.1 ± 0.1	0.5 ± 0.3	0.2 ± 0.1	0.1 ± 0.1	0.2
SE(d) ±				0.26	0.13	0.10	
CD at 5% level	NS	NS	NS	0.53	0.26	0.21	

NS = Not significant (p = 0.05).

34, 41, 49, 56 and 64 DASE respectively. In the control field, larval incidence increased upto 49 DASE and declined afterwards (0.0, 0.2, 0.7, 1.2, 0.5 and 0.5 larvae/plant on 26, 34, 41, 49, 56 and 64 DASE respectively). After first spray of plant extract, S. *litura* incidence decreased in CR + AI, MZ + AI and MZ + PP treatments. Second spray reduced larval incidence in all treatment plots except MZ + CG combination. Third spray minimized the incidence in all treatment plots. Larval population in all treatments was significant ($P < 0.05$) with control by ANOVA on 49, 56 and 64 DASE and it was not significant ($P > 0.05$) on 26, 34 and 41 DASE.

5. 3. 4. *S. litura* infestation

In all treatments, *S. litura* infestation was significantly less ($P < 0.05$) than that in the sole crop in Kharif 1998 and 2000 (Table – 24 and 25). In the sole crop the leaf damage increased through out the study period and it was recorded as 4.0, 6.7, 8.0, 8.0 9.7 and 13.3 leaves per plant on 26, 34, 41, 49, 56 and 64 DASE respectively in Kharif 1998. In Kharif 2000, in the control plot, number of damaged leaves increased as the crop grew older (Table - 25) and it was recorded as 2.8, 4.1, 7.3, 11.6, 12.9 and 13.9 leaves per plant on 26, 34, 41, 49, 56 and 64 DASE respectively.

Among the various treatments in Kharif 1998, CR + AI (2.3, 7.0, 2.7, 6.0, 3.3 and 3.0 leaves/plant) or CR + VN (4.7, 5.3, 3.3, 5.0, 3.3 and 2.7 leaves/plant) and CR + CG (5.7, 5.7, 5.3, 5.3 3.00 and 2.7 leaves per plant on 26, 34, 41, 49, 56 and 64 DASE respectively) combinations were the most effective in controlling *S. litura* damage. SB + VN combination was also effective (4.0, 4.0, 7.7, 4.0, 4.0 and 4.0 leaves/plant) next to castor + plant product combinations. In SB + VN treatment field, an average of 4.0 leaves were damaged by *S. litura* throughout the study

Table 24. Integrated effect of intercrops and plant products on the infestation of *S. litura* in kharif 1998.

Treatments	Mean number of damaged leaves/plant						Grand Mean
	26 DASE	34 DASE	41 DASE	49 DASE	56 DASE	64 DASE	
Control	4.0 ± 0.5	6.7 ± 0.8	8.0 ± 0.3	8.0 ± 1.1	9.7 ± 0.5	13.3 ± 0.5	8.3
CR + CG	5.7 ± 0.3	5.7 ± 0.5	5.3 ± 0.5	5.3 ± 0.6	3.0 ± 0.3	2.7 ± 0.3	4.6
CR + AI	2.3 ± 0.3	7.0 ± 0.5	2.7 ± 0.1	6.0 ± 0.3	3.3 ± 0.3	3.0 ± 0.0	4.1
CR + VN	4.7 ± 0.5	5.3 ± 0.5	3.3 ± 0.3	5.0 ± 0.3	3.3 ± 0.1	2.7 ± 0.1	4.1
MZ + CG	2.7 ± 0.6	9.0 ± 0.3	6.0 ± 0.3	7.0 ± 0.3	5.3 ± 0.1	3.7 ± 0.1	5.6
MZ + AI	6.3 ± 1.2	10.7 ± 1.6	8.7 ± 0.9	6.3 ± 0.9	5.7 ± 0.9	5.3 ± 1.3	7.2
MZ + PP	4.0 ± 0.5	10.0 ± 0.3	9.3 ± 0.3	7.3 ± 0.4	6.0 ± 0.3	5.3 ± 0.4	7.0
MZ + VN	0.3 ± 0.3	12.0 ± 0.5	8.0 ± 0.6	5.0 ± 0.6	4.3 ± 0.9	4.3 ± 0.6	5.7
SB + CG	0.7 ± 0.3	6.7 ± 0.5	9.0 ± 0.7	7.0 ± 0.3	6.3 ± 0.1	5.3 ± 0.1	5.8
SB + AI	4.0 ± 0.3	6.7 ± 1.2	5.7 ± 1.5	5.3 ± 0.9	4.7 ± 1.2	3.0 ± 0.6	4.9
SB + PP	6.0 ± 0.9	8.7 ± 0.5	5.7 ± 0.5	4.7 ± 0.4	4.3 ± 0.1	4.0 ± 0.3	5.6
SB + VN	4.0 ± 0.3	4.0 ± 0.6	7.7 ± 0.9	4.0 ± 0.6	4.0 ± 0.6	4.0 ± 1.0	4.6
SF + CG	4.7 ± 4.0	7.0 ± 0.5	8.7 ± 0.8	7.3 ± 0.9	3.3 ± 0.1	2.3 ± 0.4	5.6
SF + AI	2.7 ± 0.3	2.0 ± 0.6	10.7 ± 1.4	6.7 ± 0.1	7.7 ± 0.9	5.7 ± 0.3	5.9
SF + PP	7.3 ± 0.9	4.7 ± 0.4	11.3 ± 0.8	8.7 ± 0.1	4.0 ± 0.3	6.3 ± 0.1	7.1
SE(d) ±		1.6	1.6		1.0	1.0	
CD at 5% level	NS	3.2	3.3	NS	2.0	2.1	

NS = Not significant (p = 0.05).

Table 25. Impact of integration of intercrops and plant products on *S. litura* infestation in Kharif 2000 (Mean ± SE.) (n = 30).

Treatments	Mean number of damaged leaves/plant						Grand Mean
	26 DASE	34 DASE	41 DASE	49 DASE	56 DASE	64 DASE	
Control	2.8 ± 0.9	4.1 ± 0.2	7.3 ± 0.5	11.6 ± 0.4	12.9 ± 0.7	13.9 ± 0.4	8.8
CR + AI	3.9 ± 0.3	3.5 ± 0.3	6.1 ± 0. 4	6.9 ± 0.1	6.4 ± 0.5	3.8 ± 0.9	5.1
CR + PP	1.8 ± 1.0	3.9 ± 0.2	7.8 ± 0.1	7.6 ± 0.1	7.8 ± 0.2	4.8 ± 1.3	5.6
CR + VN	1.4 ± 1.4	4.3 ± 0.3	6.3 ± 0.3	6.5 ± 0.1	5.7 ± 0.4	3.0 ± 0.1	4.5
CR + CG	1.3 ± 0.8	4.7 ± 0.1	5.6 ± 0.1	6.7 ± 0.2	6.8 ± 0.2	3.3 ± 0.3	4.7
SF + AI	1.9 ± 1.2	5.7 ± 0.4	6.7 ± 0.1	7.2 ± 0.5	7.6 ± 0.4	3.1 ± 0.6	5.4
SF + PP	1.6 ± 1.6	5.0 ± 0.8	7.2 ± 0.6	7.7 ± 0.5	4.6 ± 0.4	3.4 ± 0.7	4.9
SF + VN	1.3 ± 0.7	4.6 ± 0.4	7.3 ± 0.3	7.8 ± 0.2	4.3 ± 0.3	3.2 ± 1.5	4.8
SF + CG	1.8 ± 0.9	5.3 ± 1.0	7.0 ± 0.2	7.1 ± 0.3	3.4 ± 0.8	2.7 ± 0.5	4.6
MZ + AI	3.0 ± 0.9	5.1 ± 0.3	6.4 ± 0.2	8.1 ± 0.7	5.0 ± 0.1	3.5 ± 0.3	5.2
MZ + PP	2.5 ± 0.4	5.8 ± 0.2	7.7 ± 0.4	8.2 ± 0.2	4.2 ± 0.6	3.9 ± 0.6	5.4
MZ + VN	2.2 ± 0.2	6.6 ± 0.2	6.5 ± 0.4	8.0 ± 0.5	4.0 ± 0.5	4.5 ± 0.3	5.3
MZ + CG	2.8 ± 0.9	6.7 ± 0.6	6.1 ± 0.6	7.3 ± 0.5	3.8 ± 0.9	3.8 ± 0.1	5.1
SE(d) ±		0.64	0.55	0.55	0.74	1.00	
CD at 5% level	NS	1.32	1.14	1.13	1.52	2.06	

NS = Not significant (p = 0.05).

period except on 41 DASE on which day, the damage increased from 4.0 leaves to 7.7 leaves. In Kharif 2000, lowest infestation was recorded in Cr + VN (4.5 leaves) treatment and the number of damaged leaves in this treatment on 26, 34, 41, 49, 56 and 64 DASE were 1.4, 4.3, 6.3, 6.5, 5.7 and 3.0 leaves per plant respectively. Next to this treatment, SF + CG (1.8, 5.3, 7.0, 7.1, 3.4 and 2.7 leaves/plant) and CR + CG (1.3, 4.7, 5.6, 6.7, 6.8 and 3.3 leaves/plant on 26, 34, 41, 49, 56 and 64 DASE respectively) treatments were found to be more effective in reducing *S. litura* infestation.

The first spray of plant extracts minimized the infestation only in sunflower integrated with either *A. indica* (from 2.7 to 2.0 leaves/plant) *P. pinnata* (7.3 to 4.7 leaves/plant) treatments in Kharif 1998. After the second spray, *S. litura* infestation decreased in maize, soybean and sunflower intercropped fields and third spray minimized the infestation in all treatments. In kharif 2000, first spray of plant products minimised the leaf damage in CR + AI combination (From 3.9 to 3.5 leaves/plant) only and in all other treatments, leaf damage increased. After second spray, infestation increased in all treatments and third spray decreased the infestation in all treatments except MZ + VN treatment, in which, the number of damaged leaves increased from 4.0 to 4.5 leaves per plant.

Though *S. litura* larval population in Kharif 2000 was very less or completely absent in the treatment plots during the observation periods, leaf damage caused by *S. litura* larvae was recorded in all the treatment plots. However the difference in the number of damaged leaves in treatment plots was significantly ($P < 0.05$) less than control.

5. 3. 5. Groundnut production

The groundnut production per hectare during the study period are given in the Tables 26 & 27. Among the various treatments in 1998, significantly more yield was obtained from SB + PP treated plot (1942 kg ha^{-1}) followed by SB + VN (1831 kg ha^{-1}) and SF + PP (1712 kg ha^{-1}) plots. Lowest production was obtained (1094 kg ha^{-1}) from SB + CG treated plot which was less than the yield from control plot. In kharif 2000 highest groundnut pod yield was obtained in CR + AI integrated field (1455 kg ha^{-1}) (Table - 27) and SF + AI integrated field (1360 kg ha^{-1}) and these were significantly ($P < 0.05$) difference from the yield from control (sole crop) plot (801 kg ha^{-1}). In general, castor intercropped field gave high yield. In maize intercropped field, calotropis sprayed plots yielded high groundnut production (1012 kg ha^{-1}).

5. 3. 6. Intercrops production

The inter crop production in Kharif 1998 are shown in Table 26. Castor, maize, sunflower and soybean yields were 381.5, 465.0, 241.6 and 165.5 kg/ha in neem treated field, 384.7, 465.0, 248.8 and 171.6 kg/ha in calotropis treatment field respectively. From vitex treatment plot, castor, maize and soybean productions were 380.8, 460.0 and 168.7 kg/ha respectively. Sunflower production from *P. pinnata* treated plot was 246.7 kg/ha.

In kharif 2000, castor, maize and sunflower productions were 302, 358 and 212 kg/ha in neem treatment; 294, 367 and 223 kg/ha in calotropis treatment; 312, 381 and 217 kg/ha in pongamia treatment and 321, 380 and 215 kg/ha in vitex treatment plots respectively (Table 27).

Table 26. Cost analysis in groundnut-based intercropping system with botanicals in Kharif - 1998

Treatment	Product	Yield (kg/ha)	Rate (Rs.)	Total gain (Rs.)	Total cost spent (Rs.)	Net gain (Rs.)	Cost-benefit Ratio
GN		1177.0	15301.0	15301.00	9350.00	5951	1 : 1.6
CR + AI	GN	1511.0	19643.0	24221.00	9700.00	14521	1 : 2.5
	CR	381.5	4578.0				
CR + CG	GN	1170.0	15301.0	19917.00	9700.00	10217	1 : 2.0
	CR	384.7	4616.0				
CR + VN	GN	1457.0	18941.0	23511.00	9700.00	13811	1 : 2.4
	CR	380.8	4570.0				
MZ + AI	GN	1258.0	16354.0	21004.00	9962	11042	1 : 2.1
	MZ	465.0	4650.0				
MZ + CG	GN	1307.0	16991.0	21536.00	9962	11574	1 : 2.1
	MZ	465.0	4545.0				
MZ + PP	GN	1214.0	15782.0	20369.00	9962	10407	1 : 2.0
	MZ	458.7	4587.0				
MZ + VN	GN	1236.0	16068.0	20668.00	9962	10706	1 : 2.0
	MZ	460.0	4600.0				
SB + AI	GN	1585.0	20605.0	21598.00	9688	11910	1 : 2.2
	SB	165.5	993.0				
SB + CG	GN	1094.0	14222.0	15251.00	9688	5563	1 : 1.5
	SB	171.6	1029.0				
SB + PP	GN	1942.0	25246.0	26287.00	9688	16599	1 : 2.71
	SB	173.50	1041.0				
SB + VN	GN	1831.0	23803.0	24815.00	9688	15127	1 : 2.5
	SB	168.7	1012.0				
SF + AI	GN	1630.0	21190.0	25538.00	9812	15726	1 : 2.6
	SF	241.6	4348.0				
SF + CG	GN	1451.0	18863.0	23341.00	9812	13529	1 : 2.4
	SF	248.8	4478.0				
SF + PP	GN	1712.0	2256.0	26696.00	9812	16884	1 : 2.72
	SF	246.7	4440.0				

uniformity

Table 27. Cost analysis in groundnut-based intercropping system with botanicals in kharif – 2000

Treatment	Product	Yield (kg/ha)	Rate (Rs.)	Total gain (Rs.)	Total cost spent (Rs.)	Net gain (Rs.)	Cost-benefit Ratio
GN		801	12015	12015	9500	2515	1 :1.26
CR + AI	GN	1455	21825	25449	9850	15599	1 : 2.6
	CR	302	3624				
CR + CG	GN	1044	15660	19188	9850	9338	1 :1.9
	CR	294	3528				
CR + PP	GN	1139	17085	20829	9850	10979	1 : 2.1
	CR	312	3744				
CR + VN	GN	1171	17565	21417	9850	11567	1 : 2.2
	CR	321	3852				
MZ + AI	GN	981	14715	18295	10112	8183	1 : 1.80
	MZ	358	3580				
MZ + CG	GN	1012	15180	18850	10112	8738	1. : 1.86
	MZ	367	3670				
MZ + PP	GN	823	12345	16155	10112	6043	1 : 1.60
	MZ	381	3810				
MZ + VN	GN	886	13290	17090	10112	6978	1 : 1.70
	MZ	380	3800				
SF + AI	GN	1360	20400	24216	9962	14254	1 : 2.4
	SF	212	3816				
SF + CG	GN	949	14235	18249	9962	8287	1 : 1.83
	SF	223	4014				
SF + PP	GN	864	12960	16866	9962	6904	1 : 1.70
	SF	217	3906				
SF + VN	GN	861	12915	16785	9962	6823	1 : 1.68
	SF	215	3870				

5. 3. 7. Per cent avoidable loss

Per cent avoidable yield loss in groundnut was very high in SB + PP (39.4 per cent) treatment followed by SB + VN (35.7 per cent) and SF + PP (31.3 per cent) combinations in 1998 (Fig. 12). In SB + CG combination, 7.6 per cent yield loss was recorded. In kharif 2000, per cent avoidable loss was the highest in CR + AI combination (45 per cent) followed by SF + AI (41.1 per cent) integrated field (Fig. 13). All treatments were found to be efficacious in increasing the groundnut production when compared to control.

5. 3. 8. Economics and cost – benefit ratio

Table 26 clearly shows that net gain was maximum (Rs. 16,884) in SF + PP treatment followed by SB + PP (Rs. 16,559) treatment in kharif 1998. During kharif 2000 net return per ha was the highest from CR + AI (Rs.15,599) followed by SF + AI (Rs.14,254) integrated fields (Table 27). Profit was minimum in the control plot (Rs. 5,951 per ha.). As observed in the net gain, the cost – benefit ratio was high in SF + PP (1 : 2.7) and SB + PP followed by SF + AI, SB + VN, CR + VN and SF + CG in 1998 and CR + AI and SF + AI combinations in kharif 2000.

5. 4. DISCUSSION

The present study clearly indicated that integration of intercrops and plant products was efficient in minimising the incidence and infestations of *A. modicella* and *S. litura*. All the four plant extracts did not have the same effect in all the four intercropped system. For example in Kharif 1998, calotropis leaf extract was the most effective when it was integrated with maize intercropping system in reducing *A. modicella* incidence. But in the sunflower intercropped field, calotropis was less effective. This may be due to the variation in synergistic effect posed by both the intercrop and plant product. Nandagopal *et al.* (1995) reported that intercrops

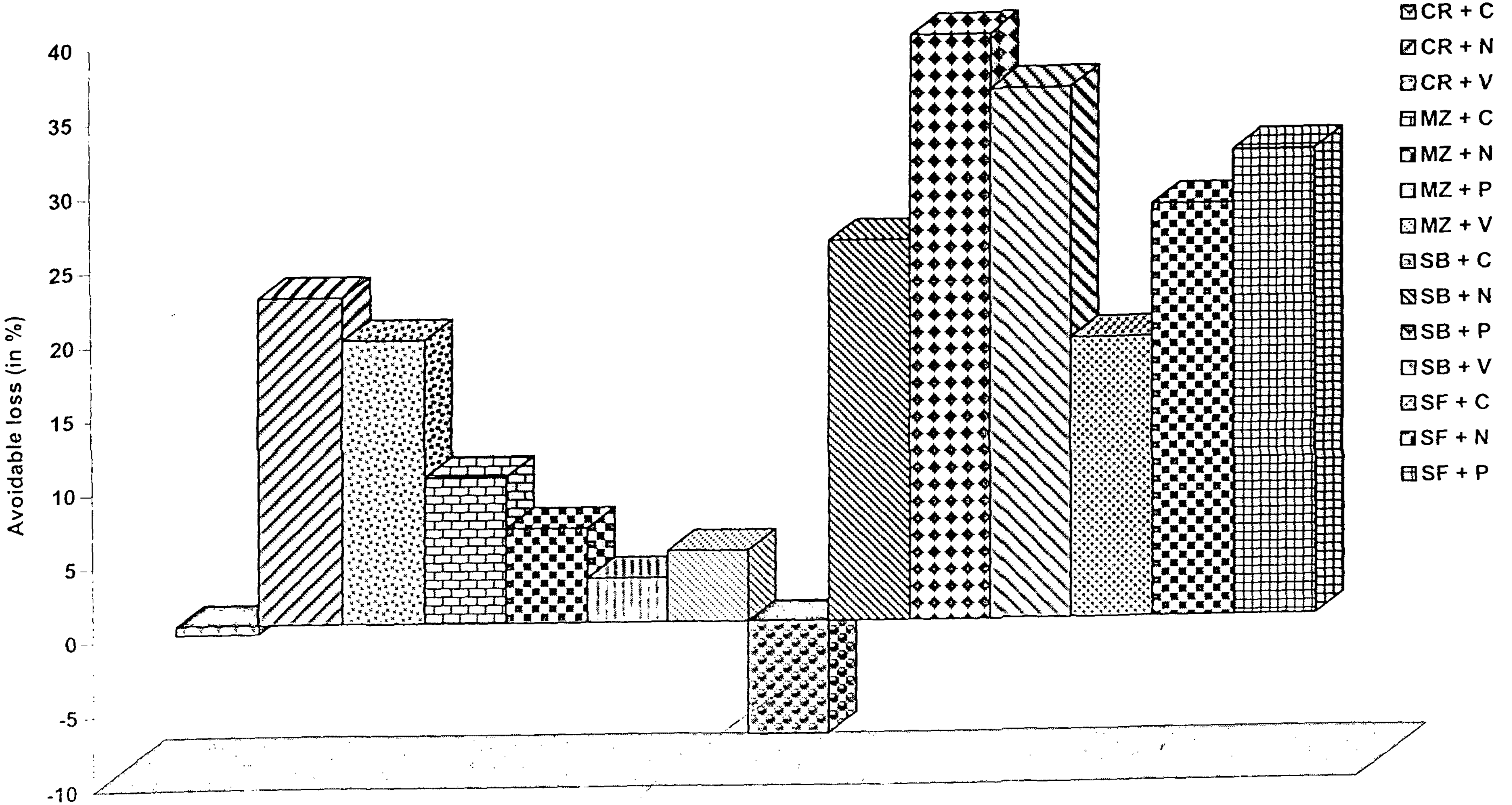


Fig. 12. Impact of intercrops and plant products on the per cent avoidable loss in kharif 1998.

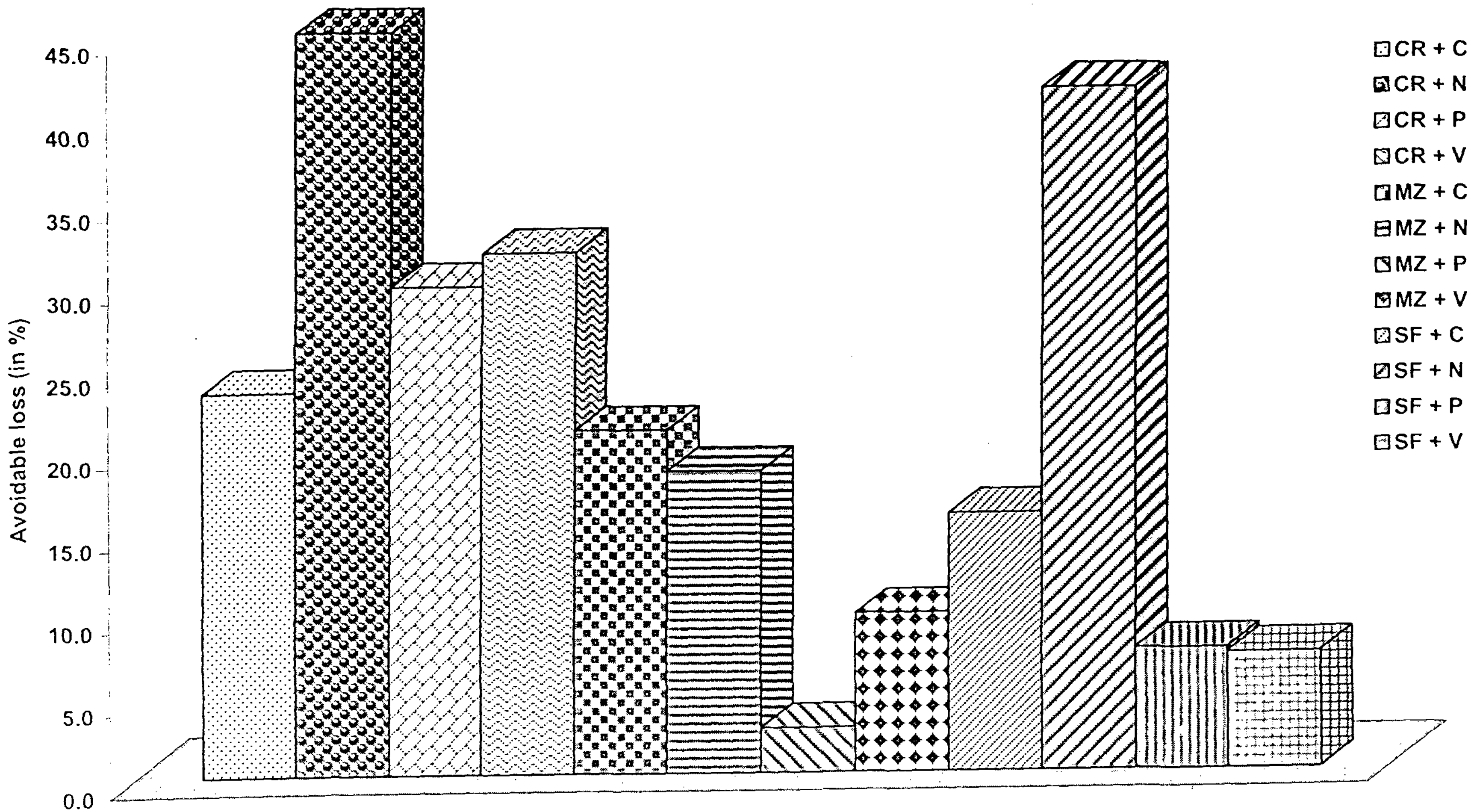


Fig. 13. Integrated effect of plant products and intercrops on per cent avoidable loss in kharif 2000.

under pesticides pressure minimised the population of groundnut pests such as jassids, thrips and *A. modicella*. The reduction of pest incidence and their infestation in the main crop in intercropping system is due to the high preference of the pest towards intercrop (Jeyaraj and Santharam, 1985) and high natural enemy complex (Ananthakrishnan, 1992; Swaminathan *et al.*, 1999). Low levels of *S. litura* incidence and its infestation were recorded in the main crop in the soybean and castor intercropped fields in both years. Soybean and castor are more preferred host of *S. litura* than groundnut (Jeyaraj and Santharam, 1985). In the case of sole crop, the pest depends only on the groundnut for food since alternate host plant is not available and this is the main reason for the high pest incidence and infestation in the sole crop.

In Kharif 2000, incidence was not recorded in many of the treatment plots. However its infestation was recorded in all the treatment plots. Since *S. litura* is active during night hours (nocturnal) they hide themselves in the soil and debris in the field and so their incidence was not visible during the observation. The leaf damage in sole crop was nearly fifty per cent of the leaves counted per plant might be the reason for the low yield. ICRISAT (1986) and Dhir *et al.* (1992) reported that considerable leaf damage by *S. litura* will lead to high reduction of groundnut yield.

Logiswaran and Mohanasundaram (1990) have found out that the yield was affected by increased leaf miner infestation. The relationship between pest incidence and infestation was not clearly exhibited in the present study. For example, among the various treatments, *S. litura* incidence was high in the sunflower + calotropis combination but its infestation was high in maize + pongamia combination. In the first two chapters, the plant products are found to be species specific and this principle may act in the present study, *i.e.* the pest is repelled by a particular plant product sprayed in the field. The incidence of *S. litura* was high in *C. gigantea* treated field but *C. gigantea* was highly toxic to this pest, it avoided to feed the foliage and thus the infestation was minimised in this treatment. In pongamia treated field, minimum number of larvae caused more leaf damage as pongamia was less toxic than calotropis. So the pressure exerted by intercrop alone on pest population might be minimum.

The groundnut production was the least in sole crop and it was due to the over defoliation caused by the pests. The net gain was highest in sunflower + *P. pinnata* combination in 1998 and castor + *A. indica* combination in kharif 2000. The inter relationship between the production and the net gain was clearly exhibited in kharif 2000 and not in Kharif 1998. In Kharif 2000, castor + *A. indica* combinations followed by sunflower + *A. indica* combination gave higher production and net gain also. However in kharif 1998, higher yield was obtained from soybean + *P. pinnata* treatment and higher net gain from sunflower + *P. pinnata* combination. Higher net income depends not only on high production of main crop, but also the market value of chosen intercrop and its production. Market value of sunflower was higher than soybean and maize and so the sunflower intercropping system gave high net income.

5. 5. CONCLUSION

It could be concluded that the plant products in combination with intercrops holds promise for potential pest management practice for much more economical and easily adoptable at the village level for managing groundnut pests. In the present study, all the four intercrops with plant product combination play vital role in minimizing pest incidence and infestation when compared to sole groundnut cultivation. However, castor and soybean and *A. indica* and *C. gigantea* are the most efficacious intercrops and plant products respectively against the groundnut pest studies. So these intercrops and plant products could be used for economic pest management in groundnut. Further studies are necessary to findout the efficacy of other plant products and intercrops either alone or in combination in field conditions against groundnut pests.

SUMMARY

SUMMARY

The efficacy of four botanicals *viz.,* vembu (neem) (*Azadirachta indica* A. Juss), erukku (madar) (*Calotropis gigantea* Linn.), pungai (karanj) (*Pongamia pinnata* Pierre) and nochi (lagundi) (*Vitex negundo* Linn.) and four intercrops such as castor, maize, soybean and sunflower was evaluated against three groundnut pests such as *Aproaerema modicella* Dev., *Helicoverpa armigera* Hubner and *Spodoptera litura* Fab. in field conditions. The plant products were evaluated against the pest larvae in the laboratory to findout the percent larval mortality, median lethal dose (LD_{50}), larval and pupal developmental periods, adult longevity and juvenometry. The thesis is summarized as follows :

1. The toxicity studies showed that neem was the most effective natural pesticide to *A. modicella* and *H. armigera* whereas *C. gigantea* was the most toxic plant to *S. litura*. In all treatments, larval mortality was concentration dependent.

2. Median lethal dose (LD_{50}) for fifth instar *H. armigera* was higher than fourth instar, whereas in the other two pests, the LD_{50} was higher in

fourth instar than fifth instar larvae except in neem treated *S. litura* larvae.

3. All the four plant products increased the larval and pupal periods when the larvae were orally treated and this effect was concentration dependent. *A. indica* treatment increased the larval and pupal periods of all the three pests. Adult longevity was reduced in the treated pests.

4. Pupal deformities were recorded in all the three pests whereas adult deformities were recorded in *H. armigera* and *S. litura* only.

5. *A. indica* and *V. negundo* produced high percentages of abnormal pupae in *S. litura*. In *H. armigera* more number of deformed pupae were produced by *A. indica* and *C. gigantea*. In *A. modicella*, all three plants except *P. glabra* produced abnormal pupae. *C. gigantea* and *V. negundo* caused deformed adults in *H. armigera*. Deformed *S. litura* adults were produced only by *V. negundo* treatment.

6. During the field trial studies, all the four plant products proved their efficacy in minimising pest incidence and infestation. *A. indica* treatment significantly reduced *A. modicella* populations in two seasons studied. *A. modicella* infestation was the least in *V. negundo* treated plot in Rabi 1999 and *A. indica* in Kharif 1999 - 2000. *S. litura* infestation was highly controlled by *P. pinnata* treatment in Rabi 1999 and *C. gigantea* in the next year. *A. indica* was found to be the most effective plant product in controlling *H. armigera* incidence and its infestations.

7. Groundnut pod yield, percent avoidable loss and cost-benefit ratio were the highest from *C. gigantea* treated plot in Rabi 1999 and *A. indica* treatment plot in the Kharif season respectively.

8. In kharif 1997, sunflower intercropping system was found to be superior over castor in controlling *A modicella* and *H. armigera* populations and their infestations. In Kharif 1999, castor was found to be the best to control *A. modicella* and *S. litura* incidences. However, the infestations of *A. modicella* and *S. litura* were the least in sunflower and castor intercropped fields respectively.

9. In 1997, high yield of groundnut was obtained from sunflower intercropping system, where as in 1999, castor intercropping system enhanced the groundnut yield. Net gain and cast-benefit ratio was significantly high in castor intercropping system in 1997 and maize intercropping system in 1999.

10. The integration of intercrops and plant products significantly control pest incidence and infestation and enhanced the production and net gain. Soybean and *C. gigantea* combination was found to be the best in reducing *A. modicella* and *S. litura* incidences in Kharif 1998. Castor with *A. indica* and castor + *C. gigantea* combinations were highly effective in controlling *A. modicella* incidence and *S. litura* population respectively in kharif 2000.

11. In Kharif 1998, Groundnut production was the highest in soybean + *P. pinnata* treatment, net gain and cost-benefit ratio were the highest in sunflower + *P. pinnata* treatment. In kharif 2000, maximum groundnut

yield was obtained from the castor + *A. indica* integrated field and the net gain and cost-benefit ratio were also the highest from the same treatment.

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* Originals not referred.

RECOMMENDATIONS

1. Since neem and calotropis were found to be the most effective plants against *A. modicella, H. armigera* and *S. litura*, farmers can use water extracts of these plants to control the above mentioned groundnut pests.

2. Intercrops such as castor, sunflower, maize and soybean could be used as intercrops in groundnut to minimize the pest attack and to increase the profit.

3. To minimize the pest attack and maximize the profits, farmers can integrate the caster either with neem or calotropsis and sunflower with pongamia.

Future areas of research

1. Since the plant products studied here are found to be species specific, mixture of two or more plant extracts should be tested for their bio-efficacy against groundnut pests.

2. The integrated effect of botanicals either with biopesticides or synthetic pesticides should be tested for their efficacy in groundnut pest management.

3. In the present study, the concentration of plant extracts used for field application was 3%. In future, this concentration can be decreased and/or increased and the effect could be tested.

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SCREENING THE RELATIVE TOXICITY OF SOME PLANT EXTRACTS TO SPODOPTERA LITURA FAB. (INSECTA : LEPIDOPTERA : NOCTUIDAE) OF GROUNDNUT

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ABSTRACT

A laboratory study was carried out to evaluate the effect of water extracts of four plant leaves in the phytophagous pest control. Various concentrations, of the extracts (0.5,1,2, 4 and 6%) were used against last instar larvae of **Spodoptera litura** Fabricious. **Calotropis giganta** was found to be the most toxic plant product followed by **Vitex negundo** Linn. **Azadirachta indica** Adr Juss. and **Pongamia glabra**. Use of these plant products, a natural ecofriendly products is suggested in the management of the **S.litura.**

Key Words: *Spodoptera litura*, **groundnut pest, plant products, relative toxicity, LD_{50}**

INTRODUCTION

Increasing use of synthetics lead to serious problems like environmental pollution long term persistence, high toxicity and insect resistance to insecticides. In recent years there has been increasing interest in the use of alternative methods. Several workers have explored the utility of plant products as one of the potential source for managing agricultural pests in search for effective, eco-friendly and economically viable options. Bai and Kandasamy[1] evaluated the effect of acetone/ diethyl ether extracted **Vitex negundo** Linn leaf extracts against the third instar larvae of **S.litura**. Antifeedant action of neem in these larvae has been recently recorded[2]. In the present paper, we report the results of our studies on the relative toxicity of some plant extracts against the last instar larvae of **Spodoptera litura** Fab. It is an important polyphagous pest distributed throughout the world. In recent years this pest has become a major threat to groundnut in India[3]. The neonate larvae which are gregarious in nature feed from under surface of leaves. Heavy defoliation due to grown up larvae results in leaving the bare stem.

* Communication author

MATERIALS AND METHODS

A culture of this pest was maintained in thefs laboratory on field collected groundnut leaves (TMV 7). Ten grams of each of the leaves of **Azadirachta indica** A.Juss, **P.glabra, C.giganta** and **V.negundo** Linn. were washed thoroughly (3-5 times) with tap water and once with distilled water. They were macerated individually in an all-glass pestle and mortar and extracted with small quantity of distilled water. The extract was passed through muslin cloth and the final volume made up to 10 ml and this was treated as stock solution. Different concentrations viz., 0.5, 1,2,4 and 6 per cent were prepared from the stock by adding distilled water. Equal and known amount of groundnut leaves (TMV 7 variety) were dipped in the different concentrations of the different plant extracts for 15 minutes. For control, the leaves were dipped in distilled water only. The leaves were shade dried and were given to the last instar larvae of **S. litura**

Ten laboratory reared last instar larvae were released in the plastic vials and covered with muslim cloth and treated leaves were already kept in the vials. Five replications were made for each treatment along with a set of control. They were exposed continuously for a period of four days and the mortality was recorded at 24, 48, 72 and 96 h following the treatment. The corrected percentage of mortality under various treatments were calculated using Abbott's formula[4]. The data were subjected to probit analysis to calculate LC_{50} and the Fiducial limits[5].

RESULTS AND DISCUSSION

It was clearly understood that **P.glabra** was less toxic and **C.giganta** was more toxic to last instar larvae of **S.litura** (Table I). For instance, in 96 hrs. of exposure, 70.37

TABLE - I

Relative toxicity of four Plant products to **Spodoptera litura** (n = 54)

Plant	Concentra-tions (in %)	Mortality after 96 hrs.	Regression equation	Variance	Chi-square	LD_{50}	Significance
A. indica	0.50	25.92	Y=0.711 x + 3.87	0.0193	0.23	3.898	P<0.05
	1.00	33.33					
	2.00	44.44					
	4.00	48.15					
	6.00	55.55					
C.giganta	0.50	44.44	Y = 0.596 x + 4.50	0.0364	0.31	0.693	P<0.05
	1.00	55.55					
	2.00	62.96					
	4.00	66.66					
	6.00	70.37					
P.glabra	0.50	22.23	Y = 0.801 x + 3.67	0.0182	0.42	4.547	P<0.05
	1.00	29.63					
	2.00	40.74					
	4.00	44.55					
	6.00	53.70					
V.negundo	0.50	37.03	Y = 0.698 x + 4.21	0.0143	0.12	1.332	P<0.05
	1.00	48.15					
	2.00	55.55					
	4.00	62.96					
	6.00	66.86					

per cent mortality was observed at 6 per cent in **C.giganta**, 66.86 per cent mortality in **V.negundo,** 55.55 per cent in **A.indica** and 53.70 per cent in **P.glabra**. From this it was clear that **P.glabra** was the least toxic plant extract and **C.giganta** was nearly 1.3 times more toxic than pongamia plant. This might be due to the presence of cardenolides in calotropis. Cardenolides (C_{22} sterolidic compounds),synthesized by the milk weed family Asclepiadacea for their self defence against herbivores insects,have been ambly documented recently [6-8] and insecticidal activities[10,11] were also documented in this plant. It was also clear that the per centage of mortality was increased both for increased concentrations and also for increased duration of exposure. In 96 hr. duration, the calculated LD_{50} values of **C.giganta, V.negundo, A.indica** and **P.glabra** were 0.693, 1.332, 3.898 and 4.547 per cent, respectively. From this, it was clear the **P.glabra** was the least toxic plant extract to the pest **S.litura**. A treatment of 40 ppm and 50 ppm of **P.glabra** acetone extracts caused 100 and 83.3 per cent mortality in **Aedes** and **Culex** larvae, respectively [12]. In this experiment **P.glabra** caused minimum mortality.

The present results clearly reflect that the plant products could safely be considered as a potential agent for **Spodopetera litura** control. But field investigations are needed before recommending these plant products in the pest management system against **S.litura.**

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Table 2. Ranking of natural enemies (predators) identified by farmers as occurring in sorghum and groundnut fields in Burkina Faso, 1996.

Arthropod predator group	Rank[1]
Spiders	1
Mantids	2
Predacious wasps	3
Ants	4
Earwigs	5

1. Mean ranking by 244 farmers surveyed in five districts.

trained in the appropriate ways of selecting, handling, and applying pesticides. Not only will this help to prevent harmful poisoning, but also contribute to protecting the environment.

For biological programs to be more efficient, and to identify safer alternatives for controlling insect pests, appropriate training is also required to change the perception of farmers and increase their cognitive knowledge of natural enemies.

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Relative Toxicity of Some Plant Extracts to Groundnut Leaf Miner, *Aproaerema modicella* Dev.

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The leaf miner, *Aproaerema modicella* Dev. (Lepidoptera: Gelichiidae) is one of the most important pests of groundnut in south and southeast Asia. In these regions unrestrained application of chemical pesticides for pest control has created several complications. Among the alternative methods of control, use of plant products has proved ecologically sound and effective. Although studies on the role of neem (*Azadirachta indica*) products have been reported on groundnut (Ghewande et al. 1997), no attempt has been made to utilize *Pongamia glabra*, and *Calotropis giganta* effects on *A. modicella*. Hence, the present study was carried out to gain comprehensive information on the relative toxicity of three plant products to the last instar larvae of *A. modicella*.

A culture of *A. modicella* was maintained in the laboratory on field-collected groundnut leaves (cv TMV 7). The plant extracts tested here were prepared according to Nandagopal (1992) and Sahayaraj and Sekar (1996) with slight modifications. Ten grams each of the leaves of *A. indica*, *P. glabra*, and *C. giganta* were washed thoroughly (3-5 times) with tap water and once with distilled water. They were macerated individually in an all-glass pestle and mortar and extracted with a small quantity of distilled water. The extract was passed through muslin cloth and the final volume made up to 10 mL and this was treated as stock solution. Different concentrations (0.5, 1, 2, 4, and 6%), were prepared from the stock by adding distilled water. Equal and known amounts of groundnut leaves (cv TMV 7) were dipped in the different concentrations of the various plant extracts for 15 min. As a control, the leaves were dipped in distilled water only. The leaves were shade dried and were given to the last instar larvae of *A. modicella*.

Ten laboratory-reared last instar larvae were released in the plastic vials with treated leaves and covered with muslin cloth. Five replications were made for each treatment along with a set of controls. They were exposed continuously for a period of 4 days and the mortality was recorded at 24, 48, 72, and 96 h intervals. The corrected percentage of mortality under various treatments was calculated using Abbott's formula (Abbott 1925). The data were subjected to probit analysis to calculate LD_{50} and the fiducial limits (Finney 1971).

The results showed that all three plant extracts tested were toxic to the last instar larvae of *A. modicella*. It was clear that *C. giganta* was a more toxic compound than *P. glabra*. For example, 96 h after exposure, 75%, 72%, and 63% mortalities were observed in *C. giganta*, *A. indica* and *P. glabra*, respectively, with 6% concentration. Schmutterer (1990) and Ghewande et al. (1997) reported that the persistence of toxicity of neem-based products was 12 days. The percentage mortality increased with concentration and also with duration of exposure.

For 96 h exposure, the calculated LD_{50} values of neem were 1.223%, calotropis 2.429%, and pongamia 2.944%. From these LD_{50} and the upper and lower fiducial limit values, it was clear that pongamia was the least toxic plant product to the *A. modicella*. Schmutterer et al. (1983) reported that larval and pupal mortalities of leaf miners were not affected by the neem products (purified neem seed extracts). In contrast, in the present findings, neem leaf extract caused high mortality except in the 6% concentration and LD_{50} value was 1.986 times lower than calotropis and 2.407 times lower than pongamia plant extracts. From this it was clear that *A. indica* was the most toxic plant product followed by *C. giganta* and *P. glabra*. Though *C. giganta* caused higher mortality, its LD_{50} value was moderate. Hence further laboratory investigations are necessary to follow up these findings. Blackening of the body, breaking of cuticle and oozing out of body fluid, small-sized pupae, and death during moulting were the other direct effects observed on treated larvae. Being safer than conventional insecticides, the plant products will fit well in the pest management of groundnut crops.

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Table 1. Effect of three plant extracts on the mortality of the final instar larvae of *Aproaerema modicella*.

Plant	Concentration (%)	Mortality after 96 h (%)	LD_{50}	Regression equation	Variance
Neem	0.50	42	1.223	Y-0.655x+4.29	0.0181
	1.00	48			
	2.00	52			
	4.00	60			
	6.00	72			
Pongamia	0.50	20	2.944	Y=1.073x+3.42	0.0070
	1.00	30			
	2.00	46			
	4.00	54			
	6.00	63			
Calotropis	0.50	5	2.429	Y-1.912x+2.35	0.0033
	1.00	35			
	2.00	45			
	4.00	60			
	6.00	75			

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Screening Groundnut Mutants for Resistance to *Spodoptera litura* and Thrips

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Spodoptera litura (F.) is a polyphagous, foliage-feeding insect distributed throughout south and southeast Asia and Australia. In India, *S. litura* has been reported as an increasingly important pest of groundnut during the rainy season causing yield losses up to 71% in Karnataka and Andhra Pradesh (Amin 1983). Similarly, in the postrainy season, thrips (*Thrips palmi*, *Frankliniella schultzei*, and *Scirtothrips dorsalis*) attain pest status in groundnut as sap feeders or vectors of viruses causing widespread crop losses. Insecticides often fail to give effective control of these pests. The development of resistant groundnut cultivars has been proposed as a potential option for integrated pest management of groundnut in India. Though the research efforts have been successful in identifying the resistant germplasm to *S. litura* (Patil et al. 1991) and thrips (Wightman and Ranga Rao 1994), most of them possess other undesirable features, making them unsuitable for direct utilization. In our laboratory, on artificial mutagenesis with ethyl methane sulphonate (EMS), Dharwad Early Runner (DER) yielded many valencia mutants. On subsequent mutagenesis with EMS, one of these mutants, VL 1, yielded many foliar diseases-resistant mutants (Motagi et al. 1996). Some of these mutants were apparently resistant to *S. litura* and thrips also. In the present study 22 mutants along with parents and controls (Table 1) were systematically screened for damage due to *S. litura* and thrips during the rainy and postrainy seasons of 1996.

Each genotype was sown in a 2-m row with an interrow spacing of 30 cm and intrarow spacing of 10 cm in a randomized block design during the rainy season 1996 for *S. litura* and the 1996 summer for thrips. The experiment was replicated twice and the

Table 1. Screening groundnut mutants for *S. litura* (rainy season) and thrips (postrainy season), University of Agricultural Sciences, Dharwad, Karnataka, India, 1996.

Genotypes	DS[1]	DT[2]	NT[3]
Mutants			
28-1	18.6	21.3	6.4
28-2	12.1	19.2	3.1
45	14.8	22.8	5.3
98-1	28.4	37.0	10.6
110	31.0	27.9	8.9
110-1	27.6	31.3	8.8
172	29.3	15.6	0.9
Parents			
VL 1	40.5	34.7	9.3
DER	46.9	46.1	8.7
Controls			
JL 24	40.6	46.7	13.3
GBFDS 272	29.3	29.7	8.3
Mean (26 genotypes)	36.7	36.3	9.0
SEm	± 3.4	± 5.2	± 1.0
CD 5%	9.6	15.2	3.0
CV (%)	18.6	20.8	16.9

1. DS – Damage due to *S. litura* (%).
2. DT – Damage due to thrips (%).
3. NT – Number of thrips.

Insecticidal Control of Spotted Bollworm, *Earias insulana* (Boisd.) on American Cotton

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Earias spp. are most serious bollworms damaging cotton. The grown up larvae of *E.insulana* were treated with recommended insecticides at their prescribed dosages and fed with the treated buds of *Hirsutum* variety F.846 in glass battery jars. There were three replications/treatment with five larvae/ieplication. Observations were made upto 72 hr daily.

Alfamethrin (Merit Alpha 10 EC), fenvalerate (Sumicidin 20 EC), cypermethrin (Bilcyp 10 EC), chlorpyriphos (Durmet 20 EC) and triazophos (Hostathion 40 EC) @ 250, 250, 500, 5000 and 1500 ml per heactare proved most effective and caused cent per cent mortality 72 hours after spray. Similarly unrecommended mixture Deltamethrin 1% + Triazophos 35% (Spark) also caused 100% mortality of the larvae 72 hours after the spray.

Effect of Neem Leaf Extract on *Amsacta albistriga* Walker

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Efficacy of neem leaf extract was tried in the laboratory against the fifth instar larvae of *Amsacta albistriga* Walker. From a stock solution of neem leaf extract prepared with distilled water, concentrations of 0.5, 1, 2, 4 and 6 per cent were prepared. Known and equal amount of groundnut leaves (TMV-7 variety) were dipped in different concentrations for 15 minutes and shade dried, and fed to *A.albistriga*. Thirty individuals were tested with three replications for each concentration. Leaves dipped in distilled water served as control. After 24 hr the larvae were removed from the treated leaves and were fed with fresh non-treated leaves. Mortality was recorded for every 24 hrs for a period of 96 hrs, and data were subjected to ANOVA.

The results showed that larval mortality increased from the lower concentration to the higher concentration (8.33, 13.33, 23.33, 36.66 and 85.71 for 0.5, 1, 2, 4 and 6 per cent, respectively). The treatments were significantly different from control (P = 0.05) except for 0.5%. Lowest concentrations caused 22.73 per cent pupal mortality. Other concentrations did not affect the pupal stage. Adult emergence ws 30 per cent in control and it decreased from 0.5 (14.11%) to 1 (10.76%) per cent concentrations. Adult did not emerge in other concentrations. The adults from treatments did not lay eggs, so prabably neem extracts affect reproduction, which needs investigation.

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Insect Pests of Kalazira in the Hills of Himachal Pradesh

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High hill dry temperate region (Kinnur dist) of Himachal Pradesh was surveyed during the first week of June, 1996 and 1997 to study the various insect pests attacking Kalazira (Black zira). Gram caterpillar *Helicoverpa armigera* (Hubner) was recorded in a serious form. The mean infestation being 28.1 per cent. Cabbage semi looper *Plusia orichalcea* (Fabricuis) was second most important pest (13%). The other insect pests of Kalazira recorded were red hairy caterpillar, *Spilosoma obliqua* (Walker), bihar hairy caterpillar, *Amsacta morei* (Butler), black aphid, cut worm and white grubs. These observations are in conformity with those of Bhardwaj and Panwar (1990) on Kalazira.

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Occurrence of *Clinteria* sp on of Apple in Himachal Pradesh

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White grub fauna of district Mandi of Himachal Pradesh was surveyed using light traps from May to September, 1997 at Chamanpur. Out of 14 species, adults of *Clinteria* sp. (Cetoninae) was trapped and was found feeding on apple fruits causing severe damage. On an average three beetles were found congregating on fruit and only red fruits were attacked by this beetle. Since apple is the main cash crop of Himachal Pradesh, it is important to develop management practices to control *Clinteria* species in apple orchards.

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TOXICITY OF SOME PLANT EXTRACTS AGAINST LIFE STAGES OF A REDUVIID PREDATOR, *RHYNOCORIS MARGINATUS*

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ABSTRACT

Laboratory experiments were conducted to test the toxic effects of leaf extracts of *Azadirachta indica* A. Juss, *Vitex negundo* Linn., *Pongamia glabra* and *Calotropis giganta* on the life stages of the reduviid predator *Rhynocoris marginatus* Fab. Toxicity of these plant extracts were tested in two ways, such as contact and stomach toxicity. The studies clearly indicated that adults were more sensitive to the tested plant products than the nymphal instars. *P. globra* is more toxic and *C. giganta* is less toxic in nature. Mortality increased with the increase in concentration of plant extracts. No mortality was observed both in adults and nymphal instars of *R. marginatus* when they were subjected to contact toxicity.

Key Words: reduviid predator, groundnut pest, toxicity, plant products

Increasing the use of synthetic pesticides in agriculture leads to serious problems like environmental pollution, health hazards and insect resistance to insecticides. In recent years, an awareness concerning the role of biopesticides in agriculture, public health and human welfare is gaining increasing attention, both at the national and international levels. Plant chemicals mainly affect the insect development and reproduction (Brower, 1985 and Cutler, 1985). Plant products like neem (Ayyangar and Rao, 1989), vitex (Bai and Kandasamy, 1985), calotropis and pongamia (Sahayaraj and Paulraj, 1998) were reported to be potential antifeedants and biopesticide against American armyworm *Spodoptera litura* Fab. The reduviid bug, *Rhynocoris marginatus* (Fab.) is a predator that is common to a wide range of natural and agricultural habitats throughout India (Sahayaraj, 1994). Moreover, this predator is identified as a good biocontrol agent of *S. litura*. No studies have been undertaken on the side-effects of plant products on reduviids. Therefore, the investigations were carried out to study the toxicity of water extracts of neem, vitex, pongamia and calotropis leaves against the life stages of *R. marginatus*. The results emanating from such studies are reported in this contribution.

MATERIALS AND METHODS

Toxicity of 3 per cent water extracts of neem, vitex, pongamia and calotropis leaves were studied on the life stages of *R. marginatus* for 4 days. For this, groundnut leaves variety TMV 7 were dipped in 0.5, 1, 2, 4 and 6 per cent of above said four plant extracts for 15 minutes. Then they were shade dried for 10 minutes. Untreated groundnut leaves were used as control. Contact toxicity of plant extracts was found out on the newly moulted (24 hrs.) nymphal instars and adults of *R. marginatus* collected from stock culture and were placed singly in plastic vials (250 ml capacity). Thirty insects were used for each treatment. Plant extracts treated groundnut leaves were placed in the vials. Nymphal instars and adults were checked for mortality every 24 hrs. for a period of four days continuously. In the second experiment, the botanical treated leaves were provided to the third and fourth instar larvae of *S. litura* for 24 hours and were provided to first, second, third, fourth and fifth nymphal instars and also to the adults of *R. marginatus* in order to find out the stomach toxicity. Observation on the mortality were recorded 24, 48, 72 and 96 hrs. after exposure in all the treatments. Moribund predators were counted as dead.

Results and Discussion

Plant extracts treated *S. litura* did not cause abnormal feeding behaviour in *R. marginatus*. Generally the mortality of *R. marginatus* was found to increase with an enhancement in concentration and time. Present investigation revealed that neem extract treated *S. litura* did not cause any mortality in the nymphal instar of *R. marginatus*. In adults 20 and 33.33 per cent mortality were observed at 4 and 6 per cent neem extracts treated *S. litura* fed *R. marginatus*. No mortality was observed in the calotropis treated *S. litura* fed *R. marginatus* nymphal instars as well as in adults. Cardenolides in a C_{23} steroidic compounds synthesized by the milkweed family Asclepiadacea (Pugalenthi and David, 1997). Cardenolides have bitter taste and induce emesis in predators (Brower, 1970 and Brower, *et. al.*,1972). In 4 per cent vitex treatment, 12.5 and 16.65 per cent mortality were observed in fourth and fifth instars of *R. marginatus,* respectively during 48 hrs. exposure. During the same period the moraltity was higher (25%) in adults predators at 6 per cent treatment. Other concentrations such as, 0.5, 1,2 and 4 per cent did not cause any moraltiy. Among the four treatments, higher mortality (both in nymphal instars and adults) was observed in *R. marginatus* fed with *P. glabra* treated *S. litura* larvae. In nymphal instars, the mortality was higher in first instar (30.0%) and it was gradually diminished when the predator grew older (20, 16.66, 12.22, 3.33 % for second, third, fourth and fifth instars, respectively) at 6 per cent concentration. Other concentrations did not cause any mortality in the nymphal instars. In adult *R. marginatus* except the 0.5 per cent all other concentrations (5.68, 8.33, 11.11 and 33.33% for 1,2,4 and 6 per cent, respectively) causes mortality. No mortality was observed when the predators were exposed to plant extract treated groundnut leaves. De Cock *et. al.*, (1996) reported that the pentatomid predator, *P. maculiventris* may be affected by insecticide spray or contact residue or indirectly by consuming contaminated water. Deformities were not observed in both expermiments. Hence, when plant products ingested via prey larvae, all the plant products tested here were more toxic to *R. marginatus* and the plant products were not active by residual contact. Clercq *et. al.*, (1995); Broadbent and Pree (1984) reported that insecticide diflubenzuron was not toxic in both residual and direct contact on a predatory pentatomid *Podisus macultiventris* (Say) and an assassin bug *Acholla multispinosa* De Geer, respectively.

From this study it is clearly understood that *C. giganta* has least toxicity followed by *A. indica, V. negundo* and *P. glabra* to *R. marginatus* nymphs and adult. Nymphal instars of *R. marginatus* were more susceptible to plant products than adults. Hence, integration of *R. marginatus* nymphal stages immature stages is worthwhile in the IPM of groundnut. More research is needed to verify the results from our laboratory experiments under conditions which are closer to those experienced by the predator in the field.

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Muraleedharan and Ananthakrishnan (1978) also reported *D. maxidentex* as predator of many species of thrips including *H. ganglbauri*. The predator is reported for the first time from Akola, Maharashtra.

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Effect of Plant Products on the Eggs of *Rhynocoris marginatus* Fab. (Hemiptera : Reduviidae)

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The present study was carried out to generate information on the effect of chosen plant leaf extracts on the hatchability and incubation period of the eggs of the predator, *Rhynocoris marginatus* Fab.

Adults of *R. marginatus* were collected from the agroecosystems of Tamil Nadu and maintained in the laboratory on *Spodoptera litura* (Fab.) larvae. Water extracts of *Azadirachta indica* A. Juss., *Vitex negundo* Linn., *Pongamia glabra* Vent. and *Calotropis gigantea* Linn. were prepared. Five concentrations (0.5, 1, 2, 4 and 6 per cent) of each extract were made with water. Freshly laid eggs of *R. marginatus* were dipped and immersed in 1 ml of each concentration separately in a petridish for 15 minutes. Thirty eggs were treated for each concentration and replicated three times. Control was treated with water alone. After the treatment, the eggs were incubated on moist cotton swabs in small plastic vials (30ml capacity) at room temperature (30 ± 2º C). Observations were made daily to record the number of nymphs hatched and time taken for hatching in each concentration separately. From this observation, incubation period (in days) and hatching percentage were calculated. After hatching, the nymphs were reared on *Spodoptera litura* Fab. larvae.

The results revealed that on an average, the incubation period was 7 days for all the concentrations of the plants tested as well as for the control. Plant extracts did not affect the incubation period of this reduviid. All the plant extracts tested here had ovicidal properties and hence the hatching percentage decreased from lower to higher concentrations. Among the four plants tested, *C. gigantea* was found to be the most toxic to the eggs of *R. marginatus* (81.40%) followed by *A. indica* (Table 1). Except in calotropis, the hatchability was higher upto 2 per cent level in *A. indica* and *P. glabra* when compared to the control and this trend was extended upto 4 per cent level in Vitex. Three per cent extract of Vitex has been recommended by

Nandagopal, *et al.* 1995 for IPM in groundnut. The present study showed that this will not affect the hatchability of *R. marginatus* eggs. Hence this predator has potential in the groundnut IPM programme.

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Aphid Preference of a Coccinellid Predator *Menochilus sexmaculatus* Fab.

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Menochilus sexmaculatus Fabricius is an important coccinellid predator of various aphid species in India and abroad. Hence, the preference of *M. sexmaculatus* on two cotton aphids *Aphis gossypii* and *A. nerii* and a cardamom aphid *Pentalonia* sp. was studied.

Adult predators starved for 12 hrs were released separately in petridishes (10 cm dia.) containing 50 freshly collected apterus aphids. Fresh, host leaves were provided as food for aphids. After 1 hr the unconsumed aphids were counted in each set to record the number of aphids consumed and another 50 fresh aphids were provided. The experiment was carried out continuously for 5 hrs. Each treatment was replicated 6 times and the mean number of aphids consumed in each set was calculated.

M. sexmaculatus adult consumed 23.17 ± 3.06, 21.47 ± 4.26 and 31.83 ± 3.06. *A. gossypii, A. nerii* and *Penalonia* sp., respectively in the first hour. The consumption was maximum in the initial hours and it decreased in the later hours for all the three aphids. Maximum consumption was noticed in *Pentalonia* sp followed by *A. gossypii* and *A. nerii* (Table 1). The present findings support the observation of Omkar *et.al* (1997) that ladybird beetles exhibit preference for certain aphid species.

is the right time to exploit the pathogen under field conditions to strengthen the existing effective ecofriendly pest management strategies. Apart from this pathogen, use of botanicals, parasitoids, and predators to contain the defoliation by less than 10% damage in 60-day-old crop had no effect on the pod yield. Preliminary confined studies of the fungal pathogenicity against *S. litura* conducted at the Regional Research Station, Vridhachalam, Tamil Nadu, India revealed that the third instar larval mummification was due to the infection on the fifth day after spraying with *N. rileyi* at a concentration of 1×10^8 spores mL^{-1}. Assessment on the dynamics of conidial dispersal and density within the groundnut crop ecosystem at field level is in progress.

In future, studies at the field level on the utilization of naturally occurring fungal pathogens such as *Beauvaria bassiana* (white muscardine fungus) and *N. rileyi* (green muscardine fungus) to contain the groundnut defoliators without any reduction in pod yield will be an accessible ecofriendly pest management strategy for sustainable groundnut cultivation.

Impact of Some Plant Products on the Behavior of *Tribolium castaneum* in Groundnut Seed

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Groundnut (*Arachis hypogaea*) is stored both as pods and seeds. Both forms are susceptible during storage to attack by insects, which cause approximately 6–10% damage in stored seed (Srivastava 1970). The red flour beetle, *Tribolium castaneum* Herbst is one of the most important pests of stored groundnut seeds (Wightman and Ranga Rao 1993). As groundnut is used for human food, the use of insecticides against this stored product pest may represent a health hazard. Use of plant-derived pesticides to manage stored product pests is a traditional method that is environmentally safe and economically viable alternative method. *Azadirachta indica* (neem) has been found to affect more than 200 insect pests (Warthen 1989, National Research Council 1992) including several stored product pests (Jacobson 1988). In the present study, the leaf extracts of *A. indica, Vitex negundo, Calotropis gigantea,* and bulb extract of *Allium cepa* (onion) were evaluated for their repellent and insecticidal properties on the adults of *T. castaneum* in groundnut seeds.

The leaf extracts of *A. indica, V. negundo,* and *C. gigantea* and bulb extract of *A. cepa* were prepared according to Sahayaraj (1998). Ten grams each of the leaves and bulbs were macerated individually in pestle and mortar and extracted with 10 mL of water. The extract was passed through muslin cloth and the final volume made up to 100 mL to get 10% extracts. It was treated as a stock solution. From the stock solution 5 different concentrations, 0.5, 1.0, 2.0, 4.0, and 6.0% were made with required quantity of water. Groundnut seeds (5 g) were dipped in different concentrations separately for 15 min and air dried for 10 min.

In control, the groundnut seeds were dipped in water only. A glass olfactometer was used to find the repellent properties of the plant extracts against *T. castaneum*. An olfactometer consists of a middle glass chamber (60 mm diameter) from which 6 equally spaced tubes (20 cm length and 2.5 cm diameter) project outwards. The middle chamber has an opening of 2.5 cm diameter. The distal end of each arm is attached with a glass beaker (7 cm diameter and 9 cm height). The repellent property of the plants was tested by choice test. Ten-day-old *T. castaneum* adults were collected from the culture medium maintained in the laboratory and used for this study. Groundnut treated with different concentrations of the plant extracts were placed separately in the beaker attached in each arm. Then they were closed with muslin cloth. Sixty *T. castaneum* adults were introduced into the olfactometer through the opening present in the middle chamber and closed with muslin cloth and allowed for 3 h. After 3 h, the number of beetles present in each concentration was recorded. From the observed value the repellence was observed and defined in terms of excess proportion index (EPI) according to Sakuma and Fukami (1985). Each experiment was replicated six times with different insects and also groundnut seeds treated with plant extracts. The EPI is defined as follows:

$$EPI = NS - NC / NS + NC$$

where NS = number of animals in the sample side and NC = number of animals in the control side. In another experiment, ten adults were placed in a plastic container (250 ml capacity) and provided with 1 g of groundnut seed treated with different concentrations of each plant extract separately. Control categories were provided with water treated groundnut seeds. Mortality was recorded in all the categories for every 24 h up to 7 days. Six replications were maintained in each category.

EPI values ranged from +1 to −1. These terms simply express polarity of the directional choice. Positive and negative values indicated positive and negative approaches respectively. The results of the experiment are summarized

Table 1. Impact of plant products on the excess proportion index (EPI) behavior of *Tribolium castaneum.*

Plant	EPI				
	0.5[1]	1	2	4	6
Azadirachta indica	−0.616	−0.813	−0.881	−0.953	−1.000
Vitex negundo	−0.382	−0.601	−0.739	−0.893	−0.933
Allium cepa	−0.319	−0.470	−0.675	−0.783	−0.900
Calotropis gigantea	−0.084	−0.225	−0.406	−0.507	−0.628

1. Concentration (%) of plant product.

in Table 1 which shows that the insect avoided feeding on groundnut seed sprayed with *A. indica*, *V. negundo*, *A. cepa*, and *C. gigantea*. The results clearly indicated that *A. indica* was the most effective repellent for *T. castaneum* followed by *V. negundo*, *A. cepa*, and *C. gigantea*. The EPI values for all the plant products used in this study showed negative values. Senguttuvan et al. (1995) reported that neem and *Vitex* leaf powders were most effective to control *Corcyra cephalonica* Stainton in stored groundnuts.

In the present investigation, the repellence increased as the concentration increased. Sain and Meloan (1986) reported that powder of *Laurus nobilis* leaves acted as a repellent to *T. castaneum*. However, the mortality experiments indicated that all the four plants tested here did not cause any mortality on *T. castaneum* during the observed period. It is concluded that all the plants tested in this study have repellent property against *T. castaneum* and could be used to protect the stored groundnut seeds from *T. castaneum* damage.

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Impact of *Tridax procumbens* Leaf Extract on *Spodoptera litura* Fab. Behaviour, Development and Juvenometry

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The tobacco army worm, *Spodoptera litura* Fab. is a serious pest of many cultivated crops. In the present study, crude leaf extract of *Tridax procumbens* was tried against fourth instar larvae of *S. litura*.

Ten grams of *T. procumbens* leaves were weighed, crushed in a mortar and pestle and extracted with small quantity of water. This extract served as stock solution. From this stock, different concentrations *viz.*, 0.5, 1, 2, 4 and 6 per cent were prepared with required quantity of water. Known and equal amount of groundnut leaves (TMV - 7 variety) (10 g) were dipped in different concentrations for 15 minutes separately and shade dried and fed to fourth instar *S. litura* larvae for a day. Thirty individuals were tested with three replications for each concentration. Leaves dipped in water served as control. After 24 hr. the larvae were removed from the treated groundnut leaves and were fed with fresh non-treated leaves. Larval and pupal mortality, deformities in pupal and adult stages were recorded. The behavioural bioassay experiment was conducted by choice experiment using olfactometers to find out Excess Proportion Index (EPI). The EPI was calculated by using the following formula.

EPI=No. of animals in sample (NS) - No. of animals in control (NC) / NS+NC

The results showed that the repellency increased as the concentration of plant extract increased. The minus values indicated the repellency. From 0.5 to 2.0 per cent extracts the repellency gradually increased (-0.09, -0.11 and -0.77, respectively) and at 4 and 6 per cents the EPI value neither increased nor decreased (-0.77). Four and six per cent extracts affected the pest at larval stage and showed 10 per cent larval mortality each. Lower concentrations (0.5 and 2 per cents) caused mortality at larval-pupal intermediate stage. Percentage of adult emergence was lower in 4 per cent (50 per cent) followed by 0.5 per cent (80 per cent) and higher in 1, 2 and 6 per cent concentrations (100 per cent). The larval period of the treated *S. litura* larva increased gradually from lower to higher concentrations except 4 per cent and it was calculated as 17.60, 17.87, 18.50, 17.50 and 19.00 days for 0.5, 1, 2, 4 and 6 per cent concentrations, respectively. In control, the larval period lasted for 17.50 days. Both the pupal (vestigial thoracic legs and presence of more space between abdominal segments, defective moulting and oozing out of haemolymph for 2, 4 and 6 per cent, respectively) and adult stage (curved and poorly developed wings and small body size for 4 and 6 per cent, respectively) showed deformities.

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Well Marked Sexual Dimorphism in a Ladybird Beetle *Micraspis discolor* (Fabricius) (Coccinellidae: Coleoptera)

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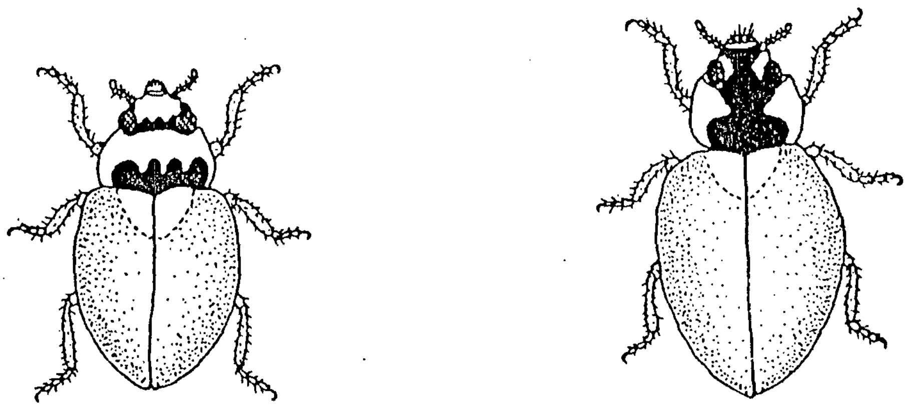
For mass rearing of coccinellids, the identification of sexes is a prerequisite. Careful observation of the ladybeetles under stereoscopic binocular (WILD stereoscopic binocular) revealed that there exists well marked distinctive features on the head of the beetle, *Micraspis* (= *Verania*) *discolor*. The anterior portion of the black coloured head of the male possesses a well marked creamish white crown which is serrated from the distal end of the head. This feature is so prominent that it can be easily noticed by the naked eyes (Figure-a). Female, in contrast, does not possess the serrated crown, instead two distinct tiny, triangular creamish white spots are present on the head (Figure-b).



(a) (b)

In addition, the two sexes can also be easily distinguished by noticing the wavy black patches over their creamish white pronotum. In the female beetle, the patch extends all along the mid dorsal line from proximal to distal end of the pronotum. This thick wavy patch has a bulging appearance toward the distal end of the pronotum. The wavy patch is constricted mid-dorsally and again it spread apart to reach the two proximal-lateral ends of the pronotum. In contrast to female, there is a black patch along the distal end of creamish white pronotum in the male beetle. This patch extends proximally somewhere upto the middle of antero-posterior length and ends proximally by wavy margin. Males of *M. discolor* are usually smaller than the females. The mean size of normal male beetle is 4.0 mm in length and 3.1 mm in width, whereas in the females the mean normal length is 4.5 mm and the width is 3.6 mm.