INTEGRATED PEST MANAGEMENT IN GRAIN AND VEGETABLE COWPEA
Vigna unguiculata (L.) Walp.

BY

SUJA G.

THESIS
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2003

Dedicated

to my

Beloved Father

DECLARATION

I hereby declare that this thesis entitled **"Integrated pest management in grain and vegetable cowpea *Vigna unguiculata* (L.) Walp."** is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title of any other University or Society.

SUJA G.

Vellayani,
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CERTIFICATE

Certified that this thesis entitled **"Integrated pest management in grain and vegetable cowpea *Vigna unguiculata* (L.) Walp."** is a record of research work done independently by **Mrs. Suja G.** under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to her.

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INTRODUCTION

Cowpea, *Vigna unguiculata* (L) Walp. is a nutritionally important food legume crop in the production system of Semi Arid Tropics, and widely grown throughout the tropics. Besides being a very rich source of protein, cowpea maintains soil fertility through biological nitrogen fixation and plays a vital role in sustainable agriculture by bacteria prevalent in root nodules.

India is the highest producer of cowpea in the world and it is the most widely grown pulse crop in Kerala. This accounts for about 75% of the total area under pulses in the state and is cultivated throughout the year as pure crop or in rice fallows and in garden lands. Its productivity is limited by a complex of interacting biotic and abiotic factors. Among the biotic stresses, insect pests are known to be the prime constraint in cowpea production.

The crop is damaged intensively by a large number of insect pests at various stages of its growth (Saxena, 1971, Raheja, 1973. and Faleiro and singh, 1985). The most damaging are those that occur during flowering and pod formation stages. Although all-round efforts are being made to realize its potential yield, attack by insects attribute to losses in yield ranging from 66 to 100 per cent (Litsinger *et al.*, 1978) and therefore makes its production non profitable.

Pest problems on cowpea persist at least in part, because of a lack of diversity in research interest in the control of these pests. To tackle these pests, farmers often resort to frequent and massive application of insecticides even in pod bearing stage which often results in persistence of pesticide residues in the harvested pods and grains and thereby making it unfit for consumption.

The chemical pesticides will still continue to be the tool of Indian farmers in pest control strategies. While selecting chemicals for use in cowpea, the selectivity in action, biodegradability, persistence and toxicity to beneficial organisms will have to be considered. There is also an urgent need for research and development of ecofriendly and biorational insecticides for pest control in cowpea.

The pest status in cowpea is related to its interaction with abiotic factors like temperature, humidity, rainfall and sunshine hours and biotic factors like natural enemies. An economic and environmentally sound pest management strategy involving the use of different pest control tactics is required against major pests of cowpea. This will reduce the pesticide contamination and other environmental hazards.

Though there are many reports on pests and natural enemy status of vegetable cowpea, the same is very meagre in dual-purpose cowpea varieties like Kanakamani, Krishnamony, Pournamy *etc.* cultivated in rice fallows of Thiruvananthapuram, Alappuzha and Palakkad districts of Kerala.

Hence, the investigations were taken up with the following objectives.

1. To survey the incidence of pests, their associated natural enemies and plant protection measures adopted by farmers in major cowpea growing tracts of Kerala.
2. To asses the efficacy of potential predators in controlling cowpea pests
3. To asses the toxicity of the biorational synthetic chemical and botanical pesticides on the potential predators of cowpea pests.
4. To evaluate the effect of synthetic chemical and botanical pesticides on the pests of cowpea and their associated natural enemies in the field to identify the most effective one to be selected as a component in the IPM programme.
5. To evaluate the effect of synthetic chemical and botanical pesticide application in the field on the incidence of pests in cowpea during storage.
6. To evaluate the effect of various field treatments on the incidence of pests of grains in storage and
7. To test the IPM package in cowpea through farmers' participation in their fields.

REVIEW OF LITERATURE

2. REVIEW OF LITERATURE

The cowpea crop is damaged by a large number of insect pests at various stages of its growth, the most damaging of all being the post flowering pests. The pests associated with cowpea and their natural enemies are listed below.

2.1. Pests of cowpea

Common name and family	Scientific name	Citation/ Reference
Pea aphid (Aphididae)	*Aphis craccivora* Koch.	Lefroy (1909)
Pea stemfly (Agromyzidae)	*Ophiomyia phaseoli*Tryon	Ayyar (1963)
Pod fly (Agromyzidae)	*Melanagromyza obtusa* M.	Ayyar (1963)
Leaf roller (Pyralidae)	*Nacoleia vulgalis* Guen.	Mammen and Joseph (1975)
Hairy caterpillar (Arctidae)	*Amsacta albistriga* Walker.	Lefroy (1909)
	Amsacta. moorei Butler.	Lefroy (1909)
	Amsacta. lineola Fabricius.	Lefroy (1909)
	Amsacta. lactinea Cramer.	Srivastava and Singh (1976)
	Pericallia ricini Fb.	Nair (1995)
Bihar hairy caterpillar (Arctidae)	*Spilosoma obliqua* (Walker).	Srivastava and Singh (1976)
Hairy caterpillar (Lymantridae)	*Euproctis fraterna* Mulsant.	Nayar *et al.* (1982)
Bihar hairy caterpillar (Lymantridae)	*Pothesia seintillans* (Walker)	Nayar *et al.* (1982)
Crab caterpillar (Notodontidae)	*Stauropus altermus* W.	Lefroy (1909)

Common name and family	Scientific name	Citation/ Reference
Green caterpillar (Noctuidae)	*Anticarsia irrorata* FB. *Polyoreycta hemirthoda* W.	Nayar *et al.* (1982) Subba Rao *et al.* (1974)
Green semilooper (Noctuidae)	*Mocis frugalis* Fabricius. *Spodoptera litura* (Fabricius) *Spodoptera. exigua* Hubner	Nayar *et al.*(1982) Lefroy (1909) Shri Ram *et al.*(1984)
Leaf miner (Agromyzidae)	*Phytomyza horticola* Goureau.	Nair (1995)
American serpentine leaf miner (Agromyzidae)	*Liriomyza trifolii* Burges.	Spencer (1973)
Lab lab miner (Cosmopterygidae)	*Cosmopteryx phaeogastra* Meyr.	Nair (1995)
Epilachna beetle (Coccinellidae)	*Henisepilachna vigintioctopunctata* Fb. *E.dodecastigma Wied.*Mulsant. *Aphidenta misera*	Srivastava and Katiyar (1972)
Foliage thrips (Thripidae)	*Megaleurothrips distalis* Karrny	Gupta and Singh (1981)
Flower thrips (Thripidae)	*Megaleurothrips sjostedti* Trybom.	Fletcher and Bainbrigge (1914)
Flower beetle (Meloidae)	*Mylabris pustulata* Thunberg.	Lefroy (1909)
Pod bugs (Coreidae)	*Riptortus pedestris* Fb. *Riptortus. linearis* Fb.	Lefroy (1909) Gupta and Singh (1981)
Pod bugs (Coreidae)	*Clavigralla gibbosa* S. *Clavigralla tomentosicollis* Stal. *Clavigralla horrens* D.	Lefroy (1909)
Lab lab bug (Pentatomidae)	*Coptosoma cribraria* Fb.	Gupta and Singh (1981)
Leaf hopper (Cicadellidae)	*Empoasca kerri* Pruthi	Nair (1995)
White fly (Aleyrodidae)	*Bemisia tabaci* (Gennadius)	Nair (1995)
Green shield bug (Pentatomidae)	*Nezara viridula* (Linnaeus)	Mathew *et al.* (1971)

Common name and family	Scientific name	Citation/ Reference
Cowbug (Membracidae)	*Anchon pilosum* W.	Nair (1978)
Pod fly (Agromyzidae)	*Melanagromyza obtusa* M.	Nair (1978)
Pod borer (Noctuidae)	*Adisura atkinsoni* M.	Lefroy (1909)
Pod caterpillar (Lycaenidae)	*Lampides boeticus* Linn.	Lefroy (1909)
Pod caterpillar (Noctuidae)	*Helicoverpa armigera* (Hb.)	Lefroy (1909)
Spotted pod borer (Pyralidae)	*Maruca vitrata* Guen.	Lefroy (1909)
Spiny pod borer (Pyralidae)	*Etiella zinckenella* Teit.	Lefroy (1909)
Plume moth (Pterophoridae)	*Exelastes atamosa* W.	Lefroy (1909)
Wax scale Coccidae)	*Ceroplastodes cajani* M.	Nair (1978)
Sphingid caterpillar (Sphingidae)	*Acherontia styx* W. *Herse convolvuli* Linn.	Nair (1978)
Mite (Tarsonemidae)	*Polyphagotarsonemus latus*(Banks)	Nair (1999)

2.2.Natural enemies associated with the pests of cowpea

Natural enemy and family	Pest	Stage of the pest	Citation
Parasites			
Musca domestica f.*callara* (Muscidae)	*M. vitrata*	larva	Taylor (1967)
Pseudoperichaeta laevis (Tachinidae)	*M. vitrata*	larva	Usua and Singh 1978, Ezuch (1991)

Natural enemy and family	Pest	Stage of the pest	Citation
Thelaitrodoms palposum (Tachinidae)	*M. vitrata*	larva	Usua (1975)
Apanteles sp. (Braconidae)	*M.vitrata*	larva	Okeyo-owuor *et al.* (1991)
Bracon sp. (Braconidae)	*M. vitrata*	larva, pupa	Okeyo-owuor *et al.* (1991)
Braunesia sp. (Braconidae)	*M. vitrata*	larva	Taylor (1967)
Chelonus sp. (Braconidae)	*M. vitrata*	larva	Okeya-owuor *et al.* (1991)
Phanerotoma sp. (Braconidae)	*M. vitrata*	larva	Taylor (1967)
Antrocephalus sp. (Chalcididae)	*M. vitrata*	pupa	Okeya-owuor *et al.*(1991)
Brachymeria sp. (Chalcididae)	*M. vitrata*	pupa	Adango (1994)
Tetrastichus sp. (Eulophidae)	*M. vitrata*	larva	Usua (1975)
Tetrastichus sesamiae (Eulophidae)	*M. vitrata*	pupa	Okeya-owuor *et al.*(1991)
Compoletis chloridae (Uchida) (Ichneumonidae)	*H. armigera*	larva	Divakar and Pawar (1982)
Eriborus sp. (Ichneumonidae)	*H. armigera*	larva	Divakar and Pawar (1982)
Bracon hebator (Braconidae)	*H. armigera*	larva	Divakar and Pawar (1982)
Bracon greeni (Braconidae)	*H. armigera*	larva	Divakar and Pawar (1982)
Apanteles sp. (Braconidae)	*H. armigera*	larva	Divakar and Pawar (1982)
Peresierola sp. (Bethylidae)	*H. armigera*	larva	Divakar and Pawar (1982)
Trichogramma chilonis (Ishii) (Trichogrammatidae)	*H. armigera*	egg	Divakar and Pawar (1982

Natural enemy and family	Pest	Stage of the pest	Citation
Eucarcelia illota. (Tachinidae)	*H. armigera*	larva	Divakar and Pawar (1982)
Palexorista laxa (Tachinidae)	*H. armigera*	larva	Divakar and Pawar (1982)
Goniopthalmus halli (Mensil) (Tachinidae)	*H. armigera*	larva	Divakar and Pawar (1982)
Microplitis sp. (Braconidae)	*H. armigera*	larva	Fang *et al.* (1984)
Chelonus blackburni (Braconidae)	*H. armigera*	egg, larva	Ragadhamaiah *et al.* (1984)
Argyrophylax nigritibialis (Tachinidae)	*H. armigera*	larva	Bindu (1997)
Hemiptarsensus semialbiclava. (Eulophidae)	*L. trifolii*	larva	Nuenschwander *et al.* (1987)
Chrysonotomyia formosa (Eulophidae)	*L. trifolii*	larva	Nuenschwander *et al.* (1987)
Ceranisus menes (Eulophidae)	*M. sjostedti*	larva	Tamo *et al.* (1993)
Megaphragma sp. (Trichogrammatidae)	*M. sjostedti*	egg	Tamo *et al.* (1993)
Oligosita sp. (Trichogrammatidae)	*M. sjostedti*	egg	Tamo *et al.* (1993)
Chrysocharis johnsoni. (Eulophidae)	epilachna beetle	larva, pupa	Subba Rao (1957)
Fusarium Pallidoroseum Cooke Sacc.	*A.craccivora*	nymphs, adults	Hareendranath *et al.* (1987)
Predators			
Menochilus sexmaculatus F. *(Chilomenes sexmaculata)* Coccinellidae)	*A.craccivora*	nymphs, adults	Lefroy (1909)
Chilomenes vicina (Coccinellidae)	*A. craccivora*	nymphs adults	Ofuya (1986)
Coccinella transversalis F. (Coccinellidae)	*A. craccivora*	nymphs, adults	Patro and Sontakke (1994)

Natural enemy and family	Pest	Stage of the pest	Citation
C. septempunctata (Linnaeus) (Coccinellidae)	*A. craccivora*	nymphs, adults	Lal and Singh (1947)
Coccinella repanda *Coccinella* sp. (Coccinellidae)	*A. craccivora*	nymphs adults	Saharia (1980) Falerio *et al.* (1990)
Scymnus quadrillum . (Coccinellidae)	*A. craccivora*	nymphs adults	Kapur (1942)
S. xerampelinus . (Coccinellidae)	*A. craccivora*	nymphs adults	Lefroy (1909)
S. nubilis. (Coccinellidae)	*A. craccivora*	nymphs adults	Kapur (1942)
S. gracilis (Coccinellidae)	*A. craccivora*	nymphs adults	Kapur (1942)
Brumus suturalis F. (Coccinellidae)	*A. craccivora*	nymphs adults	Kapur (1942)
Brumus sp. (Coccinellidae)	*A. craccivora*	nymphs adults	Khan and Hussain (1965)
Micraspis discolor. (Coccinellidae)	*A. craccivora*	nymphs adults	Agarwala *et al.* (1983)
Micraspis crocea (Mulsant) (Coccinellidae)	*A. craccivora*	nymphs adults	Rani(1995)
Rodolia cardinalis (Coccinellidae)	*A. craccivora*	nymphs adults	Subramanian (1923)
Adonia variegate (Coccinellidae)	*A. craccivora*	nymphs adults	Kapur (1942)
Ischiodon scutellare (*Xanthogramma scutellare*). (Syrphidae)	*A. craccivora*	nymphs adults	Deoras (1942)
Chrysoperla carnea (Chrysopidae)	*A. craccivora*	nymphs adults	Narasimhan (1991)
Chrysopa scelestes (Chrysopidae)	*H.armigera*	larva adults	El- dakroury *et al.* (1979)
Peaderus forcipes (Staphylinidae)	*A.craccivora* *S. litura*	adults larva	Komala Devi *et al.* (2001)
Dicyphus tamaninii	*L.trifolii*	larva	Salamero *et al.* (1987)

(Miridae)

Natural enemy and family	Pest	Stage of the pest	Citation
Polyspitota aeruginosa (Mantidae)	*M. vitrata*	adult	Usua (1975)
Spodromantis lineola (Mantidae)	*M. vitrata*	adult	Usua (1975)
Camponotus sericius	*M. vitrata*	larva	Usua (1975)
C. rutoglaucus (Formicidae)	*M. vitrata*	larva	Okeya- owuor et al. (1991)

2.3 Seasonal incidence of cowpea pests and their associated natural enemies

Sitaraman (1966) reported the highest incidence of *X. scutellare* during November to March and April and a lower population during December to February. Mathew *et al.* (1971) reported the pea aphid *A. craccivora* as a serious pest of cowpea in Kerala during dry periods. They observed high population of *A. craccivora* and its coccinellid predators during September to April and a strong correlation between aphids and predatory groups like coccinellids, syrphids and haemerobids. A positive correlation of the population of coccinellid predators of *A. craccivora* with maximum and minimum temperatures and sunshine hours and a negative correlation with relative humidity and rain fall were reported by Upadhyay *et al.* (1980). Butani and Bharodia (1984) and Patel *et al.* (1986) observed a positive correlation between aphid population and population of active stages of their coccinellid predators. The build up of *C. septempunctata* was positively correlated with temperature and morning humidity, whereas *M. sexmaculatus* was negatively correlated with temperature and afternoon humidity. High temperature and low relative humidity in March to April favoured the development of coccinellids and suppressed the rise in aphid numbers, whereas the reverse condition favoured the multiplication of aphids in cowpea (Kalushkov *et al.*, 1990). In cowpea, the population of *A. craccivora* during summer (March – May) and kharif (August – October) seasons increased rapidly with crop growth and their peaks coincided with pod formation stage, and the predator ratio also reached higher value during the peak pod formation stage and at the time of harvest (Srikanth and Lakkundi, 1990). They also reported that among the predatory coccinellids, *M. sexmaculatus* constituted 77-88 and 83-95 per cent of the total predatory fauna in two seasons, respectively and was found to be active from March to November on different crops and hibernated as adults from December to February.

Sharma and Yadav (1994) opined that the natural population of both *A. craccivora* and its coccinellid predators reacted sharply to changing weather factors *viz.* temperature and relative humidity and it accounted for a wide fluctuation in aphid population from 31.55 to as high as 99.96 per cent depending upon the crop type. The population of the coccinellid predator *M. sexmaculatus* in pigeon pea peaked in early September in Andhra Pradesh (Duffield, 1995). Rani (1995) observed a pest dependant increase in the predators of aphids *viz.*, *Chilomenes sexmaculata* and *X. scutellare* in cowpea and glyricidia. An increase in temperature from 18 to 36^{0}C resulted in faster development of the predators *C. transversalis* and

M. sexmaculatus by reducing the duration of egg, larval and pupal stage at high temperatures (Veeravel and Bhaskaran, 1996).

The number of the coccinellid predator *Brumus sp.* increased per unit area as daily temperature increased in summer, whereas spider fauna was significantly affected by maximum, minimum temperature and sunshine hours (Faleiro *et al.*, 1990).

Temperature and relative humidity were found to have great impact on the prey consumption rate by the predator *C. carnea* in cowpea (Zaki, 1987).

In a field study conducted by Alghali (1993) in Nigeria, three peaks in population were observed for *M. vitrata* in two cowpea varieties. Small peaks on crop planted between May and June and again between June and July and a larger peak on those planted between August and September. These two peaks coincided with peak in rainfall, the distribution of which over time was more crucial and hence an adjustment of planting dates is suggested as an IPM tactic against *M. vitrata*.

The pre copulation, oviposition, post oviposition and incubation periods of *C. transversalis* were higher in cooler January than in February and March, whereas fecundity and per cent hatchability were higher during March. Larval duration and longevity of adults were also higher in January than in February and March (Rai and Singh, 2001).

2.4 Efficiency of potential predators on cowpea pests

2.4.1 Coccinellids

M. sexmaculatus was found to be the most abundant and persistent predator of *A. craccivora* because of its short life cycle, larger population and fairly high feeding potential (Saharia, 1980). Rani (1995) and Bindu (1997) indicated the presence of the coccinellid predators *viz. M. sexmaculatus*, *C. septempunctata*, *Scymnus* spp. and *Micraspis crocea* on *A. craccivora* infesting cowpea. Nandakumar and Sheela (1996) reported the presence of nine species of arthropods preying on the cowpea pest *A. craccivora*, of which *M. sexmaculatus* was the most abundant and efficient one. The most abundant and efficient predators of *A. craccivora* included the coccinellids *viz. C. septempuctata*, *M. sexmaculatus* and the others were *Coccinella* sp. and *M. discolor* (Sharma, 1991 and Agarwala and Bardhanroy, 1999).

The coccinellids vary in their feeding capacities both in adult and larval stages. The coccinellid *M. sexmaculatus* developed faster when fed on *A. craccivora* on cowpeas and fecundity of the predator was also greater when fed on *A. craccivora* (Rao *et al*., 1997). But, Bhadauria *et al*. (2001) revealed that *A. nerii* was the most suitable host and fecundity was higher when fed on adult than nymphs. Under laboratory conditions, the coccinellid predator *C. vicina* consumed large number of early instars of *A. craccivora* than later instars and the feeding rates were found to have a significant positive correlation with the population density of the prey.

Various authors have reported the feeding potential of grubs and adults of *M. sexmaculatus*. According to Lefroy (1909), the total consumption of aphids by a single larva of *M. sexmaculatus* during its life time was 2400, whereas Begal and Trehan (1949) found it to be 303 and that the maximum number of aphids consumed by a pair of *M. sexmaculatus* was 16,321 during their life time with an average of 60.84 aphids per adult per day. The per day consumption of aphids by *M. sexmaculatus* was observed to be 272 by Jacob (1963). The feeding potential of the first, second and third instar larvae of *M. sexmaculatus* were recorded as 7.11, 38.44 and 70.78, respectively and the adults reared out in the laboratory consumed 27.22 aphids per day, a total of 906.7 aphids during its life time, while those reared out from pupae collected from the field consumed 92.35 aphids per day and 5611 during its life time (Devi, 1967). In a laboratory experiment, Haque and Islam (1978) observed the per day consumption of a single pair of *M. sexmaculatus* on *A. craccivora* to be ranging between 23.1 and 91.7. The average daily consumption of *M. sexmaculatus* grub was 8.50 *A. craccivora* adults and 73.52 nymphs, whereas the adult predator fed on 24.34 adults and 176.15 nymphs (Lokhande and Mohan, 1990). The grubs of *M. sexmaculatus* consumed 9 to 13 adults of *A. craccivora* on the first day after hatching, 53.05±0.93 (52.12 to 53.98) in the second day, and after eighth day, the consumption fell down sharply and the average consumption during entire life stage was 270 to 367 aphids (Das, 1991). The Larvae of *M. sexmaculatus* consumed 598.5±45.8 aphids in their lifetime and a female consumed 277.1±41.5 aphids per day compared with 208.2±21.1 aphids per day by a male (Verma *et al.*, 1993). The predatory larvae of *M. sexmaculatus* consumed on an average 3840 bean aphids per week and 96 to 100 per cent control was obtained in three weeks out of a total of 450 to 500 aphids per plant (Ahmad and Sardar, 1994). The mean number of aphids consumed by first, second and third instar larvae of *M. sexmaculatus* were 8.10, 22.50 and 56.18, respectively and total consumption during entire larval period was 86.78 aphids, *A. craccivora* (Rani, 1995). She also reported that the adults lived up to 31 days and consumed 748.9 aphids during its lifetime. Nandakumar (1999) observed the life cycle of *M. sexmaculatus* to be 15.35 days and that the grubs and adults consumed an average of 184 and 824 aphids, respectively. The per day consumption of *A. craccivora* by an adult beetle of *M. sexmaculatus* was reported to be 41.3 (Joshi *et al.*, 1999) and 31.30 ±3.48 (Das and Premsagar, 2001).

Various reports regarding the feeding potential of grubs and adults of *Coccinella* spp. are presented. The total consumption of aphids by a single larva of *C. septempunctata* during its lifetime was 420 and the maximum number of aphids consumed by a pair of adult beetles was 22,574 with an average of 106.29 aphids per adult per day (Lefroy, 1909). Comparatively higher feeding rate on *A. craccivora* was reported in the grubs of *C. septempunctata* by Talati and Bhutani (1979) which may be attributed to the size as well as nutritive status of the prey species. The predatory efficiency of *C. transversalis* on *A. craccivora* indicated that the consumption increased with the instars and reached a maximum in the final (fourth) instar and the total number of aphids consumed by a single larva varied from 401 to 736 (Debaraj and Singh,1990). The first to fourth instar larvae and adult male and female of *C. septempunctata* consumed an average of 22.78, 66.00, 72.50, 333.11, 119.80 and 140.68 *Lipaphis erysimi* Kalt. aphids, respectively (Singh and Singh, 1994). The per day consumption of *A. craccivora* by *C. septempunctata* and *C. repanda* were reported to be 42.9 and 40.6 (Joshi *et al.*, 1999) and 39.75± 5.22 and 26.97± 4.52 (Das and Premsagar, 2001), respectively.

The first to fourth instar larvae and adult male and female *Hippodamia variegata* Goeze. was reported to consume 21.83, 79.11, 162.95, 243.01, 91.56 and 115.30 aphids, *L. erysimi* per day (Singh and Singh, 1994) . The grub of *S. nubilis* consumed 50 to 63 aphids during a larval period of 8 to 11 days, whereas the beetle consumed 6 to 11 aphids per day. However, a single grub of *Scymnus* sp. consumed 139.8±11.25 *A. craccivora* during its development (Patro and Behera, 1992). *Aphis gossypii* Glover and *A. craccivora* were the most preferred ones among nine aphid species for *M. discolor* on the basis of the number of adult aphids consumed by 12 hour starved adult female (Omkar and Ahmed Pervez, 2001).

2.4.2 Syrphids

Variation in feeding potential of syrphids was reported by several workers. Lefroy (1909) reported about 67 species of syrphids in India that fed exclusively on aphids. A single syrphid larva destroyed about 484 aphids in four hours (Deoras, 1942) whereas, a single larva of the predator *X. scutellare* required on an average 123 *A. craccivora* per day (Sitaraman, 1966). The maggot of *X. scutellare* consumed 386.86 aphids during its larval period of 5.07 days (Devi, 1967). *I. scutellare* consumed an average of 471 *A. gossypii* during their larval period of 6 days (Dahiya *et al.*, 1988). The mean number of aphids consumed by the first second and third instar larvae of *X. scutellare* were 49.45, 139.11 and 259.90, respectively, the total consumption of entire larval duration being 448.46 aphids and the duration of active feeding of 3 instars were 2, 3 and 4 days, respectively (Rani, 1995). *I. scutellare* was observed to complete its life cycle in 13.30 days and the maggot consumed an average of 406 aphids (Nandakumar, 1999).

Another syrphid predator, *Paragus serratus* (Fabricius)was found to consume an average of 429 *A. gossypi* during a larval period of 6 days. (Dahiya *et al.*, 1988). The total consumption of *A. craccivora* by the maggots of *P. serratus* was observed to be 258.3 with 9.2, 33 and 34 aphids during the first, second and third instar, respectively (Patro and Behera, 1993).

2.4.3 Chrysopids and Hemerobids

In India, *C. carnea* is reported from western and northern parts of the country feeding on *Heliothes* sp. and aphids (Manjunath *et al.*, 1976). The maximum consumption of aphids was by the third instar larvae of *C. carnea* followed by second and first instars (El-dakroury *et al.,* 1979). Singh and Kumar (2000) observed that an average of 11.48, 79.52 and 83.0 aphids were consumed by first second and third instar of *C. carnea* in mustard. The mean number of aphids consumed by the first, second and third instar larvae were 73.60±15.8, 184±18.27 and 161.4±23.5, respectively and the total number of nymphs and adults of

A. craccivora consumed by the predator larvae during its development period was 419±9.14 (Abhilash, 2001).

2.4.4 Other biocontrol agents

The fungus *F. pallidoroseum,* at the rate of 7×10^6 spores ml^{-1} and 3.5×10^6 spores ml^{-1} was found to be effective as the insecticide quinalphos (0.05%) in controlling *A. craccivora* in the field and the LC_{50} of the fungus to cowpea aphid was 3.408×10^6 spores ml^{-1} and it was not found pathogenic to *M. sexmaculatus* (Hareendranath *et al*., 1987).

A pupal endoparasitoid, *Antrocephalus* sp. was found to be the most predominant pathogen of *M. vitrata* in W. Kenya and *Nosema* sp. and *Bacillus* sp. also caused 40.65 and 35.6 per cent mortality in two sites (Okeya-owuor *et al*., 1991).

2.5 Predatory behaviour of the major predators of cowpea pests

Predators can perceive their host at a distance (Thompson, 1951), but detection of the prey occurs only after a direct physical contact (Hagen, 1962).

The first instar larvae of coccinellid predators can survive longer after having cannibalized the eggs of same egg batch (Banks, 1954), but that cannibalism reduced the activity of the larvae and their success in finding prey (Pienkowski, 1965).

Banks (1957) opined that on plants, coccinellid larvae waste time and energy revisiting the same areas concerned and the edges and prominent veins of leaves determine the pattern of search and that the younger larvae take comparatively longer time to consume aphids than the older individuals.

Coccinellid larvae and adults evidently do not perceive their prey until contact. The adult of *Adalia* sp. must come into palpal contact with the aphid before it responds, and after finding the prey, the larval search pattern changes from one of the rapid movement at random, to one of more intensive search as reflected by more frequent turns and has an advantage when feeding on colonized prey (Dixon, 1959).

Kaddou (1960) reported that young searching larvae are positively phototactic and negatively geotactic, but the larvae younger than 24 hours and older larvae were negatively phototactic. He also found that aphids with long appendages were more difficult to be captured by *Hippodamia quinquesignata* Kirby larvae than the more compact and tenacious aphids with short appendages.

The young coccinellid larvae usually pierce and suck the contents from their prey, whereas the older larvae develop in addition, a chewing action and the whole prey may be consumed. The piercing and sucking activity is accompanied often by regurgitation of the contents of prey back into the prey's body (Hagen, 1962).

Extra oral digestion in *Scymnus* sp. was reported by Kapur (1942), among *Stethorus* sp. by Fleschner (1950), and in *Pullus* sp. by Deluchi (1954).

Similar feeding behaviour has been reported in coccinellini (Banks, 1957) and in Hippodamini (Kaddou, 1960).

The large size and conspicuous colonisation of the adult appear to give more warning to the threatened prey than the dull more flat form of larval stage (Dixon, 1958).

Dead aphids provided as food did not permit development of *H. quinquesignata* larvae (Kaddou, 1960), but frozen aphids were eaten by *Hippodamia convergens* Guerin (Haug, 1938).

The behaviour of locally occurring adult females of seven species of coccinellids were studied by Frazer and Mc Gregor (1994), using some models and found that the difference in frequencies of behaviour were judged to be sufficient to result in differences in the efficiency with which plants with different architecture were searched for prey.

2.6 Effect of botanicals on pests of cowpea

2.6.1 Effect of neem and neem products on cowpea pests

Neem oil (5%) reduced the incidence of cowpea mosaic virus in cowpea (Kannan and Doraiswamy, 1993). Mariappan and Samuel (1993) also revealed that neem oil (5%) exhibited high (92%) aphicidal activity against *A. craccivora* due to contact toxicity and antifeedant effect. Neem seed oil (NSO) at one per cent applied to leaf discs resulted in 94 to 100%, mortality of aphids after nine days

(Lowery and Isman, 1993). Application of two or three per cent neem seed extract (NSE) at 200 l ha^{-1} at 38, 47 and 51 days after emergence (DE) of cowpea crop or ULV spray application of 5, 10, or 20% NSE at 10 l ha^{-1} significantly reduced the incidence of flower thrips, *M. sjostedti* (Saxena and Kidiavai, 1997).

The effectiveness of neem preparation against epilachna beetle infesting cowpea was reported by many workers. Neem leaf extracts at two and five per cent killed the larvae of *Epilachna varivestis* Muls. fed on treated beans (Streets, 1975). The antifeedant activity of NSK against *E. varivestis* was reported by Ascher (1980) both in laboratory and potted plants. Among the neem preparations tested, Vepicidin, Nemidin and Vemidin were found to have high antifeedant activity at concentrations ranging from 0.05 to 0.50% against *H. vigintioctopunctata* up to 48 hours (Chitra and Kandasamy, 1988). The antifeedant action of azadirachtin rich neem fractions against adults and fourth instar grubs of epilachna beetle was also reported by Jeyarajan and Sundara Babu (1990). When leaves treated with 0.025 and 0.05% neem seed oil were fed to *Epilachna sparsa* Hbst. adults, the pre oviposition period was extended upto 21% than the insects fed on untreated leaves (Mishra *et al.*, 1990).

Various workers have reported the effectiveness of neem products against pod borers and bugs. Neem seed kernel extract (NSKE) alternated with Decis on weekly basis was found to be more effective than Decis alone, against *H. armigera*. Neem seed extract (NSE) and neem seed powder were toxic and affected the development of the Pyralid, *Maruca* sp and nymphs of coreid bug, *Clavigralla* sp. (Jackai *et al.*, 1992). The severe incidence of pod borer pests in field pea was checked with the use of neem kernels, and dry leaves powder @ 75 kg ha^{-1} gave grain yield by 20.44 quintals ha^{-1} (Singh, 2002). Minimum pod damage of 8.27% was observed in neem seed water extract (NSWE) 5% treated plots of soybean compared to untreated control with 26.22% damage (Jayappa *et al.*, 2002).

Methanolic and hexane neem extracts of field collected ripened fruits prepared by drying and decorticating kernels with moisture content of 10% and azadirachtin content of 0.7%, ground into fine powder and made into 1.25, 2.5 and 5% solution significantly reduced feeding activity of *Clavigralla scutellaris* compared with control and not interfered with predators. The feeding of adult *N. viridula* was significantly reduced in plots treated with 5% Neemix (Abudulai *et al.*, 2002). Neem seed oil at 1.00 and 1.25% caused more than 80% mortality to larvae and pupae of *L. trifolii* and the oviposition and feeding by *L. trifolii* adults was deterred by neem products like Neem Azal.S and Margosan.O (Dimetry *et al.*, 1995). NSKE 5% was reported to be effective against leaf miner in soybean (Gopal *et al.*, 1992). The bioefficacy test of botanicals conducted by Rao *et al.* (1990) revealed that NSO was the most effective one followed by Neemark, Biosol and Repelin in repellency, feeding deterancy, ovipositional deterancy, ovicidal action and growth inhibition effects against *S. litura.*

Various reports on the effectiveness of neem products against the storage pests of cowpea grains are presented. Shivendra singh (2002) evaluated the effectiveness of neem products and observed that neem seed kernel powder 0.25 to 4.0 parts per 100 parts green gram protected the grains over six months in storage. Neem seed kernel powder (NSKP) when admixed at the rate of 0.25 parts per 100 parts of green gram w/w gave 100% protection of grains against *Callosobruchus maculatus* Fabricius. (Singh, 2002)

2.6.2 Effects of other botanicals on cowpea pests

Methanolic and ethanolic extracts of *Ocimum sanctum* was reported to cause heavy mortality in aphids in Thailand (Stein *et al.*, 1988). Ether extracts of the leaves of *Clerodendron frajan, Clerodendron. calamilosum* and *Clerodendron cryptophyllum* could inhibit the feeding of *S. litura* (Hosozawa *et al.*, 1974). *Clerodendron incerne* was observed by Thripathi and Rizvi (1985) to have antifeedant activity against *Diachrisia obliqua.*

So many reports on the effects of botanicals on the control of epilachna beetles are available. The seed extracts of *Gynandropsis gynandra* was found to be the most toxic one to epilachna beetles followed by rhizome extracts of *Acorus calamus* and shade dried stem extract of *Cyperus rotunda* (Chandel *et al.*, 1987). Benzene extracts of *Eupetorium odoratum, C. infortunatum, Thevetia neriifolia* and *Nerium oleander* significantly reduced the population of epilachna beetle and aphids (Saradamma, 1989). Seed extracts of *T. neriifolia* were an effective antifeedant leading to larval starvations in epilachna beetle (Bai and Koshy, 2001)

2.7 Effect of microbial insecticides on cowpea pests

The application of spore suspension of *Fusarium pallidoroseum*(Cooke) Sacc. 3.5 X10^6 spores ml^{-1} and 7x10^6 spores ml^{-1} were as effective as the insecticide quinalphos sprayed at 0.05% in controlling *A. craccivora* in cowpea (Hareendranath *et al.*, 1987). NPV of *H. armigera* with *Steinernema filtiae* (DD-136) nematode for the control of pigeon pea revealed a significant reduction in larval population in the treatments NPV@2x10^6 PIB's ml^{-1} and NPV@2x10^6 PIB's ml^{-1} + DD136 nematode @ 3x10^3 IJ ml^{-1} (Narayanan and Gopalakrishnan, 1987). NPV and GV infections have been known to increase the susceptibility of *H. armigera* and *S. litura* larvae to insecticides like endosulfan, chlorpyriphos and fenvalerate (Rabindra, 1998).

2.8 Effect of chemical insecticides and insect growth regulators on cowpea pests

Of the 16 insecticides tested in Egypt against cowpea pests, phenthoate, iso oxathion, cyanophos, carbaryl and cypermethrin used at lower than the recommended concentration reduced populations of *A. craccivora* and cypermethrin (Ripcord at 0.04 kg ai ha^{-1}) was the most effective insecticide against *A. craccivora* (*Sharma et al.*, 1991). The insecticides *viz.* chlorpyriphos 0.05%, profenofos 0.05%, acetamiprid 0.002% and imidachloprid 0.025% recorded more than 75%

mortality to *A. craccivora* in cowpea and were superior to the check malathion (Varghese, 2002).

Excellent control of *L. trifolii* was obtained by the use of fenvalerate and permethrin (Schreiner *et al.*, 1986). The insecticides, chlorpyriphos 0.05% and profenofos 0.05% gave more than 75% mortality of *S. litura* larvae in 24 hours after treatment (Varghese, 2002). Carbaryl applied at 2.02 Kg ha^{-1} gave complete control of larvae of *L. boeticus* (EL-Ghar- GESA *et al.*, 1994). Chlorpyriphos 0.05% gave more than 75% mortality to pod bug *R. pedestris*, 24 hours after treatment followed by acephate and profenofos with 60.14 and 53.34% mortality respectively and against the third instar larvae of pod caterpillar, *L. boeticus,* chlorpyriphos and triazophos gave higher mortality of more than 75%, (Varghese 2002). The IGR, flufenoxuron applied alone or in a mixture with methomyl 0.164 kg ha^{-1} had a good residual activity against adults of *Callosobruchus* sp., 21 days post treatment (EL-Ghar-GESA *et al.*, 1994).

2.9 Effect of pesticides on the natural enemies associated with cowpea pests.

2.9.1 Effect of botanicals on natural enemies of cowpea pests

Several workers have studied the effect of botanicals on the parasitoids of cowpea pests. Application of 2% NSK suspension to the eggs of S. *litura* parasitised by *Telenomus remus* Nixon. did neither prevent emergence of parasites nor repel oviposition by female parasites (Joshi *et al.*, 1982). Grubs of

H. vigintioctopunctata freshly treated with petroleum ether extracts of *M. azedarach* and rhizomes of *A. calamus* were significantly less parasitised by *P. foveolatus* (Tewari and Moorthi, 1985). The botanical insecticides *viz.* Repelin and neem guard were relatively safe at lower concentration to *Tetrastichus australicum*, *B. hebator* and *T. israeli* in the laboratory as well as field. However, the higher concentrations of botanicals adversely affected the parasitoids (Srinivasa Babu *et al.*, (1993). The extracts of *C. infortunatum* were found to be safe to *C. johnsoni* (Lily, 1995). The leaf and seed extracts of *T. neriifolia* at field doses were also safe to *C. johnsoni* (Bai and Koshy, 2001).

Many workers reported the effect of botanicals on the predators of cowpea pests. The plant extracts of *A. indica*, *T. neriifolia* and *C. infortunatum* were not as toxic as carbaryl to the predator *M. sexmaculatus* and all these plant extracts and tobacco decoction affected the population of predator with values ranging from 10.61 to 12.68 as against 14.80 in control (Srinath, 1990). Patel and Yadav (1993) opined that the botanicals *viz.*, nicotine sulphate, Repelin and Neemark were safe to the predator *M. sexmaculatus*. Nicotine sulphate was harmless to the predator *C. septempunctata* (Singh *et al.*, 1988) and natural enemies of chilli aphid (Rao *et al.*, 1990). Neem seed oil at 0.05, 1.0 and 2.0 per cent to potted plants infested with *M. persica* resulted in total prevention of adult eclosion of *Coccinella undecimpunctata* L. and reduced adult eclosion of syrphid, *Eupeodes fumipennis* Thompson. to 11.0, 7.0 and 0.0 per cent, respectively of controls

(Lowery and Isman,1995). The botanical pesticide, azadirachtin 0.5% was found to be relatively safe to coccinellid beetles *C. septempunctata* (Meena *et al.*, 2002).

Neem seed kernel 2% was observed to be safe to *C. scelestes* (Joshi *et al.*, 1982). Better recolonisation of *Lycosa pseudoannulata* was reported in neem treated plots by Reguraman and Rajasekharan (1996). However, adverse effects of leaf extracts of *C. infortunatum* were observed on *Agriocnemis* spp. whereas the treatment with extracts of *A. indica* and *C. infortunatum* gave the lowest pest defender ratio (Ajayakumar, 2000).

2.9.2 Effect of chemical pesticides on natural enemies of cowpea pests

Mani and Krishnamoorthy (1984) tested the susceptibility of adults and cocoons of *Apanteles plutellae* to pesticides revealed that quinalphos was highly toxic to both, whereas dichlorvos, monocrotophos and endosulfan were highly toxic to adults, but relatively safer to the cocoons. Endosulfan and phosalone were highly toxic to *T. australicum*, *T. Israeli* and *B. hebator* (Srinivasa babu, 1993). Among the 17 chemicals tested for their toxicity to *C. chloridae*, monochrotophos, chlorpyriphos, malathion and endosulfan were safer (Ahmed and Sardar, 1994). Synthetic pyrethroids were highly safe to *Apanteles glomeratus,* while malathion, chlorpyriphos, quinalphos and endosulfan were toxic within 24 hours and malathion had significantly high residual toxicity up to 21 days.

Various reports on the effectiveness of different chemical pesticides to predators of cowpea pests are available. Hundred per cent mortality of *M. sexmaculatus* after malathion 0.1% spray was reported by Lingappa *et al.* (1978). High motality (95 to 100%) of *M. sexmaculatus* adults was recorded by Makar and Jadhav (1981), 72 hours after exposure to carbaryl, fenetrothion and quinalphos, while methyl demeton, phosphamidon and dimethoate were moderately toxic. Chaudhary *et al.* (1983) also reported that methyl demeton, quinalphos and dimethoate were comparatively less toxic and safer to *M. sexmaculatus*, while endosulfan 0.07% was found to be harmless. The use of dimethoate reduced its searching capacity and longevity of *M. sexmaculatus* compared to the botanical *Gardenia cramerii* (30 g in 100 ml water) (Thayaalini and Raveendranath, 1988). Dimethoate was found to be relatively more toxic than malathion to *M. sexmaculatus*. Of the seven insecticides tested to *M. sexmaculatus*, endosulfan 0.05 % had the least detrimental effect (Rao *et al.*, 1989 and Sonkar and Desai, 1998). On the contrary, it was found highly toxic by Patel and Yadev (1993).

Chlorpyriphos and Profenofos were 6.22 and 5.94 times more toxic than malathion to the third instar larvae of *M. sexmaculatus* whereas triazophos, acephate, acetamiprid and imidachloprid were less toxic with relative toxicity values of 0.49, 0.10, 0.07 and 0.03, respectively (Varghese 2002). All the predators including *M. sexmaculatus* were highly susceptible to the synthetic pyrethroids, fenvalerate 0.05%, cypermethrin 0.005% and deltamethrin 0.0014% and hence the use in orchards, where predators are actively feeding, is not recommended

(Mani and Krishnamoorthy, 1991), whereas Sharma *et al.* (1991) observed cypermethrin followed by endosulfan to be the most selective insecticide for aphid control. A 100% control of *A. craccivora* was achieved by the release of 10 predator larvae per adults along with 0.01% malathion about a week earlier compared with the action of the predator alone (Ahmad and Sardar, 1994). Dhingra *et al.* (1995) evaluated 10 insecticides by comparing their LC_{50} against *M. sexmaculatus* adults including *A. craccivora* indicated that endosulfan, lindane and demeton methyl was relatively safer whereas pyrethroids adversely affected the predator population having low LC_{50} value. The pea aphids *A. craccivora* was found to be more susceptible than their predator *M. sexmaculatus* on caged plants to malathion at 0.002, 0.001 and 0.005% active ingredient and the active feeding stage of the predator larvae were less susceptible to the insecticides than adults and inactive stages (Islam and Sardar, 1997). They also found that diazinon and dichlorvos 0.002 and 0.001% were more toxic than malathion to *M. sexmaculatus*. The efficiency of 15 larvae of *M. sexmaculatus* was significantly greater (97 to 100% reduction) than diazinon and malathion at 0.002% active ingredient (80 to 87% control) in controlling *A. craccivora* and increasing yield (Bari and Sardar, 1998). Imidachloprid and acephate were 13.78 and 4.43 times as toxic as oxydemeton methyl to *M. sexmaculatus* respectively and endosulfan was 0.62 times less toxic (Patil and Lingappa, 1999).

The predator *C. septempunctata* was more resistant than *A. craccivora* and *A. gossypii* to carbaryl (Sarup *et al.*, 1965) while methyl demeton, dimethoate and phosolone were selective to aphidophagous coccinellids (Satpathy *et al.*, 1968). Malathion, quinalphos, dimethoate and carbaryl had toxicity of 25.17, 14.36, 40.14 and 11.86 compared to 1.00 of DDT to the adults of *C. septempunctata* (Sharma and Adlakha, 1986). Acetamiprid and imidachloprid were found to be safe having safety indices of 11.47 and 2.35, respectively to *C. transversalis* (Varghese, 2002).

Oxydemeton methyl at the rate of 1.2 l ha^{-1} and isoprocarb at 1 kg ha^{-1} according to the threshold resulted in 1.5 to 2 times many arthropod natural enemies like *C. transversalis* and *C. septempunctata* than a fixed spray schedule (Ali and Karim, 1990). Shukla *et al.* (1990) also found oxydemeton methyl at 0.04% to be the most toxic one, while endosulfan at 0.07% was the least toxic to larvae and adults of *C. septempunctata*. Cypermethrin or fenvalerate at 0.04 kg ai ha^{-1} followed by endosulfan was considered to be the most selective insecticide for aphid control in chickpea considering their safety to natural enemies whereas dimethoate and monocrotophos were highly toxic to *Coccinella* spp. (Sharma *et al.*, 1991). Endosulfan was found to be the least toxic chemical to *C. transversalis* in mustard ecosystem as reported by Sonkar and Desai (1998). Kalushkov (2000) found that *C. septempunctata* had the highest survival rate when synthetic pyrethroids were applied against aphids. Profenofos was found to be 9.4 times more toxic than malathion to *C. transversalis* (Varghese, 2002).

The adult beetles of *Harmonia axyridis* (Coleoptera: Coccinellidae) survived topical application of chlorpyriphos though they were found to be lethal to larvae with a dose corresponding to 1/100 of recommended field dose (Michaund, 2002). Acetamiprid had the highest safety index of 25.77 to *C. carnea* followed by imidacloprid (3.99) in cowpea ecosystem (Varghese, 2002). The successive application of pesticide to fields resulted in qualitative as well as quantitative decline in the spider population both in relative abundance as well as in species composition (Patel *et al.*, 1987).

2.9.3. Effect of microbial insecticides on the natural enemies of cowpea pests

Hareendranath *et al.* (1987) in the bioassay using *F. pallidoroseum* on *A. craccivora* in cowpea revealed that LC_{50} of fungus was 3.408 x 10^6 spores ml^{-1} and it was not found pathogenic to *M. sexmaculatus*. The coccinellid predators of red gram pests were found to be susceptible to the microbial insecticide *Beauveria bassiana* (Manjula and Padmavathamma, 1996).

2.10 Management practices contributing to the Integrated pest management strategies in cowpea

Cowpea intercropping with pearl millet significantly reduced pest incidence and increased the coccinellid numbers (Kennedy *et al.*, 1990). The IPM practices with resistant cultivars and the adjustment of planting date were the most suitable option for residual soil moisture cowpea production in Nigeria (Alghali, 1991). He also revealed that cowpea is grown as a secondary crop requiring low inputs to boost its production and the rational pest control approach in cowpea should be integrative, locale specific and include education of farmers on control tactics, identifying and developing effective IPM strategies that are low cost and scale neutral and creating an awareness of the necessity for IPM inputs to be readily available and affordable.

Selection of tolerant varieties plays an important role in IPM. Among the different varieties of cowpea screened, VL-175 and selection-2 were found to be resistant to *A. craccivora*. The infestation averaged 14.7 to 24.6% and 25.7 to 31.12 aphids per 5 cm twig as compared with 97.9 to 100% and 86.87 to 108.5 aphids per twig in other varieties (Singh *et al.*, 1991).

Cultivation of purple and dark green poded cultivars of cowpea were more resistant to pod sucking bugs than those with light green pods and short peduncle (Khaemba, 1984). Oghiakhe (1995) found significant negative correlation between mean number of eggs laid by legume pod borer *M. vitrata* and length and density of non-glandular trichomes. He also observed positive correlation between larval penetration time on pods and length of non-glandular trichomes.

Tough pod wall requiring a force of 25 Newton per mm^2 to penetrate at pod maturity can be considered as an important factor contributing to the lower feeding damage by pod sucking bugs in cowpea (Chiang and Jackai, 1988). He also reported that phenols in addition to the tough pod wall may be important in confirming resistance to these pests.

Salifu *et al.* (1988) in their study on the mechanism of resistance to the bean flower thrips *M. sjostedti* in cowpea found that the genotype TVX 3236 consistently had lower population than others and the physical basis of ovipositional non-preference appeared to be associated with reduced air space in the calyx of the variety. Carbofuran at 3 kg ai ha^{-1} applied at planting with a cowpea variety resistant to larvae of *M. vitrata* got the best grain yield in cowpea (Olowe *et al.*, 1987). 'Skip row' spray coverage in cotton with monocrotophos, endosulfan and deltamethrin spraying resulted in larger population of *C. carnea* compared to full coverage with these pesticides (Surulivelu and Kumaraswami, 1989).

Singh and Sachan (1993) used a sex pheromone trap for *S. litura* with 9:1 mixture of (9Z, 11E) - 9, 11- tetra decadienyl acetate and (9Z, 12E)-9, 12- tetradecadienyl acetate in white plastic funnel traps in fields of Pantnagar in Utter Pradesh, India, which was very effective in checking oviposition in *V. mungo* sown in kharif crop or summer ground nut.

MATERIALS AND METHODS

3. MATERIALS AND METHODES

The present investigation was undertaken to work out an integrated pest management strategy for the important pests of cowpea in Kerala.

The various experiments were carried out at the Department of Entomology, College of Agriculture, Vellayani, Thiruvananthapuram and Onattukara Regional Agricultural Research Station (ORARS), Kayamkulam, Kerala Agricultural University during 1997 to 2001. The materials used and the methods employed in the study are presented here.

3.1 Survey of the pests of cowpea, their natural enemies and the plant protection measures adopted by the farmers in the major cowpea growing areas of Kerala.

Survey on the population of major pests and their associated natural enemies of cowpea were conducted in the selected cowpea growing tracts of Kerala *viz.*, Thiruvananthapuram, Alappuzha and Palakkad districts. Thirty farmers each having not less than 0.5acre of cowpea under cultivation were selected for the survey in each district. Observations were recorded during two stages of the crop, one at 20-25 days after sowing (DAS) and the other at the pod formation stage (55-60DAS) from each of the selected field, following suitable sampling techniques.

An interview schedule was prepared based on the objectives of the study for sample farmers (Appendix I). Observations were taken during early hours of the day. Response and observations to a set of 28 variables were obtained from each farmer

3.1.1 Assessment of pests and associated natural enemies of cowpea

The methodology adopted for recording observations on pests and their associated natural enemies is given in Table 1.

The methodology for assessing the level of incidence of pests and population of natural enemies (score) is given in Tables 2 and 3, respectively. The data were tabulated and analysed.

3.1.2 Assessment of plant protection measures adopted by the farmers cultivating cowpea

Plant protection measures *viz.*, mechanical, cultural and chemical (both organic and synthetic) methods adopted by the farmers in Thiruvananthapuram, Alappuzha and Palakkad districts were recorded and the data tabulated

3.1.3 Assessment of pesticide use pattern adopted by farmers

The usage pattern of the different pesticides by farmers in the three districts was recorded and the data tabulated.

Table 1. Method for recording observations on pests and associated natural enemies of cowpea

Sl. No.	Pests / Natural enemies	Method of observation
1.	Pea aphid *A. craccivora*	Mean number of adults and nymphs at the top 2.5 cm. length of shoot out of 10 plants selected at random per field
2.	Pea stem fly *O. phaseoli*	Mean per cent of plants infested out of 20 plants selected at random per field
3.	American serpentine leaf miner *L. trifolii*	Mean per cent of leaves infested out of 10 plants selected at random per field
4.	Pod bugs *R. pedestris* *C. gibbosa*	Number of adult bugs collected in 5 sweeps per field
5.	Pod borers *L. boeticus* *H. armigera*	1. Number of adults in 5 sweeps per field 2. Mean per cent of pods infested out of 10 plants selected at random per field
6.	Natural enemies in sweep nets	Total number of each species of parasitoids and predators collected in 5 sweeps per field
7.	Predators in aphid colony	Mean number of the larval and pupal stages of predators of coccinellids and syrphids present in aphid colony in the top 5 cm. length of shoot out of 10 plants selected at random

Table 2. Score on population / level of damage by the pests of cowpea

Sl.No.	Name of the pest	Scale/Score			
		Nil (0)	Low (1)	Medium (2)	High (3)
1	*O. phaseoli*	No incidence	1 to 25 per cent plants infested	25 to 50 per cent plants infested	>50 per cent plants infested
2	*A. craccivora*	No incidence	1 to 25 number per top 2.5cm. shoot	25 to 50 number per top 2.5 cm. shoot	>50 number per top 2.5 cm. shoot
3	*L. trifolii*	No incidence	1 to 25 per cent leaves infested	25 to 50 per cent leaves infested	>50 per cent leaves infested
4	*R. pedestris* *C. gibbosa*	No incidence	1 to 2.5 number per 5 sweeps	2.5 to 5 number per 5 sweeps	>5 number per 5 sweeps
5	*L. boeticus* *H. armigera*	1) No incidence 2) No incidence	1 to 25 per cent pods damaged 1 to 2.5 number of adults per 5 sweeps	25 to 50 per cent pods damaged 2.5 to 5 number of adults per 5 sweeps	>50 per cent pods damaged >5 number of adults per 5 sweeps

Table 3. Score on population of natural enemies associated with the pests of cowpea

Sl.No.	Natural enemies	Scale/Score			
		Nil (0)	Low (1)	Medium (2)	High (3)
1.	Coccinellids	No population	0-2.5 adults per 5 sweeps	2.5-5 adults per 5 sweeps	>5 adults per 5 sweeps
	Coccinella spp. *M.sexmaculatus* *Micraspis* sp. *Scymnus* sp.	No population	0 to 2.5 grubs/ pupae per plant	2.5 to 5 grubs/ pupae per plant	>5 grubs/ pupae per plant
2.	Syrphids	No population	0 to 2.5 maggots/ pupae per plant	0 to 2.5 maggots/ pupae per plant	>5 maggots/ pupae per plant
3.	Parasitoids	No population	0 to 2.5 parasitised larvae/pupae per plant	2.5 to 5 parasitised larvae/pupae per plant	>5 parasitised larvae/pupae per plant
4.	Gryllids, spiders, neuropterans, dragon and damsel flies	No population	0 to 2.5 adults per 5 sweeps	2.5 to 5 adults per 5 sweeps	>5 adults per 5 sweeps

3.1.5 Recording Meteorological Parameters

Data on maximum and minimum temperature, rainfall, relative humidity and sunshine hours were collected from the following observatories and presented.

District	Meteorological observatory
Thiruvananthapuram	College of Agriculture, Vellayani, Thiruvananthapuram
Alappuzha	Central Plantation Crops Research Institute, Krishnapuram, Kayamkulam.
Palakkad	Regional Agricultural Research Station, Pattambi.

3.2 Assessment of the efficiency of potential predators in controlling cowpea pests

The potential predators of the major pests of cowpea were collected from the cowpea fields of Onattukara Regional Agricultural Research Station, Kayamkulam and from the nearby farmer's fields. The predators were reared on aphids in the laboratory. Their efficacy was assessed in the following manner.

3.2.1 Assessment of the mean number of prey (*A. craccivora*) consumed by different life stages of the predators, consumption per day and longevity of the adults

3.2.1.1 *C. transversalis*

The studies were carried out using adults of *A. craccivora* as prey. Adult beetles of *C. transversalis* collected from the field on glyricidia and cowpea infested with *A. craccivora,* were placed in glass troughs for egg laying. The eggs laid by adults were collected. Ten freshly laid eggs of *C. transversalis* were kept individually in glass vials and covered with muslin cloth. The incubation period was observed. On hatching, each grub was introduced into a colony of known number of *A. craccivora* adults placed on cowpea grown in an ice cream cup wrapped at the base by wet blotting paper. Ten replications were maintained. The average duration of each instar *viz.*, first, second, third and fourth were recorded and the mean worked.

The feeding potential in terms of the number of aphids consumed daily by the second, third and fourth instar grubs were recorded and the mean worked.

The adult beetles required for the feeding experiment were reared from the pupae collected from cowpea fields. The mean consumption of *A. craccivora* by adult beetles was also recorded.

3.2.1.2 *M. sexmaculatus*

The incubation period, duration of different larval instars, pupal period and longevity of the adult beetles were recorded. The mean consumption by the second, third and fourth instars and adults of *M. sexmaculatus* was studied using *A. craccivora* adults as per the methodology given in 3.2.1.1. Ten replications were maintained for the study.

3.2.1.3 *I. scutellare*

Colonies of *A. craccivora* along with syrphid maggots were collected from twigs of glyricidia and cowpea plants and kept in rearing troughs for pupation. When the maggots pupated, the pupae were transferred to separate specimen tubes. The emerged adults were allowed to mate and provided with diluted honey soaked in cotton. The adults were allowed to lay eggs on cowpea twigs with aphid colonies. Freshly laid eggs were kept for hatching. Ten replications were maintained and the mean incubation period worked out.

The emerging maggots were introduced into separate petri dishes in which cowpea twigs with known number of aphids kept on a wet blotting paper. Aphids were provided, everyday after counting the dead aphid skins in the dish. Ten replications were maintained and the mean consumption worked out for each instar. The egg period, duration of first, second and third instar larvae and pupal period were recorded.

3.2.1.4 *C. carnea*

Freshly laid eggs of *C. carnea* were collected from the bio control laboratory maintained in the Department of Agricultural Entomology, College of Agriculture, Vellayani and kept in separate glass vials covered with muslin cloth for hatching. On hatching, each larva was introduced into a vial containing colony of aphids in cowpea twig. The number of aphids consumed daily was recorded. Ten replications were maintained and the mean consumption worked out for each larval instar. The egg period, larval duration and pupal period were also studied.

3.2.2. Predatory behaviour of the major predators associated with the pests of cowpea.

Five number each of the grubs and adults of *C. transversalis and M. sexmaculatus* starved for different periods *viz*., 1, 2 and 3 days were released into caged plants with different prey (*A. craccivora*) densities varying from 100 to 500 aphids for grubs and 200 to 1000 for adults. The characteristic feeding behaviour was recorded.

3.3 Effect of biorational insecticides on the potential predators of cowpea pests

3.3.1 Mortality of immature and adult stages of the predators on application of chemical insecticides and working out LC $_{50}$

The relative toxicity of insecticides *viz*., endosulfan, lindane and chlorpyriphos to adults and third instar grubs of *C. transversalis* and *M. sexmaculatus* was assessed in terms of LC_{50} of the different insecticides. The LC_{50} was calculated from the regression between dosage of the insecticide and the mortality of the insects. To determine the dosage mortality relations, ten graded concentrations were prepared for each insecticide. Dry film method was used to assess the toxicity (Litsinger *et al*., 1978).

One ml. of each concentration of the insecticide was taken in the petri dish and rotated for few seconds to get uniform spread over the entire area of the dish. This was dried under fan for ten minutes. Ten larvae or adults of the test insect were released in these petri plates and closed for recording mortality. Petri plates treated with acetone served as the control.

The insecticide emulsions were prepared from technical grade material of the insecticide using acetone as the solvent.

Stock solution (solution A) — One gram technical material in 100 ml solvent

0.003ml A + 10 ml acetone — 0.0003%

0.007ml A + 10 ml acetone — 0.0007%

0.015ml A + 10 ml acetone — 0.0015%

0.03 ml A + 10 ml acetone — 0.003 %

0.06 ml A + 10 ml acetone — 0.006 %

0.125 ml A + 10 ml acetone — 0.0125%

0.25 ml A + 10 ml acetone — 0.025 %

0.50 ml A + 10 ml acetone — 0.05 %

1.00 ml A + 10 ml acetone — 0.10 %

2.00 ml A + 10 ml acetone — 0.20 %

3.3.2 Mortality of immature and adult stages of the predators following application of botanical insecticides and calculation of LC_{50}

The relative toxicity of botanical insecticides *viz.* neem oil and Nimbecidine (a commercial formulation of neem) to adults and 3rd instar grubs of *C. transversalis* and *M. sexmaculatus* was assessed in terms of LC_{50}. The LC_{50} was calculated from the regression between the dosage of the botanicals and the mortality of the insects as given in 3.3.1. The emulsions were prepared using acetone as the solvent and teepol as emulsifier.

3.3.2.1 Nimbecidine

Stock solution (solution A)	—	the commercial formulation nimbecidine was taken as 100%
0.005ml A + 10 ml acetone	—	0.05 %
0.01 ml A + 10 ml acetone	—	0.1 %
0.015ml A + 10 ml acetone	—	0.15%
0.02 ml A + 10 ml acetone	—	0.2 %
0.025ml A + 10 ml acetone	—	0.25 %
0.03 ml A + 10 ml acetone	—	0.3 %

3.3.2.2 Neem oil emulsion

The neem oil emulsion was prepared from 100% neem oil using acetone as solvent and 1% teepol as emulsifier.

Stock solution (solution A) — 100% neem oil

0.1 ml A + 10 ml acetone — 1 %

0.2 ml A + 10 ml acetone — 2 %

0.4ml A + 10 ml acetone — 4 %

0.6 ml A + 10 ml acetone — 6 %

0.8 ml A + 10 ml acetone — 8 %

1.0 ml A + 10 ml acetone — 10%

Protocol for assessment of toxicity to parasitoids and predators in India

(Dry film technique – (Singh *et al.*, 2001)

Parameter	Remarks
Bio-assay method	Dry film / topical application
Test species	One or two important insect parasitoids of major crop pests and any one insect predator species of crop pests
Treatment dosages	A minimum of 5 treatment dosages giving mortality between 20 to 80 per cent
Number of test insects	10- 20 laboratory reared one- day- old adult female per replicate in the case of parasitoids and 10-12 field collected predators /replicate
Number of replications	Three more and one untreated control. For the purpose of handling insect can be chilled or anesthetised by carbon dioxide
Exposure period	6-8 hours in case of dry film method
Post treatment period	1 day in case of parasitoids and 8-12 hours in the case of predators
Test conditions	Insects should be conditioned for 6-12 hrs at temperature of 28 ± 2°C. Same temperature should be maintained for exposure and post treatment period
Mortality count	Moribund insect should be treated as dead. Abbots (1925) formula should be employed to correct mortality in control if any

The toxicity of the insecticide dilutions was determined in terms of percentage mortality of the treated insects at 24 and 48 hours after treatment. The criteria used for fixing the mortality were complete immobility of insects. The data thus obtained for the different insecticides were subjected to probit analysis (Finney 1981). Regression equations were calculated for each insecticide and LC_{50} value computed

3.3.3 Relative safety of insecticides to predators

Presuming that the insecticides would behave similarly under field condition, the LC_{50} values of the insecticides were compared with the normal recommended concentration (NRC) of the insecticides against various pests and the relative order of safety to predators was worked out (Hameed *et al.*,1973)

$$Safety\ index = \frac{LC_{50}\ of\ the\ insecticide}{Normally\ recommended\ concentration}$$

3.4 Management of cowpea pests

A pest management trial was conducted during two seasons from 2000 to 2001 in the summer rice fallows of ORARS, Kayamkulam. The first trial was conducted from January to April 2000 and was repeated during January to April 2001.

The experiment was laid out in randomized block design using the cowpea variety, Kanakamani with 13 treatments replicated thrice. A spacing of 25 cm between rows and 15 cm between plants was adopted with a plot size of 5×4 m. One to two plants were allowed in a hill.

Treatments

All the treatments received 2 per cent urea solution at seven and 20 DAS.

T_1 – Carbaryl 0.2 per cent + mechanical + cultural control

T_2 – Endosulfan 0.05 per cent + mechanical + cultural control

T_3 – Lindane 0.05 per cent + mechanical + cultural control

T_4 – Chlorpyriphos 0.05 per cent + mechanical + cultural control

T_5 – Crude neem oil emulsion 10 per cent + mechanical + cultural control

T_6 – Crude neem oil emulsion 5 per cent + garlic 20 g l^{-1} + mechanical + cultural control

T_7 – Neem kernel suspension 5 percent + mechanical + cultural control

T_8 – Neem kernel suspension 2.5 per cent + garlic 20 g l^{-1} + mechanical + cultural control

T_9 – Nimbecidine 0.2 per cent + mechanical + cultural control

T_{10} – Aqueous extract of *Hyptis suaveolens* 10 per cent + mechanical + cultural control

T_{11} – Aqueous extract of clerodendron 10 percent + mechanical + cultural control

T_{12} – mechanical + cultural control alone

T_{13} – Control

3.4.1 Preparation of pesticides

3.4.1.1 Crude neem oil emulsion 10%

Fifty grams of ordinary washing soap was dissolved in 500 ml water and mixed thoroughly with 1litre of neem oil to prepare 1.5 litre stock solution of neem oil emulsion. This was made to 15 litres with water and mixed to get the spray solution

3.4.1.2 Crude neem oil emulsion 5% + garlic 20 g l^{-1}

Fifty grams of ordinary washing soap was dissolved in 500 ml water and mixed thoroughly with 500 ml neem oil and made into an emulsion. Three hundred grams of garlic was grinded and extracted with water to get 500 ml of the extract. This extract was mixed thoroughly with the emulsion to prepare 1.5 litres stock solution. This was made to 15 litres with water and mixed to get the spray solution.

3.4.1.3 Neem kernel suspension 5%

Fifty grams of dried powdered neem kernel was kept in a muslin cloth, tied and soaked in 1 litre water for 12 hours. This was squeezed to get 1litre extract of 5% neem kernel emulsion after mixing with 1% teepol as emulsifier.

3.4.1.4 Neem kernel suspension 2.5% + garlic 20 g l^{-1}

Twenty five grams of dried powdered neem kernel was kept in a muslin cloth, tied and soaked in 750 ml water for 12 hours. Twenty grams of garlic was grinded and extracted with water to prepare 250 ml of the garlic extract. The squeezed extract of neem kernel was mixed with the garlic extract and 1% teepol as emulsifier to get 1 litre of the spray solution.

3.4.1.5 Aqueous extract of *H. suaveolens* 10%

Sixty grams of ordinary washing soap after dissolving in 500 ml water was mixed with 1litre crude extract of *H. suaveolens* to prepare 1.5 litres of stock solution. This was made to 15 litres with water to get the spray solution.

3.4.1.6 Aqueous extract of clerodendron 10%

Sixty grams of ordinary washing soap after dissolving in 500 ml water was mixed with one litre crude extract of clerodendron to prepare 1.5 litres of stock solution. This was made to 15 litres with water to get the spray solution.

3.4.2 Mechanical + Cultural control

Burning of trash.

Application of dry leaf ash at 10 DAS.

Keeping yellow sticky trap and yellow pan tray.

Removal and destruction of infested leaves, flower buds and pods.

Sweeping and destruction of pod bugs.

In all the treatments except control, mechanical and cultural control were given uniformly. Burning of trash was done during land preparation and dry leaf ash applied at 10 DAS. Yellow sticky trap was prepared by smearing carbofuran 3G over a thick paste of gum coated on a yellow painted board. Infested leaves, flower buds and pods were frequently removed. Sweeping and destruction of pod bugs were done at pod bearing stage.

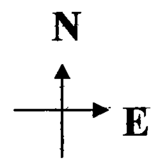
3.4.3 Observations recorded

Observations on the following items were recorded at weekly intervals.

1. Count of immature and adult stages of pests.
2. Extent of damage by the pests.
3. Count of parasitoids.
4. Count of predators.
5. Yield.
6. Terminal residues of insecticides in the produce.
7. Benefit: cost analysis.

All the operations except pest management were undertaken as per the Package of Practices Recommendations of Kerala Agricultural University (1996)

Layout



2000 January- April

R_1	R_2	R_3
T_{10}	T_7	T_5
T_{13}	T_6	T_8
T_{12}	T_{13}	T_4
T_{11}	T_1	T_{13}
T_5	T_3	T_1
T_3	T_2	T_{12}
T_6	T_{10}	T_2
T_1	T_9	T_{11}
T_4	T_8	T_6
T_7	T_{12}	T_3
T_8	T_{11}	T_9
T_9	T_5	T_7
T_2	T_4	T_{10}

2001 January- April

R_1	R_2	R_3
T_{10}	T_7	T_5
T_{13}	T_6	T_8
T_{12}	T_{13}	T_4
T_{11}	T_1	T_{13}
T_5	T_3	T_1
T_3	T_2	T_{12}
T_6	T_{10}	T_2
T_1	T_9	T_{11}
T_4	T_8	T_6
T_7	T_{12}	T_3
T_8	T_{11}	T_9
T_9	T_5	T_7
T_2	T_4	T_{10}

The pre treatment observations on the incidence of pests and associated natural enemies were recorded before the first treatment. Post treatment observations were recorded at weekly intervals until final harvest.

The observations on counts of pests and natural enemy population and extent of damage due to pest infestation were recorded from the plots as given below.

Sl.No.	Pest population / Damage	Method of taking observations
1	*O. phaseoli*	Ten plants were selected at random per plot and percentage infestation worked out
2	*Epilachna* spp.	i) Five plants were selected at random and the mean percentage of leaf damage worked out ii) Number of adults in 5 sweepings per plot
3	*A. craccivora*	Mean number of adults and nymphs at the top 2.5 cm shoot of five plants selected at random per plot
4	*L. trifolii*	Five plants were selected at random and the mean percentage of leaf infestation workedout.

5	*L. boeticus* *H. armigera* *M. vitrata*	Five plants were selected at random and the mean percentage of pod infestation worked out
6	*R. pedestris* *C. gibbosa*	Number of adult bugs collected in 5 sweeps per plot

Ten plants were selected at random per plot and the mean percentage of crinkled leaves due to aphid infestation worked out in the summer season of the year 1999.

Sl. No	**Natural enemies**	**Method of taking observation**
1.	Coccinellids	i) Mean number of grubs/pupae in aphid colonies per plant was worked out by selecting 5 plants at random ii) Number of adult beetles collected per 5 sweeps
2.	Syrphids	Mean number of maggots in aphid colonies per plant selecting 5 plants at random per plot
3.	Spiders	Total number of adults and young ones per 5 sweepings per plot
4.	Parasitoids	Mean number of parasitised larvae/ pupae per plant in five random plants

5.	Damselflies	Total number of damselflies in 5sweeps per plot
6.	*Paederus* sp.	Total number of adult beetles in 5 sweeps per plot
7.	Gryllids	Total number in 5 sweeps per plot
8.	Wasps	Total number per 5 sweeps per plot

The yield of cowpea grains at each harvest was pooled and recorded to obtain the mean yield per plot in different treatments.

The data were subjected to $\sqrt{x+1}$ transformations and statistically analysed following analysis of co-variance taking respective pre count as covariate and the adjusted means were worked out.

Estimation of terminal residues of insecticides *viz.* lindane, endosulfan and chlorpyriphos in the harvested cowpea grains

The residue of insecticides present in cowpea grains extracted from the mature pods collected from plots receiving treatments *viz.,* lindane, endosulfan and chlorpyriphos were estimated in the Pesticide Residue Laboratory under AICRP at the College of Agriculture, Vellayani.

Endosulfan

Fifty gram cowpea grain sample was extracted with 150 ml of n-hexane isopropyl alcohol 2:1 v/v in a blender for 2 minutes and the extract was filtered. The extraction was repeated twice and the filtrate pooled. The fitrate was diluted with 100 ml of water and the aqueous layer removed. The n-hexane layer was dried over anhydrous Na_2SO_4. The n-hexane extract was concentrated and dissolved in 50 ml n-hexane acetone mixture (9:1). To this 0.5 g of Darco G-60 was added and allowed the flask to stand for one minute with occasional shaking. The extract was then filtered and washed the residue with 3x 15 ml n-hexane acetone mixture 9:1. The filtrate was concentrated and dissolved in hexane for GC analysis.

Lindane

Fifty gram cowpea grain sample was transferred into a blender with 100 ml acetone and blended for 2-3 minutes and filtered. The extraction was repeated twice and the filtrate was combined and concentrated. 100 ml of saturated NaCl was added to the concentrate and extracted with 3x50 ml of n-hexane. The hexane layer was mixed and transferred into 250 ml separating funnel. To this 10 ml of concentrated H_2SO_4 was added drop wise to remove the lower acid layer. The acid layer was discarded and the hexane layer was washed with distilled water (10 ml) till the washings were neutral to litmus. The hexane layer was concentrated and re- dissolved in n-hexane for estimation in a GC.

Chlorpyriphos

Fifty gram cowpea grain sample was blended with 200 ml acetone water mixture (8:2) and extracted with 210 ml of the solvent mixture by shaking for 30 and 15 minutes in a shaker. The extract was filtered and concentrated to about 50 ml. The concentrated extract was taken in a 500 ml separating funnel and diluted with 250 ml of 5% aqueous NaCl and partitioned into 150 and 50x100 ml hexane. The filtrate was collected over anhydrous Na_2SO_4 and concentrated to near dryness and taken in about 10 ml hexane.

A chromatographic column was packed with 5 g anhydrous Na_2 SO_4, 20 g silica gel and 10 g anhydrous Na_2 SO_4 bottom upward in glass column and pre washed with 50 ml hexane and the concentrated extract was eluted with 150 ml of 5% ethyl acetate in hexane. The elutant was concentrated and made up to 10 ml in hexane for estimation by GC.

Gas chromatographic parameters

Chlorphyriphos, endosulfan and lindane residues were estimated by gas liquid chromatograph using Chemito GC-8610 equipped with 63 Ni electron capture detector. The column used was 1.5% OV-17+ 1.95% QF-1 (2m length, glass, 2mm i.d). The flow rate of carrier gas (N_2) was 40 ml min^{-1} and the temperatures of column, injector port and detector were 210, 250 and 300°C, respectively. The average recovery of chlorpyriphos, endosulfan and lindane were 84.6, 89.7 and 86.5, respectively when spiked at 0.1 $\mu g\ g^{-1}$

3.5 Evaluation of various treatments of experiments on the incidence of pulse beetle *Callosobruchus* sp. in the store.

As the infestation of pulse beetle *Callosobruchus* sp. starts from the field, the influence of the previous treatments in experiment No. 3.4 on its incidence in store was estimated.

The experiment was done with cowpea grain samples from the 13 treatments replicated thrice in a Completely Randomized Design and observed for the incidence of pests.

Observations on weight loss of grains, percentage of grain damage, number of adult bruchids per sample and counts of other storage pests observed, if any were recorded at monthly intervals.

Two hundred gram each of the samples was kept in polythene covers wrapped by a rubber band. Weight loss was recorded by taking its weight at monthly intervals. Percentage of grains damaged was worked out by counting the number of grains damaged out of 20 randomly selected grains from the sample. The total number of adult bruchids per 200g sample was recorded. The counts of other storage pests like *Rhizopertha dominica*, *Laemophleus* spp. and

Oryzaephilus surinamensis were also recorded. The data was analysed after following necessary transformations.

3.6 Field testing of Integrated Pest Management package in cowpea through farmers' participation.

The effective treatments based on the results obtained from the experiments 3.1, 3.2, 3.3 and 3.4 along with the techniques proven effective under field conditions (T_1) were tested in farmers fields at 3 locations(L_1, L_2 and L_3) comparing with farmers' practices(T_0).

Proven techniques

1. Burning of trash
2. Selecting healthy seeds
3. Soil drenching with Bordeaux mixture 1per cent wherever fungal disease is prevalent
4. Clean cultivation
5. Treating the seeds with Rhizobium culture @ 250-375 g ha^{-1}
6. Need based application of *Fusarium pallidoroseum* @ 7×10^6 spores ml^{-1} for the management of pea aphid.

Results from the experiments

1. Mechanical and cultural control found effective in experiment No.3. 4
2. Collection and release of predators identified as the most effective from experiment No.3.2
3. Need based application of the most effective biorational insecticides selected from the experiment No. 3.3and 3.4.

Observations on items 1 to 7 under experiment No.4 were recorded at weekly intervals.

The data were tabulated and statistically analysed after necessary transformations (Das and Giri, 1986).

RESULTS

4. RESULTS

4.1 Survey of the pests of cowpea, their associated natural enemies and plant protection measures adopted by the farmers in the major cowpea-growing areas of Kerala.

4.1.1 Survey

A survey was conducted in the major cowpea growing tracts of Kerala covering the districts of Thiruvananthapuram, Alappuzha and Palakkad, during January to May 1999. Thirty fields each having an area not less than 0.5 acre of cowpea under cultivation were selected from each district for the present study. The survey was carried out based on a questionnaire prepared for the purpose (Appendix 1).

4.1.1.1 Information on varieties of cowpea grown by the farmers in Thiruvananthapuram, Alappuzha and Palakkad districts.

The information on varieties of cowpea grown by the farmers in each district is given in Table 4.

The survey revealed that, of the total area cultivated with cowpea in Thiruvananthapuram district, 54.5% was occupied by local varieties of grain cowpea

Table 4. Per cent number and area of cowpea used by the farmers during January to May 1999

Name of variety	Percentage of farmers and area							
	Thiruvanantha-puram		Alappuzha		Palakkad		Total	
	Farmers %	Area %	Farmers %	Area %	Farmers %	Area %	Farmers %	Area %
Local grain type	33.33	54.50	13.33	18.20	20.00	07.20	22.20	23.50
Local vegetable type	23.33	19.40	10.00	12.60	06.67	05.80	13.30	12.30
Vaijayanthi	00.00	00.00	00.00	00.00	06.67	07.20	02.20	05.00
Kanakamani	20.00	14.90	53.33	45.80	13.33	14.50	28.90	27.00
Krishnamony	10.00	04.50	00.00	00.00	06.67	02.90	05.60	02.00
Pournami	00.00	00.00	03.33	02.50	00.00	00.00	01.10	00.80
Malika	00.00	00.00	06.67	10.90	00.00	00.00	02.20	04.80
V-118	03.33	01.50	00.00	00.00	00.00	00.00	01.10	00.00
V-240	00.00	00.00	00.00	00.00	10.00	14.80	03.40	04.50
C-152	03.33	01.50	10.00	07.80	13.33	22.20	08.90	10.20
V-130	00.00	00.00	00.00	00.00	13.33	13.20	04.40	04.00
GC-3	00.00	00.00	00.00	00.00	10.00	12.10	03.40	03.70
CO-3	03.33	02.20	00.00	00.00	00.00	00.00	01.10	00.60
CO-4	03.33	01.50	00.00	00.00	00.00	00.00	01.10	00.40
CO-6	00.00	00.00	03.33	02.20	00.00	00.00	01.10	00.80
Total	100	100	100	100	100	100	100	100

cultivated by 33.33 % of the farmers. This was followed by the local vegetable type cowpea cultivated by 23.3 %of the farmers in 19.4% of the total area. The improved varieties released and recommended by the Kerala Agricultural University *viz.*, Kanakamani and Krishnamony were adopted by 20 and 10% of the farmers in 14.9 and 4.5% of the areas, respectively, whereas only 3.3% grew the improved varieties *viz.*, V-118, C-152, CO-3 and CO-4. None of the farmers in Thiruvananthapuram district cultivated Vaijayanthi, Pournami, Malika, V-240, V-130, GC-3 and CO-6.

Considering the preference of cowpea varieties by farmers in Alappuzha district, 53.33% of the farmers adopted Kanakamani. The local grain type cowpea was cultivated by 13.33% of the farmers, while local vegetable type cowpea and C-152 were cultivated each by 10% of the farmers. The variety, CO-6 was grown by 3.33% of the farmers, while the KAU varieties like Pournami and Malika were cultivated by 3.33 and 6.67% of the farmers, respectively. Of the total area surveyed in Alappuzha district, the variety Kanakamani ranked first in their area of cultivation (45.8%).

Regarding the varieties cultivated in Palakkad district, 20 % of the farmers preferred the local grain type cowpea. The KAU variety, Kanakamani ranked second with 13.3% adoption along with C-152 and V-130. Krishnamony, Vaijayanthi and local vegetable type cowpea were cultivated by 6.67% each of the farmers, while the varieties *viz.*, V-240 and GC-3 were grown by 10% each of the farmers. In Palakkad district, the improved variety, C-152 was cultivated in major portion (22.2%) of the area surveyed.

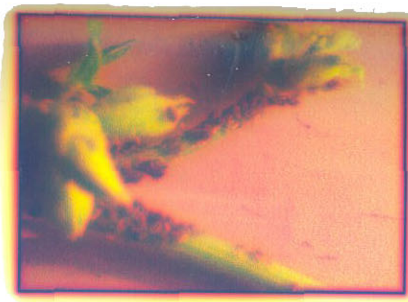
In general, the survey revealed that 64.4 % of the cowpea farmers in Kerala were found to cultivate improved varieties in 64.2% of the area and only 35.6 % cultivated local varieties (both grain and vegetable type) covering 35.8% of the total area.

4.1.1.2 Incidence of pests observed in the survey

The survey was conducted at two stages of crop growth *viz.* 20-25 DAS (early stage of crop growth) and 55-60 DAS (pod formation stage). During the early stages of crop growth, infestation by *A. craccivora, O. phaseoli* and *L. trifolii* were observed. Of the total 90 fields surveyed in the three districts, *A. craccivora* was the major one having infestation in 88.8% of the fields. *O. phaseoli* was the second major one observed in 27.8 % of the fields, followed by *L. trifolii* with 26.7% infestation (Table 5).

During pod formation stage of the crop, pod borer infestation was noticed in 81.1 % of the fields followed by pod bugs in 73.3 % of the fields. The population of *A. craccivora* was recorded in 72.2% of the fields.

There was not any significant variation in the population of these pests between different districts, both during 20-25 DAS and 55-60 DAS (Appendix IIa and IIb).

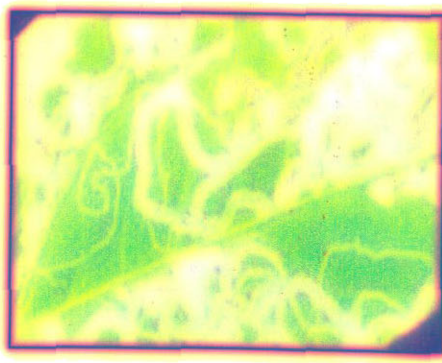

A. craccivora


O. phaseoli-adult


O. phaseoli-damage


A. misera - adult


L. trifolii-adult


L. trifolii- damage


R. pedestris

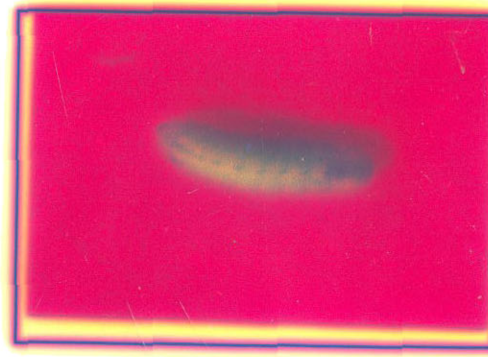

L. boeticus larva

Plate 1. Pests incidence / damage in cowpea

Table 5. Mean number and percentage of major pests observed in cowpea fields of Thiruvananthapuram, Alappuzha and Palakkad districts

Stage of the crop	Name of Pest	Number of plots having infestation (out of 30 plots)			Total (out of 90 plots)	Percentage
		Thiruvananth-apuram	Alappuzha	Palakkad		
20-25 DAS	*A. craccivora*	25	28	27	80	88.8
	O. phaseoli	03	11	11	25	27.8
	L. trifolii	06	07	11	24	26.7
60 DAS	*A. craccivora*	21	22	22	65	72.2
	Pod borers	27	30	16	73	81.1
	Pod bugs	18	25	23	66	73.3

a. Thiruvananthapuram

Data on the intensity of incidence of pests in cowpea fields in Thiruvananthapuram district are presented in Table 6.

20-25 DAS

The incidence of *A. craccivora* was observed in 83.3 % of the fields surveyed. The degree of infestation was low in 46.7 % of the fields, medium in 33.3% and severe in 3.3 % of the fields, respectively. No infestation was recorded in 16.7 % of the fields.

In the case of infestation by *O. phaseoli,* 90 % of the fields were free of damage. However, low level of infestation was observed in 6.7 % of the fields and medium in 3.3%. None of the fields showed severe infestation. In the case of *L. trifolii*, 80% of the fields were free of infestation, while 10% each recorded low and medium infestation.

The symptom of damage by the epilachna beetle, *A. misera*. was observed only in 3.3% of the fields. Low population of adult beetles (1- 2.5 adults per 5 sweeps) could be observed in 6.7% of the fields. Low incidence of *A. pilosum* and leaf webber were observed in 3.3 and 6.7% of the fields, respectively.

55-60 DAS

Observation on the pest incidence at pod formation stage of cowpea in Thiruvananthapuram district indicated low occurrence of *A. craccivora* in 36.7% of

Table 6. Intensity (percentage) of cowpea pests in farmers fields of Thiruvananthapuram district

Pest / damage	20-25 DAS				60 DAS			
	Nil	Low	Medium	Severe	Nil	Low	Medium	Severe
A. craccivora (No. / top 2.5 cm shoot)	16.7	46.7	33.3	3.3	29.9	36.7	26.7	6.7
O. phaseoli (% incidence)	90.0	6.7	3.3	0.0	-	-	-	-
L. trifolii (% incidence)	80.0	10.0	10.0	0.0	-	-	-	-
A. misera damage (% incidence)	96.7	3.3	0.0	0.0	93.4	6.7	0.0	0.0
A. misera (No. of adults /5 sweeps)	93.4	6.7	0.0	0.0	96.7	3.3	0.0	0.0
Pod borer damage (% incidence)	-	-	-	-	10.0	53.3	30.0	6.7
Pod bugs (No. /5 sweeps)	-	-	-	-	40.1	33.3	23.3	3.3
N. viridula (No.of adults / 5 sweeps)	-	-	-	-	96.7	3.3	0.0	0.0
L. boeticus (No.of adults /5 sweeps)	-	-	-	-	93.3	6.7	0.0	0.0
A. pilosum (No. of adults /5 sweeps)	96.7	3.3	0.0	0.0	-	-	-	-
Leaf webber damage (%incidence)	93.3	6.7	0.0	0.0	-	-	-	-

A. craccivora (No./top 2.5 cm shoot)
Nil – 0
Low – 0-25
Medium – 25-50
Severe – >50

Pod borers, *L. trifolii*, *A. misera* ,*O.phaseoli* leaf webber (%damage)
Nil – 0
Low – 1-25%
Medium – 25-50%
Severe – >50%

A. misera, Pod bugs *N.viridula, A. pilosum,L. boeticus* (No.of adults /5 sweeps)
Nil – 0
Low – 1-2.5
Medium – 2.5-5
Severe – >5

Hairy caterpillar (No. of larvae/*5plants)*
Nil – 0
Low – 1-2.5
Medium – 2.5-5
Severe – >5

the fields, while medium and severe incidence were observed in 26.7 and 6.7% of the fields, respectively.

In 53.3% of the fields, low infestation of pod borers was recorded. Medium and severe infestation were observed in 30 and 6.7% of the fields, respectively. Ten per cent of the plots were free of pod borer attack. Pod bugs were observed in 33.3% of the fields in low intensity, 23.3% with medium and 3.3% severe intensities.

Only very low population of adult *A. misera* (3.3%), *L. boeticus* (6.7%) and *N. viridula* (3.3%) were observed at pod bearing stage of cowpea. Though the incidence of *O. phaseoli*, *L. trifolii* and *A. pilosum* and damage by leaf webber were observed at 20-25 DAS, no infestation was recorded at 60 DAS.

Observations on the incidence of pests of cowpea in Alappuzha district are shown in Table 7

b. Alappuzha

20 - 25 DAS

At 20-25 DAS, 33.3% of the fields recorded low incidence of *A. craccivora*, whereas medium and severe incidence were recorded in 50% and 10% of the fields, respectively. However, low and medium infestation by *O. phaseoli* alone was observed in 16.7% and 20% of the fields, respectively. No infestation was recorded in 6.7% of the fields. As in the case of *O. phaseoli*, none of

Table 7. Intensity (percentage) of cowpea pests in farmers fields of Alappuzha district

Pest / damage	20-25 DAS				60 DAS			
	Nil	Low	Medium	Severe	Nil	Low	Medium	Severe
A. craccivora (No. / top 2.5 cm shoot)	6.7	33.3	50.0	10.0	26.7	26.7	33.3	13.3
O. phaseoli (% incidence)	63.3	16.7	20.0	0.0	-	-	-	-
L. trifolii (% incidence)	76.6	16.7	6.7	0.0	-	-	-	-
A. misera damage (% incidence)	-	-	-	-	96.7	3.3	0.0	0.0
Pod borer damage (% incidence)	-	-	-	-	0.0	43.3	46.7	10.0
Pod bugs (No. /5 sweeps)	-	-	-	-	16.6	30.0	46.7	6.7
L. boeticus (No.of adults /5 sweeps)	-	-	-	-	83.3	16.7	0.0	0.0
Leaf webber damage (%incidence)	93.3	0.0	6.7	0.0	-	-	-	-
Hairy caterpillar (No. per 5 plants)	93.3	0.0	6.7	0.0	96.7	0.0	3.3	0.0

A.craccivora (No./top 2.5 cm shoot)		pod borers, *L.trifolii*, *A. misera* ., *O.phaseoli* leaf webber (%damage)		Pod bugs, *L.boeticus* (No.of adults /5 sweeps)		Hairy caterpillar (No. of larvae/5plants)	
Nil –	0	Nil –	0	Nil –	0	Nil –	0
Low –	0-25	Low –	1-25%	Low –	1-2.5	Low –	1-2.5
Medium –	25-50	Medium –	25-50%	Medium –	2.5-5	Medium –	2.5-5
Severe–	>50	Severe	>50%	Severe –	>5	Severe –	>5

the fields recorded severe infestation by *L. trifolii*. Low infestation was observed in 16.7% of the fields while only 6.7% of the fields were having medium infestation.

In 6.7% of the fields, infestation by hairy caterpillar was observed with medium intensity. Similarly, 6.7% of the fields exhibited infestation by leaf webber (*N. vulgalis)* in medium intensity.

55-60 DAS

Of the 30 fields surveyed, 73.3% showed incidence of *A. craccivora*. The infestation was severe in 13.3 %, medium in 33.3% and low in 26.7% of the fields.

Cent percent of the cowpea fields in Alappuzha district were affected by pod borer pests, of which 43.3, 46.7 and 10% of the fields recorded low, medium and severe infestation, respectively. Incidence of pod bugs was not recorded in 16.6% of the fields, while 30% of the fields recorded low incidence, 46.7% medium and 6.7% severe incidence.

Damage by *A. misera* was observed only in 3.3% of the fields, that too in low intensity. Medium incidence of hairy caterpillars was recorded in 3.3% of the fields.

c. Palakkad

The results of similar study conducted in Palakkad district are presented in Table 8.

Table 8. Intensity (percentage) of cowpea pests in farmers fields of Palakkad district

Pest / damage	20-25 DAS				55-60 DAS			
	Nil	Low	Medium	Severe	Nil	Low	Medium	Severe
A.craccivora (No. / top 2.5 cm shoot)	10.0	40.0	33.3	6.7	26.7	13.3	46.7	13.3
O.phaseoli (% incidence)	63.3	30.0	6.7	0.0	-	-	-	-
L.trifolii (% incidence)	63.3	30.0	6.7	0.0	-	-	-	-
Pod borer damage (% incidence)	-	-	-	-	46.7	40.0	13.3	0.0
Pod bugs (No. / 5 sweeps)	-	-	-	-	23.4	23.3	50.0	3.3
N.viridula (No.of adults / 5 sweeps)	-	-	-	-	93.3	3.3	3.3	0.0
L.boeticus (No.of adults /5 sweeps)	-	-	-	-	70.0	16.7	3.3	0.0
A.pilosum (No. of adults /5 sweeps)	-	-	-	-	93.3	3.3	3.3	0.0
Leaf webber damage (%incidence)	96.7	3.3	0.0	0.0	-	-	-	-
Hairy caterpillar (No. per 5 plants)	96.7	0.0	3.3	0.0	-	-	-	-

A.craccivora (No./top 2.5 cm shoot)		Pod borers, *L.trifolii*, *O.phaseoli* Leaf webber (%damage)		Pod bugs, *N.viridula* *A.pilosum*, *L.boeticus* (No.of adults /5 sweeps)		Hairy caterpillar (No. of larvae/5 plants)	
N il-	0	Nil	0	Nil-	0	Nil-	0
Low-	0-25	Low	1-25%	Low-	1-2.5	Low-	1-2.5
Medium -	25-50	Medium-	25-50%	Medium-	2.5-5	Medium-	2.5-5
Severe-	>5	Severe	>50%	Severe-	>5	Severe-	>5

20-25 DAS

Aphid infestation was noticed in majority of the fields surveyed (90%) at varying levels. Forty per cent of the fields recorded low incidence of *A. craccivora*, 33.3% with medium and 6.7% with severe incidence. The degree of infestation by *L. trifolii* and *O. phaseoli* was similar. Thus, 63.3% of the fields were free of infestation. Thirty per cent of the fields had low infestation and 6.7% recorded medium infestation. None of the plots recorded severe incidence.

In the case of leaf webber damage, 3.3% of the fields exhibited infestation in low intensity. Medium population of hairy caterpillars (2.5-5 larvae per five plants) was recorded in 3.3% of the fields.

55-60 DAS

As in the seedling stage, wide spread occurrence of *A. craccivora* was observed. Thus 13.3% each of the fields recorded severe and low intensity, while 46.7% recorded medium infestation.

No infestation of pod borer was observed in 46.7% of the fields whereas 40% of the fields harboured low incidence and 13.3% medium infestation. As in the case of aphids, pod bug incidence was also wide spread. Thus 23.3% of the fields recorded low incidence, 50% medium, and 3.3% severe incidence. Low and medium incidence of *N. viridula* and *A. pilosum* were observed in 3.3 % each of the cowpea fields, respectively.

4.1.1.3. Incidence of natural enemies associated with cowpea pests in farmer's fields

The incidence of natural enemies associated with pests of cowpea in farmers fields of the three districts were recorded during two growth stages *viz*., 20-25 DAS and 55-60 DAS. The predominance of natural enemies were categorized into four groups *viz.* no incidence, low, medium and high with a score of 0, 1, 2 and 3 ,respectively.

Grubs and adults of coccinellids were observed to be the predominant predators in aphid colonies. Among them, *M. sexmaculatus* and *C. transversalis* were the major ones followed by *Coccinella* spp. *Micraspis* sp. and *Scymnus* sp., The syrphid, *I. scutellare*, dragonflies, damselflies, *Paederus* sp., *Ophionea* sp. and spiders (*Oxyopes* sp., *Lycosa* sp. and *Argiope* sp.) were the other predators.

a. Thiruvananthapuram

Data on the incidence of natural enemies associated with the pests of cowpea in Thiruvananthapuram district are presented in Table 9.

20-25 DAS

At seedling stage, the adult beetles of *Coccinella* spp. were observed in 13.3% of the fields at low intensity. In 3.3% of the fields, the beetles were seen in medium intensity, while its grubs were observed in 13.3% of the fields at medium intensity. Low intensity of both adults and grubs of *M. sexmaculatus* were observed in 10% and 6.7% of the fields, respectively. Medium incidence of adults and grubs

3rd instar grub

Pupa

Adult

Plate 2. *C.transversalis* - Coccinellid predator of *A. craccivora*

3rd instar grub and egg

Pupa

Adult

Plate 3. *M.sexmaculatus* - Coccinellid predator of *A. craccivora*

Table 9. Intensity (Percentage) of natural enemy population of cowpea pests in Thiruvananthapuram district

Pest / damage	20-25 DAS				55-60 DAS			
	Nil	Low	Medium	High	Nil	Low	Medium	High
Coccinella spp. (adult)	83.3	13.3	3.3	0.0	76.7	13.3	10.0	0.0
Coccinella spp. (grub)	86.7	0.0	13.3	0.0	86.7	3.3	10.0	0.0
M.sexmaculatus (adult)	80.0	10.0	6.7	3.3	90.0	6.7	3.3	0.0
M.sexmaculatus (grub)	83.3	6.7	10.0	0.0	93.4	3.3	3.3	0.0
Micraspis sp. (adult)	76.7	20.0	3.3	0.0	80.0	16.7	3.3	0.0
Micraspis sp. (grub)	93.4	3.3	3.3	0.0	100.0	0.0	0.0	0.0
Scymnus sp. (adult)	93.3	6.7	0.0	0.0	90.0	10.0	0.0	0.0
Scymnus sp. (grub)	86.7	0.0	13.3	0.0	73.3	3.3	16.7	6.7
I.scutellare (adult)	96.7	3.3	0.0	0.0	96.7	3.3	0.0	0.0
I.scutellare (maggot)	83.3	6.7	6.7	3.3	80.0	6.7	13.3	0.0
Dragon flies (adults)	93.3	6.7	0.0	0.0	93.3	6.7	0.0	0.0
Damsel flies (adult)	86.7	10.0	3.3	0.0	86.7	13.3	0.0	0.0
Paederus sp.	93.4	3.3	3.3	0.0	100.0	0.0	0.0	0.0
Gryllids	93.3	6.7	0.0	0.0	100.0	0.0	0.0	0.0
Parasitised larvae	93.3	6.7	0.0	0.0	100.0	0.0	0.0	0.0
Spiders	83.4	13.3	3.3	0.0	80.0	20.0	0.0	0.0

Predator grubs/maggots
(No. per plant)
Nil – 0
Low – 1- 1.25
Medium = 2.5 - 5
High - >5

Adults of predator
(No. per 5 sweeps)
Nil – 0
Low – 1 - 2.5
Medium- 2.5 - 5
High- >5

were observed in 6.7% and 10% of the fields respectively, while the adults alone were present in high intensity (3.3%).

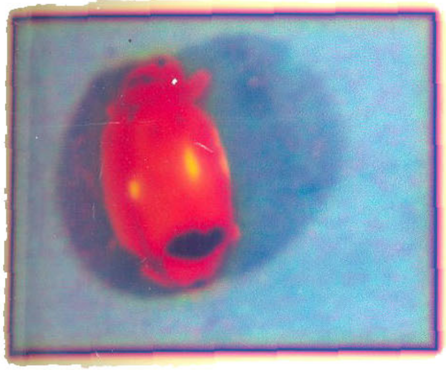
Regarding the incidence of adults of *Micraspis* sp., 20% of the fields recorded low and 3.3 % medium incidence, while the population of grubs was observed in 3.3% each of the fields with low and medium intensity. The adults of the coccinellid, *Scymnus* sp., were present in 6.7% of the fields in low levels, while the grub population was medium in 13.3% of the fields.

In the case of syrphid *I. scutellare,* the maggots of which feed on *A. craccivora,* 6.7% each of the fields recorded low and medium population, while high population was observed only in 3.3 % of the fields.

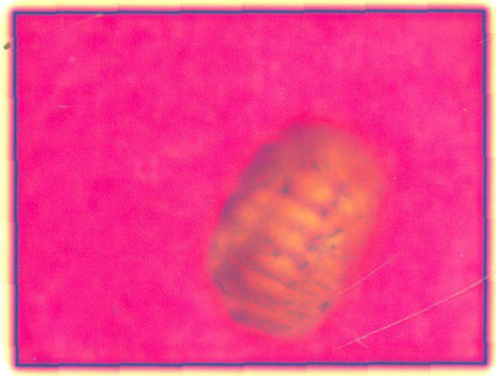
The other predators present in the field included dragon flies (low-6.7%), damsel flies (low-10% and medium-3.3%), *Paederus* sp. (low-3.3% and medium-3.3%), gryllids (low-6.7%) and spiders (low-13.3% and medium-3.3%). Parasitised lepidopteran larvae were present in 6.7% of the fields in low intensities.

55-60 DAS

At pod formation stage, low incidence of both the adults and grubs of *Coccinella* spp. were observed in 13.3 and 3.3% of the fields, respectively, while medium incidence was observed in 10% each of the fields. The adults of

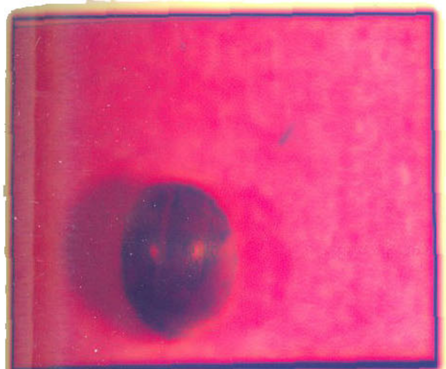


Adult



Pupa

H. octumaculata



Adult

Grub

Scymnus sp.

Micraspics discolor complex.

Brumoides suturalis

Plate 4. Predators associated with pests of cowpea

M. sexmaculatus were present at low and medium intensities in 6.7 and 3.3% of the fields respectively, while its grubs were present in 3.3% each at low and medium intensities.

In the case of *Micraspis* sp., the adults alone were present. Low incidence was recorded in 16.7% of the fields, while medium incidence was observed in 3.3%. Low population of the adults of *Scymnus* sp. were observed in 10% of the fields while the grubs present in 3.3, 16.7 and 6.7% of the fields at low, medium and high intensities, respectively.

The maggots of *I. scutellare* were recorded in 6.7 and 13.3% of the fields at low and medium intensities, respectively. Low population of spiders in 20%, dragonflies in 6.7% and damselflies in 13.3% of the fields were also observed at pod formation stage of the crop.

b Alappuzha

The relevant results of natural enemy incidence at Alappuzha district are shown in Table 10.

20-25 DAS

The coccinellid, *M. sexmaculatus* was the predominant predator at seedling stage. The adults were present at low, medium and high intensities in 23.3, 26.7 and 3.3% of the fields, respectively whereas its grubs were present in 6.7%, 33.3% and 6.7% of the fields at low, medium and high intensities respectively. The adult beetles of *Coccinella* spp. were present in 3.3 and 10% of the fields in low and medium intensities respectively, while its grubs were observed only in 3.3% of the fields, in medium intensity.

Table 10. Percentage of natural enemy population of cowpea pests in Alappuzha district

Pest / damage	20-25 DAS				55-60 DAS			
	Nil	Low	Medium	High	Nil	Low	Medium	High
Coccinella spp.(adult)	86.7	3.3	10.0	0.0	80.0	6.7	10.0	3.3
Coccinella spp. (grub)	96.7	0.0	3.3	0.0	83.3	0.0	16.7	0.0
M.sexmaculatus (adult)	46.7	23.3	26.7	3.3	70.0	13.3	16.7	0.0
M.sexmaculatus (grub)	53.3	6.7	33.3	6.7	76.7	3.3	16.7	3.3
Micraspis sp. (adult)	80.0	13.3	6.7	0.0	93.3	6.7	0.0	0.0
Micraspis sp. (grub)	93.3	0.0	6.7	0.0	100.0	0.0	0.0	0.0
Scymnus sp.(adult)	93.4	0.0	3.3	3.3	90.0	6.7	3.3	0.0
Scymnus sp.(grub)	86.7	0.0	3.3	10.0	80.0	0.0	13.3	6.7
I.scutellare (adult)	96.7	3.3	0.0	0.0	100.0	0.0	0.0	0.0
I.scutellare (maggot)	93.3	0.0	0.0	6.7	73.3	3.3	16.7	6.7
Dragon flies (adults)	90.0	10.0	0.0	0.0	90.0	10.0	0.0	0.0
Damsel flies (adult)	90.0	10.0	0.0	0.0	83.3	16.7	0.0	0.0
Chrysoperla sp. (adult)	100.0	0.0	0.0	0.0	93.3	6.7	0.0	0.0
Paederus sp.	96.7	3.3	0.0	0.0	83.3	16.7	0.0	0.0
Ophionia sp.	100.0	0.0	0.0	0.0	93.3	6.7	0.0	0.0
Gryllids	93.7	6.7	0.0	0.0	96.7	3.3	0.0	0.0
Parasitised larvae	100.0	0.0	0.0	0.0	93.3	6.7	0.0	0.0
Parsitic wasp	100.0	0.0	0.0	0.0	93.3	6.7	0.0	0.0
Spiders	86.7	13.3	0.0	0.0	86.7	13.3	0.0	0.0

Predator grubs/maggot
(No. per plant)
Nil – 0
Low – 1- 1.25
Medium – 2.5 - 5
High – >5

Adults of predator
(No. per 5 sweeps)
Nil – 0
Low – 1 - 2.5
Medium – 2.5 - 5
High– >5

The population of adults of *Micraspis* sp. was observed in low and medium intensities in 13.3 and 6.7% of the fields, respectively while grubs were present only in 6.7% of the fields in medium intensities. The adults and grubs of *Scymnus* sp. were observed at high intensity in 3.3 and 10% of the fields respectively. High incidence of the maggots of *I. scutellare* was recorded in 6.7% of the fields. Dragonflies, damselflies, *Paederus* sp., gryllids and spiders were present only at low intensity in 10.0, 10.0, 3.3, 6.7 and 13.3% of the fields, respectively.

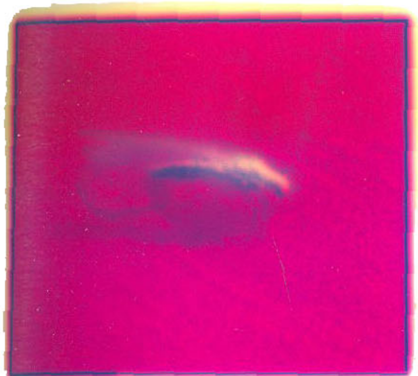
55-60 DAS

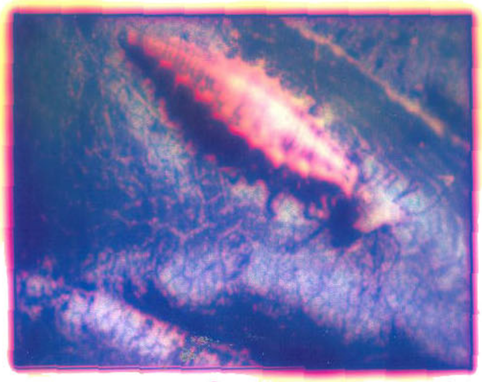
At pod formation stage, *Coccinella* spp. adults were observed in 6.7, 10 and 3.3% of the fields in low, medium and high intensities respectively, while only medium incidence of the grubs were observed in 16.7% of the fields. The adults of *M. sexmaculatus* were present in 13.3 and 16.7% of the fields at low and medium intensities whereas the grubs were present in 3.3, 16.7 and 3.3% of the fields at low, medium and high intensities, respectively.

Regarding the incidence of *Micraspis* sp., the adult beetles alone were present that too in low intensity in 6.7% of the fields. Adults of *Scymnus* sp. were present at low and medium intensities in 6.7 and 3.3% of the fields, while its grubs were present in 13.3% and 6.7% of the fields at medium and high intensities. There was a high incidence of the grubs of *I. scutellare* in 6.7% of the fields and low and medium incidence in 3.3 and 16.7% of the fields, respectively.

Maggot Pupa

I. scutellare

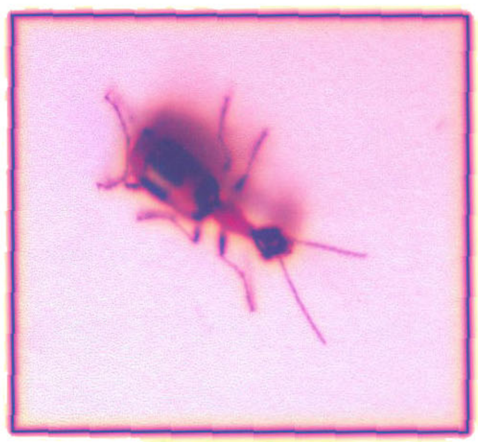




Adult Larva

C. carnea

Paederus sp.



O. nigrofaciata

Plate 5. Predators associated with pests of cowpea

All the other predators *viz.* dragon flies, damsel flies, *C.carnea*. *Paederus* sp., *Ophionea* sp. and *gryllids* as well as parasitised larvae of lepidopterans, parasitic wasps and spiders were present in low intensities only.

c. Palakkad

The results on the survey of natural enemies associated with cowpea pests in Palakkad district are shown in Table 11.

20-25 DAS

At seedling stage, the adults of the most predominant predator *Coccinella* spp. were observed at low and medium intensities in 20 and 13.3% of the fields, while high and medium incidence of grubs were recorded in 6.7 and 26.7% of the fields respectively. The adults of *M. sexmaculatus* were present in 10% each of the fields in low and medium intensities, while medium and high incidence of grubs was recorded in 13.3 and 6.7% of the fields, respectively.

In the case of *Micraspis* sp., the adult beetles were observed in 10% each of the fields in low and medium intensities, while only 3.3% of the fields recorded high intensity. In the case of grubs, none of the fields recorded low incidence while 3.3% each recorded medium and high incidence. The observation on *Scymnus* sp. revealed that, the adult beetles were present in 3.3% each of the fields in low and medium intensities whereas the grubs were observed at medium intensity in 10% of the fields.

Table 11. Percentage of natural enemy population of cowpea pests in Palakkad district

Pest / damage	20-25 DAS				55-60 DAS			
	Nil	Low	Medium	High	Nil	Low	Medium	High
Coccinella spp. (adult)	76.7	20.0	13.3	0.0	86.6	6.7	10.0	6.7
Coccinella spp. (grubs)	66.7	0.0	26.6	6.7	70.0	6.7	20.0	3.3
M.sexmaculatus (adult)	80.0	10.0	10.0	0.0	76.6	16.7	6.7	0.0
M.sexmaculatus (grubs)	80.0	0.0	13.3	6.7	90.1	3.3	3.3	3.3
Micraspis sp. (adult)	76.7	10.0	10.0	3.3	73.3	10.0	16.7	0.0
Micraspis sp. (grubs)	93.4	0.0	3.3	3.3	100.0	0.0	0.0	0.0
Scymnus sp. (adult)	93.4	3.3	3.3	0.0	83.3	10.0	6.7	0.0
Scymnus sp. (grubs)	90.0	0.0	10.0	0.0	83.3	3.3	6.7	0.0
I.scutellare (adult)	96.7	0.0	3.3	0.0	100.0	0.0	0.0	0.0
I.scutellare (maggots)	100.0	0.0	0.0	0.0	76.6	10.0	6.7	6.7
Dragonflies (adults)	93.3	6.7	0.0	0.0	90.0	10.0	0.0	0.0
Damselflies (adult)	93.3	6.7	0.0	0.0	83.3	16.7	0.0	0.0
Chrysoperla sp.(adult)	100.0	0.0	0.0	0.0	93.3	6.7	0.0	0.0
Paederus sp.	96.7	3.3	0.0	0.0	76.6	16.7	6.7	0.0
Ophionea sp.	93.3	6.7	0.0	0.0	90.0	6.7	3.3	0.0
Gryllids	100.0	0.0	0.0	0.0	96.7	0.0	3.3	0.0
Parasitised larvae	100.0	0.0	0.0	0.0	90.0	10.0	0.0	0.0
Parasitic wasp	100.0	0.0	0.0	0.0	96.7	0.0	3.3	0.0
Spiders	86.7	13.3	0.0	0.0	86.7	13.3	0.0	0.0

Predator grubs/maggots
(No. per plant)
Nil – 0
Low – 1- 1.25
Medium – 2.5 - 5
High – >5

Adults of predator
(No. per sweeps)
Nil – 0
Low – 1 - 2.5
Medium – 2.5 - 5
High – >5

Dragonflies, damselflies, and *Ophionea* sp. were present only in low intensities in 6.7% each of the fields while *Paederus* sp. was recorded in 3.3% only. However, spiders were recorded in 13.3% of the fields in low intensities.

55-60 DAS

At pod formation stage, the adult beetles of *Coccinella* sp. were observed at low, medium and high intensities in 6.7, 10 and 6.7% of the fields, while the grubs were seen in 6.7, 20 and 3.3% of the fields at low, medium and high intensities, respectively. In 16.7% of the fields, the adults of *M. sexmaculatus* were recorded at low intensity while 6.7% of the fields recorded medium incidence. The grubs of *M. sexmaculatus* were recorded in low, medium and high intensities in 3.3% each of the fields.

Adults of *Micraspis* sp. could be observed in low and medium intensities in 10 and 16.7% of the fields, respectively. Low incidence of adults of *Scymnus* sp. was observed in 10% of the fields, while low incidence of its grubs recorded in 3.3 % of fields. The maggots of *I. scutellare* were recorded at low intensities in 10% of the fields, whereas 6.7% each of the fields recorded medium and high incidence.

The other predators *viz.,* dragonflies, damselflies, *Chrysoperla carnea.,* *Paederus* sp. and *Ophionea* sp. occurred in 10, 16.7, 6.7, 16.7 and 6.7% of the fields, respectively in low intensities. Medium incidence of *Paederus* sp. could be observed in 6.7% of the fields, while only 3.3% each of the fields recorded medium incidence of *Ophionea* sp. and gryllids.

4.1.1.4 Incidence of pests and natural enemies in the unprotected cowpea field

Observations on the pests of cowpea and their natural enemies recorded from the unsprayed fields of ORARS Kayamkulam during the summer seasons of 1999 and 2000 are presented in table 12.

The population of *A. craccivora* was found to increase gradually and reached its peak during 59 DAS with a mean number of 300 and 158.52 in the first and second seasons respectively. Similarly, the mean percentage of damage by *A. misera*. also increased gradually and reached the maximum at 59 DAS, the values being 52.55 and 16.81% in the first and second seasons, respectively.

As in the case of *A. craccivora* and *A. misera*. the mean percentage of pod borer infestation has also reached its peak at 59 DAS with 56.67 and 46.00% damage in the first and second seasons respectively. Unlike the other pests, the pod bug population reached its peak at 68 DAS, the mean number per 5 sweeps being 1.67 and 2.31 in the first and second seasons, respectively.

The population level of the major predators *viz., Coccinella* spp., *M. sexmaculatus* and *I. scutellare* was initially high at 45 DAS, then it decreased and again increased at 59 DAS. At 68 DAS, the population again decreased.

Table12. Major pest incidence and natural enemy population in cowpea in the summer seasons of 1999 and 2000

Pests/natural enemies	Mean per cent damage/population									
	Season 1					Season 2				
	45DAS	52DAS	59DAS	68DAS	76DAS	45DAS	52DAS	59DAS	68DAS	76DAS
pests										
A.craccivora (No. per top 2.5cm shoot)	100.60	88.30	300.00	85.44	37.68	72.30	20.62	158.52	31.79	16.80
A. misera (% of damaged leaves)	32.97	11.67	52.55	37.05	2.31	12.67	8.61	16.81	6.43	0.00
Pod borers (% of pod damage)	0.00	12.10	56.67	12.18	2.31	0.00	8.00	46.00	13.90	2.72
Pod bugs (No. per 5sweeps)	0.33	1.00	1.30	1.60	1.00	0.67	0.67	1.67	2.31	1.45
Natural enemies										
Coccinella spp adults. (No. per 5 sweeps).	1.67	0.33	0.67	0.33	0.00	2.33	1.93	1.37	0.57	0.33
Coccinella spp. grubs (No. per plant)	5.67	0.32	1.13	1.61	2.07	4.00	1.56	2.50	1.53	0.47
M.sexmacu-Latus adults(No.per 5 sweeps)	3.67	0.67	2.67	0.33	0.00	1.30	0.00	2.67	1.33	0.67
M.sexmacu-latus grubs (No. per plant)	0.33	1.33	6,33	1.40	2.04	0.00	0.67	7.00	2.20	1.69
I.scutellare maggots (No.per plant)	1.00	0.00	0.67	0.33	0.67	0.00	0.67	0.67	0.00	0.67

Thus, it can be concluded that the predator population increases with the increase in population density of the prey, *A. craccivora* (Fig.4.)

4.1.1.5 Plant protection measures adopted by the farmers in Kerala

The data on the preference of plant protection measures followed by cowpea growing farmers of Thiruvananthapuram, Alappuzha and Palakkad districts are given in Table 13.

At 20-25 DAS, 82.2% of the farmers adopted plant protection measures, whereas only 74.1% adopted the same at 55-60 DAS.

Considering the type of plant protection measures adopted, 40.0 and 38.7% of the farmers used synthetic chemical pesticides at 20-25 and 55- 60 DAS, respectively. Botanical pesticides were used by 28.9% of the farmers at 20-25 DAS and 33.3% at 55-60 DAS. The other plant protection measures like mechanical and cultural methods were adopted by 13.3 and 2.2% of the farmers at 20-25 and 55-60 DAS, respectively.

Of all the plant protection measures adopted, majority of the farmers used neem oil at 20-25 and 55- 60 DAS, the corresponding percentage being 14.5 and 15.6. Among the chemical pesticides used, carbaryl ranked first both at 20-25 (11.1%) and 55- 60 DAS (13.3%).

Table 13. Number and percentage of plant protection practices followed by cowpea growing farmers in Thiruvananthapuram, Alappuzha and Palakkad districts

Pesticide/Practice	Thiruvananthapuram (30)				Alapuzha (30)				Palakkad (30)				Total (90 farmers)			
	20-25 DAS		60 DAS		20-25 DAS		60 DAS		20-25 DAS		60 DAS		20-25 DAS		60 DAS	
	No.	Percen-tage	No.	Percen-tage	No.	Percentage	No.	Percen-tage	No.	Percen-tage	No.	Percen-tage	No.	Percen-tage	No.	Percen-tage
HCH	-	-	1	3.3	-	-	-	-	-	-	-	-	-	-	1	1.1
Monocrot-ophos	4	13.3	1	3.3	3	10.0	2	6.7	1	3.3	-	-	8	8.9	3	3.3
DDVP	2	6.7	3	10.0	1	3.3	-	-	-	-	1	3.3	3	3.3	4	4.4
Malathion	1	3.3	3	10.0	-	-	-	-	-	-	1	3.3	1	1.1	4	4.4
Methyl parathion	-	-	-	-	-	-	-	-	1	3.3	1	3.3	1	1.1	1	1.1
Chlorpyriphos	-	-	-	-	1	3.3	-	-	-	-	-	-	1	1.1	-	-
Quinalphos	1	3.3	3	10.0	-	-	1	3.3	2	6.7	2	6.7	3	3.3	6	6.7
Phosphamidon	-	-	-	-	-	-	-	-	4	13.3	1	3.3	4	4.4	1	1.1
Carbaryl	-	-	3	10.0	3	10.0	4	13.3	7	23.3	5	16.7	10	11.1	12	13.3
Carbofuran	1	3.3	1	3.3	2	6.7	1	3.3	2	6.7	1	3.3	5	5.5	3	3.3
Total	9	29.9	15	49.9	10	33.3	8	26.6	17	56.6	12	39.9	36	40.0	35	38.7
Neem oil	4	13.3	3	10.0	4	13.3	6	20.0	5	16.7	5	167	13	14.5	14	15.6
Nimbecidine	-	-	2	6.7	-	-	1	3.3	-	-	-	-	-	-	3	3.3
Neem seed kernal Extract	-	-	-	-	4	13.3	5	16.7	1	3.3	-	-	3	3.3	5	5.5
Neem gold	-	-	-	-	-	-	-	-	-	-	1	3.3	-	-	1	1.1
Neem leaf extract	-	-	-	-	-	-	-	-	1	3.3	1	3.3	1	1.1	1	1.1
Tobacco decoction	2	6.7	2	6.7	8	26.7	1	3.3	1	3.3	-	-	8	8.9	3	3.3
Hyptis sauveolens emulsion	-	-	-	-	1	3.3	-	-	-	-	-	-	1	1.1	-	-
Garlic extract	-	-	1	3.3	-	-	2	6.7	-	-	-	-	-	-	3	3.3
Total													26	28.9	30	33.3
Dry leaf ash	2	6.7	-	-	4	13.3	-	-	1	3.3	2	6.7	7	7.8	2	2.2
Cattle urine spray	-	-	-	-	1	3.3	-	-	-	-	-	-	1	1.1	-	-
Total	8	26.7	8	26.7	22	79.9	15	50	9	29.9	9	30	39	43.3	32	35.4
Mechanical control	2	6.7	-	-	2	6.7	-	-	-	-	-	-	4	4.4	-	-
Total													12	13.3	2	2.2
Grand Total	19	63.3	23	76.7	29	96.7	23	76.7	26	86.7	21	70.0	74	82.2	67	74.1

Among the different classes of pesticides, majority of the farmers used organophosphates followed by carbamates. Of the plant protection measures adopted, 23.3 and 21.1% of the farmers used organophosphorous compounds at 20-25 and 55-60 DAS, respectively and carbamates by 16.7 each of the farmers both at 20-25 and 55-60 DAS (Table 14). At early stage of the crop, 45.6% of the farmers used contact insecticides like DDVP, malathion, methyl parathion, quinalphos and carbaryl, whereas only 14.4% of the farmers used systemic insecticides like monocrotophos, phosphamidon and carbofuran. Only 13.3% of the farmers used contact as well as systemic insecticides (Table 15a). At pod formation stage, 53.3% of the farmers used contact insecticides and 6.7% used systemic insecticides, while 14.4% of the farmers used contact as well as systemic insecticides (Table 15b). No chemical or botanical pesticides were used by 26.7 and 25.6% of the farmers during seedling and pod formation stages, respectively.

Table 16 shows the information on dose of pesticides, spray volume used, number of applications and interval between sprayings. Regarding the concentration or dose of the pesticide used at seedling stage only 37.8% of the farmers applied pesticides at recommended dose, while 27.8 and 7.8% of the farmers used doses above and below the recommended doses. Similarly, at pod formation stage 36.7% of the farmers followed the recommended dose where as 24.4 and 13.3% applied doses above and below the recommended doses, respectively.

Table 14. Number and percentage of cowpea growing farmers who adopted plant protection measures

Plant protection measures	Number of farmers who adopted plant protection measures								Percentage of farmers	
	Thiruvananthapuram		Alappuzha		Palakkad		Total			
	20-25 DAS	55-60 DAS	20-25 DAS	55-60 DAS	20-25 DAS	55-60 DAS	20-25 DAS	55-60 DAS	20-25 DAS	55-60 DAS
Organophosphates	8	10	5	3	8	6	21	19	23.3	21.1
Carbonates	1	4	5	5	9	6	15	15	16.7	16.7
Organochlorines	-	1	-	-	-	-	-	1	-	1.1
Botanicals	6	8	12	15	8	7	26	30	28.9	33.3
Others	4	-	7	-	1	2	12	2	13.3	2.2
No application	11	7	1	7	4	9	16	23	17.8	25.6
Total	30	30	30	30	30	30	90	90	100	100

Table 15a. Class of pesticides used by cowpea growing farmers in Thiruvananthapuram, Alappuzha and Palakkad districts at 20 to 25 DAS

Class of pesticide	Frequency			Percentage (out of 30)			Total perce-ntage
	Thiruvana-nthapuram	Alapp-uzha	Pala-kkad	Thiruvana-nthapuram	Alapp-uzha	Pala-kkad	
Contact	10	19	12	33.3	63.3	40.0	45.6
Systemic	5	5	3	16.7	16.7	10.0	14.4
Contact as well as Systemic	0	1	11	0.0	3.3	36.7	13.3
No insecticide	15	5	4	50.0	16.7	13.3	26.7
TOTAL	30	30	30	100	100	100	100

Table15b. Class of pesticides used by cowpea growing farmersin Thiruvananthapuram, Alappuzha and Palakkad districts at 60 DAS

Class of pesticide	Frequency			Percentage (out of 30)			Total perce-ntage
	Thiruvana-nthapuram	Alapp-uzha	Pala-kkad	Thiruvana-nthapuram	Alapp-uzha	Pala-kkad	
Contact	18	16	14	60.0	53.3	46.7	53.3
Systemic	2	3	1	6.7	10.0	3.3	6.7
Contact as well as Systemic	3	4	6	10.0	13.3	20.0	14.4
No insecticide	7	7	9	23.3	23.3	30.0	25.6
TOTAL	30	30	30	100	100	100	100

Table 16. Information on dose of insecticide, spray volume, number of applications and interval between two sprayings used by cowpea growing farmers in Thiruvananthapuram, Alappuzha and Palakkad districts

		Number of farmers who applied insecticides							
		Thiruvananthapuram		Alappuzha		Palakkad		Total % (out of 90 farmers)	
		20-25 DAS	60 DAS	20-25 DAS	60 DAS	20-25 DAS	60 DAS	20-25 DAS	60 DAS
Concentration/ Dose	Recommended	7	10	15	12	12	11	37.8	36.7
	Below recommended	2	5	3	4	2	3	7.8	13.3
	Above recommended	6	8	7	7	12	7	27.8	24.4
Spray volume	Recommended	4	8	8	7	13	10	27.8	27.7
	Below recommended	10	12	14	13	13	10	41.1	38.9
	Above recommended	1	3	3	3	0	1	4.4	7.8
No. of applications	Recommended	7	13	13	13	16	14	40.0	44.4
	Below recommended	4	5	4	2	7	3	16.7	11.1
	Above recommended	4	5	8	8	3	4	16.7	18.9
Interval between two applications	Recommended	8	11	12	9	20	10	44.4	33.3
	Below recommended	3	5	8	8	0	7	12.2	22.2
	Above recommended	4	7	5	6	6	4	16.7	18.9

As far as the spray volume of the pesticide is concerned, at seedling stage 27.8% of the farmers used the recommended volume. Only 4.4% of the farmers used a spray volume higher than the recommended dose while 41.1% used below recommended level. At pod formation stage, also 27.7% of the farmers used the recommended spray volume while 7.8 and 38.9% used above and below recommended volume of spray fluid, respectively.

In the case of the frequency of application of pesticides at seedling stage 40% of the farmers followed the recommended need based spray while 16.7% each followed above and below recommended one. Similarly, at pod formation stage 44.4% of the farmers followed the recommended need based spray and 18.9 and 11.1% used above and below the recommended one respectively.

At seedling stage, 44.4% of the farmers followed the correct interval between two sprayings whereas only 33.3% followed the recommended interval at pod formation stage. The percentage of farmers following below and above recommended interval at seedling stage were 12.2 and 16.7 respectively, while at pod formation stage the corresponding values were 22.2 and 18.9%.

The relevant data on the source of information on plant protection measures got by the farmers in three districts are presented in Table 17.

The main source of information on plant protection measures among farmers in Thiruvananthapuram district was from neighbouring farmers, mass media and his own discretion for 16.7% each of the farmers. For the farmers in Alappuzha district,

Table 17. Number and percentage of farmers who acquired information on plant protection measures in cowpea from different sources

Source	Thiruvanantha-puram		Alappuzha		Palakkad		Total	
	Frequency distribution of farmers	Percentage	Frequency distribution of farmers	Percentage	Frequency distribution of farmers	Percentage	Number	Percentage
Pesticide dealer (1)	3	10.0	2	6.7	2	6.7	7	7.8
Neighbouring farmers (2)	5	16.7	0	0.0	3	10.0	8	8.9
His own discretion (3)	5	16.7	1	3.3	2	6.7	8	8.9
Media (4)	5	16.7	0	0.0	3	10.0	8	8.9
Seminars (5)	2	6.7	1	3.3	6	20.0	9	10.0
Krishibhavans (6)	2	6.7	1	3.3	4	13.3	7	10.8
Scientists/ University (7)	1	3.3	7	23.3	1	3.3	9	10.0
Combination of 2&7	0	0.0	3	10.0	1	3.3	4	4.4
Combination of 2&5	3	10.0	3	10.0	0	0.0	6	6.7
Combination of 3&6	1	3.3	2	6.7	1	3.3	4	4.4
Combination of3&7	0	0.0	2	6.7	1	3.3	3	3.3
Combination of 3&5	0	0.0	0	0.0	0	0.0	0	0.0
Combination of 3&4	1	3.3	0	0.0	0	0.0	1	1.1
Combination of 4&7	0	0.0	3	10.0	0	0.0	3	3.3
Combination of 4&6	2	6.7	0	0.0	0	0.0	2	2.2
Combination of 5&7	0	0.0	3	10.0	5	16.7	8	8.9
Combination of 6&7	0	0.0	1	3.3	1	3.3	2	2.2
Combination of 4&5	0	0.0	1	3.3	0	0.0	1	1.1
TOTAL	30	100	30	100	30	100	90	100

the main source of information was from Scientists or University (23.3% of the farmers), while in Palakkad district the information on plant protection aspect was received mainly from seminars (20 %).

4.1.2. Meteorological parameters during the period January to May 1999 in Thiruvananthapuram, Alappuzha and Palakkad districts

The meteorological parameters such as maximum and minimum temperature, relative humidity, total rainfall and sunshine hours obtained from various centres in the three districts are given in Appendix III, IV and V, respectively.

4.2 Efficiency of potential predators in controlling cowpea pests

The potential predators identified in the survey *viz.*, grubs and adults of the coccinellids *C. transversalis, H. octomaculata* and *M. sexmaculatus*, the syrphid *I. scutellare* and the grubs of *C. carnea* were tested in the laboratory for their feeding ability and predatory behaviour.

4.2.1 Feeding ability of the potential predators

4.2.1.1 Mean duration and feeding potential of the predator *C. transversalis* reared on *A. craccivora*

The results of the mean duration of egg, larval and pupal period are presented in Table 18a.

Table 18. Biology and feeding potential of *C.transversalis* reared on *A. craccivora* in cowpea

a) Biology of *C.transversalis*

Stage of the insect	Egg	1st instar	2nd instar	3rd instar	4th instar	Pre pupa	Pupa	Total
Mean duration (days)	2.71	1.20	1.33	2.67	3.00	1.20	1.67	13.78±0.33
Range (days)	(2-3)	(1-2)	(1-2)	(2-3)	(2-3)	(1-2)	(1-2)	-

(b) Feeding potential of *C.transversalis* grub

Stage of insect	Mean number of aphids consumed during different periods after emergence (days)				
	1	2	3	Total consumption	% consumption
2nd instar grub	8.10 (6-12)	16.60 (10-20)	-	24.70±1.54	9.81
3rd instar grub	30.11 (18-40)	48.44 (41-50)	11.11 (8-18)	89.66±6.08	35.61
4th instar grub	62.00 (48-74)	40.11 (20-80)	35.33 (15-53)	137.44±6.87	54.58
TOTAL				251.80±6.74	100

Mean per day consumption – 31.48 *A. craccivora*

(b) Feeding potential of *C. transversalis* adult

	Mean number of aphids consumed per adult during different periods after emergence (weeks)					
	1	2	3	4	5	Total
Mean No. of aphids consumed	122.00	185.00	200.5	268.00	138.50	914.00±50.28
Range	(90-140)	(120-250)	(130-250)	(180-330)	95-150)	-

Mean longevity 29.7 days Mean per day consumption 30.77 *A. craccivora*

The mean number of eggs laid by a female coccinellid per cluster was 10.6 with a range of 10 to 12. The egg period ranged from two to three days with a mean of 2.71 days. The mean duration of the first instar grub was 1.2 days while that of the second, third and fourth instars were 1.33, 2.67 and 3.00 days, respectively. The mean prepupal period was 1.2 days and pupal period 1.67 days. Totally, the coccinellid took 13.78±0.33 days to complete its life cycle.

The mean number of pea aphids consumed by the second instar grub was 24.7±1.54 and its mean daily consumption ranged from 8.1 to 16.6 (Table 18b). The third instar grub consumed a mean number of 89.66±6.08 aphids, whereas the fourth instar consumed 137.44±6.87. The mean daily consumption rate of the third and fourth instar grubs ranged from 11.11 to 48.44 and 35.33 to 62.0 aphids, respectively. The mean number of aphids consumed by a single grub during its life time was 251.8±6.74.

During its life time, the adult beetle consumed a mean number of 914±50.28 *A. craccivora* adults (Table 18c). The mean number of *A. craccivora* consumed by an adult was 122.0, 185.0, 200.5, 268.0 and 138.5 during the first, second, third, fourth and fifth week, respectively.

4.2.1.2 Mean duration and feeding potential of the predator, *H. octomaculata* reared on *A. craccivora* in cowpea.

The data regarding the life cycle and feeding potential of the grubs and adults are given in Table 19.

Table 19. Biology and feeding potential of *H. octomaculata reared* on *A. craccivora* in cowpea

(a) Biology of *H. octomaculata*

Stage of the insect	Egg	1st instar	2nd instar	3rd instar	4th instar	Pre pupa	Pupa	Total
Mean duration (days)	2.20	1.50	1.83	2.36	2.36	1.20	1.82	13.27±0.31
Range (days)	(2-3)	(1-2)	(1-2)	(2-3)	(2-3)	(1-2)	(1-2)	-

(b) Feeding potential of *H. octomaculata* grub

Stage of insect	Mean number of aphids consumed during different periods after emergence (days)					
	1	2	3	4	Total consumption	% consumption
2nd instar grub	8.00 (5-15)	9.64 (7-22)	-	-	17.64±0.67	8.9
3rd instar grub	18.15 (10-30)	42.40 (12-48)	13.63 (8-25)	-	74.18±7.78	37.4
4th instar grub	85.50 (35-100)	14.08 (8-30)	6.82 (3-10)	-	106.4±9.78	53.7
TOTAL					198.22±12.90	100

Mean per day consumption 24.78 A. *craccivora*

(c) Feeding potential of *H. octomaculata* adult

	Mean number of aphids consumed per adult during different periods after emergence (weeks)					
	1	2	3	4	5	Total
Mean No. of aphids consumed	110.0	158.2	178.5	240.0	155.3	842±77.28
Range	90-160	101-200	95-250	120-300	75-200	-

Mean longevity 30.1 days Mean per day consumption 27.88 *A. craccivora*

The female *H. octomaculata* laid eggs in clusters of 8.3 (mean number per batch). The eggs hatched after a mean period of 2.2 days with a range of two to three days. The average duration of first instar grub was 1.5 days and that of second instar 1.83 days. The duration of both third and fourth instar grubs was 2.36 days, while that of prepupal and pupal period were 1.2 and 1.82 days, respectively. Thus, the total period of development from egg to adult was 13.27±0.31 days.

The mean number of *A. craccivora* consumed by the second, third and fourth instar grubs were 17.64±0.67, 74.18±7.78 and 106.4±9.78, respectively (Table 19b). The daily mean consumption of the second, third and fourth instars ranged from 8.00 to 9.64, 13.63 to 42.40 and 6.82 to 85.50 aphids respectively. Thus, the mean number of *A. craccivora* consumed by a single grub during its life time was 198.22±12.90. The consumption rate at the end of each instar prior to moulting was found to be declining.

The adult *H. octomaculata* during its life time consumed 842±77.28 *A. craccivora* (Table 19c). The feeding rate was gradually increasing up to four weeks after emergence. The mean number of *A. craccivora* consumed by an adult coccinellid was 110.0, 158.2, 178.5, 240.0 and 155.3 during the first, second, third, fourth and fifth week, respectively.

4.2.1.3 Mean duration and feeding potential of the predator *M. sexmaculatus* reared on *A. craccivora*.

The relevant results of the study are presented in Table 20.

Table 20. Biology and feeding potential of *M. sexmaculatus* reared on *A. craccivora* in cowpea

(a) Biology of *M.sexmaculatus*

Stage of the insect	Egg	1st instar	2nd instar	3rd instar	4th instar	Pre pupa	Pupa	Total
Mean duration (days)	2.10	1.20	2.80	3.60	3.80	1.80	3.40	18.70±0.91
Range (days)	(2-3)	(1-2)	(2-3)	(3-4)	(3-4)	(1-2)	(3-5)	-

(b) Feeding potential of *M. sexmaculatus* grub

Stage of insect	Mean number of aphids consumed during different periods after mergence (days)						
	1	2	3	4	5	Total consumption	% consumption
2nd instar grub	3.91 (2-5)	4.71 (2-7)	2.08 (2-4)	-	-	10.70±0.75	8.4
3rd instar grub	8.22 (2-15)	10.00 (3-22)	12.60 (6-35)	5.08 (3-9)	-	35.90±1.07	28.1
4th instar grub	18.33 (1-25)	20.00 (15-40)	22.58 (11-40)	17.59 (6-28)	2.5 (1-4)	81.00±3.20	63.5
TOTAL						127.60±3.35	100

(c) Feeding potential of *M.sexmaculatus* adult

	Mean number of aphids per adult consumed during different periods after emergence(weeks)							
	1	2	3	4	5	6	7	Total
Mean No. of aphids consu-med	110.0	148.00	152.4	160.8	102.00	42.00	18.90	734.1 ±102.4
Range	80-170	120-250	80-220	42-200	0-220	0-180	5-80	-

Mean longevity = 31.5 days   Mean per day consumption = 23.3 A. *craccivora*

The female coccinellid laid eggs in batches of 7 (mean number per batch). The mean incubation period was 2.10 days, which ranged from two to three days. The duration of the first instar grubs ranged from one to two days with a mean of 1.2 days. The mean duration of the second, third and fourth instar was 2.8 days (2-3 days) 3.6 days (3-4 days) and 3.8 days (3- 4 days), respectively. The mean pre-pupal period was 1.8 days while the pupal period ranged from three to five days with a mean of 3.4 days (Table 20a). *M. sexmaculatus* took a total developmental period of 18.70±0.91 days from egg to adult emergence.

The data on the assessment of feeding potential of the second, third and fourth instar grubs are given in Table 20b. The mean consumption of *A. craccivora* by the second, third and fourth instar grubs of *M. sexmaculatus* were 10.7± 0.75, 35.9± 1.07 and 81.0± 3.20, respectively. The daily mean consumption of the second, third and fourth instar grubs ranged from 2.08 to 4.71, 5.08 to12.60 and 2.50 to 22.58 aphids respectively. The consumption rate at the end of each instar was found to be declining prior to moulting. Thus, the mean number of *A. craccivora* consumed by a single grub during its life time was 127.6±3.35.

An adult *M. sexmaculatus* consumed an average of 734.1±102.44 *A. craccivora* during its life time (Table 20c). The feeding rate was higher and gradually increased up to 4 weeks after emergence of adult. The mean number of *A. craccivora* consumed by an adult *M. sexmaculatus* were 110.00, 148.00, 152.40, 160.80, 102.00, 42.00 and 18.90 during the first, second, third, fourth fifth, sixth and seventh week, respectively.

2.1.4 Biology and feeding potential of the predator *I scutellare* reared on *A. craccivora*

The relevant results of the study are presented in Table 21.

The female syrphid laid eggs singly among aphid colonies. The mean incubation period was 2.90 days with a range of two to four days. The mean duration of the first instar maggot was worked out to be 2.20 days with a range of two to three days. The second and third instar had duration of 2.80 and 3.50 days, respectively and the pupa took 4.90 days to emerge as adult fly. Totally, the fly took 16.30±0.45 days to complete its life cycle (Table 21a).

The relevant data on the assessment of feeding potential of the first, second and third instar maggots are presented in Table 19b. The mean consumption of the first, second and third instar maggots were 39.3 ±1.58, 152.0 ± 8.05 and 268.2±7.76 aphids, respectively. Thus, the total number of *A. craccivora* consumed by a single maggot during its life time was 459.5±7.71.

4.2.1.5 Mean duration and feeding potential of the predator *C. carnea* reared on *A. craccivora*

The results of the study are presented in Table 22.

The female *C. carnea* laid stalked eggs singly with a mean incubation period of 3.2 days. The mean duration of the first instar larva was ranging from two to three days with a mean of 2.8 days. The second and third instar larvae were having

Table 21. Biology and feeding potential of *I. scutellare* reared on *A. craccivora* in cowpea

(a) Biology of *I. scutellare*

Stage of the insect	Egg	1st instar	2nd instar	3rd instar	Pupa	Total
Mean duration (days)	2.90	2.20	2.80	3.50	4.90	16.30±0.45
Range (days)	(2-4)	(2-3)	(2-4)	(3-4)	(3-5)	-

(b) Feeding potential of *I. scutellare* maggot

Stage of insect	Mean number of aphids consumed during different periods after emergence(days)				
	1	2	3	Total consumption	% Consumption
1st instar maggot	17.20 (9-25)	22.10 (21-46)	-	39.30±1.58	8.6
2nd instar maggot	40.30 (20-48)	50.28 (23-60)	61.42 (35-90)	152.00±8.05	33.1
3rd instar maggot	72.0 (34-90)	115.10 (60-105)	81.15 (25-100)	268.20±7.76	58.4
TOTAL				459.50±7.71	100

Mean per day consumption – 57.44

Table 22. Biology and feeding potential of *C. carnea* reared on adults of *A. craccivora* in cowpea

(a) Mean duration of different life stages of *C. carnea*

Stage of the insect	Egg	1st instar	2nd instar	3rd instar	4th instar	Pupa	Total
Mean duration (days)	3.20	2.80	3.40	3.80	4.40	8.60	25.80±0.77
Range (days)	(2-3)	(2-3)	(3-4)	(3-4)	(4-5)	(8-9)	-

(b) Feeding potential of *C. carnea* larva

Stage of insect	Mean number of adult aphids consumed during different periods after emergence(days)					
	1	2	3	4	Total consumption	% consumption
1st instar larva	1.2	2.0	2.2	-	5.4±0.50	12.8
2nd instar larva	2.4	3.0	3.0	-	8.6±0.37	20.0
3rd instar larva	3.0	3.2	2.7	2.0	10.9±0.48	25.9
4th instar larva	3.2	4.8	4.4	5.0	17.4±0.76	41.3
TOTAL					42.1±1.23	100

a mean duration of 3.4 and 3.8 days, respectively, while the fourth instar larvae had a mean duration of 4.4 days. The mean pupal period was 8.6 days. A mean duration of 25.8±0.77 days was taken by *C. carnea* to complete its life cycle (Table 22a).

The data on the assessment of feeding potential of the larvae of *C. carnea* are given in Table 22b. The mean consumption of *A. craccivora* by the first, second, third and fourth instar larvae were 5.4±0.50, 8.6±0.37, 10.9±0.48 and 17.4±0.76, respectively. Thus, the mean number of *A. craccivora* adults consumed by a single larva was 42.3±1.23.

4.2.2. Predatory behaviour of the potential predators of cowpea pests

The predatory behaviour of the potential coccinellid predators *viz.*, *C. transversalis* and *M. sexmaculatus* was studied by releasing them into caged cowpea plants along with their prey *A. craccivora*.

The searching speed of adults and grubs of coccinellids was dependent on the density of *A. craccivora* in the plant and it increased with increased density of the prey. Within the plant, the aphidophagous coccinellids *viz. C. transversalis* and *M. sexmaculatus* were found to be concentrating towards the twigs with higher prey population. The adult of *C. transversalis* showed a twisting movement when the prey population was low, while direct or straight movement was exhibited when the prey population was higher. The searching speed and behaviour of coccinellids were also found to be influenced by the period of starvation or hunger level. When a one day starved grub of adult was released into a caged cowpea plant with colonies of *A. craccivora,* it showed a significantly greater speed than a three day prey deprived one.

The turning rate of the predatory coccinellid was influenced by its period of hunger or starvation level and prey density. High rate of turning and many crossings were made by the coccinellid adults which was starved for more than one day, compared with a fully fed predator. At higher prey density, the turning rate was also found increasing.

The turning angle of the predatory coccinellid was found to be influenced by prey density and period of starvation. Higher turning angle of the coccinellid was recorded at low prey density. The turning angle of the predator was increased as the hunger level increased. Higher turning by the grubs and adults were noticed when they were deprived of prey for more than one day.

Almost all the aphidophagous coccinellids were seen concentrated towards the terminal part of plants, where the aphid population was high. Regarding the behaviour of the grubs, the first and second instar grubs remained on the undersurface of the leaves. When the starved third and fourth instar grubs were released into cowpea plants with *A. craccivora*, they showed a tendency to move towards the apex of the plant again and again and descend further down each trip until finally they reached near the prey.

The younger grubs took longer time to consume aphids compared to the later instars. The later instar grubs showed reluctance in feeding the younger stages of *A. craccivora*. The first stage grubs were sluggish and the total consumption was found to be lower compared to second stage grubs. Though the second instar grub was more active than first instar, their movement was restricted to a short distance only. The third and fourth instar grubs fed voraciously on aphids, and grubs consumed appreciable number of nymphs and adults of *A. craccivora*. The rate of feeding reduced as the fourth instar grub advanced towards pupation.

The grubs and adults of coccinellid were found to eat only live aphids. The predator was found orienting towards the prey directly by slight turnings and extending its proboscis in the vicinity of the aphid. It punctured the aphid with a quick pouncing movement. The aphids attacked by the coccinellid grubs ceased struggling and become immobile on piercing. The struggling ended up to 5 to 7 minutes after piercing. The young instars pierced and sucked the contents from the prey and retained its dried skin. The piercing and sucking activity was accompanied by regurgitation of the contents of the prey back into prey's body. In later instars, a chewing action was noticed and the whole prey was consumed without any left out skin. Adult females were more efficient than males in recognizing the prey and consumed more number of aphids than males.

4.3 Effect of biorational insecticides on the potential predators of cowpea pests.

4.3.1 Bioassay

Bioassay of five biorational insecticides using the potential coccinellid predators *viz. C. transversalis* and *M. sexmaculatus* (adults and third instar grubs) were done in the laboratory and LC_{50} values were worked out following the procedure of Finney (1981).

The results of the bioassay are presented in Tables 23 to 27.

4.3.1.1 Toxicity of insecticides to third instar grubs of *C. transversalis*

At 24 HAT, the toxicity of insecticides to third instar grubs of *C. transversalis* is given in Table 23. Of the three chemical insecticides and two botanicals, neem oil was the least toxic one with an LC_{50} of 6.6848 per cent. This was followed in the ascending order by Nimbecidine, endosulfan, chlorpyriphos and lindane, the LC_{50} values being 0.5916, 0.0289, 0.0248 and 0.0239 per cent, respectively.

At 48 HAT also, a more or less similar trend was observed. Among the insecticides, neem oil was found to be the least toxic one (LC_{50} - 5.4517 %). Among the synthetic insecticides, chlorpyriphos had the least toxicity (LC_{50} - 0.0127%).

Table 23. Toxicity of different insecticides to third instar grubs of *C. transversalis*

Insecticides	24 HAT				48 HAT			
	Regression equation	LC_{50}	SE	Heterogenity (χ^2)	Regression equation	LC_{50}	SE	Heterogenity (χ^2)
Lindane	Y= 6.7537 + 1.0810 X	0.0239	0.00515	6.9749870^{NS}	Y= 6.9673 + 1.0278 X	0.0122	0.00273	10.4846374^{NS}
Chlorpyriphos	Y= 6.8163 + 1.1311 X	0.0248	0.00519	2.7145318^{NS}	Y= 7.4042 + 1.2671 X	0.0127	0.00247	3.1371700^{NS}
Endosulfan	Y= 6.2079 + 0.7847 X	0.0289	0.00829	2.4214236^{NS}	Y= 6.5385 + 0.7834 X	0.0109	0.00302	3.0968538^{NS}
Nimbecidine	Y= 5.7923 + 3.4756 X	0.5916	0.03764	0.4059566^{NS}	Y= 6.1486 + 3.7343 X	0.4925	0.03236	1.5942237^{NS}
Neem oil	Y= 2.5583 + 2.9593 X	6.6848	0.5583	3.4660125^{NS}	Y= 2.9353 + 2.8032 X	5.4517	0.50216	5.6177206^{NS}

4.3.1.2 Toxicity of insecticides to adults of *C. transversalis*

At 24 hours, the LC_{50} value (Table 24) showed that neem oil was the least toxic chemical to the adult *C. transversalis* (LC_{50} - 6.9473%) followed by Nimbecidine (LC_{50} - 0.6377%). Among the synthetic insecticides, the least toxic one was chlorpyriphos with an LC_{50} of 0.0174%.

At 48 HAT also, the least toxicity was recorded by neem oil (LC_{50} - 6.2629%). The least toxic synthetic insecticide was chlorpyriphos with an LC_{50} of 0.0048%.

4.3.1.3 Toxicity of insecticides to third instar grubs of *M. sexmaculatus*

The results are presented in Table 25.

Neem oil showed the least toxicity against the third instar grub of *M. sexmaculatus* with an LC_{50} 8.4892% at 24 HAT. Among the synthetic insecticides, the lowest toxicity was shown by chlorpyriphos with an LC_{50} of 0.0238%.

At 48 HAT also, the LC_{50} was the highest for neem oil (7.8560%), followed by Nimbecidine (LC_{50} - 0.5328%). Among the synthetic insecticides, endosulfan was found to be highly toxic with an LC_{50} value 0.0032%, while chlorpyriphos was the least toxic one (LC_{50} - 0.0063%).

Table 24. Toxicity of different insecticides to adults of *C. transversalis*

Insecticides	24 HAT				48 HAT			
	Regression equation	LC_{50}	SE	Heterogenity (χ^2)	Regression equation	LC_{50}	SE	Heterogenity (χ^2)
Lindane	Y= 6.8511 + 0.9213 X	0.0098	0.00223	1.6588529 ^{NS}	Y= 6.9402 + 0.7840 X	0,0034	0.00099	5.5188241 ^{NS}
Chlorpyriphos	Y= 6.6724 + 0.9511 X	0.0174	0.00395	1.4911542 ^{NS}	Y= 6.8156 + 0.7835 X	0,0048	0.00136	5.7378351 ^{NS}
Endosulfan	Y= 6.9545 + 0.8881 X	0.0063	0.00149	2.3765750 ^{NS}	Y= 7.6172 + 1.0096 X	0,0026	0.00064	6.3532187 ^{NS}
Nimbecidine	Y= 5.6707 + 3.4329 X	0.6377	0.04021	0.7449429 ^{NS}	Y= 5.9572 + 3.5876 X	0,5410	0.03588	2.1319567 ^{NS}
Neem oil	Y= 1.2524 + 4.4518 X	6.9473	0.41511	1.0967763 ^{NS}	Y= 1.4161 + 4.4980 X	6,2629	0.41174	2.8552148 ^{NS}

Table 25. Toxicity of different insecticides to third instar grubs of *M. sexmaculatus*

Insecticides	24 HAT				48 HAT			
	Regression equation	LC_{50}	SE	Heterogenity (χ^2)	Regression equation	LC_{50}	SE	Heterogenity (χ^2)
Lindane	Y= 6.6421 + 0.8207 X	0.0100	0.00257	2.4611511^{NS}	Y= 7.1161 + 0.8937 X	0.0043	0.00118	4.3306399^{NS}
Chlorpyriphos	Y= 6.2192+ 0.7513 X	0.0238	0.00680	3.6863345^{NS}	Y= 6.5082 + 0.6851 X	0.0063	0.00179	8.2114573^{NS}
Endosulfan	Y= 7.0809 + 0.9449 X	0.0063	0.00150	5.0498571^{NS}	Y= 7.6923 + 1.0786 X	0.0032	0.00079	7.1460299^{NS}
Nimbecidine	Y= 6.0224 + 3.9545 X	0.5514	0.03179	2.4799641^{NS}	Y= 6.1149 + 4.0770 X	0.5328	0.03203	3.3030319^{NS}
Neem oil	Y= 2.1848 + 3.0308 X	8.4892	0.76884	4.5834177^{NS}	Y= 2.1773 + 3.1532 X	7.8560	0.66540	4.9702815^{NS}

4.3.1.4 Toxicity of insecticides to *M. sexmaculatus* adults

At 24 HAT, the least toxicity to coccinellids was exhibited by neem oil with an LC_{50} of 7.5620% (Table 26). Chlorpyriphos with an LC_{50} of 0.0147% showed the least toxicity to coccinellids among the synthetic insecticides. The same trend was noticed at 48 HAT also. Thus, the highest LC_{50} value of 6.1250% was observed for neem oil and among the synthetic insecticides, chlorpyriphos had the highest LC_{50} value (0.0071%).

4.3.1.5 Toxicity of insecticides to *A. craccivora*

The LC_{50} values at 24 and 48 HAT are presented in Table 27. Among the various chemicals and botanicals used, the most toxic one was chlorpyriphos with an LC_{50} of 0.0045% at 24 HAT and the least toxic one was neem oil (LC_{50} -2.4657%).

At 48 hours also, chlorpyriphos was found to have the highest toxicity with an LC_{50} of 0.0026% followed by endosulfan, lindane, Nimbecidine and neem oil with LC_{50} values of 0.0033 and 0.0037, 0.3951 and 1.2340 per cent, respectively.

4.3.2 Relative safety of insecticides to potential predators of *A. craccivora*

Presuming that insecticides would behave similarly under field condition, LC_{50} value of insecticides was compared with the normally recommended

Table 26. Toxicity of different insecticides to adults of *M. sexmaculatus*

Insecticides	24 HAT				48 HAT			
	Regression equation	LC_{50}	SE	Heterogenity (χ^2)	Regression equation	LC_{50}	SE	Heterogenity (χ^2)
Lindane	Y= 7.9377 +1.2882 X	0.0052	0.00106	1.6010180^{NS}	Y= 8.0557 +1.1859 X	0.0027	0.00066	3.3401539^{NS}
Chlorpyriphos	Y= 6.7279+ 0.0197 X	0.0147	0.00352	0.1955805^{NS}	Y= 7.2201 +1.0339 X	0.0071	0.00160	1.7846080^{NS}
Endosulfan	Y= 7.6354 +1.1470 X	0.0050	0.00111	1.8028450^{NS}	Y= 8.0087 +1.1806 X	0.0028	0.00065	3.4001721^{NS}
Nimbecidine	Y= 6.1362 +3.9372 X	0.5145	0.12103	2.9784953^{NS}	Y= 6.4621 +3.6095 X	0.3935	0.02874	8.6462312^{NS}
Neem oil	Y= 1.9596 +3.4604 X	7.5620	0.57810	7.8353896^{NS}	Y= 2.7097 +2.9098 X	6.1250	0.07118	12.1882518^{NS}

Table 27. Toxicity of different insecticides to *A. craccivora*

Insecticides	24 HAT				48 HAT			
	Regression equation	LC_{50}	SE	Heterogenity (χ^2)	Regression equation	LC_{50}	SE	Heterogenity (χ^2)
Lindane	Y= 7.3532 +1.0908 X	0.0070	0.00161	0.8581714^{NS}	Y= 7.6838 +1.1061 X	0.0037	0.00096	2.5395165^{NS}
Chlorpyriphos	Y= 7.9316+ 1.2506 X	0.0045	0.00099	2.4381083^{NS}	Y= 8.2194 +1.2469 X	0.0026	0.00065	1.2468742^{NS}
Endosulfan	Y= 7.3925 +1.1261 X	0.0075	0.00169	2.3835225^{NS}	Y= 7.6821 +1.0821 X	0.0033	0.00088	2.8163720^{NS}
Nimbecidine	Y= 5.5941 +2.3590 X	0.5600	0.05155	3.2055996^{NS}	Y= 5.8285 +2.0543 X	0.3951	0.04623	4.5774322^{NS}
Neem oil	Y= 4.4467 +1.4116 X	2.4657	0.52055	2.5747856^{NS}	Y= 4.8879 +1.2277 X	1.2340	0.39284	3.8753489^{NS}

concentration (NRC) of insecticides and relative safety index was worked out. It was noticed that greater the values of safety index, more safe the insecticides would be.

4.3.2.1 Relative safety of insecticides to *C. transversalis*

The relative safety indices worked out for different insecticides to the adults and third instar grubs of *C. transversalis* and *M. sexmaculatus* is given in table 28.

The safest insecticide to *C. transversalis* adults was neem oil at 48 hours after treatment with a safety index of 3.132. This was followed in the descending order of safety by Nimbecidine, chlorpyriphos, lindane and endosulfan with safety indices of 2.705, 0.096, 0.068 and 0.052, respectively.

Similar results were obtained in the case of third instar grubs of *C. transversalis* also. Neem oil with a safety index of 2.726 was observed to be the safest one followed by Nimbecidine, chlorpyriphos, lindane and endosulfan in the descending order of safety with safety indices of 2.465, 0.254, 0.240 and 0.218, respectively.

4.3.2.2 Relative safety of insecticides to *M. sexmaculatus*

As in the case of the adults of *C. transversalis*, the highest safety index of 3.063 was worked out for neem oil. The other insecticides in the order of decreasing

Table 28. Relative safety of insecticides to third instar grubs and adults of *C .transversalis* and *M.* sexmaculatus at 48 HAT

Insecticide	Normally recommended concentration (%)	*C. transversalis* 3rd instar grubs		*C. transversalis* adults		*M. sexmaculatus* 3rd instar grubs		*M. sexmaculatus* adults	
		LC_{50}	Safety index	LC_{50}	Safety index	LC_{50}	Safety index	LC_{50}	Safety index
Lindane	0.05	0.0120	0.240	0.0034	0.068	0.0043	0.086	0.0027	0.054
Chlorpyriphos	0.05	0.0127	0.254	0.0048	0.096	0.0063	0.126	0.0071	0.142
Endosulfan	0.05	0.0109	0.218	0.0026	0.052	0.0032	0.064	0.0028	0.056
Nimbecidine	0.20	0.4925	2.465	0.5410	2.705	0.5328	2.665	0.3935	1.970
Neem oil	2.00	5.4517	2.726	6.2629	3.132	7.8560	3.928	6.1250	3.063

safety were Nimbecidine, chlorpyriphos, endosulfan and lindane with safety indices of 1.970, 0.142, 0.056 and 0.054, respectively (Table 28).

Similarly, in the case of third instar grubs of *M. sexmaculatus*, the order of insecticides in respect of decreasing safety were neem oil, Nimbecidine, chlorpyriphos, lindane and endosulfan with safety indices of 3.928, 2.665, 0.126, 0.086 and 0.064, respectively.

4.4 Pest management trial in cowpea

4.4.1 Season 1 (January to April 2000)

The pest management trial in cowpea using cultural, mechanical and chemical methods was conducted from January to April 2000 (Plate 6). The data on the pest population, damage incidence and natural enemy population at weekly intervals after treatment are presented.

The first round spraying was given on 45 DAS. Pre treatment observations on pest / damage and natural enemy population were recorded on the previous day of treatment. The post treatment observation was recorded at weekly intervals till harvest.

52 DAS

The data on the pests / damage incidence at 52 DAS (one week after treatment) are presented in Table 29. There was significant reduction in the

Plate 6. View of the pest management trial

Table 29. Incidence of pests/Extend of damage in different treatments at 52 DAS -Field trial-Season – 1(January to April 2000)

	Treatments	Mean number of *A.craccivora* (top 2.5 cm shoot)$^{-1}$	Mean percent leaves damaged by *A. misera.*	Mean number of podbugs (5 sweeps)$^{-1}$
T_1	Carbaryl 0.2% + Mechanical + Cultural control	1.25 (1.5)	1.19 (1.48)	0.67
T_2	Endosulfan 0.05% + Mechanical + Cultural control	0.85 (1.36)	4.38 (2.32)	0.33
T_3	Lindane 05% + Mechanical + Cultural control	0.72 (1.31)	1.37 (1.54)	0.33
T_4	Chlorpyriphos 0.05% + Mechanical + Cultural control	0.00 (0.98)	0.49 (1.22)	0.00
T_5	Crude neem oil emulsion 10% + Mechanical + Cultural control	0.51 (1.23)	2.13 (1.77)	1.00
T_6	Crude neem oil emulsion 5% + Mechanical + Cultural control	0.25 (1.12)	4.76 (2.40)	0.67
T_7	Neem kernel suspension 5% + Mechanical + Cultural control	0.32 (1.15)	1.69 (1.64)	0.00
T_8	Neem kernel suspension 2.5% + Mechanical + Cultural control	1.19 (1.48)	2.50 (1.87)	0.33
T_9	Nimbecidine 0.2% + Mechanical + Cultural control	1.92 (1.71)	0,56 (1.25)	0.33
T_{10}	Aqueous extract of *H.suaveolens* 10% + Mechanical + Cultural control	0.44 (1.20)	1.82 (1.68)	0.00
T_{11}	Aqueous extract of clerodendron 10% + Mechanical + Cultural control	0.35 (1.16)	0.74 (1.32)	0.67
T_{12}	Mechanical + Cultural control alone	1.34 (1.53)	1.19 (1.48)	1.00
T_{13}	Control	88.30 (9.45)	11.67 (3.56)	1.00
	CD (0.05)	0.87	1.32	-

The values are retransformed adjusted means from Analysis of co-variance

Figures in parentheses are $\sqrt{X+1}$ transformed values

population of *A. craccivora* in all the treatments compared to control. All the treatments were at par in controlling *A. craccivora.* No incidence was observed in the plots treated with chlorpyriphos 0.05% (T_4).

As in the case of *A craccivora,* the damage by *A. misera* was also significantly lower in all the treatments. The mean percentage of leaves damaged by *A. misera* among the treatments ranged from 0.49(T_4) to 4.76(T_6) as against 11.67 in control. The lowest mean damage of 0.49% was observed in plots receiving chlorpyriphos 0.05%(T_4) followed by the treatment Nimbecidine 0.2%(T_9) with 0.56%damage. All the treatments were on par and significantly superior to control.

The mean population of pod bugs was too low that statistical analysis could not be done and critical difference was not worked out. However, there was no incidence at all in plots treated with chlorpyriphos 0.05%, neem kernel suspension 5% (T7) and aqueous extract of *H. suaveolens* 10% (T_{10}).

The data on the population of natural enemies observed at 52 DAS are given in Table 30. The natural enemies recorded include adults and grubs of coccinellids *viz. C. transversalis, H. octomaculata* and *M. sexmaculatus*, maggots of *I. scutellare*, spiders and damsel flies. As the population of all the predators except the grubs of *Coccinella* spp. was very low, the critical difference could not be worked out for comparing means. However, the mean number of adults and grubs of *Coccinella* spp. was the maximum in plots treated with chlorpyriphos 0.05% (1.67 and 4.95, respectively).

Table 30. Population of natural enemies in different treatments in cowpea at 52 DAS- Field trial- Season-1(January to April 2000)

Treatments	Mean No. of adult *Coccinella* spp. 5 sweeps^{-1}	Mean No. of *Coccinella* spp grubs plant^{-1}	Mean No. of *Coccinella* spp pupae plant^{-1}	Mean No. of adult *M.sexmaculatus* 5 sweeps^{-1}	Mean No. of *M.sexmaculatus* grubs plant^{-1}	Mean No. of Syrphid maggots plant^{-1}	Mean No. of Spiders plant^{-1}	Mean No. of Damsel flies 5 sweeps^{-1}
T_1	0.33	1.69 (1.64)	0.33	0.33	0.00	0.00	0.00	0.00
T_2	0.00	0.04 (0.98)	2.00	0.00	0.33	0.00	0.00	0.00
T_3	0.33	1.53 (1.59)	1.67	0.00	0.00	0.33	0.00	0.00
T_4	1.67	4.95 (2.44)	1.67	0.67	1.00	1.00	0.00	0.00
T_5	0.67	1.50 (1.58)	0.00	0.00	0.00	0.00	0.00	0.00
T_6	0.67	1.62 (1.62)	0.67	0.33	0.67	0.33	0.00	0.00
T_7	0.00	0.32 (1.15)	0.00	0.67	1.67	0.00	0.67	0.33
T_8	0.67	0.12 (1.06)	1.67	0.00	0.00	0.00	0.33	0.33
T_9	0.67	1.02 (1.42)	0.00	0.33	0.00	0.00	0.00	0.00
T_{10}	0.00	0.61 (0.78)	0.00	0.33	0.00	0.00	0.00	0.00
T_{11}	0.33	1.89 (1.70)	0.00	0.67	0.67	0.00	0.00	0.00
T_{12}	0.67	1.96 (1.72)	0.00	0.00	0.00	0.00	0.00	0.00
T_{13}	0.33	0.32 (1.15)	0.00	0.67	1.33	0.00	0.00	0.00
CD (0.05)	-	NS	-	-	-	-	-	-

No grubs or adults of *M. sexmaculatus* was observed in plots treated with lindane 0.05% (T_3), crude neem oil emulsion 10% (T_5), neem kernel suspension 2.5% (T_8) and those receiving mechanical and cultural control alone. In other treatments, the mean population varied from 0.33 to 1.67.

In general, the population of syrphids (*I. scutellare*) was very low among the various treatments and the mean number ranged from 0.33 to 1.00. Similarly the spider and damsel fly population were also observed to be very low

59DAS

The data on the pest / damage incidence at 59 DAS are presented in Table 31. The pests observed included *A. craccivora*, *A. misera*, pod borers and pod bugs.

As in the case of observation at 52 DAS, there was significant reduction in population of *A. craccivora* in all the treatments over control. The lowest population was recorded in plots treated with endosulfan 0.05% and this was on par with the treatments *viz.* carbaryl 0.2%, lindane 0.05%, chlorpyriphos 0.05%, neem kernel suspension 5%, neem kernel suspension 2.5%, aqueous extract of clerodendron 10% and mechanical and cultural control alone.

The mean per cent damage by *A. misera.* was reduced significantly in all the treatments. However, the lowest damage of 3.24%was recorded in plots treated with nimbecidine 0.2 %(T9).

Table 31. Incidence of pests /Extent of damage in different treatments at 59 DAS- Field trial-Season I(January to April 2000)

Treatments	Mean number of *A.craccivora* top $(2.5\ cm\ shoot)^{-1}$	Mean per cent leaves damaged by *A. misera.*	Mean per cent of pod borer damage	Mean number of pod bugs $(5\ sweeps)^{-1}$
T_1	6.95 (2.82)	5.10 (2.47)	34.00	0.33
T_2	0.19 (1.09)	6.50 (2.55)	24.67	1.00
T_3	3.00 (2.00)	5.55 (2.56)	30.00	0.33
T_4	0.59 (1.26)	3.80 (2.19)	29.33	0.33
T_5	76.62 (8.81)	13.67 (3.83)	18.67	0.67
T_6	37.19 (6.18)	4.43 (2.33)	29.33	1.00
T_7	6.84 (2.80)	11.96 (3.60)	18.00	0.00
T_8	9.05 (3.17)	5.35 (2.52)	28.00	0.67
T_9	74.48 (8.63)	3.24 (2.06)	20.67	1.33
T_{10}	83.46 (9.91)	16.14 (4.14)	30.00	1.00
T_{11}	15.00 (4.00)	6.73 (2.78)	34.67	1.00
T_{12}	16.39 (4.17)	12.10 (3.62)	39.33	0.67
T_{13}	300.37 (17.36)	52.44 (7.31)	56.67	1.67
CD (0.05)	3.25	1.38	-	-

The values are retransformed adjusted means from Analysis of co-variance

Figures in parentheses are $\sqrt{X+1}$ transformed values

The mean per cent damage by pod borers was minimum in plots treated with neem kernel suspension 5% (18.00%) as against 56.67% in control plot. The plots treated with neem kernel suspension 5% did not harbour any pod bug while in other treatments the mean population ranged from 0.33 to 1.67. The critical difference was not worked out as the population of pod bugs was very low.

The data on the population of natural enemies recorded at 59 DAS are presented in Table 32. The natural enemy population build up was higher at 59 DAS compared to the population in 52 DAS.

The population of adult *Coccinella* spp. was less compared to the grubs and pupae. The analysis of the data indicated that there was no significant reduction in the population of *Coccinella* spp. grubs in all the treatments. On the contrary, there was significant increase in the population in plots treated with chlorpyriphos 0.05% (6.18), neem kernel suspension 5%(6.51) and Nimbecidine 0.2% (8.80) over control (1.13). At 59 DAS, the population of adult *M. sexmaculatus* was even higher than those observed in control, in plots treated with crude neem oil emulsion 10%. Maximum number of grubs (5.67) per plant was observed in both the plots treated with neem oil emulsion 5% (T_6) and neem kernel suspension 5% (T_7).

No syrphid maggots (*I. scutellare*) were recorded in plots treated with carbaryl 0.2% and lindane 0.05%. The mean number of syrphid maggots per plant in other treatments ranged from 0.33 and 1.67. The spider population was very low.

Table 32. **Population of natural enemies in different treatments in cowpea at 59 DAS-Field trial-Season-1 (January to April 2000)**

Treatments	Mean No. of adult *Coccinella* spp. 5 sweeps^{-1}	Mean No. of *Coccinella* spp grubs plant^{-1}	Mean No. of *Coccinella* spp pupae plant^{-1}	Mean No. of adult *M.sexmaculatus* 5 sweeps^{-1}	Mean No. of *M.sexmaculatus* grubs plant^{-1}	Mean No. of Syrphid maggots plant^{-1}	Mean No. of Spiders plant^{-1}
T_1	0.00	5.76 (2.60)	1.53 (1.59)	0.67	2.33	0.00	0.00
T_2	0.00	5.86 (2.62)	2.39 (1.84)	0.00	3.00	0.33	0.00
T_3	0.33	1.07 (1.44)	1.19 (1.48)	2.33	3.33	0.00	0.00
T_4	0.67	6.18 (2.68)	1.46 (1.57)	2.67	4.33	1.67	0.00
T_5	1.00	5.38 (2.32)	3.80 (2.19)	4.67	5.00	1.33	0.00
T_6	1.00	3.28 (2.07)	3.12 (2.03)	2.00	5.67	1.00	0.00
T_7	1.67	6.51 (2.74)	2.65 (1.90)	1.33	5.67	0.33	0.00
T_8	1.00	4.38 (2.32)	2.17 (1.78)	1.33	3.67	0.67	0.00
T_9	1.67	8.80 (3.13)	3.88 (2.21)	0.00	3.33	0.67	0.00
T_{10}	1.67	4.38 (2.32)	0.00 (0.98)	1.33	4.00	1.33	0.00
T_{11}	0.00	0.88 (1.37)	0.51 (1.23)	1.67	2.67	1.00	0.00
T_{12}	1.00	3.08 (2.02)	0.74 (1.32)	0.00	2.67	0.33	1.00
T_{13}	0.67	1.13 (1.77)	1.96 (1.72)	2.67	6.33	0.67	0.00
CD (0.05)	-	0.89	NS	-	-	-	-

The values are retransformed adjusted means from Analysis of co-variance

Figures in parentheses are $\sqrt{X+1}$ transformed values

At 60 days after sowing, a second round spraying was given as per the dose given for first spray and the population / damage of pests and natural enemies were recorded at weekly intervals.

68 DAS

The pest population / damage observed at one week after second treatment (68 DAS) are presented in table 33.

The pests observed included *A. craccivora, A. misera*, pod borers and pod bugs.

All the treatments were equally effective in significantly reducing the population of *A. craccivora*. The mean population was the lowest in plots treated with neem kernel suspension 5% (0.07) as against 85.44 observed in control.

As in the case of *A. craccivora*, all the treatments significantly reduced the infestation by *A. misera*. The percentage of leaf damage varied from 0.25 to 1.49 among the various treatments, while as high as 37.05 were observed in control.

The mean percent of pod borer damage was high (12.18%) in plots receiving absolute control, whereas no significant difference among other treatments and the minimum damage of 0.30% was observed in the treatment crude neem oil 5% (T_6) followed by chlorpyriphos 0.05% (0.99%). As in the previous week, the population of pod bugs was too low that the treatment means could not be compared.

Table 33. Incidence of pests /Extent of damage in different treatments in cowpea at 68 DAS - Field trial Season-I (January to April 2000)

Treatments	Mean number of *A.craccivora* top (2.5 cm shoot)$^{-1}$	Mean per cent leaves damaged by *A.misera*.	Mean per cent of pod borer damage	Mean number of podbugs(5 sweeps) $^{-1}$
T_1	1.06 (1.43)	0.82 (1.35)	1.50 (1.58)	0.33
T_2	0.32 (1.15)	0.90 (1.38)	1.53 (1.59)	0.00
T_3	1.11 (1.45)	1.47 (1.57)	1.46 (1.57)	0.33
T_4	0.24 (1.11)	0.25 (1.12)	0.99 (1.41)	0.00
T_5	2.01 (1.74)	0.86 (1.36)	2.24 (1.80)	0.33
T_6	1.44 (1.56)	1.19 (1.48)	0.30 (1.14)	0.33
T_7	0.07 (1.04)	0.38 (1.18)	1.02 (1.42)	0.00
T_8	0.58 (1.26)	1.49 (1.58)	1.13 (1.46)	1.33
T_9	2.10 (1.76)	0.27 (1.13)	1.37 (1.54)	1.00
T_{10}	0.69 (1.30)	0.50 (1.22)	1.10 (1.45)	1.00
T_{11}	0.17 (1.08)	1.03 (1.43)	1.86 (1.69)	1.00
T_{12}	0.91 (1.38)	1.41 (1.55)	1.28 (1.51)	1.33
T_{13}	85.44 (9.30)	37.05 (6.17)	12.18 (3.63)	1.33
CD (0.05)	3.00	1.51	0.77	-

The values are retransformed adjusted means from Analysis of co-variance

Figures in parentheses are $\sqrt{X+1}$ transformed values

However, no incidence was observed in plots treated with endosulfan 0.05 %(T2), chlorpyriphos 0.05% (T_4) and neem kernel suspension 5 %(T7).

The data on the observation of natural enemies at 68 DAS are given in Table 34.

As in the case of natural enemies recorded at 59 DAS, the population of adult *Coccinella* spp. was less compared to its grubs and pupae. No adult *Coccinella* spp. could be recorded in plots treated with carbaryl 0.2%. The mean number of adult *Coccinella* spp. per 5 sweeps in other treatments ranged from 0.33(T_3, T_9,T_{11} and T_{13}) to 1.33 (T_6). Perusal of the data on population of grubs of *Coccinella* spp. indicated that the population was not adversely affected by the application of either chemical or botanical pesticide. The mean population in various treatments ranged from 0.26 (T_{11}) to 7.67 (T_7).

No adult *M. sexmaculatus* was recorded in plots treated with carbaryl 0.2% (T_1) and lindane 0.05% (T_3). The mean number of *M. sexmaculatus* adults per 5 sweeps in other treatments ranged from 0.33 (T_8, T_{12} and T_{13}) to 1.33 (T_4 and T_5). No significant variation in the population of grubs of *M. sexmaculatus* was observed in all the treatments.

The population of syrphid maggots, damselflies and spiders were too low to manifest their treatment effects. The syrphid maggot (*I. scutellare*) population was observed in plots treated with chlorpyriphos 0.05 %(T_4), crude neem oil emulsion 5% (T_6), neem kernel suspension 5% (T_7), Nimbecidine 0.2% (T_9) and control (T_{13}).

Table 34. **Population of natural enemies in different treatments in cowpea at 68 DAS- Field trial-Season-1 (January to April 2000)**

Treatments	Mean No. of adult *Coccinella* spp. (5 sweeps)$^{-1}$	Mean No. of *Coccinella* spp grubs plant^{-1}	Mean No. of *Coccinella* spp pupae plant^{-1}	Mean No. of adult *M.sexmaculatus* (5 sweeps)$^{-1}$	Mean No. of *M.sexmaculatus* grubs plant^{-1}	Mean No. of Syrphid Maggots plant^{-1}	Mean No. of Spiders plant^{-1}	Mean No. of Damsel flies (5 sweeps)$^{-1}$
T_1	0.00	0.66 (1.29)	0.43 (1.20)	0.00	0.96 (1.40)	0.00	0.00	0.00
T_2	1.00	4.68 (2.38)	1.73 (1.66)	0.67	0.00 (0.99)	0.00	0.00	0.00
T_3	0.33	0.27 (1.13)	0.27 (1.13)	0.00	1.07 (1.44)	0.00	0.00	0.00
T_4	1.00	7.41 (2.90)	1.74 (1.66)	1.33	1.53 (1.59)	0.67	0.33	0.67
T_5	0.67	1.23 (1.50)	0.99 (1.41)	1.33	0.12 (1.06)	0.00	0.00	0.00
T_6	1.33	3.74 (2.18)	0.81 (1.35)	1.00	0.82 (1.35)	0.33	0.00	0.00
T_7	1.00	7.67 (2.95)	2.55 (1.89)	0.67	1.62 (1.62)	0.33	0.00	0.00
T_8	1.00	1.24 (1.50)	1.54 (1.59)	0.33	1.28 (1.51)	0.00	0.00	0.00
T_9	0.33	4.43 (2.33)	0.59 (1.26)	0.67	0.88 (1.37)	0.33	0.67	0.00
T_{10}	0.67	1.26 (1.50)	0.76 (1.33)	1.00	0.46 (1.21)	0.00	0.00	0.00
T_{11}	0.33	0.26 (1.12)	1.11 (1.45)	0.67	1.22 (1.49)	0.00	0.00	0.00
T_{12}	0.67	1.64 (1.62)	0.94 (1.39)	0.33	1.40 (1.55)	0.00	0.00	0.00
T_{13}	0.33	1.61 (1.61)	0.24 (1.11)	0.33	1.40 (1.55)	0.33	0.00	0.00
CD (0.05)	-	1.80	NS	-	NS	-	-	-

The values are retransformed adjusted means from Analysis of co-variance

Figures in parentheses are $\sqrt{X+1}$ transformed values

76 DAS

Observations on the pests / damage incidence at 76 DAS is presented in Table 35.

A. craccivora, pod borers and pod bugs were the pests observed. All the treatments effectively controlled *A. craccivora.* No population was recorded in plots treated with carbaryl 0.2% (T_1), endosulfan 0.05% (T_2), lindane 0.05%(T_3) chlorpyriphos 0.05% (T_4) and neem kernel suspension 5% (T_7). The mean number of *A. craccivora* per top 2.5 cm shoot in other treatments ranged from 0.12 (T_5) to 37.68 (T_{13}).

No significant variation in pod borer damage was observed among various treatments. However, the plots receiving the treatment chlorpyriphos 0.05% (T_4) was free of pod borer damage. Pod bug population was not recorded in plots treated with carbaryl 0.2% (T_1) chlorpyriphos 0.05% (T_4) and neem kernel suspension 5% (T_7). In other treatments, the population ranged from 0.33 (T_2, T3, T_6, T_9, T_{11} and T_{12}) to 1.00 (T_{13}).

The data on the population of natural enemies observed at 76 DAS is presented in Table 36.

The population of *Coccinella* spp. adults was low and the mean number per 5 sweeps ranged from 0.00(T_8 and T13) to 1.00(T_6). No significant variation was observed in the population of grubs and pupae among treatments, the range being 0.00 (T_1) to 2.45 (T_7) and 0.00 (T_1 and T_{11}) to 1.84 (T_9), respectively. However, the

Table 35. Incidence of pests/extend of damage in different treatments at 76 DAS- Field trial- Season-1 (January to April 2000)

Treatments	Mean number of *A.craccivora* (top 2.5 cm shoot)$^{-1}$	Mean per cent of pod borer damage	Mean number of pod bugs (5 sweeps)$^{-1}$
T_1	0.00 (0.90)	0.28 (1.13)	0.00
T_2	0.00 (0.95)	0.54 (1.24)	0.33
T_3	0.00 (0.98)	0.30 (1.14)	0.33
T_4	0.00 (0.61)	0.00 (0.99)	0.00
T_5	0.12 (1.06)	0.69 (1.30)	0.67
T_6	0.74 (1.32)	0.28 (1.13)	0.33
T_7	0.00 (0.95)	0.37 (1.17)	0.00
T_8	1.72 (1.65)	0.56 (1.25)	0.67
T_9	0.34 (1.16)	0.56 (1.25)	0.33
T_{10}	0.19 (1.09)	0.35 (1.16)	0.67
T_{11}	0.70 (1.30)	0.28 (1.13)	0.33
T_{12}	0.15 (1.07)	0.49 (1.22)	0.33
T_{13}	37.68 (6.22)	2.31 (1.82)	1.00
CD (0.05)	2.71	NS	-

The values are retransformed adjusted means from Analysis of co-variance

Figures in parentheses are $\sqrt{X+1}$ transformed values

***Table 36.* Population of natural enemies in different treatments at 76 DAS- Field trial-Season–1(January to April 2000)**

Treatments	Mean No. of adult *Coccinella* spp. (5 sweeps)$^{-1}$	Mean No. of *Coccinella* spp grubs plant^{-1}	Mean No. of *Coccinella* spp pupae plant^{-1}	Mean No. of adult *M.sexmaculatus* (5 sweeps)$^{-1}$	Mean No. of *M.sexmaculatus* grubs plant^{-1}	Mean No. of Syrphid maggots plant^{-1}	Mean No. of Spiders plant^{-1}	Mean No. of Damsel flies (5 sweeps)$^{-1}$
T_1	0.33	0.00(0.95)	0.00(0.95)	0.33	0.59(1.26)	0.00	0.00	0.00
T_2	0.67	0.55(1.25)	0.68(1.30)	0.67	0.23(1.11)	0.33	0.00	0.00
T_3	0.67	0.86(1.37)	0.48(1.22)	0.00	0.10(1.05)	0.00	0.00	0.00
T_4	0.67	2.00(1.73)	0.44(1.20)	0.33	0.51(1.23)	0.33	0.33	0.00
T_5	0.67	0.90(1.86)	0.81(1.35)	1.00	0.00(0.92)	0.00	0.00	0.00
T_6	1.00	2.00(1.39)	1.28(1.51)	0.00	0.02(1.01)	1.00	0.00	0.00
T_7	0.67	2.45(1.02)	1.74(1.66)	0.67	2.61(1.90)	0.67	0.67	0.33
T_8	0.00	0.94(1.52)	0.34(1.16)	0.33	0.96(1.40)	0.00	0.00	0.00
T_9	0.33	0.04(1.50)	1.84(1.68)	0.33	0.90(1.38)	0.00	0.00	0.00
T_{10}	0.33	1.31(1.52)	0.27(1.13)	0.00	0.93(1.39)	0.00	0.00	0.00
T_{11}	0.33	1.24(1.50)	0.00(0.98)	0.67	1.13(1.46)	0.00	0.00	0.00
T_{12}	0.33	1.19(1.48)	0.56(1.25)	0.33	1.49(1.22)	0.00	0.00	0.00
T_{13}	0.00	2.07(1.75)	0.35(1.16)	0.00	2.04(1.74)	0.67	0.00	0.00
CD (0.05)	-	NS	NS	-	NS	-	-	-

The values are retransformed adjusted means from Analysis of co-variance

Figures in parentheses are $\sqrt{X+1}$ transformed values

highest population of *Coccinella* spp. grubs (2.45) even higher than that of control T_{13} (2.07) was observed in plots which received the treatment neem kernel suspension 5% (T_7). As in 68 DAS, very low population of *M. sexmaculatus* adults was observed, the range being 0.00 (T_3, T_6, T_{10} and T_{13}) to 1.00 (T_5). No significant variation in the grubs of *M. sexmaculatus* was observed among various treatments, though the highest mean population of 2.61 was recorded in the treatment neem kernel suspension 5% (T_7).

The mean syrphid maggot (*I. scutellare*) population per plant ranged from 0.00 to 1.00 in the treatment T_6. Practically very low levels of damsel flies and spiders could be observed so that the comparison of treatment means could not be done.

Yield of cowpea grains

Two harvests were done at fortnightly intervals from 76 DAS onwards. The relevant data are presented in Table 37.

The treatments *viz.* chlorpyriphos 0.05% (T_4), crude neem oil emulsion 10% (T_5), crude neem oil emulsion 5%(T_6), neem kernel suspension 5% (T_7) and Nimbecidine 0.2% (T_9) recorded significantly higher yield over control. The mean yield of cowpea grains per hectare varied from 310kg (T_{13}) to 750 kg (T_4). The highest yield of 750 kg ha^{-1} of cowpea grains was obtained from plots treated with chlorpyriphos 0.05 % (T_4).

Table 37. Mean yield and marginal benefit: cost ratio– Field trial– Season– 1(January to April 2000)

Treatments	Grain yield kg ha^{-1}	Increase in yield over control kg ha^{-1}	Additional * income Rs. ha^{-1}	Cost of plant protection Rs./-**	Marginal benefit: cost ratio
T_1	535	225	4500	1580	2.8
T_2	500	190	3800	1280	3.0
T_3	485	175	3500	1402	2.5
T_4	750	440	8800	1826	4.8
T_5	625	315	6300	2000	3.1
T_6	660	350	7000	1900	3.6
T_7	700	390	7800	2000	3.9
T_8	510	200	4000	1500	2.7
T_9	550	240	4800	1280	3.8
T_{10}	485	175	3500	1050	3.3
T_{11}	460	150	3000	1050	2.9
T_{12}	370	60	1200	600	2.0
T_{13}	310	-	-	-	-
CD (0.05)	225.5	-	-	-	-

* Price of grain cowpea- Rs. 20/- per kg

* * Labour requirement for preparing and spraying leaf and seed extracts and insecticides were 3, 3, 2, respectively .

Wages per labourer-Rs.150/- per day.

The treatments *viz.* neem kernel suspension 5%(T_7), crude neem oil emulsion 5%(T_6), crude neem oil emulsion 10%(T_5), Nimbecidine 0.2%(T_9), and carbaryl 0.2%(T_1) recorded a per hectare yield in the order of 700, 660 625 , 550 and 535 kg, respectively and these were at par with the treatment chlorpyriphos 0.05% (T_4).

The highest marginal benefit: cost ratio of 4.8 was worked out for the treatment chlorpyriphos 0.05% followed by 3.9 for the treatment neem kernel suspension 5% (T_7). In the other treatments, the marginal benefit: cost ratio ranged from 2.0 to 3.8.

4.4.2 Season 2 (January to April 2001)

The second season experiment was conducted from January to April 2001.

The relevant results on the pest population / damage incidence and population of natural enemies at weekly intervals after treatment are presented.

As in the case of Season 1, the first round spraying was conducted on 45 DAS. Pre treatment observations on the pest / damage and natural enemy population were recorded on the previous day of treatment and the post treatment observations recorded at weekly intervals till harvest.

52 DAS

The pests observed at 52 DAS included *A. craccivora*, *A. misera* and pod bugs. The data on the pest / damage incidence at one week after treatment (52 DAS) are presented in Table 38.

As in season 1, there was significant reduction in population of *A. craccivora* in all the treatments over control. Though all the treatments were on par in controlling *A. craccivora*, no incidence was observed in plots receiving chlorpyriphos 0.05% (T_4) spray. No symptoms of leaf crinkling due to aphid infestation were observed in plots receiving chlorpyriphos 0.05 %(T_4) and neem kernal suspension 5% (T_7).

In the case of chlorpyriphos 0.05% treated plots, neither the symptoms of leaf damage nor population of grubs/adults of *A. misera* could be observed. The mean per cent damage in other treatments ranged from 0.37 (T_1) to 1.07 (T_7) as against 8.61 in the control (T_{13}). Thus, all the treatments were superior to control in reducing the damage by the epilachna beetle *A. misera*.

As in season 1, the mean population of pod bugs 5sweeps^{-1} was negligible and there was no incidence at all in plots treated with lindane 0.05%(T_3), chlorpyriphos 0.05% (T_4), crude neem oil emulsion 10% (T_5), crude neem oil emulsion 5% (T_6) and neem kernel suspension 5% (T_7).

Table 38. Incidence of pests/Extent of damage in different treatments at 52 DAS-Field trial-Season- 2 (January to April 200)

Treatments	Mean No. of *A.craccivora* top (2.5 cm shoot) $^{-1}$	Mean % of crinkled leaves due to feeding by *A.craccivora*	Mean percent leaves damaged by *A. misera.*	Mean No. of *A. misera.* grubs plant $^{-1}$	Mean No. of *A. misera.* pupae	Mean No. of podbugs (5 sweeps) $^{-1}$
T_1	1.50 (1.58)	2.07	0.37 (1.17)	0.19 (1.09)	0.00	0.33
T_2	3.37 (2.09)	3.73	0.42 (1.19)	0.25 (1.12)	0.13	0.67
T_3	1.22 (1.49)	1.10	0.39 (1.18)	0.14 (1.07)	0.00	0.00
T_4	0.00 (0.98)	0.00	0.00 (0.86)	0.00 (0.95)	0.00	0.00
T_5	1.01 (1.45)	3.17	0.59 (1.26)	0.10 (1.05)	0.07	0.00
T_6	0.21 (1.100)	1.23	0.99 (1.41)	0.21 (1.10)	0.00	0.00
T_7	0.04 (1.02)	0.00	1.07 (1.44)	0.19 (1.09)	0.00	0.00
T_8	0.70 (1.33)	2.40	0.39 (1.18)	0.04 (1.02)	0.07	0.67
T_9	1.13 (1.46)	1.93	0.56 (1.25)	0.02 (1.01)	0.07	0.33
T_{10}	1.04 (1.43)	1.03	1.02 (1.42)	0.30 (1.14)	0.07	0.67
T_{11}	0.72 (1.31)	0.77	0.64 (1.28)	0.14 (1.07)	0.00	0.33
T_{12}	0.37 (1.17)	0.87	0.85 (1.36)	0.49 (1.22)	0.07	0.33
T_{13}	20.62 (4.65)	6.00	8.61 (3.10)	3.80 (2.19)	2.0	0.67
CD (0.05)	1.33	-	0.65	0.35	-	-

The values are retransformed adjusted means from Analysis of co-variance

Figures in parentheses are $\sqrt{X+1}$ transformed values

The data on the natural enemy population observed at 52 DAS are presented in Table 39.

Predators *viz.* *C. transversalis*, *M. sexmaculatus Micraspis* sp., *Scymnus* sp., *I. scutellaris*, *Paederus* sp. and damsel flies were the natural enemies observed at 52 DAS.

There was no significant difference in the natural enemy population among the various treatments except in the case of the grubs of *Coccinella* spp. The mean number of *Coccinella* spp. grubs recorded per plant in the plots treated with neem kernel suspension 5% (T_7) was the maximum (5.81) and was significantly superior to all other treatments. No population of adult beetles of *M. sexmaculatus* could be observed in the treatments, lindane 0.05%, crude neem oil 10%, aqueous extract of clerodendron 10% and control, while no grubs could be recorded in plots treated with carbaryl 0.2% (T_1). In other treatments, very low population of *M. sexmaculatus* grubs was observed and the mean number varied from 0.33 to 0.67

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The mean population of syrphid maggots (*I. scutellare*) per plant ranged from 0.00 (T_{10}) to 1.67 (T_4). The adult beetles of *Micraspis* sp. could be observed only in the treatments chlorpyriphos 0.05%(T_4), neem kernel suspension 5%(T_7) and Nimbecidine 0.2%(T_9) with a mean of 0.67 each where as the grubs of *Scymnus* sp. were observed in the treatments chlorpyriphos 0.05% (T_4), neem kernel suspension 5% (T_7) and control (T_{13}). The population of adults of *Paederus* sp. and damsel flies was very low.

Table 39. **Population of natural enemies in different treatments in cowpea at 52 DAS -Field trial-Season -2 (January to April 2001)**

Treatments	Mean No. of adult *Coccinella* spp. 5 sweeps^{-1}	Mean No. of *Coccinella* spp grubs plant^{-1}	Mean No. of adult *M.sexmaculatus* 5 sweeps^{-1}	Mean No. of *M.sexmac-ulatus* grubs plant^{-1}	Mean No. of Syrphid maggots plant^{-1}	Mean No. of *Micraspis* spp. adults 5sweeps^{-1}	Mean No. of *Scymnus* spp. grubs plant^{-1}	Mean No.of *Paederus* sp. adults 5sweeps^{-1}	Mean No. of Damsel flies 5 sweeps^{-1}
T_1	0.25 (1.12)	1.01 (1.45)	0.33	0.00	0.33	0.00	0.00	0.00	0.00
T_2	0.64 (1.28)	1.37 (1.54)	0.33	0.33	0.33	0.00	0.00	0.00	0.00
T_3	0.13 (1.46)	0.85 (1.36)	0.00	0.33	0.33	0.00	0.00	0.00	0.00
T_4	0.69 (1.64)	1.19 (1.48)	0.67	0.67	1.67	0.67	0.67	0.67	0.67
T_5	1.62 (1.62)	0.08 (1.04)	0.00	0.67	0.67	0.00	0.00	0.00	0.00
T_6	0.66 (1.29)	0.61 (1.27)	0.33	0.33	1.00	0.00	0.00	0.33	0.67
T_7	0.82 (1.35)	5.81 (2.61)	1.00	0.67	0.67	0.67	0.67	0.33	0.67
T_8	1.34 (1.53)	2.31 (1.82)	0.67	0.33	0.33	0.00	0.00	0.00	0.00
T_9	0.99 (1.41)	1.16 (1.47)	0.33	0.67	0.67	0.67	0.00	0.00	0.00
T_{10}	1.28 (1.51)	1.59 (1.61)	0.33	0.33	0.00	0.00	0.00	0.00	0.00
T_{11}	0.66 (1.29)	2.13 (1.77)	0.00	0.33	0.33	0.00	0.00	0.00	0.33
T_{12}	1.40 (1.55)	1.82 (1.68)	0.33	0.67	0.33	0.00	0.00	0.00	0.00
T_{13}	1.93 (1.39)	1.56 (1.60)	0.00	0.67	0.67	0.00	0.67	0.00	0.00
CD (0.05)	NS	0.72	-	-	-	-	-	-	-

The values are retransformed adjusted means from Analysis of co-variance

Figures in Parentheses are $\sqrt{X+1}$ transformed values

59 DAS

The data on the pests/damage incidence at 59 DAS are presented in Table 40.

The pests included *A. craccivora*, *A. misera,* pod borers and pod bugs.

As in the case of observation at 52 DAS, no incidence of *A. craccivora* was recorded in plots treated with chlorpyriphos 0.05 %(T4). There was significant reduction in population of *A. craccivora* in all the treatments over control.

As observed in season 1, the mean percent of leaf damage by *A. misera* (0.54%) and the mean number of its grubs (0.17) were the lowest in the plots received Nimbecidine 0.2 % (T9). All the treatments were equally effective in significantly reducing the leaf damage by *A. misera* over control.

The mean percent of damage by pod borers was the lowest in plots treated with chlorpyriphos 0.05% (T_4) followed by crude neem oil 5% (T_6) the value being 0.80% and 1.33%, respectively. As in season-1, the plots treated with neem kernel suspension 5% did not harbour any pod bugs, while in other treatments, the mean population ranged from 1.33 to 1.67.

The data on the population of natural enemies at 59 DAS are presented in Table 41.

Table 40. Incidence of pests/Extent of damage in different treatments in cowpea at 59 DAS - Field trial -Season- 2 (January to April 2001)

Treatments	Mean No. of *A.craccivora* top (2.5 cm shoot) $^{-1}$	Mean percent leaves damaged by *A.misera*	Mean No. of *A.misera* . grubs	Mean No. of *A.misera* pupae plant^{-1}	Mean per cent of pod borer damage	Mean No. of pod bugs (5 sweeps) $^{-1}$
T_1	0.28 (1.13)	2.38 (1.84)	0.44 (1.20)	0.17	6.97	1.33
T_2	6.62 (2.76)	3.00 (2.00)	0.74 (1.32)	0.33	6.93	1.33
T_3	8.30 (3.05)	1.40 (1.55)	0.56 (1.25)	0.00	14.97	1.33
T_4	0.00 (0.77)	1.04 (1.43)	0.04 (1.02)	0.00	0.80	1.00
T_5	36.00 (6.08)	0.77 (1.33)	0.59 (1.26)	0.60	9.17	1.33
T_6	2.03 (1.74)	1.37 (1.54)	0.59 (1.26)	0.17	1.33	1.33
T_7	4.71 (2.39)	1.43 (1.56)	0.54 (1.24)	0.00	7.33	0.00
T_8	21.00 (4.69)	1.99 (1.73)	0.56 (1.25)	0.40	6.60	1.33
T_9	13.98 (3.87)	0.54 (1.24)	0.17 (1.08)	0.00	3.83	1.67
T_{10}	4.76 (2.40)	1.16 (1.47)	0.64 (1.28)	0.33	6.17	1.33
T_{11}	28.59 (5.44)	1.92 (1.71)	0.23 (1.11)	0.00	7.83	1.67
T_{12}	24.0 (5.00)	1.28 (1.51)	1.93 (1.39)	0.67	11.00	1.67
T_{13}	158.52 (12.63)	16.81 (4.22)	9.11 (3.18)	5.67	46.00	1.67
CD (0.05)	2.43	1.10	0.54	-	-	-

The values are retransformed adjusted means from Analysis of co-variance

Figures in parentheses are $\sqrt{X+1}$ transformed values

Table 41. Population of natural enemies in different treatments in cowpea at 59 DAS - Field trial - Season– 2 (January to April 2001)

Treatments	Mean No. of adult *Coccinella* spp. 5 sweeps^{-1}	Mean No. of *Coccinella* spp grubs plant^{-1}	Mean No. of adult *M.sexmaculatus* 5 sweeps^{-1}	Mean No. of *M.sexmaculatus* grubs plant^{-1}	Mean No. of Syrphid maggots plant^{-1}	Mean No. of gryllids 5sweeps-1	Mean No. of Spiders plant^{-1}	Mean No. of Damsel flies sweeps^{-1}
T_1	0.56(1.25)	3.71(2.17)	0.67	1.67	0.00	0.67	0.33	0.00
T_2	1.69(1.64)	3.93(2.22)	0.00	4.33	0.33	0.67	0.33	0.00
T_3	0.39(1.18)	2.31(1.82)	0.67	2.67	0.33	1.33	0.33	0.33
T_4	1.06(1.75)	7.29(2.88)	2.00	2.67	0.33	0.00	0.33	0.67
T_5	1.69(1.64)	3.62(2.15)	2.67	4.00	0.00	0.00	1.67	0.00
T_6	1.69(1.64)	3.20(2.05)	3.33	4.33	0.67	0.67	0.67	0.00
T_7	1.46(1.57)	4.20(2.28)	0.67	3.33	1.33	0.67	1.00	0.33
T_8	1.69(1.64)	4.71(2.39)	0.33	3.00	0.67	0.67	0.00	0.33
T_9	2.50(1.87)	8.80(3.13)	0.67	3.00	1.00	0.67	1.00	0.33
T_{10}	2.24(1.80)	4.20(2.28)	1.00	3.33	0.67	0.67	0.00	0.67
T_{11}	2.39(1.84)	4.52(2.35)	1.67	3.33	0.33	0.67	0.67	0.33
T_{12}	1.79(1.67)	3.80(2.19)	0.67	3.00	0.67	1.67	0.67	1.00
T_{13}	1.37(1.54)	2.50(1.87)	2.67	7.00	0.67	1.00	0.33	0.33
CD (0.05)	0.26	0.52	-	-	-	-	-	-

The values are retransformed adjusted means from Analysis of co-variance

Figures in parentheses are $\sqrt{X+1}$ transformed values

As in season 1, the natural enemy population build up was higher at 59 DAS compared to the population at 52 DAS. The natural enemies observed included *Coccinella* spp., *M. sexmaculatus*, *I. scutellare*, gryllids, damsel flies and spiders.

The population of adults of *Coccinella* spp. was less compared to the grubs. The analysis of the data indicated that there was no significant reduction in population of *Coccinella* spp. grubs in all the treatments. The maximum population was recorded in plots treated with Nimbecidine 0.2% (8.80) followed by chlorpyriphos 0.05% (7.29). At 59 DAS, the population of grubs and adults of *M. sexmaculatus* was maximum in the treatment crude neem oil emulsion 5% (T_7), the mean number being 4.33 and 3.33, respectively.

Maggots of *I. scutellare* were not observed in the treatment carbaryl 0.2% (T_1) and crude neem oil emulsion 10% (T_5). In other treatments, the population ranged from 0.33 to 1.33.

Similarly, gryllids were not recorded in the treatments chlorpyriphos 0.05% (T_4) and crude neem oil emulsion 10% (T_5), while in other treatments, the population ranged from o.67 to 1.67. The mean number of damsel flies ranged from 0.33 to 1.00 in the treatments except carbaryl 0.2%, endosulfan 0.05%, crude neem oil emulsion 10% and crude neem oil emulsion 5%, where no population was observed. The spider population was recorded in all the treatments except aqueous extract of *H. suaveolens* 10% (T_{10}) with a range of 0.33 to 1.67.

A second round spraying was given at 60 days after sowing as per the dose given for first spraying and the population/ damage of the pests and natural enemies recorded at weekly intervals till harvest.

68 DAS

The population / damage observed at one week after second treatment (68DAS) are presented in Table 42.

The pests observed were *A. craccivora*, *A. misera*, pod borers and pod bugs.

All the treatments were equally effective in significantly reducing the population of *A. craccivora*. However, the lowest population of *A. craccivora* was recorded in the plots treated with chlorpyriphos 0.05% (T_4) followed by neem kernel suspension 5% (T_7), the mean number per plant being 0.16 and 0.43, respectively.

As in the case of *A. craccivora,* all the treatments significantly reduced the infestation by *A. misera*. The mean percent of leaf damage was the lowest in the treatment chlorpyriphos 0.05% (0.25%) followed by Nimbecidine 0.2% (0.31%). No incidence of grubs could be observed in the treatment nimbecidine 0.2%.

There was significant reduction in the damage caused by pod borers in all the treatments over control, the mean percent damage observed was the lowest in the treatment crude neem oil 5% (T_6). Though there was no significant reduction of the pod bug population in any of the treatment over control, the lowest population of 0.37 was recorded in plots receiving neem kernel suspension 5% (T_7).

Table 42. ***Incidence of pests/extent of damage in different treatments in cowpea at 68 DAS -Field trial- Season - 2 (January to April 2001)***

Treatments	Mean No. of *A.craccivora* top (2.5 cm shoot) $^{-1}$	Mean per cent leaves damaged by *A. misera*	Mean No. of *A. misera* grubs plant $^{-1}$	Mean per cent of pod borer damage	Mean No. of pod bugs (5 sweeps) $^{-1}$
T_1	0.62(1.27)	1.00(1.42)	0.63(1.28)	0.66(1.29)	0.72(1.31)
T_2	1.18(1.48)	0.31(1.14)	0.61(1.27)	1.31(1.52)	0.72(1.31)
T_3	1.60(1.61)	0.97(1.40)	0.33(1.15)	1.53(1.59)	1.22(1.49)
T_4	0.16(1.08)	0.25(1.12)	0.37(1.17)	1.99(1.41)	0.77(1.33)
T_5	7.67(2.91)	0.71(1.31)	0.07(1.04)	0.51(1.23)	0.74(1.32)
T_6	1.78(1.67)	0.85(1.36)	0.81(1.35)	0.42(1.19)	0.77(1.33)
T_7	0.43(1.20)	0.76(1.33)	0.24(1.12)	2.19(1.48)	0.37(1.17)
T_8	2.18(1.78)	1.26(1.50)	0.13(1.06)	1.31(1.52)	1.40(1.55)
T_9	1.83(1.68)	0.31(1.14)	0.00(1.00)	0.96(1.40)	0.90(1.38)
T_{10}	1.28(1.51)	0.67(1.29)	0.25(1.12)	1.28(1.51)	0.64(1.28)
T_{11}	0.65(1.28)	0.76(1.33)	0.35(1.16)	2.03(1.74)	0.90(1.38)
T_{12}	0.77(1.33)	0.71(1.31)	0.27(1.13)	2.65(1.91)	0.56(1.25)
T_{13}	31.79(5.73)	6.43(2.73)	5.38(2.53)	13.90(3.86)	2.31(1.82)
CD (0.05)	1.99	0.88	0.74	0.90	NS

The values are retransformed adjusted means from Analysis of co-variance

Figures in parentheses are $\sqrt{X+1}$ transformed values

The relevant data on the natural enemy population at 68 DAS are presented in Table 43.

Analysis of the data on population of grubs and adults of *Coccinella* spp. indicated that the population was not adversely affected by the application of either chemical or botanical pesticides. The mean population of adult *Coccinella* spp. in various treatments ranged from 0.33 to 2.01 and the highest population (2.01) was recorded in plots treated with nimbecidine 0.2% (T_9). The highest population of *Coccinella* spp. grubs (2.42) was recorded in the treatment neem kernel suspension 5%.

No adult *M. sexmaculatus* was recorded in plots treated with carbaryl 0.2% (T_{10}) and endosulfan 0.05% (T_2), while the mean number in other treatments ranged from 0.33 (T_{12}) to 1.67 (T_4). No significant difference in grub population was observed among various treatments.

The population of syrphids (*I. scutellare*), *Paederus* sp., damsel flies and spiders was relatively very low and the mean ranged from 0.0 to 1.0 among various treatments so that their treatment effects could not be manifested.

76 DAS

The observations on the pests/ damage incidence at 76 DAS are presented in Table 44.

A. craccivora, pod borers and pod bugs were the pests observed.

Table 43. **Population of natural enemies in different treatments in cowpea at 68 DAS -Field trial - Season - 2 (January to April 2001)**

Treatments	Mean No. of adult *Coccinella* spp. 5 $sweeps^{-1}$	Mean No. of *Coccinella* spp grubs $plant^{-1}$	[1] Mean No. of adult *M.sexmaculatus* 5 $sweeps^{-1}$	Mean No. of *M.sexmaculatus* grubs $plant^{-1}$	Mean No. of Syrphid maggots $plant^{-1}$	Mean No. of *Paederus* sp. 5sweeps-1	Mean No. of spiders $plant^{-1}$	Mean No. of damsel flies 5 $sweeps^{-1}$
T_1	0.33 (1.15)	0.61 (1.67)	0.00	0.39 (1.18)	0.00	0.00	0.00	0.00
T_2	0.33 (1.15)	1.71 (1.65)	0.00	0.28 (1.73)	0.00	0.00	0.00	0.00
T_3	0.08 (1.04)	0.46 (1.21)	0.67	0.61 (1.27)	0.33	0.00	0.00	0.67
T_4	1.78 (1.67)	1.56 (1.60)	1.67	2.03 (1.74)	0.67	0.33	0.67	0.33
T_5	1.39 (1.55)	1.40 (1.55)	1.33	0.25 (1.12)	0.00	0.00	0.00	0.00
T_6	0.69 (1.30)	1.95 (1.72)	1.00	0.88 (1.37)	1.00	0.00	0.33	1.00
T_7	1.06 (1.43)	2.42 (1.85)	0.67	1.90 (1.38)	0.00	0.00	0.67	0.67
T_8	1.07 (1.44)	2.12 (1.77)	1.00	1.34 (1.53)	0.67	0.00	0.67	0.00
T_9	2.01 (1.73)	0.80 (1.34)	0.67	0.64 (1.28)	0.33	0.00	0.00	0.67
T_{10}	1.98 (1.72)	1.17 (1.47)	1.00	0.90 (1.38)	0.67	0.33	0.00	0.00
T_{11}	1.83 (1.68)	1.38 (1.54)	0.67	0.90 (1.38)	0.00	0.00	0.00	0.00
T_{12}	0.99 (1.41)	2.12 (1.77)	0.33	0.56 (1.25)	0.00	0.00	0.00	0.00
T_{13}	0.57 (1.25)	1.53 (1.59)	1.33	2.20 (1.79)	0.00	0.00	0.00	0.00
CD (0.05)	NS	NS	-	NS	-	-	-	-

The values are retransformed adjusted means from Analysis of co-variance

Figures in parentheses are $\sqrt{X+1}$ transformed values

Table 44. Incidence of pests /Extent of damage in different treatments in cowpea at 76 DAS Field trial-Season 2 (January to April 2001)

Treatments	Mean number of *A.craccivora* top (2.5 cm shoot)$^{-1}$	Mean per cent of pod borer damage	Mean number of pod bugs (5 sweeps)$^{-1}$
T_1	0.81 (1.35)	0.35 (1.16)	0.23 (1.11)
T_2	0.92 (1.39)	0.80 (1.34)	0.23 (1.11)
T_3	0.83 (1.35)	0.69 (1.30)	0.35 (1.16)
T_4	0.10 (1.05)	0.02 (1.01)	0.08 (1.04)
T_5	1.45 (1.57)	0.42 (1.19)	0.66 (1.29)
T_6	0.62 (1.27)	0.30 (1.14)	0.08 (1.04)
T_7	0.80 (1.34)	0.37 (1.17)	0.23 (1.11)
T_8	1.64 (1.62)	0.72 (1.31)	0.23 (1.11)
T_9	0.43 (1.19)	1.16 (1.47)	0.90 (1.38)
T_{10}	0.53 (1.24)	0.74 (1.32)	0.23 (1.11)
T_{11}	0.52 (1.23)	0.49 (1.22)	0.54 (1.24)
T_{12}	0.98 (1.41)	0.67 (1.29)	0.54 (1.24)
T_{13}	16.80 (4.22)	2.72 (1.93)	1.10 (1.45)
CD (0.05)	1.42	NS	NS

The values are retransformed adjusted means from Analysis of co-variance

Figures in parentheses are $\sqrt{X = 1}$ transformed values

All the treatments effectively controlled the population of *A. craccivora*. Significant reduction in population of *A. craccivora* was observed in all the treatments compared to control. No significant variation in the pod borer damage was observed in the various treatments, the range being 0.02 (T_4) to 2.72% (T_{13}). Similarly, there was no significant variation in pod bug population among all the treatments and the mean number of bugs per 5 sweeps ranged from 0.08 (T_4) to 1.10 (T_{13}).

The data on the population on natural enemies observed at 76 DAS are given in Table 45. The natural enemies observed included *C. transversalis*, *M. sexmaculatus*, *Micraspis* sp. and spiders.

No adult *C. transversalis* population was recorded in plots treated with crude neem oil 10% (T_5) and aqueous extract of clerodendron 10 % (T_{11}). In other treatments, the population ranged from 0.33 to 1.33. The population of the adults and grubs of *C. transversalis* was recorded to be the highest in plots treated with neem kernel suspension 5% (T_7), the mean values being 1.33 and 2.74, respectively. Analysis of the data indicated that the population of *C. transversalis*. grubs were not adversely affected by any of the treatments and the mean population ranged from 0.00 (T_{12}) to 2.74 (T_7).

No adult *M. sexmaculatus* population was recorded in plots treated with carbaryl 0.2% (T_1) and endosulfan 0.05% (T_2). The mean number of *M. sexmaculatus* adults in other treatments ranged from 0.33 to 1.33. Perusal of the

Table 45. Population of natural enemies in different treatments in cowpea at 76 DAS-Field trial-Season-2 (January to April 2001)

Treatments	Mean No. of adult *Coccinella* spp. 5 sweeps^{-1}	Mean No. of *Coccinella* spp grubs plant^{-1}	Mean No. of adult *M.sexmaculatus* 5 sweeps^{-1}	Mean No. of *M.sexmaculatus* grubs plant^{-1}	Mean No. of Syrphid maggots plant^{-1}	Mean No. of adult *Micraspis* sp. 5sweeps-1	Mean No. of spiders plant^{-1}
T_1	0.33	0.97 (1.41)	0.00	0.39 (1.18)	0.00	0.00	0.00
T_2	0.33	0.87 (1.37)	0.00	0.02 (0.99)	0.00	0.00	0.00
T_3	0.33	0.07 (1.03)	0.67	0.61 (1.27)	0.00	0.00	0.67
T_4	0.67	1.20 (1.48)	1.00	0.91 (1.41)	0.00	0.67	0.67
T_5	0.00	0.32 (1.15)	0.67	0.25 (1.12)	0.00	0.00	0.00
T_6	0.67	1.19 (1.09)	0.67	0.28 (1.13)	1.00	0.33	0.00
T_7	1.33	2.74 (1.93)	1.33	2.06 (2.06)	0.00	0.00	0.00
T_8	0.67	1.30 (1.52)	0.33	0.80 (1.34)	0.00	0.00	0.00
T_9	0.67	0.21 (1.10)	1.33	0.56 (1.25)	0.00	0.00	0.00
T_{10}	0.33	1.20 (1.09)	0.67	0.90 (1.38)	0.00	0.00	0.00
T_{11}	0.00	0.19 (1.09)	1.00	0.99 (1.41)	0.00	0.00	0.00
T_{12}	0.33	0.00 (0.97)	1.33	0.54 (1.24)	0.67	0.00	0.00
T_{13}	0.33	0.47 (1.21)	0.67	1.69 (1.64)	0.67	0.00	0.00
CD (0.05)	-	1.01	-	NS	-	-	-

The values are retransformed adjusted means from Analysis of co-variance

Figures in parentheses are $\sqrt{X+1}$ transformed values

data on population of grubs indicated that the grub population was not adversely affected by the application of either chemical or botanical pesticides. The highest mean population of 2.06 was recorded in the treatment neem kernel suspension 5 %.

The adults of *Micraspis* sp. was recorded only in the treatments chlorpyriphos 0.05 % (T_4) and crude neem oil emulsion 5% (T_6). Very low population of adults of *Micraspis* sp., syrphid maggots and spiders were recorded.

Yield of cowpea grains

As in season-1, harvest of mature pods was done at 76 and 90 DAS. The data are presented in Table 46.

All the treatments except the aqueous extract of *H. sauveolens* 10% (T_{10}), aqueous extract of clerodendron 10% (T_{11}) and mechanical and cultural control alone recorded significantly higher grain yield than control (295 kg ha^{-1}).

The highest yield of 785 kg ha^{-1} in the second season also was obtained from plots treated with chlorpyriphos 0.05% (T_4). This was followed by the treatment neem kernel suspension 5 % (T_7) with a per hactare yield of 735 kg, which was on par with the treatment chlorpyriphos 0.05 % (T_4).

The highest marginal benefit : cost ratio of 5.4 was worked out for the treatment chlorpyriphos 0.05 % (T_4) followed by the treatment neem kernel suspension 5 % (T_7) with a ratio of 4.4 as in the previous season.

Table 46. Mean yield and marginal benefit: cost ratio- Field trial- Season- 2 (January to April 2001)

Treatments	Grain yield kg ha^{-1}	Increase in yield over control kg ha^{-1}	Additional income * Rs. ha^{-1}	Cost of plant protection* * Rs. ha^{-1}	benefit:cost ratio
T_1	485	190	3800	1580	2.4
T_2	515	220	4400	1280	3.4
T_3	535	165	4800	1402	3.4
T_4	785	490	9800	1826	5.4
T_5	520	225	4500	2000	2.25
T_6	610	315	6300	1900	3.3
T_7	735	440	8800	2000	4.4
T_8	500	205	4100	1500	2.7
T_9	550	255	5100	1280	4.0
T_{10}	435	140	2800	1050	2.7
T_{11}	385	90	1800	1050	1.7
T_{12}	400	105	2100	600	3.5
T_{13}	295	-	-	-	-
CD (0.05)	161	-	-	-	-

* Price of grain cowpea- Rs. 20/- per kg

* * Labour requirement for preparing and spraying leaf and seed extracts and insecticides were 3, 3 and 2 respectively.

Wages per labourer-Rs.150/- per day.

4.4.3 Terminal residues of insecticides in cowpea grains

The terminal residues of the insecticides in cowpea grains obtained from plots receiving the treatments lindane, chlorpyriphos and endosulfan at 15 days after last application of insecticides were estimated and the data presented in Table 47.

Table 47. Terminal residues (ppm) of insecticides in cowpea grains

Season	Mean terminal residues					
	Lindane	Chlorpyriphos	Endosulfan			
			α endosulfan	β endosulfan	Endosulphate	Total
S_1	0.060	0.052	0.060	0.046	0.062	0.168
S_2	0.045	0.065	0.030	0.030	0.054	0.114
MRL ppm	3	2				2

The terminal residues of lindane estimated from the cowpea grain samples were 0.060 and 0.045 ppm during the first and second seasons, respectively which were below the MRL of 3ppm fixed for cowpea. Similarly, the residue levels of chlorpyriphos were estimated as 0.052 and 0.065 in the first and second seasons respectively which also came below the MRL of 2ppm for cowpea. The residue components of endosulfan *viz.* α , β and endosulphate were estimated to be 0.060, 0.046 and 0.062 ppm during the first season and 0.03, 0.03 and 0.054ppm in the second season, respectively. However, the total residue level of endosulfan in season-1 (0.168ppm) and season-2 (0.114ppm) were also observed to be below the MRL fixed for cowpea (2ppm).

4.5 Evaluation of the effect of various field treatments on the incidence of pulse beetle *Callosobruchus* spp. in store

The cowpea grain samples weighing 200 g each collected from the various treatments of field experiment 4.4.1 and 4.4.2 during January to May 2000 and 2001 were observed for the incidence of pests for a period of six months in storage.

Loss of grain weight, percentage of grain damage by bruchids, mean population of adult bruchids, saw toothed grain beetle, lesser grain borer and flat grain beetle were recorded at monthly intervals, the results of which are presented in Tables 48 to 53.

4.5.1 Loss of grain weight due to pests of stored cowpea grains

The data on the per cent weight loss of grains at monthly intervals starting from the date of storage during the two seasons are presented in Table 48.

During the first season, there was no weight loss in treatments, neem kernel suspension 5% (T_7), neem kernel suspension 2.5% (T_8) and Nimbecidine 0.2% (T_9) throughout the period of observation in grains stored up to 5 months. Similar results were recorded up to three months in the treatment chlorpyriphos 0.05% (T_4), whereas in the treatments carbaryl 0.2 % (T_1) and aqueous extract of clerodendron 10 % (T_{11}), the similar effect was seen up to two months only.

During the first month of storage, significantly lower level of infestation was recorded in all the treatments except neem oil emulsion 10% (T_5) compared

Table 48. **Percent weight loss due to pests of stored cowpea grains**

Treatments	Season – 1 (MOS)					Season – 2 (MOS)				
	1	2	3	4	5	1	2	3	4	5
T_1	0.00(1.00)	0.00(1.00)	0.00(1.00)	1.40(1.55)	2.10(1.76)	0.00(1.00)	0.35(1.16)	1.22(1.49)	2.03(1.74)	3.04(2.01)
T_2	0.00(1.00)	1.19(1.48)	2.35(1.83)	5.10(2.47)	6.67(2.77)	0.00(1.00)	0.82(1.35)	2.13(1.77)	4.29(2.30)	9.11(3.18)
T_3	0.00(1.00)	1.89(1.70)	2.53(1.88)	5.35(2.52)	8.82(2.97)	0.00(1.00)	2.73(1.93)	4.38(2.32)	5.76(2.60)	8.80(3.13)
T_4	0.00(1.00)	0.00(1.00)	0.00(1.00)	0.37(1.17)	0.74(1.32)	0.00(1.00)	0.37(1.17).	0.61(1.27)	1.77(1.33)	3.88(2.21)
T_5	5.71(2.59)	6.29(2.70)	7.29(2.88)	5.25(2.50)	10.02(3.32)	0.00(1.00)	1.46(1.57)	2.42(1.85)	3.71(2.17)	5.92(2.63)
T_6	0.00(1.00)	4.95(2.44)	32.06(5.75)	24.00(5.00)	30.47(5.61)	0.00(1.00)	1.04(1.43)	1.04(1.43)	7.47(2.91)	11.53(3.54)
T_7	0.00(1.00)	0.00(1.00)	0.00(1.00)	0.00(1.00)	0.00(1.00)	0.00(1.00)	1.59(1.26)	2.06(1.75)	2.39(1.84)	4.34(2.31)
T_8	0.00(1.00)	0.00(1.00)	0.00(1.00)	0.00(1.00)	0.00(1.00)	0.00(1.00)	1.59(1.26)	1.61(1.27)	0.61(1.27)	1.85(1.36)
T_9	0.00(1.00)	0.00(1.00)	0.00(1.00)	0.00(1.00)	0.00(1.00)	0.00(1.00)	1.59(1.61)	1.92(1.71)	2.20(1.79)	3.37(2.09)
T_{10}	0.00(1.00)	0.14(1.07)	0.64(1.28)	1.28(1.51)	1.37(1.54)	0.00(1.00)	5.62(1.37)	1.25(1.50)	2.10(1.76)	3.45(2.11)
T_{11}	0.00(1.00)	0.00(1.00)	1.30(1.14)	1.90(1.38)	2.34(1.53)	0.00(1.00)	0.66(1.29)	0.37(1.67)	2.76(1.94)	3.45(2.11)
T_{12}	0.12(1.06)	0.30(1.14)	1.85(1.36)	1.31(1.52)	2.06(1.75)	0.00(1.00)	0.85(1.36)	1.19(1.48)	1.79(1.67)	3.62(2.15)
T_{13}	3.54(2.13)	4.81(2.41)	6.13(2.67)	11.32(3.51)	27.73(5.36)	0.00(1.00)	1.43(1.56)	2.96(1.99)	5.81(2.61)	5.92(2.63)
C D(0.05)	0.55	0.96	1.46	1.23	0.82	-	NS	NS	NS	NS

Figures in parenthesis are $\sqrt{X+1}$ transformed values

MOS- Months of storage

to control. The same trend was noticed during the second, third and fourth month in all the treatments except endosulfan 0.05 % (T_2), lindane 0.05% (T_3), neem oil emulsion 10% and neem oil emulsion 5% (T_6). During the fifth month of storage, all the treatments could protect the grains from significant weight loss except crude neem oil emulsion 5% (T_7).

Observations recorded on the second season indicated that, on the first month of storage, no reduction in the grain weight was recorded in any of the treatments. Though slight reduction was recorded during the second to fifth months of storage in all the treatments, it was not statistically significant.

4.5.2 Percentage infestation by bruchids in cowpea grains under storage

The percentage of infestation by bruchids in cowpea grains under storage is given in Table 49.

No infestation of bruchids was observed during storage in the grains collected from plots receiving chlorpyriphos 0.05% (T4) up to fifth month of storage in both the seasons whereas, the treatments neem kernel suspension 5% (T_7) and neem kernel suspension 2.5% (T_8) could protect the grains from infestation up to fourth month. However, during the second season, no infestation of bruchids was noticed in plots receiving lindane 0.05% in addition to chlorpyriphos 0.05% up to fifth month. Similarly, protection could be observed up to fourth month in grains collected from plots receiving carbaryl 0.2% and endosulfan 0.05% during both the seasons.

Table 49. **Percentage of infestation by bruchids in cowpea grains under storage**

Treat-ments	Season – 1 (MOS)					Season – 2 (MOS)				
	1	2	3	4	5	1	2	3	4	5
T_1	0.00(1.00)	0.00(1.00)	0.00(1.00)	5.00(2.45)	7.67(2.77)	0.00(1.00)	0.00(1.00)	0.00(1.00)	0.00(1.00)	7.82(2.97)
T_2	0.00(1.00)	0.00(1.00)	0.00(1.00)	5.11(2.26)	9.18(3.03)	0.00(1.00)	0.00(1.00)	0.00(1.00)	0.00(1.00)	14.92(3.99)
T_3	0.00(1.00)	0.00(1.00)	0.00(1.00)	2.88(1.97)	0.00(1.00)	0.00(1.00)	0.00(1.00)	0.00(1.00)	0.00(1.00)	0.00(1.00)
T_4	0.00(1.00)	0.00(1.00)	0.00(1.00)	.00(1.00)	0.00(1.00)	0.00(1.00)	0.00(1.00)	0.00(1.00)	0.00(1.00)	0.00(1.00)
T_5	8.18(3.03)	9.18(3.03)	15.76(3.97)	17.56(4.19)	26.67(5.26)	5.62(2.37)	2.13(1.77)	3.00(2.00)	0.00(1.00)	0.00(1.00)
T_6	11.53(3.54)	23.11(4.91)	24.81(5.08)	33.22(5.85)	48.84(7.06)	39.56(6.29)	21.75(4.77)	13.44(3.80)	12.10(3.62)	19.07(4.48)
T_7	0.00(1.00)	0.00(1.00)	0.00(1.00)	0.00(1.00)	6.51(2.74)	0.00(1.00)	0.00(1.00)	0.00(1.00)	0.00(1.00)	2.13(1.77)
T_8	0.00(1.00)	0.00(1.00)	0.00(1.00)	0.00(1.00)	3.00(2.00)	0.00(1.00)	0.00(1.00)	0.00(1.00)	0.00(1.00)	2.13(1.77)
T_9	1.19(1.48)	1.19(1.48)	0.00(1.00)	0.00(1.00)	0.00(1.00)	6.84(2.80)	3.80(2.19)	0.00(1.00)	0.00(1.00)	0.00(1.00)
T_{10}	2.13(1.77)	2.13(1.77)	5.11(2.26)	0.00(1.00)	1.19(1.48)	0.00(1.00)	0.00(1.00)	0.00(1.00)	0.00(1.00)	3.80(2.19)
T_{11}	1.19(1.48)	2.13(1.77)	5.11(2.26)	0.00(1.00)	0.00(1.00)	0.00(1.00)	3.00(2.00)	0.00(1.00)	0.00(1.00)	3.80(2.19)
T_{12}	2.88(1.97)	2.13(1.77)	2.88(1.97)	5.00(2.45)	8.18(3.03)	1.19(1.48)	3.57(12.74)	1.19(1.48)	0.00(1.00)	6.67(2.77)
T_{13}	7.82(2.97)	18.27(4.39)	20.62(4.65)	39.31(6.27)	54.06(7.42)	20.16(4.60)	44.43(6.74)	41.38(6.51)	42.43(6.59)	17.75(4.33)
C D(0.05)	1.12	1.47	1.53	0.83	1.48	2.67	2.75	1.74	0.82	2.45

Figures in parenthesis are $\sqrt{X+1}$ transformed values

MOS - Months of storage

4.5.3 Population of adult bruchids in cowpea grains under storage

In the first season, though low level of population of adult bruchids was observed in the first month, further no population was recorded in subsequent months to fifth month of storage in the treatments neem kernel suspension 2.5% and Nimbecidine 0.2% (Table 50).

In the second season, though significantly low population of adult bruchids could be observed in the treatments endosulfan 0.05% (T_2), chlorpyriphos 0.05%, neem kernel suspension 5% (T_7) and aquous extract of *H. sauveolens* 10% (T_{10}) during the first month of storage, only the treatment chlorpyriphos 0.05% (T_4) could continuously give protection up to fifth month of storage. The treatments neem kernel suspension 2.5% (T_8), Nimbecidine 0.2% (T_9) and aqueous extract of *H. sauveolens* 10% could protect the grains up to fourth month of storage.

4.5.4 Population of other insect pests in cowpea grains under storage

In addition to bruchids, low population of the adults of *Laemophleus* sp., O. *surenamensis* and *R. dominica* were also recorded during storage though their population was very low so that the means could not be compared statistically.

The mean number of adult beetles of *Laemophleus* sp. in cowpea grains under storage is presented in Table 51. The data indicated that no adult beetles of *Laemophleus* sp. was recorded in any of the treatments during the first month of storage in both the seasons. The mean population among various treatments in the

Table 50. Mean number of adult bruchids in cowpea grains under storage

Treat-ments	Season – 1 (MOS)					Season – 2 (MOS)				
	1	2	3	4	5	1	2	3	4	5
T_1	12.40(3.66)	3.28(2.07)	1.22(1.49)	1.22(1.49)	8.49(3.08)	1.79(1.67)	4.76(2.40)	7.41(2.91)	0.00(1.00)	37.07(6.17)
T_2	4.90(2.43)	0.00(1.00)	0.54(1.24)	0.54(1.24)	0.00(1.00)	0.00(1.00)	4.76(2.40)	4.81(2.41)	0.00(1.00)	34.28(5.94)
T_3	4.02(2.24)	0.00(1.00)	0.54(1.24)	0.54(1.24)	0.00(1.00)	14.92(3.99)	0.00(1.00)	0.00(1.00)	2.40(1.87)	0.00(1.00)
T_4	6.84(2.80)	1.22(1.49)	0.00(1.00)	0.00(1.00)	0.00(1.00)	0.30(1.14)	0.00(1.00)	0.00(1.00)	0.00(1.00)	0.00(1.00)
T_5	19.96(4.58)	6.56(2.75)	9.96(3.31)	3.33(2.08)	37.19(6.18)	2.19(1.48)	6.51(2.74)	2.13(1.11)	0.00(1.00)	21.66(4.76)
T_6	70.91(8.48)	119.34(10.9)	236.47(15.41)	165.15(12.89)	69.22(8.38)	34.05(5.92)	21.37(4.73)	54.65(7.46)	77.50(8.86)	22.62(4.86)
T_7	5.25(2.50)	0.00(1.00)	0.54(1.24)	0.00(1.00)	0.00(1.00)	0.00(1.00)	0.00(1.00)	0.30(1.14)	0.00(1.00)	2.50(1.87)
T_8	3.84(2.20)	0.00(1.00)	0.00(1.00)	0.00(1.00)	0.00(1.00)	0.54(1.24)	0.00(1.00)	0.00(1.00)	0.00(1.00)	6.51(2.74)
T_9	9.89(3.30)	0.00(1.00)	0.00(1.00)	0.00(1.00)	0.00(1.00)	11.04(3.47)	0.00(1.00)	0.00(1.00)	0.00(1.00)	0.30(1.14)
T_{10}	3.45(2.11)	0.00(1.00)	0.54(1.24)	0.00(1.00)	0.00(1.00)	0.00(1.00)	0.00(1.00)	0.00(1.00)	0.00(1.00)	12.47(3.67)
T_{11}	1.99(1.41)	0.00(1.00)	0.54(1.24)	0.00(1.00)	0.00(1.00)	2.50(1.87)	4.43(2.33)	0.30(1.14)	0.00(1.00)	0.00(1.00)
T_{12}	13.06(3.75)	0.00(1.00)	0.00(1.00)	0.00(1.00)	0.00(1.00)	0.77(1.33)	7.12(2.85)	0.90(1.38)	0.00(1.00)	0.99(1.41)
T_{13}	35.24(6.12)	70.57(8.46)	103.86(10.24)	176.94(13.34)	257.57(16.08)	13.62(3.69)	48.70(7.05)	20.07(4.59)	71.08(8.49)	69.39(8.39)
CD (0.05)	1.89	1.35	1.37	1.47	3.13	2.54	4.97	1.78	1.08	4.08

Figures in parenthesis are $\sqrt{x+1}$ transformed values

MOS - Months of storage

Table 51. Mean number of *Laemophleus* sp. adults in cowpea grains under storage

Treatments	Season – 1 (MOS)					Season – 2 (MOS)				
	1	2	3	4	5	1	2	3	4	5
T_1	0.00	3.33	13.67	5.33	0.00	0.00	0.00	0.00	0.00	0.00
T_2	0.00	0.00	5.33	1.33	0.00	0.00	0.00	0.00	0.00	0.00
T_3	0.00	6.00	14.67	4.67	16.00	0.00	0.33	0.00	0.00	3.33
T_4	0.00	4.00	8.67	4.00	6.67	0.00	0.00	0.33	0.00	0.00
T_5	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.67	0.00	0.00
T_6	0.00	0.00	0.00	3.33	7.33	0.00	0.00	0.00	0.00	1.00
T_7	0.00	2.67	10.67	2.00	4.67	0.00	0.33	0.33	0.00	1.33
T_8	0.00	2.67	12.67	3.33	0.00	0.00	0.67	0.00	0.00	2.00
T_9	0.00	1.33	3.33	1.33	0.00	0.00	0.33	0.00	0.00	0.00
T_{10}	0.00	2.00	10.67	4.00	9.33	0.00	0.00	0.00	0.00	0.67
T_{11}	0.00	2.00	8.67	4.67	21.33	0.00	1.33	0.00	0.00	0.00
T_{12}	0.00	1.33	2.67	0.67	0.00	0.00	0.00	0.00	0.00	0.00
T_{13}	0.00	0.00	4.00	1.33	0.00	0.00	0.00	0.00	0.00	0.00

subsequent months till 5 MOS. ranged from 0.00 to 21.33 and 0.00 to 3.33 among the various treatments during the first and second seasons, respectively.

The mean population of adult beetles of *O. surenamensis* in cowpea grains under storage is given in Table 52. In both the seasons, no population of *O. surenamensis* was recorded in any of the treatments during the first month of storage. The mean population of adult beetles in subsequent months ranged from 0.00 to 25.33 during the first season and 0.00 to 14.67 in the second season.

As in the case of *O. surenamensis*, relatively low population of adult beetles of *R. dominica* was recorded during the second season. In subsequent months, the mean population ranged from 0.00 to 26.67 and 0.00 to 1.00 during the first and second seasons, respectively (Table 53).

4.6 Field testing of IPM package for cowpea through farmer's participation

From the results of the two field experiments conducted during January to May 2000 and 2001, the following significant findings were observed.

Though all the treatments were equally effective in controlling *A. craccivora* by bringing the population to less than 1.00 compared to 16.80 in control, in terms of damage intensity (percentage of crinkled leaves), plots receiving chlorpyriphos 0.05% (T_4) and neem kernel suspension 5% (T_7) alone were totally free from infestation. In the case of other major pests *viz. A. misera*, pod borers and pod bugs, the same treatments were found to be effective.

Table 52. Mean number of *O.surenamensis* adults in cowpea grains under storage

Treatments	Season – 1 (MOS)					Season – 2 (MOS)				
	1	2	3	4	5	1	2	3	4	5
T_1	0.00	0.00	1.33	1.33	2.67	0.00	1.00	0.00	0.00	0.00
T_2	0.00	0.00	11.33	6.67	5.33	0.00	8.00	0.00	0.00	0.00
T_3	0.00	0.00	3.33	3.33	2.00	0.00	0.00	0.00	0.00	0.00
T_4	0.00	0.00	8.67	6.67	13.33	0.00	0.00	0.00	0.00	1.00
T_5	0.00	0.00	5.33	5.33	2.67	0.00	1.33	0.00	0.00	0.00
T_6	0.00	0.00	0.00	3.33	6.67	0.00	0.00	0.00	0.00	0.67
T_7	0.00	0.00	5.33	6.00	6.00	0.00	0.00	0.67	0.00	0.00
T_8	0.00	0.00	3.33	1.33	2.67	0.00	0.67	0.00	0.00	2.00
T_9	0.00	0.00	3.33	4.67	4.67	0.00	0.00	0.00	0.00	2.67
T_{10}	0.00	0.00	11.67	8.00	12.00	0.00	0.67	0.00	0.00	0.00
T_{11}	0.00	0.00	4.67	3.33	4.67	0.00	0.00	0.33	0.00	0.00
T_{12}	0.00	0.00	2.67	2.00	1.33	0.00	0.00	0.33	0.00	0.67
T_{13}	0.00	0.00	22.00	20.00	25.33	0.00	0.67	2.67	7.67	14.67

MOS- Months of storage

Table 53. Mean number of *R. dominica* adults in cowpea grains under storage

Treatments	Season – 1 (MOS)					Season – 2 (MOS)				
	1	2	3	4	5	1	2	3	4	5
T_1	0.00	0.00	2.00	2.67	7.33	0.00	0.67	0.00	0.00	0.00
T_2	0.00	0.00	12.00	6.67	0.00	0.00	1.00	0.00	0.00	0.00
T_3	0.00	0.00	4.67	2.00	7.33	0.00	0.00	0.00	0.00	0.00
T_4	0.00	0.00	8.67	6.00	6.67	0.00	0.33	0.00	0.00	0.00
T_5	0.00	0.00	8.00	5.33	26.67	0.00	0.67	0.00	0.00	0.00
T_6	0.00	0.00	0.00	0.00	4.00	0.00	0.00	0.00	0.00	0.00
T_7	0.00	0.00	5.33	0.67	0.00	0.00	1.00	0.00	0.00	0.00
T_8	0.00	0.00	3.33	2.67	6.67	0.00	1.00	0.00	0.00	0.00
T_9	0.00	0.00	4.67	1.33	0.00	0.00	0.00	0.00	0.00	0.00
T_{10}	0.00	0.00	12.67	7.33	17.33	0.00	1.00	0.00	0.00	0.00
T_{11}	0.00	0.00	4.00	4.00	13.33	0.00	1.00	0.00	0.00	0.00
T_{12}	0.00	0.00	5.33	2.67	0.00	0.00	0.33	0.00	0.00	0.00
T_{13}	0.00	0.00	6.67	2.67	25.33	0.00	0.00	0.00	0.00	0.00

MOS – Months of storage

Taking into consideration, the safety of synthetic chemicals to natural enemies, it was seen that among the synthetic insecticides, chlorpyriphos 0.05% had the highest safety index. The field population of natural enemies was also not adversely affected in plots receiving treatments *viz.,* neem kernel suspension 5% (T_7) and chlorpyriphos 0.05% (T_4).

Considering the data on yield and benefit: cost ratio, the results proved the superiority of these two treatments. The treatment chlorpyriphos 0.05% (T_4) have the highest benefit:cost ratio of 4.8 and 5.4 during the first and second seasons, respectively. This was followed by neem kernel suspension 5% (T_7) with benefit: cost ratio of 3.9 and 4.4, respectively for the first and second seasons.

Considering all these factors, the treatments chlorpyriphos 0.05% and neem kernel suspension 5% were selected for further field testing through farmers' participation to develop an IPM package.

The following technologies emerged effective from experiments 4.1, 4.2, 4.3 and 4.4 were selected for testing in the field along with the proven techniques

1. Monitoring of cowpea fields for incidence/damage of pests and population of natural enemies especially at 52-59 DAS (for *A. craccivora, A. misera* and pod borers) and at 60-68 DAS (for pod bugs).

2. Adoption of mechanical and cultural control measures *viz.,* burning of trash before sowing, application of dry leaf ash at 10 DAS, keeping yellow sticky trap/yellow pan tray, removal and destruction of infested leaves, flower buds and pods and sweeping and destruction of pod bugs.

3. Collection and release of natural enemies associated with major pests proved to be efficient *viz.,* grubs and adults of *M. sexmaculatus*, *C. transversalis* and *H. octomaculata* and maggots of *I. scutellare*.

4. Need based application of neem kernel suspension 5% /chlorpyriphos 0.05% during 45DAS in case of moderate incidence of *A. craccivora* *A. misera* and pod borers. A second spray using neem kernel suspension 5% on 60 DAS, if needed against pod borers, pod bugs and *A. craccivora*.

The field testing of IPM package was conducted at three locations viz., Chettikulangara, Krishnapuram and Pathiyur of Onattukara region in comparison with farmer's practices as check. The results of the field trial are presented in tables 54 to 60.

The mean number of *A. craccivora* in the fields which received IPM technologies was significantly low compared to that with the farmers practice, during all the five weeks starting from 45 to 76 DAS (Table 54). Regarding the

Table 54. Mean number of *A. craccivora* and percentage of crinkled leaves due to attack in IPM plot and farmers practice

Location X treatment	Mean number of *A. craccivora* / top 2.5 cm shoot DAS					Mean % of crinkled leaves due to *A. craccivora* attack DAS		
	45	52	59	68	76	45	52	59
L_1T_0	136.51 (11.73)	106.57(10.37)	164.01 (12.85)	139.75 (11.86)	118.70 (10.94)	6.6	7.0	5.0
L_2T_0	70.89 (8.48)	42.27 (6.58)	78.43 (8.91)	11.98 (10.63)	98.10 (9.95)	15.0	12.0	12.0
L_3T_0	55.48 (7.52)	68.50 (8.34)	89.06 (9.49)	47.65 (6.97)	72.09 (8.55)	0.0	0.0	0.0
T_0 Mean	84.38 (9.24)	70.04 (8.73)	107.50 (10.42)	95.48 (9.82)	95.33 (9.81)	7.2	6.3	5.6
L_1T_1	109.64 (10.52)	8.73 (3.12)	19.18 (4.49)	4.35 (2.31)	2.42 (1.85)	4.0	5.0	1.0
L_2T_1	40.02 (6.40)	1.34 (1.53)	12.16 (3.63)	4.59 (2.37)	1.29 (1.51)	13.0	9.0	1.0
L_3T_1	34.38 (5.95)	2.13 (1.77)	5.96 (2.64)	1.57 (1.60)	3.38 (2.09)	0.0	0.0	0.0
T_1 Mean	57.12 (7.62)	3.58 (2.14)	11.86 (3.59)	3.38 (2.09)	2.31 (1.82)	5.7	4.7	0.67

	CD 5%	SE
Location	1.01	0.36
Treatment	0.83	0.29
Location X Treatment	NS	–

L_0- Location-1
L_2- Location-2
L_3- Location- 3

T_0- Farmers practice
T_1- IPM practices

Figures in parenthesis are $\sqrt{x+1}$ transformed values

symptoms of aphid (*A. craccivora*) infestation, percentage of crinkled leaves was the lowest in the IPM plots.

The data on the incidence of mean percentage of damage by. *A. misera* are presented in Table 55. As in the case of *A. craccivora,* the mean percentage of damage by *A. misera* was significantly low in the IPM plots in comparison to control, the mean population of the grubs ranged between 0.03 to 2.60 and 2.78 to 3.80, respectively.

The mean percentage of pod borer attack was significantly low in the treated plots compared to control from 45 to 76 DAS (Table 56). No significant decrease in the population of pod bugs per 5 sweeps at 59 DAS was observed in the IPM plots at different periods of observation up to harvest in comparison to control plots with farmers practice.

The data on the population of natural enemies *viz.,* adults and grubs of *M. sexmaculatus* and *Coccinella* spp. and the maggots of *I. scutellare* are presented in Tables 57 to59.

Among the major natural enemies, significantly high population of the adults of *M. sexmaculatus* and maggots of *I. scutellare* were observed in the IPM plots compared to control. Regarding the other major predators, though not significant, there was a general increase in the population of the adults and grubs of *Coccinella* spp. and grubs of *M. sexmaculatus* through out the period of observation.

Table 55. Mean percentage of damage by *A .misera* and mean number of grubs per 5 plants in IPM plot and farmers practice

Location x Treatment	Mean % of damage				Mean No. of grubs/ 5plants			
	45DAS	52 DAS	59 DAS	68 DAS	45 DAS	52 DAS	59 DAS	68 DAS
L_1T_0	14.63 (22.48)	12.49 (20.69)	18.0	15.0	2.32 (1.52)	3.20	3.60	3.20
L_2T_0	11.51 (19.82)	11.37 (19.7)	12.0	13.0	4.85 (2.20)	4.20	3.80	4.20
L_3T_0	5.0 (12.92)	2.85 (9.72)	3.0	5.0	1.17 (1.08)	3.20	4.00	3.00
T_0 mean	9.98 (18.41)	8.27 (16.70)	11.0	11.0	2.78 (1.60)	3.53	3.80	3.47
L_1T_1	11.51 (19.82)	1.82 (7.75)	2.0	1.0	3.15 (1.78)	0.60	0.10	0.80
L_2T_1	9.52 (17.96)	0.81 (5.17)	2.0	2.0	2.93 (1.71)	0.20	0.00	1.00
L_3T_1	5.0 (12.92)	0.63 (4.56)	1.0	1.0	1.72 (1.31)	0.00	0.00	0.00
T_1 mean	8.96 (16.90)	1.03 (5.82)	1.67	1.33	2.60 (1.60)	0.27	0.03	0.60

	CD5%	SE	CD5%	SE
Location	4.20	1.47	0.29	9.75
Treatment	3.43	1.20	NS	-
Location x Treatment	NS	-	0.40	0.14

Figures in parenthesis angular transformed values

Figures in parenthesis are $\sqrt{x}$ transformed **values**

L_0- Location-1
L_2- Location-2
L_3- Location- 3

T_0- Farmers practice
T_1- IPM practices

Table 56. Mean percentage of pod borer damage and number of pod bugs per 5 sweeps in IPM plot and farmers practice

Location X treatment	Mean % of damage				Mean No. of pod bugs/ 5 sweeps			
	45	52	59	68	45	52	59	68
L_1T_0	14.73 (22.56)	11.47 (19.79)	9.66 (18.10)	7.0	3.81 (1.95)	3.00	3.00	3.00
L_2T_0	20.69 (27.05)	22.60 (28.37)	16.98 (24.33)	3.0	7.76 (2.78)	5.00	4.00	2.00
L_3T_0	5.49 (13.54)	6.68 (14.97)	7.99 (16.42)	2.0	5.86 (2.42)	6.00	1.00	2.00
T_0 mean	12.91 (21.05)	12.90 (21.04)	11.28 (19.61)	4.0	5.81 (2.38)	4.67	2.67	2.33
L_1T_1	19.24 (26.01)	0.89 (5.42)	0.81 (5.14)	0.0	5.64 (2.38)	0.00	1.00	1.00
L_2T_1	7.86 (16.27)	1.57 (7.20)	0.65 (4.61)	0.0	3.88 (1.97)	1.00	0.00	0.00
L_3T_1	7.67 (16.07)	0.00 0.00)	0.00 (0.00)	2.0	7.76 (2.79)	0.00	1.00	0.00
T_1 mean	11.10 (19.45)	0.54 (4.20)	0.32 (3.25)	0.67	5.76 (2.38)	0.33	0.67	0.33

	CD 5%	SE	CD5%	SE
Location	2.89	1.02	0.48	0.16
Treatment	2.36	0.83	NS	-
Location X Treatment	4.08	1.4	0.68	0.23

Figures in parenthesis are angular transformed values

Figures in parenthesis are $\sqrt{x}$ transformed values

L_0- Location-1
L_2- Location-2
L_3- Location- 3

T_0- Farmers practice
T_1- IPM practices

Table 57. Mean number of *M. sexmaculatus* in IPM plot and farmers practice

Location X Treatment	Adult population (Mean No./ 5sweeps)						Grub population (Mean No. per 5 plants)					
	45	52	59	68	76	84	45	52	59	68	76	84
L_1T_0	3.79 (2.19)	2.77 (1.94)	0.00 (1.00)	1.39 (1.55)	0.00	0.00	2.77 (1.94)	0.87 (1.37)	2.72 (1.03)	2.66 (1.91)	0.95 (1.39)	0.00
L_2T_0	3.65((2.16)	1.97 (1.72)	1.04 (1.43)	0.65 (1.28)	3.00	2.00	2.38 (1.84)	1.63 (1.62)	1.39 (1.55)	3.96 (2.23)	2.95 (1.99)	2.00
L_3T_0	0.00 (1.00)	0.51 (1.23)	0.81 (1.35)	0.00 (1.00)	1.00	0.00	0.00 (1.00)	1.71 (1.65)	8.42 (3.07)	1.84 (1.69)	0.89 (1.37)	0.00
T_0 Mean	2.17 (1.78)	1.66 (1.63)	0.58 (1.26)	0.63 (1.28)	1.33	0.67	1.54 (1.59)	1.39 (1.54)	3.76 (2.18)	2.77 (1.94)	1.50 (1.58)	0.67
L_1T_1	2.97 (1.99)	4.64 (2.38)	3.52 (2.12)	1.63 (1.62)	0.00	2.00	4.61 (2.37)	3.27 (2.07)	5.81 (2.61)	3.69 (2.17)	2.97 (1.99)	1.00
L_2T_1	5.92 (2.63)	2.10 1.76)	2.75 (1.94)	3.02 (2.01)	2.00	1.00	1.45 (1.57)	1.45 (1.57)	3.57 (2.14)	2.58 (1.89)	0.87 (1.37)	1.00
L_3T_1	0.89 (1.38)	0.31 (1.15)	0.66 (1.29)	0.81 (1.35)	1.00	0.00	1.45 (1.57)	0.89 (1.38)	12.70 (3.70)	1.87 (1.69)	0.00 (1.00).	1.00
T1 Mean	3.00 (2.00)	2.10 (1.76)	2.18 (1.78)	1.75 (1.60)	1.00	1.00	2.36 (1.83)	1.7 (1.67)	6.93 (2.82)	2.68 (1.92)	1.11 (1.45)	1.00

	CD 5%	SE	CD 5%	SE
Location	0.21	0.07	NS	-
Treatment	0.17	0.06	NS	-
Location X Treatment	NS		0.35	0.12

L_0- Location-1

L_2- Location-2

L_3- Location- 3

T_0- Farmers practice

T_1- IPM practices

Figures in parenthesis are $\sqrt{x+1}$ transformed values

Table 58. Mean population of *Coccinella* spp. in IPM plot and farmers practice

Location X Treatment	Adult population (Mean No./ 5 sweeps)						Grub population (Mean No./ 5 plants)					
	45	52	59	68	76	84	45	52	59	68	76	84
L_1T_0	1.93(1.71)	2.87(1.97)	1.84(1.69)	1.00	0.00	0.00	5.76(2.60)	1.77(1.67)	0.89(1.38)	1.00	0.00	0.00
L_2T_0	3.84(2.20)	2.66(1.91)	0.89(1.38)	2.00	3.00	2.00	1.69(1.64)	2.71(1.93)	2.71(1.93)	3.00	1.00	2.00
L_3T_0	3.46(2.11)	1.81(1.68)	2.70(1.92)	0.00	2.00	0.00	4.69(2.39)	0.81(1.35)	0.00(1.00)	0.00	1.00	0.00
T_0 Mean	3.03(2.21)	2.43(1.85)	1.76(1.66)	1.00	1.67	0.67	3.88(2.21)	1.71(1.65)	1.06(1.43)	1.33	0.67	0.67
L_1T_1	2.75(1.94)	1.87(1.69)	1.81(1.68)	0.00	5.00	1.00	3.87(2.21)	2.00(1.73)	1.81(1.68)	2.00	0.00	3.00
L_2T_1	2.97(1.99)	2.93(1.98)	2.70(1.92)	1.00	1.00	1.00	2.93(1.98)	4.57(2.36)	4.69(2.39)	1.00	3.00	0.00
L_3T_1	0.81(1.35)	2.63(1.91)	2.41(1.85)	2.00	1.00	1.00	3.94(2.22)	1.81(1.68)	0.81(1.35)	0.00	2.00	0.00
T_1 Mean	2.09(1.76)	2.46(1.86)	2.30(1.82)	1.00	2.33	1.00	3.57(2.14)	2.70(1.92)	2.25(1.80)	1.00	1.67	1.00

	Adult CD 5%	Adult SE	Grub CD 5%	Grub SE
Location	NS	-	0.25	0.09
Treatment	NS	-	NS	-
Location X Treatment	NS	-	NS	-

L_0- Location-1
L_2- Location-2
L_3- Location- 3

T_0- Farmers practice
T_1- IPM practices
Figures in parenthesis are $\sqrt{x+1}$ transformed values

Table 59. Mean number of syrphid maggots per plant in IPM plot and farmers practice

Location X treatment	Days after sowing (duration)				
	45	52	59	68	76
$L_1 T_0$	3.46 (2.11)	0.00 (1.00)	1.81 (1.68)	1.45 (1.57)	1.04 (1.43)
L_2T_0	1.87 (1.69)	3.81 (2.19)	0.87 (1.37)	1.81 (1.68)	2.81 (1.95)
L_3T_0	0.00 (1.00)	1.81 (1.68)	1.54 (1.59)	1.84 (1.69)	0.77 (1.33)
T_0 mean	1.57 (1.60)	1.64 (1.62)	1.39(1.55)	1.70 (1.64)	1.47 (1.47)
L_1T_1	2.95 (1.99)	2.58 (1.89)	3.59 (2.14)	0.77 (1.33)	2.32 (1.82)
L_2T_1	3.83 (2.20)	1.81 (1.68)	2.87 (1.97)	1.81 (1.68)	3.83 (2.20)
L_3T_1	1.77 (1.67)	0.81 (1.35)	1.81 (1.68)	0.87 (1.37)	1.87 (1.69)
T_1 mean	2.80 (1.95)	1.68 (1.64)	2.72 (1.93)	1.12 (1.46)	2.63 (2.63)

	CD 5%	SE
Location	0.20	0.07
Treatment	0.17	0.06
Location X Treatment	NS	–

Figures in parenthesis are $\sqrt{x+1}$ transformed values

L_0- Location- 1 T_0- Farmers practice
L_2- Location- 2 T_1- IPM practices
L_3- Location- 3

The mean population of the other natural enemies per 5 sweeps/per plant is presented in Table 60. In general, the population of all other natural enemies *viz.* grubs of *Scymnus* sp., maggots, dragonflies, gryllids and *Paederes* sp. were equivalent to those in plots following farmers practices.

The data on yield of grains and marginal benefit: cost ratio are presented in Table 61. A higher mean yield of 808.3 kg ha^{-1} was obtained from IPM plots as against 312.5 kg ha^{-1} from the fields received farmers practice. The benefit: cost ratio for IPM plots was worked out as 4.5.

Table 60. Mean number of other natural enemies per 5 sweeps / 5 plants in IPM plot and farmers practice

Natural enemies	Days after sowing (Duration)											
	45		52		59		68		76		84	
	T_0	T_1	T_0	T_1	T_0	T_1	T_0	T_1	T_0	T_1	T_0	T_1
No. of *Scymnus* sp. grubs $plant^{-1}$	1.00	0.67	1.33	1.33	1.33	1.67	0.67	2.00	1.33	1.67	0.00	0.00
No. of parasitized *A. misera.* Grubs $plant^{-1}$	1.67	1.33	1.00	2.33	2.00	2.00	1.00	2.00	0.00	0.00	0.00	0.00
No. of dragon flies $5sweeps^{-1}$	0.33	0.67	1.00	0.33	0.33	1.00	0.33	0.33	0.00	0.33	0.33	0.00
No. of damsel flies $5sweeps^{-1}$	1.00	1.00	0.67	1.00	0.33	0.33	0.67	0.33	0.33	0.67	0.33	0.67
No. of gryllids 5 $sweeps^{-1}$	0.67	0.67	0.67	0.33	0.00	1.00	0.33	0.33	0.33	0.33	0.00	3.33
No. of *Paederus* sp .5 $sweeps^{-1}$	0.67	0.33	0.67	1.00	0.33	0.67	0.33	0.33	0.67	1.00	0.00	0.00

Table 61. Yield of cowpea grains and marginal benefit: cost ratio in the IPM plots and farmers practice

Treatments	Yield of cowpea grains						Mean yield Kg ha^{-1}	Increase in yield over farmers practice Kg ha^{-1}	Additional income Rs ha^{-1}	Cost of IPM measure Rs ha^{-1}	Marginal B : C ratio
	Location 1		Location 2		Location 3						
	Kg $plot^{-1}$	Kg ha^{-1}	Kg $plot^{-1}$	Kg ha^{-}	Kg $plot^{-1}$	Kg ha^{-}					
Farmers practice (T_0)	12.0	300.0	15.0	375.0	10.5	262.5	312.5	-	-	900	-
IPM plots (T_1)	35.0	875.0	32.0	800.0	30.0	750.0	808.3	495.8	9916	2200	4.5

DISCUSSION

DISCUSSION

The results of the present investigation on the integrated pest management in cowpea are discussed below.

5.1 Survey of the pests of cowpea, their associated natural enemies and plant protection measures adopted by the farmers in the major cowpea growing areas of Kerala.

The results of the survey conducted in Thiruvananthapuram, Alappuzha and Palakkad districts indicated that majority of the farmers (33.1%) in Thiruvananthapuram district used local grain type cowpea in 54.5% of the area surveyed (Table 4). This might be due to the lack of awareness about the improved varieties and also the non availability of quality seeds in time. In Alappuzha district, 53.3% of the cultivators used the variety Kanakamani, released and recommended by the Kerala Agricultural University. In this district especially in the Onattukara tract, majority of the farmers prefer to raise sesamum as well as cowpea as third crop in rice fields. This had an effect on enriching the poor loamy sand soil with low nutrient status. The high yielding short duration cowpea crop might be suitable for fitting in the cropping system. Majority of the farmers in Palakkad district used improved varieties of grain cowpea recommended by the Kerala Agricultural University. However, the major area (22.2%) was cultivated with the variety C-152.

At the first stage of survey (20-25 DAS), the pests recorded included A. *craccivora*, *O. phaseoli* and *L. trifolii* of which *A. craccivora* was the major one (Table 5). Mathew *et al.* (1971), Rani (1995) and Bindu (1997) also reported the predominance of *A. craccivora* in cowpea in Thiruvananthapuram district. The other pests reported by them were *R. pedestris, C. gibbosa*, *H. armigera*, *L. boeticus* and *M. testulali*. The second major pest was the pea stem fly *O. phaseoli*. The serpentine leaf miner *L. trifolii* came in the third position, which has been mentioned as a pest of cowpea by Spencer (1973). At pod formation stage (55-60 DAS) of the crop (Table 5), pod borer infestation was the major problem followed by pod bugs and pea aphid *A. craccivora*. The pod borers and bugs were mentioned earlier as serious pests of cowpea by Nair (1986). Mensah (1988) also reported pod bugs as one of the major post flowering pests of cowpea.

Though wide spread incidence of *A. craccivora* (88.8%) was observed in the fields at 20 to 25 DAS, the degree of infestation was however low in Thiruvananthapuram, Alappuzha and Palakkad districts with 46.7, 33.3 and 40% incidence, respectively. Similarly, during the pod formation stage, though pod borer infestation was observed in 81.1% of the fields surveyed, the intensity of the pest was low in 53.3, 43.3 and 40.0% of the fields of Thiruvananthapuram, Alappuzha and Palakkad districts, respectively.

In Thiruvananthapuram district, *A. craccivora* was observed to be the major pest at 20 to 25 DAS. At 55-60 DAS, majority of the fields were infested with pod borers followed by pea aphid *A. craccivora.* Srikanth and Lakkundi (1990) observed *A. craccivora* population in summer (March- May) and kharif (August- September) seasons, increased rapidly with crop growth and their peaks coincided with pod formation stage. Rani (1995) reported that the growth stage of the crop and their nutritive status were suggested as the major factors influencing population build up of *A. craccivora.*

Unlike in Thiruvananthapuram district, the incidence of *A. craccivora* was medium in 50% and 33.3% of the fields at 20-25 DAS and 55-60 DAS, respectively in Alappuzha district. Cent per cent of the cowpea fields in Alappuzha district were affected by pod borer pests at 55-60 DAS (Table 7). In Alappuzha district, majority of the farmers cultivated high yielding improved varieties and that might be the reason for the high infestation by pod borers in that district. Lateef and Reed (1981) in their field survey also observed severe pod damage by lepidopteran pod borers (29.7%), where early maturing short duration pigeon pea varieties were grown and also the pod borer *H. armigera* was a key pest in southern India.

In Palakkad district also, *A. craccivora* was the major pest recorded in 90% of the fields surveyed at 20-25 DAS, of which 40% had low incidence. At 55-60 DAS, 40% of the fields harboured low infestation by pod borers (Table 8).

Thus considering the percentage of occurrence in all the 90 plots surveyed, the major pests observed in cowpea at 20 to 25 DAS were the pea aphid *A. craccivora*, stemfly *O. phaseoli* and American serpentine leaf miner *L. trifolii* and at pod formation stage (55-60 DAS) were the pod borers, pod bugs and *A. craccivora*. Adepala *et al.* (2000) also opined that the common farmers considered aphids and pod borers as the most important pests of cowpea, followed by pod sucking bugs.

The natural enemies associated with the pests of cowpea were in general low except the grubs and adults of coccinellid predators *viz., C. transversalis, H. octomaculata* and *M. sexmaculatus*. The predators of cowpea which observed in the present study were in agreement with the species observed by Saxena, (1970), Srikanth and Lakkundi (1990), Verma *et al.* (1990) and Patro and Sontakke (1994) who ranked *M. sexmaculatus* and *C. transversalis* in the top position constituting 77 to 88% of the total population.

At 20 to 25 DAS and at 55-60 DAS, the grubs and adults of *M. sexmaculatus* and *Micraspis* sp. dominated the predatory fauna in the cowpea fields of Thiruvananthapuram and Alappuzha districts (Table 9 and 10) while *Coccinella* spp. dominated in Palakkad district. The grubs of *Scymnus* sp., maggots of *I. scutellare,* dragonflies, damselflies, the rove beetle *Paederus* sp., the ground beetle *Ophionea* sp., *Chrysoperla carnea* and the spider *Argiope* sp. were the other predators recorded in all the three districts.

Observations recorded from the unprotected cowpea fields in the summer seasons of 1999 and 2000 at ORARS Kayamkulam (Table 12) indicated that the population of *A. craccivora* and percentage infestation by pod borers reached its peak at 59 DAS as shown in Fig.1 and Fig.2. Similar observations were made by Srikanth and Lakkundi (1990). This could be attributed to the sweetness due to the high content of sucrose in the terminal shoot at flowering and early pod formation stage for the aphids and pod borers to feed. The pod bug incidence was the maximum at 68 DAS because they prefer to feed on maturing pods in the grain maturity stage (Fig.3).

Thus, the incidence of all the major pests *viz.,* mean number of *A. craccivora*, mean percentage of leaf damage by *A. misera* and pod damage by pod borers were found to be the maximum at 59 DAS except the pod bugs. The total predator population also showed a more or less similar trend with a peak population level at 59 DAS (Fig.4). This shows that irrespective of all other factors except pesticide application, the predator population in cowpea fields increases with the increase in prey population

A comparison of the pest incidence / damage and the total natural enemy population in the unprotected cowpea fields of ORARS, Kayamkulam and that of the nearby farmer's fields is given in Fig.5. The population of

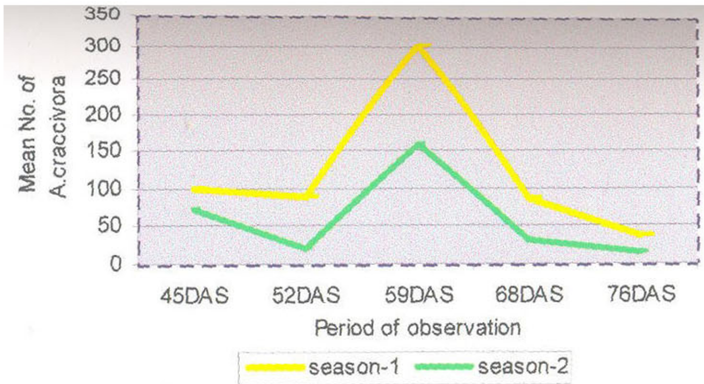


Fig.1. Mean number of A.craccivora per top 2.5cm shoot of cow pea in unprotected field

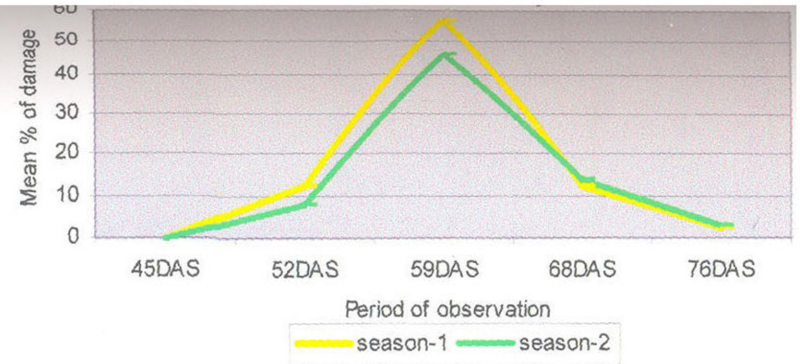


Fig.2. Mean percent damage by pod borers in unprotected cow pea field

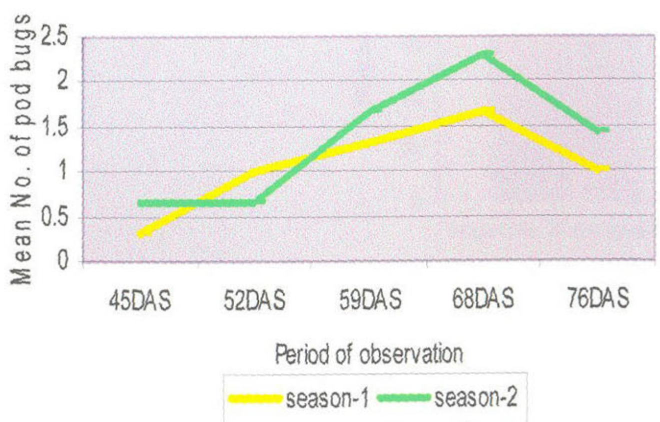


Fig. 3. Mean number of pod bugs per 5 sweeps in unprotected cow pea field

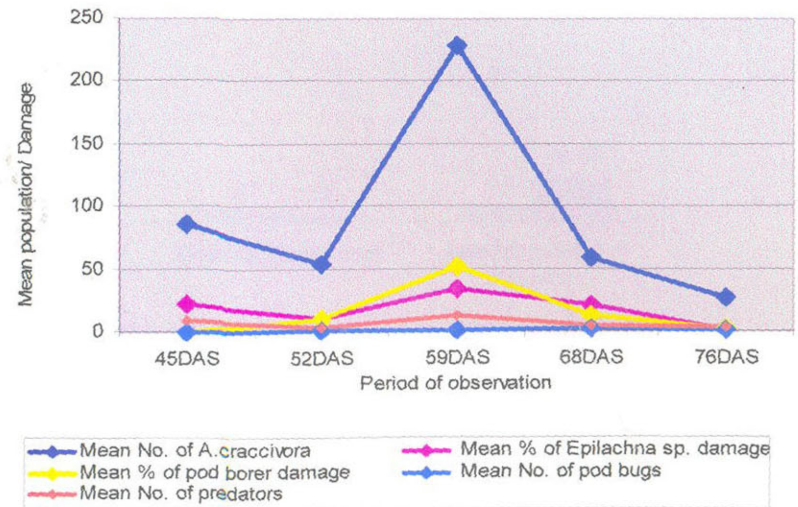


Fig.4. Pestspopulation/percent damage and predator population in unprotected cowpea field

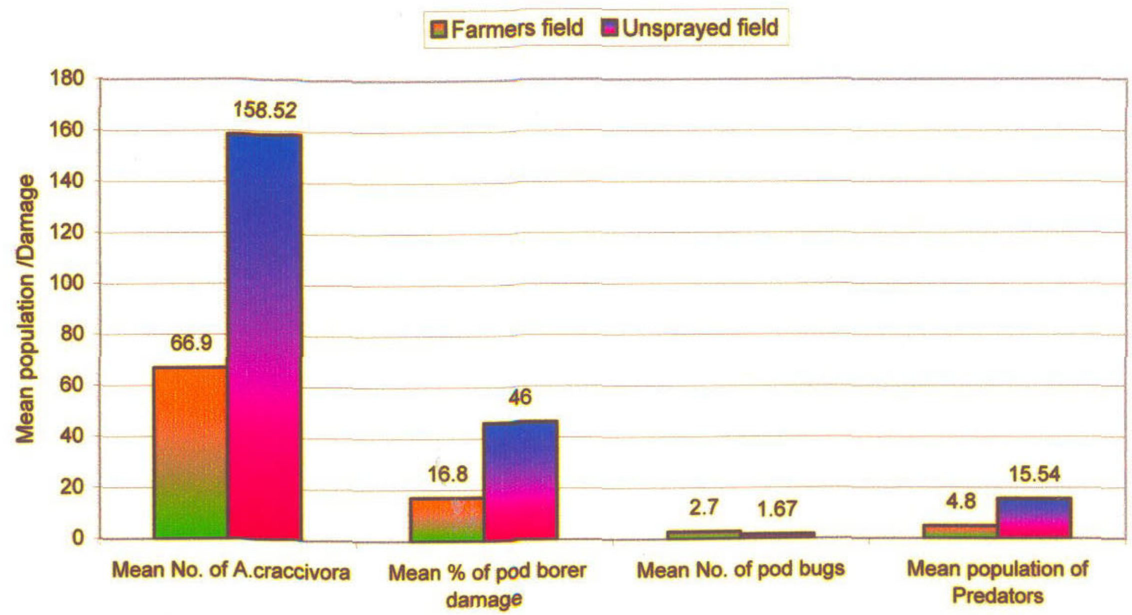


Fig.5. Mean incidence of pests and natural enemies in the farmers fields and unsprayed fields

A. craccivora and the percentage of pod borer damage were more in unprotected fields compared to farmers' fields. However, the pod bug population was low in the unprotected fields compared with that in the farmers' fields. In the case of predators also, the same trend of high population was observed in the unprotected fields. This clearly shows that the predator population was highly reduced by the application of harmful insecticides in farmer's fields.

The survey revealed that 82.2% of the farmers adopted chemical, mechanical or cultural plant protection measures at 20-25 DAS, whereas only 74.1% of the farmers adopted the same at 55-60 DAS. Similar observations were made by Marimuthu (1982) among the chilli farmers of Tamilnadu. The use of chemical insecticides was the most important pest control method practiced by the farmers. At 20-25 DAS, 40% of the farmers used synthetic chemicals and 28.9% used botanical pesticides, whereas, 38.7% and 33.3%of the farmers used synthetic chemicals and botanicals at 55-60 DAS, respectively (Table 13).

Of all the insecticides, neem oil was used by majority of the farmers compared to other pesticides followed by carbaryl both at 20-25 DAS and 55-60 DAS. Majority of the farmers used contact insecticides than systemic both at 20-25 DAS and 55-60 DAS (Table 15.a and 15.b). The most widely used group of synthetic insecticides was organophosphates, among which monocrotophos ranked first at 20-25 DAS (Fig. 6) and quinalphos at 55-60 DAS (Fig 7). Earlier, Nandakumar (1999) also reported that organophosphate pesticides were the most

Fig.6. Pesticide consumption pattern in major cowpea growing areas 20-25 DAS

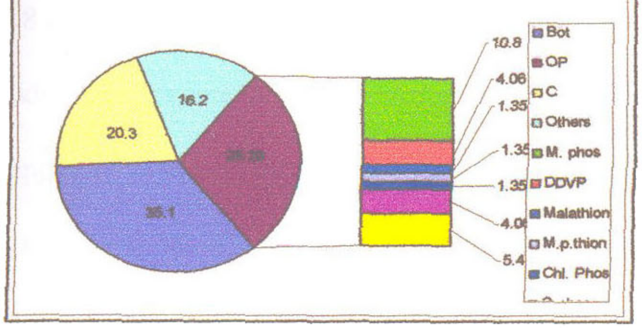
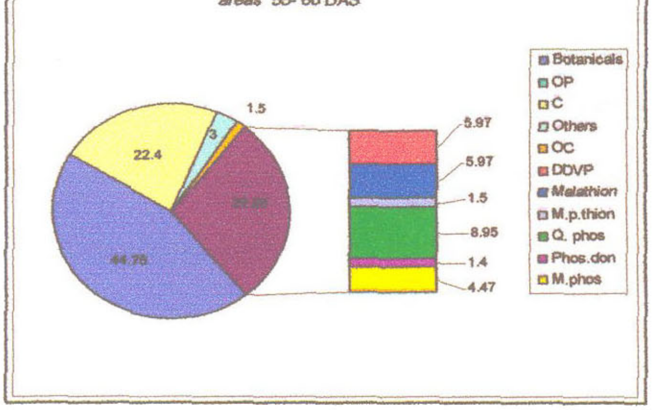


Fig.7. Pesticide consumption pattern in major cowpea growing areas 55- 60 DAS



widely used group, among which five insecticides including monocrotophos and quinalphos were commonly used by the farmers.

Only 37.8 and 36.7 per cent of the farmers followed the use of recommended dose of insecticides for spraying at 20-25 DAS and 55-60 DAS, respectively (Fig.8). The pesticide application above and below the recommended doses might have resulted in the increased incidence of sucking pests like aphids and reduced the number of natural enemies. Higher dosage of even the botanical pesticides *viz.,* Repelin and Neem guard, than the recommended one adversely affected the parasitoids and increased pest population (Srinivasa babu, 1993).

Irrespective of the dose of pesticides, majority of the farmers used a spray volume below the recommended one (Fig. 8). However, most of the farmers (44.4%) followed only need-based application of the pesticides. Another finding was that majority of the farmers (33.3%) followed the recommended and need based interval between two sprayings. Altogether, out of 90 cowpea fields surveyed, 73.3 and 74.4% of the farmers applied pesticides at 20-25 DAS and 55-60 DAS, respectively.

The meteorological parameters *viz.,* maximum and minimum temperature, relative humidity, total rainfall and sunshine hours recorded from the three districts *viz.* Thiruvananthapuram, Alappuzha and Palakkad are given in Appendix III, IV and V, respectively.

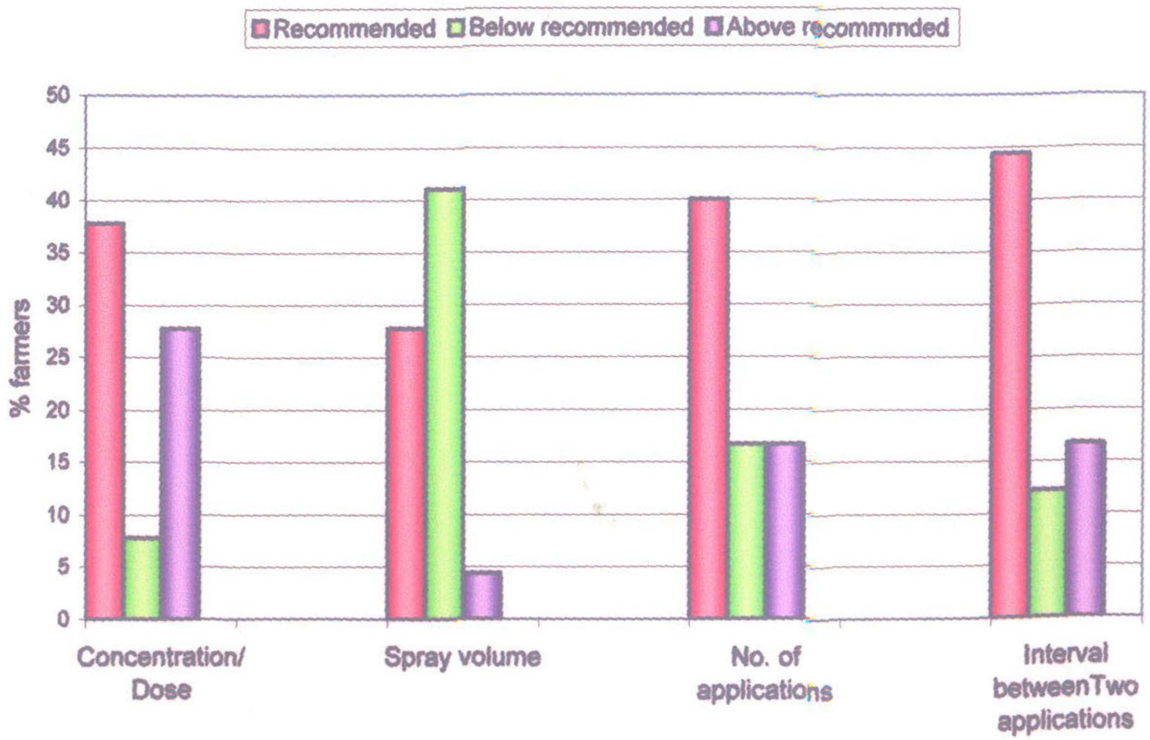


Fig.8. Percentage of farmers adopting pesticide application

Most of the cowpea-growing farmers in Thiruvananthapuram district, gained information on plant protection measures through mass media and neighboring farmers (Table 17). Similar observation was made by Nandakumar (1999) also. This might be the reason for low adoption of recommended dose, spray volume and other pesticide use patterns. Meera (1995) opined that irrational use of pesticides was due to lack of adequate knowledge and unfavourable attitude towards scientific plant protection. In Alapuzha district, the farmers gained information mainly from the Scientists / University. In Palakkad district, the main source of information on plant protection measures to farmers was from seminars followed by those from a combination of seminars and Scientists / University.

5.2 Feeding ability of the potential predators

5.2.1 Efficiency of potential predators in controlling cowpea pests

The biology and feeding potential of the major predators of the pests of cowpea found in the survey were studied and discussed.

Among the coccinellid predators, *C. transversalis*, *H. octomaculata* and *M. sexmaculatus* were the predominant ones. The incubation period, the duration of four instars, the pre pupal and pupal period of *C. transversalis* were 2.71, 1.20, 1.33, 2.67, 3.00, 1.20 and 1.67 days, respectively. These findings were in agreement with those of Begal and Trehan (1949) and Hagen (1962). On the contrary, Rai and singh (2001) reported a higher incubation period of 8.7 ± 0.24 days in January than in February (8.1±0.12) and March (5.8 ± 0.11) which they explained to be due to the low temperature prevailed in January.

The incubation period, duration of first, second, third and fourth instar grubs, pre pupae and pupae of *H. octomaculata* are presented in para 4.2.1.2. The mean duration from egg to adult was observed to be 13.27±0.31 days.

With regard to *M. sexmaculatus* (Para 4.2.1.3), the incubation period, duration of the first, second, third and fourth instar grubs, pre pupa and pupa were 2.10, 1.20, 2.80, 3.60, 3.80, 1.80 and 3.40 days respectively (Table 20a). Earlier Rao *et al.* (1997) observed faster development of *M. sexmaculatus* when fed on *A. craccivora* in cowpea. The data on the life cycle also agreed with those observed by Verma *et al.* (1993) and Devi (1967). Nandakumar (1999) observed the total duration of *M. sexmaculatus* from egg to adult as 15.35 days. Begal and Trehan (1949) reported that the duration and even the number of instars vary with season.

Among the three major predators *viz. C. transversalis*, *H. octomaculata* and *M. sexmaculatus*, the grubs of *C. transversalis* consumed the maximum number of 251.80±6.74 *A. craccivora* (fig 9). The percentage consumption by the second, third and fourth instar grubs were 9.81, 35.61 and 54.58 aphids, respectively with a mean per day consumption of 31.48. This was followed by *H. octomaculata* with a feeding potential of 198.22±12.90 *A. craccivora* with an average per day consumption of 24.78. Joshi et al. (1997) observed *H. octomaculata* to be feeding on *A. craccivora* infesting *Casia auriculata* and *Crotalaria mucronata.*

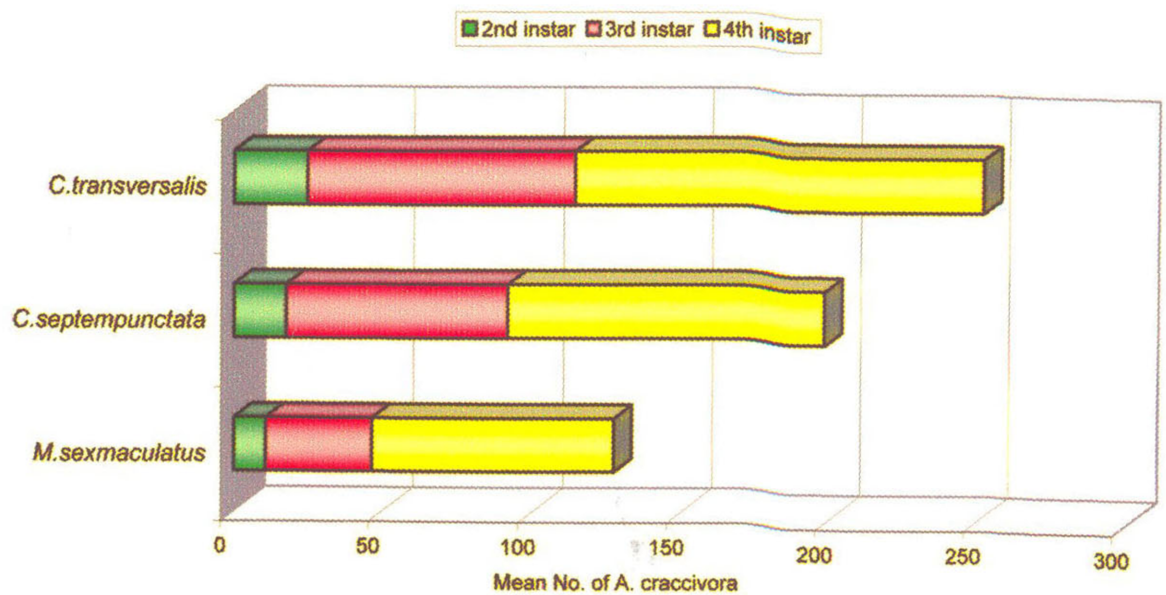


Fig.9. Mean number of A.craccivora consumed by the grubs of major coccinellid predators

The non- feeding of the first instar grub observed in the present study may be attributed towards the cannibalistic behaviour of first instar on unfertile eggs of the same batch. Similar findings were earlier reported by Banks (1956), Dixon (1959) and Murdoch (1971). A wide variation in the consumption of aphids by a single grub of *C. transversalis* (401 to 736) was observed by Debraj and Singh (1990), whereas Begal and Trehan (1949) observed a variation of 106.29 to 420 in the consumption of aphids by *Coccinella* sp.

With regard to *M. sexmaculatus*, the mean total consumption of *A. craccivora* by a single grub was 127.60±3.35, the percentage consumption being 8.4, 28.1 and 63.5 by the second, third and fourth instar, respectively. Lokhandae and Mohan (1990) and Rani (1995) earlier reported that a single grub consumed 73.52 and 84 aphids, respectively whereas Begal and Trehan (1949) observed a high rate of 303 aphids per grub.

A similar trend in the consumption of *A. craccivora* was observed in the case of the adults of these coccinellids also (Fig. 10). A per day consumption of 30.77, 27.88 and 23.30 and a total consumption of 914±50.28, 842±77.28 and 734.1 ±102.44 *A. craccivora* was observed in the case of *C. transversalis*, *H. octomaculata* and *M. sexmaculatus*, respectively. Das and Premsagar (2001) observed the per day consumption of *A. craccivora* by *C. septempunctata* to be 26.97± 4.52, whereas Joshi *et al.* (1999) observed it to be 40.6. A wide variation in

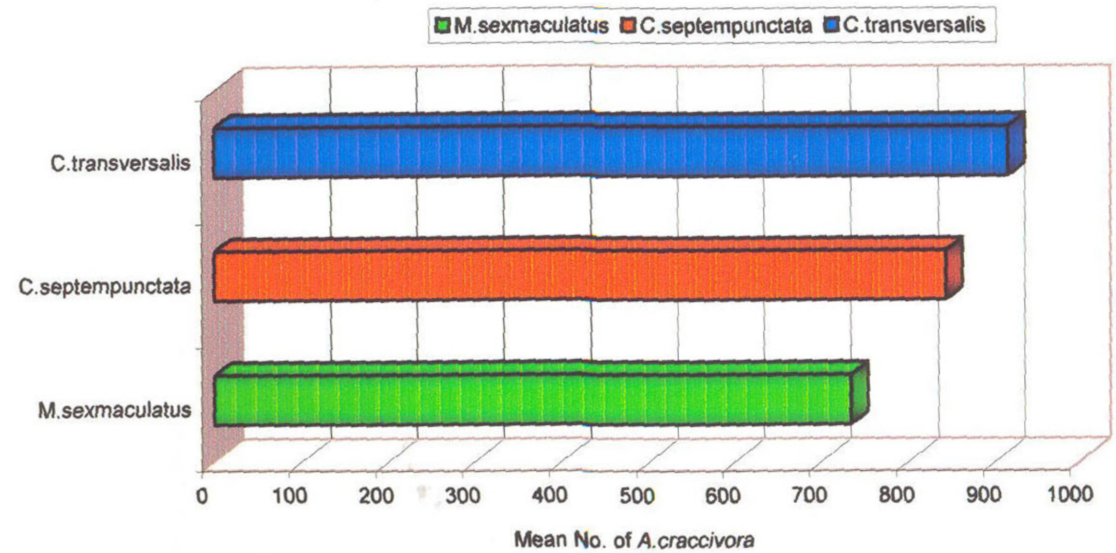


Fig. 10. Mean number of *A.craccivora* consumed by adults of the major coccinellid predators in cowpea

the per day consumption of aphids (17 to 57) was reported by several workers (Devi, 1967 and Haque and Islam, 1978).

The incubation period, duration of first, second and third larval instars and pupa of *I. scutellare* (Table 21a) were 2.90, 2.20, 2.80, 3.50 and 4.90 days, respectively with a total of 16.30±0.45 days. The present finding on the life cycle of the predator agreed with the observation made earlier by Sitaraman (1966), Rani (1995) and Nandakumar (1999). A single maggot of *I. scutellare* consumed a mean number of 459.5±7.71 *A. craccivora* during different larval stages over a period of 8.5 days, the percentage consumption being 8.6, 33.1 and 58.4 % by the first, second and third instars. The per day consumption of *A. craccivora* by a single maggot of *I. scutellare* was observed to be 57.44. The mean numbers of aphids consumed by a single maggot of *I. scutellare* were 450, 386.86, 448.46 and 400, respectively as reported by Sitaraman (1966), Devi (1967), Rani (1995) and Nandakumar (1999).

The incubation period, duration of the first, second, third and fourth instar larvae and pupa of *C. carnea* were 3.20, 2.80, 3.40, 3.80, 4.40 and 8.60 days respectively with a mean total duration of 25.80 ±0.77days. The incubation period of *C. carnea* was earlier reported to be 3 days at 27°C by Verma and Shenhmar (1983) and 4 days by Butler and Ritchie (1970) and Sharma and Verma (1991). The duration of larval instars was observed to be 14.4 days. This finding agreed broadly with the observations made by Pasqualini (1975), Awadallah *et al.* (1976), Goutham (1990) and Sharma and Verma (1991) with mean larval duration of 14.80, 13.5, 12.08 and 10.6 days, respectively. The duration of pupal period (8.69 days) also agreed with that observed by Sharma and Verma (1991). A single grub of *C. carnea* consumed a mean number of 42.3±1.23 adult *A. craccivora* during its life time, the percentage consumption being 12.8, 20.0, 25.9 and 41.3 aphids by the first, second, third and fourth instars, respectively. Singh and Kumar (2000) observed an average of 11.8, 79.52 and 83.0 aphids consumed by the first, second and third instar grub of *C. carnea* in mustard. Abhilash (2001) observed the consumption of both adults and nymphs of *A. craccivora* by *C. carnea* during its development period as 419 ± 9.14. Even with same predator and prey species combination, the prey consumption data differ considerably and the predatory potential was found to increase with increased prey density in the case of cowpea aphid *A. craccivora* (Balasubramani, 1991).

Of the predators *viz.*, coccinellids, syrphids and chrysopids, the coccinellids especially *C. transversalis* and *M. sexmaculatus* were commonly seen in large numbers in cowpea fields during both Kharif and Rabi seasons. A comparison of the feeding potential of the different instars of grubs and adults of *C. transversalis*, *H. octomaculata* and *M. sexmaculatus* also proved the high potential of both the grubs and adults of *C. transversalis* (Fig.9 and Fig.10). Moreover, these are seen in both Kharif and Rabi seasons in garden lands and wet lands. Since both the adults and grubs are predatory in nature unlike the other predators, they could be rated as efficient predators in the cowpea ecosystem.

5.2.2 Predatory behaviour of the potential predators of cowpea pests

The predatory behaviour of the potential predators *viz. C. transversalis* and *M. sexmaculatus* was described in Para 4.2.2.

The searching and feeding behaviour of the natural enemies may change as the pest population densities increase. So each individual consumed more pests as the pest density increased. Searching speed of adults and grubs of *C. transversalis* and *M. sexmaculatus* was found to be increasing with increased prey density. Similar observations were made by Hagen and Bosch (1968) and Antoclaver and Ambrose (2001). This might be due to the high probability of contact at higher prey density than lower. Marks (1977) reported that *C. septempunctata* is unable to detect its prey either by vision or by infection and its random search.

Within the plant, *C. transversalis* and *M. sexmaculatus* were found to concentrate towards the twigs with a higher prey population. The adults of *C. transversalis* showed a twisting movement when the prey population was low, while a moreover straight movement was exhibited when prey density was high. This was in confirmation with the findings of Sandness and Mc Murtry (1972).

The searching speed of the coccinellids was found to be influenced by the period of starvation. Daily fed adults showed a greater speed than the starved ones. Sandness and Mc Murtry (1992) and Mols (1993) found that hunger negatively influenced the speed of predatory beetles. Weber and Ferro (1994) also stated that fed insects were characterised by short steps of rapid walking.

The turning rate of the predatory coccinellids was also influenced by its period of hunger. Higher turning rate by grubs and adults were exhibited when they were deprived off prey for more than one day and at a higher prey density. Mols (1993) opined that hungry predators frequently turned leading to an area-restricted search.

The prey density and period of starvation was found to influence the turning angle of the predator. Sandness and Mc Murtry (1972) stated that the turning angle of predators increased as hunger level increased. Higher turning by the grubs and adults were noticed when they were deprived of prey for more than one day.

Almost all the aphidophagous coccinellids were seen concentrated towards the terminal part of the plant where the aphid population was high. Positive phototaxis and negative geotaxis lead aphidophagous coccinellids to terminal parts of the plants, where aphids are most likely to be found (Dixon, 1959).

The first and second instar grubs remained on the undersurface of the leaves whereas third and fourth instar showed a tendency to move towards the apex of the plant again and again and descend further each trip until finally they reached near the prey. Similar observations were made by Kaddou (1960), Banks (1954 and 1957).

The time taken by the younger grubs to consume aphids was longer than the later instars and the later instars preferred to feed on adult aphids. Similar observation was made by Banks (1957). The first stage grubs were sluggish when compared to second instar, but the number of aphids consumed was more by the second instar. These agreed with the observations made by Banks (1957). Though the second instar grubs were little active, their movement was restricted to a short distance. The third and fourth instar grubs were found to consume an appreciable number of nymphs and adults of *A. craccivora.* This might be due to the increased age and capture efficiency by a process of learning (Murdoch, 1971). The rate of feeding was reduced as the fourth instar advanced towards pupation. The reduction in the consumption of aphids by fourth instar grub of coccinellids may be due to entering pre-pupation (Murdoch, 1971). Another reason might be the increase in age of predatory grubs resulting in the rapidity of predatory response following prey contact, thereby taking less time to catch and consume more number of preys (Wratten, 1973).

The grubs and adults of *C. transversalis* and *M. sexmaculatus* were found to eat only live aphids. Similar observations were made by Hagen (1962) and Haug (1938). The coccinellids orient towards the aphid directly and puncture its body with a quick pouncing movement. After five to seven minutes of piercing, it ceased struggling and became immobile. The young instars sucked only the juice and retained the dried skin of aphids, while the later instars exhibited a chewing action consuming the whole body of the aphid. These observations agreed with the findings of Hagen (1962). Adult females were more efficient than males in recognizing, attacking and consuming aphids.

5.3 Effect of biorational insecticides on the potential predators of cowpea pests

The toxicity of lindane, chlorpyriphos, endosulfan, Nimbecidine and neem oil which were reported effective against the pests of cowpea, were evaluated on the third instar grubs and adults of *C. transversalis* and *M. sexmaculatus* by dry film technique and the LC_{50} values calculated by probit analysis (Table 23 to 26). The LC_{50} values calculated were the highest for neem oil to both the third instar grubs and adults of *C. transversalis* and *M. sexmaculatus* followed by Nimbecidine. These findings are broadly in agreement with the reports of Natarajan (1990) Venkateswara Rao and Rosaiah (1993), and Nandakumar (1999).

Among the chemical pesticides, endosulfan was the safest (LC_{50} value-0.0289%) to third instar grubs of *C. transversalis* whereas lindane was the most toxic one (LC_{50}-0.0239%). Chlorpyriphos was the least toxic one (LC_{50} value-0.0174%) to the adults of *C.transversalis* at 24 HAT. This was in agreement with the findings of Shukla *et al.* (1990) and Sonkar and Desai (1998) who reported the safety of endosulfan to *C. septempuctata* and *C. transversalis,* respectively. The high toxicity of lindane to the third instar grubs observed in the present study might be attributed to its direct contact action. Varghese (2002) observed the relative toxicity of chlorpyriphos to *C. transversalis* as 7.17 compared to malathion. Among the chemical insecticides tested against the third instar grub and adult of *M.sexmaculatus*, chlorpyriphos was the least toxic one with LC_{50} values 0.0238 and 0.0147 percent, respectively at 24 HAT. This was followed by lindane and endosulfan. The relative safety of endosulfan and lindane was reported earlier by Chaudhuri *et al.* (1983) and Dhingra *et al.* (1995). Varghese (2002) reported a very low safety index of 0.005 for chlorpyriphos. On the contrary Jena and Kuila (1997) reported that chlorpyriphos was less toxic than malathion to *C. transversalis*.

The results presented in para 4.3.1.5 revealed that among all the synthetic chemical pesticides tested against *A.craccivora*, chlorpyriphos was the most toxic one. This finding broadly agreed with those of Jena and Kuila (1997), Nasser *et al.* (2000) and Varghese (2002).

Presuming that insecticides would behave similarly under field condition, LC_{50} values of insecticides to the predators were compared with normally recommended concentration and relative safety index worked out at 48 DAS. Considering the safety of these insecticides to third instar grubs of *C. transversalis*, neem oil was the safest insecticide with a safety index of 2.726 followed by Nimbecidine (2.465). Among the chemical pesticides, chlorpyriphos ranked first with a safety index of 0.254. The others in the order of decreasing safety were lindane and endosulfan, their safety indices being 0.240 and 0.218, respectively. In the case of adult beetles of *C. transversalis* also, the same trend was observed. Their safety indices in decreasing order were neem oil > Nimbecidine > chlorpyriphos > lindane > endosulfan with safety indices of 3.132, 2.705, 0.096, 0.068 and 0.052, respectively (Fig. 11).

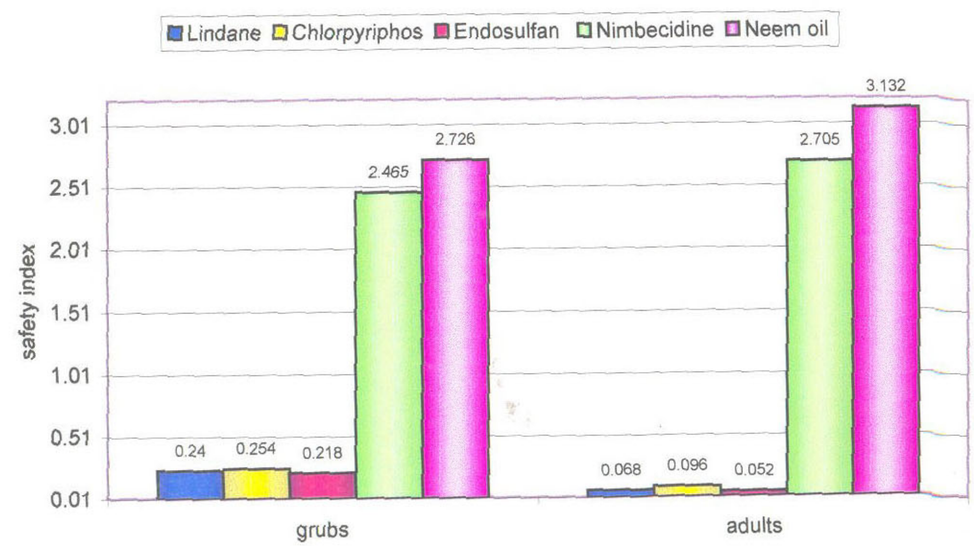


Fig.11. Relative safety of insecticides to third instar grubs and adults of *C.transversalis*

In the case of *M. sexmaculatus*, the order of safety was more or less similar for both the third instar grubs and adults. The safest insecticide was neem oil with safety indices of 3.928 and 3.063, respectively for grubs and adults. The other insecticides in the order of decreasing safety to third instar grubs were Nimbecidine (2.665) > chlorpyriphos (0.126) > lindane (0.086), > endosulfan (0.064) and to adult beetles were Nimbecidine (1.970) > chlorpyriphos (0.142) > endosulfan (0.056) > lindane (0.054), respectively (Fig.12).

Considering the safety indices of the insecticides to the predators and their efficacy against pests, all these insecticides viz. lindane, chlorpyriphos, endosulfan, Nimbecidine and neem oil were included in the ensuing pest management trials.

5.4 Pest management trial in cowpea

The results of the pest management trial in cowpea conducted in two seasons *viz.*, January to April 2000 and 2001 are presented under Para 4.4. The pests and natural enemy population in the two seasons are being discussed week wise after treatment.

At 52 DAS, (one week after first treatment) chlorpyriphos 0.05% ranked first in controlling aphids, though all the treatments were equally effective over control (Table 29 and 38). This finding was in agreement with the observations made by Verma and Lal (1978), Jena and Kuila (1997), Nasser *et al.* (2000) and Verghese (2002). In the second season, when the assessment of aphid attack was made in terms of damage intensity (percentage of crinkled leaves), plots treated with neem

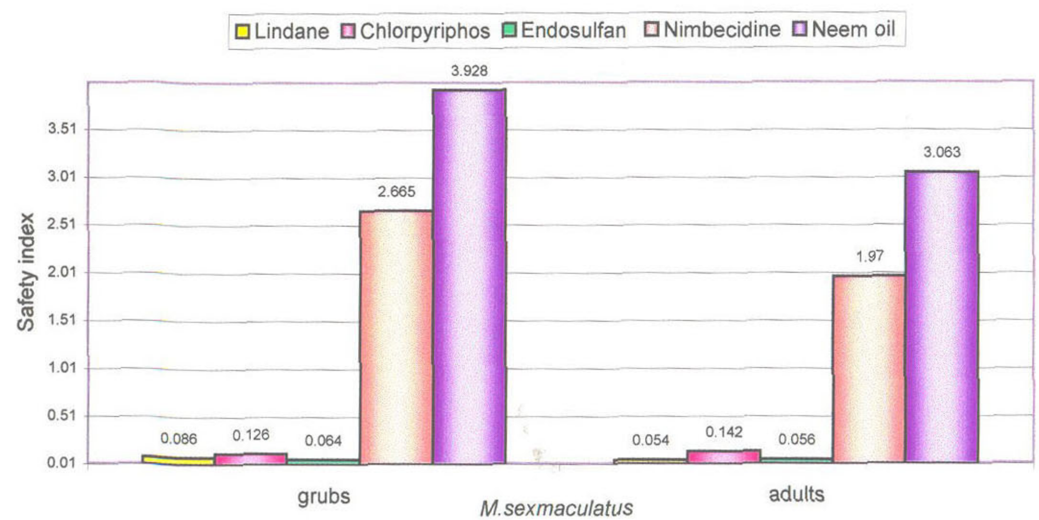


Fig.12. Relative safety of insecticides to third instar grubs and adults of *M.sexmaculatus*

kernel suspension 5% was also free from incidence of *A. craccivora* as in the case of chlorpyriphos 0.05%. The effectiveness of neem seed extract against cowpea pests was reported earlier by Jackai *et al.* (1992). In the case of damage by *A. misera*, chlorpyriphos 0.05% was the most effective treatment during both the seasons followed by Nimbecidine 0.2% and carbaryl 0.2% in the first and second seasons, respectively. The effectiveness of carbaryl against *Epilachna* spp. was earlier reported by Borah and Saharia (1982) and KAU (1996).

Neem kernel suspension 5% and among the chemical pesticides, chlorpyriphos 0.05% and lindane 0.05% could protect the cowpea crop at 52DAS from pod bug attack. Djuwarso and Harnoto (1998) reported that chlorpyriphos spray just before egg hatching could effectively control pod-infesting pests in soybean. Neem kernel suspension 5% was also found promising against pod infesting pests (Dar *et al.*, 2001).

A perusal of natural enemies (Table 30 and 39) indicated the presence of the predators *viz., C. transversalis, H. octomaculata, M. sexmaculatus, Micraspis* sp., *Scymnus* sp., *I. scutellare, Paederus* sp. damsel flies and spiders.

The highest population of *C. transversalis* could be observed in the treatments, chlorpyriphos 0.05% and neem kernel suspension 5% in the first and second seasons, respectively. Islam and Sardar (1997) earlier reported that *A. craccivora* was found to be susceptible than the predators on caged plants to insecticides and active feeding stage of coccinellid larvae were less susceptible to insecticides than adults and inactive stages. Similar finding was reported by Sarup *et al.* (1965) also. In the case of *M. sexmaculatus* also, the treatments neem kernel suspension 5% and chlorpyriphos 0.05% ranked first in population in both the seasons. The population of grubs was totally absent in carbaryl treated plots indicating its high toxicity. High mortality (95-100%) of *M. sexmaculatus* was recorded by Makar and Jadhav (1981) 72 hours after exposure to carbaryl. This also agreed with the finding of Srinath (1990).

Though the population of syrphid maggots was very low during both the seasons, they were present equally in all the treatments receiving chemical and botanical insecticides. The other predators *viz.* adults of *Micraspis sp.*, grubs of *Scymnus* sp., *Paederus* sp., damsel flies and spiders were totally absent in the plots which received synthetic chemical pesticides except chlorpyriphos 0.05%

At 59 DAS also, though all the treatments were equally effective in controlling aphids (Table 31 and 40), no incidence was recorded in chlorpyriphos 0.05% treated plots in the second season. As in 52 DAS, the treatment Nimbecidine 0.2% could protect the crop significantly from damage by *A. misera.* Earlier Nandakumar (1999) also reported the effectiveness of Nimbecidine 0.4% against epilachna beetles in bitterguard. The treatments crude neem oil emulsion 5% and chlorpyriphos 0.05% could reduce the pod borer damage to minimum compared to the other treatments. The effectiveness of chlorpyriphos 0.05% against pod borers were reported by Singh and Allen (1980) and Djuwarso and Harnoto (1998) and Verghese (2002). The pod bugs could be controlled effectively by the treatment neem kernel suspension 5% during both the seasons. Gupta et al. (2002) also reported that all the three concentrations of neem seed extract *viz.,* 1.25, 2.5 and 5% significantly reduced the feeding activity of *C. scutellaris* and not interfered with their natural enemies

Among the predators at 59 DAS, significant population of the grubs of *Coccinella* spp. was recorded in the treatments Nimbecidine 0.2%, neem kernel suspension 5% and chlorpyriphos 0.05%, whereas the population of *M. sexmaculatus* grubs was the highest in the treatments neem kernel suspension 5% and crude neem oil emulsion 5% followed by chlorpyriphos 0.05% (Table 32 and 41). The effectiveness of NSKE 5% against aphids and safety to coccinellid predators were earlier reported by Devakumar *et al.* (1986) and Singh (2001). In the toxicity studies also, high safety of Nimbecidine was obtained for *C. transversalis* and neem oil against *M. sexmaculatus.* No population of adult beetles of *M. sexmaculatus* could be observed in the treatment endosulfan 0.05%. This finding is in agreement with the reports of Patel and Yadav (1993) who observed high toxicity of endosulfan to *M. sexmaculatus*. There are other reports on the safety of endosulfan to *M. sexmaculatus* by Sonkar and Desai (1998) and Patil and Lingappa (1999). Earlier Makar and Jadhav (1981) reported 95 to 100% mortality of *M. sexmaculatus* adults 72 hours after treatment with carbaryl. Sharma and Adlakha (1986) also observed a toxicity of 11.86 in carbaryl treatment compared to 1.00 of DDT to the adults. Syrphid maggots were totally absent in the treatments, carbaryl 0.2%, lindane 0.05% and crude neem oil emulsion 10%. Lowery and Isman (1995) observed a reduced adult eclosion of the syrphid *Eupedes fumipennis*.Thompson. to 11.0, 7.00 and 0.00 percent by the application of neem seed oil at 0.5, 1.0 and 2.00 percent concentration. No population of spiders was observed in the plots that received chemical pesticides. This agreed with the observations made by Patel *et al.* (1987) who reported a decline in spider population both quantitative and qualitative, due to successive application of chemical pesticides.

At 60 DAS, a second round spray was given for all the treatments as per the dose given for the first spray.

At 68 DAS (one week after the second treatment), chlorpyriphos 0.05% and neem kernel suspension 5% continued to be the best treatments against *A. craccivora* (Table 33 and 42). Like the earlier observations, nimbecidine 0.2% could effectively control *A. misera*. However, chlorpyriphos 0.05% was also found to be effective at 68 DAS against *A. misera*, which ranked first in second season. As in the previous observation, crude neem oil emulsion 5% and chlorpyriphos 0.05% came in the first and second place in controlling pod borer pests. Earlier Babu and Rajasekharan (1984) reported that neem oil 3 or 5 percent permitted the lowest damage rate against pod borer *H. armigera*. The pod bug population was totally absent in the treatment chlorpyriphos 0.05% and neem kernel suspension 5% during the first season.

Among the predators, the *Coccinella* spp. grubs were found to be the maximum in the treatment neem kernel suspension 5% (Table 34 and 43). Though no significant variation in the population of grubs of *M. sexmaculatus* was observed among the treatments, no adult beetles could be recorded in carbaryl 0.2% treated plots. Makar and Jadhav (1981) also made similar finding. The population of syrphids, damselflies and spiders was very low during the period that the treatment effects could not be manifested.

At 76 DAS also, all the treatments were giving significant control of *A. craccivora*. However, all the chemical treatments along with the botanical neem kernel suspension 5% gave cent percent control in the first season (Table35 and 44). The works of EL-Ghar-GESA *et al.* (1994) and Saxena (1978) revealed the effectiveness of these pesticides against *A. craccivora*. Cent per cent control of the pod borer damage could be obtained from the treatment chlorpyriphos 0.05%, which was followed by carbaryl 0.2% and crude neem oil emulsion 5% in the first season, whereas carbaryl 0.2%, chlorpyriphos 0.05%, and neem kernel suspension 5% gave cent percent control of pod bugs. The effectiveness of carbaryl and chlorpyriphos against pod infesting pests was reported by Singh and Allen (1980).

The population of *Coccinella* spp. grubs was not adversely affected by any of the treatments except carbaryl 0.2% in the first season (Table 36 and 45). These findings are in agreement with the reports of Sharma and Adlakha (1986) and Islam and Sardar (1997). The highest population of the grubs of *M. sexmaculatus* could be observed in the treatment neem kernel suspension 5%. The other predators *viz.*, syrphid maggots, *Micraspis* sp., damselflies and spiders were very low in number.

Thus from the observations on major pests in the experiments conducted for two seasons indicated that the mean population of *A. craccivora* per top 2.5 cm shoot was significantly low in the two treatments viz., NKS 5% and chlorpyriphos 0.05% compared to control throughout the period of observation (Fig.13). Similarly, the mean percentage of leaf damage by *A. misera* was also significantly low compared to the control. Similar trend was observed in the case of mean percentage of pod borer damage and mean number of pod bugs per 5 sweeps also.

In the case of major predators, there was not any significant reduction or increase in the population of grubs and adults of *Coccinella* spp., *M. sexmaculatus* and the syrphid *I. scutellare* (Fig.14).

Significantly higher grain yield of cowpea was obtained from the treatment chlorpyriphos 0.05 % (T4) with 750 kg and 785 kg per hectare during the first and second seasons, respectively. This was on par with the treatment NKS 5% (T_7) with a per hectare grain yield of 700kg and 735kg, respectively for season-1 and season-2 (Fig.15). The present finding on the superiority of these treatments might be explained in terms of effectiveness of these chemicals in controlling the pod borers and pod bugs which are the most serious pests of cowpea, the infestation of which may adversely affect the grain yield. The highest marginal benefit: cost ratio of 4.8

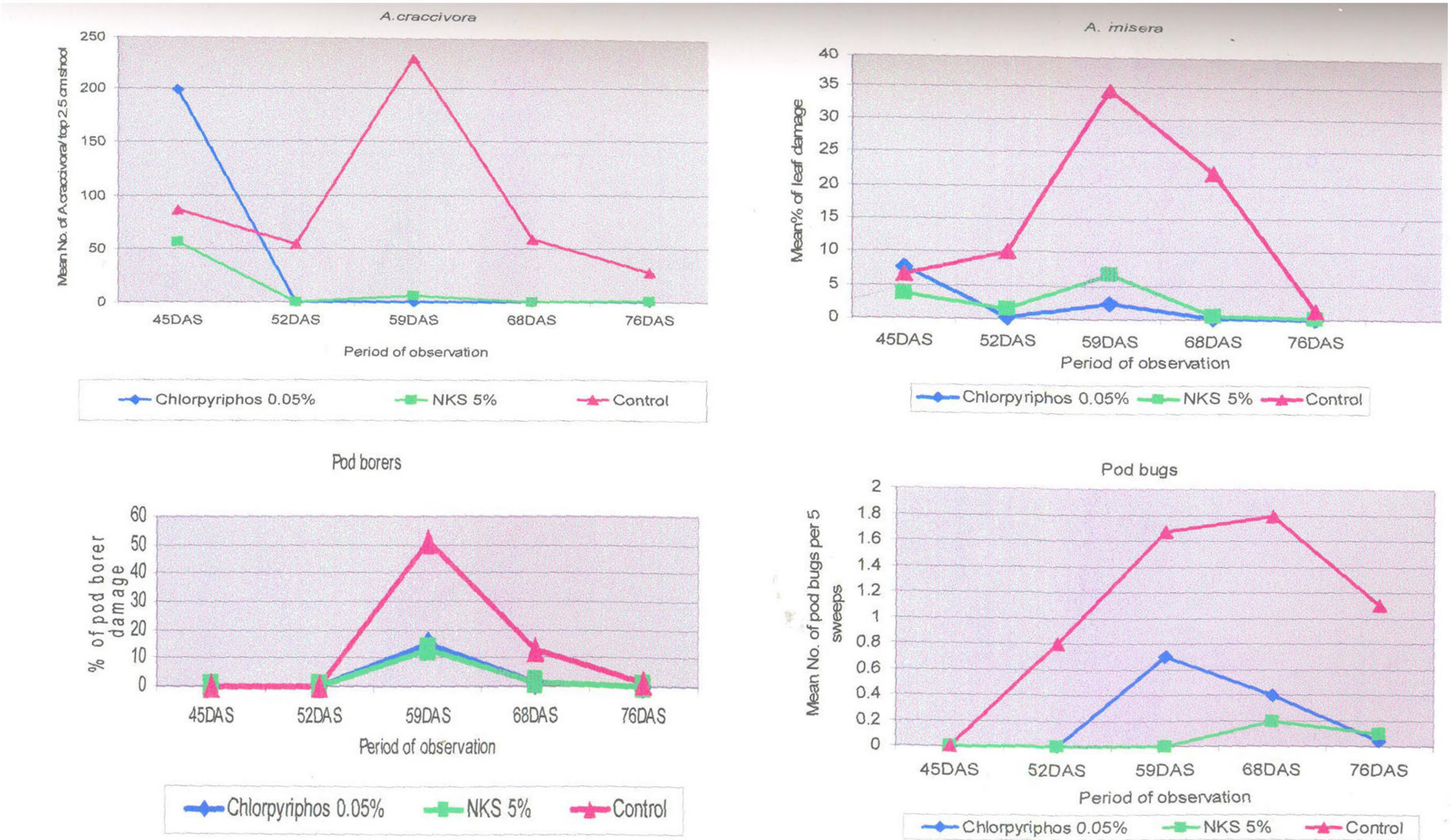
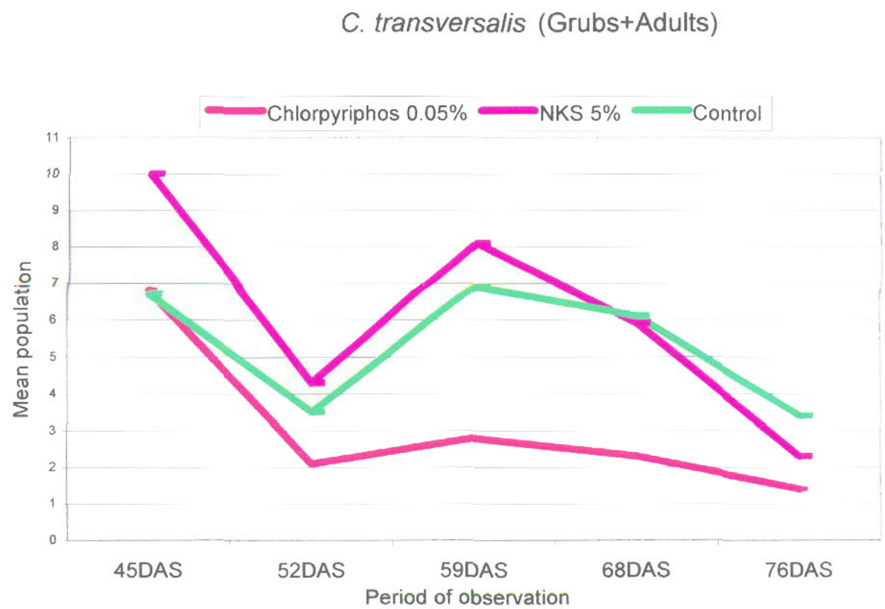


Fig. 13. Pest incidence / damage by major pests in the effective treatments in pest management trial



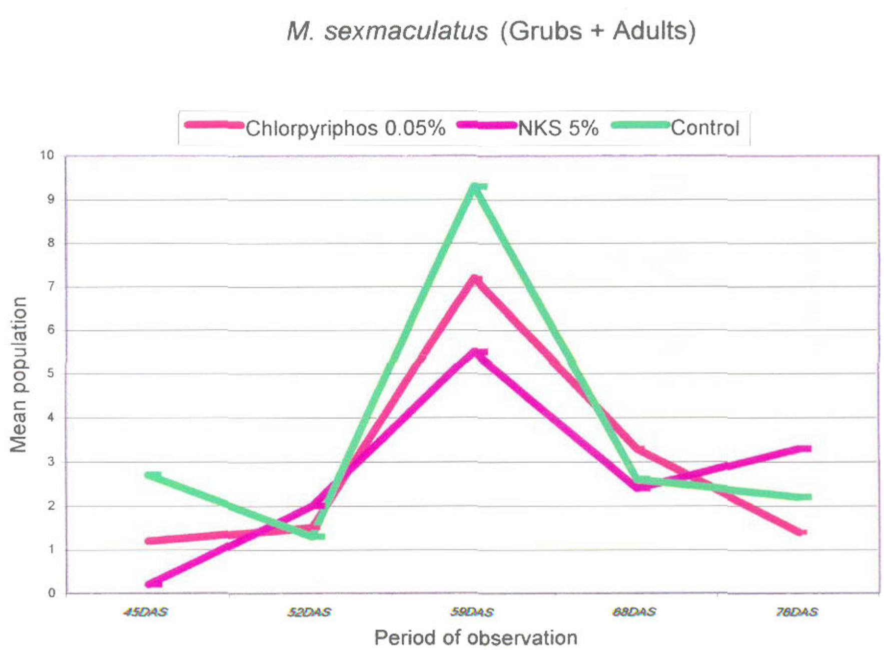


Fig. 14. Predator population in effecive treatments in pest management trials

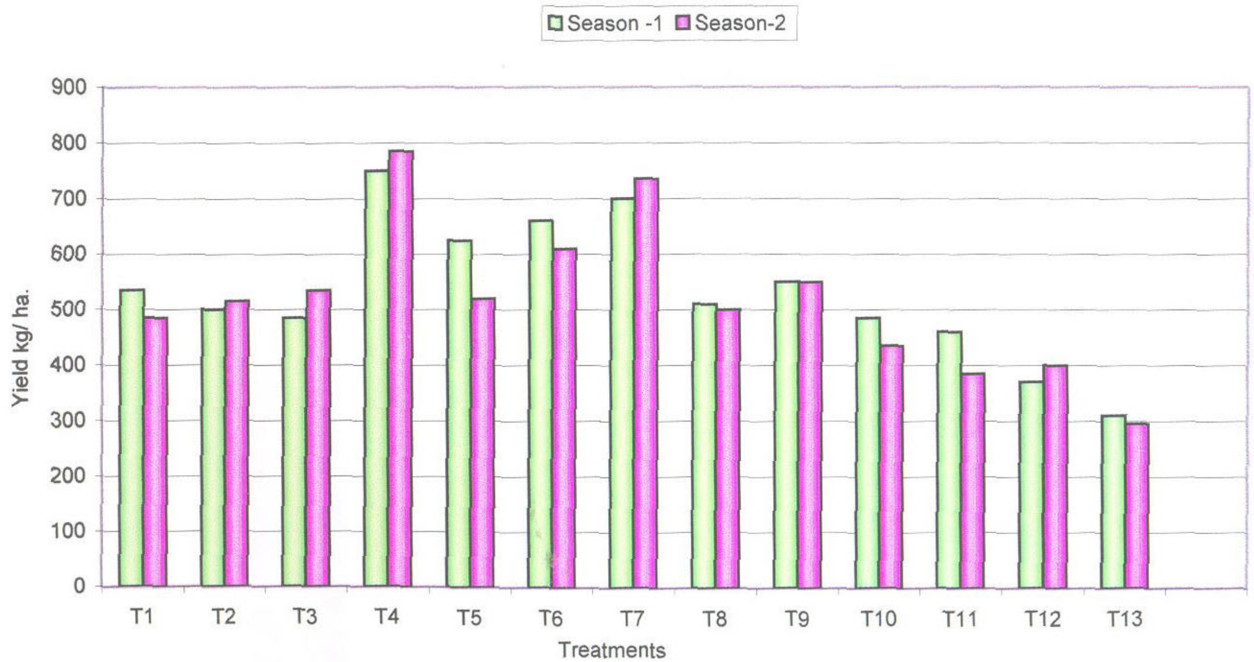


Fig.15. Yield of cowpea grains in pest management trial during two seasons
(2000 and 2001)

and 5.4, respectively for first and second season was also realised from the treatment chlorpyriphos 0.05% (T_4) (Fig.16). This was closely followed by the treatment NKS 5 % (T7) with a marginal benefit: cost ratio of 3.9 and 4.4 for season -1 and season -2, respectively. Considering the effectiveness of these insecticides against major pests viz., *A. craccivora*, pod borers and pod bugs and also the safety to major predators in the cowpea ecosystem *viz*., the grubs and adults of *C. transversalis* and *M. sexmaculatus*, the highest score was obtained for neem kernel suspension 5% which was closely followed by chlorpyriphos 0.05% (Table 62). More over considering the very low level of terminal residues of the chemical chlorpyriphos 0.05% in grains which was below MRL (Table 47), these two treatments could be recommended as one of the components in the IPM package against cowpea pests.

5.5. Evaluation of the effect of various field treatments on the incidence of pulse beetle *Callosobruchus* spp. in store

The results of the experiment on the assessment of the loss of grain weight, percentage of grain damage by bruchids, mean population of adult bruchids and other stored grain pests are given in Para 4.5.

No significant variation in weight loss was recorded among various treatments in both the seasons. Though the population of bruchids could be detected in some of the treatments, no symptom of damage was detected in grains received chlorpyriphos 0.05% throughout the period of observation during the first season. However, in the second season at fifth month of storage in addition to

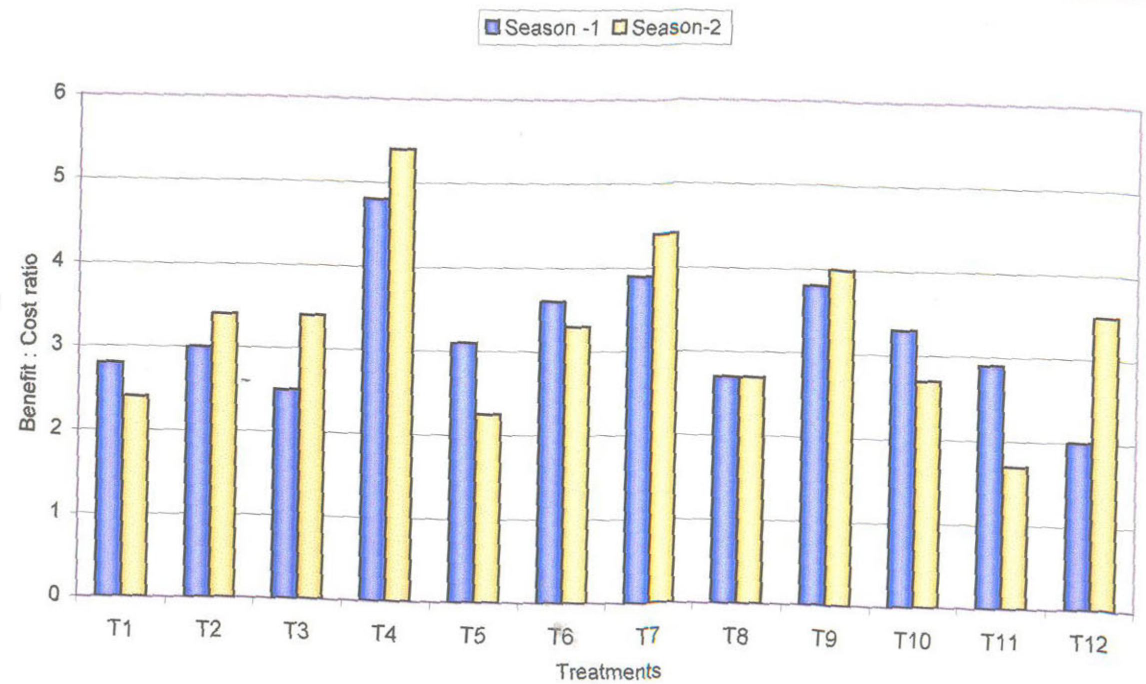


Fig.16. Benefit : cost ratio of pest management trial in cowpea during two seasons (2000and 2001)

Table 62. Performance of promising treatments with respect to their effectiveness against major pests and safety to major predators

Treatments	Relative score based on % reduction over control						Ralative score based on safety to major predators of *A..craccivora*			
	A.craccivora		Pod borers		Pod bugs		*C.transversalis*		*M.sexmaculatus*	
	S_1	S_2	S_1	S_2	S_1	S_2	grub	adult	grub	adult
Endosulfan	++++	++++	++	+++	+++	++	++	+	+	+
Lindane	++++	++++	+++	+++	+++	+++	++	+	+	+
Chlorpyriphos	++++	++++	+++	++++	++++	+++	++++	+	+	+
Neem oil	++++	+++	++	+++	++	+++	++	+++	+++	++
Neem kernel suspension	++++	++++	+++	+++	++++	++++	+++	++	++	+
Nimbecidine	++++	++++	+++	+++	++	+	+	+	+	+

S_1 – Season 1 S_2 – season 2
One + sign indicates 25% reduction
One + sign indicates 25% safety

chlorpyriphos 0.05%, lindane 0.05%, crude neem oil emulsion 10%, neem kernel suspension 5%, neem kernel suspension 2.5% and Nimbecidine 0.2% also recorded significantly lower infestation. The infestation by bruchids on cowpea grains starts from the field itself before harvest. Though the terminal residue status of these chemicals in grains was below MRL, this protective effect up to fifth months of storage could be attributed to the fact that these chemicals may have protected the grains from oviposition by bruchids in the field. The effectiveness of neem products against stored grain pests was also reported by Singh (2002). Regarding the number of adult bruchids, all the treatments recorded significantly low population during the fifth month of storage. However, during the second season at fifth month, only the treatments except carbaryl 0.05%, endosulfan 0.05%, crude neem oil emulsion 10 % and 5% could record significantly low population of adult bruchids.

The adult beetles of *Laemophleus* sp. were recorded from the second month of storage, while *O. surenamensis* and *R. dominica* could be recorded only from third month onwards. However, no population of *O. surenamensis* was recorded in the treatment chlorpyriphos 0.05% throughout the period of observation in the second season. The efficacy of neem seed extract against stored grain pest *R. dominica* was reported by Rao *et al.* (2002).

Though there are not much variation among treatments, the treatments selected in the pest management trial *viz.*, chlorpyriphos 0.05% and neem kernel suspension 5% were found to be superior in the store also by giving protection against the major pests of stored cowpea grains.

5.5 Field testing of IPM package in cowpea through farmers' participation

Based on the results of the experiment (Para 4.4), the treatments chlorpyriphos 0.05% and neem kernel suspension 5% were selected against major pests viz. *A. craccivora*, *A. misera*, pod borers and pod bugs for further field testing through farmer's participation. These treatments were superior in their effectiveness against the major pests, safety to natural enemies, yield of grains per hectare, benefit: cost ratio and persistence of terminal residue below MRL.

The results of the other experiments *viz.*, efficiency of potential predators in controlling cowpea pests (Para 4.2) and the effect of biorational insecticides on the potential predators of cowpea pests (Para 4.3) were also considered for field testing through farmer's participation and to work out an IPM strategy with the following technologies along with the proven techniques under field condition.

5. Monitoring of cowpea fields for incidence/damage of pests and population of natural enemies especially at 52-59 DAS (for *A. craccivora*, *A. misera* and pod borers) and at 60-68 DAS (for pod bugs).

6. Adoption of mechanical and cultural control measures *viz.* burning of trash before sowing, application of dry leaf ash at 10 DAS, keeping yellow sticky trap / yellow pan tray, removal and destruction of

infested leaves, flower buds and pods and sweeping and destruction of pod bugs.

7. Collection and release of natural enemies associated with major pests proved to be efficient *viz.,* grubs and adults of *M. sexmaculatus*, *C. transversalis* and *H. octomaculata* and maggots of *I. scutellare*.

8. Need based application of neem kernel suspension 5% /chlorpyriphos 0.05% during 45DAS in case of moderate incidence of *A. craccivora* *A. misera* and pod borers. A second spray using neem kernel suspension 5% on 60 DAS, if needed against pod borers, pod bugs and *A. craccivora.*

The results of the field trials using IPM technologies as one of the treatments along with farmer's practices as check are presented in Table 54 to 61.

The mean population and extent of damage by all the pests observed in IPM plots viz., *A. craccivora A. misera*, pod borers and pod bugs were significantly low compared to the farmer's practice during all the five weeks starting from 52 to 76 DAS (Fig. 17).

Among the major natural enemies, significantly high population of the adults of *M. sexmaculatus* and maggots of *I. scutellare* were observed in IPM plots compared to control. The adults and grubs of *C. transversalis* and *M. sexmaculatus* were though not significant, showed a general increase in population in IPM plots (Fig. 18). A higher mean yield of 808.3 kg ha^{-1} was obtained from IPM plots as

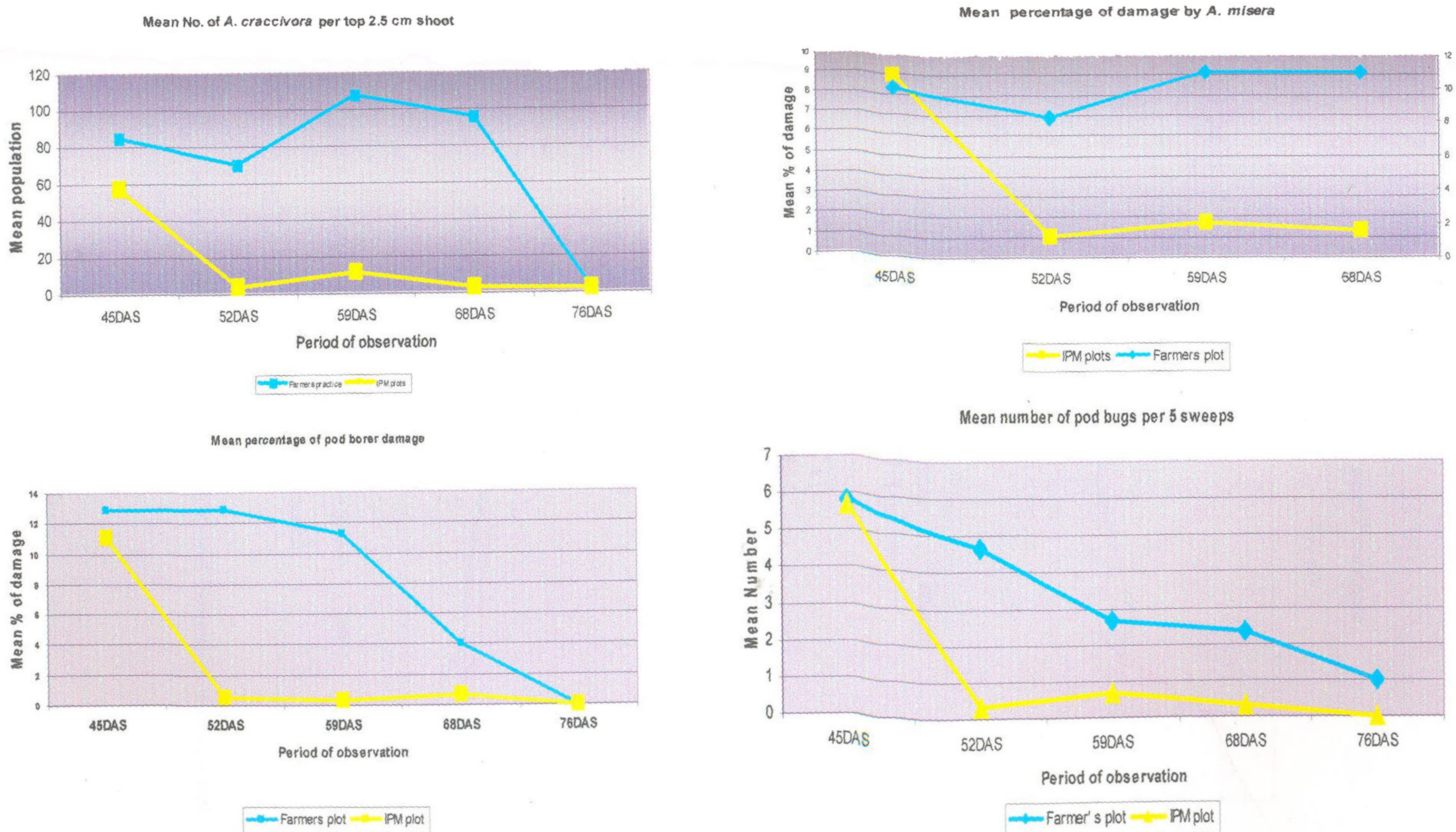
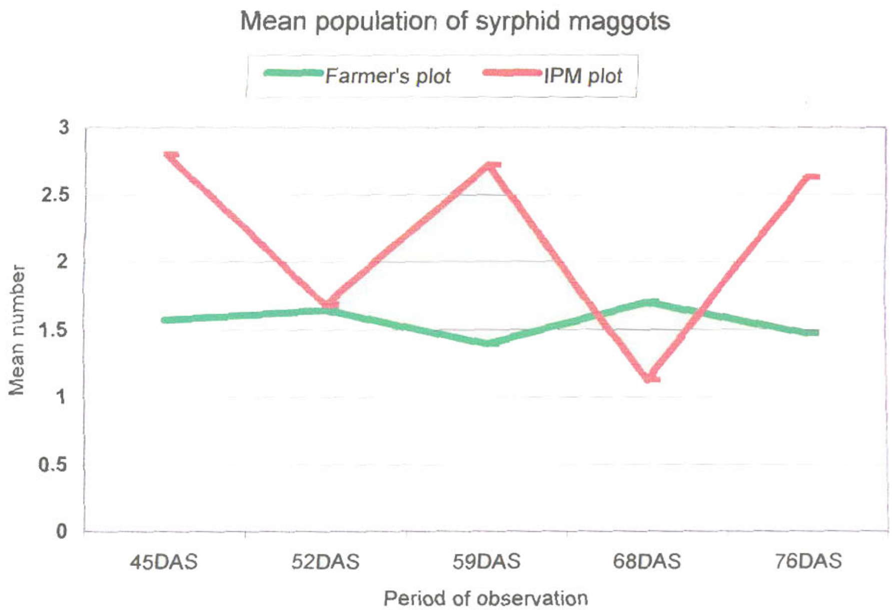


Fig. 17. Pest incidence / damage in the IPM and farmers plot of cowpea



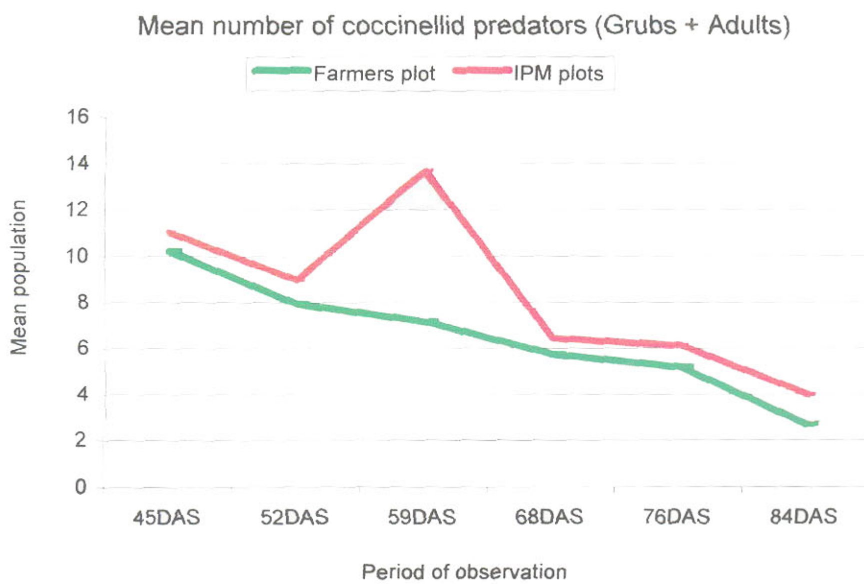


Fig. 18. Predator population in IPM and farmers plot of cowpea

against 312.5 kg ha^{-1} from the fields with farmers practice. A high marginal benefit: cost ratio of 4.5 was also realised from the IPM plots.

Thus, an IPM strategy in cowpea could be developed based on the results of the present study along with the proven techniques under field condition.

- Burning of trash before sowing
- Selecting healthy seeds
- Soil drenching with Bordeaux mixture 1% wherever fungal disease is prevalent
- Clean cultivation including weeding
- Treating the seeds with rhizobium culture @ 250-375 g ha^{-1} before sowing
- Monitoring the fields for incidence of pests / population of natural enemies especially at 52-59 DAS (for *A. craccivora, A. misera* and pod borers) and at 68 DAS (for pod bugs).
- Adoption of mechanical methods of pest control such as application of dry leaf ash at 10 DAS, keeping yellow sticky trap / yellow pan tray, collection and destruction of infested leaves, flower buds and pods and sweeping and destruction of the pests.
- Collection and release of potential natural enemies *viz*., grubs and adults of *C. transversalis*, *M. sexmaculatus H. octomaculata and maggots of I. scutellare*

- Need based application of *F. pallidoroseum* @7x 10^6 spores ml^{-1} specifically for the management of *A. craccivora*
- Need based application of neem kernel suspension (NKS) 5% or chlorpyriphos 0.05% during 45 DAS in the case of moderate incidence of *A. craccivora, A. misera* and pod borers and a second spray using NKS 5% at 60 DAS if needed against pod borers and pod bugs.

By following this IPM strategy, higher production of cowpea grains can be achieved with a high benefit: cost ratio.

The future line of work should aim in research on developing an IPM strategy for vegetable cowpea including screening of varieties with various biophysical characters against pod infesting pests. Various new biorational insecticides can be evaluated. Standardisation techniques for mass multiplication and release of the efficient biocontrol agents in an extensive manner can be done in future to strengthen the IPM strategy.

SUMMARY

SUMMARY

A survey was conducted during January to May 1999 at two stages of the crop *viz.,* 20-25 days after sowing (DAS) and 55-60 DAS, to monitor the incidence of the pests of cowpea and their associated natural enemies, to evaluate the plant protection measures adopted and their methods of application and to find out the sources of information on plant protection measures among the farmers of three major grain cowpea growing areas of Kerala *viz.,* Thiruvananthapuram, Alappuzha and Palakkad districts. Laboratory experiments were conducted to assess the efficiency of major predators in cowpea fields on the major pests, study the predatory behaviour of the major predators, and study the effect of biorational (synthetic chemicals and botanicals) insecticides on the potential predators and major pests. Based on the results, a pest management trial on cowpea was conducted for 2 seasons (from January to May 2000 and 2001). Evaluation on the effect of the various field treatments on the incidence of pulse beetle C*allosobruchus* spp. in store was also conducted. All those results were combined with the proven technologies and an Integrated Pest Management (IPM) package was worked out in grain cowpea and tested in the farmers' fields through their participation in comparison with their practice.

Majority of the farmers in Thiruvananthapuram district used local grain type cowpea in more than fifty percent of the area. In Alappuzha district, more than fifty per cent of the farmers cultivated the improved variety, Kanakamani. The improved variety, C-152 was cultivated in major portion of the cowpea growing areas in Palakkad district.

At the first stage of the survey (20-25 DAS), the pea aphid *A. craccivora,* stem fly *O. pheaseoli* and the American Serpentine Leaf Miner (ASLM) *L. trifolii* were the major pests recorded, of which more than eighty percent of the plots were infested with *A. craccivora*. At pod formation stage (55-60 DAS) of the crop, pod borers were the major pests in more than eighty percent of the area surveyed followed by pod bugs and *A. craccivora*. The cow bug A. *pilosum*, green shield bug *N. viridula*, hairy caterpillars and leaf webbers were the other pests recorded during the survey.

The natural enemies associated with the pests of cowpea were in general low both at 20-25 DAS and 55-60 DAS. The grubs and adults of *M. sexmaculatus* and *Micraspis* sp. dominated the predatory fauna in the cowpea fields of Thiruvananthapuram and Alappuzha districts while *Coccinella* spp. particularly *C. transversalis* dominated in Palakkad district. Grubs and adults of *Scymnus* sp., *Brumoides suturalis*, maggots of the syrphid *I. scutellare*, the rove beetle *Paederus* sp., the ground beetle *O. nigrofaciata*, *C. carnea*, dragonflies, damselflies and spiders were the other predators recorded in all the three districts.

An observation made in the unprotected cowpea fields of Onattukara Regional Agricultural Research Station (ORARS), Kayamkulam revealed that the population of *A. craccivora* and the percentage of damage by pod borers reached its peak at 59 DAS and that of pod bugs at 68 DAS. The total natural enemy population was also the highest at 59 DAS and showed a similar trend in population level as that of the pests. A comparison of the population/damage of the pests in an unprotected cowpea field with those of nearby farmer's field revealed that the *A. craccivora* population and percentage of pod borer damage were higher in unprotected plots compared to farmers fields. A similar trend was observed in the case of predators also, the population of which were higher in the unprotected plots.

The plant protection measures were adopted by 82.2 and 74.1% of the farmers at 20-25 DAS and 55-60 DAS, respectively. At 20 -25 DAS, 40% of the farmers used synthetic chemicals and 28.9% used botanical pesticides, whereas, 38.7 and 33.3%of the farmers used synthetic chemicals and botanicals at 55-60 DAS, respectively. Of all the insecticides, neem oil was used by majority of the farmers compared to others followed by carbaryl both at 20-25 DAS and 55-60 DAS. Majority of the farmers used contact insecticides rather than systemic, at both stages of the crop. Organophosphates were the major group of synthetic insecticides used, among which monocrotophos ranked first at 20-25 DAS and quinalphos at 55-60 DAS.

Majority of the farmers (37.8 and 36.7 per cent) used recommended dose of insecticides for spraying at 20-25 DAS and 55-60 DAS. Irrespective of the dose of pesticides, most of the farmers used a spray volume below the recommended one. As far as the frequency of application and interval between two applications were concerned, majority followed the recommendation.

Most of the cowpea growing farmers in Thiruvananthapuram district, gained information on plant protection measures, through mass media and neighboring farmers. In Alappuzha district, the farmers gained information mainly from the scientist/University while in Palakkad, the main source of information was seminars.

Regarding the efficiency of potential predators, coccinellids ranked first. Among them, *C. transversalis*, *H. octomaculata* and *M. sexmaculatus* were the predominant species in cowpea fields. *H. octomaculata* had the shortest life cycle of 13.27±0.31 days followed by *C. transversalis* with 13.78±0.33 days and *M. sexmaculatus* with 18.70±0.91 days. The total life cycle of the syrphid *I. scutellare* and *C. carnea* were worked out as 16.43±0.45 and 25.80±0.77 days, respectively.

Among the major predators, the grubs of *C. transversalis* consumed the maximum number of 251.8±6.74 *A. craccivora* followed by *H. octomaculata* with 198.22±12.90 aphids and *M. sexmaculatus* with 127.60±3.35 aphids. A similar trend in the consumption of *A. craccivora* was observed in the case of adults also. A per day consumption of 30.77, 27.88 and 23.33 aphids and a total consumption of

914±50.28, 842±77.28 and 734.1±102.44 *A. craccivora* were observed in the case of adults of *C. transversalis*, *H. octomaculata* and *M. sexmaculatus*, respectively. A single maggot of the syrphid predator *I. scutellare* consumed a mean number of 459.5±7.71 aphids during its larval period and the total consumption of adult *A. craccivora* consumed by a single larva of *C. carnea* was 42.1±1.23.

`The searching speed of the adult coccinellids increased with increase in prey density but decreased with increase in hunger level. The turning rate was also found to be increasing with increase in pray density and hunger level. The turning angle of the grubs and adults were increased as the hunger level increased.

Almost all the aphidophagous coccinellids were seen concentrated towards the terminal part of plant. The first and second instar remained on the undersurface of cowpea leaves and the third and fourth instar showed a tendency to move towards the terminal shoot.

The first instar grubs were found to be cannibalistic on its own unfertile eggs, and the second instar preferred to feed on aphid nymphs. The third and fourth instars were voracious feeders, but the feeding rate was found to be reduced as the grubs enter pre pupation. The grubs and adults of coccinellids were found to eat only live aphids. Adult females were more efficient than males in recognizing, attacking and consuming aphids.

The highest LC_{50} values (lowest toxicity) were calculated for neem oil to both the third instar grubs and adults of *C. transversalis* and *M. sexmaculatus* followed by Nimbecidine. Among the synthetic chemicals *viz.* lindane, endosulfan and chlorpyriphos, the lowest LC_{50} (highest toxicity) value was obtained for endosulfan on the third instar grubs of *C. transversalis* at 24 HAT. But in case of the third instar grubs of *M. sexmaculatus* and adults of both *C. transversalis* and *M. sexmaculatus*, chlorpyriphos was found to be the least toxic one with the highest LC_{50} values.

Among the insecticides, neem oil was the safest one with a safety index of 2.726 for the third instar grubs and 3.132 for the adults of *C. transversalis*. In the case of *M. sexmaculatus,* the safety index of neem oil was 3.928 and 3.063, respectively for grubs and adults. Among the synthetic chemical insecticides though the difference was not so significant, chlorpyriphos had the highest safety index for both the third instar grubs and adults of *C. transversalis* and *M. sexmaculatus*.

A pest management trial conducted for two seasons (January to April 2000 and 2001) indicated that the treatments *viz.*, neem seed kernel suspension (NKS) 5% + mechanical + cultural control and chlorpyriphos 0.05% + mechanical + cultural control at 45 and 60 DAS were equally effective in respect of their effectiveness against the pests and safety to natural enemies. A per hectare yield of 750 kg and 785 kg were obtained for the treatment chlorpyriphos 0.05% in the first and second seasons, respectively. In the treatment NKS 5%, the per hectare yield was 700kg and 735kg, respectively for the first and second season. The highest marginal benefit: cost ratio was also realized from these treatments, the corresponding values for the treatment chlorpyriphos 0.05% were 4.8 and 5.4 and for NKS 5% were 3.9 and 4.4 for the first and second seasons, respectively.

The terminal residues of the insecticides estimated at 14 days after application in the harvested produce were well below the MRL fixed for lindane (3ppm), chlorpyriphos (2ppm) and endosulfan (2ppm).

The harvested grains were kept under storage for evaluation of the field treatments on the incidence of the storage pests. The results indicated no significant variation in weight loss among various treatments up to five months of storage (MOS) in both the seasons. Though the population of bruchids could be detected in some of the treatments, no symptoms of damage was detected in grains received the treatment chlorpyriphos 0.05% up to 5 MOS and NKS 5% upto 4 MOS. The adults of *Laemophleus* sp. was recorded from the second month of storage, while *O. surinamensis* and *R. domonica* could be recorded only from third month onwards. Thus, based on the results of the various experiments, the technologies emerged superior was tested along with the already proven techniques in farmer's fields at three locations through their participation in comparison with farmers practice to work out an IPM strategy against the major pests.

The mean population and extent of damage by all the pests in IPM plots were significantly low compared to farmers practice. The population of natural enemies though not significant in all the stages, was high compared to those in farmer's practices. The IPM treatments were superior in terms of yield and marginal benefit: cost ratio also.

Thus, an IPM strategy against major pests of cowpea could be developed as

- Burning of trash before sowing.
- Selecting healthy seeds.
- Soil drenching with Bordeaux mixture 1% wherever fungal disease is prevalent.
- Clean cultivation.
- Treating the seeds with rhizobium culture @ 250-375 g ha^{-1} before sowing
- Monitoring the fields for incidence of pests / population of natural enemies especially at 52-59 DAS for *A.craccivora,* epilachna beetles and pod borers and at 60- 68 DAS for pod bugs.
- Adopting mechanical methods of pest control such as application of dry leaf ash at 10 DAS, keeping yellow sticky trap / yellow pan tray and collection and destruction of infested leaves, flower buds and pods and sweeping and destruction of the pests.
- Collection and release of potential natural enemies *viz*., grubs and adults of *C. transversalis*, *M. sexmaculatus H. octomaculata and maggots of I. scutellare.*

- Need based application of *F. pallidoroseum* @ 7x10^6 spores ml^{-1} specifically for the management of *A. craccivora.*
- Need based application of neem kernel suspension (NKS) 5% or chlorpyriphos 0.05% during 45 DAS in the case of moderate incidence of *A. craccivora,* epilachna beetles and pod borers and a second spray using NKS 5% at 60 DAS if needed against pod borers and pod bugs.

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APPENDICES

APPENDIX 1

PROFORMA FOR THE SURVEY ON THE INCIDENCE OF PESTS OF COWPEA, THEIR PARASITES, PREDATORS AND MANAGEMENT PRACTICES IN FARMERS' FIELDS

1. Location : Block : Panchayat :
2. Name of farmer :
3. Address :
4. Age (in completed years) :
5. Stage of the crop (Weeks after planting) :
6. Education :
7. Size of holding (Hectares) :
8. Soil type :
9. Income :
10. Main occupation :
11. Subsidiary Occupation :
12. Whether wet land/garden land :
13. Leased land :
14. Own land :
15. Seeds
    a) Variety used and area :
    b) Source of seed :
16. Method of cultivation :
17. Details of organic manure used :
18. Details of chemical fertilizers used :

19.a Incidence of pests / Population of natural enemies at 20-25 DAS

Name of the pest/ natural enemy	Population/ Damage	Sweep count

19.b Incidence of pests / Population of natural enemies 55-60 DAS

Name of the pest/ Natural enemy	Population/ Damage	Sweep count

20.a Intensity of pest incidence / Population of natural enemies 20-25 DAS

Name of pest/ natural enemy	Intensity Low	Medium	Severe/High.

20.b Intensity of pest incidence / Population of natural enemies 55-60 DAS

Name of pest/ natural enemy	Intensity Low	Medium	Severe/High.

21.a Plant protection measures adopted at 20-25 DAS

Name of Pest	Cultural/ Mechanical	Organic formulation	Chemical measures	Extent of control poor	good	excellent

If spraying is done

Name of pest	What chemical	At what dose (spray volume)	Equipment used	Coverage

21.b Plant protection measures adopted at 55-60 DAS

Name of Pest	Cultural/ Mechanical	Organic formulation	Chemical measures	Extent of control poor	good	excellent

If spraying is done

Name of pest	What chemical	At what dose (spray volume)	Equipment used	Coverage

22.a Particulars of chemical insecticides used at 20-25 DAS

chemical used	Dose	Interval	Whether spraying is on identification of the problem	Purpose	Method of application

22.b Particulars of chemical insecticides used at 55-60 DAS

chemical used	Dose	Interval	Whether spraying is on identification of the problem	Purpose	Method of application

23.a. Any additional practice known and adopted for pest management

Practices	Adoption	S/US

23.b. Any additional practice known and adopted for pest management

Practices	Adoption	S/US

24. Source of information

1) Dealer :
2) Neighbouring farmers :
3) His own discretion :
4) Media :
5) Seminars :
6) Krishibhavans :
7) Scientists/University :

25. Benefit: cost ratio of pesticide used :

26. How the produce is marketed :

Source	Percentage	Price Poor/fair/good/excellent

27. Constraints in the cultivation :

28. Any other information :

APPENDIX II a

Pest incidence / damage in cowpea at 20-25 DAS

A. craccivora

District	Degree of incidence				Total
	No incidence	Low	Medium	Severe	
Thiruvananthapuram	5	14	10	1	30
Alappuzha	2	10	15	3	30
Palakkad	3	12	10	5	30
Total					90

$\chi_2^{\,2} = 3.29^{NS}$

O. phaseoli

District	Degree of incidence				
	No incidence	Low	Medium	Severe	Total
Thiruvananthapuram	27	2	1	0	30
Alappuzha	19	5	6	0	30
Palakkad	19	9	2	0	30
Total					90

$\chi_1^{\,2} = 1.77^{NS}$

L. trifolii

District	Degree of incidence				
	No incidence	Low	Medium	Severe	Total
Thiruvananthapuram	24	3	3	0	30
Alappuzha	23	5	2	0	30
Palakkad	19	9	2	0	30
Total					90

$\chi_2^{\,2} = 2.39^{NS}$

APPENDIX II b

Pest incidence/damage in cowpea at 55-60 DAS

A. craccivora

District	Degree of incidence				Total
	No incidence	Low	Medium	Severe	
Thiruvananthapuram	9	11	8	2	30
Alappuzha	8	8	10	4	30
Palakkad	8	4	14	4	30
Total					90

$\chi_4^2 = 5.58^{NS}$

Pod borers

District	Degree of incidence				Total
	No incidence	Low	Medium	Severe	
Thiruvananthapuram	3	16	9	2	30
Alappuzha	0	13	14	3	30
Palakkad	14	12	4	0	30
Total					90

$\chi_1^2 = 0.02^{NS}$

Pod bugs

District	Degree of incidence				Total
	No incidence	Low	Medium	Severe	
Thiruvananthapuram	12	10	7	1	30
Alappuzha	5	9	14	2	30
Palakkad	7	7	15	1	30
Total					90

$\chi_4^2 = 6.99^{NS}$

APPENDIX III

Weather Parameters
Thiruvananthapuram District

Period	Temperature °C		Relative humidity		Total rain fall (mm)	Sun-shine hours
	Maximum	Minimum	Morning	Evening		
01-01-99 to 07-01-99	30.9	22.4	96	91	3.2	4.4
08-01-99 to 14-01-99	31.4	22.1	98	92	0.0	9.4
15-01-99 to 21-01-99	31.7	22.4	93	59	0.0	9.5
22-01-99 to 28-01-99	31.1	20.9	95	61	0.0	7.4
29-02-99 to 04-02-99	30.7	22.2	93	61	2.0	8.1
05-02-99 to 11-02-99	30.7	22.4	96	77	78.6	9.0
12-02-99 to 18-02-99	31.6	23.1	95	62	0.0	9.6
19-02-99 to 25-02-99	31.8	23.0	95	72	0.0	7.5
26-02-99 to 04-03-99	32.2	23.0	94	68	0.0	9.7
05-03-99 to 11-03-99	32.2	23.2	92	64	0.0	9.2
12-03-99 to 18-03-99	32.7	24.4	92	71	56.0	8.4
19-03-99 to 25-03-99	32.8	25.6	94	68	0.0	9.0
02-04-99 to 08-04-99	32.7	25.4	94	68	0.0	8.5
09-04-99 to 15-04-99	32.2	24.5	88	72	10.2	6.2
16-04-99 to 22-04-99	32.3	25.4	90	75	14.0	8.4
23-04-99 to 29-04-99	31.4	25.4	92	75	16.4	4.8
30-04-99 to 06-05-99	29.3	24.0	95	81	115.0	5.5
07-05-99 to 13-05-99	31.8	25.5	89	78	0.8	7.5
14-05-99 to 20-05-99	31.2	24.1	92	72	44.0	5.9
21-05-99 to 27-05-99	30.6	23.7	90	83	172.4	5.9
28-05-99 to 03-06-99	29.4	23.3	97	82	122.6	4.8

APPENDIX IV

Weather Parameters
Alappuzha District

Period	Temperature °C		Relative humidity		Total rain fall (mm)	Sun-shine hours
	Maximum	Minimum	Morning	Evening		
01-01-99 to 07-01-99	32.3	21.0	91	54	-	6.7
08-01-99 to 14-01-99	33.0	20.6	95	52	3.4	9.0
15-01-99 to 21-01-99	33.8	19.7	93	47	-	10.0
22-01-99 to 28-01-99	32.4	18.6	92	47	-	7.3
29-02-99 to 04-02-99	32.5	21.5	95	56	-	8.3
05-02-99 to 11-02-99	33.4	22.2	94	56	2.6	8.9
12-02-99 to 18-02-99	34.3	21.9	94	49	-	9.6
19-02-99 to 25-02-99	35.0	21.5	91	45	-	7.4
26-02-99 to 04-03-99	35.0	22.2	93	50	-	9.9
05-03-99 to 11-03-99	33.6	23.1	95	60	21.0	9.7
12-03-99 to 18-03-99	33.5	23.8	95	63	31.0	8.8
19-03-99 to 25-03-99	33.5	24.1	96	63	2.1	9.0
02-04-99 to 08-04-99	33.9	24.5	95	61	1.2	8.0
09-04-99 to 15-04-99	33.4	23.5	91	63	5.8	7.5
16-04-99 to 22-04-99	33.0	23.3	94	64	74.6	7.2
23-04-99 to 29-04-99	31.9	23.9	96	71	23.8	5.0
30-04-99 to 06-05-99	30.3	23.4	96	84	216.7	3.3
07-05-99 to 13-05-99	32.5	24.5	96	68	41.6	6.2
14-05-99 to 20-05-99	31.6	23.7	94	70	58.2	6.2
21-05-99 to 27-05-99	30.6	23.9	96	79	74.6	5.6
28-05-99 to 03-06-99	29.7	23.4	95	82	132.5	2.2

APPENDIX V

Weather Parameters
Palakkad District

Period	Temperature °C		Relative humidity		Total rain fall (mm)	Sun-shine hours
	Maximum	Minimum	Morning	Evening		
01-01-99 to 07-01-99	31.7	20.5	80	44	-	9.3
08-01-99 to 14-01-99	32.6	19.7	85	42	-	9.0
15-01-99 to 21-01-99	32.8	21.1	75	40	-	9.6
22-01-99 to 28-01-99	33.0	17.7	87	35	-	7.4
29-02-99 to 04-02-99	33.9	20.5	91	40	-	9.5
05-02-99 to 11-02-99	34.5	22.3	89	41	8.4	8.9
12-02-99 to 18-02-99	35.5	21.7	85	31	-	9.3
19-02-99 to 25-02-99	34.8	21.8	73	28	-	6.9
26-02-99 to 04-03-99	36.7	19.7	87	21	-	9.9
05-03-99 to 11-03-99	36.6	22.6	89	34	-	9.2
12-03-99 to 18-03-99	36.0	24.2	89	45	0.4	8.3
19-03-99 to 25-03-99	35.5	23.9	89	49	-	7.9
02-04-99 to 08-04-99	35.4	24.4	88	50	-	7.7
09-04-99 to 15-04-99	35.0	24.1	89	49	7.4	7.9
16-04-99 to 22-04-99	33.8	23.9	90	54	22.2	7.8
23-04-99 to 29-04-99	33.4	25.7	85	57	0.8	5.6
30-04-99 to 06-05-99	33.0	24.8	88	54	7.4	4.6
07-05-99 to 13-05-99	34.4	24.9	87	53	33.7	7.8
14-05-99 to 20-05-99	31.3	23.4	89	69	59.8	6.4
21-05-99 to 27-05-99	30.8	24.0	92	70	39.3	4.8
28-05-99 to 03-06-99	28.8	23.1	95	83	259.3	2.3

ABSTRACT

The research on "Integrated Pest Management in grain and vegetable cowpea, *Vigna unguiculata* (L.) Walp." was carried out in the college of Agriculture, Vellayani and Onattukara Regional Agricultural Research Station, Kayamkulam to evolve a suitable integrated management strategy against the major pests attacking grain cowpea.

A survey was conducted to monitor the incidence of major pests of cowpea, their associated natural enemies and the plant protection measures adopted among the 90 farmers in the three major grain cowpea growing areas *viz.* Thiruvananthapuram, Alappuzha and Palakkad districts. The major pests recorded in the survey were *Aphis craccivora Koch. Ophiomyia phaseoli* Tryon and *Liriomyza trifolii* Burgess at 20-25 DAS and Pod borers, Pod bugs and *A. craccivora* at 55-60 DAS. Among the natural enemies observed, *Coccinella transversalis* F. was the predominant one in Palakkad district, whereas *Menochilus sexmaculatus* F. and *Micraspis* sp. dominated in Alappuzha and Thiruvananthapuram districts.

The peak population of *A. craccivora* and percentage infestation by pod borers were observed at peak flowering and pod formation stage (59 DAS), whereas the pod bug population was maximum at pod maturity stage (68 DAS).

The population of predators was also observed to be maximum at 59 DAS. The *A. craccivora* population and the percentage of pod borer damage were higher in the unprotected cowpea fields compared to that in the nearby farmer's fields. A similar trend was observed in the case of predators also.

The plant protection measures were adopted by 82.2 and 74.1 percent of the farmers at 20-25 DAS and 55-60 DAS, respectively. Synthetic insecticides were used by majority of the farmers, of which the organophosphates took the major share. Most of the farmers used contact insecticides rather than systemic, at both the stages of the survey. Majority of the farmers used the recommended dose of insecticides while the volume of spray fluid used was below the recommended one. Most of the cowpea growing farmers in Thiruvananthapuram district gained information on plant protection measures through mass media and neighboring farmers, whereas in Alappuzha and Palakkad districts the main source of information was from the Scientist/University and seminars, respectively.

Among the major predators, coccinellids were found to be the most efficient one since both the grubs and adults were predaceous in nature and present in cowpea fields in all the seasons. The maximum feeding potential was observed for *C. transversalis* with a mean total consumption of 251.8±6.74 and 914±50.28 *A. craccivora* by a single grub and adult, respectively.

In the study on the predatory behaviour of coccinellids revealed that the searching speed and turning rate were found to be increasing with increase in prey density. The turning rate increased with increase in hunger level, but searching speed decreased with increase in hunger level. The first and second instar grubs remained on the undersurface of cowpea leaves while the third and fourth instar moved towards the terminal shoot. The first instar grubs were cannibalistic on their own unfertile eggs, the second instar fed on the nymphs of aphids and third and fourth instar fed voraciously on adult and nymphs of aphids. Adult females were more efficient than males in recognizing, attacking and consuming aphids.

The bioassay using bio rational insecticides indicated that neem oil was having the highest LC_{50} value (least toxicity) and safety index to both the third instar grubs and adults of *C. transversalis* and *M. sexmaculatus*, followed by Nimbecidine. Among the synthetic insecticides, chlorpyriphos was having the highest safety index on the third instar grubs and adults of *C. transversalis* and *M. sexmaculatus*.

From the pest management trial conducted for two seasons (January to May 2000 and 2001), two treatments *viz.,* neem kernel suspension 5% + mechanical + cultural control and chlorpyriphos 0.05% + mechanical + cultural control were found to be the promising ones in terms of their effectiveness against major pests, safety to natural enemies, highest per hectare yield, highest marginal benefit: cost ratio and the very low level of terminal residues (below MRL).

Evaluation studies in storage also indicated no damage in the grains obtained from the treatments received chlorpyriphos 0.05% followed by NKS 5% up to five months of storage. No significant variation in weight loss was observed among the various treatments.

The technologies emerged superior in various experiments along with the already proven techniques was tested in farmers' fields in 3 locations through their participation, in comparison with farmers practice to work out an IPM strategy.

The mean population and extent of damage by all the pests in IPM plots were significantly low compared to farmer's practices. The population of natural enemies though not significant, in all the stages, was high compared to those in farmer's practices. The IPM treatments were superior in terms of yield and benefit: cost ratio also.

Thus, an IPM strategy against major pests of cowpea could be developed as

- Burning of trash before sowing
- Selecting healthy seeds
- Soil drenching with Bordeaux mixture 1% wherever fungal disease is prevalent
- Clean cultivation
- Treating the seeds with rhizobium culture @ 250-375 g ha^{-1} before sowing
- Monitoring the fields for incidence of pests / population of natural enemies especially at 52-59 DAS for *A. craccivora,* epilachna beetles and pod borers and 60- 68 DAS for pod bugs.

- Adopt mechanical methods of pest control such as application of dry leaf ash at 10 DAS, keeping yellow sticky trap / yellow pan tray and collection and destruction of infested leaves, flower buds and pods and sweeping and destruction of the pests.
- Collection and release of potential natural enemies *viz*., grubs and adults of *C. transversalis*, *M. sexmaculatus Harmonia octomaculata and maggots of I. scutellare*
- Need based application of *Fusarium pallidoroseum* @7x 10^6 spores ml^{-1} specifically for the management of *A. craccivora*
- Need based application of neem kernel suspension (NKS) 5% or chlorpyriphos 0.05% during 45 DAS in the case of moderate incidence of *A. craccivora, epilachna* beetles and pod borers and a second spray using NKS 5% at 60 DAS if needed against pod borers and pod bugs