POPULATION DYNAMICS AND MANAGEMENT OF APHIDS IN VEGETABLE ECOSYSTEM

D. THAMILVEL

Thesis submitted in partial fulfilment of the requirement for the degree of

Doctor of Philosophy in Agriculture

Faculty of Agriculture
Kerala Agricultural University, Thrissur

2009

Department of Agricultural Entomology
COLLEGE OF AGRICULTURE
VELLAYANI, THIRUVANANTHAPURAM 695 522

ii

DECLARATION

I hereby declare that this thesis entitled "**Population dynamics and management of aphids in vegetable ecosystem**" 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 of any degree, diploma, associateship, fellowship or other similar title, of any other university or society.

Vellayani,

9-12-2009

9/12/09

D. THAMILVEL
(2005-21-106)

CERTIFICATE

Certified that this thesis entitled "**Population dynamics and management of aphids in vegetable ecosystem**" is a record of research work done independently by Mr. D. Thamilvel (2005-21-106) under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to him.

Vellayani,
9-12-2009

Dr. Hebsy Bai
(Chairperson, Advisory Committee)
Professor,
Department of Agricultural Entomology,
College of Agriculture, Vellayani,
Thiruvananthapuram – 695 522

Approved by

Chairperson :

Dr. HEBSY BAI
Professor,
Department of Agricultural Entomology,
College of Agriculture, Vellayani,
Thiruvananthapuram-695 522.

Members :

Dr. M. S. SHEELA
Professor and Head,
Department of Agricultural Entomology,
College of Agriculture, Vellayani,
Thiruvananthapuram-695 522.

Dr. S. NASEEMA BEEVI
Professor,
Department of Agricultural Entomology,
College of Agriculture, Vellayani,
Thiruvananthapuram-695 522.

Dr. VIJAYARAGHAVA KUMAR
Professor and Head,
Department of Agricultural Statistics,
College of Agriculture, Vellayani,
Thiruvananthapuram-695 522.

Dr. D. GEETHA
Professor,
Department of Plant Pathology,
College of Agriculture, Vellayani,
Thiruvananthapuram-695 522.

EXTERNAL EXAMINER :

Dr. S. MANISEGARAN
Professor,
Department of Agricultural Entomology,
Agricultural College and Research Institute,
Madurai-625 104

ACKNOWLEDGEMENT

There is paucity of research investigations in the life of people and plants. I have made a very small and humble attempt to reduce a fraction of it. Could I do it all by myself! The answer is big 'No' for everything needs to be guided in this world. So is my case.

With ineffable gratitude, I wish to express my heartfelt feelings and sincere thanks to **Dr. Hebsy Bai**, Professor, Chairperson of my Advisory Committee for her inestimable and meticulous guidance, sustained interest, constant encouragement, pragmatic views, constructive ideas, continuous help, enthusiasm and critical suggestions shown throughout the entire course of my research work.

I am grateful to **Dr. M. S. Sheela**, Professor and Head, Department of Agricultural Entomology and member of my Advisory Committee for her valuable suggestions, technical advice and wholehearted approach during the investigation.

I owe my immense gratitude with pleasure to **Dr. T. Nalina Kumari**, Professor, Department of Agricultural Entomology and member of my Advisory Committee for her critical suggestions and help during the course of my study.

I express my sincere gratitude to **Dr. S. Naseema Beevi**, Professor, Department of Agricultural Entomology and member of the Advisory committee for the enlightened guidance, keen interest, valuable suggestions and unstinted help extended during the course of my investigation.

I wish to place on record my sincere thanks to **Dr. Vijayaraghava Kumar**, Professor and Head, Department of Agricultural Statistics, and member of the Advisory Committee for his expert advice during the project work and in refining the manuscript.

I express my heartfelt gratitude to **Dr. D. Geetha**, Professor, Department of Plant Pathology and member of the Advisory committee for her inestimable help, encouragement and guidance during my course of study.

I express my sincere gratitude to **Dr. T. Jiji**, Professor, Department of Agricultural Entomology for her enlightened guidance, keen interest, valuable suggestions and unstinted help extended during the course of my investigation.

I am deeply indebted to express my deep sense of gratitude and sincere thanks to **Dr. A. Naseema**, Professor, Department of Plant Pathology who has been providing me valuable suggestions, inestimable help, guidance and also for carrying out the microbial study during the entire course of the study.

I wish to express my heartfelt gratitude to **Dr. K. D. Prathapan**, Assistant Professor, Department of Agricultural Entomology, for his kind help in the identification of the insect specimens.

I convey my heartful thanks to Dr. C. NandaKumar, Dr. J. Arthur Jacob, Dr. N. Anitha, Dr. M.H. Faizal, Dr. K. S. Premila, Dr. K. Sudharma and non teaching staff of the Department of Entomology, for their timely help, constant encouragement and cooperation given during the course of work.

I express my sincere thanks to **Dr. Sunil Joshi**, Scientist, Project Directorate of Biological Control (PDBC), Bangalore, for the identification of the aphids, syrphids and parasitoid specimens and permitting me to use the lab and library and for the valuable guidance. Also, I am deeply indebted to **Dr. J. Poorani**, Scientist, PDBC, Bangalore, for the identification of the coccinellids and neuropteran specimens.

I owe a special thanks to my heartful friends Dr. A. Haridass, Dr. D. Jaganathan (ARS), Dr. D. Vijayababu, T. Ramalingam (IRS), Sathiasudaram

(IPS) and Parimalarangan for their moral support and companionship during the entire course of the study.

I convey my heartful thanks to Mr. K. Ramalingam, Joint Director of Agriculture, Villupuram and Mr. K. Rajasekar, Assistant Director of Agriculture, Vikravandi for their timely help and moral support.

I feel happy to express my immense thanks to my friends Dr. Jithesh, Dr. Madhu Kumar, Siju simon, Ratheesh, Suresh, Udaya Kumar, Srikant, Vimarsh, Kumaran, Kumannan, Selvaraju, Pradeep, Suriya, Binu, Anjana, George and Shahid for their constant help and support during various stages of my course programme.

I am grateful to Kerala Agricultural University granting me the Senior Research Fellowship for the doctorate programme.

My heartful thanks to my brothers Shanmugavel, Vengaimarban, Vetriselvan and sister Iswariya for their kind affection, timely persuation and inner hearted support.

Above all, I bow my head before God "Sriyaandavar" without whose grace and blessings this study would have been impossible.

D. Thamilvel

CONTENTS

LIST OF TABLES

LIST OF TABLES CONTINUED

LIST OF TABLES CONTINUED

LIST OF TABLES CONTINUED

LIST OF TABLES CONTINUED

LIST OF FIGURES

LIST OF PLATES

LIST OF PLATES CONTINUED

LIST OF ABBREVIATIONS

%	Per cent
/m^2	Per square metre
@	At the rate of
a.i	Active ingredient
CD	Critical difference
cm	Centimetre(s)
DAS	Days after sowing
DAT	Days after treatment
EC	Emulsifiable concentrate
et al.	And others
Fig.	Figure
g	Gram
h	Hour
ha^{-1}	Per hectare
HAS	Hours after spraying
kg	Kilogram
m	Metre
ml	Millilitre
mm	Millimetre
ORE	Order of relative efficacy
PTI	Persistent toxicity index
SC	Suspension concentrate
SL	Soluble concentrate
spp.	Species
viz.	Namely
WG	Water dispersible granule
WS	Water dispersible powder for slurry treatment
WSC	Water soluble concentrate
WDP	Water dispersible powder

Dedicated to

My Ever Loving Appa, Amma,

Brothers and Sister

Introduction

1. INTRODUCTION

Aphids, "the little blighters that suck the life out of plants" are the recent bane of vegetable growers. With their parthenogenetic and sexual generations, paedogenesis, polymorphism, polyphenism and obligate shifting between unrelated host-plant taxa, they are the most fascinating group of phytophagous insects. They are related to Adelgids and Phylloxerids, all of which probably evolved about 280 million years ago. Presently, around 4700 aphid species are known world over, 10 per cent of which are pests. However, only 250 species are reckoned as serious pests of crops (Emden and Harrington, 2007). The aphid fauna of India and adjacent countries constitute about 16 per cent of the world fauna (Joshi, 2005). The species, *Aphis gossypii* Glover, *Aphis craccivora* Koch, *Aphis spiraecola* Patch, *Lipaphis erysimi* (Kaltenbach), *Macrosiphum euhorbiae* (Kaltenbach), *Myzus persicae* (Sulzer), *Brevicoryne brassicae* Linn., *Aphis rumicis* L. *Macrosiphum pisi* K., and *Myzus ornatus* L. are reported to cause economic damage to vegetables (Nair, 1999 and Kumar et al., 2004).

Aphid feeding on plants results in the depletion of nutritional resources, leading to substantial yield loss. Seed setting too is reduced to a large extent (Blackman and Eastop, 2000). Infestation by the pea aphid, *A. craccivora* is estimated to cause an yield loss of 20 to 40 per cent in cowpea in Asia (Singh and Allen, 1980) whereas *L. erysimi* causes up to 96 per cent in crucifers (Bakhetia, 1989). Apart from the direct damage, the homopteran is involved in disease transmission in plants. Around 247 viral diseases have been listed (Kennedy et al., 1962) among which, 164 are stated to be transmitted by nearly 200 species of aphids (Singh, 2000). Being the primary vectors of most plant viruses, any factor that increases aphid abundance is likely to increase the spread of the virus and the potential for a virus epidemic (Jeger et al., 2004). Though many species infest vegetables, only *A. gossypii*, *A. craccivora*, *M. persicae* (Nair, 1995) and *A. spiraecola* (Vijayasree, 2006) have been recorded from the major vegetables in Kerala. Recently, other species too were observed on several vegetables and certain weeds in the vegetable fields in the State. Obviously, a consolidated account of the detrimental species and their alternate hosts is required for visualizing the magnitude of aphid problem in vegetable ecosystem.

An assortment of factors influences the demographic parameters of aphids. Climatic conditions play a significant role in their population dynamics. Changes in weather affect the abundance of aphids dramatically (Trumble et al., 1983; Maiti et al., 1989). Density dependant forces too have been implicated in the regulation of the pest within and between years (Sequeira and Dixon, 1997). Intraspecific competition on crowded plants resulted in high mortality, low reproductive success and increased rate of dispersal among aphids (Dixon, 1998). Natural enemies too play a vital role in the regulation of aphid population. Hence, identification of the bioagents of the different aphid species is crucial for their effective utilization.

Despite a range of options available, insecticides still form the first line of defense in the strategies adopted by farmers to tackle pests. Overuse and misuse of highly toxic, persistent and broad-spectrum insecticides at short intervals are common practices among vegetable growers. Notwithstanding, frequent harvesting is done to obtain tender marketable fruits which contain insecticide residues over and above the tolerance limits, exposing the consumer to unwarranted health hazards. Moreover, unscrupulous pesticide application causes pest flare ups due to development of insecticide resistance in pests, resurgence of the target pest and secondary pest out breaks, leading to crop failure. Consequently, there is an urgent need to identify safer and effective insecticides for the control of the pest. The eco friendly botanicals and the newer synthetic molecules with their different modes of action, low dose requirement, less mammalian toxicity and good environmental characteristics have the potential to manage pests sustainably.

The present study was undertaken to address the above-mentioned gaps in the knowledge on the aphids and their management in vegetable ecosystem with the following objectives

(i) To document the aphids infesting vegetables.

(ii) To identify their natural enemies and alternate hosts

(iii) To study the population dynamics of the major aphid pests of vegetables

(iv) To evaluate the efficacy of botanicals and newer molecules of synthetic insecticides in controlling the pest and to assess their effect on non target organisms

Review of literature

2. REVIEW OF LITERATURE

The aphids infesting vegetables, their natural enemies and attendant ant species, the population dynamics of the two dominant aphid pests of vegetables identified viz., *A. gossypii* and *A. craccivora* and the effect of botanicals and newer molecules of synthetic insecticides on the pest and other non target organisms were explored in the present investigation. Information on aphids being exhaustive, only the literature relatable to the investigations is reviewed briefly.

2.1 APHIDS INFESTING VEGETABLES

Globally, 4703 aphid species had been reported (Remaudière and Remaudière, 1997) of which, 1015 species occurred in the Oriental region (Agarwala and Ghosh, 1984). Around 653 species belonging to 208 genera were recorded from India (Ghosh and Singh, 2000). Among the species documented, 250 were serious pests of crops world over (Emden and Harrington, 2007). Forty five species were commonly encountered as pests of economically important plants in the tropics (Martin, 1983) of which approximately 20 species were seen to infest different vegetables (Nasir and Yousuf, 1995; Bambaradeniya, 2006). Several species of aphids infesting vegetables were recorded from India too. Since aphids and their natural enemies vary from place to place depending on the type of crop, climate and topography, only literature relevant to the species identified in the study is reviewed herein.

2.1.1 Aphid Species

Aphis gossypii **Glover**

Distribution: World: World-wide, particularly abundant and well distributed in the tropics, including many Pacific islands.

India: Throughout India (Ayyar, 1940; David 1956; 1958a, 1958b; Deshpande, 1937; George, 1927; Krishnamurti, 1928)
Season: Throughout the year but more prevalent in July to September (Joshi, 2005).

Aphis craccivora **Koch**
Distribution: World: World-wide; well distributed throughout the tropics,
India: All over India (Ayyar, 1940; David 1956; 1958a, 1958b; Deshpande, 1937; George, 1927; Krishnamurti, 1950)
Season: Throughout the year on different host plants (Joshi, 2005).

Aphis spiraecola **Patch**
Distribution: World: North America, Mediterranean region, Africa and Australia
India: All over India (Singh and Rao, 1978; Lyla and Joy, 1987)
Season: Throughout the year

Lipaphis erysimi **(Kaltenbach)**
Distribution: World-wide
India: Throughout north and in south India from Tamil Nadu, Maharashtra, Karnataka and Andhra Pradesh (David, 1958a; Deshpande, 1937; Krishnamurti, 1928).
Season: Throughout the year but more prevalent in December to February (Joshi, 2005).

Myzus persicae **(Sulzer)**
Distribution: World: World-wide.
India: All over India (Raychaudhuri et al. 1981: Ayyar, 1940; David 1956; 1958a, 1958b; Deshpande, 1937; George, 1927; Krishnamurti, 1928).
Season: All through the year with heavy infestation in winter and early summer (Joshi, 2005).

Aphis nerii **Boyer de Fonscolombe**

Distribution: World: Widely distributed through the Old and New World tropics and subtropics including many Pacific islands (Joshi, 2005).

India: Throughout north and in south India. It has been recorded from Tamil Nadu, Maharashtra, Karnataka and Andhra Pradesh (David, 1958a; Deshpande, 1937; Krishnamurti, 1928).

Aphis fabae **Scopoli**

Distribution: World: Wide spread in temperate regions of the northern hemisphere, south America and Africa, not common in the hotter parts of the tropics and the Middle East (Joshi, 2005).

India: Through out India (Ayyar, 1940; David 1958a, Joy et al., 1983).

Season: January to March and post-rainy season (July-August)

Hysteroneura setariae **(Thomas)**

Distribution: World: Australia, South Africa, Japan, Korea, Phillippines and Taiwan

India: All over India. In south India recorded from Madurai, Anantapur, Coonoor, Madras, Tambaram, Tindivanam, Coimbatore and Bangalore (David, 1967 and Gadiyappanavar, 1970).

Season: June to September (Joshi, 2005).

2.1.2 Host Plants

Most aphids are monophagous. However, on agricultural crops some species tend to have a wider host range. While *L. erysimi* mostly infested cruciferous plants and *A. fabae* on leguminous plants (Singh, 2004), *A. gossypii* and *M.persicae* developed on 400 and 270 species of plants, respectively (Raychaudhuri, 1980; Chakrabarti and Sarkar, 2001). Though, twenty five per cent of all plant species are infested with aphids, not all groups of plants are equally parasitised. The Compositae (605 species) followed by Coniferae (363 species) and Rosaceae (293) species of plants supported most aphid species. The richness and diversity of aphid fauna in diverse flora in India had been documented (Raychaudhuri, 1983 and Chakrabarti and Sankar ,2001)). The important vegetables and other host plants pertaining to the aphids documented in the study are given in Table 1.

2.1.3 Natural Enemies

All insect populations are regulated to a certain extent by natural enemies in nature. Information on the potential ones would form the basis for assessing pest population density and predicting outbreaks.

Coccinellids

Coccinellids are the most common predators of aphids and are well known world over. Puttarudriah and Channa Basavanna (1952, 1953, 1955, 1956 and1958) and Agarwala et al. (1980, 1981, and 1983) contributed greatly to the records of aphidophagous species in India. Thirty six species of aphidophagous coccinellids were listed from different regions of the country (Agarwala and Ghosh, 1988). The coccinellid species recorded on different aphid hosts in India are presented in Table 2.

Syrphids

The syrphids are a very important predatory group of insects from the economic point of view. Syrphid larvae feed exclusively on aphids and a single larva could destroy about 484 aphids in four hours (Deoras, 1942). Above 67 species of syrphids were reported to prevail in India (Lefroy, 1909). Aphidophagous syrphids played an important role in the suppression of many aphid hosts of economic importance (Verma, 2003). The syrphid species recorded on different aphid hosts from different states in India are depicted in Table 3.

Table 1. Vegetables and other host plants of aphids recorded from South India

Host plant	Family	Reference
Aphis gossypii Glover		
Vegetables		
Abelmoschus esculentus Moench	Malvaceae	George (1927); Nair (1995); Joshi (2005)
Benincasa hispida Cogn.	Cucurbitaceae	George (1927); Ayyar (1940)
Capsicum annum Linn.	Solanaceae	David (1958b); Nair (1995)
Capsicum frutescens Linn.	Solanaceae	David (1958b); Nair (1995)
Cucurbita maxima Wall.	Cucurbitaceae	David (1958b); Joshi (2005)
Lagenaria vulgaris Ser.	Cucurbitaceae	David (1958b); Nair (1995)
Luffa cylindrica (Linn.)M. Roem.	Cucurbitaceae	David (1958b); Nair (1995)
Lycopersicon esculentum P. Miller	Solanaceae	Krishnamurti (1928); Joshi (2005)
Momordica charantia Descourt	Cucurbitaceae	Krishnamurti (1928); Joshi (2005)
Solanum melongena Linn.	Solanaceae	David (1958b); Joshi (2005)
Other host plants		
Aralia sp.	Araliaceae	Joshi (2005)
Basella rubra Linn.	Chenopodiaceae	Joshi (2005)
Cajanus cajan (Linn.) Millsp.	Fabaceae	Nair (1995); Joshi (2005)
Carum copticum Benth. & Hook.	Apiaceae	Joshi (2005)
Catharanthus pusillus G. Don.	Apocynaceae	Joshi (2005)
Catharanthus roseus (Linn.) G. Don.	Apocynaceae	Rani and Sridhar (2005)
Chrysanthemum sp	Asteraceae	Krishnamurti (1928); Joshi (2005)
Colocasia esculenta Schott	Araceae	Joshi (2005)
Coriandrum sativum Linn.	Apiaceae	Joshi (2005)
Cuminum sativum Linn.	Apiaceae	David (1958b); Joshi (2005)
Eucalyptus sp.	Myrtaceae	Joshi (2005)
Ficus bengalensis Linn.	Moraceae	Krishnamurti (1928)
Ficus religiosa Forsk.	Moraceae	Krishnamurti (1928)
Gossypium herbaceum Linn.	Malvaceae	Krishnamurti (1928); Joshi (2005)
Gossypium hirsutum Linn.	Malvaceae	Krishnamurti (1928); Joshi (2005)
Helianthus annuus Linn.	Asteraceae	Nair (1995); Joshi (2005)
Hibiscus cannabinus Linn.	Malvaceae	Krishnamurti (1928); Joshi (2005)
Hibiscus rosa-sinensis Linn.	Malvaceae	Krishnamurti (1928); Joshi (2005)
Kalanchoe serrata Mann. & Boit.	Crassulaceae	Joshi (2005)
Lagerstroemia sp.	Lythraceae	David (1958b); Nair (1995)
Lawsonia alba Lam.	Lythraceae	David (1958b); Nair (1995)
Mangifera indica Linn.	Anacardiaceae	Krishnamurti (1928); Joshi (2005)
Medicago sativa Linn.	Fabaceae	Krishnamurti (1928); Joshi (2005)
Nyctanthes arbortristis Linn.	Oleaceae	Joshi (2005)
Nerium sp.	Apocynaceae	Raychaudhuri et al. (1981)
Polyalthia longifolia Benth. & Hook	Annonaceae	Ghosh (1974)
Psidium guajava Linn.	Myrtaceae	Krishnamurti (1928) ; Joshi (2005)
Rosa sp.	Rosaceae	Ghosh (1974); Nair (1995); Joshi (2005)
Solanum tuberosum Linn.	Solanaceae	David (1958b); Joshi (2005)
Spathodea campanulata P. Beauv.	Bignoneaceae	Joshi (2005)
Tagetes erecta Linn.	Asteraceae	Nair (1995); Joshi (2005)
Tectona grandis Linn.	Verbanaceae	Raychaudhuri et al. (1981); Joshi (2005)
Vicia faba Linn.	Fabaceae	David (1958); Nair (1995); Joshi (2005)
Abutilon indicum Linn.	Malvaceae	David (1958b); Nair (1995)

Table 1. Continued

Aphid species / Host plant	Family	Reference
Acalypha hispida Brum. f.	Euphorbiaceae	Krishnamurti (1928); Joshi (2005)
Ageratum conyzoides Linn.	Asteraceae	Raychaudhuri et al. (1981); Joshi (2005)
Amaranthus viridis Linn.	Amaranthaceae	Nair (1995); Joshi (2005)
Bidens pilosa Linn.	Asteraceae	Raychaudhuri et al. (1981); Nair (1995)
Calotropis procera (Aiton) W.T.Aiton	Asclepiadaceae	Raychaudhuri et al.(1981); Joshi (2005)
Cestrum nocturnum Linn.	Solanaceae	Nair (1995); Joshi (2005)
Chromolaena odorata (L.) King & Robs.	Asteraceae	David (1958b); Joshi (2005)
Clerodendron inerme Gaertn.	Verbanaceae	Joshi (2005)
Clerodendron viscosum Linn.	Verbanaceae	Joshi (2005)
Cuscuta sp.	Convolvulaceae	Joshi (2005)
Lantana camara Linn.	Verbanaceae	Raychaudhuri et al. (1981)
Mikania micrantha (Linn.) Kunth	Asteraceae	Joshi (2005)
Ocimum sanctum Linn.	Lamiaceae	Ghosh (1974)
Parthenium hysterophorus Linn.	Asteraceae	Nair (1995); Joshi (2005)
Solanum nigrum Linn.	Solanaceae	David (1958b); Joshi (2005)
Tridax procumbens Linn.	Asteraceae	Raychaudhuri et al. (1981); Nair (1995)
Aphis craccivora Koch		
Vegetables		
Abelmoschus esculentus Moench	Malvaceae	George (1927); Joshi (2005)
Benincasa hispida Cogn.	Cucurbitaceae	George (1927); Ayyar (1940)
Cucurbita maxima Wall.	Cucurbitaceae	Krishnamurti (1928); Joshi (2005)
Dolichos lablab Linn.	Fabaceae	Nair (1995); Joshi (2005)
Lagenaria vulgaris Ser.	Cucurbitaceae	David (1958b); Nair (1995)
Luffa cylindrica (Linn.)M. Roem.	Cucurbitaceae	Raychaudhuri et al. (1981); Joshi (2005)
Lycopersicon esculentum P. Miller	Solanaceae	Raychaudhuri et al. (1981); Joshi (2005)
Moringa oleifera Lam.	Fabaceae	Nair (1995); Joshi (2005)
Sesbania grandiflora Pers.	Fabaceae	George (1927); Krishnamurti (1928)
Solanum melongena Linn.	Solanaceae	David (1958b); Nair (1995); Joshi (2005)
Vigna unguiculata (L.) Walp.	Fabaceae	Raychaudhuri et al. (1981); Joshi (2005)
Other host plants		
Abrus sp.	Fabaceae	Joshi (2005)
Arachis hypogaea Willd.	Fabaceae	George (1927); Joshi (2005)
Asparagus mauritianus Lam.	Liliaceae	Ayyar (1940); Joshi (2005)
Bougaivillea spectabilis Willd.	Nyctaginaceae	George (1927); Krishnamurti (1928)
Cajanus cajan (Linn.) Millsp	Fabaceae	George (1927); Joshi (2005)
Calanthe sylvatica (Thou.) Lindl.	Orchidiaceae	Joshi (2005)
Carica papaya Linn.	Caricaceae	George (1927); Joshi (2005)
Cassia fistula Linn.	Fabaceae	Joshi (2005)
Cicer arietinum Linn.	Fabaceae	Nair (1995); Joshi (2005)
Crotalaria juncea Linn.	Fabaceae	Krishnamurti (1928); Joshi (2005)
Cyamopsis psoralioides DC.	Fabaceae	Ayyar (1940) Nair (1995); Joshi (2005)
Dalbergia sissoo Roxb.	Fabaceae	Nair (1995); Joshi (2005)
Gliricidia maculata (Jacq.) Kunth	Fabaceae	Nair (1995); Joshi (2005)
Glycine max Merrill.	Fabaceae	Raychaudhuri et al. (1981); Joshi (2005)
Helianthus annuus Linn.	Asteraceae	Raychaudhuri et al. (1981); Joshi (2005)
Hibiscus rosa-sinensis Linn.	Malvaceae	Raychaudhuri et al. (1981); Joshi (2005)
Jasminum sp.	Oleaceae	Krishnamurti (1928); Joshi (2005)

Table 1. Continued

Aphid species / Host plant	Family	Reference
Lathyrus sativus Linn.	Fabaceae	Raychaudhuri et al. (1981); Joshi (2005)
Lens culinaris Medic.	Fabaceae	Raychaudhuri et al. (1981); Joshi (2005)
Medicago sativa Linn.	Fabaceae	Raychaudhuri et al. (1981); Joshi (2005)
Mussaenda sp.	Rubiaceae	Joshi (2005)
Mucuna pruriens (L.)DC	Fabaceae	Rani and Sridhar (2005)
Ocimum sanctum Linn.	Lamiaceae	Joshi (2005)
Phaseolus mungo Linn.	Fabaceae	Raychaudhuri et al. (1981); Joshi (2005)
Phaseolus sinensis Hort.ex Schur	Fabaceae	Raychaudhuri et al. (1981); Joshi (2005)
Pisum sativum Linn.	Fabaceae	Krishnamurti (1928); Joshi (2005)
Sesbania speciosa (Soland.Ex Seem.)	Fabaceae	Raychaudhuri et al. (1981); Joshi (2005)
Tagetes erecta Linn.	Asteraceae	David (1958b); Nair (1995)
Trigonella sp.	Fabaceae	David (1958b); Nair (1995)
Vicia faba	Fabaceae	Krishnamurti (1928); Joshi (2005)
Ageratum conyzoides Linn.	Asteraceae	Krishnamurti (1928); Joshi (2005)
Amaranthus viridis Linn.	Amaranthaceae	Nair (1995); Joshi (2005)
Crotalaria mucronata Desvaux	Fabaceae	Raychaudhuri et al. (1981); Joshi (2005)
Cuscuta sp.	Convolvulaceae	Joshi (2005)
Ipomoea sp.	Convolvulaceae	Raychaudhuri et al. (1981)
Mimosa pudica Mill.	Fabaceae	Ayyar (1940) Nair (1995); Joshi (2005)
Saraca indica Linn.	Fabaceae	Ayyar (1940); Joshi (2005)
Solanum nigrum Linn.	Solanaceae	Raychaudhuri et al. (1981); Nair (1995)
Sonchus sp.	Asteraceae	David (1958b); Joshi (2005)
Tephrosia purpurea Pers.	Fabaceae	Raychaudhuri et al. (1981); Nair (1995)
Aphis spiraecola **Patch**		
Vegetables		
Coccinia grandis (L.) Voigt.	Cucurbitaceae	Vijayasree (2006)
Solanum melongena Wall	Solanaceae	Raychaudhuri et al. (1981); Joshi (2005)
Other host plants		
Ageratum conyzoides Linn.	Asteraceae	Lyla and Joy (1987) ; Joshi (2005)
Aralia sp.	Araliaceae	Joshi (2005)
Aster sp.	Asteraceae	Joshi (2005)
Bidens pilosa Linn.	Asteraceae	Singh and Rao (1978); Joshi (2005)
Bauhinia sp.	Fabaceae	Raychaudhuri et al. (1981)
Bridelia sp.	Euphorbiaceae	Raychaudhuri et al. (1981)
Bougauinvillea spectabilis Willd.	Nyctaginaceae	Singh and Rao (1978);
Cajanus cajan (Linn.) Millsp.	Fabaceae	Singh and Rao (1978) ; Joshi (2005)
Cestrum diurnum H.B. & K.	Solanaceae	Joshi (2005)
Chromolaena odorata (L.) King & Robs.	Asteraceae	Lyla and Joy (1987) ; Joshi (2005)
Citrus sp.	Rutaceae	Singh and Rao (1978); Joshi (2005)
Colocasia sp.	Araceae	Singh and Rao (1978); Joshi (2005)
Dahlia variabilis Desf.	Asteraceae	Joshi (2005)
Ipomoea fistulosa Choisy	Convolvulaceae	Raychaudhuri et al. (1981); Joshi (2005)
Lantana camara Linn.	Verbenaceae	Raychaudhuri et al. (1981); Joshi (2005)
Michelia champaka Linn.	Magnoliaceae	Joshi (2005)
Mikania micrantha (L.) Kunth	Asteraceae	Raychaudhuri et al. (1981); Joshi (2005)
Parthenium hysterophorus Linn.	Asteraceae	Raychaudhuri et al. (1981); Joshi (2005)
Sonchus sp.	Asteraceae	Joshi (2005)
Solanum sp.	Solanaceae	Raychaudhuri et al. (1981)

Table 1. Continued

Aphid species / Host plant	Family	Reference
	Myzus persicae (Sulzer)	
Vegetables		
Beta vulgaris Linn.	Brassicaceae	David (1958ab)
Brassica oleracea Linn. var. *botrytis*	Brassicaceae	David (1958b) Joshi (2005)
Brassica oleracea Linn. var. *capitata*	Brassicaceae	David (1958b) Joshi (2005)
Brassica oleracea Linn. var. *gongyloides*	Brassicaceae	David (1958b) Joshi (2005)
Raphanus sativus Linn.	Brassicaceae	Raychaudhuri et al. (1981)
Solanum melongena Wall.	Solanaceae	Joshi (2005)
Other host plants		
Ageratum conyzoides Linn.	Asteraceae	Deshpande (1937)
Brassica campestris Linn.	Brassicaceae	David (1958b) Joshi (2005)
Brassica juncea (Linn.)	Brassicaceae	David (1958b) Joshi (2005)
Bryophyllum pinnatum (Lam.) Oken	Crassulaceae	Joshi (2005)
Clerodendrum serratum Linn.	Verbenaceae	Joshi (2005)
Emilia sonchifolia (Linn.) DC	Asteraceae	Joshi (2005)
Solanum nigrum Linn.	Solanaceae	Joshi (2005); Rani and Sridhar (2005)
Withania sominifera Linn.	Solanaceae	Rani and Sridhar (2005)
	Lipaphis erysimi **(Kaltenbach)**	
Vegetables		
Brassica oleracea Linn. var. *botrytis*	Brassicaceae	George (1927); Joshi (2005)
Brassica oleracea Linn. var. *capitata*	Brassicaceae	Joshi (2005)
Brassica oleracea Linn. var. *gongyloides*	Brassicaceae	George (1927); Joshi (2005)
Raphanus sativus Linn.	Brassicaceae	Raychaudhuri et al. (1981)
Other host plants		
Brassica campestris Linn.	Brassicaceae	George (1927); Joshi (2005)
Brassica juncea (Linn.)	Brassicaceae	Joshi (2005)
Gynandropsis pentaphylla (L.) DC.	Capparidaceae	Joshi (2005)
	Aphis nerii **Boyer de Fonscolombe**	
Vegetables		
Capsicum annum Linn.	Solanaceae	David (1958b) ; Joshi (2005)
Capsicum frutescens Linn.	Solanaceae	David (1958b); Joshi (2005)
Solanum melongena Linn.	Solanaceae	Krishnamurti (1928) ; Joshi (2005)
Other host plants		
Gymnema sylvestre (Retz.) Schult.	Asclepiadaceae	Rani and Sridhar (2005)
Holostemma annularis Schum.	Asclepiadaceae	David (1958b); Joshi (2005)
Leptadenia reticulata Wight	Asclepiadaceae	Krishnamurti (1928) ; Joshi (2005)
Marsdenia volubilis Cooke	Asclepiadaceae	Deshpande (1937) ; David (1958b)
Nerium sp.	Apocynaceae	David (1958b); Joshi (2005)
Pergularia extensa N.E.Brown	Asclepiadaceae	Deshpande (1937) ; David (1958b)
Tylophora indica Merrill	Asclepiadaceae	David (1958b); Joshi (2005)
Asclepias currasavica Linn.	Asclepiadaceae	Rani and Sridhar (2005)
Asclepias physocarpa Schlechter	Asclepiadaceae	Deshpande (1937) ; David (1958b)
Calotropis gigantea (L.) W.T.Aiton	Asclepiadaceae	Krishnamurti (1928) ; Joshi (2005)
Calotropis procera (L.) W.T.Aiton	Asclepiadaceae	Deshpande (1937) ; David (1958b)

Table 1. Continued

Aphid species / Host plant	Family	Reference
	***Aphis fabae* Scopoli**	
Other host plants		
Alove vera (Linn.) N. L. Burman	Liliaceae	Raychaudhuri et al. (1981); Joshi (2005)
Cestrum nocturnum Linn.	Solanaceae	David (1958b); Nair (1995)
Datura sp.	Solanaceae	Krishnamurti (1928); Joshi (2005)
Solanum nigrum Linn.	Solanaceae	Raychaudhuri et al. (1981); Nair (1995)
Ipomoea fistulosa Mart.ex Choisy	Convolvulaceae	David (1958b); Joshi (2005)
Tagetes erecta Linn.	Asteraceae	Nair (1995); Joshi (2005)
Tecoma stans Griseb.	Bignoneaceae	Joshi (2005)
Vicia faba Linn.	Fabaceae	Joshi (2005)
	***Hysteroneura setariae* (Thomas)**	
Other host plants		
Oryza sativa Linn.	Poaceae	David (1967); Joshi (2005)
Saccharum officinarum Linn.	Poaceae	Raychaudhuri et al. (1981); Joshi (2005)
Sorghum vulgare Pers.	Poaceae	Gadiyappanavar(1970); Joshi (2005)
Zea mays Linn.	Poaceae	Gadiyappanavar(1970); Joshi (2005)
Bothriochloa insculpta (Hochst.)	Poaceae	Gadiyappanavar(1970); Joshi (2005)
Cenchrus setigerus Vahl.	Poaceae	Raychaudhuri et al. (1981); Joshi (2005)
Cymbopogon sp.	Poaceae	Raychaudhuri et al. (1981); Joshi (2005)
Cynodon dactylon (Linn.) Pers.	Poaceae	David (1967); Gadiyappanavar(1970)
Cyperus rotundus Miq.	Cyperaceae	Raychaudhuri et al. (1981)
Cyperus sp	Cyperaceae	Raychaudhuri et al. (1981)
Chloris barbata Sw.	Poaceae	David (1967);Gadiyappanavar(1970)
Chlorophytum sp.	Liliaceae	Raychaudhuri et al. (1981)
Dactyloctenium aegyptium (Desf.) Beauv.	Poaceae	David (1967); Joshi (2005)
Digitaraia longiflora (Retz.) Pers.	Poaceae	Raychaudhuri et al. (1981)
Eleusine corocana (Linn.) Gaertn.	Poaceae	Raychaudhuri et al. (1981)
Eragrostis sp.	Poaceae	David (1967); Gadiyappanavar(1970)
Panicum antidotale Retz.	Poaceae	Gadiyappanavar(1970); Joshi (2005)
Panicum flavidum Retz.	Poaceae	Raychaudhuri et al. (1981); Joshi (2005)
Panicum montanum Gaudich	Poaceae	Raychaudhuri et al. (1981); Joshi (2005)
Pennisetum sp.	Poaceae	Raychaudhuri et al. (1981); Joshi (2005)
Saccharum spontaneum Linn.	Poaceae	Raychaudhuri et al. (1981); Joshi (2005)
Tridax procumbens Linn.	Asteraceae	Raychaudhuri et al. (1981); Joshi (2005)

Table 2. Coccinellid predators associated with aphids in India

Coccinellid species	Aphid prey	References
Brumoides suturalis (Fab.)	*Aphis craccivora*	Behura (1963)
	Aphis gossypii	Kapur (1942)
	Aphis nerii	Nath and Sen (1976)
	Lipaphis erysimi	Rahman and Khan (1941)
	Myzus persicae	Joshi (2005)
	Aphis spiraecola	Agarwala et al.(1980)
	Aphis craccivora	Anard (1984)
	Aphis fabae	Atwal et al. (1971)
	Aphis gossypii	Behura (1963)
	Aphis nerii	Joshi (2005)
	Lipaphis erysimi	Nath and Sen (1976)
	Myzus persicae	Ghosh et al. (1981)
Coccinella transversalis Fab.	*Aphis craccivora*	Suja (2003)
	Aphis gossypii	Behura (1965)
	Lipaphis erysimi	Bose and Ray (1975)
	Myzus persicae	Khan and Hussain (1965)
Coccinella undecimpunctata L.	*Aphis gossypii*	Behura (1963)
	Lipaphis erysimi	Rahman and Khan (1941)
	Myzus ornatus	Agarwala and Ghosh (1988)
Harmonia eucharis (Mulsant)	*Aphis spiraecola*	Ghosh et al. (1981)
	Aphis craccivora	Suja (2003)
	Myzus persicae	Agarwala and Ghosh (1988)
Menochilus sexmaculatus (Fab.)	*Aphis craccivora*	Suja (2003)
	Aphis gossypii	Agarwala and Ghosh (1988)
	Aphis fabae	Agarwala and Ghosh (1988)
	Aphis nerii	Joshi (2005)
	Myzus persicae	Agarwala and Ghosh (1988)
Micraspis discolor (Fab.)	*Aphis craccivora*	Suja (2003)
	Aphis gossypii	Agarwala and Saha (1986)
	Lipaphis erysimi	Ghosh et al. (1981)
Nephus regularis Sicard	*Aphis gossypii*	Behura (1963)
Oenopia kirbyi Mulsant	*Aphis spiraecola*	Agarwala (1983)
	Aphis gossypii	Kotwal et al. (1984)
Pseudoasapidimerus sp.	*Aphis spiraecola*	Behura (1963)
	Aphis craccivora	Johnson (1984)
	Aphis gossypii	Kapur (1948)
	Aphis nerii	Nayak et al. (1981)
Scymnus (Pullus) castaneus (Sicard)	*Aphis gossypii*	Behura (1963)
	Aphis nerii	Behura (1965)
Scymnus (Pullus) guimeti Mulsant	*Aphis gossypii*	Behura (1965)
	Aphis nerii	Behura (1965)
Scymnus (P.) pyrocheilus Mulsant	*Aphis spiraecola*	Ghosh et al. (1981)
	Aphis craccivora	Nayak and Behura (1969)
	Aphis gossypii	Agarwala and Ghosh (1988)
	Lipaphis erysimi	Agarwala and Ghosh (1988)

Table 3. Syrphid predators associated with aphids in India

Syrphid species	Aphid prey	Location	References
Allograpta javana (Wiedemann)	*Aphis craccivora*	Delhi,	Rai (1976)
	Aphis gosssypii	Bangalore	Ghorpade (1973)
Betasyrphus linga Ghorpade	*Aphis craccivora*	Bangalore	Joshi et al.(1999)
Betasyrphus fletcheri Ghorpade	*Aphis craccivora*	Bangalore	Joshi et al.(1999)
Dideopsis aegrota (Fabricius)	*Aphis craccivora*	Bangalore	Joshi et al.(1999)
	Aphis gosssypii	Bangalore	Ghorpade (1973)
Episyrphus balteatus (De Geer)	*Aphis craccivora*	Coimbatore	Rao (1969)
	Aphis fabae	Bangalore	Ghorpade (1973)
	Aphis gosssypii	Bangalore	Ghorpade (1973)
	Lipaphis erysimi	Anand	Patel and Patel (1969)
Ischiodon scutellaris (Fabricius)	*Aphis craccivora*	Trivandrum	Suja (2003)
	Aphis spiraecola	Bangalore	Ghorpade (1973)
	Aphis gosssypii	Anand	Patel and Patel (1969)
	Aphis nerii	Anand	Ghosh (1974)
	Lipaphis erysimi	Kalyani	Roy and Basu (1978)
	Myzus persicae	Anand	Ghosh (1974)
Metasyrphus confrater (Wiedemann)	*Aphis craccivora*	Dehra Dun	Rao (1969)
	Aphis gosssypii	Delhi	Ghosh (1974)
	Lipaphis erysimi	Lucknow	Roy and Basu (1978)
	Myzus persicae	Srinagar	Rao (1969)
Metasyrphus latifaciatus (Macquart)	*Aphis craccivora*	Coimbatore	Kalyanam (1970)
	Aphis gosssypii	Bangalore	Kalyanam (1970)
Paragus serratus (Fabricius)	*Aphis craccivora*	Bangalore	Joshi et al.(1999)
	Aphis gosssypii	Trivandrum	Malini (2007)
	Lipaphis erysimi	Bangalore	Ghorpade (1973)
	Aphis spiraecola	Gawhati	Ghosh (1974)
Paragus tibialis (Fallen)	*Aphis gosssypii*	Jullundur	Rao (1969)
	Myzus persicae	Dinhata	Rao (1969)
Paragus yerburiensis Stuckenberg	*Aphis craccivora*	Bangalore	Joshi et al.(1999)
	Aphis gosssypii	Mandya	Ghorpade (1973)
	Aphis spiraecola	Nilambur	Ghosh (1974)
Sphaerophoria spp.	*Lipaphis erysimi*	Bangalore	Ghorpade (1981)
	Myzus persicae	Bangalore	Ghorpade (1981)

Leucopis **sp.**

Larvae of Chamaemyiidae are predators of various stages of scale insects, mealybugs and aphids, apparently preferring aphids (Clausen, 1940). Several species, particularly of the genus *Leucopis*, have been successfully used for the classical biological control of adelgids, mainly in North America. *A. gossypii* and *M. persicae* were preyed upon by *Leucopis griseola* L. (Nayar et al., 1976). Population of *Leucopis* sp. larvae was high at peak aphid incidence, thereby rendering it to be the most promising predator of *L. erysimi* in mustard (Kalra, 1988).These silver fly larvae were found on colonies of *Aphis pomi* De Geer and *A. spiraecola* in Canada (Frechette et al., 2008).

Neuropterans

Natural populations of neuropterans especially *Chrysoperla* sp. have been recorded as important aphid predators. Lacewings achieved various levels of control of aphids in potato, tomato and egg plant in USA. On peas and cabbage some degree of aphid control was obtained only with large numbers of lacewings(Hoffmann and Frodsham, 1993).

Over 60 species of chrysopids have been recorded in India of which *Chrysoperla carnea* Stephens, *Apertochrysa crassinervis* L., *Mallada boninensis* L., *M. astur* were most common in vegetable fields(Singh and Narasimham, 1992).

Spiders

Spiders are carnivorus arthropods found in almost every kind of habitat, occurring in fairly large numbers and diversity. Eighty one species in 34 genera belonging to 13 families were recorded from guar in Texas and Oklahoma (Rogers and Horner, 1977). Several spiders were found to predate on the larvae of the soybean pest *Heydelepta indicata* (Fabricius) in Taiwan (Chien et al., 1984). The crab spider *Thomisus* sp. predated on caterpillars and adults of *H. armigera* in tomato fields of Bangalore in India (Ansari and

Pawar, 1980).The occurrence of the spiders *Tetragnatha* sp. and *Oxyopes* sp. from bittergourd was reported by Nandakumar and Saradamma (1996). In a laboratory trial, *Oxyopes javanus, Neoscona mukerjei* and *Tetragnatha mandibulata* preferred *A.gossypii* of okra and *A. craccivora* of cowpea for feeding (Manu, 2005). Thirty species of spider predators belonging to nine families were documented from various vegetable fields of Trivandrum district of Kerala (Manu and Hebsy Bai, 2006).

Parasitoids

Two hymenopteran families, Aphidiidae (Ichneumonoidea) and Aphelinidae(Chalcidoidea), constitute the parasitoids of aphids, in addition to a few species from other hymenopteran families and some species of gall midges (Mackauer and Chow,1986). The most abundant and important aphid parasitoids belong to aphidiidae. More than 400 species of this family were reported (Stary, 1988).

In India, the status of aphidiids is known from the works of Krishnamurthi and Usman (1955) from Karnataka. *Aphidius* sp. and *Aphelinus* sp. parasitised eighty per cent of aphids (*A. gossypii* and *M. persicae*) in unsprayed chilli field (Mani and Krishamoorthy, 1994). Fourteen species of aphidiid parasitoids and two species of aphelinid parasitoids parasitising seventeen species of aphids in different host plants were recorded (Joshi, 2005)

2.1.4 Aphidocolous Ants

Most of the literature available on ant-aphid association refers to the European aphid species. Various physiological (Broadbent, 1951), ethological (Banks, 1958; Banks and Macaulay, 1967; Addicott, 1978) and ecological (Curtright, 1965; Skinner and Whittaker, 1981) studies on aphid ant mutualism have been made from European countries.

References on the association of aphid and ants are available from Orissa, Assam, Meghalaya, Rajasthan (Kurl and Misra, 1980), West Bengal, Sikkim (Datta et al.1982; Datta et al.1983), Manipur (Devi and Singh, 1986; Devi et al, 1987; Devi et al, 2001) and Uttranchal (Bisht et al. 2002) in India.

The role of establishment of root aphid on finger millet through ant association was studied in India (Gadiyappanvar ,1970). Interspecific association of *A. gossypii*, *Cheliomenes sexmaculata* (Fab.) and *Camponotus compressus* Fabricius was studied in guava ecosystem (Verghese and Tandon 1987). Veeresh and Musthak Ali (1990) gave a list of aphidocolous ants from South India. Eleven species of ants viz., *C. compressus*, *C. rufoglaucus* Jerd., *Crematogaster ransonneti* Mayr., *Crematogaster soror* Forel., *Oecophylla smaragdina* Smith, *Monomorium gracillium* Smith, *Monomorium* sp., *Myrmicaria brunnea* Saunders, *Solenopsis geminata* Fabricius, *Tapinoma melanocephalum* Fabricius and *Technomyrmex albipes* Smith were found associated with 24 species of aphids infesting 42 host plants in Karnataka (Joshi, 2008).

2.2 POPULATION DYNAMICS

A. gossypii

The population of the pest is regulated by abiotic and biotic factors. Natural enemies play a crucial role in the control and regulation of *A. gossypii*. Any factor reducing parasitoids, predators or other biological control agent could result in economic damage to the crop (Kaplan and Eubanks, 2002). Natural enemies effective against the aphid included lady beetles *Coccinella septempunctata* L. and *Hippodamia convergens* Guerin., the green lacewing *C. carnea* and wasps *Lysiphlebus testaceipes* (Cress) and *Aphidius colemani* L. (Howard et al. 1985; Van Driesche and Bellows, 1996; Kaplan and Eubank, 2002).

The population of *A. gossypii* was more during January to March as compared to October to December in chilli field (Gowda and Reddy, 1982). Maximum incidence of *A. gossypii* on okra, chilli and brinjal was recorded in July, August and November, respectively (Banerjee and Raychaudhuri, 1986). In another study, the same aphid prevailed on okra from early December to late February (at 18 to 24 °C and 62 to 71 % RH) and early March to late May (at 27 to 34 °C and 65 to 85% RH)(Maiti et al. ,1989). The peak population of *A. gossypii* was recorded during January and weather parameters viz., temperature, rainfall, dew point and photoperiod showed significant negative effect but relative humidity showed insignificant positive effect (Karim et al., 2004). Studies on the population build up of *A. gossypii* on different vegetables indicated that the pest was active from August to December. However, the aphid population was high on brinjal (2.4-66 aphids/ 3 leaves) followed by cabbage (1.2-47 aphids/3 leaves) and low on tomato (0.62-4.6 aphids/3 leaves). The peak population of the aphid was recorded during second week of September to fourth week of October on brinjal, cabbage, spinach, chilli and tomato (Kumar et al. 2004).

A. craccivora

The pea aphid *A. craccivora* was noted to be a serious pest of cowpea in Kerala during dry periods. High population of the aphid and its coccinellid predators were recorded during September to April and a strong positive correlation was established between the aphid and the predatory groups viz., coccinellids, syrphids and hemerobiids (Mathew et al., 1971). 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 rainfall were reported (Upadhyay et al., 1980). A positive correlation between the aphid population and population of active stages of their coccinellid predators was also observed in cowpea (Butani and Bharodia, 1984). The temperature and relative humidity were found to have greater impact on the aphid prey consumption rate by the predator, *C. carnea* in cowpea (Zaki, 1987).

Low temperature and high humidity favoured the multiplication of aphids in cowpea whereas the reverse condition prevalent in March to April favoured the development of coccinellids and suppressed the increase in aphid numbers. Population build up of *C. septempuctata* was positively correlated with temperature and morning humidity, whereas *M. sexmaculatus* was negatively correlated with temperature and afternoon humidity (Kalushkov et al., 1990). 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 in cowpea. Among the predatory coccinellids, *M. sexmaculatus* constituted 77-88 and 83-95 per cent of the total predatory fauna in two seasons, respectively. It was found active from March to November on different crops and hibernated as adults from December to February (Srikanth and Lakkundi, 1990). The population of the coccinellid predator, *M. sexmaculatus* in pigeon pea peaked in early September in Andhra Pradesh (Duffield, 1995). A pest dependent increase in the predators of *A. craccivora* viz. *C. sexmaculata* and *X. scutellare* was observed in cowpea and glyricidia (Rani, 1995). An increase in temperature from 18 to 36 °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 temperature in cowpea ecosystem (Veeravel and Bhaskaran, 1996).

2.3 MANAGEMENT

Several botanicals and newer molecules of synthetic insecticides are known to be especially effective against aphids.

2.3.1 Efficacy of Botanicals

Numerous reports are available on the use of botanicals especially, neem formulations against aphids and other major pests of vegetables.

The efficacy of neem products like neem leaf extract (Phadke et al. (1988) , neem oil(Schmutterer, 1990 and Sarode et al., 1995)and neem seed kernel extract (Sarode et al., 1995 and Rosaiah and Reddy ,1996) in controlling aphids is widely acclaimed. Neem seed oil 2.5 or 5 % with garlic @ 20 g l^{-1} effectively controlled jassid, aphid and mite on bitter gourd (KAU, 1996) and at 2.5 % was very effective in controlling aphids in snake gourd compared to chemicals (Sivakumar, 2001). The efficacy of the commercial formulations NeemAzal and Econeem against *A. craccivora* in cowpea (Hebsy Bai et al., 2002) and NeemAzal against *A. gossypii* (Chandrasekaran, 2001 and Thilagam et al. 2008) have been reported. Pongamia oil one per cent effectively reduced the population of *A. gossypii* infesting *Plantago ovata* L. (Premsagar, 1992).Illupai oil (1 % and 2 %) was superior against rose aphid *Microsiphum rosae* L. (Reddy et al., 2002).

Neem oil at different concentrations has been reported to be effective against vegetable pests like *Bemisia tabaci* Gennadius (Natarajan and Sundaramurthy, 1990 and Rosaiah and Reddy ,1996), *Amrasca biguttula biguttula* Ishida (Sarode et al., 1995), *Aleurodicus dispersus* Russel (Mariam and Chandramohan, 2000 ; Rani, 2004)) and *Lampides boeticus* L.(Irulandi and Balasubramanian , 2000). Similarly, the efficacy of NSKE 5% against *A. biguttula biguttula* (Sarode et al., 1995), *A. dispersus* Russel (Mariam and Chandramohan, 2000 ; Rani, 2004), *Maruca vitrata* (Fab.) (Lakshmi et al. 2002) and *Scirtothrips dorsalis* Hood(Gundannavar et al. (2007) has been documented. Several commercial formulations of neem like Repelin (Jayaraj and Rangarajan 1987), Neemark (Patel and Patel, 1996) and Navneem (Dhawan and Simwat 1992) against *A. biguttula biguttula* ; Nimbecidine (Rao et al., 1996) and Neemrich (Singh and Gupta, 1993) against *B. tabaci* and NeemAzal against *H. armigera* (Dhawan and Smiwat 1994) and *S. dorsalis* (Gundannavar et al. ,2007) had been reported.

2.3.2 Efficacy of New Synthetic Insecticides

A number of new groups of insecticides with different modes of action have been introduced for crop protection. With the introduction of these insecticides, heavy reliance on the conventional molecules has been minimized.

Imidacloprid

Imidacloprid is a new systemic, chloronicotinyl group of insecticide, with broad spectrum activity, particularly against sucking insect pests such as leafhoppers, aphids, whiteflies and thrips (Mote et al., 1994; Chao et al., 1997). Imidacloprid 70 WS at 10 g kg^{-1} protected okra from leafhoppers, aphids and thrips upto nine weeks and resulted in higher fruit yield (Sivaveerapandian, 2000).Similarly, treatment of okra seeds with the chemical (Gaucho 600 FS) @ 12 ml kg^{-1} of seed reduced leafhopper infestation (Kumar et al., 2001). In field trials on okra, imidacloprid 200 SL (0.004 %) gave higher per cent reduction in population of aphids, leafhopper and whitefly with increased yield and higher cost: benefit ratio (Chandrasekaran, 2001). At 0.02 kg a.i. ha^{-1} the neonicotinoid was on par with dimethoate 30EC 0.188 kg a.i. ha^{-1} against *A. biguttula biguttula* (Singh et al., 2002). At 125 and 150 ml ha^{-1} the insecticide was highly effective against sucking pest complex of chilli *viz.*, aphid (*A. gossypii*) and the jassid (*A. biguttula biguttula*) and proved to be better than monocrotophos and dimethoate (Patil et al., 2002). Application of 1:20 and 1:30 dilutions of imidacloprid 17.8 SL to the apical portion of the stem to a length of 2 to 4 inches leaving top 4 to 6 inches resulted in 98.0 and 87.7 per cent reduction in the population of *A. gossypii* respectively in okra (Raj and Punnaiah, 2003). Foliar application of imidacloprid 0.02% was highly effective against sucking pest complex of okra *viz.*, *A. gossypii*, *A. biguttula biguttula* and *B. tabaci* and proved to be better than dimethoate 0.05% (Thamilvel, 2004).

Thiamethoxam

A new insecticide of thianicotinyl compound, thiamethoxam was found to be very effective for the control of homopterans (Mohan and Katiyar, 2000). Thiamethoxam (Actara 25 WG) was on par with imidacloprid (Gaucho 600 FS) for seed treatment at 12 ml kg^{-1} of seed in reducing the leafhopper, *A. biguttula biguttula* infestation on okra (Kumar *et al.*, 2001). Thiamethoxam and imidacloprid used at 25 g a.i ha^{-1} proved most effective for the control of the aphid, *A. gossypii* and the jassid, *A. biguttula biguttula* on okra (Misra, 2002). In laboratory studies, thiamethoxam was the most toxic insecticide to the third instar nymphs of leafhopper, *A. biguttula biguttula* with LC_{50} value of 0.000314 µg mL^{-1} (Ravikumar et al., 2003). Foliar application of thiamethoxam 0.02% was highly effective against sucking pest complex of okra *viz.*, *A. gossypii*, *A. biguttula biguttula* and *B. tabaci* and proved to be better than dimethoate 0.05% (Thamilvel, 2004).

Acetamiprid

Acetamiprid is a novel, neonicotinoid insecticide having N-cyano acetamidine compound that provides excellent control of sucking pests. The compound has excellent systemic and translaminar activities. Most of the literature available pertains to the effect of the nicotinoid on pests of cotton.

Foliar application of acetamiprid at 60 g a.i. ha^{-1} suppressed totally aphid development up to 24 days after application exceeding the efficacy obtained with an application of 210 g a.i. ha^{-1} of imidacloprid in cotton (Horowitz et al., 1998). At 10 g a.i. ha^{-1} the insecticide gave significant control of aphids and leafhoppers, whereas for whitefly control, the dose had to be increased to 20 and 40 g a.i. ha^{-1}, respectively in cotton (Ramnathsubramanian and Natarajan, 1998). Acetamiprid (Saurus 200 PS) at 10, 15 and 20 g a.i. ha^{-1}, gave more than 91 per cent control of *A. gossypii* on cotton on 2, 5, 7, 10 and 15 days after application, while cypermethrin at 12.5 g a.i. ha^{-1} and methamidophos (Tamaron BR) at 300 g a.i. ha^{-1} gave 54.9 and 49.8 per cent control , respectively two days after application and 0.5 and 13.4 per cent control, respectively 15 days after application in Parana, Brazil, during 1996-97 (Bellettini et al., 1999). The insecticide at 10 g a.i. ha^{-1} provided consistently better control of cotton leafhoppers and aphids for longer period (Kumar et al., 1999). At 20 g a.i. ha^{-1} , the insecticide was highly effective in checking the populations of aphids, leafhoppers, thrips and whiteflies in cotton (Patil et al., 2001; Patil and Rajanikantha, 2004; Jayaprabhavathi, 2005). Against the spiralling whitefly, *A. dispersus* infesting cotton, buprofezin (Applaud 25 SC) at 0.025 per cent and acetamiprid at 0.01 per cent were found most effective in reducing nymphal population followed by acephate (0.1125%), triazophos (0.06%) and fenpropathrin (0.01%) (Kendappa et al., 2004).

Acetamiprid 20 SP @ 80 and 40 g a.i. ha^{-1} were effective in reducing the sucking pests of chillies followed by acetamiprid 20 SP @ 20 g a.i. ha^{-1} and recorded maximum green chilli yield (Jayewar et al., 2003).

Diafenthiuron

More than 80 per cent control of *B. tabaci* on tomato was achieved by using diafenthiuron (Salguero and Morales, 1994). The possibility of alternating diafenthiuron and buprofezin with insect growth regulators like pyriproxifen for controlling aleurodids in vegetables as part of integrated resistance management strategies was established (Horowitz, 1995). The insecticide at 225, 300 and 377g a.i. ha^{-1} caused significant reduction in mustard aphid population upto 7days in cabbage fields (Patel et al., 1998). Similarly, diafenthiuron 0.05% controlled the aphid population in bhendi upto two weeks after application (Surekha and Rao , 2001).

Profenofos

Application of this organophosphate insecticide @ 1000 g a.i. ha^{-1} was highly effective against the aphid *A. gossypii* and proved to be better than monocrotophos at 540g a.i ha^{-1} and diazinon at 250 g a.i. ha^{-1} on chilli (Dey et al., 2001). The insecticide at 0.05 per cent was effective against *A. gossypii* (Surekha and Rao, 2001) and at 800 g a.i. ha^{-1} against cotton jassid *A. biguttula biguttula* (Sandeepkaur, 2002) in okra. When evaluated against cowpea pests, profenofos 0.05 per cent gave effective control of the *A. craccivora* (Varghese, 2003). The insecticide at 0.05% was highly effective against sucking pest complex of okra *viz., A. gossypii, A. biguttula biguttula* and *B. tabaci* (Thamilvel, 2004). The LC_{50} value of 0.019 mg mL^{-1} of profenofos proved high mortality to *A. gossypii* (Dhawan et al. 2008).

Triazophos

Triazophos at 0.1 per cent was effective against the bhindi aphid, *A. gossypii* and the cotton leafhopper, *A. biguttula biguttula* on okra (Prasad et al., 1993). Soil application of carbofuran 3G at 0.5 kg a.i. ha^{-1} 15 days after transplanting followed by continuous spray of triazophos 0.04 per cent at 10 days intervals from 30 days after transplanting effectively controlled *S. dorsalis* infesting chilli (Patel et al., 1999). Panickar and Patel (2001) also reported the effectiveness of triazophos 0.04 per cent in managing *S. dorsalis* and preventing the incidence of leaf curl in chilli. Triazophos 0.05 per cent was found promising against pea aphid, leaf caterpillars and pod borers and ineffective against pod bugs on cowpea (Varghese, 2003).

Acephate

The LC 50 and LC 90 of acephate against the green peach aphid, *M. persicae* on the leaves of brinjal were found to be 0.0046 per cent and 0.01462 per cent, respectively (Sandhya and Dethe, 1991). At 0.1 per cent and 0.15 per cent, the insecticide was effective against *A. gossypii* and *A. biguttula biguttula* on okra (Prasad et al., 1993) and *B. tabaci* in tomato (Salguero and Morales, 1994). Application of acephate during the early seedling stages caused only less foliar damage by the thrips, *Frankliniella fusca* (Hinds), *Frankiniella tritici* (Fitch) and *Scricothirps variabilis* (Beach) (Sweeden et al., 1994). At 0.05 per cent concentration, it was effective against *A. craccivora* on cowpea (Varghese, 2003).

Profenofos 40% + cypermethrin 4%

Profenofos and its combination with cypermethrin gave good control of *B. tabaci* in tomato. The mixture resulted in more than 80 per cent mortality within 2-3 days and was better than individual application of profenofos (Salguero and Morales, 1994). Profenofos (Curacron) @ 2 l ha^{-1} and profenofos + cypermethrin combination (Polytrin C) @ 2 l ha^{-1} were the most effective in reducing the damage by *Earias* spp. *A. biguttula biguttula* and *A. gossypii* in okra (Sivakumar et al., 2003). Rocket (profenofos 40% + cypermethrin 4%) @ 660g a.i ha^{-1} proved to be better than profenofos 600 g a.i ha^{-1} against mixed population of aphids (*M. persicae* and *A. gossypii*) in tomato(Sarangdevot et al., 2006).

Acephate 25% + fenvalerate 3%

Koranda (acephate 25% + fenvalerate 3%) @ 560g a.i. ha^{-1} was highly effective against the leaf webber *Antigästra catalaunalis* (Dupon.) and gave the lowest pod damage (5.5 per cent) and recorded highest seed yield in til (Misra, 2003). At 0.05 per cent concentration, the insecticide mixture caused 100 per cent larval mortality of third instar larvae of cabbage butterfly, *Pieris brassicae* L (Singh et al., 2003b). Application of koranda 0.05 per cent was effective against third instar larvae of *H. armigera* (Dhingra et al., 2003).

Dimethoate

Dimethoate 30EC at 0.06 per cent (Nagia et al., 1990) and 200 g a.i. ha^{-1} (Borach, 1994) was found to be the most effective chemical to control *A. biguttula biguttula* in okra. Weekly and fortnightly application of dimethoate at 0.05 per cent gave effective control of *B. tabaci* (Borach and Nath, 1996). The lowest concentration of dimethoate at 0.025 per cent gave a high level of mortality to *A. craccivora* after three days (Deka and Borach, 1998). Dimethoate (0.06 %) and dichlorvos (0.2 %) were effective in reducing *A. gossypii* and *A. biguttula biguttula* population in okra (Masoodkhan et al., 2001).

2.3.3 Toxicity to Natural Enemies

2.3.3.1 Neem based products

Neem based pesticides were safe to *Tetrastichus* sp., *Chrysocharis johnsoni* Rao, *Tetragnatha* sp. and *Oxyopes* sp observed in bittergourd field. (Nandakumar and Saradamma, 1996). Field application of NeemAzal T/S @ 3.0 ml l^{-1} was harmless to the larvae of *C. carnea* (Vogt et al., 1996). Econeem and NeemAzal T/S at 0.1 and 1.0 %, respectively were safer to the egg parasitoid, *Trichogramma japonicum* (Ashmead) than insecticides like quinalphos and chlorpyrifos (Lakshmi et al., 1997). Similarly, NeemAzal T/S at 3%, NeemAzal F at 1%, Nimbecidine at 1%, Neem Gold at 1% and NSKE at 5% were safe to the egg parasitoids, *Trichogramma chilonis* Ishii, *T. japonicum* and *T. brasiliense* (Srinivasan and Babu, 2001). The field dose of neem insecticides did not cause any apparent adverse effects on the survival and foraging behaviour of the larval parasitoid, *Diadegma mollipla* (Holmgren) of the diamond back moth (Akol et al., 2001). NeemAzal and neem oil both at 3.0 ml l^{-1} were found to be safe to coccinellid predators of okra pest complex *viz. M. sexmaculata* and *Micraspis vincta* (Gorham) (Gowri et al., 2002). NeemAzal F 0.015 per cent and NSKE 3 % were found safe to the predatory fauna of *A. gossypii* (Patel et al., 2003). NeemAzal 1 % T/S at 0.004 % concentration was benign to coccinellids and spiders like *Oxyopes* sp. and *Tetragnatha* sp. in bhindi (Thamilvel, 2004). Neem oil 2% also caused less than 50 per cent mortality of various spiders found in vegetable ecosystem when applied topically (Manu, 2005). Again, neem oil 2% and azadirachtin 0.004 % sprays in a coccinia crop were safe to spiders (Vijayasree, 2006).

2.3.3.2 Acetamiprid

Field application of acetamiprid against aphids had no negative effects on beneficial arthropods (Pollini and Bariselli, 1997). The insecticide was safe to majority of the natural enemies including coccinellids, *Chrysopa* spp., syrphids, *Aphidoletes* spp. and spiders with coccinellids being the least affected (Yequming et al., 1996). But it showed high lethal contact toxicity to *Rodolia cardinalis* (Mulsant) and the encyrtid, *Leptomastix dactylopii* (Howard). But the development of mature larvae of the aphelinid, *Encarsia formosa* Gahan in pupal case of *T. vaporariorum* was not significantly affected (Viggiani ,1998). In a study on the toxicity of newer molecules of insecticides, acetamiprid (20 g a.i. ha^{-1}), thiamethoxam (25 g a.i. ha^{-1}), imidacloprid (25 g a.i. ha^{-1}), NACLFMOA (20 g a.i. ha^{-1}) and abamectin (20 g a.i.ha^{-1}) were found to be relatively safer to the predatory ladybird beetles (Acharya et al., 2002). At 0.002 per cent concentration, the insecticide was safer to the aphid predators *viz*., *C. carnea* and *M. sexmaculata*. and *C. transversalis* than organophosphate insecticides like chlorpyriphos (0.05 %), profenofos (0.05 %) and triazophos (0.05 %) on cowpea (Varghese, 2003).

2.3.3.3 Imidacloprid

Imidacloprid had no effect on spiders (Xin and Xi, 1995). In plants treated with the insecticide, there was significant decrease in the general mobility of the coccinellid predator, *Coliomegilla maculata* (De Geer) (Smith and Krischik, 1999). The toxicity of imidacloprid to the mirid predators *viz., Macrolophus calignosus* Wagner and *Dicyphus tamaninii* Wagner was reported (Figuls et al., 1999). Laboratory studies showed that the nicotinoid at 0.07 % was persistent upto 15 days and caused 24.7 per cent mortality of *C. sexmaculata* adults (Patil and Lingappa, 2000). The green lacewing, *C. carnea* and imidacloprid 0.34 kg a.i. ha^{-1} were compatible and they together controlled the whitefly, *B. tabaci* resulting in the highest yield and moderate plant viral infection in tomato (Ruiz and Medina, 2001). Imidacloprid 200 SL (0.004 %) were safe to predators like occinellids, spiders and chrysopids as evidenced by the highest survival ate after the use of these insecticides under field condition (Chandrasekaran 2001). Imidacloprid at 0.025 % were safer to the aphid predators *viz.*, *C. arnea* and *M. sexmaculata*. and *C. transversalis* than organophosphate nsecticides like chlorpyriphos (0.05 %), profenofos (0.05 %) and triazophos 0.05 %) on cowpea (Varghese, 2003).

.3.3.4 Dimethoate

Application of dimethoate (0.05%) was found to have some adverse ffects on predatory insects (Nurindah and Bondra, 1988). At 250 g a.i. ha^{-1} he insecticide resulted in 100 per cent mortality of the parasitoid, *Aphidius* pp. within 24 hours (Tonet et al., 1997). At 0.07 % concentration, imethoate was highly toxic to *Aphytis melinus* DeBach and *Chilocorus igrita* (Fabricius) (Kirshnamoorthy and Rajagopal, 1998). The insecticide as also toxic to *C. sexmaculata* (Thayaalini and Raveendranath , 1998) and howed high residual toxicity to *Cryptolaemus montrouzeieri* Mulsant Sundari, 1998). Dimethoate at 0.05 per cent produced sub-lethal effect on he aphid parasitoid, *Diacretiella rapae* McIntoch (Umoru and Powell, 002). Foliar application of dimethoate 0.05% was more toxic to coccinellid, yrphid, spider and braconid population upto ten days after spraying in okra Thamilvel, 2004).

.3.4 Effect of insecticides on soil fauna

Among the commonly used insecticides, carbamates were the most oxic and deadly to earthworms. Even small concentrations at recommended ates of application severely reduced earthworm population (Kring, 1969; inlayson et al., 1975; Martin, 1976; Lebrun et al., 1981; Medts, 1981). oliar application of imidacloprid @ 500 g a.i ha^{-1} showed only a transient ffect on the population of *L. terrestris* (Pfluger and schmuck, 1991). pplication of endosulfan @ 3 ml l^{-1} reduced cent per cent population of the arthworm species viz., *Drawida willisi* Mich. and *Lampito mauritii* Kinberg

(Reddy and Reddy, 1992). Chlorpyriphos was the least toxic at different dosages to various earthworms including *Eudrilus eugeniae* (Kinberg) (Mantur, 1998). Contrarily, endosulfan and carbofuran were highly toxic to earthworm population (Awaknavar and Karabhantanai, 2004).

Laboratory studies showed that dimethoate @ 1.75 l ha^{-1} gave highest mortality to *E. eugeniae* when applied topically on the earthworm food materials (Biradar et al., 2007).

Foliar application of imidacloprid 0.002% (Confidor 200SL) had no adverse effect on diplopoda and spiders such as Linyphiidae, Araneidae and carabid beetle *Philonthus* sp.(Pfluger and schmuck, 1991). Field studies on the effect of Margosan-O (MO) containing azadirachtin at 3.0 g a.i and chlorpyriphos 0.03 per cent on different invertebrates inhabiting a turf grass system indicated that MO was less detrimental than chlorpyriphos to most of the invertebrate's species. However, oribatid mites were more sensitive to MO than chlorpyriphos. Sminthurid and non-sminthurid collembolans were also susceptible to MO, although less so than to chlorpyriphos (Stark, 1992). Toxic effect of dimethoate to soil invertebrate species, *Aporrectodea caliginosa tuberculata* (Eisen), *Folsomia candida* (Willem)and *Enchytraeus crypticus* Westheide and Graefe in artificial, clayey and humus sandy soil varied between species and the soil tested, with toxicity tending to decrease with increasing organic matter content (Martikainen,1996). Chlorpyriphos (0.05%) foliar application affected collembolan population adversely than by dimethoate (0.05%). Epigeal collembola took longer time than predatory arthropods to recover from the effects of chlorpyriphos (Frampton, 1997). Collembolan and mite populations were not reduced by HCH treatment in banana ecosystem. Significant reduction was observed for 2 months after the first and second application of carbofuran and phorate (Sujeetha et al., 1999). Imidacloprid at 0.34 and 0.45 kg a.i $ha^{-1}$was also toxic to the predatory coleopteran larvae and histerid beetles in turf grass. However, the ants, carabids, spiders and staphylinids were largely unaffected (Kunkel et al., 1999).

2.3.5 Effect of insecticides on soil flora

Phorate when applied at 2 kg a.i ha^{-1}around brinjal seedlings showed moderate antifungal action and was less toxic to soil bacteria (Satpathy, 1974). More than 50 per cent reduction in bacterial colony was observed 10 days after application in the treated plots and the toxic effect of phorate was reduced significantly. Phorate @ 1.5 kg a.i. ha^{-1} and 3 kg a.i ha^{-1} in soil did not affect the population of fungi but it stimulated the actinomycetes and bacterial populations for a period of 7 months after application in rice(Visalakshy et al., 1980 and Beevi, 1987) In laboratory and field studies, imidacloprid had no significant effect on the activity of soil microorganisms even at a high dose of 2000 g a.i ha^{-1} (Pfluger and Schmuck, 1991). Carbaryl and carbofuran treated plots had reduced microbial population whereas phorate treated plot had a slight enhancement of the population of bacteria and fungi in banana ecosystem (Sujeetha, 2008).

2.3.6 Residues of acetamiprid, imidacloprid and dimethoate in vegetables

Two different formulations of acetamiprid viz., 20 SP and 20 SL both applied @ 20 g a.i. $ha^{-1}$and 40 g a.i. ha^{-1}had 0.0207, 0.0405, 0.0244 and 0.1039 μg g^{-1} of initial deposits in chilli. The half-life values of acetamiprid in chilli were in the range of 2.24 - 4.84 days (Sanyal et al., 2008).

Initial deposits of imidacloprid in tomato fruits were found to be 1.35 and 2.40 mg Kg^{-1} from 20 and 40 g a.i. ha^{-1} treatments, respectively. The imidacloprid residues reduced progressively with time and on the seventh day the concentration was reported to be 0.08 and 0.18 mg Kg^{-1} from respective treatments and became non detectable on the tenth day from normal dose (20 g a.i. ha^{-1}) and the safe waiting period was seven days after treatment(Dikshit and Pachauri, 2000). reported that In okra fruits, the residues of imidacloprid were found to be 0.08, 0.10, 0.14 and 0.24 mg Kg^{-1} from 3, 5.4, 10.8 and 21.6 g a.i. Kg^{-1} seed treatments, respectively, after 55 days of sowing and became non detectable after 60 days of sowing (Dikshit et al., 2000). The metabolites of the insecticide were found to be translocated up to 10 days in eggplant, cabbage leaves and mustard leaves (Mukherjee and Gopal, 2000). Harvest time residues of imidacloprid applied as seed and foliar application was at BDL on the fruits of tomato (Tolman et al., 2000) and okra (Indumathi et al.2001; Sivaveerapandian et al., 2002).Harvest time residues of imidacloprid 17.8 SL (foliar application) were at below detectable level (BDL) in bhendi (fruits), chilli (fruits) and radish tubers (Suganthy, 2003). In green chillies, initial residues of imidacloprid were 0.38 and 0.56 ppm in spray treatment of 100 and 150 ml ha^{-1} ,respectively and these residues reached below detectable limit (BDL) of more than 0.05 ppm in 4.19 to 5.48 days (Kharbade et al., 2003). However, the analysis of imidacloprid residues in vegetables, fruits, and water samples from Palestine indicated that the highest and lowest imidacloprid concentrations were found in eggplant (0.46 mg Kg^{-1}) and green beans (0.08 mg Kg^{-1}), respectively and the imidacloprid residue concentrations in several crops were found to exceed the CODEX maximum residue limit (Daraghmeh et al., 2007).

Pea grain and chilli (green and red) samples were contaminated with dimethoate above MRL in Hariana (Madan and Beenakumari ,1996). In a study on the residues of the organophosphate insecticides in different vegetables, forty three per cent of cowpea samples were contaminated with above MRL followed by cucumber (25 per cent), snake gourd (22.3 per cent) and bitter gourd (16.7 per cent)(Santhoshkumar, 1997). The initial deposits of dimethoate @ 300 g on green chilli was 0.331 mg which dissipated to below maximum residue level after 24 hours. The residues in harvested red chillies were below detectable levels (Reddy et al., 2007).

Materials and methods

3. MATERIALS AND METHODS

Survey was conducted in Thiruvananthapuram district of Kerala to document the aphids infesting various vegetables. Studies on the population dynamics of the two dominant aphids in vegetable ecosystem identified in the survey, were carried out in farmers' fields in Kalliyoor panchayat of the district. The trials on the evaluation of botanicals and newer molecules of synthetic insecticides were done at the Department of Entomology and Instructional farm, College of Agriculture, Vellayani. The details of the materials used and the methods followed are presented here under.

3.1 DOCUMENTATION OF APHIDS

Two panchayats with extensive vegetable cultivation were identified in each of the four taluks viz., Thiruvananthapuram, Neyyattinkara, Nedumangad and Cherayinkizhil of Thiruvananthapuram district for the study during 2005-07. Ten locations were selected randomly in each panchayat and the vegetables grown, weeds in the crop field and other plants in the vicinity were observed for aphid infestation. The aphid colony characters, such as colour of the live aphids, plant parts infested and extent of damage caused were recorded. The aphids, their natural enemies and attendant ants were collected for identification.

3.1.1 Identification of Aphids

The infested plant parts along with the aphid colony were excised and transferred to polythene bags. At times, the aphids were collected directly into 12 x 7 cm small plastic containers from the plants using a camel hair brush. The aphids thus collected were preserved in 70 % ethyl alcohol in five ml plastic vials furnished with a label containing information on locality, host plant, date and collector's name.

Slide Preparation

Slides of the aphids were prepared as per the method suggested by Eastop and Van Emden (1972) with slight modification. The aphids were boiled in 95 % ethyl alcohol for five to ten minutes. The alcohol was then decanted off and the insects were boiled again in 10 % potassium hydroxide solution till the specimens turned transparent. The aphids were then rinsed in 95 % ethyl alcohol and transferred to glacial acetic acid for two to three minutes. Clove oil was added to clear the specimens further, after decanting the acetic acid. One to three aphids were then transferred to a drop of Canada balsam taken on a clean micro slide. Care was taken to keep the dorsal side of the aphids uppermost with the appendages spread out. The specimens were covered with a clean cover slip and dried in an oven at 50° C for 12 hours. Two labels, one with details of the host plant, locality, date and name of collector, and the other with scientific name and the name of the scientist identifying the same were pasted on the slide. The aphids were identified using the keys in the works of Martin (1983) and Blackman and Eastop (2000). Dr. Sunil Joshi, Scientist, Project Directorate of Biological control, Bangalore, confirmed the aphid identification.

3.1.2 Identification of Predators, Parasitoids and Ants

The predators, parasitoids and ants collected were also preserved in 70 % alcohol in five ml plastic vials furnished with labels indicating the host plant, locality, date of collection and collector's name. The unknown predators, parasitoids and ants were identified by the specialists mentioned in the acknowledgements.

3.1.3 Assessment of Aphid Damage

The intensity of damage caused by the two dominant aphids identified in the survey viz., *A. gossypii* and *A. craccivora* on the vegetable host plants was assessed. One plot of each vegetable was selected in the four taluks from the 10 locations identified and observed during the vegetative and reproductive stages of the crops. The population of the aphid, damage caused and the mosaic disease incidence were recorded as detailed below.

Aphid Population

Fifteen plants were selected randomly during each phase of the crop and counts of aphids in 15 cm shoot were recorded.

Aphid Damage Index (ADI)

Thirty plants were selected at random and graded based on the extent of damage caused by the aphids as follows

Grade value	Extent of damage (%)
0	no damage symptom
1	1-10
2	11-25
3	26-50
4	above 50

$$ADI = \frac{\text{Frequency in each grade x grade value}}{\text{Total number of plants x value of highest grade}} \times 100$$

Mosaic Disease Incidence (MDI)

Thirty plants were examined at random in each location and the number of plants infected were recorded. The disease incidence was assessed using the formula

$$\text{Percentage of MDI} = \frac{\text{Number of plants infected}}{\text{Total number of plants observed}} \times 100$$

3. 2 DETERMINATION OF PEAK INCIDENCE

The population fluctuation and peak period of incidence of *A. gossypii* and *A. craccivora* in chilli and winged bean, respectively in a cropping season were studied during 2006-07 and 2007-08.

3.2.1 Assessment of Aphid Population

A plot of 40 cents of each of the vegetable raised without any plant protection measures was selected in Kalliyoor panchayat for recording the observations. Incidence of the pest was assessed at weekly intervals during the entire crop period, commencing from 30 days after sowing. Fifteen plants were selected at random and the number of aphids in the terminal shoot upto 15 cm length along with the leaves of each plant was recorded and the mean number of aphids per shoot was worked out.

3.2.2 Assessment of Population of Natural Enemies

Fifteen aphid infested plants were selected at random in each plot and the number of the predators viz., coccinellids, chrysopids, hemerobiids, syrphids, chamaemyiids and spiders on each plant was recorded. Ten sweep net collections were taken from each plot to assess the population of the parasitoids.

3.2.3 Recording Meteorological Parameters

The weather parameters viz., maximum and minimum temperature, relative humidity, rainfall, wind speed, number of rainy days were recorded from the Department of Meteorology, College of Agriculture, Vellayani. The average of the weekly data was worked out and correlated with the population of aphids and their natural enemies during the period of study.

3.3. EVALUATION OF BOTANICALS AND INSECTICIDES

Twelve botanicals comprising of five plant oils, six plant extracts and one commercial formulation and ten synthetic insecticides were tested in the laboratory against *A. gossypii* and *A. craccivora*. The promising ones were further evaluated in the field for their efficacy in controlling the pests.

3.3.1 Laboratory Evaluation

Two sets of experiments were conducted, one with twelve botanicals and the other with ten synthetic insecticides. The experiments were laid out in completely randomized block design with three replications and an untreated check. The treatments were as detailed in Tables 4 and 5.

3.3.1.1 Raising of Test Plants

Chilli (cv. Jwalamuki) seedlings were raised in an area of one square metre. One month old seedlings were transplanted to earthen pots of 20 cm diameter filled with potting mixture @ three plants per pot. Seeds of cowpea (cv. Malika) were sown @ three seeds per pot to raise the test plants. The plants were thinned to one after establishment and maintained under optimum conditions.

3.3.1.2 Rearing of Aphids

Twigs of chilli and cowpea infested with *A. gossypii* and *A. craccivora* , respectively were collected from unsprayed fields of the Instructional farm, Vellayani and the aphids were allowed to infest chilli and cowpea plants, respectively raised in earthen pots as described in 3.3.1.1. When the plants became severely stunted, the aphids were transferred to healthy plants. The pots were placed in moist sand to maintain high humidity and watered regularly.

3.3.1. 3 Mass Culturing of Predators

Coccinellids

The adults of *M. sexmaculatus*, *C. transversalis*, *P. trinotatus*, *H. octomaculata*, *S. (P.) latemaculatus* and *C. septempunctata* were collected from vegetable fields and reared in the laboratory. *M. sexmaculatus*, *C. transversalis* and *P. trinotatus* were reared on *A. craccivora* and *H. octomaculata*, *S. latemaculatus* and *C. septempunctata* on *A. gossypii*. Aphid infested twigs of chilli and cowpea plants were excised from the culture

Table 4. Botanicals tested against *Aphis gossypii* and *Aphis craccivora*

Sl. No.	Common Name	Dose	Source
1	Castor oil	2 %	Madurai agrochemicals Pvt. Ltd.
2	Pongamia oil	2 %	Madurai agrochemicals Pvt. Ltd.
3	Illupai oil	2 %	Madurai agrochemicals Pvt. Ltd.
4	Neem oil	2 %	Madurai agrochemicals Pvt. Ltd.
5	Neem oil + garlic emulsion	2 %	Preparation
6	NSKE	5 %	Preparation
7	NeemAzal T/S	4 ml/l	E.I.D. Parry (India) Ltd.
8	*Capsicum frutescens* fruit extract	5 %	Preparation
9	*Andrographis paniculata* leaf extract	5 %	Preparation
10	*Adathoda vasica* leaf extract	5 %	Preparation
11	*Azadirachta indica* leaf extract	5 %	Preparation
12	*Vitex negundo* leaf extract	5 %	Preparation

Table 5. Newer molecules of synthetic insecticides tested against *Aphis gossypii* and *Aphis craccivora*

Sl. No	Common Name	Trade Name	Dose	Company
1	Imidacloprid	Confidor 200 SL	0.003%	Bayer (India) Ltd.
2	Thiamethoxam	Actara 25 WG	0.002%	Syngenta India Ltd.
3	Acetamiprid	Award 20 SP	0.002%	Meghamani Organic Ltd.
4	Diafenthiuron	Polo 50 WP	0.02%	Syngenta India Ltd.
5	Profenofos	Curacron 50 EC	0.05%	Novartis India Ltd.
6	Triazophos	Hostathion 40 EC	0.05%	Agro Evo India Ltd.
7	Acephate	Asataf 75 SP	0.05%	Rallis Tata Enterprise
8	Profenofos 40 % + cypermethrin 4 %	Polytrin 44 EC	0.05%	Novartis India Ltd.
9	Acephate 25% + fenvalerate 3%	Koranda 28 EC	0.05%	Rallis Tata Enterprise
10	Dimethoate	Rogor 30 EC	0.05%	Sree Ramcides Chemicals Pvt. Ltd.

plants maintained as described in 3.3.1.2. The cut end of the twigs was covered with moistened cotton and inserted into small glass vials containing water. The twigs along with the vials were placed in cylindrical 20 x 15 cm glass troughs covered with muslin cloth. The beetles were introduced into the troughs containing their respective prey for mating and egg laying. The neonate larvae of the coccinellids were transferred to similar glass troughs containing their respective aphid prey. The troughs were cleaned and replenished with sufficient aphid prey daily. The newly moulted third instar larvae and two day old adults obtained from the culture were used for the various studies.

Syrphids

Colonies of *A. gossypii* with maggots of *I. scutellaris*, *D. aegrota* and *P. serratus* were collected from unsprayed chilli plants and kept in individual glass troughs for pupation. The maggots were provided with sufficient prey as described under coccinellids till pupation. The pupae of each of the syrphid were then transferred to separate specimen tubes. The emerging adults were introduced into glass troughs containing chilli twigs with aphid colonies and diluted honey soaked in cotton. The adults were allowed to mate and lay eggs on the chilli twigs. The emerging maggots were introduced into separate glass troughs in which chilli twigs with aphids were kept for rearing. The twigs were replaced daily with fresh ones. The newly moulted third instar larvae were used for the study.

***Micromus* sp.**

Micromus sp. was reared in the laboratory on *A. craccivora*. Twigs of cowpea with aphid colonies harbouring larvae of *Micromus* sp. were collected from unsprayed cowpea fields. The larvae were separated from the colonies and introduced individually into 5 cm glass vials with the aphid prey till pupation. The vials were replenished with the aphid daily. The pupae were kept together in a separate container and the freshly emerged adults were transferred to clean glass troughs provided with aphid prey and honey solution for mating and oviposition as described under coccinellids. The larvae were maintained in the troughs with sufficient prey till the fourth instar. From the fourth instar onwards, they were reared individually in separate vials as detailed above to avoid cannabalism. The third instar larvae were used for the study.

3.3.1.4 Preparation of Spray Solution

Oil emulsion

Ordinary bar soap were cut into small pieces and 5g of the sliced soap was dissolved in 500ml of water to prepare soap solution. Twenty ml of the plant oil was added to the soap solution with continuous stirring. The solution was made up to one litre to prepare 2 per cent oil emulsion.

Neem oil + garlic emulsion

Soap solution was prepared by dissolving 5g sliced ordinary washing soap in 500 ml of lukewarm water. Twenty ml of neem oil was added to it and mixed thoroughly to form an emulsion. Twenty gram of garlic was ground in 500 ml water, filtered through muslin cloth and the extract was mixed with neem oil emulsion to get one litre of 2 per cent neem oil-garlic emulsion.

Neem Seed Kernel Extract (NSKE)

Neem seed kernels were powdered and 50g of the powder was taken in a muslin pouch and soaked overnight in 500 ml water. The pouch was squeezed repeatedly till the outflow turned light brown. Soap solution was prepared by dissolving 5g bar soap in 500 ml water. The kernel extract was filtered and mixed thoroughly with the soap solution to prepare five per cent neem seed kernel extract.

Leaf / fruit extract

Fresh leaves / fruits of the respective plants were washed thoroughly ,chopped into small pieces and 50g of the material was homogenized with 500 ml water in a high speed blender .The macerated product was kept for twenty four hours and then strained through muslin cloth . The extract was made up to one litre using distilled water to prepare five per cent extract.

Synthetic Insecticides

The required quantity of chemical insecticides was weighed or pipetted and mixed with a small quantity of water and made up to one litre.

3.3.1.5 Assessment of Toxicity to Aphids

Chilli and cowpea were raised as described in 3.3.1.1. Sufficient numbers of thirty five- day- old plants were sprayed with the botanicals and insecticide solutions at required concentrations with a hand sprayer. Twigs of the treated plants were excised one, three, six, nine, twelve and fifteen days after treatment. The cut end of the twigs was covered with moistened cotton and inserted into small glass vials containing water. The twigs along with the vials were placed on petri plates with wet filter papers and covered with glass chimneys. Fifteen apterous adults were collected from the culture maintained in the laboratory with a fine camel hair brush and released on each of the twigs. The top end of the chimney was closed with a wet muslin cloth (Plate 1). Mortality of aphids at 24 hours after each release was recorded. The moribund aphids were also taken as dead. Three replications were maintained for each treatment.

3.3.1.6 Assessment of Toxicity to Predators

The two promising botanicals and synthetic insecticides identified in the experiment 3.3.1.5 were evaluated for their relative toxicity to the adults and larvae of the coccinellids viz., *M. sexmaculatus*, *C. transversalis*, *P. trinotatus*, *H. octomaculata*, *S. (P.) latemaculatus and C. septempunctata*, larvae of the syrphids *I. scutellaris*, *D. aegrota* and *P. serratus* and *Micromus* sp. in the laboratory.

Plate 1. Glass chimneys containing insecticide treated chilli and cowpea twigs exposed to (a) *A. gossypii* and (b) *A. craccivora* respectively in laboratory evaluation

Coccinellids

Cowpea leaves were sprayed uniformly with each of the botanical and insecticidal solution with a hand sprayer and dried under a ceiling fan. The dried leaves were spread in 15 x 8 cm plastic bowls. Fifteen larvae of the respective coccinellids were released in each of the bowls on the treated leaves and covered with a lid having aeration facility. The larvae were allowed to remain in contact with the sprayed leaves for 45 minutes, subsequent to which they were transferred to glass troughs and fed with their respective aphid prey as detailed in 3.3.1.3. The food was changed daily. A control treatment without any insecticidal spray was also maintained. Three replications were maintained for each treatment. Mortality was recorded one, two and three days after treatment. The toxicity of the insecticides to the adults of the predator was assessed through the same method.

Syrphids

Fifteen third instar larvae of syrphids were transferred to chilli leaves treated with insecticides and kept in plastic bowls and allowed to remain in contact with the sprayed leaves for 45 minutes. The larvae were then transferred to glass troughs for predation on *A. gossypii* as detailed in 3.3.1.3. Three replications were maintained for each treatment Mortality was recorded one, two and three days after treatment.

***Micromus* sp.**

Cowpea leaves treated with botanicals and synthetic insecticides were kept in plastic bowls and fifteen larvae of *Micromus* sp. were released and allowed to remain in contact for 45 minutes. The larvae were then transferred to glass troughs containing *A. craccivora* that served as food. Three replications were maintained for each treatment Mortality was recorded one, two and three days after treatment.

The mortality data of the predators were corrected with Abbott's (1925) formula.

3.3.2 Field Evaluation

Two field trials, one each on chilli and winged bean were conducted to evaluate the efficacy of the botanicals, NeemAzal T/S and neem oil + garlic-emulsion and the new molecules of synthetic insecticides, acetamiprid and imidacloprid in controlling *A. gossypii* and *A. craccivora*, respectively (Plate 2). The effects were compared with the insecticide, dimethoate and an untreated check. The experiments were laid out in randomized block design with six treatments and four replications. The treatments were as detailed below.

Treatments	Dose
T_1 - Neem Azal T/S	4ml/ l
T_2 - Neem oil + garlic-emulsion	2%
T_3 - Acetamiprid	0.002%
T_4 - Imidacloprid	0.003%
T_5 - Dimethoate	0.05%
T_6 - Untreated control	

3.3.2.1 Raising of Chilli

Nursery was raised in 1.0 m x 1.0 m plots. Plots of 4.0 m x 5.0 m were prepared in the mainfield and trenches of 30 cm width were taken 60 cm apart in each plot. One month old chilli (Variety – Jwalamuki) seedlings were transplanted at a spacing of 40 cm. The plants were maintained as per the Package of Practices Recommendations of KAU (2007). The first spray of botanicals and synthetic insecticides were given on the thirty fifth day after transplanting in synchronization with the appearance of aphids. A second spray was given on the fiftieth day after transplanting.

3.3.2.2 Raising of Winged Bean

Plots of 4.0 m x 5.0 m were prepared and trenches of 30 cm width were taken 125 cm apart in each plot. Seeds of winged bean variety Revathy were dibbled in the centre of the trenches at 50 cm spacing. The plants were maintained as per the Package of Practices

Chilli

Winged bean

Plate 2. Experimental plots of chilli and winged bean

Recommendations of KAU (2007). The first application of the insecticides was done on the fifty fifth day after sowing with the first appearance of aphids and a second application on the seventieth day after sowing.

3.3.2.3 Assessment of Pest Population

Five plants were selected at random and tagged in each plot leaving the border rows. The pests infesting the crop were noted and the population of the major pests was recorded from the observational plants one, three, seven and fifteen days after each spraying.

Aphids

Counts of aphids were taken from the terminal shoot up to 15 cm length and recorded.

Other Sucking Insects

The number of leafhoppers, thrips and white flies on three leaves from top, middle and bottom portions of the tagged plants were recorded. The number of pod bugs was recorded from the whole plant.

Pod borer

The number of larvae observed on the flower buds, flowers and pods were recorded.

3.3.2.4 Assessment of Natural Enemy Population

Ten plants were selected at random from each plot and population of coccinellids, chrysopids, hemerobiids, chamaemyiids, syrphids and spiders were recorded. Parasitoid population was assessed by 10 sweep net collection from each plot.

3.3.2.5 Estimation of Soil Invertebrates

The population of the soil invertebrates were estimated one, three, seven, fifteen and twenty one days after application of insecticides.

Earthworms

Three pits of 30 cm^3 were taken randomly from each plot and the soil in the pits were examined for recording the earthworm population. The soil lumps were broken and the sifted through the fingers to sort out the worms and the smaller worms were collected by passing through a sieve of 3-4 mm size. The worms were counted.

Macro -arthropods

Three samples of one kg soil were collected randomly from each plot and the population of the macro arthropods viz., soil coleopterans, termites, ants was estimated by direct visual counting.

Micro -arthropods

One kg soil sample along with litter were taken randomly from three different locations in each plot. Micro arthropods in the samples were extracted by Berlese-Tullgren funnel method (Macfadyen, 1961). One kg of soil along with the litter sample was placed on wire gauze over a steep sided funnel and the soil was heated gently using a 40 watts electric bulb for one day. The soil arthropods were collected in the collecting vial kept at the tail of the funnel containing water. The content in the collecting vial was directly transferred to a counting dish and the population of collembolans and mites were counted under a binocular microscope.

Microbial Population

One kg of soil sample was taken at 10 cm depth randomly from three locations in a plot. The total count of fungi, bacteria, actinomycetes was assessed by serial dilution plate technique (Johnson and Curl, 1972). The media compositions of different groups of microorganisms are given in Appendix I.

Serial dilution

One gram soil was added to 100 ml of sterilized distilled water in a 250 ml conical flask under aseptic condition and shaken for 30 minutes in orbital shaker for uniform mixing and for obtaining 10^{-2} dilution. One ml of 10^{-2} dilution was transferred to 99 ml sterile water blank with a sterile pipette and mixed well to obtain a 10^{-4} dilution. One ml of the 10^{-4} dilution was further transferred to 99 ml of sterile water blank and mixed well to obtain a 10^{-6} dilution . One ml aliquots of 10^{-4} dilution were transferred to sterile petri dishes for enumeration of fungi and actinomycetes. Similarly, one ml aliquot of 10^{-6} dilution was used for the estimation of bacteria. Melted Martins rose bengal agar, soil extracts agar and glycerol asparagine agar media were poured into these petridishes @ 20 ml / dish for the estimation of fungi, bacteria and actinomycetes, respectively. The plates were incubated at 28° C. Colony counts of bacteria, fungi and actinomycetes were taken after 24, 72 and 154 hours, respectively.

3.3.2.6 Estimation of Insecticide Residues

The harvest time residues of acetamiprid, dimethoate and imidacloprid in chilli and winged bean fruits were estimated in the Pesticide Residue Laboratory under the All India network Project on pesticide residues at College of Agriculture, Vellayani. Chilli and winged bean fruit samples were collected from each treatment during the first three harvests at 5 days interval to determine residues.

Acetamiprid

The fruit samples were chopped into small pieces and twenty gram of the homogenized sample was extracted with 100 ml methanol in a rotary shaker for one hour. The extract was filtered through Buchner funnel. The extraction was repeated two more times with 25 ml methanol each time. The filtrate was concentrated to 5 ml in a rotary vacuum evaporator at 40° C. The extract was taken in a 500 ml separatory funnel containing 100 ml of 5 per cent sodium chloride solution. The extract was then partitioned with hexane (50 + 50 ml) twice and the hexane layer was discarded. The extract was further partitioned with dichloromethane (100 + 100 ml) two times and collected by passing through anhydrous sodium sulphate. The extract was concentrated to near dryness using rotary vacuum evaporator at 35° C. The extract was cleaned up by column chromatography (1.5 cm i.d x 50 cm length glass column) packed with florisil® (9g) and hexane. The column was prewashed with 20 ml of mixed solvent of acetone and hexane (20:80 v/v) and discarded. The residue was poured on the top of the column by means of a pipette and allowed to percolate. The residue was eluted with 120 ml of solvent mixture of acetone and hexane (50:50 v/v). The elutant was concentrated to dryness and diluted with 2ml of acetone before GC analysis.

Operating conditions of GC

Instrument	: Gas chromatography (GC- Shimadzu 2010 A) with Ni ^{63}ECD
Column	: 5% PEG HT/ chrmosorb W HP, 60- 80 mesh, 3.2 mm i.d x 1 m
Temperature of	
Injector/ Detector	: 320° C
Column	: 260° C
Carrier gas: N_2	: 30-40 ml/min

Dimethoate

The fruit samples were cut into small pieces and a representative sample of 100 g each were extracted with (2 x 100 ml portions) acetone in a high speed blender. The contents were filtered through Buchner funnel using filter paper No.1. The filtrates were combined and evaporated to about 20 ml using a rotary vacuum evaporator and transferred to separatory funnel. The extract was diluted with 200 ml (2 x 100) of hexane and dichloromethane (1:1) mixture. After shaking well, the aqueous layer was again extracted with 30 ml sodium chloride solution and partitioned twice (2 x 50 ml) with dichloromethane. The extract was passed through anhydrous sodium sulphate for removal of traces of moisture and evaporated to dryness. The dried residues were dissolved in 10 ml hexane and passed through a glass chromatographic column (1.5 cm i.d x 50 cm length) containing florisil (4 g) and sodium sulphate (2 g). The column was eluted with 100 ml mixture of hexane and acetone (9:1). The cleaned extract was evaporated to dryness and finally dissolved in 2 ml hexane for determination of dimethoate residues using gas chromatograph (GC – Shimadzu 2010 A) equipped with FPD.

Operating conditions of GC

Name of the column	: DB-5
Temperature of	
Injector	: 250° C
Column	: 100° C-15° C-160° C- 8° C -250° C
Detector	: 290° C
Column flow	: 1.50 ml/min
Injection volume	: 2 μ l
LOD	: 0.05 ppm
LOQ	: 0.01 ppm

Imidacloprid

The weighed fruit samples (100 g) were homogenized with acetonitrile (250 ml) by using high speed blender and filtered through Buchner funnel. After repeated washing, the pooled acetonitrile extract was evaporated to near dryness (5 ml) using rotary vacuum evaporator and the aqueous remainder was treated with 50 ml of saturated sodium chloride and 150 ml of hexane (three 50 ml portions) in a 1000 ml separating funnel. After shaking well, the lower aqueous phase was collected and to which 100 ml of hexane:ethyl acetate (98:2 V/V) was added and shaken well. Once again, the lower aqueous phase was collected and partitioned with three 50 ml portions of dichloromethane. The pooled dichloromethane extract was passed through anhydrous sodium sulphate and evaporated to near dryness (5 ml) and the aqueous remainder was dissolved in 10 ml of ethyl acetate and the same was added to a glass chromatographic column (1.5 cm i.d x 50 cm length) containing 4.5g of florisil® deactivated with 5 per cent water and sandwiched with 2 cm layer of anhydrous sodium sulphate. The column was prewashed with 20 ml ethyl acetate and thereafter, the extract was eluted out of the column with 50 ml acetonitrile. The eluate was concentrated to dryness, the residue dissolved in 2 ml acetonitrile (HPLC grade) and fed into High Performance Liquid

Chromatography (HPLC), Schimadzu LC 20AT with PDA detector with the following operating parameters.

Mobile phase	:	Acetonitrile (HPLC grade): Water (HPLC grade) (35:65 V/V)
Column	:	Luna C-18
Flow rate	:	1 ml min^{-1}.
Wave length	:	270 nm
Quantity injected	:	20 µl (fixed loop)
LOD	:	0.01 ppm
LOQ	:	0.02 ppm

3.3.2.7 Yield

The weight of chilli and winged bean harvested were recorded and expressed as kg/plot. The benefit cost ratio was worked out.

3.3.2.8 Statistical Analysis

The data obtained from the laboratory and field experiments were subjected to statistical analysis by applying analysis of variance technique of Panse and Sukhatme (1978).

Results

4. RESULTS

Aphids are an intimidating group of sucking pests found in agro ecosystems. At least one aphid species infests almost every major crop.Their incomparable reproductive capacity makes them well suited to colonize plants grown in monoculture. Information on the species infesting a crop and their population dynamics are imperative for the adoption of apt management measures. The results of the studies conducted on the aphid species in the vegetable ecosytem in Thiruvananthapuram district of Kerala, their population dynamics and sensitivity to insecticides are presented in Tables 6 to 86.

4.1 Aphids infesting vegetables

Eight species of aphids belonging to four genera and two tribes under the sub family Aphidinae were recorded from 32 vegetables in Thiruvananthapuram district of Kerala. The species recorded under the tribe Aphidini included *A. gossypii* (melon aphid), *A. craccivora* (cowpea aphid), *A. spiraecola* (spirea aphid), *A. nerii* (oleander aphid), *A. fabae* (bean aphid) and *H. setariae* (rusty plum aphid) (Plate 3). *M. persicae* (green peach aphid) and *L. erysimi* (mustard aphid) were the species recorded under the tribe Macrosiphini (Plate 4).

4.1.1. Description of the Aphid Species

The species collected are well described. Hence, detailed description of the species was not attempted. Appearance of the live (Plate 5) aphid and other simple characters aiding in the provisional identification of the species are dealt with.

Aphis gossypii

The colour of the apterae varies from blackish green to green or pale yellow to almost white depending on the host plant from which they are recorded. The alatae forms differ from dark green to almost black or pale yellow to almost white colour with double oblique vein on the hind wings.

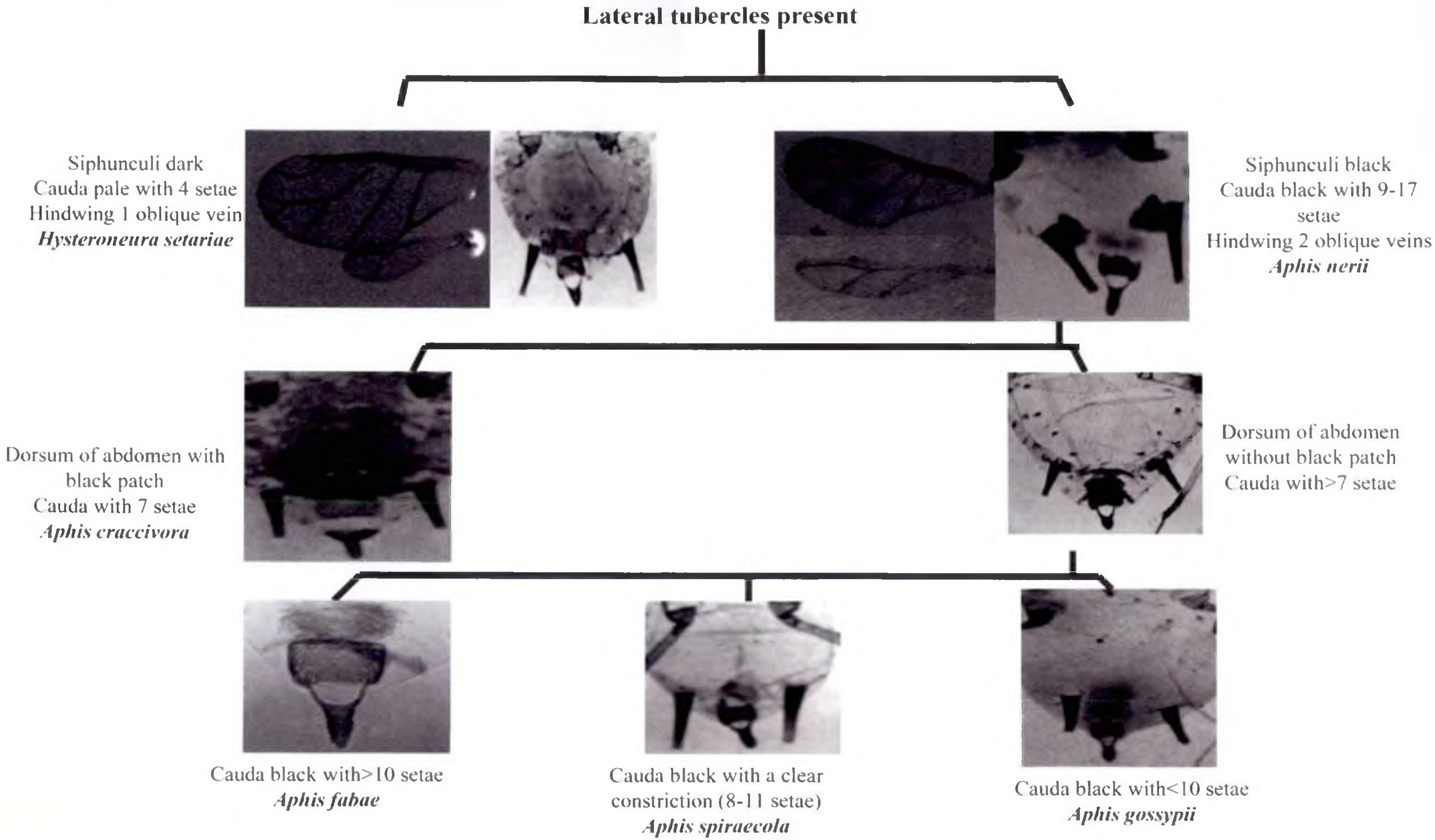
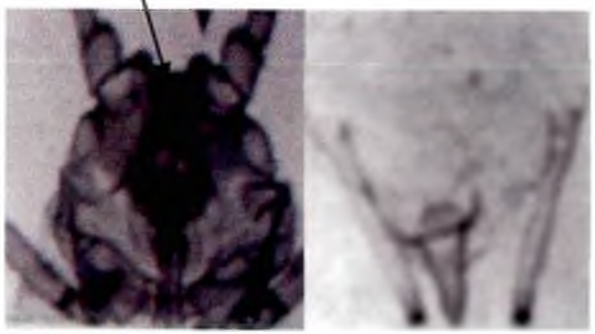


Plate 3. Pictorial key to (Aphidini) six aphid species that commonly colonize vegetable ecosystem in Thiruvananthapuram

Lateral tubercles absent

Antennal tubercles well developed and convergent and head spinulose
Myzus persicae



Antennal tubercles well developed and divergent and head not spinulose
Lipaphis erysimi

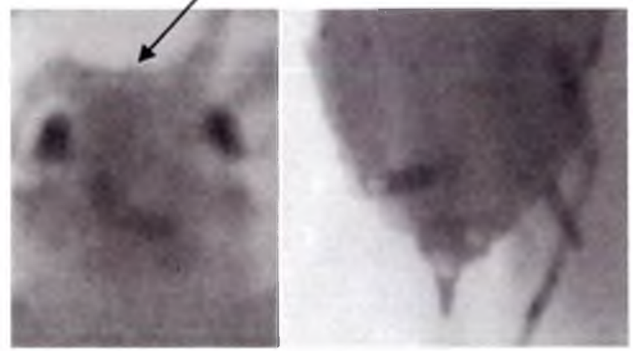


Plate 4. Pictorial key to (Macrosiphini) two aphid species that commonly colonize vegetable ecosystem in Thiruvananthapuram

Aphis gossypii

Aphis craccivora

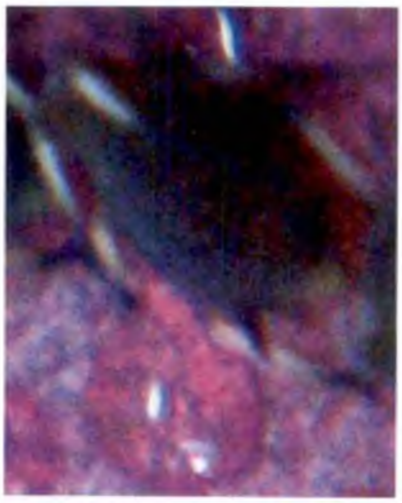
Aphis spiraecola

Myzus persicae

Lipaphis erysimi

Aphis nerii

Aphis fabae



Hysteroneura setariae

Plate 5. Aphid species recorded from different vegetables

The siphunculi are dark and the cauda pale or dusky. The colour of the nymphs vary from light green to dark green. Antennal tubercles are undeveloped.

Aphis craccivora

The apterae are always shiny black with large black patch on the dorsum of abdomen and strikingly white legs. The alatae are shiny black with lateral areas and hind wings with double oblique vein. Siphunculi and cauda are black. Nymphs may be light brownish. Antennal III, IV and basal half of V^{th} segments are pale. Young colonies are concentrated on growing points of the host plant. Antennal tubercles are undeveloped.

Aphis spiraecola

The apterae are bright yellowish green to apple green. The alatae have dark brown head and thorax, yellowish green abdomen with a dusky lateral patch on each segment and hind wings with double oblique vein. Both the siphunculi and cauda are dark brown to black. Nymphs are yellowish green to pale green. Legs and antennae are mainly pale. Antennal tubercles are undeveloped. The aphid resembles *A. gossypii* but can be distinguished from it by the black cauda as compard to the pale or dusky cauda of *A. gossypii*.

Lipaphis erysimi

The apterae are small to medium-sized, yellowish green, grey green, or olive green, with light wax coating. The alatae have a dusky green abdomen with conspicuous dark lateral sclerites, and hind wings with double oblique vein. The colour of the nymphs varies from dull green to grey green. Siphunculi are dark at apex and pale at distal. Cauda is pale and tongue-shaped. Antennal tubercles are well developed and divergent.

Myzus persicae

The apterae are small to medium-sized, whitish green, pale yellow-green, grey-green, mid- green, pink, red or almost black. The alatae have a black central dorsal patch on the abdomen and hind wings with double oblique vein. Siphunculi are cylindrical to slightly swollen and pale in colour with dark tip. Cauda is pale to dusky and tarsi may be dark. Nymphs may be whitish green. Antennal tubercles are well developed and convergent.

Aphis nerii

The apterae are bright yellow with black siphunculi and cauda. The antennae and legs are also predominantly dark. The alatae are yellow with dark wing veins and pigmented thorax and hind wings with double oblique vein. Nymphs are light yellow to dark yellow. Antennal tubercles are undeveloped.

Aphis fabae

The apterae are always dull black due to waxy covering. The alatae are dull black with dark lateral areas and hind wings with double oblique vein. Siphunculi and cauda are black. Nymphs are dark brown to black. Cauda is thick black than siphunculi. Antennal tubercles are undeveloped.

Hysteroneura setariae

The apterae are dark reddish brown, apical area of tibiae dark, siphunculi dark to almost black and with a long pale cauda. Greenish-grey abdomen of alatae has hind wings with a single oblique vein. Antennal tubercles are undeveloped.

4.1.2 Host Plants of the Aphids

Besides the 32 vegetables, 122 plants inclusive of weeds in the crop field, and other plants seen in the border and adjacent areas were recorded as host plants of the different species of aphids.

Aphis gossypii

The melon aphid, *A. gossypii* infesting twenty vegetables distributed in seven families was the predominant aphid observed in the vegetable ecosystem of Thiruvananthapuram district (Table 6 and Plate 6). The pest was recorded from 10 cucurbitaceous vegetables viz., *B. hispida, C. lanatus, C. grandis, C. sativus, C. melo* var. *Conomon, C. moschata, L. siceraria, L. actangula, M. charantia* and *T. anguina* and four solanaceous vegetables viz., *C. annuum, C. frutescens, L. esculentum* and *S. melongena*. The other vegetable host plants included *P. tetragonolobus* and *V. unguiculata* (Fabaceae), *A. esculentus* (Malvaceae), *M. oleifera* (Moringaceae), *A. tricolor* (Amaranthaceae) and *D. carota* L. var. *sativa* (Umbelliferae). Attack of the hemipteran was recorded from the leaves and tender shoots of all the vegetables. Additionally, the pest was noted infesting the flowers of *A. tricolor, C. annuum*, C. *grandis*, *S. melongena*, *P. tetragonolobus* and *T. anguina* and fruits of *C. annuum*, C. *grandis*, and *P. tetragonolobus*. The intensity of infestation of the aphid was high in *A. esculentus, C. annuum* and *C. grandis*. Medium infestation was noticed in *A. tricolor, C. frutescens, C. sativus, L. esculentum, M. charantia, P. tetragonolobus, S. melongena* and *T. anguina*. While the extent of infestation was low in *B. hispida, C.lanatus, C. melo* var. *Conomon, C. moschata, L. siceraria, L. actangula, M. oleifera* and *V. unguiculata*, the occurrence of the pest was very low in *D. carota* L. var. *sativa*.

Sixty other plants distributed in 28 families seen in the vegetable ecosystem were recorded as host plants of *A. gossypii*. Among the plants recorded, 45 were weeds observed in different vegetable fields (Plate 7). Six of the weed plants viz., *A. conyzoides, E. prostrata, E. sonchifolia,*

Table 6. Host plants of *Aphis gossypii* recorded from Thiruvananthapuram district

Sl.No.	Host plant	Family	Plant part infested	Intensity of infestation
	Vegetables			
1	*Abelmoschus esculentus* (L.) Moench	Malvaceae	L, Sh, Ft	High
2	*Amaranthus tricolor* Linn.	Amaranthaceae	L, Sh, If	Medium
3	*Benincasa hispida* (Thunb.) Cogn.	Cucurbitaceae	L, Sh	Low
4	*Capsicum annuum* Linn.	Solanaceae	L, Sh, If, Ft	High
5	*Capsicum frutescens* Linn.	Solanaceae	L, Sh	Medium
6	*Citrullus lanatus* (Thunb.) Mansf.	Cucurbitaceae	L, Sh	Low
7	*Coccinia grandis* (L.) Voigt*	Cucurbitaceae	L, Sh, If, Ft	High
8	*Cucumis sativus* Linn.	Cucurbitaceae	L, Sh	Medium
9	*Cucumis melo* var. *conomon* Mak.	Cucurbitaceae	L, Sh	Low
10	*Cucurbita moschata* (Duch.) Poir.	Cucurbitaceae	L, Sh	Low
11	*Daucus carota* L. var. *sativa* DC.	Umbelliferae	L, Sh	Very low
12	*Lagenaria siceraria* (Mol.) Standl.	Cucurbitaceae	L, Sh	Low
13	*Luffa actangula* (L.) Rorb.	Cucurbitaceae	L, Sh	Low
14	*Lycopersicon esculentum* Mill.	Solanaceae	L, Sh	Medium
15	*Momordica charantia* Linn.	Cucurbitaceae	L, Sh	Medium
16	*Moringa oleifera* Lam.*	Moringaceae	L, Sh	Low
17	*Psophocarpus tetragonolobus* (L.) DC. ®	Fabaceae	L, Sh, If, Ft	Medium
18	*Solanum melongena* Linn.	Solanaceae	L, Sh, If	Medium
19	*Trichosanthes anguina* Linn.	Cucurbitaceae	L, Sh, If	Medium
20	*Vigna unguiculata* (L.)Walp.	Fabaceae	L, Sh	Low

Sl.No.	Host plant	Family	Intensity of infestation
	Weeds		
1	*Abutilon indicum* (L.) Sweet	Malvaceae	Medium
2	*Acalypha indica* Linn. *	Euphorbiaceae	Low
3	*Ageratum conyzoides* Linn.*	Asteraceae	High
4	*Alternanthera Philoxeroides* Mart. ®	Amaranthaceae	Medium
5	*Alternanthera sessilis* (L.)DC. ®	Amaranthaceae	Very low
6	*Amaranthus spinosus* Linn.	Amaranthaceae	Low
7	*Amaranthus viridis* Linn.	Amaranthaceae	Medium
8	*Asystacia gangetica* (L.) T. And. ®	Acanthaceae	High
9	*Barleria motana* Linn. ®	Acanthaceae	High
10	*Barleria prionitis* Linn. ®	Acanthaceae	Medium
11	*Boerhavia repens* Linn. ®	Nyctaginaceae	High
12	*Cardiospermum halicacabum* Linn. ®	Sapindaceae	Medium
13	*Catharanthus pusillus* (Murry) G. Don. ®	Apocynaceae	Medium
14	*Catharanthus roseus* (L.) G. Don. *	Apocynaceae	High
15	*Centella asiatica* Urban. ®	Apiaceae	Low
16	*Cleome burmanni* Wight & Arn. ®	Cleomaceae	Low
17	*Commelina benghalensis* Linn. ®	Commelinaceae	Low
18	*Corchorus aestuans* Linn. ®	Tiliaceae	Medium

Table 6. continued

Sl.No.	Host plant	Family	Intensity of infestation
19	*Cyanotis axillaris* Schult. ®	Commelinaceae	Low
20	*Cyanotis cucullata* Kunth. ®	Commelinaceae	Medium
21	*Cyperus iria* Linn. ®	Cyperaceae	Low
22	*Eclipta prostrata* Linn. ®	Asteraceae	Low
23	*Emilia sonchifolia* (L.)DC.*	Asteraceae	Low
24	*Euphorbia hirta* Linn.*	Euphorbiaceae	Low
25	*Glinus lotoides* Linn. ®	Molluginaceae	Low
26	*Hemidesmus indicus* (L.)R.Br. ®	Asclepiadaceae	Low
27	*Justicia prostrata* Gamble. ®	Acanthaceae	Low
28	*Leucas aspera* (Willd.) ®	Lamiaceae	High
29	*Ludwigia perennis* Linn. ®	Onagraceae	Medium
30	*Mollugo nudicaulis* Lam. ®	Molluginaceae	Medium
31	*Ocimum canum* Sims. ®	Lamiaceae	Low
32	*Oldenlandia affinis* (Roemer &Schutes.)DC. ®	Rubiaceae	Low
33	*Oxalis corniculata* Linn. ®	Oxalidaceae	Low
34	*Phyllanthus amarus* Webster *	Euphorbiaceae	Medium
35	*Physalis minima* Linn. ®	Convolvulaceae	Low
36	*Portulaca oleraceae* Linn. ®	Portulacaceae	Low
37	*Portulaca quadrifida* Linn. ®	Portulacaceae	Medium
38	*Rotala densiflora* Koehne. ®	Lythraceae	Very low
39	*Ruellia tuberosa* Linn. ®	Acanthaceae	Low
40	*Scoparia dulcis* Linn. ®	Scrophulariaceae	Low
41	*Sida acuta* Burm.f.	Malvaceae	Low
42	*Sida cordifolia* Linn.*	Malvaceae	Low
43	*Synedrella nodiflora* Gaertner ®	Asteraceae	Low
44	*Tridax procumbens* Linn.*	Asteraceae	High
45	*Vernonia cinerea* (L.) Less *	Asteraceae	Medium
46	*Waltheria indica* Linn. ®	Sterculiaceae	Low
	Other Plants		
1	*Bacopa monnieri* (L.) Pennel. ®	Scrophulariaceae	Low
2	*Costus speciosus* (Koenig) Smith®	Zingiberaceae	Medium
3	*Crossandra infundibuliformis* Nees®	Acanthaceae	Low
4	*Duranta erecta* Linn. ®	Verbenaceae	Medium
5	*Gloriosa superba* Linn. ®	Liliaceae	Very low
6	*Hibiscus bifurcatus* Linn. ®	Malvaceae	Low
7	*Hibiscus vitifolius* Linn. ®	Malvaceae	Medium
8	*Ixora* sp. ®	Rubiaceae	Low
9	*Lantana camera* Linn.*	Verbenaceae	Low
10	*Ocimum tenuiflorum* L.	Lamiaceae	Low
11	*Stachytarpheta jamaicensis* (L.)Vahl. ®	Verbenaceae	Very low
12	*Wedelia triloba* (Rich.)Bello®	Asteraceae	Low
13	*Withania somnifera* (L.) Dunal.*	Solanaceae	Medium
14	*Zinnia peruviana* Linn. ®	Asteraceae	Medium

L-Leaf, Sh-Shoot, If- Inflorescence / Flower Ft-Fruit / Pod,
® First record from South India * First record from Kerala

Abelmoschus esculentus

Capsicum annuum

Coccinia grandis

Daucus carota

Lycopersicon esculentum

Momordica charantia

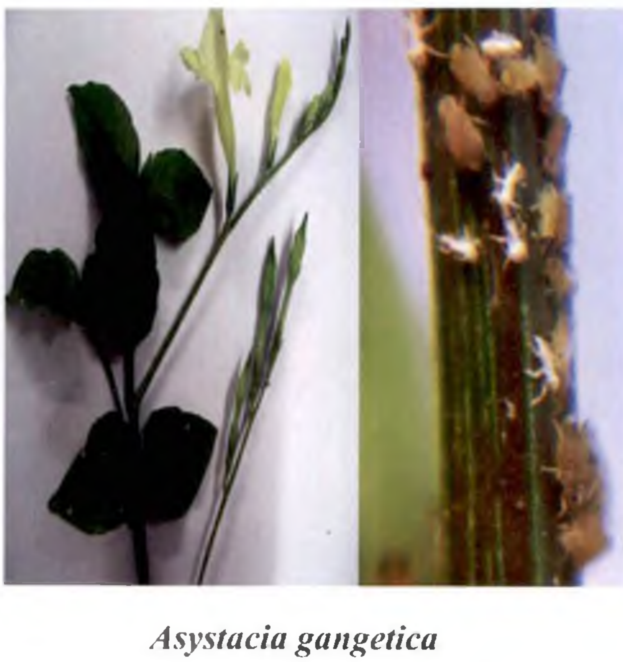
Plate 6. Vegetables infested by *Aphis gossypii*

Abutilon indicum

Acalypha indica

Ageratum conyzoides

Amaranthus viridis



Asystacia gangetica

Euphorbia hirta

Plate 7. Weeds infested by *Aphis gossypii*

Barleria motana

Barleria prionitis

Boerhavia repens

Cardiospermum halicacabum

Catharanthus pusillus

Centella asiatica

Plate 7 (continued). Weeds infested by *Aphis gossypii*

Cleome burmanni

Commelina benghalensis

Cyanotis axillaris

Cyperus iria

Hemidesmus indicus

Emilia sonchifolia

Plate 7 (continued). Weeds infested by *Aphis gossypii*

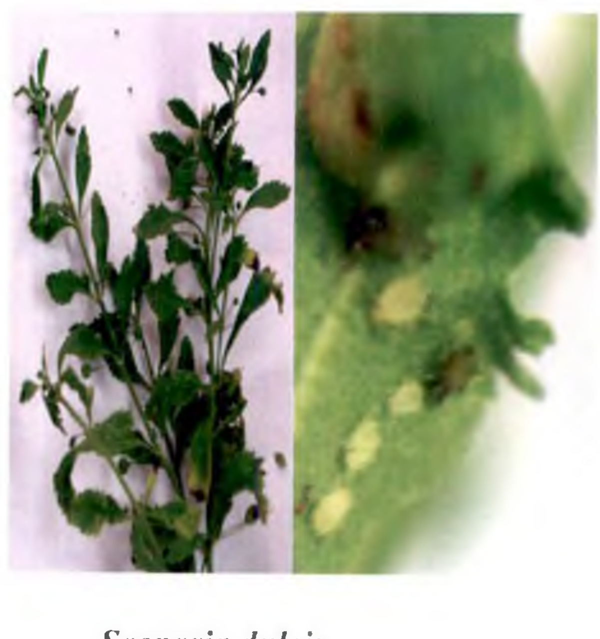
Oxalis corniculata

Phyllanthus amarus

Physalis minima

Portulaca oleraceae

Ruellia tuberosa



Scoparia dulcis

Plate 7 (continued). Weeds infested by *Aphis gossypii*

Leucas aspera

Ludwigia perennis

Ocimum canum

Oldenlandia affinis

Sida acuta

Sida cordifolia

Synedrella nodiflora

Tridax procumbens

Vernonia cinerea

Plate 7 (continued). Weeds infested by *Aphis gossypii*

S. nodiflora, T. procumbens and *V. cinerea* belonged to the family Asteraceae. While five of the weed hosts viz., *A. gangetica, B. motana, B. prionitis, J. prostrata,* and *R. tuberosa* were from Acanthaceae, four viz., *A. philoxeroides, A. sessilis, A. spinosus* and *A. viridis* were from Amaranthaceae. Three plants were noticed from the families Malvaceae (*A. indicum, S. acuta* and *S. cordifolia*), Commelinaceae (*C. benghalensis, C. axillaris* and *C. cucullata*), Verbenaceae (*D. erecta, L. camera* and *S. jamaicensis*) and Euphorbiaceae (*A. indica, E. hirta* and *P. amarus*). Two plants each were recorded from Lamiaceae (*L. aspera* and *O. canum*), Apocynaceae (*C. pusillus* and *C. roseus*), Portulacaceae (*P. oleraceae* and *P. quadrifida*) and Molluginaceae (*M. nudicaulis* and *G. lotoides*). The other weed host plants identified viz., *O. affinis* , *S. dulcis, C. asiatica, H. indicus, C. iria, P. minima, C. burmanni, B. repens, R. densiflora, L. perennis, O. corniculata, W. indica, C. halicacabum, C. aestuans* were from Rubiaceae, Scrophulariaceae, Apiaceae, Asclepiadaceae, Cyperaceae, Convolvulaceae., Cleomaceae, Nyctaginaceae, Lythraceae, Onagraceae, Oxalidaceae, Sterculiaceae, Sapindaceae and Tiliaceae respectively.

Other than the weeds, plants like *W. triloba, Z. peruviana* (Asteraceae) *C. infundibuliformis* (Acanthaceae) *H. bifurcates, H. vitifolius* (Malvaceae) *O. tenuiflorum* (Lamiaceae), *Ixora* sp (Rubiaceae), *B. monnieri* (Scrophulariaceae), *G. superba* (Liliaceae), *W. somnifera* (Solanaceae) and *C. speciosus* (Zingiberaceae) seen on the bunds and nearby areas were also seen to host the aphid (Plate 8).

High infestation was observed on *A. conyzoides, B. motana, B. repens, A. gangetica, C. roseus, L. aspera* and *T. procumbens* whereas medium infestation was noticed on *A. indicum, A. philoxeroides, A. viridis, B. prionitis, C. halicacabum, C. pusillus, C. aestuans, C. speciosus, C. cucullata, D. erecta, H. vitifolius, L. perennis, M. nudicaulis, P. amarus, P. quadrifida, V. cinerea, W. somnifera* and *Z. peruviana*. Only low infestation of the aphid was recorded in *A. indica, A. spinosus, B. monnieri, C. asiatica, C. burmanni, C. benghalensis, C. infundibuliformis, C. axillaris,*

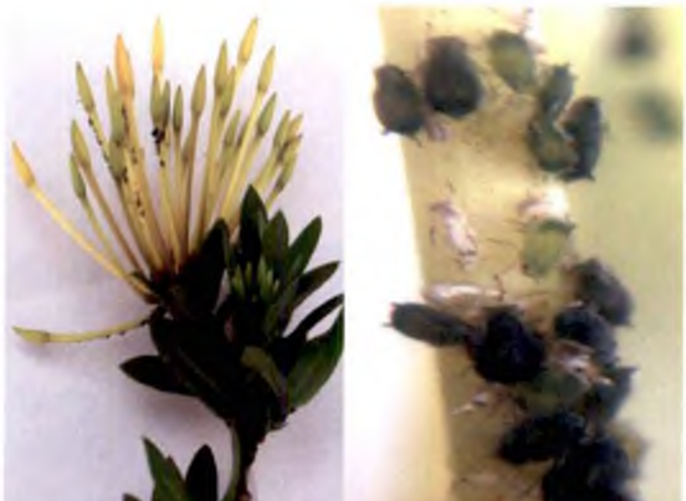
Bacopa monnieri

Duranta erecta

Gloriosa superba

Hibiscus bifurcatus

Hibiscus vitifolius



Ixora sp.

Plate 8. Other plants infested by *Aphis gossypii*

Lantana camera

Ocimum tenuiflorum

Stachytarpheta jamaicensis

Weddelia triloba

Withania somnifera

Zinnia peruviana

Plate 8 (continued). Other plants infested by *Aphis gossypii*

C. iria, E. prostrata, E. sonchifolia, E. hirta, G. lotoides, H. bifurcates, H. indicus, Ixora sp, *J. prostrata, L. camera, O. canum, O. tenuiflorum, O. affinis, O. corniculata, P. minima, P. oleraceae, R. tuberose, S. dulcis, S. acuta, S. cordifolia, S.nodiflora, W. indica* and *W. triloba. A. sessilis, G. superba, R. densiflora* and *S. jamaicensis* had only very low infestation.

Aphis craccivora

Next to *A. gossypii,* the cowpea aphid *A. craccivora* dominated in the vegetable ecosystem (Table 7). Nine vegetables were recorded as hosts of *A. craccivora* of which *C. gladiata, C. tetragonoloba, L. purpureus, P. vulgaris, P. tetragonolobus, S. grandiflora* and *V. unguiculata* were from Fabaceae family. *A. tricolor* and *M. oleifera* belonged to amaranthaceae and moringaceae, respectively (Plate 9). The occurrence of the aphid was noted on leaf, shoot and flowers in all the vegetables. With the exception of *A. tricolor, M. oleifera* and *S. grandiflora* the aphid colonies were observed on the fruits of other vegetables too. Infestation of the aphid was high in *P. tetragonolobus* and *V. unguiculata*. Medium infestation was observed in *A. tricolor, M. oleifera C. tetragonoloba* and *L. purpureus*, whereas low infestation was noticed on *C. gladiata, P. vulgaris* and *S. grandiflora*

Twenty nine other plants were infested by *A. craccivora,* of which 20 weeds were observed in different vegetable fields. Fifteen of the weeds viz., *A. indica, A. rugosus, C. ternatea, D. dischotomum, D. triflorum, I. hirsuta, I. tinctoria, I. tirta, M. pudica, R. minima, T. purpurea, T. tinctoria, T. terrestris, V. luteola* and *V. trilobata* belonged to Fabaceae (Plate 10). The other weed host plants recorded included *J. tranquedariensis* (Acanthaceae), *T. portulacastrum* (Aizoaceae), *P. maderaspatensis* (Euphorbiaceae), *W. indica* (Sterculiaceae) and *P. elongata* (Polygalaceae).

Among the other plants seen in the vicinity, excepting *H. indicum* (Broaginaceae) all the other plants viz., *C. auriculata, C. occidentalis, C. pallida, C. verucosa, G. maculata, S. aculeata, S. guianensis* and *S. scabra* were from Fabaceae (Plate11). The intensity of infestation was high in *A. indica, C. ternatea, C. pallida, G. maculata, I. tinctoria, P. maderaspatensis* and

Table 7. Host plants of *Aphis craccivora* recorded from Thiruvananthapuram district

Sl.No.	Host plant	Family	Plant part infested	Intensity of infestation
	Vegetables			
1	*Amaranthus tricolor* Linn.	Amaranthaceae	L, Sh, If	Medium
2	*Canavalia gladiata* (Jack) DC.*	Fabaceae	Sh, If, Ft	Low
3	*Cyamopsis tetragonoloba* (L.) Taub.	Fabaceae	Sh, If, Ft	Medium
4	*Lablab purpureus* (L.) Sweet	Fabaceae	Sh, If, Ft	Medium
5	*Moringa oleifera* Lamk	Moringaceae	L, Sh, If	Medium
6	*Phaseolus vulgaris* Linn.	Fabaceae	Sh, If, Ft	Low
7	*Psophocarpus tetragonolobus* (L.) DC.*	Fabaceae	L,Sh, If, Ft	High
8	*Sesbania grandiflora* L. *	Fabaceae	L, Sh, If	Low
9	*Vigna unguiculata* (L.) Walp.	Fabaceae	L, Sh, Ft	High

Sl.No.	Host plant	Family	Intensity of infestation
	Weeds		
1	*Aeschynomene indica* Linn. ®	Fabaceae	High
2	*Alysicarpus rugosus* DC. ®	Fabaceae	Medium
3	*Clitoria ternatea* Linn.	Fabaceae	High
4	*Desmodium dischotomum* (Willd.) DC. ®	Fabaceae	Low
5	*Desmodium triflorum* (L.) DC. ®	Fabaceae	Low
6	*Indigofera hirsuta* Linn. ®	Fabaceae	Medium
7	*Indigofera tinctoria* Linn. ®	Fabaceae	High
8	*Indigofera tirta* Linn.	Fabaceae	Low
9	*Justicia tranquedariensis* Linn.f. ®	Acanthaceae	Low
10	*Mimosa pudica* Linn.*	Fabaceae	Low
11	*Phyllanthus maderaspatensis* Linn. ®	Euphorbiaceae	High
12	*Polygala elongata* Klein ex Willd. ®	Polygalaceae	Medium
13	*Rhynchosia minima* (L.) DC. ®	Fabaceae	Medium
14	*Tephrosia purpurea* (L.) Pers.	Fabaceae	Low
15	*Tephrosia tinctoria* (L.)Pers. ®	Fabaceae	Medium
16	*Trianthema portulacastrum* Linn. ®	Aizoaceae	High
17	*Tribulus terrestris* Linn.	Fabaceae	Low
18	*Vigna luteola* Jacq. ®	Fabaceae	Medium
19	*Vigna trilobata* (L.) Verdc. ®	Fabaceae	Low
20	*Waltheria indica* Linn. ®	Sterculiaceae	Low
	Other Plants		
1	*Cassia auriculata* Linn.	Fabaceae	Very low
2	*Cassia occidentalis* Linn.	Fabaceae	Very low
3	*Crotolaria pallida* Aiton®	Fabaceae	High
4	*Crotolaria verucosa* Linn. ®	Fabaceae	Low
5	*Gliricidia maculata* (Jacq.) Kunth	Fabaceae	High
6	*Heliotropium indicum* Linn. ®	Boraginaceae	Very low
7	*Sesbania aculeata* Linn.*	Fabaceae	Low
8	*Stylosanthes guianensis* Linn. ®	Fabaceae	Low
9	*Stylosanthes scabra* Linn. ®	Fabaceae	Very low

L-Leaf, Sh-Shoot, If- Inflorescence / Flower Ft-Fruit / Pod,
® First record from South India * First record from Kerala

Canavelia gladiata

Cyamopis tetragonoloba

Phaseolus vulgaris

Vigna unguiculata

Psophocarpus tetragonolobus

Plate 9. Vegetables infested by *Aphis craccivora*

Aeschynomene sensitiva

Clitoria ternatea

Desmodium dischotomum

Desmodium triflorum

Indigofera hirsuta

Indigofera tinctoria

Justicia tranquedariensis

Mimosa pudica

Plate 10. Weeds infested by *Aphis craccivora*

Polygala elongata

Phyllanthus maderaspatensis

Tephrosia purpurea

Tephrosia tinctoria

Trianthema protulacastrum

Vigna trilobata

Plate 10 (continued) . Weeds infested by *Aphis craccivora*

Cassia occidentalis

Crotolaria pallida

Heliotropium indicum

Sesbania aculeata

Plate 11. Other plants infested by *Aphis craccivora*

T. portulacastrum and medium in *A. rugosus, I. hirsuta, R. minima, P. elongata, T. tinctoria* and *V. luteola*. Contrarily, the intensity of infestation was low in *C. verucosa, D. dischotomum, D. triflorum, I. tirta, J. tranquedariensis, M. pudica, S. aculeata, S. guianensis, T. purpurea, T. terrestris, V. trilobata* and *W. indica*. Very low infestation was seen in *C. auriculata, C. occidentalis, H. indicum* and *S. scabra*.

Aphis spiraecola

Nine vegetables belonging to six families were infested by *A. spiraecola* (Table 8 and Plate 12). The vegetables included *A. tricolor* (Amaranthaceae), *C. sativus, C. grandis, M. charantia* (Cucurbitaceae), *C. tetragonoloba, P. tetragonolobus* (Fabaceae), *M. oleifera* (Moringaceae) and *M. koeingii* (Rutaceae) which showed low rate of infestation and *S. androgynus* (Euphorbiaceae) recording very low occurrence of the pest. In all the plants infestation was mostly confined to the leaf and shoot. The aphid was also observed infesting the flowers of *C. sativus* and *C. grandis* and fruits of *P. tetragonolobus*.

Apart from the vegetables, *A. spiraecola* was also recorded from 27 other plants, of which 22 were weeds distributed in 11 families (Plate 13). Majority of the plant taxa belonged to Amaranthaceae (*A. lanata, A. tomentosa, A. nodiflora* and *A. sessilis*), Asteraceae (*A. conyzoides, C. odorata, T. procumbens* and *V. cinerea*) and Euphorbiaceae (*E. heterophylla, E. hirta, P. amarus* and *P. maderaspatensis*). Two plants each were recorded from the families Rubiaceae (*S. latifolia* and *S. pusilla*), Malvaceae (*M. coromandelianum* and *S. cordifolia*) and Verbenaceae (*C. viscosum* and *C. paniculatum*). The other weed host plants identified included *J. prostrata* (Acanthaceae), *I. tirta* (Fabaceae), *H. suaveolens* (Lamiaceae) and *L. perennis* (Onagraceae). The other plants like *C. thalictroides* (Parkeriaceae), *M. punicifolia* (Rutaceae), *T. cordifolia* (Mensipermaceae), *G. superba* (Liliaceae) and , *P. rosea* (Plumbaginaceae) seen on the bunds and nearby areas were also seen to host the aphid

Table 8. Host plants of *Aphis spiraecola* recorded from Thiruvananthapuram district

Sl.No.	Host plant	Family	Plant part infested	Intensity of infestation
	Vegetables			
1	*Amaranthus tricolor* Linn. ®	Amaranthaceae	L, Sh	Low
2	*Cucumis sativus* Linn. ®	Cucurbitaceae	L, Sh, If	Low
3	*Coccinia grandis* (L.) Voigt.	Cucurbitaceae	L, Sh, If	Low
4	*Cyamopsis tetragonoloba* (L.)Taub. ®	Fabaceae	Sh	Low
5	*Moringa oleifera* Lamk®	Moringaceae	Sh	Low
6	*Momordica charantia* Linn. ®	Cucurbitaceae	L, Sh	Low
7	*Murraya koeingii* (L.) Spreng. ®	Rutaceae	L, Sh	Low
8	*Psophocarpus tetragonolobus* (L.) DC. ®	Fabaceae	L, Sh, Ft	Low
9	*Sauropus androgynus* Merr. ®	Euphorbiaceae	L, Sh	Very low

Sl.No.	Host plant	Family	Intensity of infestation
	Weeds		
1	*Aerva lanata* (L.) Juss. ®	Amaranthaceae	Medium
2	*Aerva tomentosa* Forsk. ®	Amaranthaceae	Low
3	*Ageratum conyzoides* Linn.*	Asteraceae	High
4	*Allmania nodiflora* (Linn.f)R.Br. ®	Amaranthaceae	Low
5	*Alternanthera sessilis* (Linn.)DC. ®	Amaranthaceae	Low
6	*Chromolaena odorata* (L.) King & Robs.	Asteraceae	High
7	*Clerodendrum viscosum* Vent. ®	Verbenaceae	High
8	*Clerodendrum paniculatum* Linn. ®	Verbenaceae	Medium
9	*Euphorbia heterophylla* Linn. ®	Euphorbiaceae	Low
10	*Euphorbia hirta* Linn. ®	Euphorbiaceae	Low
11	*Hyptis suaveolens* Poit. ®	Lamiaceae	Low
12	*Indigofera tirta* Linn. ®	Fabaceae	Low
13	*Justicia prostrata* Gamble. ®	Acanthaceae	Low
14	*Ludwigia perennis* Linn. ®	Onagraceae	Low
15	*Malvastrum coromandelianum* (L.) Gacrke ®	Malvaceae	Low
16	*Phyllanthus amarus* Webster ®	Euphorbiaceae	Low
17	*Phyllanthus maderaspatensis* Linn. ®	Euphorbiaceae	Low
18	*Sida cordifolia* Linn. ®	Malvaceae	Low
19	*Spermacoe latifolia* Aublet. ®	Rubiaceae	Very low
20	*Spermacoe pusilla* Wall. ®	Rubiaceae	Low
21	*Tridax procumbens* Linn. ®	Asteraceae	Low
22	*Vernonia cinerea* (Linn.) Less ®	Asteraceae	Low
	Other Plants		
1	*Ceratopteris thalictroides* (L.) Brongn. ®	Parkeriaceae	Low
2	*Gloriosa superba* Linn. ®	Liliaceae	Very low
3	*Malphigia punicifolia* Linn. ®	Rutaceae	Medium
4	*Plumbago rosea* Linn. ®	Plumbaginaceae	Very low
5	*Tinospora cordifolia* (Willd) Miers. ®	Menispermaceae	Low

L-Leaf, Sh-Shoot, If- Inflorescence / Flower Ft-Fruit / Pod,
® First record from South India * First record from Kerala

Amaranthus tricolour

Amaranthus sp.

Cucumis sativus

Coccinia grandis

Cyamopsis tetragonoloba

Moringa oleifera

Plate 12. Vegetables infested by *Aphis spiraecola*

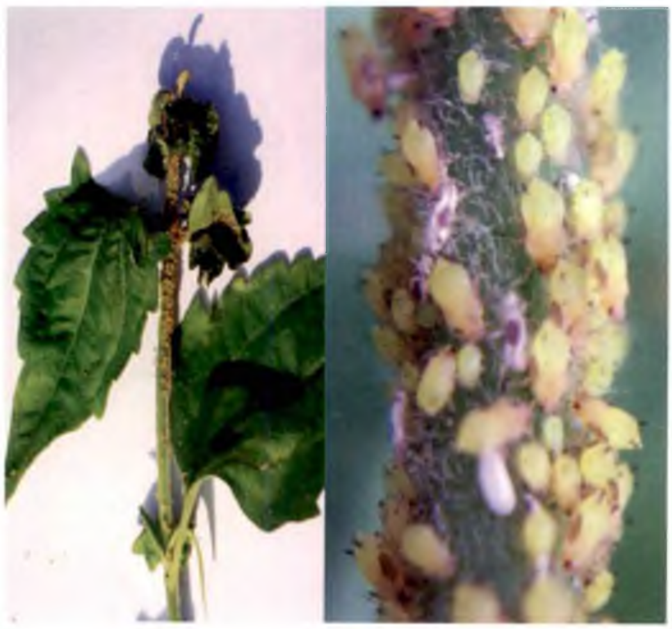
Aerva lanata

Ageratum conyzoides

Allmania nodiflora

Alternanthera sessilis

Clerodendrum viscosum



Chromolaena odorata

Plate 13. Weeds infested by *Aphis spiraecola*

Euphorbia heterophylla

Euphorbia hirta

Hyptis suaveolens

Indigofera tirta

Justicia prostata

Ludwigia perennis

Malvastrum coromandelianum

Phyllanthus maderaspatensis

Spermacoe latifolia

Spermacoe pusilla

Plate 13 (continued). Weeds infested by *Aphis spiraecola*

Ceratopteris thalictroides

Gloriosa superba

Malphigia punicifolia

Plumbago rosea

Tinospora cordifolia

Plate 14. Other plants infested by *Aphis spiraecola*

(Plate 14). Heavy infestation was noted in *A. conyzoides*, *C. odorata* and *C. viscosum*. *A. lanata*, *C. paniculatum* and *M. punicifolia* showed medium incidence whereas *A. tomentosa*, *A. nodiflora*, *A. sessilis*, *C. thalictroides*, *E. heterophylla*, *E. hirta*, *H. suaveolens*, *I. tirta*, *J. prostrata*, *L. perennis*, *M. coromandelianum*, *P. amarus*, *P. maderaspatensis*, *S. cordifolia*, *S. pusilla*, *T. cordifolia*, *T. procumbens* and *V. cinerea* registered low infestation. Very low infestation was noticed on *G. superba*, *P. rosea* and *S. latifolia*.

Lipaphis erysimi

Four brassicaceous vegetables viz., *B. oleracea* L. var. *Botrytis*, *B. oleracea* L. var. *Capitata*, *B. oleracea* L. var. *gongylodes* and *R. sativus* with medium infestation was recorded as host plants of *L. erysimi* (Table 9). Very low infestation of the pest was noticed on *D. carota* L.var. *sativa* (Umbelliferae) . The aphid colonized on the leaves and shoots of the plants (Plate 15).

Twelve weeds in nine families were identified as host plants of the aphid (Plate 16). The weeds identified included *C. viscosa* and *C. burmanni* (Cleomaceae), *H. corymbosa* (Rubiaceae), *A. spinosus*, *A. dubius* (Amaranthaceae), *A. indica*, *E. hirta*, *Phyllanthus* sp. (Euphorbiaceae), *B. juncea* (Brassicaceae), *P. oleraceae* (Portulacaceae), *B. erecta* (Nyctaginaceae) and *E. prostrata* (Asteraceae).The weeds viz., *C. viscosa* and *C. burmanni* showed high infestation whereas *H. corymbosa*, *A. spinosus*, *A. dubius*, *A. indica*, *E. hirta*, *Phyllanthus* sp., *B. juncea*, *E. prostrata* and *P. oleraceae* recorded low infestation. Very low infestation was noticed in *B. erecta*.

Myzus persicae

The aphid was recorded from five vegetables viz., *L. esculentum* *C. annuum*, *S. melongena* (Solanaceae), *R. sativus* (Brassicaceae) and *A. tricolor* (Amaranthaceae) (Table 10 and Plate 17). The infestation of the pest was mainly confined to the leaves of the plants with the exception of

C. annuum and S. melongena where infestation was seen on flowers and shoots too, the intensity of infestation was low in *L. esculentum* and *R. sativus* and very low in *A. tricolor, C. annuum* and *S. melongena.*

The weeds S. *nigrum* (Solanaceae) and *A. viridis* (Amaranthaceae) were identified as host plants of the aphid. However, only very low infestation was seen in the plants.

Aphis nerii

The pest was recorded from the two solanaceous vegetables viz., *C. annuum* and *C. frutescens* (Solanaceae) (Table 11 and Plate 17). Only very low infestation was seen on the crops.

Two other plants viz., *C. gigantea* (Asclepiadaceae) and *Nerium* sp. (Apocynaceae) were found to be attacked by the aphid and the intensity of infestation in the plants was low and very low, respectively.

Aphis fabae

The fabaceous vegetables viz., *P. tetragonolobus* and *V. unguiculata* were recorded as host plants of *A. fabae* (Table 12 and Plate 17). The damage was confined to the flowers and pods and very low infestation of the pest was recorded in the vegetables.

Very low infestation was seen in the weed host *S. nigrum* and other plant like *C. pallida.*

Hysteroneura setariae

The leafy vegetables *A. tricolor* and *A. dubius* (Amaranthaceae) were found to harbour the aphid on leaves and inflorescences at low intensities (Table 13 and Plate 18). Twenty weeds were recorded as host plants of the aphid. Fifteen of the plants (15) viz., *B. mutica, C. citratus, C. dactylon, C.barbata, D. aegyptium, D. ciliaris, D. sanguinalis, E. colona, E. indica, I. rugosum, L. hexandra, P. maximum, P. repens, P. scrobiculatum* and

Table 9. Host plants of *Lipaphis erysimi* recorded from Thiruvananthapuram district

Sl.No.	Host plant	Family	Plant part infested	Intensity of infestation
	Vegetables			
1	*Brassica oleracea* L. var. *botrytis* L.	Brassicaceae	L, Sh	Medium
2	*Brassica oleracea* L. var. *capitata* L.	Brassicaceae	L, Sh	Medium
3	*Brassica oleracea* L. var. *gongylodes* L.	Brassicaceae	L, Sh	Medium
4	*Daucus carota* L.var. *sativa* DC.	Umbelliferae	L, Sh	Very low
5	*Raphanus sativus* Linn.	Brassicaceae	L, Sh	Medium

Sl.No.	Host plant	Family	Intensity of infestation
	Weeds		
1	*Hedyotis corymbosa* (L.)Lam. ®	Rubiaceae	Low
2	*Amaranthus spinosus* Linn. *	Amaranthaceae	Low
3	*Acalypha indica* Linn. ®	Euphorbiaceae	Low
4	*Amaranthus dubius* Linn. *	Amaranthaceae	Low
5	*Boerhavia erecta* Linn. ®	Nyctaginaceae	Very low
6	*Brassica juncea* (L.)Czern. &Coss.	Brassicaceae	Low
7	*Eclipta prostrata* Linn. *	Asteraceae	Low
8	*Cleome viscosa* Linn. ®	Cleomaceae	High
9	*Cleome burmanni* Wight&Arn. ®	Cleomaceae	High
10	*Euphorbia hirta* Linn. ®	Euphorbiaceae	Low
11	*Phyllanthus* sp. ®	Euphorbiaceae	Low
12	*Portulaca oleraceae* Linn. ®	Portulacaceae	Low

Table 10. Host plants of *Myzus persicae* recorded from Thiruvananthapuram district

Sl.No.	Host plant	Family	Plant part infested	Intensity of infestation
	Vegetables			
1	*Amaranthus tricolor* Linn.*	Amaranthaceae	L	Very low
2	*Capsicum annuum* Linn.	Solanaceae	L, Sh, If	Very low
3	*Solanum melongena* Wall	Solanaceae	L, Sh, If	Very low
4	*Lycopersicon esculentum* Mill.	Solanaceae	L	Low
5	*Raphanus sativus* Linn.*	Brassicaceae	L	Low

Sl.No.	Host plant	Family	Intensity of infestation
	Weeds		
1	*Solanum nigrum* Linn.*	Solanaceae	Very low
2	*Amaranthus viridis* Linn.*	Amaranthaceae	Very low

Table 11. Host plants of *Aphis nerii* recorded from Thiruvananthapuram district

Sl.No.	Host plant	Family	Plant part infested	Intensity of infestation
	Vegetables			
1	*Capsicum annuum* Linn. *	Solanaceae	L, Sh	Very low
2	*Capsicum frutescens* Linn. *	Solanaceae	L, Sh	Very low

Sl.No.		Family	Intensity of infestation
	Other Plants		
1	*Calotropis gigantea* (L.) W.T.Aiton *	Asclepiadaceae	Low
2	*Nerium* sp.*	Apocynaceae	Very low

L-Leaf, Sh-Shoot, If- Inflorescence / Flower Ft-Fruit / Pod,

® First record from South India * First record from Kerala

Table 12. Host plants of *Aphis fabae* recorded from Thiruvananthapuram district

Sl.No.	Host plant	Family	PPI	II
	Vegetables			
1	*Psophocarpus tetragonolobus* (L.) DC. ®	Fabaceae	If, Ft	Very low
2	*Vigna unguiculata* (L.) Walp. ®	Fabaceae	If, Ft	Very low

Sl.No.	**Other Plant**	Family	II
1	*Crotolaria pallida* Aiton ®	Fabaceae	Very low
2	*Solanum nigrum* Linn.*	Solanaceae	Very low

Table 13. Host plants of *Hysteroneura setariae* recorded from Thiruvananthapuram district

Sl.No.	Host plant	Family	PPI	II
	Vegetables			
1	*Amaranthus tricolor* Linn. ®	Amaranthaceae	L, If	Low
2	*Amaranthus dubius* Mart. Ex. Thell. ®	Amaranthaceae	L, If	Low

Sl.No.	**Weeds**	Family	II
1	*Achyranthus aspera* Linn. ®	Amaranthaceae	Low
2	*Brachiaria mutica* Stapf. ®	Poaceae	Low
3	*Cymbopogon citratus* (DC.)Stapf. ®	Poaceae	Low
4	*Cynodon dactylon* (Linn.)Pers.*	Poaceae	High
5	*Cyperus difformis* Linn. ®	Cyperaceae	Low
6	*Cyperus rotundus* Linn.*	Cyperaceae	Low
7	*Chloris barbata* Sw.*	Poaceae	High
8	*Dactyloctenium aegyptium* Beau.*	Poaceae	High
9	*Digitaria ciliaris* (Retz.) Koeler	Poaceae	Low
10	*Digitaria sanguinalis* (Linn.)Scop. ®	Poaceae	Low
11	*Echinochloa colona* Link. ®	Poaceae	Low
12	*Eleusine indica* (Linn.) Gaertn.*	Poaceae	High
13	*Gomphrena celosioides* Martius ®	Amaranthaceae	Low
14	*Ischaemum rugosum* Salisb. ®	Poaceae	Low
15	*Leersia hexandra* Sw. ®	Poaceae	Low
16	*Panicum maximum* Jacq. ®	Poaceae	Low
17	*Panicum repens* Linn. ®	Poaceae	Very low
18	*Paspalum scrobiculatum* Linn. ®	Poaceae	Low
19	*Perotis indica* (Linn.) Kuntze ®	Poaceae	Low
20	*Tridax procumbens* Linn. ®	Asteraceae	Low

L-Leaf, Sh-Shoot, If- Inflorescence / Flower Ft-Fruit / Pod,
® First record from South India * First record from Kerala

Brassica oleracea var. ***botrytis***

Brassica oleracea var. ***capitata***

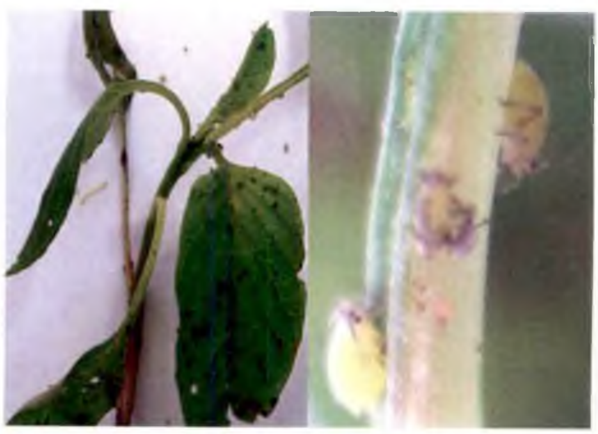
Brassica oleracea var. ***gongyloides***

Raphanus sativus

Hedyotis corymbosa

Amaranthus spinosus

Acalypha indica



Amaranthus dubius

Plate 15. Vegetables and weeds infested by *Lipaphis erysimi*

Boerhavia erecta

Brassica juncea

Eclipta prostrata

Cleome viscosa

Euphorbia hirta

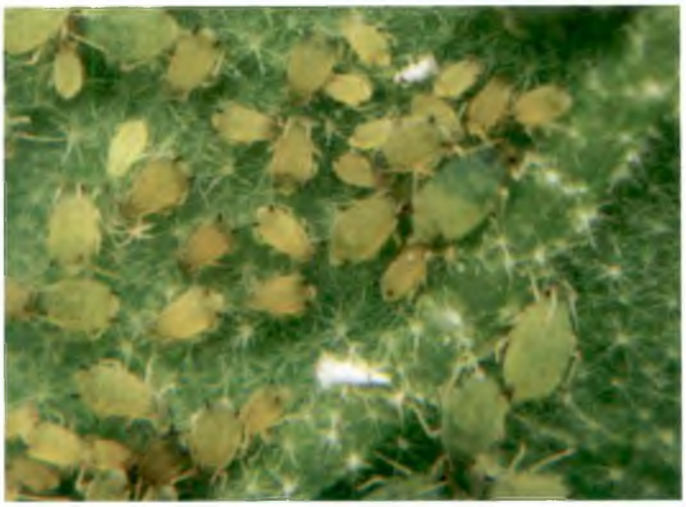
Phyllanthus sp.

Portulaca oleraceae

Plate 16. Weeds infested by *Lipaphis erysimi*

Myzus persicae

Lycopersion esculentum



Solanum melongena

Aphis nerii

Capsicum annuum

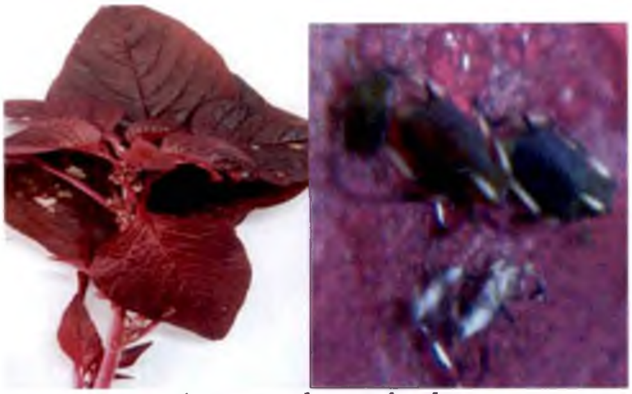
Calotropis gigantea

Aphis fabae

Psophocarpus tetragonolobus

Crotolaria pallida

Plate 17. Plants infested by *Myzus persicae*, *Aphis nerii* and *Aphis fabae*



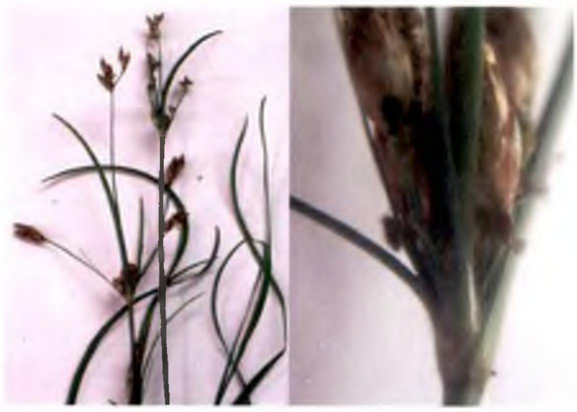
Amaranthus tricolor

Amaranthus dubius

Achyranthes aspera

Brachiaria mutica

Cynodon dactylon



Cyperus rotundus

Chloris barbata

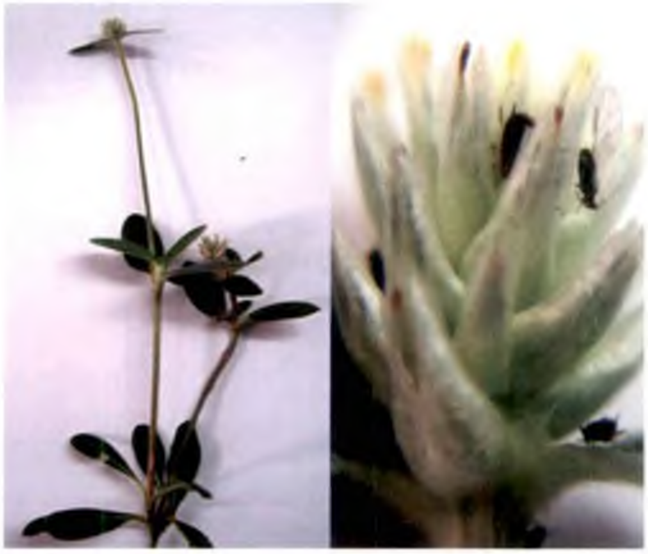
Dactyloctenium aegyptium

Plate 18. Vegetables and weeds infested by *Hysteroneura setariae*

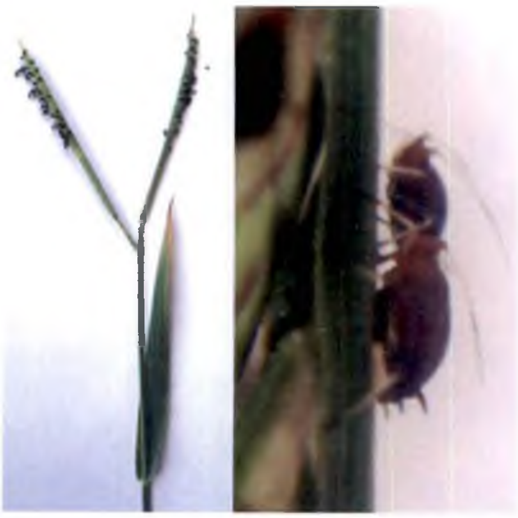
Digitaria ciliaris

Digitaria sanguinalis

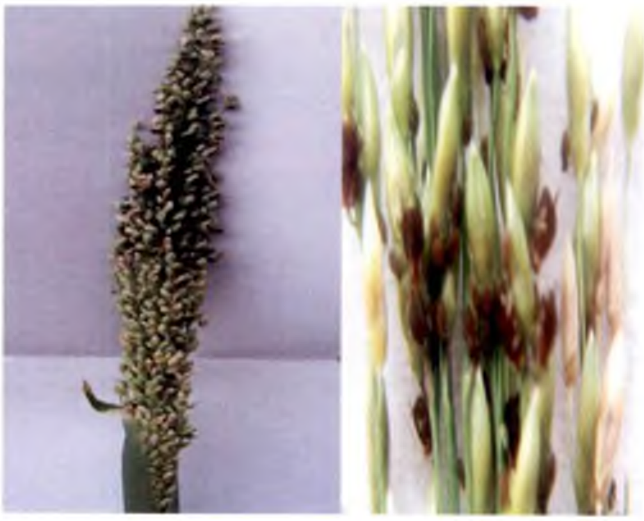
Eleusine indica



Gomphrena celosioides



Ischaemum rugosum



Panicum maximum

Plate 19 . Weeds infested by ***Hysteroneura setariae***

P. indica belonged to Poaceae (Plate 19). The rest of the host plants belonged to Amaranthaceae (*G. celosioides* and *A. aspera*), Cyperaceae (*C. difformis* and *C. rotundus*) and Asteraceae (*T. procumbens*). High infestation of the pest was noted in *C. dactylon, C. barbata, D. aegyptium* and *E. indica*. *A. aspera, B. mutica, C. citratus, C. difformis, C. rotundus, D. ciliaris, D. sanguinalis, E. colona, G. celosioides, I. rugosum, L. hexandra, P. maximum, P. scrobiculatum, P. indica* and *T. procumbens* showed low infestation whereas *P. repens* showed at very low infestation.

4.1.3 Predators

Coccinellids, syrphids, chamaemyiids, chrysopids, hemerobiids and spiders were the major group of aphidophagous predators recorded from the vegetable ecosystem.

Coccinellids

Twenty species of coccinellids viz., *Menochilus sexmaculatus* (Fabricius), *Coccinella transversalis* Fabricius, *Scymnus (Pullus) latemaculatus* Motschulsky, *Coccinella septempunctata* Linnaeus, *Pseudaspidimerus trinotatus* (Thunberg), *Harmonia octomaculata* (Fabricius), *Brumoides suturalis* (Fabricius), *Micraspis discolor* (Fabricius), *Propylea japonica* (Thunberg), *Nephus* sp., *Pseudaspidimerus flaviceps* (Walker), *Sticholotis obscurella* Weise, *Scymnus (Pullus) o-nigrum* Mulsant, *Cryptogonus orbiculus* (Gyllenhal), *Scymnus (Pullus) castaneus* Sicard, *Scymnus (Pullus) coccivora* Ayyar, *Synona rougeti* (Mulsant), *Phrynocaria perrotteti* (Mulsant), *Sticholotis* sp., *Telsimia* sp. were recorded from various aphid prey infesting different host plants (Table 14 and Plate 20).

M. sexmaculatus was found predating on *A. gossypii* feeding on the vegetables *A. esculentus, A. tricolor, C. annuum, C. frutescens, C. grandis, C. sativus, L. esculentum, M. charantia, S. melongena, T. anguina* and other plants like *A. conyzoides, A. indica, B. prionitis, B. repens, C. halicacabum, C. pusillus, C. roseus, C. asiatica, C. burmanni, C. benghalensis, G. superba, S. jamaicensis, V. cinerea*; *A. craccivora* on the vegetables

Table 14. Aphidophagus coccinellids (Coccinellidae: Coleoptera) recorded from Thiruvananthapuram district

Species	Associated aphid species	Host plant
Menochilus sexmaculatus (Fabricius)	*Aphis gossypii*	*Abelmoschus esculentus* (L.) Moench *Amaranthus tricolor* Linn. *Capsicum annuum* Linn. *Capsicum frutescens* Linn. *Coccinia grandis* (L.) Voigt. *Cucumis sativus* Linn. *Lycopersicon esculentum* Mill. *Momordica charantia* Linn. *Solanum melongena* Linn. *Trichosanthes anguina* Linn. *Ageratum conyzoides* Linn. *Acalypha indica* Linn. *Barleria prionitis* Linn. *Boerhavia repens* Linn. *Cardiospermum halicacabum* Linn. *Catharanthus pusillus* (Murry) G *Catharanthus roseus* (L.) G. Don. *Centella asiatica* Urban. *Cleome burmanni* Wight & Arn. *Commelina benghalensis* Linn. *Gloriosa superba* Linn. *Stachytarpheta jamaicensis* (L.) *Vernonia cinerea* (L.) Less
	Aphis craccivora	*Amaranthus tricolor* Linn. *Canavalia gladiata* (Jack) DC. *Cyamopsis tetragonoloba* (L.) Taub. *Lablab purpureus* (L.) Sweet *Psophocarpus tetragonolobus* (L.) *Vigna unguiculata* (L.) Walp. *Aeschynomene indica* Linn. *Indigofera tinctoria* Linn. *Crotolaria pallida* Aiton *Tephrosia purpurea* (L.) Pers.
	Hysteroneura setariae	*Amaranthus tricolor* Linn. *Chloris barbata* Sw. *Dactyloctenium aegyptium* Beau. *Digitaria ciliaris* (Retz.) Koeler
	Myzus persicae	*Solanum melongena* Wall. *Lycopersicon esculentum* Mill. *Solanum nigrum* Linn.
	Aphis nerii	*Capsicum annuum* Linn. *Calotropis gigantea* (L.) W.T.Aiton
	Lipaphis erysimi	*Raphanus sativus* Linn. *Cleome viscosa* Linn.

Table 14. continued

Species	Associated aphid species	Host plant
Coccinella transversalis Fabricius	*Aphis gossypii*	*Abelmoschus esculentus* (L.) Moench *Amaranthus tricolor* Linn. *Capsicum annuum* Linn *Coccinia grandis* (L.) Voigt. *Cucumis sativus* Linn. *Lycopersicon esculentum* Mill. *Momordica charantia* Linn. *Moringa oleifera* Lamk *Psophocarpus tetragonolobus* (L.) *Solanum melongena* Linn. *Trichosanthes anguina* Linn. *Catharanthus pusillus* (Murry) G. *Catharanthus roseus* (L.) G. Don. *Centella asiatica* Urban. *Cleome burmanni* Wight&Arn. *Commelina benghalensis* Linn. *Tridax procumbens* Linn.
	Aphis craccivora	*Amaranthus tricolor* Linn. *Canavalia gladiata* (Jack) DC. *Cyamopsis tetragonoloba* (L.) *Lablab purpureus* (L.) Sweet *Psophocarpus tetragonolobus* (L.) *Vigna unguiculata* (L.) Walp. *Aeschynomene indica* Linn. *Indigofera tinctoria* Linn. *Cassia auriculata* Linn. *Crotolaria pallida* Aiton *Tephrosia purpurea* (L.) Pers. *Tephrosia tinctoria* (L.) Pers. *Trianthema portulacastrum* Linn.
	Aphis spiraecola	*Cucumis sativus* Linn. *Coccinia grandis* (L.) Voigt. *Allmania nodiflora* (Linn.f)R.Br.
	Hysteroneura setariae	*Amaranthus tricolor* Linn. *Chloris barbata* Sw *Dactyloctenium aegyptium* Beau. *Digitaria ciliaris* (Retz.) Koeler *Echinochloa colona* Link. *Eleusine indica* (L.) Gaertn.
	Lipaphis erysimi	*Raphanus sativus* Linn. *Cleome viscosa* Linn.

Table 14 . continued

Species	Associated aphid species	Host plant
Scymnus (Pullus) latemaculatus Motschulsky *	*Aphis gossypii*	*Abelmoschus esculentus* (L.) Moench *Capsicum annuum* Linn. *Coccinia grandis* (L.) Voigt. *Cucumis sativus* Linn. *Lycopersicon esculentum* Mill. *Momordica charantia* Linn. *Solanum melongena* Linn. *Trichosanthes anguina* Linn. *Ageratum conyzoides* Linn. *Gloriosa superba* Linn. *Ruellia tuberosa* Linn. *Tridax procumbens* Linn. *Vernonia cinerea* (Linn.) Less *Withania somnifera* (Linn.) Dunal.
	Aphis craccivora	*Amaranthus tricolor* Linn. *Canavalia gladiata* (Jack) DC. *Cyamopsis tetragonoloba* (L.)Taub. *Lablab purpureus* (L.) Sweet *Moringa oleifera* Lam. *Phaseolus vulgaris* Linn. *Psophocarpus tetragonolobus* (L.) *Vigna unguiculata* (L.) Walp. *Tephrosia purpurea* (L.) Pers. *Trianthema portulacastrum* Linn.
	Aphis spiraecola	*Chromolaena odorata* (L.) *Clerodendrum viscosum* Vent.
	Hysteroneura setariae	*Eleusine indica* (L.) Gaertn. *Panicum maximum* Jacq.
	Myzus persicae	*Lycopersicon esculentum* Mill. *Solanum nigrum* Linn.
	Aphis fabae	*Psophocarpus tetragonolobus* (L.)
Coccinella septempunctata Linnaeus	*Aphis gossypii*	*Abelmoschus esculentus* (L.) Moench *Amaranthus tricolor* Linn. *Capsicum annuum* Linn. *Coccinia grandis* (L.) Voigt. *Cucumis sativus* Linn. *Ageratum conyzoides* Linn.
	Aphis spiraecola	*Amaranthus tricolor* Linn. *Coccinia grandis* (L.) Voigt. *Chromolaena odorata* (L.) *Clerodendrum viscosum* Vent.
	Aphis craccivora	*Psophocarpus tetragonolobus* (L.) *Vigna unguiculata* (L.) Walp.

Table 14. continued

Species	Associated aphid species	Host plant
Pseudaspidimerus trinotatus (Thunberg)*	*Aphis craccivora*	*Amaranthus tricolor* Linn.. *Canavalia gladiata* (Jack) DC. *Cyamopsis tetragonoloba* (L.) Taub. *Lablab purpureus* (L.) Sweet *Moringa oleifera* Lamk *Phaseolus vulgaris* Linn. *Psophocarpus tetragonolobus* (L.) *Vigna unguiculata* (L.) Walp.
	Aphis gossypii	*Abelmoschus esculentus* (L.) Moench *Capsicum annuum* Linn. *Coccinia grandis* (L.) Voigt.
Harmonia octomaculata (Fabricius)	*Aphis gossypii*	*Abelmoschus esculentus* (L.) Moench *Amaranthus tricolor* Linn. *Capsicum annuum* Linn.
	Aphis craccivora	*Psophocarpus tetragonolobus* (L.) *Vigna unguiculata* (L.) Walp.
	Aphis nerii	*Capsicum annuum* Linn. *Calotropis gigantea* (L.) W.T.Aiton
	Aphis spiraecola	*Moringa oleifera* Lamk *Chromolaena odorata* (L.)
Brumoides suturalis (Fabricius)	*Aphis gossypii*	*Abelmoschus esculentus* (L.) Moench *Capsicum annuum* Linn. *Commelina benghalensis* Linn. *Portulaca oleraceae* Linn.
	Aphis craccivora	*Psophocarpus tetragonolobus* (L.) *Vigna unguiculata* (L.) Walp. *Aeschynomene indica* Linn. *Indigofera tinctoria* Linn.
Micraspis discolor (Fabricius)	*Aphis gossypii*	*Abelmoschus esculentus* (L.) Moench *Amaranthus tricolor* Linn. *Capsicum annuum* Linn.
	Aphis craccivora	*Psophocarpus tetragonolobus* (L.) *Vigna unguiculata* (L.) Walp.
	Hysteroneura setariae	*Dactyloctenium aegyptium* Beau.
Propylea japonica (Thunberg)*	*Aphis gossypii*	*Abelmoschus esculentus* (L.) Moench *Amaranthus tricolor* Linn. *Capsicum annuum* Linn. *Coccinia grandis* (L.) Voigt. *Cucumis sativus* Linn. *Solanum melongena* Wall.

Table 14 . continued

Species	Associated aphid species	Host plant
Nephus sp.	*Aphis gossypii*	*Abelmoschus esculentus* (L.) Moench
		Amaranthus tricolor Linn.
		Capsicum annuum Linn.
	Aphis craccivora	*Psophocarpus tetragonolobus* (L.)
		Vigna unguiculata (L.) Walp.
Pseudaspidimerus flaviceps (Walker)*	*Aphis gossypii*	*Abelmoschus esculentus* (L.) Moench
		Capsicum annuum Linn.
		Coccinia grandis (L.) Voigt.
	Aphis craccivora	*Psophocarpus tetragonolobus* (L.)
		Vigna unguiculata (L.) Walp.
Sticholotis obscurella Weise *	*Aphis gossypii*	*Abelmoschus esculentus* (L.) Moench
		Capsicum annuum Linn.
		Solanum melongena Wall
	Aphis craccivora	*Psophocarpus tetragonolobus* (L.)
Scymnus (Pullus) o-nigrum Mulsant *	*Aphis craccivora*	*Psophocarpus tetragonolobus* (L.)
		Vigna unguiculata (L.) Walp.
	Aphis fabae	*Psophocarpus tetragonolobus* (L.)
Cryptogonus orbiculus (Gyllenhal) *	*Aphis gossypii*	*Abelmoschus esculentus* (L.) Moench
		Capsicum annuum Linn.
Scymnus (Pullus) castaneus Sicard *	*Aphis craccivora*	*Psophocarpus tetragonolobus* (L.)
		Vigna unguiculata (L.) Walp.
Scymnus (Pullus) coccivora Ayyar *	*Aphis craccivora*	*Psophocarpus tetragonolobus* (L.)
		Vigna unguiculata (L.) Walp.
Synona rougeti (Mulsant) *	*Aphis gossypii*	*Capsicum annuum* Linn.
		Solanum melongena Wall.
Phrynocaria perrotteti (Mulsant)*	*Aphis gossypii*	*Capsicum annuum* Linn.
Sticholotis sp. *	*Aphis gossypii*	*Capsicum annuum* Linn.
Telsimia sp. *	*Aphis gossypii*	*Capsicum annuum* Linn.

* New record from Kerala

Brumoides suturalis

Coccinella septempunctata

Coccinella transversalis

Cryptogonus orbiculus

Harmonia octomaculata

Menochilus sexmaculatus

Plate 20. Aphidophagous coccinellids recorded from vegetable ecosystem

Micraspis discolor

Nephus sp.

Phrynocaria perrotteti

Propylea japonica

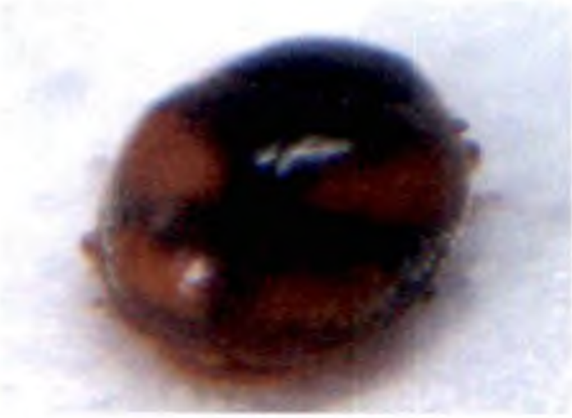
Pseudaspidimerus flaviceps

Pseudaspidimerus trinotatus

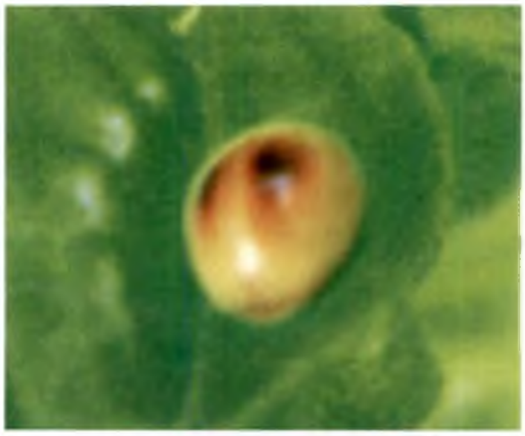
Plate 20 (continued). Aphidophagous coccinellids recorded from vegetable ecosystem

Scymnus (Pullus) castaneus

Scymnus (Pullus) coccivora



Scymnus (Pullus) latemaculatus

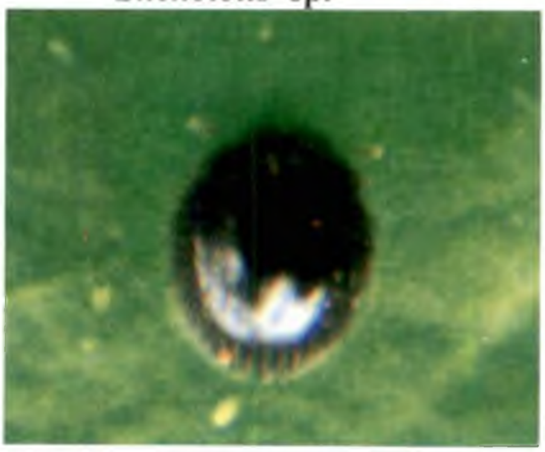


Scymnus (Pullus) o-nigrum

Sticholotis obscurella

Sticholotis sp.

Synona rougeti



Telsimia sp.

Plate 20(continued). Aphidophagous coccinellids recorded from vegetable ecosystem

A. tricolor, C. gladiata, C. tetragonoloba, L. purpureus, P. tetragonolobus, V. unguiculata and other plants viz., *A. indica, I. tinctoria, C. pallida* and *T. purpurea; H. setariae* on *A. tricolor, C.barbata, D. aegyptium, D. ciliaris*; *M. persicae* on *S. melongena, L. esculentum, S. nigrum*; *A. nerii* on *C. annuum, C. gigantea* and *L. erysimi* on *R. sativus* and *C. viscosa*.

C. transversalis was noticed predating upon *A. gossypii* infesting *A. esculentus, A. tricolor, C. annuum, C. grandis, C. sativus, L. esculentum, M. charantia, M. oleifera, P. tetragonolobus, S. melongena, T. anguina, C. pusillus, C. roseus, C. asiatica, C. burmanni, C. benghalensis, T. procumbens*; *A. craccivora* feeding on *A. tricolor, C. gladiata, C. tetragonoloba, L. purpureus, P. tetragonolobus, V. unguiculata, A. indica, I. tinctoria, C. auriculata, C. pallida, T. purpurea, T. tinctoria, T. portulacastrum*; *A. spiraecola* infesting on *C. sativus, C. grandis, A. nodiflora*; *H. setariae* feeding on *A. tricolor, C.barbata, D. aegyptium, D. ciliaris, E. colona, E. indica* and *L. erysimi* infesting on *R. sativus* and *C. viscosa*.

The aphid prey range of *S.* (*P.*) *latemaculatus* included *A. gossypii* which infested *A. esculentus, C. annuum, C. grandis, C. sativus, L. esculentum, M. charantia, S. melongena, T. anguina, A. conyzoides, G. superba, R. tuberosa, T. procumbens, V. cinerea, W. somnifera*; *A. craccivora* feeding on *A. tricolor, C. gladiata, C. tetragonoloba, L. purpureus, M. oleifera, P. vulgaris, P. tetragonolobus, V. unguiculata, T. purpurea, T. portulacastrum; A. spiraecola* infesting *C. odorata, C. viscosum*; *H. setariae* damaging *E. indica, P.maximum*; *M. persicae* on *L. esculentum, S. nigrum* and *A. fabae* on *P. tetragonolobus*.

C. septempunctata predated on *A. gossypii* in *A. esculentus, A. tricolor, C. annuum, C. grandis, C. sativus, A. conyzoides*; *A. spiraecola* in *A. tricolor, C. grandis, C. odorata, C. viscosum* and *A. craccivora* in *P. tetragonolobus* and *V. unguiculata. H. octomaculata* preyed upon *A. gossypii* which infested *A. esculentus, A. tricolor, C. annuum*; *A. craccivora* feeding on *P. tetragonolobus, V. unguiculata*; *A. nerii* colonizing on

C. annuum, C. gigantea and *A. spiraecola* on *M. oleifera* and *C. odorata*. *M. discolor* preyed on *A. craccivora* which infested *A. esculentus, A. tricolor, C. annuum*; *A. craccivora* which occurred on *P. tetragonolobus, V. unguiculata* and *H. setariae* on *D. aegyptium*.

P. trinotatus preyed on *A. craccivora* which infested *A. tricolor, C. gladiata, C. tetragonoloba, L. purpureus, M. oleifera, P. vulgaris, P. tetragonolobus, V. unguiculata* and *A. gossypii* on *A. esculentus, C. annuum* and *C. grandis*. *B. suturalis* was noticed predating on *A. gossypii* which occurred on *A. esculentus, C. annuum, C. benghalensis, P. oleraceae* and *A. craccivora* feeding on *P. tetragonolobus, V. unguiculata, A. indica* and *I. tinctoria*. *Nephus* sp. was also recorded feeding on *A. gossypii* damaging *A. esculentus, A. tricolor, C. annuum* and *A. craccivora* infesting *P. tetragonolobus* and *V. unguiculata*. *P. flaviceps* preyed on *A. gossypii* which infested *A. esculentus, C. annuum, C. grandis* and *A. craccivora* seen on *P. tetragonolobus* and *V. unguiculata*. *S. obscurella* also preyed on *A. gossypii* which infested *A. esculentus, C. annuum, S. melongena* and *A. craccivora* damaging *P. tetragonolobus*. *S. (P.) o-nigrum* predated on *A. craccivora* which infested *P. tetragonolobus* and *V. unguiculata* and *A. fabae* on *P. tetragonolobus*.

P. japonica was observed only on *A. gossypii* infesting *A. esculentus, A. tricolor, C. annuum, C. grandis, C. sativus* and *S. melongena*. *C. orbiculus* preyed on *A. gossypii* which occurred on *A. esculentus* and *C. annuum*. Both *S. (P.) castaneus* and *S. (P.) coccivora* preyed on *A. craccivora* which infested *P. tetragonolobus* and *V. unguiculata*. *S. rougeti* preyed upon *A. gossypii* which infested *C. annuum*. Three other coccinellids viz., *P. perrotteti, Sticholotis* sp., *Telsimia* sp. were observed as predators of *A. gossypii* in *C. annuum*.

Syrphids

Four species of syrphid viz., *Ischiodon scutellaris* (Fabricius), *Paragus yerburiensis* Stuckenberg, *Paragus serratus* (Fabricius) and *Dideopsis aegrota* (Fabricius) were observed as important predators of aphids infesting vegetables (Table 15 and Plate 21).

I. scutellaris was noted to predate on *A. gossypii* which infested *A. esculentus, A. tricolor, C. annuum, C. grandis, C. sativus, L. esculentum, M. charantia, M. oleifera, P. tetragonolobus, S. melongena, T. anguina, C. pusillus, C. roseus, C. asiatica, C. burmanni, C. benghalensis, T. procumbens* ; *A. craccivora* feeding on *A. tricolor, C. gladiata, C. tetragonoloba, L. purpureus, P. tetragonolobus, V. unguiculata, A. indica, I. tinctoria, C. auriculata, C. pallida, T. purpurea, T. tinctoria, T. portulacastrum*; *A. spiraecola* infesting *C. sativus, C. grandis, A. conyzoides, C. odorata, C. viscosum*; *H. setariae* feeding on *C. barbata, D. aegyptium, D. ciliaris, E. indica*; *L. erysimi* infesting *B. oleracea* L. var. *capitata, R. sativus, C. viscosa* and *A. nerii* on *C. annuum* and *C. gigantea.*

P. serratus was recorded as the predator of *A. gossypii* which infested *A. esculentus, A. tricolor, C. annuum; A. craccivora* occurring on *P. tetragonolobus, V. unguiculata*; *A. nerii* on *C. annuum* and *C. gigantea*; *A. spiraecola* feeding on *A. conyzoides, C. odorata*; *H. setariae* colonizing on *D. aegyptium, P. maximum* and *L. erysimi* infesting *B. oleracea* L. var. *botrytis* and *R. sativus.*

P. yerburiensis preyed upon *A. craccivora* which infested on *P. tetragonolobus, V. unguiculata, A. indica, I. tinctoria*; *A. gossypii* feeding on *A. esculentus, C. annuum, C. benghalensis, P. oleraceae*; *A. spiraecola* infesting *C. sativus, C. grandis, A. conyzoides, C. odorata* and *H. setariae* feeding on *D. aegyptium, P. maximum, E. indica* and *P. indica. D. aegrota* was noticed predating on *A. craccivora* damaging *C. gladiata, C. tetragonoloba, L. purpureus, P. tetragonolobus, V. unguiculata, G. maculata* and *A. gossypii* which infested on *A. esculentus, A. tricolor, C. annuum, C. sativus* and *C. grandis.*

Table 15. Syrphids (Syrphidae: Diptera) recorded from Thiruvananthapuram district

Species	Associated aphid species	Host plant
Ischiodon scutellaris (Fabricius)	*Aphis gossypii*	*Abelmoschus esculentus* (Linn.) Moench *Amaranthus tricolor* Linn. *Capsicum annuum* Linn. *Coccinia grandis* (Linn.) Voigt. *Cucumis sativus* Linn. *Lycopersicon esculentum* Mill. *Momordica charantia* Linn. *Moringa oleifera* Lam. *Psophocarpus tetragonolobus* DC. *Solanum melongena* Linn. *Trichosanthes anguina* Linn. *Catharanthus pusillus*(Murry) G. Don. *Catharanthus roseus* (Linn.) G. Don. *Centella asiatica* Urban. *Cleome burmanni* Wight&Arn. *Commelina benghalensis* Linn. *Tridax procumbens* Linn.
	Aphis craccivora	*Amaranthes tricolor* Linn. *Canavalia gladiata* (Jacq) DC. *Cyamopsis tetragonoloba* (L.) Taub. *Lablab purpureus* (L.) Sweet *Psophocarpus tetragonolobus* DC. *Vigna unguiculata* (L.) Walp. *Aeschynomene indica* Linn. *Indigofera tinctoria* Linn. *Cassia auriculata* Linn. *Crotolaria pallida* Aiton *Tephrosia purpurea* (Linn.) Pers. *Tephrosia tinctoria* (Linn.)Pers. *Trianthema portulacastrum* Linn.
	Aphis spiraecola	*Cucumis sativus* Linn. *Coccinia grandis* (Linn.) Voigt. *Ageratum conyzoides* Linn. *Chromolaena odorata* (L.) King & Robs. *Clerodendrum viscosum* Vent.
	Hysteroneura setariae	*Chloris barbata* Sw. *Dactyloctenium aegyptium* Beau. *Digitaria ciliaris* (Retz.) Koeler *Eleusine indica* (Linn.) Gaertn.
	Lipaphis erysimi	*Brassica oleracea* L. var. *capitata* *Raphanus sativus* Linn. *Cleome viscosa* Linn.
	Aphis nerii	*Capsicum annuum* Linn. *Calotropis gigantea* (Linn.) W.T.Aiton

Table 15. continued

Species	Associated aphid species	Host plant
Paragus yerburiensis Stuckenberg *	*Aphis craccivora*	*Psophocarpus tetragonolobus* DC. *Vigna unguiculata* (L.) Walp. *Aeschynomene indica* Linn. *Indigofera tinctoria* Linn.
	Aphis gossypii	*Abelmoschus esculentus* (Linn.) Moench *Capsicum annuum* Linn. *Commelina benghalensis* Linn. *Portulaca oleraceae* Linn.
	Aphis spiraecola	*Cucumis sativus* Linn. *Coccinia grandis* (Linn.) Voigt. *Ageratum conyzoides* Linn. *Chromolaena odorata* (L.) King & Robs.
	Hysteroneura setariae	*Dactyloctenium aegyptium* Beau. *Panicum maximum* Jacq. *Eleusine indica* (Linn.) Gaertn. *Perotis indica* (Linn.) Kuntze
Paragus serratus (Fabricius)	*Aphis gossypii*	*Abelmoschus esculentus* (Linn.) Moench *Amaranthus tricolor* Linn. *Capsicum annuum* Linn.
	Aphis craccivora	*Psophocarpus tetragonolobus* DC. *Vigna unguiculata* (L.) Walp.
	Aphis nerii	*Capsicum annuum* Linn. *Calotropis gigantea* (Linn.) W.T.Aiton
	Aphis spiraecola	*Ageratum conyzoides* Linn. *Chromolaena odorata* (L.) King & Robs.
	Hysteroneura setariae	*Dactyloctenium aegyptium* Beau. *Panicum maximum* Jacq.
	Lipaphis erysimi	*Brassica oleracea* L. var. *botrytis* *Raphanus sativus* Linn.
Dideopsis aegrota (Fabricius) *	*Aphis craccivora*	*Canavalia gladiata* (Jacq) DC. *Cyamopsis tetragonoloba* (L.) Taub. *Lablab purpureus* (L.) Sweet *Psophocarpus tetragonolobus* DC. *Vigna unguiculata* (L.) Walp. *Gliricidia maculata* (Jacq.) Kunth
	Aphis gossypii	*Abelmoschus esculentus* (Linn.) Moench *Amaranthus tricolor* Linn. *Capsicum annuum* Linn. *Coccinia grandis* (Linn.) Voigt. *Cucumis sativus* Linn.

Dideopsis aegrota

Ischiodon scutellaris

Paragus serratus

Paragus yerburiensis

Plate 21. Syrphids recorded from vegetable ecosystem

Chamaemyiid

Leucopis sp. was found to be an important predator of *A. gossypii* which occurred (Table 16 and Plate 22) on *A. esculentus, A. tricolor, C. annuum, C. grandis, C. sativus, L. esculentum, M. charantia, M. oleifera, P. tetragonolobus, S. melongena, T. anguina, C. pusillus, C. roseus, C. asiatica, C. burmanni, C. benghalensis, T. procumbens*; *A. craccivora* damaging *A. tricolor, C. gladiata, C. tetragonoloba, L. purpureus, P. tetragonolobus, V. unguiculata, A. indica, I. tinctoria, C. auriculata, C. pallida, T. purpurea, T. tinctoria, T. portulacastrum*; *H. setariae* infesting *C. barbata, D. aegyptium, D. ciliaris, E. indica, P. maximum* and *P. repens* and *M. persicae* feeding on *S. melongena, L. esculentum, R. sativus* and *S. nigrum*.

Neuropterans

Chrysopids *viz., Chrysoperla carnea* (Stephens) and *Ankylopteryx octopunctata* (Fabricius) were recorded as important predators of aphids infesting vegetables during the survey (Table 17 and Plate 23). *C. carnea* preyed upon *A. gossypii* seen on *A. esculentus, C. annuum, M. charantia, S. melongena* and *C. roseus*; *A. craccivora* on *P. tetragonolobus* and *V. unguiculata*. *A. octopunctata* preyed on *A. gossypii* infesting *A. esculentus, C. annuum, S. melongena* and *A. craccivora* found on *P. tetragonolobus* and *V. unguiculata*.

Hemerobiid, *Micromus* sp. was observed to (Table 17) predate on *A. gossypii* which infested *A. esculentus, A. tricolor, C. annuum, C. grandis, M. charantia, S. melongena, T. anguina* and *A. conyzoides*; *A. craccivora* on *P. tetragonolobus, V. unguiculata* and *M. oleifera* and *A. spiraecola* on *C. grandis, C. odorata* and *C. viscosum*.

Table 16. Aphid – host plant association of *Leucopis* sp. (Chamaemyiidae: Diptera) recorded from Thiruvananthapuram district

Aphid species	Host plant
Aphis gossypii	*Abelmoschus esculentus* (Linn.)Moench *Amaranthus tricolor* Linn. *Capsicum annuum* Linn. *Coccinia grandis* (Linn.) Voigt. *Cucumis sativus* Linn. *Lycopersicon esculentum* Mill. *Momordica charantia* Linn. *Moringa oleifera* Lam. *Psophocarpus tetragonolobus* DC. *Solanum melongena* Linn. *Trichosanthes anguina* Linn. *Catharanthus pusillus* (Murry) G. Don. *Catharanthus roseus* (Linn.) G. Don. *Centella asiatica* Urban. *Cleome burmanni* Wight&Arn. *Commelina benghalensis* Linn. *Tridax procumbens* Linn.
Aphis craccivora	*Amaranthus tricolor* Linn. *Canavalia gladiata* (Jacq) DC. *Cyamopsis tetragonoloba* (L.) Taub. *Lablab purpureus* (L.) Sweet *Psophocarpus tetragonolobus* DC. *Vigna unguiculata* (L.) Walp. *Aeschynomene indica* Linn. *Indigofera tinctoria* Linn. *Cassia auriculata* Linn. *Crotolaria pallida* Aiton *Tephrosia purpurea* (Linn.) Pers. *Tephrosia tinctoria* (Linn.)Pers. *Trianthema portulacastrum* Linn.
Hysteroneura setariae	*Chloris barbata* Sw. *Dactyloctenium aegyptium* Beau. *Digitaria ciliaris* (Retz.) Koeler *Eleusine indica* (Linn.) Gaertn. *Panicum maximum* Jacq. *Panicum repens* Linn.
Myzus persicae	*Solanum melongena* Wall. *Lycopersicon esculentum* Mill. *Raphanus sativus* Linn. *Solanum nigrum* Linn.

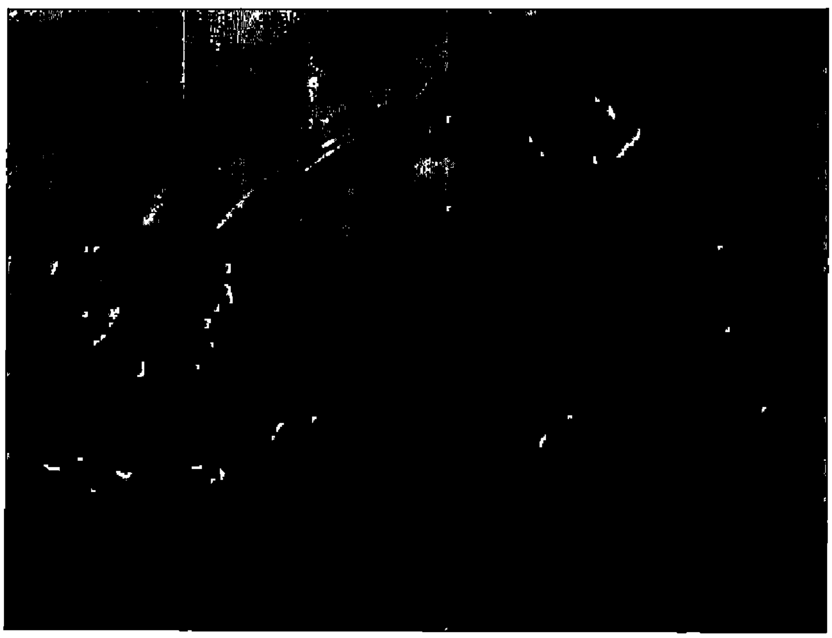
Table 17. Neuropterans recorded from Thiruvananthapuram district.

Species	Associated aphid species	Host plant
Chrysoperla carnea (Stephens) (Chrysopidae: Neuroptera)	*Aphis gossypii*	*Abelmoschus esculentus* (L.) Moench *Capsicum annuum* Linn. *Momordica charantia* Linn. *Solanum melongena* Linn. *Catharanthus roseus* (Linn.) G.
	Aphis craccivora	*Psophocarpus tetragonolobus* (L.) *Vigna unguiculata* (L.) Walp.
Ankylopteryx octopunctata (Fabricius) (Chrysopidae: Neuroptera)*	*Aphis gossypii*	*Abelmoschus esculentus* (L.) *Capsicum annuum* Linn. *Solanum melongena* Linn.
	Aphis craccivora	*Psophocarpus tetragonolobus* (L.) *Vigna unguiculata* (L.) Walp.
Micromus sp.(Hemerobiidae: Neuroptera)	*Aphis gossypii*	*Abelmoschus esculentus* (L.) *Amaranthus tricolor* Linn. *Capsicum annuum* Linn. *Coccinia grandis* (L.) Voigt. *Momordica charantia* Linn. *Solanum melongena* Linn. *Trichosanthes anguina* Linn. *Ageratum conyzoides* Linn.
	Aphis craccivora	*Psophocarpus tetragonolobus* (L.) *Vigna unguiculata* (L.) Walp. *Moringa oleifera* Lamk
	Aphis spiraecola	*Coccinia grandis* (L.) Voigt. *Chromolaena odorata* (L.) *Clerodendrum viscosum* Vent.

* Predator first record from Kerala

Leucopis sp.

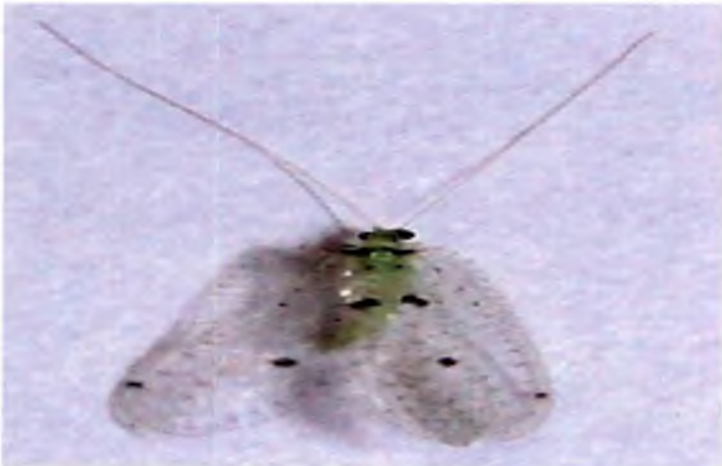
Adult



Larva feeding on *Myzus persicae*

Plate 22. *Leucopis* sp. recorded from vegetable ecosystem

Chrysoperla cornea



Ankylopteryx octopunctata

Micromus sp.

Plate 23. Neuropterans recorded from vegetable ecosystem

Spiders

Eleven species of spiders viz., *Oxyopes javanus* Thorell, *Tetragnatha mandibulata* Cambridge, *Oxyopes quadridentatus* Thorell, *Oxyopes shweta* Tikader, *Phidippus* sp., *Cheiracanthium* sp., *Neoscona* sp., *Tetragnatha* sp., *Oxyopes* sp., *Argiope* sp. and *Thomisus* sp. were recorded from different species of aphids in vegetable ecosystem (Table 18 and Plate 24).

T. mandibulata was observed to predate on *A. gossypii* which occurred on *A. esculentus, C. annuum, C. sativus, M. charantia, S. melongena, C. roseus, R. tuberosa*; *A. craccivora* on *P. tetragonolobus, V. unguiculata*; *H. setariae* on *C. barbata* and *D. aegyptium*; *A. nerii* on *C. gigantea* and *M. persicae* on *S. nigrum*.

O. javanus was recorded as predator of *A. gossypii* which was found on *A. esculentus, C. annuum, C. grandis, C. sativus, M. charantia, S. melongena, T. anguina* and *A. craccivora* on *A. tricolor, C. gladiata, C. tetragonoloba, L. purpureus, M. oleifera, P. vulgaris, P. tetragonolobus* and *V. unguiculata*.

O. quadridentatus preyed upon *H. setariae* infesting *A. tricolor, C. barbata, D. aegyptium, D. ciliaris, E. colona, E. indica*; *A. spiraecola* which hosted on *C. sativus, C. grandis, A. nodiflora* and *L. erysimi* on *R. sativus* and *C. viscosa*.

O. shweta was spotted predating on *A. craccivora* on *C. gladiata, P. vulgaris, P. tetragonolobus, V. unguiculata*; *A. gossypii* on *A. esculentus, A. tricolor, C. annuum*; *A. nerii* on *C. annuum* and *C. gigantea* and *A. spiraecola* on *M. oleifera* and *C. odorata*.

Phidippus sp. preyed on *A. gossypii* which infested *A. esculentus, C. annuum, C. grandis, C. melo* var. *Conomon, S. melongena, T. anguina* and *A. craccivora* on *M. oleifera, P. tetragonolobus* and *V. unguiculata*.

Cheiracanthium sp. predated on *A. gossypii* infesting *A. esculentus, A. tricolor, C. annuum, C. grandis, C. sativus* and *S. melongena*. *Neoscona* sp. also preyed on *A. gossypii* occurring on *A. esculentus, C. annuum, C. grandis* and *A. craccivora* on *P. tetragonolobus* and *V. unguiculata*.

Table 18. Spiders recorded from Thiruvananthapuram district

Species	Associated aphid species	Host plant
Oxyopes javanus Thorell (Oxyopidae)	*Aphis gossypii*	*Abelmoschus esculentus* (L.) Moench *Capsicum annuum* Linn. *Coccinia grandis* (L.) Voigt. *Cucumis sativus* Linn. *Momordica charantia* Linn. *Solanum melongena* Linn. *Trichosanthes anguina* Linn.
	Aphis craccivora	*Amaranthus tricolor* Linn. *Canavalia gladiata* (Jack) DC. *Cyamopsis tetragonoloba* (L.) Taub. *Lablab purpureus* (L.) Sweet *Moringa oleifera* Lamk *Phaseolus vulgaris* Linn. *Psophocarpus tetragonolobus* (L.) *Vigna unguiculata* (L.) Walp.
Tetragnatha mandibulata Cambridge (Tetragnathidae)	*Aphis gossypii*	*Abelmoschus esculentus* (L.) Moench *Capsicum annuum* Linn. *Cucumis sativus* Linn. *Momordica charantia* Linn. *Solanum melongena* Linn. *Catharanthus roseus* (L.) G. Don. *Ruellia tuberosa* Linn.
	Aphis craccivora	*Psophocarpus tetragonolobus* (L.) *Vigna unguiculata* (L.) Walp.
	Hysteroneura setariae	*Chloris barbata* Sw. *Dactyloctenium aegyptium* Beau.
	Aphis nerii	*Calotropis gigantea* (L.) W.T.Aiton
	Myzus persicae	*Solanum nigrum* Linn.
Oxyopes quadridentatus Thorell (Oxyopidae)	*Hysteroneura setariae*	*Amaranthus tricolor* Linn. *Chloris barbata* Sw. *Dactyloctenium aegyptium* Beau. *Digitaria ciliaris* (Retz.) Koeler *Echinochloa colona* Link. *Eleusine indica* (L.) Gaertn.
	Aphis spiraecola	*Cucumis sativus* Linn. *Coccinia grandis* (L.) Voigt. *Allmania nodiflora* (Linn.f) R.Br.
	Lipaphis erysimi	*Raphanus sativus* Linn. *Cleome viscosa* Linn.

Table 18. continued

Species	Associated aphid species	Host plant
Oxyopes shweta Tikader (Oxyopidae)	*Aphis craccivora*	*Canavalia gladiata* (Jack) DC. *Phaseolus vulgaris* Linn. *Psophocarpus tetragonolobus* (L.) *Vigna unguiculata* (L.) Walp.
	Aphis gossypii	*Abelmoschus esculentus* (L.) Moench *Amaranthus tricolor* Linn. *Capsicum annuum* Linn.
	Aphis nerii	*Capsicum annuum* Linn. *Calotropis gigantea* (L.) W.T.Aiton
	Aphis spiraecola	*Moringa oleifera* Lamk *Chromolaena odorata* (L.)
Phidippus sp. (Salticidae)	*Aphis gossypii*	*Abelmoschus esculentus* (L.) Moench *Capsicum annuum* Linn. *Coccinia grandis* (L.) Voigt. *Cucumis melo* var. *conomon* Mak. *Solanum melongena* Linn. *Trichosanthes anguina* Linn.
	Aphis craccivora	*Moringa oleifera* Lamk *Psophocarpus tetragonolobus* (L.) *Vigna unguiculata* (L.) Walp.
Cheiracanthium sp. (Miturgidae)	*Aphis gossypii*	*Abelmoschus esculentus* (L.) Moench *Amaranthus tricolor* Linn. *Capsicum annuum* Linn. *Coccinia grandis* (L.) Voigt. *Cucumis sativus* Linn. *Solanum melongena* Wall.
Neoscona sp. (Araneidae)	*Aphis gossypii*	*Abelmoschus esculentus* (L.) Moench *Capsicum annuum* Linn. *Coccinia grandis* (L.) Voigt.
	Aphis craccivora	*Psophocarpus tetragonolobus* (L.) *Vigna unguiculata* (L.) Walp.
Tetragnatha sp. (Tetragnathidae)	*Aphis gossypii*	*Capsicum annuum* Linn. *Cucumis sativus* Linn. *Momordica charantia* Linn.
	Aphis craccivora	*Psophocarpus tetragonolobus* (L.)
Oxyopes sp. (Oxyopidae)	*Aphis craccivora*	*Amaranthus tricolor* Linn. *Canavalia gladiata* (Jack) DC. *Cyamopsis tetragonoloba* (L.) Taub.
Argiope sp. (Araneidae)	*Aphis gossypii*	*Capsicum annuum* Linn.
Thomisus sp. (Thomisidae)	*Aphis craccivora*	*Moringa oleifera* Lamk

Cheiracanthium sp.

Neoscona sp.

Oxyopes javanus

Oxyopes sp.

Phidippus sp.

Tetragnatha mandibulata

Tetragnatha sp.

Thomisus sp.

Plate 24. Spiders species recorded from vegetable ecosystem

Tetragnatha sp. was perceived to be a predator of *A. gossypii* which infested *C. annuum, C. sativus, M. charantia* and *A. craccivora* on *P. tetragonolobus*. *Oxyopes* sp. also preyed on *A. craccivora* which damaged *A. tricolor, C. gladiata, C. tetragonoloba.* *Argiope* sp. and *Thomisus* sp. were noticed predating on *A. gossypii* (*C. annuum*) and *A. craccivora* (*M. oleifera*) respectively.

4.1.4 Parasitoids

Three species viz., *Aphidius* sp., *Aphelinus* sp.and *Diaeretiella rapae* (McIntosh) were the parasitoids recorded (Table 19 and Plate 25).

Aphidius sp. was recorded from *A. gossypii* seen on *A. esculentus, C. annuum, C. sativus, M. charantia, S. melongena, C. roseus, R. tuberosa*; *A. craccivora* on *P. tetragonolobus, V. unguiculata*; *H. setariae* on *C. barbata* and *D. aegyptium*; *A. nerii* on *C. gigantea* and *M. persicae* on *S. nigrum.*

Aphelinus sp. was obtained from *A. gossypii* which infested *A. esculentus, C. annuum, C. grandis, C. melo* var. *conomon, M. charantia, S. melongena, T. anguina* and *A. craccivora* on *M. oleifera, P. tetragonolobus* and *V. unguiculata.*

D. rapae was recorded as an important parasitoid of *L. erysimi* seen on *R. sativus* and *C. viscosa, C. burmanni* and *M. persicae* on *S. nigrum.*

4.1.5 Aphidocolous ants

Seven species of ants viz., *Camponotus compressus* Fabricius, *Monomorium* sp., *Camponotus* sp., *Solenopsis geminata* Fabricius, *Meranoplus* sp., *Oecophylla smaragdina* Smith, and *Crematogaster* sp. were observed attending various aphids on different host plants (Table 20 and Plate 26).

C. compressus was associated with *A. gossypii* prevailing on *A. esculentus, A. tricolor, C. annuum, C. grandis, C. sativus, L. esculentum, M. charantia, M. oleifera, P. tetragonolobus, S. melongena, T. anguina,*

Table 19. Parasitoids recorded from Thiruvananthapuram district

Species	Associated aphid species	Host plant
Aphidius sp. (Braconidae:Aphidiinae)	*Aphis gossypii*	*Abelmoschus esculentus* (L.)Moench *Capsicum annuum* Linn. *Cucumis sativus* Linn. *Momordica charantia* Linn. *Solanum melongena* Linn. *Catharanthus roseus* (L.) G. *Ruellia tuberosa* Linn.
	Aphis craccivora	*Psophocarpus tetragonolobus* *Vigna unguiculata* (L.) Walp.
	Hysteroneura setariae	*Chloris barbata* Sw. *Dactyloctenium aegyptium*
	Aphis nerii	*Calotropis gigantea* (L.) W.T.Aiton
	Myzus persicae	*Solanum nigrum* Linn.
Aphelinus sp. (Chalcididae:Aphelininae)	*Aphis gossypii*	*Abelmoschus esculentus* (L.)Moench *Capsicum annuum* Linn. *Coccinia grandis* (L.) Voigt. *Cucumis melo* var. *conomon*. *Momordica charantia* Linn. *Solanum melongena* Linn. *Trichosanthes anguina* Linn.
	Aphis craccivora	*Moringa oleifera* Lamk *Psophocarpus tetragonolobus* *Vigna unguiculata* (L.) Walp.
Diaeretiella rapae (McIntosh) (Braconidae:Aphidiinae)	*Lipaphis erysimi*	*Raphanus sativus* Linn. *Cleome viscosa* Linn. *Cleome burmanni* Wight&Arn.
	Myzus persicae	*Solanum nigrum* Linn.

Table 20. Aphidocolous ants (Hymenoptera : Formicidae) recorded from Thiruvananthapuram district

Species	Associated aphid species	Host plant
Camponotus compressus Fabricius	*Aphis gossypii*	*Abelmoschus esculentus* (L.) Moench *Amaranthus tricolor* Linn. *Capsicum annuum* Linn. *Coccinia grandis* (L.) Voigt. *Cucumis sativus* Linn. *Lycopersicon esculentum* Mill. *Momordica charantia* Linn. *Moringa oleifera* Lamk *Psophocarpus tetragonolobus* (L.) *Solanum melongena* Linn. *Trichosanthes anguina* Linn. *Catharanthus pusillus* (Murry) *Catharanthus roseus* (L.) G. Don. *Centella asiatica* Urban. *Commelina benghalensis* Linn.
	Aphis craccivora	*Canavalia gladiata* (Jack) DC. *Cyamopsis tetragonoloba* (L.) Taub. *Lablab purpureus* (L.) Sweet *Psophocarpus tetragonolobus* (L.) *Vigna unguiculata* (L.) Walp. *Gliricidia maculata* (Jacq.) Kunth *Indigofera tinctoria* Linn. *Cassia auriculata* Linn. *Crotolaria pallida* Aiton *Tephrosia purpurea* (L.) Pers.
	Aphis spiraecola	*Cucumis sativus* Linn. *Coccinia grandis* (L.) Voigt *Ageratum conyzoides* Linn. *Chromolaena odorata* (L.)
	Hysteroneura setariae	*Chloris barbata* Sw. *Dactyloctenium aegyptium* Beau. *Digitaria ciliaris* (Retz.) Koeler *Eleusine indica* (L.) Gaertn.
	Lipaphis erysimi	*Brassica oleracea* L.var. *capitata* L. *Raphanus sativus* Linn. *Cleome viscosa* Linn.
	Aphis nerii	*Capsicum annuum* Linn. *Calotropis gigantea* (L.)

Table 20. continued

Species	Associated aphid species	Host plant
Monomorium sp.	*Aphis gossypii*	*Abelmoschus esculentus* (L.)Moench *Capsicum annuum* Linn. *Coccinia grandis* (L.) Voigt. *Cucumis sativus* Linn. *Momordica charantia* Linn. *Psophocarpus tetragonolobus* (L.) *Solanum melongena* Linn. *Catharanthus roseus* (L.) G. Don. *Cleome burmanni* Wight&Arn. *Commelina benghalensis* Linn. *Tridax procumbens* Linn.
	Aphis craccivora	*Amaranthes tricolor* Linn. *Canavalia gladiata* (Jack) DC. *Cyamopsis tetragonoloba* (L.)Taub. *Lablab purpureus* (L.) Sweet *Psophocarpus tetragonolobus* (L.) *Vigna unguiculata* (L.) Walp. *Aeschynomene indica* Linn. *Indigofera tinctoria* Linn. *Mimosa pudica* Linn. *Tephrosia tinctoria* (L.) Pers.
	Hysteroneura setariae	*Dactyloctenium aegyptium* Beau. *Digitaria ciliaris* (Retz.) Koeler *Eleusine indica* (L.) Gaertn.
	Lipaphis erysimi	*Brassica oleracea* L. var. *capitata* L. *Raphanus sativus* Linn. *Cleome viscosa* Linn.
	Aphis nerii	*Capsicum annuum* Linn. *Calotropis gigantea* (L.) W.T.Aiton
Camponotus sp.	*Aphis gossypii*	*Abelmoschus esculentus* (L.)Moench *Amaranthus tricolor* Linn. *Capsicum annuum* Linn. *Coccinia grandis* (L.) Voigt. *Cucumis sativus* Linn. *Lycopersicon esculentum* Mill. *Momordica charantia* Linn. *Moringa oleifera* Lamk *Solanum melongena* Linn. *Catharanthus roseus* (L.) G. Don. *Commelina benghalensis* Linn.
	Aphis craccivora	*Amaranthus tricolor* Linn. *Cyamopsis tetragonoloba* (L.) Taub. *Lablab purpureus* (L.) Sweet *Psophocarpus tetragonolobus* (L.) *Vigna unguiculata* (L.) Walp.
	Aphis spiraecola	*Ageratum conyzoides* Linn. *Chromolaena odorata* (L.) *Clerodendrum viscosum* Vent.

Table 20. continued

Species	Associated aphid species	Host plant
	Hysteroneura setariae	*Chloris barbata* Sw. *Dactyloctenium aegyptium* Beau. *Digitaria ciliaris* (Retz.) Koeler
	Myzus persicae	*Solanum melongena* Wall. *Lycopersicon esculentum* Mill. *Solanum nigrum* Linn.
	Lipaphis erysimi	*Cleome viscosa* Linn.
Solenopsis geminata Fabricus	*Aphis gossypii*	*Abelmoschus esculentus* (L.) Moench *Capsicum annuum* Linn. *Coccinia grandis* (L.) Voigt. *Cucumis sativus* Linn. *Psophocarpus tetragonolobus* (L.) *Trichosanthes anguina* Linn. *Catharanthus roseus* (L.) G. Don. *Commelina benghalensis* Linn.
	Aphis craccivora	*Amaranthus tricolor* Linn. *Lablab purpureus* (L.) Sweet *Psophocarpus tetragonolobus* (L.) *Vigna unguiculata* (L.) Walp. *Aeschynomene indica* Linn. *Indigofera tinctoria* Linn. *Crotolaria pallida* Aiton *Tephrosia tinctoria* (L.)Pers.
	Hysteroneura setariae	*Eleusine indica* (L.) Gaertn.
Meranoplus sp.	*Aphis spiraecola*	*Ageratum conyzoides* Linn. *Chromolaena odorata* (L.) *Clerodendrum viscosum* Vent. *Euphorbia heterophylla* Linn. *Euphorbia hirta* Linn. *Gloriosa superba* Linn.
	Aphis gossypii	*Abelmoschus esculentus* (L.) *Capsicum annuum* Linn. *Coccinia grandis* (L.) Voigt. *Cucumis sativus* Linn.
Oecophylla smaragdina Smith	*Aphis spiraecola*	*Coccinia grandis* (L.) Voigt. *Ageratum conyzoides* Linn. *Chromolaena odorata* (L.) *Clerodendrum paniculatum* Linn. *Euphorbia heterophylla* Linn. *Tinospora cordifolia* (Willd) Miers.
Crematogaster sp.	*Aphis spiraecola*	*Ageratum conyzoides* Linn. *Chromolaena odorata* (L.) *Clerodendrum viscosum* Vent.

Aphelinus sp.

Aphidius sp.

Diaeretiella rapae

Plate 25. Parasitoids recorded from aphids infesting vegetables

Camponotus compressus attending
A. gossypii on chilli

Crematogaster **sp.** attending
A. spiraecola on winged bean

Meranoplus **sp.** attending ***A. spiraecola***
on ***Chromolaena odorata***

Monomorium **sp** attending
A.gossypii on ***Ocimum*** **sp.**

Oecophylla smaragdina attending
A. craccivora on cowpea

Solenopsis geminata attending
A. gossypii on chilli

Plate 26. Ant species associated with aphids

C. pusillus, C. roseus, C. asiatica, C. burmanni, C. benghalensis; *A. craccivora* occurring on *C. gladiata, C. tetragonoloba, L. purpureus, P. tetragonolobus, V. unguiculata, G. maculata, I. tinctoria, C. auriculata, C. pallida, T. purpurea*; *A. spiraecola* on *C. sativus, C. grandis, A. conyzoides, C. odorata*; *H. setariae* on *C. barbata, D. aegyptium, D. ciliaris, E. indica*; *L. erysimi* on *B. oleracea* L. var. *capitata, R. sativus, C. viscosa* and *A. nerii* on *C. annuum* and *C. gigantea.*

Monomorium sp. existed in colonies of *A. gossypii* on *A. esculentus, C. annuum, C. grandis, C. sativus, L. esculentum, M. charantia, M. oleifera, P. tetragonolobus, S. melongena, C. roseus, C. burmanni, C. benghalensis, T. procumbens; A. craccivora* on *A. tricolor, C. gladiata, C. tetragonoloba, L. purpureus, P. tetragonolobus, V. unguiculata, A. indica I. tinctoria, M. pudica, T. tinctoria*; *H. setariae* on *D. aegyptium, D. ciliaris, E. indica*; *L. erysimi* on *B. oleracea* L. var. *capitata, R. sativus, C. viscosa* and *A. nerii* on *C. annuum* and *C. gigantea.*

Camponotus sp. was related with *A. gossypii* which infested *A. esculentus, A. tricolor, C. annuum, C. grandis, C. sativus, L. esculentum, M. charantia, M. oleifera, S. melongena, C. roseus, C. burmanni, C. benghalensis*; *A. craccivora* on *A. tricolor, C. tetragonoloba, L. purpureus, P. tetragonolobus, V. unguiculata*; *A. spiraecola* on *A. conyzoides, C. odorata, C. viscosum*; *H. setariae* on *C. barbata, D. aegyptium, D. ciliaris*; *M. persicae* on *S. melongena, L. esculentum, S. nigrum* and *L. erysimi* on *C. viscosa.*

S. geminata was associated with *A. gossypii* found on *A. esculentus, C. annuum, C. grandis; A. craccivora* hosted on *A. tricolor, L. purpureus, P. tetragonolobus, V. unguiculata, A. indica I. tinctoria, C. pallida, T. tinctoria* and *H. setariae* on *E. indica.*

Meranoplus sp. was associated with *A. spiraecola* on *A. conyzoides, C. odorata, C. viscosum, E. heterophylla, E. hirta, G. superba* and *A. gossypii* on *A. esculentus, C. annuum, C. grandis* and *C. sativus.*

O. smaragdina was associated with *A. spiraecola* on *C. grandis, A. conyzoides, C. odorata, C. paniculatum, E. heterophylla, T. cordifolia. Crematogaster* sp.was also associated with *A. spiraecola* on *A. conyzoides, C. odorata* and *C. viscosum.*

4.1.6 Population of Aphids in Different Vegetables

The population of the two dominant aphids viz., *A. gossypii, A. craccivora* at vegetative and reproductive stages in the popular vegetables of Thiruvananthapuram district during 2006-2007 expressed as number per 15 cm shoot is presented in Table 21.

A. gossypii

At the vegetative stage, the population of the aphid ranged from 3.3 to 5.0 per 15 cm shoot in amaranthus. In the solanaceous vegetables, the population of the pest ranged from 6.6 to 11.6 (brinjal), 1.6 to 9.2 (tomato) and 15.8 to 19.2 (chilli) per 15 cm shoot. Okra harboured 8.3 to 15.8 aphids per 15 cm shoot. Appreciable population of the pest was also recorded from the cucurbitaceous vegetables viz., cucumber (11.6 to 15.8), coccinia (17.5 to 24.2), snake gourd (1.6 to 10.8) and bittergourd (9.2 to 11.6). Comparatively, low population of the aphid was seen in the legumes viz., winged bean (1.6 to 7.5) and cowpea (1.6 to 8.3).

In the reproductive stage, 5.0 to 9.2 aphids per 15 cm shoot were recorded on amaranthus. Brinjal, tomato and chilli registered 14.2 to 19.2, 6.6 to 8.3 and 25.8 to 38.3 aphids per 15 cm shoot, respectively. The population of the pest in okra ranged from 12.5 to 32.5 aphids per 15 cm shoot. The cucurbitaceous vegetables viz., cucumber (4.6 to 8.3), coccinia (20.8 to 29.2), snake gourd (6.6 to 9.2) and bittergourd (12.5 to 15.8) recorded lower population. The population of the aphid in winged bean and cowpea ranged from 8.3 to 10.8 and 6.6 to 12.5 per 15 cm shoot, respectively.

Table 21. Population of *Aphis gossypii* and *Aphis craccivora* in different vegetables in Thiruvananthapuram district, 2006-2007

Aphids/Crops	Mean number of aphids per 15 cm shoot							
	Thiruvanathapuram		Neyyattinkara		Nedumangad		Cherayinkizhil	
	VS	RS	VS	RS	VS	RS	VS	RS
A.gossypii								
Amaranthus	3. 3	5. 0	4. 2	8. 3	3. 3	9. 2	5. 0	7. 5
Brinjal	10.8	18.3	6. 6	14.2	7. 5	17.5	11.6	19.2
Okra	13.3	29.2	10.8	13.3	8. 3	12.5	15.8	32.5
Tomato	7. 5	8. 3	1. 6	7. 5	9. 2	6. 6	3. 3	6. 6
Chilli	18.3	33.3	15.8	25.8	17.5	36.6	19.2	38.3
Cucumber	15.8	8. 3	12.5	7. 5	11.6	4. 6	14.2	5. 8
Coccinia	22.5	28.3	24.2	26.6	17.5	20.8	21.6	29.2
Bitter gourd	11.6	13.3	10.8	14.2	9. 2	12.5	10.8	15.8
Snake gourd	3. 3	8. 3	1. 6	6. 6	10.8	8. 3	1. 6	9. 2
Winged bean	1. 6	8. 3	3. 3	9. 2	5. 8	10.8	7. 5	9. 2
Cowpea	8. 3	12.5	1. 6	6. 6	1.6	9. 2	8. 3	10.8
A. craccivora								
Amaranthus	1. 6	3. 3	2. 5	7. 5	2. 5	6. 6	8. 3	9. 2
Cowpea	23.3	28.3	25.8	31.6	14.2	19.2	18.3	26.6
Cluster bean	12.5	14.2	9. 2	11.6	10.8	13.3	9. 2	15.8
Dolichos bean	10.8	16.6	11.6	19.2	13.3	22.5	13.3	23.3
Winged bean	16.6	32.5	19.2	30.8	15.8	24.2	21.6	33.3

VS- Vegetative stage RS- Reproductive stage

A. craccivora

The population of the aphid ranged from 1.6 to 8.3 per 15 cm shoot in amaranthus during the vegetative stage. Cowpea recorded 14.2 to 25.8 aphids per 15 cm shoot. The population of the pest in cluster bean, dolichos bean and winged bean ranged from 9.2 to 12.5, 10.8 to 13.3 and 15.8 to 21.6 respectively.

During the reproductive stage, 3.3 to 9.2 aphids per 15 cm shoot was observed in amaranthus. High population of the pest was seen in cowpea the number per 15 cm shoot ranging from 19.2 to 31.6. While cluster bean recorded 11.6 to 15.8 aphids per 15 cm shoot. The population of the pest in dolichos bean and winged bean ranged from 16.6 to 23.3 and 24.2 to 33.3 per 15 cm shoot, respectively.

4.1.7 Aphid Damage Index (ADI)

The data on aphid damage index (ADI) on various vegetables in Thiruvananthapuram district during 2006-2007 are presented in Table 22.

A. gossypii

The damage by the aphid in amaranthus (0 to 1.6) was comparatively low in the vegetative phase. Among the solanaceous vegetables, the damage in chilli was higher (10.8 to 12.5) than in brinjal (2.5 to 7.5) and tomato (0 to 3.3) as indicated by the damage indices computed. The extent of damage in okra ranged from 3.3 to 8.3. The cucurbitaceous vegetables viz., cucumber, coccinia, bitter gourd and snake gourd registered 5.8 to 8.3, 9.2 to 12.5, 3.3 to 5.8 and 0 to 2.5 damage indices respectively. Lower damage was seen in winged bean (0 to 2.5) and cowpea (0 to 2.5).

In the reproductive phase too, low damage was seen in amaranthus (2.5 to 3.3). The solanaceous vegetables, brinjal, tomato and chilli recorded 9.1 to 14.2, 1.6 to 2.5 and 17.5 to 27.5 damage indices respectively. The extent of damage in okra ranged from 5.8 to 21.6. Among the cucurbitaceous vegetables, higher damage was seen in coccinia (12.5 to 18.3) than in cucumber (1.6 to 2.5), bittergourd (6.6 to 8.3) and snakegourd (1.6 to 3.3).

A. craccivora

Infestation by *A. craccivora* was very low in amaranthus as indicated by the damage index (0 to 3.3) in the vegetative phase. The legumes cowpea (6.6 to 14.2), cluster bean (3.3 to 7.5), dolichos bean (4.2 to 7.5) and winged bean (7.5 to 11.6) showed higher damage.

A similar trend was seen in the reproductive phase too. While the damage index in amaranthus ranged from 0 to 3.3, it was 8.3 to 18.3 in cowpea, 4.2 to 8.3 in cluster bean, 8.3 to 12.5 in dolichos bean and 13.3 to 18.3 in winged bean.

4.1.8 Mosaic Disease Incidence

Incidence of mosaic disease was noted in 10 vegetables and the data on the percentage of plants infected are presented in Table 23.

At the vegetative stage, the percentage of plants affected in amaranthus ranged from 3.55 to 11.60. While the percentage of diseased plants in brinjal ranged from 2.42 to 7.65, it ranged from 2.23 to 6.45 in chilli. Incidence of the disease was high in the cucurbitaceous vegetable like bitter gourd (12.85 to 24.42), coccinia (12.85 to 20.65) and cucumber (11.60 to 16.28). Comparated to these cucurbitaceous vegetables, lower incidence was noticed in snake gourd (2.50 to 8.50). Among the legumes, higher incidence was seen in cowpea (8.25 to 16.62). Both dolichos bean (2.25 to 10.50) and winged bean (0 to 4.35) showed lower incidence of the disease.

The percentage of plants infected in amaranthus ranged from 9.55 to 15.83 in the reproductive stage. Brinjal and chilli recorded 6.32 to 10.61 and 5.54 to 8.74 per cent diseased plants, respectively. As in the vegetative phase, high incidence of the disease was noted in bitter gourd (16.25 to 32.81), coccinia (18.54 to 28.35) and cucumber (15.30 to 22.25). The percentage of infected plants ranged from 6.34 to 12.25 in snake gourd. While 10.40 to 20.67 per cent diseased plants were recorded in cowpea, the percentage of plants infected ranged from 7.67 to 14.25 in dolichos bean and 2.24 to 7.82 in winged bean.

Table 22. Extent of damage caused by *Aphis gossypii* and *Aphis craccivora* in different vegetables in Thiruvananthapuram district, 2006-2007

Aphids/Crops	Damage index							
	Thiruvanathapuram		Neyyattinkara		Nedumangad		Cherayinkizhil	
	VS	RS	VS	RS	VS	RS	VS	RS
A.gossypii								
Amaranthus	1. 6	2. 5	1. 6	2. 5	0.0	3. 3	1. 6	3. 3
Brinjal	7. 5	14.2	2. 5	9. 1	2. 5	9. 2	4. 2	13.3
Okra	8. 3	20.8	6. 6	9. 2	3. 3	5. 8	8. 3	21.6
Tomato	2. 5	2. 5	0.0	2. 5	3. 3	2. 5	0.0	1. 6
Chilli	11.6	24.2	10.8	17.5	11.6	25.8	12.5	27.5
Cucumber	6. 6	2. 5	5. 8	2. 5	5. 8	1. 6	8. 3	1. 6
Coccinia	11.6	14.2	12.5	12.5	9. 2	12.5	12.5	18.3
Bitter gourd	5. 8	6. 6	5. 8	8. 3	3. 3	7. 5	4. 2	8. 3
Snake gourd	0.0	2. 5	0.0	1. 6	2. 5	2. 5	0.0	3. 3
Winged bean	0.0	2. 5	0.0	3. 3	1. 6	3. 3	2. 5	2. 5
Cowpea	2. 5	3. 3	0.0	1. 6	0.0	3. 3	2. 5	3. 3
A. craccivora								
Amaranthus	0.0	0.0	0.0	1. 6	0.0	1. 6	3. 3	3. 3
Cowpea	11.6	12.5	14.2	18.3	6. 6	8. 3	9. 2	14.2
Cluster bean	7. 5	8. 3	3. 3	4. 2	4. 2	7. 5	3. 3	8. 3
Dolichos bean	4. 2	8. 3	5. 8	9. 2	6. 6	11.6	7. 5	12.5
Winged bean	7. 5	18.3	10.8	17.5	8. 3	13.3	11.6	18.3

VS- Vegetative stage RS- Reproductive stage

Table 23. Incidence of mosaic disease in different vegetables in Thiruvananthapuram district, 2006-07

Crops	Plants infected (per cent)							
	Thiruvananthapuram		Neyyattinkara		Nedumangad		Cherayinkizhil	
	VS	RS	VS	RS	VS	RS	VS	RS
Amaranthus	6.05	11.25	11.60	15.83	3.55	9.55	7.80	12.82
Bitter gourd	16.32	30.66	24.42	32.81	17.25	32.43	12.85	16.25
Brinjal	3.50	8.85	7.65	10.61	4.25	6.32	2.42	8.75
Chilli	4.32	6.22	2.23	5.54	6.45	8.74	5.30	8.62
Coccinia	17.20	25.23	20.65	28.35	12.85	18.54	14.35	24.73
Cowpea	8.25	10.40	16.62	20.67	11.50	18.24	14.35	16.21
Cucumber	11.60	18.83	14.23	17.31	16.28	22.25	12.75	15.30
Dolichos bean	2.25	8.72	4.36	7.67	6.20	9.23	10.50	14.25
Snake gourd	3.65	7.85	2.50	6.34	4.55	10.65	8.50	12.25
Winged bean	2.25	4.65	4.35	7.82	0.00	2.24	3.65	5.35

VS- Vegetative stage RS- Reproductive stage

4.2. SEASONAL INCIDENCE

The results of the studies on the population fluctuation and peak period of incidence of *A. gossypii* and *A. craccivora* in chilli and winged bean, respectively and their natural enemies in a cropping period are presented in Tables 24 to 27. The population of the aphid is expressed as number per 15 cm shoot, predators as number per plant and parasitoids as number per sweep.

4.2.1 Chilli

2006-07

The melon aphid, *A. gossypii* prevailed in chilli throughout the cropping season (Table 24). Occurrence of the pest was noticed during the first week of October (2.24) and was seen in low density upto the second week (2.35). An increase in the population was observed from the third week recording 4.24, 10.31, 15.93, 23.81 and 27.62 aphids per 15 cm shoot during the third and fourth week of October and first, second and third week of November, respectively. High population of the pest was seen from the fourth week of November (30.27) to first week of January (31.13). During the period, population of the aphid was the maximum during the third week of December (40.21). During the first, second, fourth and fifth week of December, 38.36, 39.42, 37.62 and 37.24 aphids per 15 cm shoot were recorded, respectively. After the first week of January, a declining trend was noted in the population of the pest, the population being 26.52, 22.12 and 16.25 per 15 cm shoot during second, third and fourth week of January, respectively.

With regard to the population of the predators and parasitoids during the period, the population of coccinellids was very low during the month of October to first week of November (0.04 to 0.74). The population increased from the second week of November (1.11) to the first week of December (1.85). Comparatively high population of the coccinellid was prevalent in the field from the second week of December (2.00) to the second week of

Table 24. Incidence of *Aphis gossypii* and its natural enemies on chilli, 2006-2007

Period		Aphid/ 15 cm shoot	Natural enemies (number per plant)						Parasitoids/ sweep
Month & Week	Std. Week		Coccinellids	Chrysopids	Hemerobiids	Syrphids	*Leucopis* spp.	Spiders	
October									
I	40	2.24	0.04	0.02	0.00	0.00	0.02	0.00	0.03
II	41	2.35	0.07	0.04	0.01	0.09	0.09	0.09	0.07
III	42	4.24	0.31	0.08	0.16	0.32	0.58	0.15	0.14
IV	43	10.31	0.44	0.24	0.45	0.58	0.98	0.42	0.20
November									
I	44	15.93	0.74	0.44	0.72	0.89	1.56	0.74	0.33
II	45	23.81	1.11	0.56	0.86	1.10	2.41	0.86	0.36
III	46	27.62	1.36	0.68	0.93	1.22	2.78	0.81	0.56
IV	47	30.27	1.56	0.92	0.98	1.25	3.29	0.88	0.65
December									
I	48	38.36	1.85	0.98	1.00	1.28	3.48	0.97	0.69
II	49	39.42	2.00	1.02	1.06	1.36	3.62	0.96	0.89
III	50	40.21	2.22	0.89	1.09	1.12	3.68	1.08	1.11
IV	51	37.62	2.45	0.84	0.97	0.95	3.89	1.24	1.17
V	52	37.24	2.15	0.78	0.90	0.97	3.35	1.35	0.76
January									
I	1	31.13	2.22	0.75	0.87	0.89	3.22	1.48	0.66
II	2	26.52	2.00	0.71	0.85	0.96	3.09	1.30	0.56
III	3	22.12	1.93	0.69	0.77	1.02	2.95	1.22	0.54
IV	4	16.25	1.41	0.57	0.70	1.00	2.68	1.14	0.73
Mean		23.86	1.40	0.60	0.73	0.88	2.45	0.86	0.56

January (2.00). Maximum population was seen during the fourth week of December (2.45). The population noticed during third week and fifth week of December and first week of January were 2.22, 2.15 and 2.22 per plant, respectively. A decline in the population was noticed from third (1.93) to fourth (1.41) week of January.

The population of chrysopids was very low in the field throughout the cropping season. The population was negligible during October (0.02 to 0.24). During November too the population was substantially low (0.44 to 0.92). The highest population (1.02) was recorded during the second week of December. Thereafter, again a decline in the population of the predator was seen during December (0.89 to 0.78) and January (0.75 to 0.57).

The population of hemerobiids too was low in the field. With the exception of 1.00, 1.06 and 1.09 hemerobiids per plant observed during first, second and third week of December, the population of the predator was insignificant during the other periods (0 to 0.98). Contrarily, more number of syrphids were observed during the cropping season. The predator first appeared during the second week of October (0.09) and prevailed in low numbers upto the first week of November (0.32 to 0.89). An increase in the population of the syrphids was seen from the second week onwards (1.10) being 1.22, 1.25, 1.28 and 1.36 per plant during third and fourth week of November and first and second week of December, respectively. A decline in the population was noticed from the third week of December (1.12) to the second week of January (0.89 to 0.97). Subsequently, an increase in the population was seen during the third (1.02) and fourth (1.00) weeks of January.

The population of the chamaemyiid, *Leucopis* sp. was comparatively high in the chilli plot during the cropping season. During the month of October, population of the predator was low ranging from 0.02 (first week of October) to 0.98 (fourth week of October) per plant. The population started increasing from the first week of November (1.56) and recorded 2.41 and 2.78 per plant *Leucopis* sp. per plant during the second and third week, respectively. Subsequently, high population of the predator was seen in the chilli plot from the fourth week of November to the first week of January, the population recorded being 3.29 (fourth week of November), 3.48 (first week of December), 3.62 (second week of December), 3.68 (third week of December), 3.89 (fourth week of December), 3.35 (fifth week of December), 3.22 (first week of January) and 3.09 (second week of January) per plant. Though, a decline in the population was seen during the third (2.95) and fourth (2.68) weeks of January, the population was relatively higher than that of other predators.

The population of spiders was low during the early and mid stages of the crop from October first week to second week of December, the population ranging from 0.00 to 0.96 during the period. From the third week of December till the end of the cropping season, appreciable number of spiders were seen in the plot being 1.08, 1.24 and 1.35 per plant during the third, fourth and fifth week of December, respectively and 1.48, 1.30, 1.22 and 1.14 per plant during first, second, third and fourth week of January, respectively.

Compared to the predators population of parasitoids was very low in the plot. With the exception of 1.11 and 1.17 parasitoids observed per sweep during the third and fourth week of December respectively, the population of the bioagent was very low during the other periods ranging from 0.03 to 0.89 per sweep from first week of October to second week of December and 0.54 to 0.76 per sweep during fifth week of December to fourth week of January.

2007-08

During 2007-08 too *A. gossypii* was observed throughout the cropping season (Table 25). Though low population was seen during the first (2.04) and second week (2.43) of October, the population started building up during the third week (9.37). Henceforth, a steady increase in the population

Table 25. Incidence of *Aphis gossypii* and its natural enemies on chilli, 2007-2008

Period		Aphid/ 15 cm shoot	Natural enemies (number per plant)						Parasitoids/ sweep
Month & Week	Std. Week		Coccinellids	Chrysopids	Hemerobiids	Syrphids	*Leucopis* spp.	Spiders	
October									
I	40	2.04	0.11	0.02	0.00	0.00	0.04	0.00	0.02
II	41	2.43	0.11	0.11	0.12	0.11	0.08	0.11	0.08
III	42	9.37	0.15	0.22	0.23	0.22	0.35	0.18	0.24
IV	43	15.14	0.28	0.43	0.55	0.49	0.71	0.47	0.28
November									
I	44	20.13	0.69	0.57	0.79	0.67	1.63	0.82	0.29
II	45	24.86	0.98	0.68	0.99	0.71	2.06	0.91	0.41
III	46	28.11	1.24	0.80	1.02	0.82	2.28	1.22	0.65
IV	47	30.42	1.33	0.81	1.09	0.94	2.46	1.28	0.73
December									
I	48	31.15	1.34	0.88	1.15	0.99	2.77	1.37	0.79
II	49	30.81	1.35	0.89	1.26	1.08	2.69	1.57	1.02
III	50	27.32	1.67	0.95	1.15	1.15	2.96	1.50	1.22
IV	51	24.34	1.50	0.89	1.26	1.05	3.22	1.70	1.30
V	52	23.61	1.37	0.86	1.02	1.10	3.08	1.51	1.22
January									
I	1	20.45	1.26	0.67	0.98	0.95	3.02	1.44	1.17
II	2	20.58	1.24	0.64	0.96	0.92	2.81	1.22	0.89
III	3	17.25	1.06	0.57	0.83	0.89	2.55	1.35	0.92
IV	4	15.54	0.95	0.49	0.75	0.95	2.54	1.08	0.81
Mean		20.21	0.98	0.62	0.83	0.77	2.07	1.04	0.71

was seen, the number of aphids per 15 cm shoot being 20.13 and 24.86 during the first and second week of November. High population was noted from the third week of November to the third week of December, the number of aphids recorded being 28.11 (third week of November), 30.42 (fourth week of November), 31.15 (first week of December), 30.81 (second week of December) and 27.32 (third week of December) per 15 cm shoot. Thereafter, a decrease was noted in the population, the population registered being 24.34 and 23.61 per 15 cm shoot during fourth and fifth week of December, respectively and 20.45, 20.58, 17.25 and 15.54 per 15 cm shoot during first, second, third and fourth week of January, respectively.

Very low number of coccinellid predators were recorded during the early cropping phase (first week of October to second week of November) the population ranging from 0.11 to 0.98 per plant. Subsequently, appreciable population of the predator was seen from the third week of November to third week of January. The population of the coccinellids during the period ranged from 1.24 to 1.35 per plant during the fourth week of November to second week of December and 1.06 to 1.67 per plant during the fifth week of December to third week of January with a high population of 1.67 and 1.50 coccinellids per plant during the third and fourth week of December, respectively.

The population of the chrysopids was very low in the plot compared to the other predators. Only 0.02 to 0.95 chrysopids per plant were seen in the plot during the cropping season. Contrarily, higher population of hemerobiids was seen in the plot. Substantial population of the predator was seen from the third week of November to the fifth week of December, the numbers recorded being 1.02 and 1.09 per plant in the third and fourth week of November, respectively and 1.15, 1.26, 1.15, 1.26 and 1.02 per plant during first, second, third and fourth week of December, respectively. During the early (October first week to November second week) and later phase of the crop (January) very low population of the predator was noted ranging from 0 to 0.99 and 0.75 to 0.98 per plant, respectively.

Syrphid population ranged from 0 to 0.99 per plant from the first week of October to first week of December. Subsequently, an increase in the population was seen being 1.08, 1.15, 1.05 and 1.10 per plant during second, third, fourth and fifth week of December, respectively. Thereafter, the population declined, ranging from 0.89 to 0.95 per plant. High population of *Leucopis* sp. was seen in the chilli plot. With the exception of the low population seen during the first month (0.04 to 0.71), substantial population of the predator prevailed throughout the cropping period. During November, the population ranged from 1.63 to 2.46 per plant. Higher population was recorded during December being 2.77 (first week), 2.69 (second week), 2.96 (third week), 3.22 (fourth week) and 3.08 (fifth week) per plant. During January too, the population was high being 3.02, 2.81, 2.55 and 2.54 per plant in the first, second, third and fourth week, respectively.

The population of spiders was low during the early stages of the crop ranging from 0 to 0.91 per plant (first week of October to second week of November). Subsequently, higher population prevailed till the end of the cropping season. While the population ranged from 1.22 to 1.37 per plant during the third week of November to the first week December, the number of spiders recorded during second, third, fourth and fifth week of December was 1.57, 1.50, 1.70 and 1.51 per plant, respectively. A slight decrease was noted thereafter, being 1.44, 1.22, 1.35 and 1.08 per plant during the four weeks of January, respectively.

The population of parasitoids was also very low in the field. With the exception of 1.02, 1.22, 1.30, 1.22 and 1.17 parasitoids recorded per sweep during second, third, fourth and fifth week of December and first week of January, respectively, the population of the natural enemy during the other periods was very low, ranging from 0.02 to 0.79 per sweep from October to first week of December and 0.81 to 0.92 per sweep from the second week of January to fourth week of January.

4.2.2 Winged bean

2006-07

Aphid incidence was recorded from the first week of October (Table 26). During the month, population of the pest was low (2.83 to 7.14). High incidence of the aphid was noted during the first week of November (20.43) and 20.92, 21.04 and 21.08 aphids per 15 cm shoot were recorded during the subsequent consecutive three weeks. High population of the pest was also seen during December being 23.42, 24.86, 25.05, 27.32 and 30.28 per 15 cm shoot during the five weeks respectively and January being 26.04, 24.15, 24.82 and 22.05 per 15 cm shoot during the four weeks, respectively. Subsequently, the population declined the number recorded being 17.84, 15.12, 11.85 and 10.25 per 15 cm shoot during the consecutive four weeks of February, respectively.

Appreciable coccinellid population was recorded from the field during the cropping season. While the population was low to the middle of November (0.02 to 0.96), an increase was seen subsequently from the third week of November to third week of December (1.50 to 1.95). High population was seen from the fourth week of December to fourth week of January (2.16 to 2.35). A slight decline in the population was noted there after, the population registered being 1.69, 1.79, 1.99 and 2.02 per plant during the four consecutive weeks of February.

Low population of hemerobiids was recorded upto mid November (0.02 to 0.88). Subsequently, an increase in the population was seen and more or less uniform population was seen in the field throughout the cropping season (1.08 to 1.87). Similarly, only low population of syrphids was recorded from the winged bean plot throughout the season (0.09 to 0.97. Contrarily, high population of *Leucopis* sp. was seen in the plot. While low population was recorded during October (0.09 to 0.81), an increase in the population was noted in November (1.48 to 2.31). During, December and first week of January too high population of the predator was noticed in the plot (3.08 to 3.78). Again, a remarkable increase in the population was

Table 26. Incidence of *Aphis craccivora* and its natural enemies on winged bean, 2006-2007

Period		Aphid/ shoot	Natural enemies (number per plant)					Parasitoids/ sweep
Month & Week	Std. Week		Coccinellids	Hemerobiids	Syrphids	*Leucopis* spp.	Spiders	
October I	40	2.83	0.02	0.02	0.09	0.09	0.08	0.04
II	41	5.21	0.10	0.04	0.22	0.24	0.16	0.08
III	42	6.31	0.18	0.28	0.29	0.68	0.19	0.16
IV	43	7.14	0.28	0.43	0.42	0.81	0.26	0.45
November I	44	20.43	0.82	0.75	0.55	1.48	0.30	0.46
II	45	20.92	0.96	0.88	0.68	1.76	0.39	0.63
III	46	21.04	1.50	1.08	0.75	2.04	0.39	0.66
IV	47	21.08	1.64	1.32	0.83	2.31	0.42	0.73
December I	48	23.42	1.72	1.62	0.83	3.08	1.15	0.89
II	49	24.86	1.91	1.74	0.88	3.21	1.16	0.95
III	50	25.05	1.95	1.79	0.97	3.55	1.24	1.13
IV	51	27.32	2.16	1.86	0.90	3.68	1.51	1.30
V	52	30.28	2.29	1.87	0.74	3.76	1.55	1.34
January I	1	26.04	2.22	1.90	0.72	3.88	1.48	1.27
II	2	24.15	2.19	1.81	0.61	4.04	1.43	1.15
III	3	24.82	2.31	1.79	0.68	4.15	1.35	0.96
IV	4	22.05	2.35	1.69	0.72	4.29	1.21	0.90
February I	5	17.84	1.69	1.61	0.62	4.45	1.08	0.82
II	6	15.12	1.79	1.38	0.58	4.35	0.95	1.10
III	7	11.85	1.99	1.24	0.48	4.45	1.03	1.04
IV	8	10.25	2.02	1.08	0.47	4.56	0.89	1.15
Mean		18.47	1.53	1.25	0.62	2.90	0.87	0.82

observed from the second week of January and the population showed an increasing trend even towards the end of the cropping season. The number of *Leucopis* sp. recorded per plant was 4.04, 4.15 and 4.29 during second, third and fourth week of January, respectively and 4.45, 4.35, 4.45 and 4.56 during the consecutive weeks of February, respectively.

Considering the population of spiders, only low population was seen during October and November(0.08 to 0.42). Higher population was noted during the different weeks of December (1.15 to 1.55) and January (1.21 to1.48). A slight reduction was noted in the population during February (0.89 to 1.08).

Though the population of parasitoids was low during the months of October and November (0.04 to 0.73), notable increase was seen from the third week of December to second week of January (1.13 to 1.34). It was followed by a decrease during the third week (0.96) and fourth week (0.90) of January and first week of February (0.82). From the second week of February, again an increase was observed in the population (1.04 to 1.15).

2007-08

Incidence of *A. craccivora* was noted during the first week of October and the population of the pest ranged from 1.12 to 5.22 per 15 cm shoot during the month (Table 27). A remarkable increase was noted from the first week on November (15.84), registering 16.70, 17.23 and 18.12 aphids per 15 cm shoot during the second, third and fourth week respectively. High population was seen in December, the number recorded being 19.26 (first week), 20.44 (second week), 21.55 (third week), 22.41 (fourth week) and 21.92 (fifth week) per 15 cm shoot. From January onwards a gradual decrease was observed in the population, the number of aphids per 15 cm shoot declining from 19.72 to 7.82 during the last week of February.

The population of coccinellids was low during the first week of October (0.05) to the second week of November (0.95). The population

Table 27. Incidence of *Aphis craccivora* and its natural enemies on winged bean, 2007-2008

Period		Aphid/ 15 cm shoot	Natural enemies (number per plant)					Parasitoids/ sweep
Month & Week	Std. Week		Coccinellids	Hemerobiids	Syrphids	*Leucopis* spp.	Spiders	
October I	40	1.12	0.05	0.00	0.08	0.08	0.04	0.01
II	41	2.04	0.08	0.08	0.20	0.28	0.09	0.09
III	42	3.76	0.27	0.22	0.26	0.74	0.12	0.19
IV	43	5.22	0.41	0.41	0.38	1.02	0.15	0.55
November I	44	15.84	0.88	0.82	0.43	1.45	0.22	0.61
II	45	16.78	0.95	0.95	0.55	2.02	0.31	0.82
III	46	17.23	1.12	1.15	0.71	2.15	0.34	0.83
IV	47	18.12	1.38	1.21	0.75	2.46	0.43	0.93
December I	48	19.26	2.10	1.34	0.85	2.56	0.88	1.03
II	49	20.44	2.21	1.55	0.90	2.67	1.12	1.11
III	50	21.25	2.34	1.58	1.06	2.85	1.28	1.21
IV	51	22.41	2.36	1.63	1.07	3.08	1.35	1.45
V	52	21.92	2.43	1.77	1.14	3.20	1.63	1.56
January I	1	19.72	2.65	1.75	1.22	3.11	1.71	1.39
II	2	15.88	2.68	1.68	1.21	3.28	2.01	1.38
III	3	16.32	2.81	1.61	1.11	3.37	1.88	1.19
IV	4	13.04	2.90	1.58	1.05	3.56	1.64	1.12
February I	5	12.46	2.22	1.35	0.89	3.68	1.49	1.11
II	6	9.78	2.36	1.21	0.81	3.75	1.45	1.14
III	7	8.31	2.28	1.15	0.68	3.91	1.25	1.24
IV	8	7.82	2.56	1.01	0.72	3.95	1.08	1.39
Mean		13.74	1.76	1.15	0.77	2.53	0.98	0.97

started increasing from the third week of November (1.12). During December, notable population of the predator was observed in the field (2.10 to 2.43). Higher population was seen during January (2.65 to 2.90). Substantial population of the predator was also seen during February (2.22 to 2.56).

The hemerobiids appeared in the field during the second week of October and the population ranged from 0.08 to 0.95 per plant to second week of November. Subsequently, there was an increase in the population of the predator and throughout the cropping season more or less uniform population was seen in the field (1.01 to 1.77). Very low population of syrphids was seen from first week of October to second week of December (0.08 to 0.90). Subsequently, the population increased till the fourth week of January (1.06 to 1.22). A decline was noted from February onwards (0.89 to 0.72).

With the exception of the low population observed during October (0.08 to 1.02), appreciable population of *Leucopis* sp. was seen throughout the cropping period. While the population of the predator per plant ranged from 1.45 to 2.46 during November, it was 2.56 to 3.20 during December, 3.11 to 3.56 in January and 3.68 to 3.95 in February.

The population of spiders was low upto the first week of December (0.04 to 0.88). From the second week onwards, an increase in the population was seen (1.12 to 1.71) till the fifth week of December and reaching a peak during the second week of January (2.01). Subsequently, a decrease was noticed, the population declining from the third week of January (1.88) to fourth week of February (1.08).

The population of parasitoids was low during October (0.01 to 0.55) and November (0.61 to 0.93). The population started increasing from the first week of December and was comparatively high during the month (1.03 to 1.56). The population of the parasitoid ranged from 1.11 to 1.39 per sweep during January and February.

4.2.3 Correlation between aphids - predators - weather factors

Chilli

The population of *A.gossypii* in chilli was significantly and positively correlated with the natural enemies viz., coccinellids, chrysopids, hemerobiids, syrphid, *Leucopis* sp., spiders and parasitoids when observed during 2006-07, the correlation coefficient being 0.9230, 0.9636, 0.9382, 0.8516, 0.9556, 0.8036 and 0.8969, respectively (Table 28). The population of coccinellids (0.5922), spiders (0.5530) and parasitoids (0.4823) were significantly and positively correlated with the maximum temperature. However, the population of coccinellids (-0.6143), *Leucopis* sp. (-0.5205), spiders (-0.6777) and parasitoids (-0.5725) showed a significant negative correlation with the minimum temperature. Coccinellid (-0.5644) and spider (-0.6521) populations were negatively correlated with relative humidity. The population of the aphid (-0.5731), coccinellids (-0.6846), chrysopids (-0.5751), *Leucopis* sp. (-0.6173), spiders (-0.6390) and parasitoids (-0.6091) showed significant negative correlation with rainfall.

During 2007-08 also, the population of *A. gossypii* was highly significant and positively correlated with their natural enemies viz., coccinellids (0.8744), chrysopids (0.9602), hemerobiids (0.9506), syrphids (0.8611), *Leucopis* sp. (0.8098), spiders (0.8479) and parasitoids (0.6636). Population of aphid (0.5185), coccinellids (0.6344), chrysopids (0.5191), hemerobiids (0.5729), syrphids (0.6264), *Leucopis* sp (0.6096), spiders (0.6157) and parasitoids (0.4998) showed significant positive correlation with maximum temperature (Table 29). The population of parasitoids (-0.5371) was significantly and negatively correlated with minimum temperature. The population of coccinellids (-0.5130), syrphids (-0.5108), *Leucopis* sp. (-0.5179), spiders (-0.5339) and parasitoids (-0.5726) showed a significant negative correlation with rainfall.

Table 28. Correlation between *A. gossypii* on chilli, its predators and weather factors during October 2006 to January 2007

Parameters	Aphid	Coccinellids	Chrysopids	Hemerobiids	Syrphids	*Leucopis* spp.	Spiders	Parasitoids
Aphid	1.0000	0.9230**	0.9636**	0.9382**	0.8516**	0.9556**	0.8036**	0.8969**
Maximum Temperature	0.3161	0.5922*	0.3638	0.2555	0.1949	0.4627	0.5530*	0.4823*
Minimum Temperature	-0.4046	-0.6143**	-0.4515	-0.4023	-0.3194	-0.5205*	-0.6777**	-0.5725*
Relative humidity	-0.2414	-0.5644*	-0.2942	-0.2476	-0.1812	-0.4241	-0.6521**	-0.4202
Rainfall	-0.5731*	-0.6846**	-0.5751*	-0.4623	-0.3868	-0.6173*	-0.6390**	-0.6091**
Wind velocity	0.0516	-0.2122	-0.0142	0.0540	0.1031	-0.0956	-0.3845	0.0187

Table 29. Correlation between *A.gossypii* on chilli, its predators and weather factors during October 2007 to January 2008

Parameters	Aphid	Coccinellids	Chrysopids	Hemerobiids	Syrphids	*Leucopis* spp.	Spiders	Parasitoids
Aphid	1.0000	0.8744**	0.9602**	0.9506**	0.8611**	0.8098**	0.8479**	0.6636**
Maximum Temperature	0.5185*	0.6344**	0.5191*	0.5729*	0.6264*	0.6096*	0.6157*	0.4998*
Minimum Temperature	0.0476	-0.3328	-0.1051	-0.1612	-0.3626	-0.4370	-0.3824	-0.5371*
Relative humidity	0.0295	-0.3004	-0.1121	-0.1904	-0.3986	-0.4132	-0.3683	-0.4658
Rainfall	-0.2750	-0.5130*	-0.3853	-0.4157	-0.5108*	-0.5179*	-0.5339*	-0.5726*
Wind velocity	-0.1974	-0.3620	-0.2627	-0.3180	-0.3923	-0.4629	-0.3779	-0.4214

** Highly significant at 1% level   * Significant at 5% level

Winged Bean

Highly significant positive correlation was observed between aphids and their natural enemies viz., coccinellids (0.7774), hemerobiids (0.8809), syrphids (0.8968), *Leucopis* (0.5776), spiders (0.7489) and parasitoids (0.7382) during 2006-07 (Table 30). Highly significant positive correlation was also seen between the populations of coccinellids (0.6802), hemerobiids (0.5495), *Leucopis sp.* (0.7609), spiders (0.6627) and parasitoids (0.6175) with maximum temperature, while a significant negative correlation was observed with minimum temperature, the correlation coefficients being -0.7053 (coccinellids), -0.6467 (hemerobiids), -0.6965 (*Leucopis sp*), -0.6946 (spiders) and -0.6697 (parasitoids). Similarly, the populations of coccinellids (-0.6863), hemerobiids (-0.5737), *Leucopis* sp. (-0.8447), spiders (-0.7093) and parasitoids (-0.6463) were significantly and negatively correlated with relative humidity. Likewise, populations of the aphid (-0.4942), coccinellids (-0.7421), hemerobiids (-0.6716), *Leucopis* sp.(-0.7363), spiders (-0.7261) and parasitoids (-0.6675) were significantly and negatively correlated with rainfall. *Leucopis* population (-0.5273) showed a significant negative correlation with wind velocity.

During 2007-08 too, the aphid population showed highly significant positive association with coccinellids (0.5948), hemerobiids (0.8491), syrphids (0.7793), *Leucopis* sp. (0.4993), spiders (0.4935) and parasitoids (0.7028). Significant positive correlation was also observed with the populations of coccinellids (0.6560), hemerobiids (0.5398), syrphids (0.5071), *Leucopis* sp.(0.7437), spiders (0.5823) and parasitoids (0.5506) with maximum temperature and significant negative correlation while minimum temperature (coccinellids -0.6473; hemerobiids -0.5566; syrphids -0.6555; *Leucopis* sp. -0.5091; spiders -0.8062 and parasitoids -0.5052). The natural enemies viz., coccinellid (-0.7008), hemerobiid (-0.4133), syrphid (-0.4393), *Leucopis* (-0.7278), spider (-0. 6709) and parasitiod (-0.5258) were negative correlated with relative humidity. The population of coccinellids (-

0.5744), hemerobiids (-0.5580), syrphids (-0.5763), *Leucopis* sp.(-0.5564), spiders (-0.5710) and parasitoids (-0.5924) showed a significant negative correlation with rainfall. *Leucopis* sp. population (-0.4463) revealed a significant negative association with wind velocity (Table 31).

4.3. EFFECT OF INSECTICIDES

The results of the studies on the efficacy of botanicals and newer molecules of synthetic insecticides against the two major aphid pests of vegetables viz. *A. gossypii* and *A. craccivora* when evaluated in the laboratory and field are presented in Tables 32 to 86

4.3.1. Laboratory Evaluation

Tables 32 to 34 depict the results of the studies on the effect of the botanicals *viz.*, castor oil, pongamia oil, illupai oil, neem oil, neem oil + garlic emulsion, NSKE, NeemAzal T/S, fruit extract of *C. frutescens*, leaf extracts of *A. paniculata, A. vasica, A.indica, V. negundo* and the insecticides *viz.*, imidacloprid, thiamethoxam, acetamiprid, diafenthiuron, profenofos, triazophos, acephate, profenofos + cypermethrin, acephate+ fenvalerate and dimethoate on *A. gossypii* and *A. craccivora* when screened in the laboratory. The results are expressed as per cent mortality.

4.3.1.1 Effect of botanicals

On *A. gossypii*

Among the various plant based insecticides evaluated, NeemAzal T/S 4 ml/l recorded the highest mortality (71.15) of the aphid and was superior to all other botanicals on the first day after treatment (Table 32). It was followed by neem oil + garlic emulsion 2% (63.35), *A. vasica* leaf extract 5% (63.35) and NSKE 5% (61.15) which were on par. *A. indica* leaf extract 5% (57.78), neem oil 2% (54.46) and *V. negundo* leaf extract 5% (54.44) also recorded more than 50 per cent mortality of the aphid and were on par. The other treatments viz., pongamia oil 2 % (51.11), *C. frutescens* fruit extract 5% (51.11) and illupai oil 2 % (48.88) were on par. Castor oil 2%

Table 30. Correlation between *Aphis craccivora* on winged bean, its predators and weather factors during October 2006 to February 2007

Parameters	Aphid	Coccinellids	Hemerobiids	Syrphids	*Leucopis* spp.	Spiders	Parasitoids
Aphid	1.0000	0.7774**	0.8809**	0.8968**	0.5776**	0.7489**	0.7382**
Maximum Temperature	0.2276	0.6802**	0.5495**	0.2027	0.7609**	0.6627**	0.6175**
Minimum Temperature	-0.4153	-0.7053**	-0.6467**	-0.3834	-0.6965**	-0.6946**	-0.6697**
Relative humidity	-0.2206	-0.6863**	-0.5737**	-0.1290	-0.8447**	-0.7093**	-0.6463**
Rainfall	-0.4942*	-0.7421**	-0.6716**	-0.4123	-0.7363**	-0.7261**	-0.6675**
Wind velocity	-0.0281	-0.4246	-0.2669	0.1598	-0.5273*	-0.3743	-0.4030

Table 31. Correlation between *Aphis craccivora* on winged bean, its predators and weather factors during October 2007 to February 2008

Parameters	Aphid	Coccinellids	Hemerobiids	Syrphids	*Leucopis* spp.	Spiders	Parasitoids
Aphid	1.0000	0.5948**	0.8491**	0.7793**	0.4993**	0.4935**	0.7028**
Maximum Temperature	0.2342	0.6560**	0.5398*	0.5071*	0.7437**	0.5823**	0.5506**
Minimum Temperature	-0.2101	-0.6473**	-0.5566**	-0.6555*	-0.5091*	-0.8062**	-0.5052*
Relative humidity	0.0190	-0.7008**	-0.4133	-0.4393*	-0.7278**	-0.6709**	-0.5258*
Rainfall	-0.3269	-0.5744**	-0.5580**	-0.5763**	-0.5564**	-0.5710**	-0.5924**
Wind velocity	-0.3512	-0.3973	-0.4130	-0.4303	-0.4463*	-0.4117	-0.4010

** Highly significant at 1% level   * Significant at 5% level

(46.64) and *A. paniculata* leaf extract 5% (42.21) did not show any significant effect, recording less than 50 per cent mortality. On the third day after treatment, again NeemAzal T/S registered the highest mortality (68.90) and was on par with neem oil + garlic emulsion (65.61). Neem oil (51.11) and *A. vasica* leaf extract (50.00) too recorded above 50 per cent mortality and were on par. All the other botanicals viz., NSKE (43.32), *A. indica* leaf extract (43.32) pongamia oil (43.32), *V. negundo* leaf extract (42.22), illupai oil (39.98), *C. frutescens* fruit extract (37.77), castor oil (35.52) and *A. paniculata* leaf extract (33.30) recorded less than 50 per cent mortality. However, none of the treatments recorded more than 50 per cent mortality of the aphid on the sixth day after treatment, the extent of mortality ranging from 5.43 to 41.11 per cent.

An overall analysis of the effect of different botanicals on *A. gossypii* indicated that NeemAzal T/S recording maximum mortality (60.68 per cent) was superior to all other plant products in controlling the aphid. Neem oil + garlic emulsion (52.92) proved to be the next effective botanical against the pest. All the other botanicals registered only less than 50 per cent mortalities, demonstrating their ineffectiveness against the pest.

With regard to the persistent bioactivity of the various botanicals, the effect of none of the plant products persisted up to the sixth day after treatment. NeemAzal T/S, neem oil + garlic emulsion , neem oil and *A. vasica* leaf extract recorded more than 50 per cent mortality only upto three days after treatment .

On *A. craccivora*

Treatment with NeemAzal T/S 4 ml/l (70.03) and neem oil + garlic emulsion 2% (63.35) resulted in significantly higher mortality of *A. craccivora* one day after treatment (Table 32), both the botanicals being on par. *A.indica* leaf extract 5% (55.57), neem oil 2% (54.45), Illupai oil 2% (53.33), NSKE 5% (53.33), *A. vasica* leaf extract 5% (52.22), castor oil 2%

Table 32. Effect of botanicals on *Aphis gossypii* and *Aphis craccivora*

Treatments	Percentage mortality							
	A. gossypii				*A. craccivora*			
	1 DAT	3 DAT	6 DAT	Pooled mean	1 DAT	3 DAT	6 DAT	Pooled mean
Castor oil 2 %	46.64 (43.08)	35.52 (36.59)	8.65 (17.11)	28.48 (32.26)	51.11 (45.64)	37.77 (37.92)	4.32 (11.99)	27.85 (31.85)
Pongamia oil 2 %	51.11 (45.63)	43.32 (41.16)	10.88 (19.26)	33.48 (35.35)	45.55 (42.45)	23.27 (28.84)	4.32 (11.99)	21.70 (27.76)
Illupai oil 2 %	48.88 (44.36)	39.98 (39.22)	8.65 (17.11)	30.56 (33.56)	53.33 (46.91)	41.11 (39.88)	7.95 (16.38)	31.90 (34.39)
Neem oil 2 %	54.46 (47.56)	51.11 (45.63)	10.88 (19.26)	37.03 (37.48)	54.45 (47.55)	44.44 (41.81)	21.09 (27.34)	39.43 (38.90)
Neem oil + garlic emulsion 2 %	63.35 (52.74)	65.61 (54.10)	29.96 (33.19)	52.92 (46.68)	63.35 (52.74)	51.95 (46.12)	33.30 (35.25)	49.48 (44.70)
NSKE 5 %	61.15 (51.44)	43.32 (41.16)	22.14 (28.07)	41.71 (40.23)	53.33 (46.91)	50.00 (45.00)	37.77 (37.92)	46.99 (43.28)
NeemAzal T/S 4 ml/l	71.15 (57.52)	68.90 (56.10)	41.11 (39.88)	60.68 (51.17)	70.03 (56.81)	65.56 (54.06)	38.88 (38.58)	58.37 (49.82)
Capsicum frutescens fruit extract 5 %	51.11 (45.63)	37.77 (37.92)	10.88 (19.26)	31.71 (34.27)	48.89 (44.36)	43.32 (41.16)	17.75 (24.91)	35.90 (36.81)
Andrographis paniculata leaf extract 5%	42.21 (40.52)	33.30 (35.25)	5.43 (13.48)	24.62 (29.75)	43.32 (41.16)	32.14 (34.54)	3.33 (10.51)	23.12 (28.74)
Adathoda vasica leaf extract 5 %	63.35 (52.74)	50.00 (45.00)	17.75 (24.91)	42.84 (40.89)	52.22 (46.27)	43.32 (41.16)	13.21 (21.31)	34.96 (36.25)
Azadirachta indica leaf extract 5 %	57.78 (49.47)	43.32 (41.16)	14.41 (22.31)	37.31 (37.65)	55.57 (48.20)	44.44 (41.81)	23.27 (28.84)	40.66 (39.62)
Vitex negundo leaf extract 5 %	54.44 (47.55)	42.22 (40.52)	5.43 (13.48)	31.02 (33.85)	50.00 (45.00)	42.21 (40.52)	5.43 (13.48)	29.66 (33.00)
CD (0.05) Treatment	2.29				3.25			
CD (0.05) Treatment × Interval	3.96				5.63			

Figures in parentheses are angular transformed values

DAT: Days after treatment

(51.11), *V. negundo* leaf extract 5% (50.00) recorded more than 50 per cent mortality and were on par. *C. frutescens* fruit extract 5 % (48.89), pongamia oil 2% (45.55) and *A. paniculata* leaf extract 5% (43.32) recorded only less than 50 per cent mortality. On the third day after treatment, NeemAzal T/S recorded the highest mortality (65.56) and was superior to all the other treatments. Neem oil + garlic emulsion (51.95), NSKE (50.00), *A. indica* leaf extract (44.44), neem oil (44.44), *A. vasica* leaf extract (43.32), *C. frutescens* fruit extract (43.32), and *V. negundo* leaf extract (42.21) were on par in their effect. Illupai oil (41.11), castor oil (37.77), *A. paniculata* leaf extract (32.14) and pongamia oil (23.27) recorded only low mortality of the pest. None of the treatments recorded more than 50 per cent mortality on the sixth day after treatment, the extent of mortality ranging from 3.33 to 38.88 per cent.

Analysis of the overall efficacy of the different botanicals against *A.craccivora* indicated that application of NeemAzal T/S resulted in significantly high mortality of the aphid (58.37). This was followed by neem oil + garlic emulsion (49.48) and NSKE (46.99). All the other botanicals were ineffective recording only less than 50 per cent mortality.

Regarding the persistent toxicity of each of the botanicals, none of them showed significant toxicity upto six days after treatment. The pest regulatory effect of NeemAzal T/S, neem oil + garlic emulsion and NSKE was significantly higher than that of other botanicals, recording more than 50 per cent mortality upto three days after treatment. *A. indica* leaf extract, neem oil, Illupai oil, *A. vasica* leaf extract, castor oil and *V. negundo* leaf extract showed noticeable toxicity only on the first day after treatment. Pongamia oil, *C. frutescens* fruit extract and *A. paniculata* leaf extract did not register any significant toxicity against the pest.

4.3.1.2 Effect of synthetic insecticides

On *A. gossypii*

All the insecticides recorded high mortality of the pest on the first day after treatment (Table 33). Acetamiprid 0.002% gave the highest mortality (95.54) and was on par with acephate + fenvalerate 0.05% (92.21), dimethoate 0.05% (88.85) and profenofos + cypermethrin 0.05% (88.85). Acephate 0.05% (83.30), imidacloprid 0.003% (83.30) and thiamethoxam 0.002 % (81.07) were on par. Similarly, profenofos 0.05% (79.97) and triazophos 0.05% (78.87) were on par in their toxicity to the pest. Diafenthiuron 0.02% recorded comparatively lower mortality (69.97). After three days too, cent per cent mortality was recorded in acetamiprid treatment and it was on par with imidacloprid (97.75), profenofos + cypermethrin (97.75) and dimethoate (95.52). This was followed by thiamethoxam (89.97), acephate (88.85) and acephate + fenvalerate (83.30) which were on par. The other treatments viz., triazophos (81.07), profenofos (76.63) and diafenthiuron (73.30) were similar in their effects. On the sixth day after treatment, acetamiprid (93.31) recorded maximum mortality of the aphid. It was followed by imidacloprid (79.97) and thiamethoxam (76.63) which were superior to dimethoate (73.30). Profenofos + cypermethrin (73.30), acephate + fenvalerate (69.97), acephate (66.63) and triazophos (63.30) differed significantly from each other in their toxicity to the aphid. Profenofos (59.96) and diafenthiuron (58.87) recorded low mortality and were on par. On the ninth day, acetamiprid (82.21) registered the highest mortality and was superior to all the other treatments. It was followed by imidacloprid (62.18) and dimethoate (63.30) which were on par. Acephate + fenvalerate which recorded 59.96 per cent mortality of the aphid was on par with thiamethoxam (53.29), triazophos (52.17) and profenofos+ cypermethrin (51.09). Only less than 50 per cent mortality was seen in acephate (49.96), profenofos (48.83) and diafenthiuron (47.76). On the twelfth day after treatment, with the exception of acetamiprid (56.42) and imidacloprid (51.05) all the other insecticides recorded less than 50 per cent mortality of the aphid, the extent of mortality ranging from 23.25 to 45.53. Excepting acetamiprid (44.42), all the insecticides recorded less than 40 per cent mortality when observed on the fifteenth day after treatment.

Analysis of the overall efficacy of the insecticides revealed that acetamiprid (77.10) was superior to all other treatments in its toxicity to *A. gossypii*. It was followed by imidacloprid (67.56) which was superior to dimethoate (64.41). While thiamethoxam (60.12) and acephate+ fenvalerate (59.44) were at par, profenofos+ cypermethrin (52.36) was on par with acephate (50.02). The other insecticides viz., profenofos (47.15), triazophos (43.15) and diafenthiuron (43.14) did not show any appreciable toxicity.

Considering the persistent toxicity of the different insecticides, efficacy of acetamiprid and imidacloprid against the pest persisted upto 12 days after treatment. Likewise, the toxicity of dimethoate, acephate + fenvalerate, profenofos +cypermethrin, thiamethoxam, and triazophos persisted upto nine days after treatment. Noteworthy toxicity of acephate, profenofos and diafenthiuron was recorded upto six days after treatment.

On *A. craccivora*

One day after treatment, acetamiprid 0.002% recorded the highest mortality (97.75) of the aphid and was on par with imidacloprid 0.003% (92.21) (Table 34). Treatment with acephate + fenvalerate 0.05% (89.97), dimethoate 0.05% (86.64), profenofos + cypermethrin (83.30) and triazophos 0.05% (83.30) also resulted in significantly high mortality of the pest, the treatments being on par. Acephate 0.05% registered 81.10 per cent mortality of *A. craccivora* and was on par with thiamethoxam 0.002 % (75.54) which in turn was at par with profenofos 0.05% (73.30). Diafenthiuron 0.02% recorded comparatively lower mortality (63.30) of the pea aphid. Three days after treatment, hundred per cent mortality was recorded in acetamiprid treatment and the neonicotinoid differed significantly from all other insecticides.It was followed by dimethoate (92.13), imidacloprid (91.07), acephate + fenvalerate (87.76) and acephate (87.72) all of which were on par. Profenofos + cypermethrin and

Table 33. Effect of insecticides on *Aphis gossypii*

Treatments	Percentage mortality						Pooled mean
	1 DAT	3 DAT	6 DAT	9 DAT	12 DAT	15 DAT	
Imidacloprid 0.003 %	83.30 (9.18)	97.75 (9.93)	79.97 (8.99)	62.18 (7.94)	51.05 (7.21)	39.95 (6.39)	67.56 (8.28)
Thiamethoxam 0.002 %	81.07 (9.05)	89.97 (9.53)	76.63 (8.81)	53.29 (7.36)	42.16 (6.56)	29.93 (5.56)	60.12 (7.81)
Acetamiprid 0.002%	95.54 (9.82)	100 (10.04)	93.31 (9.71)	82.21 (9.12)	56.42 (7.57)	44.42 (6.73)	77.10 (8.83)
Diafenthiuron 0.02%	69.97 (8.42)	73.30 (8.62)	58.87 (7.73)	47.76 (6.98)	29.93 (5.56)	5.44 (2.53)	43.14 (6.64)
Profenofos 0.05 %	79.97 (8.99)	76.63 (8.81)	59.96 (7.80)	48.83 (7.05)	23.25 (4.92)	15.27 (4.03)	47.15 (6.93)
Triazophos 0.05 %	78.87 (8.93)	81.07 (9.05)	63.30 (8.01)	52.17 (7.29)	29.93 (5.56)	0.00 (1.00)	43.15 (6.64)
Acephate 0.05 %	83.30 (9.18)	88.85 (9.47)	66.63 (8.22)	49.96 (7.13)	27.75 (5.36)	11.06 (3.47)	50.02 (7.14)
Profenofos 40% + cypermethrin 4% (0.05%)	88.85 (9.47)	97.75 (9.93)	73.30 (8.62)	51.09 (7.21)	33.27 (5.85)	6.40 (2.72)	52.36 (7.30)
Acephate 25% + fenvalerate 3% (0.05%)	92.21 (9.65)	83.30 (9.18)	69.97 (8.42)	59.96 (7.80)	43.28 (6.65)	23.25 (4.92)	59.44 (7.77)
Dimethoate 0.05 %	88.85 (9.47)	95.52 (9.82)	73.30 (8.62)	63.30 (8.01)	45.53 (6.82)	32.20 (5.76)	64.41 (8.08)

CD (0.05) Treatment : 0.16
CD (0.05) Treatment × Interval : 0.40

Figures in parentheses are √(x+1) transformed values
DAT: Days after treatment

Table 34. Effect of insecticides on *Aphis craccivora*

Treatments	Percentage mortality						Pooled mean
	1 DAT	3 DAT	6 DAT	9 DAT	12 DAT	15 DAT	
Imidacloprid 0.003 %	92.21 (9.65)	91.07 (9.59)	81.10 (9.06)	59.96 (7.80)	45.50 (6.81)	36.61 (6.13)	65.89 (8.17)
Thiamethoxam 0.002 %	75.54 (8.74)	79.97 (8.99)	71.10 (8.49)	59.96 (7.80)	42.16 (6.56)	28.86 (5.46)	57.98 (7.68)
Acetamiprid 0.002%	97.75 (9.93)	100 (10.04)	89.97 (9.53)	81.10 (9.06)	55.53 (7.51)	42.20 (6.57)	76.08 (8.77)
Diafenthiuron 0.02%	63.30 (8.01)	68.87 (8.35)	63.30 (8.01)	49.96 (7.13)	20.98 (4.68)	0.00 (1.00)	37.49 (6.20)
Profenofos 0.05 %	73.30 (8.62)	71.07 (8.48)	59.96 (7.80)	53.29 (7.36)	38.87 (6.31)	16.55 (4.19)	49.86 (7.13)
Triazophos 0.05 %	83.30 (9.18)	74.43 (8.68)	61.03 (7.87)	51.02 (7.21)	24.33 (5.03)	0.00 (1.00)	41.22 (6.49)
Acephate 0.05 %	81.10 (9.06)	87.72 (9.41)	62.18 (7.94)	57.70 (7.66)	43.28 (6.65)	19.90 (4.57)	56.04 (7.55)
Profenofos 40% + cypermethrin 4% (0.05%)	83.30 (9.18)	81.10 (9.06)	75.54 (8.74)	58.87 (7.73)	36.61 (6.13)	13.19 (3.76)	54.33 (7.43)
Acephate 25% + fenvalerate 3% (0.05%)	89.97 (9.53)	87.76 (9.42)	76.63 (8.81)	63.30 (8.01)	44.38 (6.73)	23.25 (4.92)	61.54 (7.90)
Dimethoate 0.05 %	86.64 (9.36)	92.13 (9.65)	77.76 (8.87)	67.76 (8.29)	43.28 (6.65)	33.27 (5.85)	64.85 (8.11)

CD (0.05) Treatment : 0.15
CD (0.05) Treatment × Interval : 0.37

Figures in parentheses are √(x+1) transformed values
DAT: Days after treatment

thiamethoxam recorded 81.10 and 79.97 per cent mortality, respectively and were at par. Still lower mortality was observed in triazophos (74.43), profenofos (71.07) and diafenthiuron (68.87) treatments. On the sixth day after treatment, acetamiprid (89.97) recorded maximum mortality of the aphid. It was followed by imidacloprid (81.10), dimethoate (77.76), acephate + fenvalerate (76.63) and profenofos + cypermethrin (75.54) which were on par.Treatment with thiamethoxam resulted in 71.10 per cent mortality of the pest. Significantly lower mortality was seen in diafenthiuron (63.30), acephate (62.18), triazophos (61.03) and profenofos (59.96) treatments and they were on par. On the ninth day, acetamiprid (81.10) registered the highest mortality and was superior to all the other treatments. It was followed by dimethoate (67.76) and acephate + fenvalerate (63.30) which were on par. Only 59.96 per cent mortality of the aphid was seen in imidacloprid treatment. Thiamethoxam (59.96), profenofos+ cypermethrin (58.87), acephate (57.70), profenofos (53. 29), triazophos (51.02) and diafenthiuron (49.96) too recorded low mortality of the pest. With the exception of acetamiprid (55.53), all the other insecticides recorded less than 50 per cent mortality of the aphid on the twelfth day after treatment, the extent of mortality ranging from 20.98 to 45.50 per cent. None of the insecticides recorded more than 50 per cent mortality on the fifteenth day.

Scrutiny of the pooled data on the effect of insecticides revealed the supremacy of acetamiprid over other insecticides in controlling *A. craccivora*. The neonicotinoid recorded 76.08 per cent mortality of the pest. Imidacloprid (65.89) which ranked next was on par with dimethoate (64.85). Acephate + fenvalerate recorded 61.54 per cent mortality and differed significantly in its effect from other treatments. Thiamethoxam (57.98), acephate (56.04) and profenofos+ cypermethrin (54.33) were on par in their efficacy. Profenofos (49.86), triazophos (41.22) and diafenthiuron (37.49) recorded only less than 50 per cent mortality of the pest.

The efficacy of the insecticides persisted upto nine days after treatment, recording more than 50 per cent mortality of the aphid. The extent of toxicity was further significantly reduced on the twelvth and fifteenth day after treatment.

4.3.1.3 Effect on predators

The results on the effect of the promising botanicals viz., NeemAzal T/S and neem oil+garlic emulsion and synthetic insecticidesviz., acetamiprid and imidacloprid identified against *A. gossypii* and *A.craccivora* on the major predators of the aphids, expressed as per cent mortality are presented in Tables 35 to 42.

M. sexmaculatus

Larva: Low mortality of the larvae of *M. sexmaculatus* was observed in the various treatments one day after treatment with none of them recording more than 50 per cent mortality (Table 35). Comparatively, dimethoate 0.05% (47.49) recorded higher mortality followed by acetamiprid 0.002% (28.32). Imidacloprid 0.003% (13.24) and neem oil + garlic emulsion 2% were on par in their effect, registering only 13.24 and 11.61 per cent mortality, respectively. Least mortality of the predator was observed in NeemAzal T/S 4 ml/l (7.50). On the second day, significantly high mortality of the larvae was observed in dimethoate (79.23). While acetamiprid recorded 39.99 per cent mortality, imidaclopirid differed significantly, registering only 29.97 per cent mortality. Neem oil + garlic emulsion (14.96) and NeemAzal T/S (12.05) were significantly less toxic to the predator. On the third day, again dimethoate (89.33) showed maximum mortality of the coccinellid. More than 50 per cent mortality was also recorded in acetamiprid (56.67) and imidacloprid (50.83) treatments, though they differed significantly in their effect. Neem oil + garlic emulsion and NeemAzal recorded only 19.09 and 14.96 per cent larval mortality, respectively.

Adult: Dimethoate was highly toxic to the adults of *M. sexmaculatus,* recording 69.20 per cent mortality, one day after treatment. Lesser mortality was observed in the neonicotinoids, acetamiprid (33.31) and imidacloprid (19.09), both the treatments differing significantly. Very low mortality was seen in NeemAzal T/S (12.37) and neem oil + garlic emulsion (11.61), both the botanicals being at par. On the second day, mortality of the predator was significantly the highest in dimethoate (82.59) treatment. Comparatively, lower mortality of the adults was recorded in acetamiprid (41.46) and imidacloprid (39.99) and both the treatments were on par. Significantly low mortality of the adults was seen in neem oil + garlic emulsion (18.23) and NeemAzal T/S (14.96) treatments and they were at par. On the third day as well, dimethoate (91.01) recorded significantly higher mortality of the adults. The neonicotinoids too showed significant toxicity to the predator, recording more than 50 per cent mortality in acetamiprid (71.68) and imidacloprid (63.35) treatments and both the insecticides differed significantly. Neem oil + garlic emulsion (21.64) and NeemAzal T/S (19.94) were significantly less toxic than the synthetic insecticides and were at par.

C. transversalis

Larva: Significantly high mortality of larvae of *C. transversalis* was recorded in dimethoate 0.05% (72.54) one day after treatment (Table 36). None of the other treatments showed more than 50 per cent mortality. Acetamiprid 0.002% recorded only 32.47 per cent mortality of the larvae. This was followed by NeemAzal T/S 4 ml/l (10.66) which was on par with imidacloprid 0.003% (9.87). Very low mortality was seen in neem oil + garlic emulsion 2% (6.45) treatment. On the second day, all the treatments differed significantly in their effect on the larvae of *C. transversalis*. Maximum mortality was seen in dimethoate (79.23). More than 50 per cent mortality of the larvae was also recorded in acetamiprid (50.83). Imidacloprid (29.97) recorded only low mortality of the predator. NeemAzal

Table 35. Relative toxicity of botanicals and synthetic insecticides to *Menochilus sexmaculatus*

Treatments	Percentage mortality					
	Larva			Adult		
	1 DAT	2 DAT	3 DAT	1 DAT	2 DAT	3 DAT
NeemAzal T/S 4 ml/l	7.50 (16.70)	12.05 (21.33)	14.96 (22.75)	12.37 (20.59)	14.96 (22.75)	19.94 (26.53)
Neem oil + garlic 2%	11.61 (19.92)	14.96 (22.75)	19.09 (25.91)	11.61 (19.92)	18.30 (25.33)	21.64 (27.72)
Acetamiprid 0.002%	28.32 (32.15)	39.99 (39.22)	56.67 (48.83)	33.31 (35.25)	41.46 (42.09)	71.68 (57.85)
Imidacloprid 0.003%	13.24 (21.34)	29.97 (33.19)	50.83 (45.48)	19.09 (25.91)	39.99 (39.22)	63.35 (52.74)
Dimethoate 0.05%	47.49 (43.56)	79.23 (62.89)	89.33 (70.94)	69.20 (56.29)	82.59 (65.34)	91.01 (72.55)
CD (0.05)	2.80	2.89	3.23	3.19	4.10	2.97

Table 36. Relative toxicity of botanicals and synthetic insecticides to *Coccinella transversalis*

Treatments	Percentage mortality					
	Larva			Adult		
	1 DAT	2 DAT	3 DAT	1 DAT	2 DAT	3 DAT
NeemAzal T/S 4 ml/l	10.66 (19.05)	13.63 (22.75)	16.70 (25.33)	9.87 (18.31)	13.24 (21.34)	18.30 (25.33)
Neem oil + garlic 2%	6.45 (14.72)	9.87 (18.31)	14.96 (22.75)	4.06 (11.62)	9.87 (18.31)	13.24 (21.34)
Acetamiprid 0.002%	32.47 (34.74)	50.83 (45.48)	74.21 (59.48)	34.13 35.75)	42.49 (40.68)	69.20 (56.29)
Imidacloprid 0.003%	9.87 (18.31)	29.97 (33.19)	55.00 (47.87)	16.59 (24.04)	34.13 (35.75)	50.83 (45.48)
Dimethoate 0.05%	72.54 (58.40)	79.23 (62.89)	93.54 (75.28)	80.05 (63.47)	85.03 (67.24)	90.13 (71.69)
CD (0.05)	3.99	3.08	3.05	3.30	3.15	3.14

DAT: Days after treatment

Figures in parentheses are angular transformed values

T/S (13.63) and neem oil + garlic emulsion (9.87) also showed significantly low mortality of the predator. By the third day, 93.54 per cent mortality was recorded in dimethoate and the treatment differed significantly from all other treatments. High mortality of the larvae was also seen in acetamiprid (74.21) and imidacloprid (55.00), both the neonicotinoids differing significantly in their effect. Only low mortality was recorded in NeemAzal T/S (16.70) and neem oil + garlic emulsion (14.96) treatments.

Adult: All the treatments differed significantly in their toxicity to the adults of *C. transversalis*. Dimethoate was again the most toxic insecticide to the predator. One day after treatment, the insecticide recorded 80.05 per cent mortality. While 34.13 per cent mortality was seen in acetamiprid, only 16.59 per cent mortality was recorded in imidacloprid. The botanicals, NeemAzal T/S (9.87) and neem oil + garlic emulsion (4.06) registered only very low mortality. On the second day too, the mortality of the adult predator was significantly the highest in dimethoate (85.03) treatment. Acetamiprid and imidacloprid recorded 42.49 and 34.13 per cent mortality respectively and differed significantly. Again significantly low mortality was seen in NeemAzal T/S (13.24) and neem oil + garlic emulsion (9.87) both the botanicals being on par. By the third day dimethoate registered 90.13 per cent mortality of the adults and differed significantly from all other treatments. While treatment with acetamiprid resulted in 69.20 per cent mortality, imidacloprid recorded 50.83 per cent mortality and the treatments differed significantly in their effect. Only significantly low mortality was seen in NeemAzal T/S (18.30) and neem oil + garlic emulsion (13.24) treatments.

P. trinotatus

Larva: Treatment with dimethoate 0.05% (60.85) resulted in maximum mortality of *P.trinotatus* one day after treatment and the insecticide differed significantly from all the other treatments (Table 37).

Acetamiprid 0.002% and imidacloprid 0.003% recorded 29.13 and 25.78 per cent mortality, respectively and were on par. NeemAzal T/S 4 ml/l (8.98) and neem oil + garlic emulsion 2% (6.45) which were on par recorded very low mortality of the larvae. Similarly, on the second day also, mortality of the larvae was significantly high in dimethoate (75.89) followed by acetamiprid (50.83), both the treatments differing significantly. Imidacloprid recorded only 42.49 per cent mortality of the predator. Still lower mortality was seen in NeemAzal T/S (23.29) and neem oil + garlic emulsion (15.74) treatments. By the third day, 100 per cent mortality of the predator was seen in dimethoate treatment. Acetamiprid (71.68) and imidacloprid (64.19) also recorded significant mortality of the predator. Comparatively, lower mortality was seen in NeemAzal T/S (42.49) and neem oil + garlic emulsion (35.81) treatments.

Adult: Considering the toxicity of the various insecticides to the adults of *P.trinotatus* one day after treatment, 53.33 per cent mortality was recorded in dimethoate. It was followed by imidacloprid (33.31) and acetamiprid (29.97) which were on par. Very low mortality was observed in NeemAzal T/S (10.66) and neem oil + garlic emulsion (4.86) treatments. On the second day, the extent of mortality in dimethoate was 80.90 per cent. All the other treatments registered only less than 50 per cent mortality of the adult predator.While acetamiprid (49.16) and imidacloprid (45.82) were on par, neem oil + garlic emulsion (22.44) and NeemAzal T/S (19.94) which recorded still lower mortality were at par. By the third day, 99.16 per cent mortality of the predator was seen in dimethoate treatment. Acetamiprid (69.20) and imidacloprid (53.33) also recorded more than 50 per cent mortality and differed significantly in their toxicity to the adult predator. Neem oil + garlic emulsion (30.79) and NeemAzal T/S (29.97) were significantly less toxic.

H. octomaculata

Larva: The organophosphorus insecticide, dimethoate 0.05% was highly toxic to the larvae of *H. octomaculata.* One day after treatment, the insecticide recorded maximum mortality (74.25) of the predator (Table 38). Significantly lesser mortality was seen in acetamiprid 0.002% (36.65) and imidacloprid 0.003% (32.47) treatments and they were on par. NeemAzal T/S 4 ml/l (9.87) and neem oil + garlic emulsion 2% (2.22) did not show any significant toxicity to the larvae. On the second day, the extent of mortality was significantly high in dimethoate (86.75). Acetamiprid and imidaclopirid were on par, registering 51.67 and 47.49 per cent mortality. NeemAzal T/S (17.41) and neem oil + garlic emulsion (8.98) were significantly less toxic to the predator. On the third day too dimethoate (98.77) showed maximum mortality of the coccinellid. High mortality was also recorded in acetamiprid (62.52) and imidacloprid (61.70) treatments and they were at par. NeemAzal T/S (25.78) and neem oil + garlic emulsion (19.09) did not show any appreciable mortality.

Adult: Dimethoate was highly toxic to the adults also recording 60.85 per cent mortality one day after treatment. Lesser mortality was observed in the neonicotinoids, acetamiprid (29.97) and imidacloprid (26.63) and both the treatments differed significantly. Very low mortality was seen in NeemAzal T/S (5.53) and neem oil + garlic emulsion (1.71). On the second day, mortality of the predator was significantly the highest in dimethoate (78.45) treatment. Lower mortality was recorded in acetamiprid (39.15) and imidacloprid (36.65) and the nicotinoids were on par. Significantly low mortality of the adults was seen in NeemAzal (16.59) and neem oil + garlic emulsion (9.87) treatments. By the third day, 85.19 per cent mortality of the adults was seen in dimethoate treatment. The neonicotinoids too showed significant toxicity to the predator, recording 55.01 and 52.50 per cent mortality in acetamiprid and imidacloprid treatments, respectively and the

Table 37. Relative toxicity of botanicals and synthetic insecticides to *Pseudaspidimerus trinotatus*

Treatments	Percentage mortality					
	Larva			Adult		
	1 DAT	2 DAT	3 DAT	1 DAT	2 DAT	3 DAT
NeemAzal T/S 4 ml/l	8.98 (17.44)	23.29 (28.85)	42.49 (40.68)	10.66 (19.05)	19.94 (26.53)	29.97 (33.19)
Neem oil + garlic 2%	6.45 (14.72)	15.74 (23.37)	35.81 (36.75)	4.86 (12.73)	22.44 (28.27)	30.79 (33.71)
Acetamiprid 0.002%	29.13 (32.66)	50.83 (45.48)	71.68 (57.85)	29.97 (33.19)	49.16 (44.52)	69.20 (56.29)
Imidacloprid 0.003%	25.78 (30.52)	42.49 (40.68)	64.19 (53.24)	33.31 (35.25)	45.82 (42.60)	53.33 (46.91)
Dimethoate 0.05%	60.85 (51.26)	75.89 (60.59)	100.00 (90.00)	53.33 (46.91)	80.90 (64.09)	99.16 (84.73)
CD (0.05)	3.82	3.09	2.35	3.31	3.06	4.78

Table 38. Relative toxicity of botanicals and synthetic insecticides to *Harmonia octomaculata*

Treatments	Percentage mortality					
	larva			adult		
	1 DAT	2 DAT	3 DAT	1 DAT	2 DAT	3 DAT
NeemAzal T/S 4 ml/l	9.87 (18.31)	17.41 (24.66)	25.78 (30.52)	5.53 (13.60)	16.59 (24.04)	24.11 (29.41)
Neem oil + garlic 2%	2.22 (9.00)	8.98 (17.44)	19.09 (25.91)	1.71 (7.89)	9.87 (18.31)	18.30 (25.33)
Acetamiprid 0.002%	36.65 (37.25)	51.67 (45.96)	62.52 (52.25)	29.97 (33.19)	39.15 (38.73)	55.01 (47.88)
Imidacloprid 0.003%	32.47 (34.74)	47.49 (43.56)	61.70 (51.76)	26.63 (31.07)	36.65 (37.25)	52.50 (46.43)
Dimethoate 0.05%	74.25 (59.51)	86.75 (68.66)	98.77 (83.63)	60.85 (51.26)	78.45 (62.34)	85.19 (67.37)
CD (0.05)	5.29	3.87	5.92	4.86	3.48	3.75

DAT: Days after treatment

Figures in parentheses are angular transformed values insecticides were on par. NeemAzal T/S (24.11) and neem oil + garlic emulsion (18.30) did not show any significant toxicity to the adult predator.

S. (P.) latemaculatus

Larva : One day after treatment, the botanicals and insecticides differed significantly in their effect on the larvae of *S. (P.) latemaculatus*. Application of dimethoate 0.05% (70.02) resulted in maximum mortality (Table 39). Significantly lesser mortality was seen in acetamiprid 0.002% (39.99) and imidacloprid 0.003% (31.60) treatments. NeemAzal T/S 4 ml/l (14.04) and neem oil + garlic emulsion 2% (8.98) had no significant toxic effect on the larvae of the predator. On the second day, dimethoate (92.09) again recorded significantly high larval mortality. Acetamiprid and imidaclopirid were on par and showed 52.50 and 50.83 per cent mortality, respectively. NeemAzal T/S (23.29) and neem oil + garlic emulsion (19.09) were significantly less toxic to the predator. Hundred per cent mortality of the larvae was observed in dimethoate treatment by the third day. Acetamiprid (76.70) and imidacloprid (66.68) treatments also resulted in significantly high mortality of the predator. Only low mortality of the larvae was noticed in NeemAzal T/S (34.95) and neem oil + garlic emulsion (28.32) treatments.

Adult: Adult mortality was the highest in dimethoate (75.09) one day after treatment. While 44.99 per cent mortality was noted in acetamiprid treatment, only 19.09 per cent mortality was seen in imidacloprid, both the neonicotinoids differing significantly in their effect. Very low mortality was observed in NeemAzal T/S (8.25) and neem oil + garlic emulsion (5.73). On the second day, mortality of the predator was significantly the highest in dimethoate (85.19) treatment. Significantly high mortality was also recorded in acetamiprid (68.39) compared to the low mortality in imidacloprid (34.95). NeemAzal T/S (16.59) and neem oil + garlic emulsion (14.04) recorded significantly low mortality of the adults and were on par. By the third day, 96.37 per cent mortality of the adults was seen in dimethoate treatment. Acetamiprid also showed significant toxicity to the predator, recording 77.56 per cent mortality of the adults. Imidacloprid (44.98), NeemAzal T/S (31.60) and neem oil + garlic emulsion (22.44) did not show any significant toxicity.

C. septempunctata

Larva: All the treatments differed significantly in their toxicity to the larvae of *C. septempunctata.* Dimethoate 0.05% was the most toxic, recording 81.01 per cent mortality of the predator one day after treatment (Table 40). Significantly lower mortality was observed in acetamiprid 0.002% (39.15) followed by imidacloprid 0.003% (22.44). NeemAzal T/S 4 ml/l (10.66) and neem oil + garlic emulsion 2% (6.45) were significantly less toxic to the larvae.A similar trend was observed on the second day too. While dimethoate (94.46) recorded significantly high mortality of the larvae, acetamiprid recorded only 50.00 per cent motality. Imidaclopirid differed significantly from these insecticides, causing only 29.97 per cent mortality. NeemAzal T/S (21.54) and neem oil + garlic emulsion (14.04) were significantly less toxic to the predator. Hundred per cent mortality of the coccinellid was seen in dimethoate by the third day. Acetamiprid (63.35) too was toxic to the predator. However, significantly low mortality was recorded in imidacloprid (45.82) and the neonicotinoid was on par with NeemAzal (41.64). The larval mortality was significantly low in neem oil + garlic emulsion (28.26).

Adult: One day after treatment, significantly high mortality of the adults was noticed in dimethoate (75.09) treatment. Lesser mortality was observed in the neonicotinoids, acetamiprid (26.63) and imidacloprid (18.30). Very low mortality was seen in NeemAzal T/S (6.45) and neem oil + garlic emulsion (5.53), both the botanicals being at par. On the second day, mortality of the predator was significantly the highest in dimethoate

Table 39. Relative toxicity of botanicals and synthetic insecticides to *Scymnus (P.) latemaculatus*

Treatments	Percentage mortality					
	larva			adult		
	1 DAT	2 DAT	3 DAT	1 DAT	2 DAT	3 DAT
NeemAzal T/S 4 ml/l	14.04 (22.01)	23.29 (28.85)	34.95 (36.24)	8.25 (16.70)	16.59 (24.04)	31.60 (34.21)
Neem oil + garlic 2%	8.98 (17.44)	19.09 (25.91)	28.32 (32.15)	5.73 (13.85)	14.04 (22.01)	22.44 (28.27)
Acetamiprid 0.002%	39.99 (39.22)	52.50 (46.43)	76.70 (61.14)	44.99 (42.13)	68.39 (55.79)	77.56 (61.72)
Imidacloprid 0.003%	31.60 (34.21)	50.83 (45.48)	66.68 (54.75)	19.09 (25.91)	34.95 (36.24)	44.98 (42.12)
Dimethoate 0.05%	70.02 (56.80)	92.09 (73.66)	100.00 (90.00)	75.09 (60.06)	85.19 (67.37)	96.37 (79.02)
CD (0.05)	3.66	4.12	2.56	3.28	4.14	6.28

Table 40. Relative toxicity of botanicals and synthetic insecticides to *Coccinella septempunctata*

Treatments	Percentage larval mortality			Percentage adult mortality		
	1 DAT	2 DAT	3 DAT	1 DAT	2 DAT	3 DAT
NeemAzal T/S 4 ml/l	10.66 (19.05)	21.54 (27.66)	41.64 (40.19)	6.45 (14.72)	13.24 (21.34)	31.60 (34.21)
Neem oil + garlic 2%	6.45 (14.72)	14.04 (22.01)	28.26 (32.11)	5.53 (13.60)	11.39 (19.72)	24.11 (29.41)
Acetamiprid 0.002%	39.15 (38.73)	50.00 (45.00)	63.35 (52.74)	26.63 (31.07)	38.30 (38.23)	50.00 (45.00)
Imidacloprid 0.003%	22.44 (28.27)	29.97 (33.19)	45.82 (42.60)	18.30 (25.33)	28.26 (32.11)	39.15 (38.73)
Dimethoate 0.05%	81.01 (67.37)	94.46 (76.38)	100.00 (90.00)	75.09 (60.06)	85.43 (70.94)	91.20 (76.38)
CD (0.05)	4.29	4.07	3.00	4.19	4.48	3.83

DAT: Days after treatment   Figures in parentheses are angular transformed values

(85.43) treatment. Comparatively, lower mortality of the adults was recorded in acetamiprid (38.30) and imidacloprid (28.26). Significantly low mortality of the adults was seen in NeemAzal T/S (13.24) and neem oil + garlic emulsion (11.39) treatments and they were at par. On the third day, again dimethoate (91.20) recorded significantly high mortality of the adults. While acetamiprid recorded 50 per cent mortality, imidacloprid treatment showed only 39.15 per cent mortality. NeemAzal T/S (31.60) and neem oil + garlic emulsion (24.11) were significantly less toxic than the synthetic insecticides.

I. scutellaris

Larva: Among the botanicals and synthetic insecticides evaluated, dimethoate 0.05% was highly toxic to *I.scutellaris*, recording 92.88 per cent mortality one day after treatment (Table 41). Significantly high mortality was also seen in acetamiprid 0.002% (70.02) treatment. While 49.16 per cent larval mortality was observed in imidacloprid 0.003%, 41.64 and 33.31 per cent mortality were seen in NeemAzal T/S 4 ml/l and neem oil + garlic emulsion 2% treatments, all the three differing significantly in their toxicity to the predator. On the second day, the extent of mortality was significantly high both in dimethoate (96.77) and acetamiprid (81.81) though the treatments differed significantly. Imidaclopirid (63.35) and NeemAzal T/S (58.29) also registered high mortality and were on par. Compared to the other treatments, neem oil + garlic emulsion (42.49) recorded significantly less mortality of the predator. By the third day, all the treatments showed appreciable toxicity against the predator recording more than 50% mortality. Dimethoate resulted in cent per cent mortality of the syrphid larvae and differed significantly from all other treatments. Acetamiprid recorded 98.77 per cent mortality. Imidacloprid (75.09) and NeemAzal T/S (72.54) were at par followed by neem oil + garlic emulsion (52.50).

D. aegrota

Larva: Dimethoate 0.05% (68.39) was highly toxic to the predator when observed one day after treatment and differed significantly from all other treatments (Table 41). The neonicotinoids, acetamiprid 0.002% and imidacloprid 0.003% recorded only 34.95 and 29.97 per cent mortality and were on par. Very low mortality of the predator was seen in NeemAzal T/S 4 ml/l (13.24) and neem oil + garlic emulsion 2% (8.98) treatments. On the second day, the extent of mortality was significantly high in dimethoate (98.77). Acetamiprid (44.98) and imidaclopirid (41.64) were on par in their effect. NeemAzal T/S (39.15) and neem oil + garlic emulsion (29.97) recorded significantly less mortality of the predator and were at par. By the third day all the synthetic insecticides showed appreciable toxicity to the predator recording more than 50% mortality. While dimethoate registered cent per cent mortality, acetamiprid and imidacloprid recorded 72.54 and 66.68 per cent mortality, respectively and differed significantly among themselves. NeemAzal T/S (46.66) and neem oil + garlic emulsion (39.99) showed significantly less toxicity to the larvae of the predator.

P. serratus

Larva: One day after treatment, only dimethoate 0.05% (86.25) was highly toxic to the predator and differed significantly from all other treatments (Table 42). The neonicotinoids, acetamiprid 0.002 % (32.40) and imidacloprid 0.003% (24.11) did not show any significant toxicity and were on par. Only very low mortality of the predator was seen in NeemAzal T/S 4 ml/l (19.09) and neem oil + garlic emulsion 2% (16.59) treatments. On the second day, the extent of mortality was significantly high in dimethoate (99.16). Acetamiprid (46.66) and imidaclopirid (43.32) were on par in their effect. NeemAzal T/S (36.65) and neem oil + garlic emulsion (24.98) recorded significantly less mortality of the predator and were at par. By the third day, all the synthetic insecticides showed noticeable toxicity to the predator, recording more than 50% mortality. While dimethoate registered cent per cent mortality, acetamiprid and imidacloprid recorded 63.35 and 60.01 per cent mortality, respectively. NeemAzal T/S (45.82) and neem oil + garlic emulsion (39.99) showed significantly less toxicity to the larvae of the predator.

Micromus sp.

Larva: Dimethoate 0.05% (75.89) recorded the maximum mortality of the predator, one day after treatment and differed significantly from all other treatments (Table 42). Acetamiprid 0.002% and imidacloprid 0.003% were on par in their toxicity, recording 43.32 and 39.99 per cent larval mortality. NeemAzal T/S 4 ml/l (33.31) and neem oil + garlic emulsion 2% (29.97) showed significantly less toxicity. On the second day, the extent of mortality was the highest in dimethoate (83.37). Acetamiprid (59.18) and imidaclopirid (52.50) too recorded significant toxicity and were at par. NeemAzal T/S (42.49) and neem oil + garlic emulsion (40.81) recorded significantly lesser mortality of the predator. By the third day, all the treatments showed appreciable toxicity to the predator, recording more than 50% mortality. Dimethoate recorded 98.60 mortality of the larvae of *Micromus* sp. and differed significantly from all other treatments. Acetamiprid recorded 74.21 per cent mortality. Imidacloprid (59.19) and NeemAzal T/S (58;35) were at par followed by neem oil + garlic emulsion (52.50).

4.3.2 Field Evaluation

The results of the field trials on the effect of the botanicals, neem oil garlic emulsion and NeemAzal T/S and the synthetic insecticides, acetamiprid, imidacloprid and dimethoate on aphids and their natural enemies, other pests of chilli and winged beans, soil macrofauna and microflora are presented in Tables 43 to 86.

Table 41. Relative toxicity of botanicals and synthetic insecticides to *Ishiodon scutellaris* and *Dideopsis aegrota*

Treatments	Percentage larval mortality					
	Ishiodon scutellaris			*Dideopsis aegrota*		
	1 DAT	2 DAT	3 DAT	1DAT	2 DAT	3 DAT
NeemAzal T/S 4 ml/l	41.64 (40.19)	13.24 (21.34)	39.15 (38.73)	46.66 (43.08)	58.29 (52.26)	72.54 (58.40)
Neem oil + garlic 2%	33.31 (35.25)	8.98 (17.44)	29.97 (33.19)	39.99 (39.22)	42.49 (40.68)	52.50 (46.43)
Acetamiprid 0.002%	70.02 (56.80)	34.95 (36.24)	44.98 (42.12)	72.54 (58.40)	81.81 (64.76)	98.77 (83.63)
Imidacloprid 0.003%	49.16 (44.52)	29.97 (33.19)	41.64 (40.19)	66.68 (54.75)	63.35 (52.74)	75.09 (60.06)
Dimethoate 0.05%	92.88 (74.53)	68.39 (55.79)	98.77 (83.63)	100.00 (90.00)	96.77 (83.63)	100.00 (90.00)
CD (0.05)	4.01	3.80	5.89	2.34	6.02	5.86

DAT: Days after treatment Figures in parentheses are angular transformed values

Table 42. Relative toxicity of botanicals and synthetic insecticides to *Paragus serratus* and *Micromus* sp

Treatments	Percentage larval mortality					
	Paragus serratus			*Micromus* sp		
	1 DAT	2 DAT	3 DAT	1 DAT	2 DAT	3 DAT
NeemAzal T/S 4 ml/l	19.09 (25.91)	33.31 (35.25)	42.49 (40.68)	58.35 (49.81)	36.65 (37.25)	45.82 (42.60)
Neem oil + garlic 2%	16.59 (24.04)	29.97 (33.19)	40.81 (39.71)	52.50 (46.43)	24.98 (29.98)	39.99 (39.22)
Acetamiprid 0.002%	32.40 (34.70)	43.32 (41.16)	59.18 (50.29)	74.21 (59.48)	46.66 (43.08)	63.35 (52.74)
Imidacloprid 0.003%	24.11 (29.41)	39.99 (39.22)	52.50 (46.43)	59.19 (50.29)	43.32 (41.16)	60.01 (50.77)
Dimethoate 0.05%	86.25 (68.24)	75.89 (63.63)	83.37 (69.23)	98.60 (87.37)	99.16 (84.73)	100.00 (90.00)
CD (0.05)	4.83	3.70	5.16	4.65	4.58	2.24

DAT: Days after treatment Figures in parentheses are angular transformed values

4.3.2.1.Chilli

The results of the studies on chilli are depicted in Tables 43 to 64.

4.3.2.1.1. Effect on *A. gossypii*

The results on the effect of various treatments on *A. gossypii* expressed as number per 15cm shoot are presented in Table 43

First spray: One day after spraying, significant reduction in the population of the aphid was registered in the plots treated with dimethoate 0.05 % (1.92). Acetamiprid 0.002 % (3.23) and imidacloprid 0.003% (3.78) too reduced the pest population significantly and were on par. Compared to the untreated plots (14.29), NeemAzal T/S 4ml/l (6.28) and neem oil + garlic emulsion 2% (6.77) also reduced the aphid population significantly. On the third day, significant reduction in the population of *A. gossypii* was seen in all the treatments. While no aphids were observed in the plots sprayed with dimethoate and acetamiprid, the population of the pest was negligible (0.36) in plots treated with imidacloprid. NeemAzal T/S (4.44) and neem oil + garlic emulsion (6.97) treated plots too recorded significantly lower population of the hemipteran as against 16.04 per15 cm shoot in the unsprayed plots. On the seventh day, dimethoate (2.04) and acetamiprid (2.99) again recorded low population of the aphids and were on par. The population of the pest was significantly low in the plots sprayed with imidacloprid (3.44) too. Though, NeemAzal T/S (11.93) and neem oil + garlic emulsion (12.88) recorded significantly lower population when compared to control (17.24), it was significantly higher than that in insecticide sprayed plots. On the fifteenth day, significantly lower population of the aphid was seen in dimethoate (12.99), acetamiprid (12.99) and imidacloprid (17.07) treated plots. However, incidence of the pest in NeemAzal T/S (19.14) and neem oil + garlic emulsion (18.50) sprayed plots was on par with that of control (19.59).

Second spray: After the second spray too, significant reduction in the population of the aphid was observed in all the treatments one day after the spraying. The insecticides, acetamiprid (1.73), dimethoate (2.33) and imidacloprid (2.04) recorded low aphid population and were on par. NeemAzal T/S (8.44) and neem oil + garlic emulsion (9.93) treated plots too registered significantly low population as against 20.86 in the untreated plots. On the third day, no population of the aphid was observed in acetamiprid treated plots which was on par with dimethoate (0.09). Imidacloprid (0.28) also recorded very low population of the aphid. Significant reduction in the number of aphids was observed in the plots treated with NeemAzal T/S (7.13) and neem oil + garlic emulsion (8.70), the botanicals differing significantly from each other and from the unsprayed plots (24.64). All the treatments reduced the aphid population significantly when compared to the unsprayed plots (26.89) on the seventh day also. The plots treated with dimethoate (2.65) recorded the lowest population followed by acetamiprid (4.18) and imidacloprid (6.09). NeemAzal T/S (17.70) and neem oil + garlic emulsion (17.48) were on par. On the fifteenth day, acetamiprid (13.33) recorded the lowest population and was superior to all other treatments. It was followed by dimethoate (16.14) and imidacloprid (18.18) treatments. NeemAzal T/S (28.43) and neem oil + garlic emulsion (27.79) were on par with control (29.79).

Pooled analysis of the data indicated that dimethoate (3.58) and acetamiprid (3.79) significantly reduced the aphid population. Imidacloprid (5.12) too recorded low population of the aphid. Though inferior to the insecticides, NeemAzal T/S (11.95) and neem oil + garlic emulsion (12.91) also reduced the population of the aphid significantly when compared to control (20.87).

Considering the persistent toxicity of the botanical and synthetic insecticides, acetamiprid and dimethoate, showed appreciably toxicity upto fifteen days and imidacloprid upto seven days after treament. The effect of NeemAzal and neem oil + garlic emulsion persisted upto three days. An increase in the population was seen from the seventh day onwards.

4.3.2.1.2. Effect on other pests

The other pests recorded on chilli during the cropping season were chilli thrips (*Scirtothrips dorsalis*), leaf hopper(*Amrasca biguttula biguttula*), spiralling white fly (*Aleurodicus dispersus*) and chilli mite (*Polyphagotarsonemus latus*) of which only chilli thrips, leaf hopper and spiralling white fly were noted in appreciable densities. The results on the effect of the botanicals and insecticides on these pests are presented in Tables 44, 45 and 46. The population of the pests is presented as number per plant.

Chilli thrips (*S. dorsalis*)

First spray: Very low population of thrips was observed in acetamiprid 0.002% (0.50) and imidacloprid 0.003% (0.48) treated plots one day after the first spray (Table 44). This was followed by NeemAzal T/S 4 ml/l (1.45) and dimethoate 0.05% (1.50) treatments. Neem oil + garlic emulsion 2% (2.40) too recorded significantly low population of the thrips when compared to the unsprayed plots (5.79). On the third day, no thrips were seen in dimethoate treated plots. Acetamiprid (0.19) and imidacloprid (0.49) recorded very low population. In NeemAzal T/S (1.00) and neem oil + garlic emulsion (1.30) treated plots, the incidence of the pest was significantly lower than that in the control plots (6.00). On the seventh day, acetamiprid (2.19) and dimethoate (2.40) again recorded low population of the thrips and were on par. The population of the pest was also significantly low in plots sprayed with imidacloprid (2.94). When compared to the control plots (6.70), significantly low population was observed in NeemAzal T/S (4.20) and neem oil + garlic emulsion (4.84) treatments. On the fifteenth day, too significantly lower population of thrips was seen in acetamiprid (5.95) and dimethoate (6.65) sprayed plots. Imidacloprid (6.95) and NeemAzal T/S (7.60) also reduced the pest incidence. However, the pest population in neem oil + garlic emulsion (7.75) treated plots was on par with that of the check plots (8.52).

Table 43. Effect of botanical and chemical insecticides on *Aphis gossypii* in chilli

Treatments	Number per 15 cm shoot								Pooled mean
	I spray				II spray				
	1 DAS	3 DAS	7 DAS	15 DAS	1 DAS	3 DAS	7 DAS	15 DAS	
NeemAzal T/S 4 ml/l	6.28 (2.70)	4.44 (2.33)	11.93 (3.59)	19.14 (4.49)	8.44 (3.07)	7.13 (2.85)	17.70 (4.32)	28.43 (5.42)	11.95 (3.60)
Neem oil + garlic 2%	6.77 (2.78)	6.97 (2.82)	12.88 (3.72)	18.50 (4.42)	9.93 (3.31)	8.70 (3.11)	17.48 (4.29)	27.79 (5.37)	12.91 (3.73)
Acetamiprid 0.002%	3.23 (2.05)	0.00 (1.00)	2.99 (1.99)	12.99 (3.74)	1.73 (1.65)	0.00 (1.00)	4.18 (2.28)	13.33 (3.79)	3.79 (2.19)
Imidacloprid 0.003%	3.78 (2.17)	0.36 (1.17)	3.44 (2.11)	17.07 (4.25)	2.04 (1.74)	0.28 (1.11)	6.09 (2.66)	18.18 (4.38)	5.12 (2.47)
Dimethoate 0.05%	1.92 (1.71)	0.00 (1.00)	2.04 (1.74)	12.99 (3.74)	2.33 (1.82)	0.09 (1.05)	2.65 (1.91)	16.14 (4.14)	3.58 (2.14)
Untreated control	14.29 (3.91)	16.04 (4.13)	17.24 (4.27)	19.59 (4.54)	20.86 (4.68)	24.64 (5.06)	26.89 (5.28)	29.79 (5.55)	20.87 (4.68)

CD (0.05) Treatment : 0.07 Figures in parentheses are $\sqrt{(x+1)}$ transformed values
CD (0.05) Treatment × Interval : 0.20 DAS: Days after spraying

Table 44. Effect of botanical and chemical insecticides on *Scirtothrips dorsalis*

Treatments	Number per plant								Pooled mean
	I spray				II spray				
	1 DAS	3 DAS	7 DAS	15 DAS	1 DAS	3 DAS	7 DAS	15 DAS	
NeemAzal T/S 4 ml/l	1.45 (1.56)	1.00 (1.41)	4.20 (2.28)	7.60 (2.93)	3.27 (2.07)	3.44 (2.11)	9.08 (3.18)	14.30 (3.91)	4.91 (2.43)
Neem oil + garlic 2%	2.40 (1.84)	1.30 (1.52)	4.84 (2.42)	7.75 (2.96)	3.69 (2.17)	4.44 (2.33)	10.89 (3.45)	14.25 (3.91)	5.62 (2.57)
Acetamiprid 0.002%	0.50 (1.22)	0.19 (1.09)	2.19 (1.79)	5.95 (2.64)	1.94 (1.72)	0.60 (1.26)	3.00 (2.00)	6.65 (2.77)	2.28 (1.81)
Imidacloprid 0.003%	0.48 (1.22)	0.49 (1.22)	2.94 (1.98)	6.95 (2.82)	2.10 (1.76)	0.48 (1.22)	2.55 (1.88)	7.34 (2.89)	2.51 (1.87)
Dimethoate 0.05%	1.50 (1.58)	0.00 (1.00)	2.40 (1.84)	6.65 (2.77)	1.70 (1.64)	0.00 (1.00)	2.99 (2.00)	7.33 (2.89)	2.38 (1.84)
Untreated control	5.79 (2.61)	6.00 (2.65)	6.70 (2.81)	8.52 (3.09)	9.35 (3.22)	10.60 (3.41)	12.95 (3.74)	14.90 (3.99)	9.15 (3.19)

CD (0.05) Treatment : 0.05 Figures in parentheses are $\sqrt{(x+1)}$ transformed values
CD (0.05) Treatment × Interval : 0.14 DAS: Days after spraying

Second spray: One day after the second spray, dimethoate (1.70), acetamiprid (1.94) and imidacloprid (2.10) recorded low population of thrips and were at par. NeemAzal T/S (3.27) and neem oil + garlic emulsion (3.69) which were on par in their effect, recorded significantly lower population of thrips than in the control plots (9.35). All the treatments significantly reduced the population over control (10.60) on the third day. While no thrips were seen in dimethoate treated plots, very low population was observed in imidacloprid (0.48) and acetamiprid (0.60) sprayed plots. NeemAzal T/S (3.44) and neem oil + garlic emulsion (4.44) also recorded significantly low population of the thysanopteran. On the seventh day, the insecticide treatments were at par and reduced the pest incidence significantly, the number of thrips recorded per plant being 2.55, 2.99 and 3.00 in imidacloprid, dimethoate and acetamiprid treatments, respectively as against 12.95 in the untreated plots. NeemAzal (9.08) and neem oil + garlic emulsion (10.89) were on par. On the fifteenth day, acetamiprid (6.65), dimethoate (7.33) and imidacloprid (7.34) recorded significantly low population of thrips and were at par. NeemAzal T/S (14.30) and neem oil + garlic emulsion (14.25) were on par with control (14.90).

Perusal of the overall mean revealed that acetamiprid (2.28) and dimethoate (2.38) equally reduced the thrips population significantly. Imidacloprid (2.51) too recorded low population of the thrips and was on par with dimethoate. Significant reduction in the population of the thrips was also noted in the plots treated with NeemAzal T/S (4.91) and neem oil + garlic emulsion (5.62) when compared to the check plots (9.15).

Acetamiprid, dimethoate and imidacloprid showed appreciable toxicity upto seven days after treatment. NeemAzal T/S and neem oil + garlic emulsion reduced the population of the pest notably upto three days. An increase in the population was seen on the seventh day which come at par with control by the fifteenth day.

Leaf hopper (*A. biguttula biguttula*)

First spray: Significantly low population of the hopper was recorded in the plots treated with acetamiprid 0.002% (1.04), dimethoate 0.05% (1.18) and imidacloprid 0.003% (1.19) one day after the first spray (Table 45). Compared to control (8.29), NeemAzal T/S 4 ml/l (3.94) and neem oil + garlic emulsion 2% (3.15) also reduced the population of the leaf hopper significantly. On the third day, very low population of the hopper was seen in acetamiprid (0.19) sprayed plots and the neonicotinoid was superior to all other treatments. The population of the pest in plots treated with dimethoate (0.53) and imidacloprid too was significantly low (0.79). While 8.59 hoppers per plant was recorded from the control plots, only 4.10 and 3.99 hoppers were noticed in NeemAzal T/S and neem oil + garlic emulsion treated plots. On the seventh day, low population of the hopper was observed in acetamiprid (3.63), dimethoate (3.99) and imidacloprid (3.77) treatments and they were on par. NeemAzal T/S (7.77) and neem oil + garlic emulsion (7.18) recorded significantly lower population when compared to the control plots (9.44). Acetamiprid (6.70), imidacloprid (7.39) and dimethoate (9.34) treated plots registered significantly low population of the hopper on the fifteenth day after spraying. However, NeemAzal T/S (12.03) and neem oil + garlic emulsion (12.58) did not check the hopper effectively and were on par with control (13.39).

Second Spray: Acetamiprid (1.55), dimethoate (1.92) and imidacloprid (2.09) resulted in a significant reduction of the hopper population when observed one day after the second spray and the treatments were on par. NeemAzal T/S (3.69) and neem oil + garlic emulsion (5.44) also recorded lower number of hoppers when compared to the untreated plots (14.05). Negligible population of the pest was observed in the insecticide treated plots on the third day, the number per plant being 0.09, 0.60 and 0.93 in acetamiprid, dimethoate and imidacloprid, respectively. NeemAzal T/S (4.69) and neem oil + garlic emulsion (6.09) also reduced the hopper population. On the seventh day, while high population of the hopper was seen in the untreated plots (17.24), acetamiprid (5.00) recorded the lowest population. This was followed by dimethoate (6.84) and imidacloprid (7.05). NeemAzal T/S (10.93) and neem oil + garlic emulsion (11.14) were on par. On the fifteenth day too, acetamiprid recorded the lowest population (9.59) and was superior to all other treatments. It was followed by dimethoate (10.49) and imidacloprid (11.53). NeemAzal T/S (18.88) and neem oil + garlic emulsion (18.94) were on par with control (18.14).

Overall analysis of the data revealed the efficacy of acetamiprid in controlling the leafhopper (2.90). The treatment was superior to all other treatments. It was followed by imidacloprid (3.75) and dimethoate (3.69) which were on par. NeemAzal T/S (7.64) and neem oil + garlic emulsion (7.97) also reduced the leafhopper population significantly when compared to the untreated plots (12.88).

Noticeable toxicity was recorded for acetamiprid upto fifteen days after spraying and for dimethoate and imidacloprid upto seven days. NeemAzal T/S and neem oil + garlic emulsion reduced population of the pest markedly upto three days.

Spiralling white fly (*A. dispersus*)

First spray: One day after the first spray, significant reduction in the population of the spiralling whitefly was seen in the various treatments (Table 46). The plots treated with acetamiprid 0.002% (1.14) recorded the lowest population and it was on par with dimethoate 0.05% (1.19). This was followed by imidacloprid 0.003% which recorded 1.49 white flies per plant. The insecticide was on par with the botanical NeemAzal T/S 4 ml/l (1.55). Application of neem oil + garlic emulsion 2% (2.24) also resulted in significant reduction of the pest when compared to the untreated plot (3.75). On the third day after spraying, all the treatments differed significantly in their effect. The lowest population was recorded in acetamiprid treated plots (0.15). Imidacloprid (0.70) and dimethoate (1.00) too reduced the population of the pest significantly. Only 1.04 and 1.55 whiteflies per plant were

Table 45. Effect of botanical and chemical insecticides on *Amrasca biguttula biguttula* in chilli

Treatments	Number per plant								Pooled mean
	I spray				II spray				
	1 DAS	3 DAS	7 DAS	15 DAS	1 DAS	3 DAS	7 DAS	15 DAS	
NeemAzal T/S 4 ml/l	3.94 (2.22)	4.10 (2.26)	7.77 (2.96)	12.03 (3.61)	3.69 (2.17)	4.69 (2.39)	10.93 (3.45)	18.88 (4.46)	7.64 (2.94)
Neem oil + garlic 2%	3.15 (2.04)	3.99 (2.23)	7.18 (2.86)	12.58 (3.69)	5.44 (2.54)	6.09 (2.66)	11.14 (3.48)	18.94 (4.47)	7.97 (3.00)
Acetamiprid 0.002%	1.04 (1.43)	0.19 (1.09)	3.63 (2.15)	6.70 (2.77)	1.55 (1.60)	0.09 (1.05)	5.00 (2.45)	9.59 (3.25)	2.90 (1.97)
Imidacloprid 0.003%	1.19 (1.48)	0.79 (1.34)	3.77 (2.19)	7.39 (2.90)	2.09 (1.76)	0.93 (1.39)	7.05 (2.84)	11.53 (3.54)	3.75 (2.18)
Dimethoate 0.05%	1.18 (1.48)	0.53 (1.24)	3.99 (2.23)	9.34 (3.22)	1.92 (1.71)	0.60 (1.26)	6.84 (2.80)	10.49 (3.39)	3.69 (2.17)
Untreated control	8.29 (3.05)	8.59 (3.10)	9.44 (3.23)	13.39 (3.79)	14.05 (3.88)	15.90 (4.11)	17.24 (4.27)	18.14 (4.38)	12.88 (3.73)

CD (0.05) Treatment : 0.07 Figures in parentheses are √(x+1) transformed values
CD (0.05) Treatment × Interval : 0.19 DAS: Days after spraying

Table 46. Effect of botanical and chemical insecticides on *Aleurodicus dispersus* in chilli

Treatments	Number per plant								Pooled mean
	I spray				II spray				
	1 DAS	3 DAS	7 DAS	15 DAS	1 DAS	3 DAS	7 DAS	15 DAS	
NeemAzal T/S 4 ml/l	1.55 (1.60)	1.04 (1.43)	3.35 (2.09)	6.55 (2.75)	3.15 (2.04)	2.20 (1.79)	3.30 (2.07)	8.69 (3.11)	3.45 (2.11)
Neem oil + garlic 2%	2.24 (1.80)	1.55 (1.60)	3.05 (2.01)	6.99 (2.83)	3.35 (2.09)	2.40 (1.84)	4.50 (2.34)	9.20 (3.19)	3.90 (2.21)
Acetamiprid 0.002%	1.14 (1.46)	0.15 (1.07)	0.79 (1.34)	3.30 (2.07)	1.95 (1.72)	0.35 (1.16)	2.35 (1.83)	5.75 (2.60)	1.74 (1.66)
Imidacloprid 0.003%	1.49 (1.58)	0.70 (1.30)	1.30 (1.52)	3.74 (2.18)	2.20 (1.79)	0.59 (1.26)	2.99 (2.00)	7.99 (3.00)	2.34 (1.83)
Dimethoate 0.05%	1.19 (1.48)	1.00 (1.41)	2.10 (1.76)	4.85 (2.42)	2.40 (1.84)	0.89 (1.38)	3.49 (2.12)	7.25 (2.87)	2.65 (1.91)
Untreated control	3.75 (2.18)	4.20 (2.28)	5.05 (2.46)	6.74 (2.78)	7.00 (2.83)	7.95 (2.99)	10.40 (3.38)	12.19 (3.63)	6.93 (2.82)

CD (0.05) Treatment : 0.04 Figures in parentheses are √(x+1) transformed values
CD (0.05) Treatment × Interval : 0.10 DAS: Days after spraying

observed in NeemAzal T/S and neem oil + garlic emulsion treated plots, respectively when the population was 4.20 whiteflies per plant in the untreated plots. Similarly, significant reduction in the pest population was seen in all the treatments on the seventh day after spraying. The plots treated with acetamiprid recorded the lowest population (0.79) and was superior to other treatments. Only 1.30 and 2.10 flies per plant were observed in the plots sprayed with imidacloprid and dimethoate, respectively. Both the botanicals reduced the pest incidence significantly when compared to control (5.05) and were on par in their effect. While 3.05 whiteflies were recorded per plant in neem oil + garlic emulsion treated plot, 3.35 flies per plant was observed in NeemAzal T/S sprayed plots. On the fifteenth day, with the exception of NeemAzal T/S (6.55) and neem oil + garlic emulsion (6.99), the synthetic insecticides viz., acetamiprid (3.30), imidacloprid (3.74) and dimethoate 0.05% (4.85) significantly reduced the population over control (6.74).

Second spray: Significant decrease in the population of spiralling whitefly was observed one day after second spraying too. Acetamiprid treated plots showed the lowest population (1.95) and were on par with imidacloprid (2.20). Dimethoate recorded 2.40 flies per plant. Significant reduction was also noticed in NeemAzal T/S (3.15) and neem oil + garlic emulsion (3.35) treatments when compared to the check plots (7.00). On the third day, significant reduction in the population of spiralling whitefly was observed in all the treatments. Acetamiprid (0.35) and imidacloprid (0.59) were on par and superior to dimethoate (0.89). Compared to the untreated plots (7.95), significant reduction in the population of the pest was observed in NeemAzal T/S (2.20) and neem oil + garlic emulsion (2.40) sprayed plots and both the treatments were on par. On the seventh day, the lowest population of *A. dispersus* was recorded in acetamiprid (2.35). Imidacloprid 0.003% (2.99) too recorded low population of the pest and it was on par with NeemAzal T/S (3.30) which in turn was on par with dimethoate (3.49).

Significantly low population of the white fly was also seen in neem oil + garlic emulsion (4.50) treated plots when compared to the control plots (10.40). Observations recorded on the fifteenth day after spraying too indicated that the plots which received acetamiprid treatment recorded the lowest population of *A. dispersus* (5.75) followed by dimethoate (7.25) and imidacloprid (7.99). While 12.19 whiteflies were noticed per plant in the unsprayed plots, it was only 8.69 and 9.20 in NeemAzal T/S 4 and neem oil + garlic emulsion sprayed plots, respectively.

Pooled analysis of the data indicated that acetamiprid (1.74) was superior to rest of the treatments in controlling the pest. Imidacloprid (2.34) was the next best insecticide and was superior to dimethoate (2.65). NeemAzal T/S (3.45) and neem oil + garlic emulsion (3.90) also reduced the population of the pest significantly when compared to control (6.93).

Consistent toxicity of the synthetic insecticides was seen up to seven days. NeemAzal T/S and neem oil + garlic emulsion reduced the population appreciably only upto three days.

4.3.2.1.3 Effect on natural enemies

Tables 47 to 53 depict the results on the effect of the botanicals and synthetic insecticides on the natural enemies prevalent in the crop field. The population of the bioagents is presented as number per 10 plants.

Coccinellid Predators

First spray: The population of coccinellids was significantly low in all the treatments when compared to the control plot (4.75) on one day after spraying (Table 47). Among the treatments, dimethoate 0.05% (1.50), acetamiprid 0.002% (1.50) and imidacloprid 0.003% (1.75) were highly toxic to the coccinellids. NeemAzal T/S 4 ml/l (2.50) and neem oil + garlic emulsion 2% (2.75) were significantly less toxic. On the third day after spraying also, the lowest coccinellid population (0.50) was recorded in dimethoate treated plots followed by acetamiprid (1.25). Imidacloprid

(2.75), NeemAzal T/S (2.75) and neem oil + garlic emulsion (3.25) were significantly less toxic to the coccinellids. Dimethoate (2.50) and acetamiprid (2.75) continued to be significantly toxic to the predators when observed on the seventh day. Imidacloprid (3.75), neem oil + garlic emulsion (3.75) and NeemAzal T/S (3.50) sprayed plots recorded comparatively higher coccinellid population and were on par. On the fifteenth day, while dimethoate (4.25) acetamiprid (5.25) and imidacloprid (5.50) recorded significantly lower population of coccinellds, neem oil + garlic emulsion (6.00) and NeemAzal T/S (6.00) recorded higher number of the predator and were on par with untreated control (6.25).

Second spray: Similar to the effect observed after the first spray, there was significant reduction of coccinelld population in all the treatments on one and three days after the second spray. While 0.50 and 0.25 coccinellids per 10 plants were seen in dimethoate treated plots on the first and third day after spraying, respectively, 1.75 and 1.50 and 2.50 and 2.50 predators per ten plants were recorded in acetamiprid and imidacloprid treated plots as against 6.50 and 7.25, respectively in the control plot. NeemAzal T/S and neem oil + garlic emulsion recorded 3.25 and 3.50 and 4.00 and 4.25 per 10 plants on these days, respectively. Again significant reduction in the population of the coccinellids was seen in dimethoate (2.50) on the seventh day. The other treatments viz., acetamiprid (3.75), imidacloprid (4.50), NeemAzal T/S (5.75) and neem oil + garlic emulsion (7.25) recorded low population and they differed significantly among themselves. Only dimethoate (5.50) and acetamiprid (8.50) resulted in significantly low population of the coccinellid on the fifteenth day. Imidacloprid (9.25), neem oil + garlic emulsion (9.50) and NeemAzal T/S (9.50) recorded significantly higher population and were on par with untreated control (9.50).

Analysis of the cumulative effect of various treatments indicated that dimethoate was highly toxic to coccinellids. Only 2.19 coccinellids were seen per ten plants in the treatment in contrast to 6.69 in the untreated plots. This was followed by acetamiprid (3.28) and imidacloprid (4.06). Compared to the insecticides NeemAzal T/S (4.53) and neem oil + garlic emulsion (5.09) treated plots recorded significantly higher population of the predator.

Toxicity of the insecticides to the coccinellids persisted upto seven days. On the other hand, perceptible adverse effect of the botanicals was noted only upto three days. Thereafter, an increase in the population of the predator was observed which came on par with control by the fifteenth day.

Syrphid Predators

First spray: One day after the first spraying, significant reduction in the population of syrphids was observed in the plots treated with synthetic insecticides (Table 48) when compared to the control plots (2.75). Among the treatments, acetamiprid 0.002% (0.50) and dimethoate 0.05% (0.75) were highly toxic to the predators. Imidacloprid 0.003% (1.25), NeemAzal T/S 4 ml/l (1.25) and neem oil + garlic emulsion 2% (1.50) treated plots too recorded low population and were on par. A similar effect was observed on the third day after spraying. No syrphids were observed in dimethoate sprayed plots and it was on par with acetamiprid (0.25) and imidacloprid (0.75). NeemAzal T/S (1.50) and neem oil + garlic emulsion (1.75) were on par in their effect. On the seventh day also, the treatments reduced the population of the syrphids significantly. Compared to the untreated plot (3.75), acetamiprid (1.50), dimethoate (1.25) and imidacloprid (1.75) recorded significantly lower number of syrphids and were on par. NeemAzal T/S (2.75) and neem oil + garlic emulsion (3.25) recorded significantly higher population than the insecticides. With the exception of dimethoate (2.25) and acetamiprid (3.50) all the other treatments viz., imidacloprid (3.75), NeemAzal T/S (4.25) and neem oil + garlic emulsion (4.25) were on par with control (4.50) in their effect on the syrphids on the fifteenth day after spraying.

Second spray: A similar trend was observed following the second round of spraying. The population of the syrphids was significantly reduced in all the treatments one day after the second spraying when compared to the

Table 47. Effect of botanical and chemical insecticides on coccinellids in chilli

Treatments	Number per 10 plants								Pooled mean
	I spray				II spray				
	1 DAS	3 DAS	7 DAS	15 DAS	1 DAS	3 DAS	7 DAS	15 DAS	
NeemAzal T/S 4 ml/l	2.50	2.75	3.50	6.00	3.25	3.50	5.75	9.50	4.53
Neem oil + garlic 2%	2.75	3.25	3.75	6.00	4.00	4.25	7.25	9.50	5.09
Acetamiprid 0.002%	1.50	1.25	2.75	5.25	1.75	1.50	3.75	8.50	3.28
Imidacloprid 0.003%	1.75	2.75	3.75	5.50	2.50	2.50	4.50	9.25	4.06
Dimethoate 0.05%	1.50	0.50	2.50	4.25	0.50	0.25	2.50	5.50	2.19
Untreated control	4.75	5.25	5.50	6.25	6.50	7.25	8.25	9.50	6.69

CD (0.05) Treatment : 0.27 DAS: Days after spraying

CD (0.05) Treatment × Interval : 0.77

Table 48. Effect of botanical and chemical insecticides on syrphids in chilli

Treatments	Number per 10 plants								Pooled mean
	I spray				II spray				
	1 DAS	3 DAS	7 DAS	15 DAS	1 DAS	3 DAS	7 DAS	15 DAS	
NeemAzal T/S 4 ml/l	1.25	1.50	2.75	4.25	1.00	1.50	5.00	7.00	3.03
Neem oil + garlic 2%	1.50	1.75	3.25	4.25	1.50	1.75	5.50	7.00	3.31
Acetamiprid 0.002%	0.50	0.25	1.50	3.50	0.50	0.25	2.25	6.50	1.91
Imidacloprid 0.003%	1.25	0.75	1.75	3.75	1.00	0.50	2.50	6.50	2.25
Dimethoate 0.05%	0.75	0.00	1.25	2.25	0.25	0.00	1.25	2.75	1.06
Untreated control	2.75	3.25	3.75	4.50	4.75	5.50	6.50	6.75	4.81

CD (0.05) Treatment : 0.26 DAS: Days after spraying

CD (0.05) Treatment × Interval : 0.75

untreated plots (4.75). Dimethoate (0.25), acetamiprid (0.50), imidacloprid (1.00) and NeemAzal T/S (1.00) with very low population were on par in their effect. Furthermore, imidacloprid and NeemAzal T/S were on par with neem oil + garlic emulsion (1.50). Significant reduction of syrphid population was observed in dimethoate (0.00) treated plots which was on par with acetamiprid (0.25) and imidacloprid (0.50) on the third day after spraying. The botanicals viz., NeemAzal T/S (1.50) and neem oil + garlic emulsion (1.75) recorded significantly higher population of the predator than the insecticides, though it was lower than that in control (5.50). Despite a gradual build up of the population in all the treatments on the seventh day, significant difference was noticed over control (6.50). While dimethoate (1.25), acetamiprid (2.25) and imidacloprid (2.50) were on par, NeemAzal T/S (5.00) and neem oil + garlic emulsion (5.50) were at par. Excepting in dimethoate (2.75) treated plots, the population of the syrphid in all the other treatments were on par with the untreated control (6.75) on the fifteenth day, the population in acetamiprid, imidacloprid, NeemAzal T/S and neem oil + garlic emulsion being 6.50, 6.50,7.00 and 7.00 per 10 plants respectively.

Considering the overall effect of the botanicals and insecticides, the lowest population of the predator was recorded in dimethoate (1.06) treated plot. This was followed by acetamiprid and imidacloprid which recorded 1.91 and 2.25 syrphids per 10 plants respectively. NeemAzal T/S and neem oil + garlic emulsion recorded 3.03 and 3.31 predators per 10 plants respectively.

Toxicity of the insecticides to the coccinellids persisted upto seven days. Noticeable adverse effect of the botanicals was noted only upto three days. Thereafter, an increase in the population of the predator was observed which came on par with control by the fifteenth day.

Chamaemyiids (*Leucopis* sp.)

First spray: The population of *Leucopis* sp. was significantly lower in all the treatments than in control (6.75) when observed on one day after spraying (Table 49). Dimethoate 0.05% (0.50) and acetamiprid 0.002% (1.25) were highly toxic to the chaemyaeiids followed by imidacloprid 0.003% (1.75). NeemAzal T/S 4 ml/l (3.25) and neem oil + garlic emulsion 2% (3.50) were on par in their effect. On the third day, all the treatments differed significantly in their effect on the predator. No *Leucopis* sp. was recorded in dimethoate treated plots. Acetamiprid (1.75) and imidacloprid (2.25) recorded significantly low population and were at par. Compared to the unsprayed plots (7.50), significantly lower population of the predator was seen in NeemAzal T/S (3.50) and neem oil + garlic emulsion (4.25) treated plots. Dimethoate (3.25) continued to be significantly toxic to the predator when observed on the seventh day. Acetamiprid (6.25), NeemAzal T/S (6.75) imidacloprid (7.00) and neem oil + garlic emulsion (7.50) sprayed plots recorded comparatively higher population of *Leucopis* sp. though they were significantly lower than that in untreated control (8.50). On the fifteenth day too, significant reduction was observed in the population of the predator in dimethoate (5.50) treated plots. Acetamiprid (9.25) and imidacloprid (9.25) were on par in their effect. Neem oil + garlic emulsion (10.25) and NeemAzal T/S (10.25) recorded high population and were on par with untreated control (10.50).

Second spray: The population of *Leucopis* sp. was negligible in dimethoate (0.25) treated plot one day after the second spray when compared to the untreated plots (10.75). Significant reduction in the number of the predator was also noticed in acetamiprid (1.75) and imidacloprid (2.25) treated plots. Compared to the check plot (10.75), significantly low population was also recorded in NeemAzal T/S (3.50) and neem oil + garlic emulsion (4.25) treatments. No *Leucopis* sp. was seen in dimethoate treated plots on the third day after spraying. Acetamiprid (2.25) and imidacloprid (2.50) treated plots too recorded low population of the predator. The botanicals viz., NeemAzal T/S (4.50) and neem oil + garlic emulsion (5.50) recorded significantly higher population of the predator than the insecticides, though it was lower than that in control (11.50). On the seventh day, significantly low population was noticed in dimethoate (3.75) sprayed plots. While, 6.50 and 7.75 *Leucopis* sp. per 10 plants was recorded in acetamiprid and imidacloprid treated plots, 8.00 and 10.50 *Leucopis* sp. per 10 plants were observed in NeemAzal T/S and neem oil + garlic emulsion treatments as against 12.25 in control. Excepting dimethoate (8.00) and acetamiprid (11.25), the population of the predator in all the other treatments was on par with that in untreated control (12.25) on the fifteenth day, the population in imidacloprid, NeemAzal T/S and neem oil + garlic emulsion sprayed plots being 12.25, 12.25 and 12.50 per 10 plants, respectively.

Analysis of the cumulative effect of various treatments indicated that dimethoate (2.66) was highly toxic to *Leucopis* sp. followed by acetamiprid (5.03) and imidacloprid (5.63). Compared to the insecticides, significantly higher population of the predator was observed in NeemAzal T/S (6.47) and neem oil + garlic emulsion (7.28) treated plots.

Toxicity of dimethoate to the predator persisted upto fifteen days. Appreciable toxicity of acetamiprid and imidacloprid was observed upto seven days. The adverse effect of the botanicals was noted only upto three days.

Hemerobiids

No hemerobiids were observed during the first spray. The population of hemerobiids observed after the second spraying is given in Table 50.

Second spray: No hemerobiids were observed in the plots sprayed with dimethoate 0.05% one day after second spraying and the treatment was on par with acetamiprid 0.002% (0.25) which in turn was on par with imidacloprid 0.003%, recording 0.75 hemerobiids per 10 plants. NeemAzal T/S 4 ml/l (0.75) and neem oil + garlic emulsion 2% (1.25) too were on par with imidacloprid in their toxicity to the predators compared to the untreated plots (3.25). Three days after spraying too, no hemerobiids were detected in the plots sprayed with dimethoate. Plots sprayed with acetamiprid also recorded very low population (0.50) of the predator. Imidacloprid (1.25) and NeemAzal T/S (1.50) were on par in their toxicity to the predator. Compared to all the treatments, higher population of hemerobiids was recorded in neem oil + garlic emulsion (2.25) treated plots though it was significantly less than that in the control plots (3.50). On the seventh day, only 0.75 hemerobiids per ten plants were seen in dimethoate sprayed plots. Acetamiprid (2.25) recorded significantly higher population and was on par with imidacloprid (2.75) and NeemAzal T/S (2.75). Again, higher population of the predator was observed in neem oil + garlic emulsion (3.25) treatment. On the fifteenth day too, significantly low population of hemerobiids was seen in dimethoate (2.50) treated plots. Acetamiprid (3.25) and imidacloprid (3.50) recorded comparatively higher population of the predator and were on par. NeemAzal T/S (5.75) and neem oil + garlic emulsion (6.25) were on par with control (6.25) in their effect.

The cumulative data on the effect of the different treatments showed the high toxicity of dimethoate to the predator, recording only 0.81 hemerobiids per ten plants. Acetamiprid and imidacloprid too was toxic, the number of hemerobiids recorded per ten plants being 1.56 and 2.06 respectively. NeemAzal T/S and neem oil + garlic emulsion were less toxic, registering 2.69 and 3.25 hemerobiids per ten plants respectively as against 4.38 hemerobiids per ten plants in the untreated plot.

Considering the persistent toxicity, dimethoate showed high toxicity upto fifteen days. Acetamiprid and imidacloprid showed appreciable toxicity only upto seven days. Adverse effect of NeemAzal T/S and neem oil + garlic emulsion was observed only for one day. Subsequently, higher population of the predator prevailed in the treated plots.

Chrysopids

Second spray: One day after spraying, there was significant reduction in the number of chrysopids in the three insecticide treated plots and they were on par (Table 51). While the plots treated with dimethoate 0.05%

Table 49. Effect of botanical and chemical insecticides on *Leucopis* sp in chilli

Treatments	Number per 10 plants								Pooled mean
	I spray				II spray				
	1 DAS	3 DAS	7 DAS	15 DAS	1 DAS	3 DAS	7 DAS	15 DAS	
NeemAzal T/S 4 ml/l	3.25	3.50	6.75	10.25	3.50	4.50	8.00	12.25	6.47
Neem oil + garlic 2%	3.50	4.25	7.50	10.25	4.25	5.50	10.50	12.50	7.28
Acetamiprid 0.002%	1.25	1.75	6.25	9.25	1.75	2.25	6.50	11.25	5.03
Imidacloprid 0.003%	1.75	2.25	7.00	9.25	2.25	2.50	7.75	12.25	5.63
Dimethoate 0.05%	0.50	0.00	3.25	5.50	0.25	0.00	3.75	8.00	2.66
Untreated control	6.75	7.50	8.50	10.50	10.75	11.50	12.25	12.50	10.06

CD (0.05) Treatment : 0.29 DAS: Days after spraying
CD (0.05) Treatment × Interval : 0.83

Table 50. Effect of botanical and chemical insecticides on hemerobiids in chilli

Treatments	Number per 10 plants				Pooled mean
	II spray				
	1 DAS	3 DAS	7 DAS	15 DAS	
NeemAzal T/S 4 ml/l	0.75	1.50	2.75	5.75	2.69
Neem oil + garlic 2%	1.25	2.25	3.25	6.25	3.25
Acetamiprid 0.002%	0.25	0.50	2.25	3.25	1.56
Imidacloprid 0.003%	0.75	1.25	2.75	3.50	2.06
Dimethoate 0.05%	0.00	0.00	0.75	2.50	0.81
Untreated control	3.25	3.50	4.50	6.25	4.38

CD (0.05) Treatment : 0.34
CD (0.05) Treatment × Interval : 0.69

Table 51. Effect of botanical and chemical insecticides on chrysopids in chilli

Treatments	Number per 10 plants				Pooled mean
	II spray				
	1 DAS	3 DAS	7 DAS	15 DAS	
NeemAzal T/S 4 ml/l	1.75	2.50	4.25	6.50	3.75
Neem oil + garlic 2%	2.25	2.75	4.50	7.50	4.25
Acetamiprid 0.002%	0.50	0.75	3.50	5.25	2.50
Imidacloprid 0.003%	0.75	1.25	2.50	5.75	2.56
Dimethoate 0.05%	0.25	0.00	2.50	4.50	1.81
Untreated control	4.25	4.75	5.50	7.50	5.50

CD (0.05) Treatment : 0.37 DAS: Days after spraying
CD (0.05) Treatment × Interval : 0.73

recorded 0.25 chrysopids per 10 plants, 0.50 and 0.75 chrysopids were observed in acetamiprid 0.002% and imidacloprid 0.003% sprayed plots, respectively. When compared to the insecticides, significantly higher population was seen in NeemAzal T/S 4 ml/l (1.75) and neem oil + garlic emulsion 2% (2.25) treated plots. However, the population in these treatments was significantly lower than that in the unsprayed plots (4.25). While no chrysopids were observed in dimethoate treated plots on the third day after spraying, acetamiprid (0.75) and imidacloprid (1.25) treatments recorded significantly low population and were on par. NeemAzal T/S (2.50) and neem oil + garlic emulsion (2.75) recorded higher population. On the seventh day, only 2.50 chrysopids per ten plants was recorded in dimethoate treated plots, and it was on par with imidacloprid (2.50). Acetamiprid (3.50), NeemAzal T/S (4.25) and neem oil + garlic emulsion (4.50) recorded comparatively higher population though it was significantly lower than that in the control plots (5.50) .The data on fifteenth day after spraying indicated significantly low population in dimethoate (4.50) sprayed plots. Acetamiprid (5.25) and imidacloprid (5.75) were on par in their effect. While 6.50 chrysopids per 10 plants were seen in NeemAzal T/S treatment, 7.50 chrysopids per 10 plants were observed both in neem oil + garlic emulsion treated and control plots.

Pooled toxicity of the various insecticides showed significant reduction of chrysopids in all the treatments over control. Among the treatments, dimethoate recorded the lowest population (1.81). This was followed by acetamiprid (2.50) and imidacloprid (2.56). NeemAzal T/S and neem oil + garlic emulsion recorded 3.75 and 4.25 chrysopids per 10 plants respectively as against 5.50 in the untreated plots.

Considering the persistent toxicity, dimethoate and imidacloprid showed high toxicity upto seven days. Acetamiprid recorded appreciable toxicity only upto three days. Adverse effect of NeemAzal T/S and neem oil + garlic emulsion was observed only for one day.

Spiders

First spray: The population of spiders in all the treatments was significantly lower than (Table 52) that in the untreated plots (3.75) one day after spraying. The insecticides viz., acetamiprid 0.002% (1.25), imidacloprid 0.003% (1.50) and dimethoate 0.05% (1.50) were on par in their effect. The botanical viz., NeemAzal T/S 4 ml/l (2.25) was on par with not only imidacloprid 0.003% and dimethoate 0.05%, but also with neem oil + garlic emulsion 2% (2.50). On the third day, while 5.25 spiders were seen in the control plot, dimethoate treated plots recorded the lowest population (0.50) and the treatment was on par with acetamiprid (1.25). Imidacloprid recorded 1.50 spiders per 10 plants which was significantly lower than those recorded from NeemAzal T/S (2.50) and neem oil + garlic emulsion (3.50) sprayed plots. On the seventh day, dimethoate (1.50) and acetamiprid (2.50) recorded significantly low population of spiders when compared to that in control (5.50).There was a gradual build up of the spider population in imidacloprid (4.25), NeemAzal T/S (4.50) and neem oil + garlic emulsion (4.75) treatments. On the fifteenth day, acetamiprid (5.50), imidacloprid (5.00) and dimethoate (3.50) recorded significantly lower population. On the other hand, NeemAzal T/S (6.25) and neem oil + garlic emulsion (6.50) recorded high spider population and were on par with control (6.50).

Second spray: One day after the second spraying, the lowest population of spiders was seen in dimethoate (0.25) treated plots. Acetamiprid (1.75) and imidacloprid (2.50) also were toxic to the araneae. Compared to the insecticide treatments, higher population was observed in NeemAzal T/S (3.25) and neem oil + garlic emulsion (4.25) treated plots though significantly lower than that in unsprayed plots (7.25). On the third day too significant reduction was observed in the spider population in all treatments over control (8.00). Again, the plots treated with dimethoate (0.25) recorded the lowest population. Imidacloprid (2.00) and acetamiprid (2.00) were on par in their effect. NeemAzal T/S (4.25) and neem oil + garlic emulsion (4.75) were on par in their influence on the population of the predator. On the seventh day too, the plots treated with dimethoate (2.00) recorded the lowest population followed by acetamiprid (4.50). Significantly higher population was seen in imidacloprid (6.50) treated plot and it was on par with that in NeemAzal T/S (6.50) treatment. Neem oil + garlic emulsion recorded 8.00 spiders per 10 plants as against 9.50 spiders per 10 plants in the control plot. On the fifteenth day, again significantly lower population was recorded in dimethoate (6.50 against 11.50 in control). Comparatively, higher population of spiders was seen in NeemAzal T/S (10.25), acetamiprid (10.25), imidacloprid (11.25) and neem oil + garlic emulsion (11.00) treated plots were on par with control.

Analysis of the overall efficiency of the treatments indicated that dimethoate (2.00) was the most toxic followed by acetamiprid and imidacloprid which recorded 3.66 and 4.31 spiders per 10 plants respectively as against 7.16 in the control plot.The botaniclas viz., NeemAzal T/S (4.97) and neem oil + garlic emulsion (5.66) which recorded higher population were less toxic than the insecticides.

Regarding the persistent toxic effect of the various insecticides, dimethoate exerted detrimental effect even on the fifteenth day. Remarkable toxicity of acetamiprid and imidacloprid persisted only upto seven days and that of the botanicals to three days.

Parasitoids

First spray: Significant reduction was observed in the number of parasitoids in the insecticide treated plots over control (6.50) one day after the first spray (Table 53). The population in dimethoate 0.05%, acetamiprid 0.002% and imidacloprid 0.003% treated plots were 0.50, 0.75 and 1.25 respectively and they were on par. Neem oil + garlic emulsion 2% (5.00) and NeemAzal T/S 4 ml/l (4.00) recorded comparatively higher population of the parasitoids than the insecticides. On the third day, only 0.50 parasitoids per 10 plants were observed in the dimethoate sprayed plot when 7.5 parasitoids were seen per 10 plants in the control plot. In the plots treated with

Table 52. Effect of botanical and chemical insecticides on spiders in chilli

Treatments	Number per 10 plants								Pooled mean
	I spray				II spray				
	1 DAS	3 DAS	7 DAS	15 DAS	1 DAS	3 DAS	7 DAS	15 DAS	
NeemAzal T/S 4 ml/l	2.25	2.50	4.50	6.25	3.25	4.25	6.50	10.25	4.97
Neem oil + garlic 2%	2.50	3.50	4.75	6.50	4.25	4.75	8.00	11.00	5.66
Acetamiprid 0.002%	1.25	1.25	2.50	5.50	1.75	2.00	4.50	10.50	3.66
Imidacloprid 0.003%	1.50	1.50	4.25	5.00	2.50	2.00	6.50	11.25	4.31
Dimethoate 0.05%	1.50	0.50	1.50	3.50	0.25	0.25	2.00	6.50	2.00
Untreated control	3.75	5.25	5.50	6.50	7.25	8.00	9.50	11.50	7.16

CD (0.05) Treatment : 0.32 DAS: Days after spraying
CD (0.05) Treatment × Interval : 0.92

Table 53. Effect of botanical and chemical insecticides on parasitoids in chilli

Treatments	Number per 10 sweeps								Pooled mean
	I spray				II spray				
	1 DAS	3 DAS	7 DAS	15 DAS	1 DAS	3 DAS	7 DAS	15 DAS	
NeemAzal T/S 4 ml/l	4.00	5.75	7.50	10.00	4.50	8.50	11.50	13.00	8.09
Neem oil + garlic 2%	5.00	6.00	7.75	10.00	5.50	8.00	11.50	12.50	8.28
Acetamiprid 0.002%	0.75	2.50	5.50	9.75	0.50	2.50	7.25	12.50	5.16
Imidacloprid 0.003%	1.25	3.50	7.00	10.00	1.50	3.00	8.00	12.25	5.81
Dimethoate 0.05%	0.50	0.50	3.75	8.50	0.25	0.00	3.50	8.50	3.19
Untreated control	6.50	7.50	8.25	9.50	10.75	11.75	12.50	13.25	10.00

CD (0.05) Treatment : 0.35 DAS: Days after spraying
CD (0.05) Treatment × Interval : 1.00

acetamiprid and imidacloprid 2.50 and 3.50 parasitoids, respectively were recorded. NeemAzal T/S (5.75) and neem oil + garlic emulsion (6.00) recorded significantly higher population than the insecticides and were on par. Though a build up of the population was noticed in all the treatments on the seventh day, it was significantly lower than that in the untreated plot. Dimethoate (3.75) recorded the lowest population and differed significantly from the other treatments. The population in acetamiprid and imidacloprid treated plots were 5.50 and 7.00 per 10 plants, respectively. NeemAzal T/S (7.50) and neem oil + garlic emulsion (7.75) were on par with the unsprayed plots (8.25). With the exception of dimethoate treatment (8.50), the population of parasitoids in all the other treatments was on par with that of control (9.50) on the fifteenth day. While the population in acetamiprid was 9.75 per 10 plants, it was 10.00 per 10 plants in imidacloprid, NeemAzal T/S and neem oil + garlic emulsion.

Second spray: Significant reduction was seen in the population of parasitoids one day after second spraying in all the treatments when compared to the control plot (7.27). Dimethoate (0.25) and acetamiprid (0.50) were equally toxic followed by imidacloprid (1.50). Comparatively NeemAzal T/S (4.50) and neem oil + garlic emulsion (5.50) recorded significantly higher population. No parasitoids were noticed in dimethoate sprayed plot on the third day. Acetamiprid (2.50) and imidacloprid (3.00) were on par in their effect. Neem oil + garlic emulsion (8.00) and NeemAzal T/S (8.50) recorded comparatively higher population than other treatments though significantly lower than that in the control plot (11.75). On the seventh day, neem oil + garlic emulsion (11.50) and NeemAzal T/S (11.50) which were on par recorded significantly higher population than the insecticides. Significant reduction in the population of parasitoids was seen in dimethoate (3.50) treated plots. Acetamiprid (7.25) and imidacloprid (8.00) too recorded low population and were on par in their effect. On the fifteenth day after the second spray, the parasitoids established in the different treatments and their population which ranged from 12.25 to 13.00

was on par with that of control (13.25). However, dimethoate (8.50) recorded significantly low population.

The data on the accruing effect of the two sprays indicated the toxicity of dimethoate (3.19) to parasitoids. Acetamiprid (5.16) and imidacloprid (5.81) too recorded low population and differed significantly in their effect. Plots receiving NeemAzal T/S (8.09) and neem oil + garlic emulsion (8.28) sprays had significantly higher population of parasitoids though it was lower than that in the control plot (10.00).

Notable toxicity of dimethoate was seen upto seven days while the neonicotinoids and botanicals affected the parasitoids adversely upto three days.

4.3.2.1.4 Effect on soil invertebrates

Earthworm

The results on the influence of various treatments on earthworm assessed as number per 30 cm^3 pit are presented in Table 54.

Significant reduction in the number of earthworms was noticed in dimethoate 0.05% (1.25) sprayed plots one day after the first spraying. Acetamiprid 0.002% (3.25) too recorded a significant reduction when compared to the unsprayed plots (4.50). Contrarily, imidacloprid 0.003% (3.75), NeemAzal T/S 4 ml/l (4.75) and neem oil + garlic emulsion 2% (4.50) were non toxic to the earthworms. On the third day, the population of the invertebrate was significantly low in dimethoate (0.50) and acetamiprid (2.75) sprayed plots. However, the population of earthworm in imidacloprid (3.50) NeemAzal T/S (4.50) and neem oil + garlic emulsion (4.50) treated plots were on par with untreated plot (4.75). On the seventh again dimethoate (2.50) recorded significantly low population of earthworms. All the other treatments were on par with control (4.75), the number of earthworms in the various treatments ranging from 4.50 to 4.75 per 30 cm^3. No significant difference was observed in the population of the earthworm in the different treatments on the fifteenth day after spraying, the number of earthworms ranging from 5.25 to 5.50 per 30 cm^3 as against 5.50 in the control plot.

After the second spray also, significant reduction in the population of earth worms was seen in dimethoate (1.00) treated plot one day after the spray. It was followed by acetamiprid (2.75) and imidacloprid (3.50) which were on par. The population of the worms in NeemAzal T/S (5.25) and neem oil + garlic emulsion (5.25) treatments did not differ significantly from that in the unsprayed plots (5.50). On the third too significantly low population of earthworms was noticed in dimethoate (2.25) and acetamiprid (3.75) sprayed plots. Imidacloprid (4.75), NeemAzal T/S (5.50) and neem oil + garlic emulsion (5.75) were on par with the unsprayed plot (5.75). On the seventh, fifteenth and twenty first days no significant difference was observed in the population in the treated and untreated plots. The population of earthworms on these days ranged from 6.00 to 6.25, 7.00 to 7.25 and 7.25 to 7.75 per 30 cm^3, respectively.

Considering the overall effect of the botanicals and insecticides, dimethoate (3.75) was the most toxic, recording the lowest population of earthworm. It was followed by acetamiprid (4.78) and imidacloprid (5.06) treatments which were on par. NeemAzal T/S (5.56) and neem oil + garlic emulsion 2% (5.56) did not affect the earthworm significantly when compared to the control plot (5.81).

Regarding the persistent toxicity, while the effect of dimethoate and acetamiprid persisted upto seven days, no persistent adverse effect was noticed for imidacloprid and the botanicals .

Soil coleopterans

The population of soil coleopterans observed at different intervals after spraying are given in Table 55. The population is expressed as number per kg soil.

Significant reduction in the population of soil coleopterans was noticed in dimethoate 0.05% (0.25), acetamiprid 0.002% (0.75) and

Table 54. Population of earthworm in chilli plots sprayed with botanicals and chemical insecticides

Treatments	Number per pit (30 cm^3)									Pooled mean
	I spray				II spray					
	1 DAS	3 DAS	7 DAS	15 DAS	1 DAS	3 DAS	7 DAS	15 DAS	21 DAS	
NeemAzal T/S 4 ml/l	4.75	4.50	4.75	5.50	5.25	5.50	6.00	7.25	7.75	5.56
Neem oil + garlic 2%	4.50	4.50	4.75	5.25	5.25	5.75	6.25	7.00	7.25	5.56
Acetamiprid 0.002%	3.25	2.75	4.50	5.25	2.75	3.75	6.00	7.00	7.75	4.78
Imidacloprid 0.003%	3.75	3.50	4.50	5.25	3.50	4.75	6.00	7.25	7.25	5.06
Dimethoate 0.05%	1.25	0.50	2.50	5.50	1.00	2.25	6.25	7.25	7.50	3.75
Untreated control	4.50	4.75	4.75	5.50	5.50	5.75	6.25	7.00	7.25	5.81

CD (0.05) Treatment : 0.38
CD (0.05) Treatment × Interval : 1.13

Table 55. Population of soil coleopterans in chilli plots sprayed with botanicals and chemical insecticides

Treatments	Number per kg soil									Pooled mean
	I spray				II spray					
	1 DAS	3 DAS	7 DAS	15 DAS	1 DAS	3 DAS	7 DAS	15 DAS	21 DAS	
NeemAzal T/S 4 ml/l	2.25	2.50	3.25	4.25	2.50	3.25	6.25	7.25	8.25	4.39
Neem oil + garlic 2%	2.25	2.25	3.50	4.50	2.75	3.75	6.00	7.75	8.25	4.56
Acetamiprid 0.002%	0.75	2.25	3.25	4.50	1.25	3.00	5.25	7.50	8.00	3.89
Imidacloprid 0.003%	1.00	2.00	3.75	4.25	1.50	3.25	5.50	7.25	7.75	3.98
Dimethoate 0.05%	0.25	0.75	2.50	4.25	0.50	0.25	2.50	7.25	8.50	2.64
Untreated control	2.25	2.50	3.50	4.50	5.50	5.75	6.25	7.50	8.00	5.25

CD (0.05) Treatment : 0.29
CD (0.05) Treatment × Interval : 0.87

DAS: Days after spraying

imidacloprid 0.003% (1.00) treated plots, one day after the first spray. No reduction in the population was seen in NeemAzal T/S 4 ml/l (2.25) and neem oil + garlic emulsion 2% (2.25) sprayed plots and they were on par with the untreated plot (2.25). On the third day, significant reduction of soil coleopterans was again observed in dimethoate (0.75) sprayed plots. All the other treatments viz., imidacloprid (2.00), acetamiprid (2.25), NeemAzal T/S (2.50) and neem oil + garlic emulsion (2.25) did not have any adverse effect on the soil coleopterans and were on par with control (2.50) in their effect. On the seventh day after spraying too dimethoate recorded significantly low population (2.50). Acetamiprid, imidacloprid, NeemAzal T/S and neem oil + garlic emulsion were on par with the untreated plot (3.50). There was no significant difference in the population of coleopterans in the treated and untreated plots on the fifteenth day, the population ranging from 4.25 to 4.50 in the different plots.

Significant decrease in the population of coleopterans was seen in all the treatments over control (5.50) one day after the second spray also. Among the treatments, the plot sprayed with dimethoate (0.50) recorded the lowest population and was on par with acetamiprid (1.25) which in turn was on par with imidacloprid (1.50). NeemAzal T/S (2.50) and neem oil + garlic emulsion (2.75) were on par. Three days after the second spray also, all the treatments significantly reduced the coleopteran population over control (5.75). With the exception of dimethoate (0.25) all the treatments were on par in their effect, the population of coleopterans in acetamiprid, imidacloprid, NeemAzal T/S and neem oil + garlic emulsion being 3.00, 3.25, 3.25 and 3.75 respectively. Dimethoate recorded the lowest population (2.50) and varied significantly from the other treatments on the seventh day. Acetamiprid (5.25) and imidacloprid (5.50) recorded significantly lower population than control. Neem oil + garlic emulsion (6.00) and NeemAzal T/S (6.25) were on par with control (6.25). No significant reduction was noted on the fifteenth and twenty first day after spraying, the population ranging from 7.25 to 7.50 and 7.75 to 8.50 on these days respectively.

The cumulative data indicated significant reduction in the population in the insecticide treated plots. The plots treated with dimethoate recorded significantly the lowest population of 2.64 as against 5.25 in control. Acetamiprid and imidacloprid recorded 3.89 and 3.98 respectively and were on par. NeemAzal T/S and neem oil + garlic emulsion recorded 4.39 and 4.56 coleopterans per kg soil respectively and were on par.

Appreciable toxic effect of dimethoate was observed only upto three days after treatment . Acetamiprid , imidacloprid, NeemAzal T/S and neem oil + garlic emulsion showed a drop in the population only on the first day after spraying.

Termite

The population of termites was significantly reduced in the insecticide treatments one day after first spraying and the treatments were on par (Table 56). While no population was observed in imidacloprid 0.003% treated plot, 0.22 termites per kg soil was recorded both in acetamiprid 0.002% and dimethoate 0.05% treated plots. No significant reduction in the termite population was seen in NeemAzal T/S 4 ml/l (1.23) and neem oil + garlic emulsion 2% (1.48) sprayed plots, the treatments being on par with control (1.48). On the third day, no termites were observed in acetamiprid, imidacloprid and dimethoate treated plots. NeemAzal T/S (1.96) and neem oil + garlic emulsion (2.24) did not affect the isopteran significantly and were on par with control (2.24). On the seventh day, again dimethoate (0.46), acetamiprid (0.93) and imidacloprid (0.72) treated plots recorded significantly lower population than that in the control plot and were on par in their effect. Neem oil + garlic emulsion (2.19) and NeemAzal T/S (2.24) did not reduce the population of termites significantly and were on par with control (2.24). The population of termites recorded in all the treatments was on par with untreated control (2.48) on the fifteenth day, the population ranging from 2.24 to 2.48 per kg soil.

A trend similar to that observed in the first spray was seen after the second spray too. No termites were observed in imidacloprid treated plot and it was on par with acetamiprid (0.22) and dimethoate (0.22) treatments in its effect one day after spray. Neem oil + garlic emulsion (2.74) and NeemAzal T/S (3.24) did not affect the termites significantly and were on par with control (3.49). On the third day too, no termites were observed in dimethoate and acetamiprid sprayed plots. Only negligible number of termites were seen in imidacloprid (0.46) treated plots. NeemAzal T/S (3.24) and neem oil + garlic emulsion (3.49) were on par with control (3.49). Again on the seventh day, imidacloprid (0.93), dimethoate (1.23), acetamiprid (1.48) were on par in their effect and differed significantly from the botanicals. No significant reduction was seen in NeemAzal T/S (4.49) and neem oil + garlic emulsion (4.24) sprayed plots, the treatments being on par with control (4.49). On the fifteenth and twenty first day, the isopteran population in the various treatments did not differ significantly from that in the untreated plot. The population in the treatments ranged from 4.49 to 4.74 and 4.74 to 5.24 respectively as against 4.74 and 4.98 in the control plot respectively.

An overall analysis of the data revealed that dimethoate, acetamiprid and imidacloprid were toxic to the termites and recorded significantly lower population than in the control plot (3.24), the population being 1.08, 1.11 and 1.26 per kg soil respectively. Neem oil + garlic emulsion (3.07) and NeemAzal T/S (3.05) were non toxic to the termites.

Regarding the persistent effect of the treatments, imidacloprid, dimethoate, and acetamiprid showed significant toxicity upto seven days. NeemAzal T/S and neem oil + garlic emulsion did not show any toxicity to the termite.

Ants

Significant reduction in the population of ants was observed in dimethoate 0.05% (2.50) and acetamiprid 0.002% (4.50) sprayed plots one day after spraying (Table 57). All the other treatments viz., imidacloprid 0.003% (6.50), neem oil + garlic emulsion 2% (7.00) and NeemAzal T/S 4 ml/l (8.25) did not affect the ant population significantly when compared to control (8.00). On the third day, the lowest population of ants was seen in

Table 56. Population of termites in chilli plots sprayed with botanicals and chemical insecticides

Treatments	Number per kg soil									Pooled mean
	I spray				II spray					
	1 DAS	3 DAS	7 DAS	15 DAS	1 DAS	3 DAS	7 DAS	15 DAS	21 DAS	
NeemAzal T/S 4 ml/l	1.23 (1.49)	1.96 (1.72)	2.24 (1.80)	2.24 (1.80)	3.24 (2.06)	3.24 (2.06)	4.49 (2.34)	4.49 (2.34)	5.24 (2.50)	3.05 (2.01)
Neem oil + garlic 2%	1.48 (1.57)	2.24 (1.80)	2.19 (1.79)	2.48 (1.87)	2.74 (1.93)	3.49 (2.12)	4.24 (2.29)	4.74 (2.40)	4.74 (2.40)	3.07 (2.02)
Acetamiprid 0.002%	0.22 (1.10)	0.00 (1.00)	0.93 (1.39)	2.48 (1.87)	0.22 (1.10)	0.00 (1.00)	1.48 (1.57)	4.74 (2.40)	5.22 (2.49)	1.26 (1.50)
Imidacloprid 0.003%	0.00 (1.00)	0.00 (1.00)	0.72 (1.31)	2.24 (1.80)	0.00 (1.00)	0.46 (1.21)	0.93 (1.39)	4.74 (2.40)	4.98 (2.45)	1.11 (1.45)
Dimethoate 0.05%	0.22 (1.10)	0.00 (1.00)	0.46 (1.21)	2.24 (1.80)	0.22 (1.10)	0.00 (1.00)	1.23 (1.49)	4.49 (2.34)	4.74 (2.40)	1.08 (1.44)
Untreated control	1.48 (1.57)	2.24 (1.80)	2.24 (1.80)	2.48 (1.87)	3.49 (2.12)	3.49 (2.12)	4.49 (2.34)	4.74 (2.40)	4.98 (2.45)	3.24 (2.06)

CD (0.05) Treatment : 0.07
CD (0.05) Treatment × Interval : 0.22

Figures in parentheses are √(x+1) transformed values
DAS: Days after spraying

Table 57. Population of ants in chilli plots sprayed with botanicals and chemical insecticides

Treatments	Number per kg soil									Pooled mean
	I spray				II spray					
	1 DAS	3 DAS	7 DAS	15 DAS	1 DAS	3 DAS	7 DAS	15 DAS	21 DAS	
NeemAzal T/S 4 ml/l	8.25	8.25	9.00	10.50	10.00	10.50	10.50	10.50	11.75	9.86
Neem oil + garlic 2%	7.00	8.75	9.75	10.25	9.00	9.75	11.00	11.00	11.25	9.75
Acetamiprid 0.002%	4.50	3.75	6.25	10.25	4.50	5.50	7.00	10.00	11.25	7.00
Imidacloprid 0.003%	6.50	5.00	8.00	10.50	6.50	7.00	9.50	11.00	11.50	8.22
Dimethoate 0.05%	2.50	1.00	5.50	10.00	2.75	1.75	5.75	10.75	11.25	5.64
Untreated control	8.00	8.50	9.50	10.50	10.50	11.00	10.75	10.50	11.75	10.11

CD (0.05) Treatment : 0.51
CD (0.05) Treatment X Interval : 1.53

DAS: Days after spraying

plots sprayed with dimethoate (1.00). It was followed by acetamiprid (3.75) and imidacloprid (5.00) which were on par. The population of ants in NeemAzal T/S (8.25) and neem oil + garlic emulsion (8.75) treated plots were on par with that in the control plot (8.50). On the seventh day after spraying also significant reduction of population was observed in dimethoate (5.50), acetamiprid (6.25) and imidacloprid (8.00) treated plots and the treatments varied among themselves. NeemAzal T/S (9.00) and neem oil + garlic emulsion (9.75) were on par with control (9.50). No reduction in the population of ants was observed on the fifteenth day, the population of the ants in the different treatments ranging from 10.00 to 10.50 as against 10.50 in the unsprayed plot.

Again one day after the second spray, significant reduction in the ant population was recorded in dimethoate (2.75) followed by acetamiprid (4.50) and imidacloprid (6.50) treatments. The population in NeemAzal (10.00) and neem oil + garlic emulsion (9.00) treated plots was on par with that in the control plot (10.50). On the third day again, significantly low population was seen in dimethoate (1.75), acetamiprid (5.50) and imidacloprid (7.00) sprayed plots. NeemAzal T/S (10.50) and neem oil + garlic emulsion (9.75) did not differ significantly from control (11.00). A similar trend was seen on the seventh day too. Dimethoate (5.75), acetamiprid (7.00) and imidacloprid (7.00) treated plots recorded significantly lower number of ants. NeemAzal T/S (10.50) and neem oil + garlic emulsion (11.00) did not differ significantly from control (10.75). On the fifteenth and twenty first days the ant population in all the treatments was on par with that in untreated control. The population ranged from 10.00 to 11.00 on the fifteenth day and 11.25 to 11.75 on the twenty first days.

An overall analysis of the data indicated that the insecticides viz., dimethoate, acetamiprid and imidacloprid were toxic to ants, recording significantly low population of 5.64, 7.00 and 8.22 per kg soil respectively as against 10.11 in control. The botanicals viz., NeemAzal T/S and neem oil

+ garlic emulsion did not affect the hymenopteran, recording 9.86 and 9.75 ant per kg soil and were on par with control.

Regarding the persistent toxic effect, dimethoate showed appreciable toxicity upto seven days after treatment, while imidacloprid and acetamiprid exhibited toxicity upto three days. NeemAzal T/S and neem oil + garlic emulsion did not show any toxicity to the ants.

Collembolans

The data on one day after first spraying revealed significant reduction of collembolan population in all the treatments over control (Table 58). The treatments significantly varied among themselves too. As against 14.99 collembolans per kg soil in the unsprayed plots, 3.49, 7.24, 8.49, 9.99 and 11.99 collembolans per kg soil were recorded in dimethoate 0.05%, acetamiprid 0.002%, imidacloprid 0.003%, NeemAzal T/S 4 ml/l and neem oil + garlic emulsion 2% respectively. On the third day, dimethoate (3.98) treated plots recorded the lowest population followed by acetamiprid (9.49) and imidacloprid (9.99) sprayed plots which were on par. NeemAzal T/S (12.99) differed significantly from neem oil + garlic emulsion (14.50) in its effect, which, was on par with control. On the seventh day after spraying also significantly lower population was observed in dimethoate (10.74), acetamiprid (13.99) and imidacloprid (12.70) treated plots and the treatments varied significantly among themselves. NeemAzal T/S (16.50) and neem oil + garlic emulsion (16.25) were on par with control (16.50). On the fifteenth day, the collembolans recorded in all the treatments were on par with that in the control plot, the number recorded ranging from 17.08 to 17.49.

A similar trend was observed following the second round of spraying. One day after the second spray, the population of collembola was significantly decreased in all the treatments when compared to control and the treatments differed significantly among themselves. While only 2.48 (dimethoate), 8.49 (acetamiprid), 9.99 (imidacloprid), 10.99 (NeemAzal

T/S) and 13.99 (neem oil + garlic emulsion) were recorded in the various treatments, 17.75 collembolans per kg soil was seen in the unsprayed plot. On the third day too, significantly low population was recorded in dimethoate (4.49), acetamiprid (10.50), imidacloprid (11.99), NeemAzal T/S (12.50) and neem oil + garlic emulsion (14.99) treated plots, contrary to that in the unsprayed plot (20.24). On the seventh day after the second spray, the lowest population of 14.99 collembolans per kg soil was recorded in the plot sprayed with dimethoate. Acetamiprid (20.49) and imidacloprid treated plots (20.48) were on par in the population recorded. NeemAzal T/S 4 (20.99) and neem oil + garlic emulsion (20.99) were on par with control (22.00). No significant difference was observed in the population of the collembolans in the treated and untreated plot on the fifteenth and twenty first day after second spraying, the population ranging from 22.99 to 23.24 and 23.74 to 24.50 on these days respectively.

Analysis of the cumulative data revealed significant difference in the population of collembola in all the treatments over untreated control. While the insecticides dimethoate, acetamiprid and imidacloprid recorded 9.89, 14.25 and 14.77 collembolans per kg soil, the botanicals, NeemAzal T/S and neem oil + garlic emulsion recorded 16.19 and 17.30 collembolans per kg soil as against 19.03 in the untreated plots.

Dimethoate persisted in its toxicity to collembola upto three days after spraying. Appreciable toxicity of acetamiprid and imidacloprid was seen only for one day. The botanicals did not show any persistent toxic effect.

Soil mite

One day after the first spray, dimethoate 0.05% recorded the lowest population of the mite (2.75) and differed significantly from the other treatments (Table 59). Acetamiprid 0.002% (5.00), NeemAzal T/S 4 ml/l (5.00) ,imidacloprid 0.003% (5.50) and neem oil + garlic emulsion 2% (5.50) were on par in their effect on the mite. Neem oil + garlic emulsion

Table 58. Population of collembola in chilli plots sprayed with botanicals and chemical insecticides

Treatments	Number per kg soil									Pooled mean
	I spray				II spray					
	1 DAS	3 DAS	7 DAS	15 DAS	1 DAS	3 DAS	7 DAS	15 DAS	21 DAS	
NeemAzal T/S 4 ml/l	9.99 (3.32)	12.99 (3.74)	16.50 (4.18)	17.25 (4.27)	10.99 (3.46)	12.50 (3.67)	20.99 (4.69)	23.24 (4.92)	24.50 (5.05)	16.19 (4.15)
Neem oil + garlic 2%	11.99 (3.60)	14.50 (3.94)	16.25 (4.15)	17.49 (4.30)	13.99 (3.87)	14.99 (4.00)	20.99 (4.69)	23.00 (4.90)	24.50 (5.05)	17.30 (4.28)
Acetamiprid 0.002%	7.24 (2.87)	9.49 (3.24)	13.99 (3.87)	17.08 (4.25)	8.49 (3.08)	10.50 (3.39)	20.49 (4.64)	23.00 (4.90)	23.74 (4.97)	14.25 (3.91)
Imidacloprid 0.003%	8.49 (3.08)	9.99 (3.32)	12.70 (3.70)	17.25 (4.27)	9.99 (3.32)	11.99 (3.60)	20.48 (4.63)	22.99 (4.89)	23.74 (4.97)	14.77 (3.97)
Dimethoate 0.05%	3.49 (2.12)	3.98 (2.23)	10.74 (3.43)	17.08 (4.25)	2.48 (1.87)	4.49 (2.34)	14.99 (4.00)	23.24 (4.92)	23.95 (4.99)	9.89 (3.30)
Untreated control	14.99 (4.00)	15.50 (4.06)	16.50 (4.18)	17.25 (4.27)	17.75 (4.33)	20.24 (4.61)	22.00 (4.80)	23.24 (4.92)	24.00 (5.00)	19.03 (4.48)

CD (0.05) Treatment : 0.05
CD (0.05) Treatment × Interval : 0.15

Figures in parentheses are $\sqrt{(x+1)}$ transformed values
DAS: Days after spraying

Table 59. Population of soil mite in chilli plots sprayed with botanicals and chemical insecticides

Treatments	Number per kg soil									Pooled mean
	I spray				II spray					
	1 DAS	3 DAS	7 DAS	15 DAS	1 DAS	3 DAS	7 DAS	15 DAS	21 DAS	
NeemAzal T/S 4 ml/l	5.00	7.25	9.00	10.50	9.75	11.50	12.50	14.25	15.75	10.61
Neem oil + garlic 2%	5.50	7.75	9.50	10.75	9.50	11.75	12.75	14.25	15.25	10.78
Acetamiprid 0.002%	5.00	6.75	9.25	10.50	9.75	11.00	12.25	14.25	15.00	10.36
Imidacloprid 0.003%	5.50	7.50	9.00	11.50	9.75	11.50	12.75	14.50	15.25	10.68
Dimethoate 0.05%	2.75	3.50	7.00	10.75	3.50	4.25	10.00	14.25	15.75	7.97
Untreated control	6.25	8.00	9.25	10.50	11.00	11.50	12.50	14.25	15.25	10.94

CD (0.05) Treatment : 0.39
CD (0.05) Treatment X Interval : 1.17

DAS: Days after spraying

and imidacloprid were also on par with control (6.25) in their effect. Three days after the first spraying, significant reduction of mite population was observed in dimethoate (3.50). Excepting acetamiprid (6.75), all the other treatments viz., imidacloprid (7.50), NeemAzal T/S (7.25) and neem oil + garlic emulsion (7.75) were on par with control (8.00) in their effect on the soil mite. Dimethoate (7.00) again reduced the population of mite significantly when observed on the seventh day. All the other treatments were on par with control (9.25), the population in the treatments ranging from 9.00 to 9.50. There was no significant reduction of population in all the treatments when observed on the fifteenth day, the population in the treatments ranging from 10.50 to 11.50 per kg soil as against 10.50 per kg soil in the control plot.

One day after the second spraying, significant reduction of population was observed in all the treatments over control (11.00). All the treatments were on par with each other, except dimethoate which, recorded the lowest population (3.50). The population of mite in the other treatments ranged from 9.50 to 9.75 per kg soil. On the third day, again dimethoate (4.25) recorded significantly low population. All the other treatments were on par with control (11.50), the population ranging from11.00 to 11.75 mites per kg soil. On the seventh day, the population of mite in dimethoate (10.00) treated plot alone differed significantly from that in the control plot (12.50). All the other treatments were on par with control, the population of mite in the treatments ranging from 12.25 to 12.75 per kg soil. No significant difference was observed in the population of the soil mites in the treated and untreated plots on the fifteenth and twenty first day after second spraying, the population ranging from 14.25 to 14.50 and 15.00 to 15.75 on these days respectively.

Considering the overall effect of the treatments on soil acari dimethoate was most toxic, recording the lowest population (7.97). Acetamiprid too recorded lower number of mites (10.36). Imidacloprid

(10.68), NeemAzal T/S (10.61) and neem oil + garlic emulsion (10.78) did not reduce the population of soil mite being at par with control (10.94).

With the exception of dimethoate whose toxicity persisted upto seven days, all the other treatments did not show any appreciable persistent toxicity.

4.3.2.1.5 Effect on soil microflora

The results of the studies conducted on the effect of various botanicals and synthetic insecticides on the soil microflora expressed as number of colonies x 10^4 cfu g^{-1} in the cases of fungi and actinomycetes and number of colonies x 10^6 cfu g^{-1} in the case of bacteria are presented in Tables 60 to 62.

Fungi

One day after the first spray, a significant reduction in the fungal population was noticed in dimethoate 0.05% (3.50) treated plot (Table 60). Acetamiprid 0.002% (7.75) and imidacloprid 0.003% (8.50) were on par in their effect on the soil fungi. NeemAzal T/S 4 ml/l (9.00) and neem oil + garlic emulsion 2% (9.00) recorded high population and were on par with control (9.00). On the third day after spraying too, a decline in the population of soil fungi was noted in dimethoate treated plots (4.25). Again acetamiprid (8.00) and imidacloprid (8.25) were on par in their effect. Application of NeemAzal T/S (9.50) and neem oil + garlic emulsion (9.50) did not affect the population of soil fungi adversely (10.25 in control plot). The data on seventh day after first spraying also indicated significant population reduction in dimethoate (8.25) treated plots. Acetamiprid (9.50), imidacloprid (9.25), NeemAzal T/S (10.25) and neem oil + garlic emulsion (10.00) were on par with control (10.25). No reduction in the fungal population was recorded in the treatments on the fifteenth day.

Significant reduction in the fungal population was noted in dimethoate (3.75) one day after the second spray too. Acetamiprid (6.25) and imidacloprid (7.25) were on par in their effect. While neem oil + garlic emulsion recorded 7.75 x 10^4 cfu g^{-1}, NeemAzal T/S (8.75) did not differ significantly from the unsprayed plots (9.00). On the third day, with the exception of dimethoate (4.50) which recorded significantly low population of the fungi, the other treatments did not vary in their effect from that of control (8.25). On the seventh, fifteenth and twenty first days no significant reduction of fungal population was observed in all the treatments. The population ranged from 8.75 to 9.50 x 10^4 cfu g^{-1}, 10.00 to 11.25 x 10^4 cfu g^{-1} and 10.75 to 11.25 x 10^4 cfu g^{-1} on these days, respectively.

The pooled data indicated toxic effect of dimethoate (7.19) to soil fungi. Acetamiprid (9.00) and imidacloprid (9.11) were less toxic. NeemAzal T/S and neem oil + garlic emulsion were safe to fungi as evidenced by the high fungal population of 9.69 and 9.58 x 10^4 cfu g^{-1} recorded in the treaments as against 9.69 x 10^4 cfu g^{-1} in the control plot.

Dimethoate significantly inhibited soil fungi upto three days while all the other treatments did not show any appreciable inhibition of the fungal population.

Soil bacteria

Among the treatments, the plot treated with dimethoate 0.05% recorded significantly the lowest population of bacteria (7.25) one day after the first spraying (Table 61). Imidacloprid 0.003% (12.00) too recorded significantly low population of the bacteria. Population of soil bacteria in acetamiprid 0.002% (14.00), NeemAzal T/S 4 ml/l (14.25) and neem oil + garlic emulsion 2% (14.50) treated plots was on par with that in the unsprayed plot (14.75). Excepting the plot treated with dimethoate (7.75), no significant reduction in the soil bacterial population was seen in acetamiprid (15.25), imidacloprid (15.25), NeemAzal T/S (14.75) and neem oil + garlic emulsion (15.50) treated plots on the third day when compared to the untreated plot (15.50). The bacterial populations in all treatments were on par with untreated control on seven and 15 days after spraying. The population of bacteria in the treatments ranged from 16.00 to 16.75 x 10^4 cfu

g^{-1} and 17.50 to 18.25 x 10^4 cfu g^{-1} as against 16.25 and 17.75 x 10^4 cfu g^{-1} respectively in the control plot.

Similarly one day after second spraying, dimethoate (13.25) recorded significantly low population of soil bacteria followed by acetamiprid (16.50) which was on par with imidacloprid (17.50). The bacterial population in NeemAzal T/S (18.00) and neem oil + garlic emulsion (18.00) did not differ from that in the control plot (18.25). On the third day after spraying too, dimethoate (11.50) recorded low population of soil bacteria. However, acetamiprid (18.00), imidacloprid (18.25), NeemAzal T/S (17.75) and neem oil + garlic emulsion (18.25) were on par with control (18.50). From the seventh day onwards, no significant reduction was observed in the population of bacteria in the various treatments. While the population ranged from 18.75 to 20.00 x 10^4 cfu g^{-1} on the seventh day, it was 20.00 to 20.75 x 10^4 cfu g^{-1} and 20.50 to 21.25 x 10^4 cfu g^{-1} respectively on the fifteenth and twenty first days.

The cumulative effect of the treatments indicated that dimethoate (14.83) was toxic to the bacteria, All the other treatments viz., acetamiprid, imidacloprid, NeemAzal T/S and neem oil + garlic emulsion did not hamper the bacterial population, the population recorded being 17.58, 17.55, 17.94 and 18.03 x 10^4 cfu g^{-1} respectively as against 17.89 x 10^4 cfu g^{-1} in untreated control.

With the exception of dimethoate which significantly inhibited soil bacteria upto three days, all the other treatments did not show any appreciable inhibition of the bacterial population.

Actinomycetes

The data on one, three, seven and fifteen days after first spraying showed that with the exception of the significantly low population of 1.75 and 2.00 x 10^4 cfu g^{-1} recorded one and three days after spraying in dimethoate treatment , no significant reduction in the actinomycete population was observed in the various treatments (Table 62). The

Table 60. Fungal population in chilli plots sprayed with botanicals and chemical insecticides

Treatments	Population of soil fungi (x 10^4 cfu g^{-1} soil)									Pooled mean
	I spray				II spray					
	1 DAS	3 DAS	7 DAS	15 DAS	1 DAS	3 DAS	7 DAS	15 DAS	21 DAS	
NeemAzal T/S 4 ml/l	9.00	9.50	10.25	11.25	8.75	8.00	9.25	10.50	10.75	9.69
Neem oil + garlic 2%	9.00	9.50	10.00	11.25	7.75	8.00	9.00	11.25	10.75	9.58
Acetamiprid 0.002%	7.75	8.00	9.50	11.50	6.25	7.25	9.50	10.00	11.25	9.00
Imidacloprid 0.003%	8.50	8.25	9.25	10.75	7.25	7.50	9.00	10.50	11.00	9.11
Dimethoate 0.05%	3.50	4.25	8.25	10.75	3.75	4.50	8.75	10.00	11.00	7.19
Untreated control	9.00	9.50	10.25	11.00	9.00	8.25	8.75	10.50	11.00	9.69

CD (0.05) Treatment : 0.35 CD (0.05) Treatment × Interval : 1.07 DAS: Days after spraying

Table 61. Bacterial population in chilli plots sprayed with botanicals and chemical insecticides

Treatments	Population of soil bacteria (x 10^6 cfu g^{-1} soil)									Pooled mean
	I spray				II spray					
	1 DAS	3 DAS	7 DAS	15 DAS	1 DAS	3 DAS	7 DAS	15 DAS	21 DAS	
NeemAzal T/S 4 ml/l	14.25	14.75	16.75	18.00	18.00	17.75	20.00	20.75	21.25	17.94
Neem oil + garlic 2%	14.50	15.50	16.25	18.25	18.00	18.25	19.50	20.75	21.25	18.03
Acetamiprid 0.002%	14.00	15.25	16.50	17.50	16.50	18.00	19.75	20.00	21.25	17.58
Imidacloprid 0.003%	12.00	15.25	16.50	18.00	17.50	18.25	19.25	20.50	21.00	17.55
Dimethoate 0.05%	7.25	7.75	16.00	18.00	13.25	11.50	18.75	20.25	20.75	14.83
Untreated control	14.75	15.50	16.25	17.75	18.25	18.50	19.50	20.00	20.50	17.89

CD (0.05) Treatment : 0.34 CD (0.05) Treatment × Interval : 1.04 DAS: Days after spraying

Table 62. Actinomycetes population in chilli plots sprayed with botanicals and chemical insecticides

Treatments	Population of soil actinomycetes (x 10^4 cfu g^{-1} soil)									Pooled mean
	I spray				II spray					
	1 DAS	3 DAS	7 DAS	15 DAS	1 DAS	3 DAS	7 DAS	15 DAS	21 DAS	
NeemAzal T/S 4 ml/l	3.50	3.75	3.25	3.75	3.75	3.50	2.50	3.75	4.00	3.53
Neem oil + garlic 2%	3.25	3.50	3.50	3.75	3.25	3.50	2.50	3.50	4.50	3.47
Acetamiprid 0.002%	3.25	3.50	3.25	3.50	3.25	3.25	3.00	4.00	4.25	3.47
Imidacloprid 0.003%	3.25	3.50	3.50	4.25	3.25	3.75	3.00	4.00	4.75	3.69
Dimethoate 0.05%	1.75	2.00	3.25	4.00	2.50	1.75	2.75	3.75	4.50	2.92
Untreated control	3.50	3.50	3.25	4.25	3.75	3.50	2.75	3.75	4.25	3.67

CD (0.05) Treatment : 0.28 CD (0.05) Treatment × Interval : 0.84 DAS: Days after spraying population of actinomycete ranged from 3.25 to 3.50 x 10^4 cfu g^{-1}, 3.50 to 3.75 x 10^4 cfu g^{-1}, 3.25 to 3.50 x 10^4 cfu g^{-1} and 3.75 to 4.25 x 10^4 cfu g^{-1} on these days respectively.

One and three days after the second spraying, significantly low population was recorded in dimethoate treated plot (2.50 and 1.75 respectively). All the other treatments were on par with control (3.75 and 3.50), the population in the treatments ranging from 3.25 to 3.75 x 10^4 cfu g^{-1} on both the days. From the seventh day onwards, no significant reduction was noted in the population of actinomycete in all the treatments. The population of actinomycete ranged from, 2.50 to 3.00 x 10^4 cfu g^{-1}, 3.50 to 4.00 x 10^4 cfu g^{-1} and 4.00 to 4.75 x 10^4 cfu g^{-1} on 7, 15 and 21 days after spraying respectively.

An overall analysis of the data revealed that dimethoate (2.92) was significantly toxic to the soil actinomycetes. Acetamiprid (3.47), imidacloprid (3.69), NeemAzal T/S (3.53), neem oil + garlic emulsion (3.47) had no significant effect on the soil micro flora being at par with control (3.67).

With the exception of dimethoate which showed toxicity to soil actinomycete upto three days, all the other treatments did not show any appreciable inhibition of the actinomycete population.

4.3.2.1.6 Yield and Benefit- Cost Ratio

Compared to the untreated plot, significantly higher yield was obtained from all the treated plots (Table 63). The highest yield was recored from the plot which received dimethoate 0.05% (16.44 kg) spray and it was on par with the yield obtained from acetamiprid 0.002% (15.75 kg) and imidacloprid 0.003% (15.47 kg) treated plots. NeemAzal T/S 4ml/l and neem oil + garlic emulsion 2% recorde 13.89 kg and 13.54 kg of chilli per plot.

The data on benefit-cost revealed that dimethoate gave Rs.1.58 in return for every one rupee invested as against control which gave only one rupee. The next best return was from acetamiprid which gave Rs.1.51.

Benefit: cost ratio of imidacloprid, NeemAzal T/S and neem oil + garlic emulsion were 1.49, 1.33 and 1.26 respectively.

4.3.2.1.7 Residues of insecticides in chilli fruit

Residues of acetamiprid (0.083 ppm), imidacloprid (0.087 ppm) and dimethoate (1.701 ppm) were detected in chilli fruit five days after spraying (Table 64). On the tenth day after spraying, 0.078 and 0.135 ppm residues of acetamiprid, and dimethoate respectively were detected in the fruit samples. Imidacloprid was below detectable level (BDL). Residues of all the three insecticides were below detectable level when estimated fifteen days after spraying.

4.3.2.2. Winged bean

The results of the field trial on winged bean are presented in Tables 65 to 86.

4.3.2.2.1 Effect on *A. craccivora*

The results on the effect of botanicals and insecticides on *A. craccivora* when applied in the field are presented in Table 65. The population of the aphid is expressed as number of aphids per 15 cm shoot

First spray: Plots treated with acetamiprid 0.002% (5.18) recorded the lowest population of the aphid, one day after the first spray and the nicotinoid differed significantly from all other treatments in its toxicity. Low population of the aphid was also recorded in the plots sprayed with dimethoate 0.05% (7.33) and imidacloprid 0.003% (8.48). NeemAzal T/S 4 ml/l (11.73) and neem oil + garlic emulsion 2% (13.64) too reduced the population of *A. craccivora* significantly when compared to the unsprayed plots (24.18). On the third day, the population of the aphid was significantly low in acetamiprid (2.51), dimethoate (2.78) and imidacloprid (3.17) treated plots, the insecticides being at par. The population of the aphid in neem oil + garlic emulsion (6.84) and NeemAzal T/S (8.38) treated plots was significantly lower than that in the control plot (24.84). All the treatments

Table 63. Effect of botanicals and synthetic insecticides on yield of chilli and the resultant BC ratio

Treatments	Mean fruit yield (kg / 20 m^2 plot)	Yield of healthy fruits (kg ha^{-1})	Cost of cultivation (Rs ha^{-1})	Expense for insecticides (Rs ha^{-1})	Total expense (Rs ha^{-1})	Gross income (Rs ha^{-1})	Net income (Rs ha^{-1})	B:C ratio
NeemAzal T/S 4 ml/l	13.89	6948	61415	910	62325	83376	21051	1.33
Neem oil + garlic 2%	13.54	6770	61415	2800	64215	81240	17025	1.26
Acetamiprid 0.002%	15.75	7875	61415	782	62197	94500	32303	1.51
Imidacloprid 0.003%	15.47	7735	61415	744	62159	92820	30661	1.49
Dimethoate 0.05%	16.44	8220	61415	972	62387	98640	36253	1.58
Untreated control	10.28	5140	61415	0	61415	61680	265	1.00
CD (0.05%)	1.72							

Table 64.Harvest time residues of insecticide in chilli

Treatments	Mean residues (ppm) at intervals (days)		
	5	10	15
Acetamiprid 0.002%	0.083	0.078	BDL
Imidacloprid 0.003%	0.087	BDL	BDL
Dimethoate 0.05%	1.701	0.135	BDL

BDL-Below detectable level

Table 65. Effect of botanicals and chemical insecticides on *Aphis craccivora* in winged bean

Treatments	Number per 15 cm shoot								Pooled Mean
	I spray				II spray				
	1 DAS	3 DAS	7 DAS	15 DAS	1 DAS	3 DAS	7 DAS	15 DAS	
NeemAzal T/S 4 ml/l	11.73 (3.57)	8.38 (3.06)	12.59 (3.69)	25.64 (5.16)	11.84 (3.58)	9.09 (3.18)	22.45 (4.84)	30.04 (5.57)	15.66 (4.08)
Neem oil + garlic 2%	13.64 (3.83)	6.84 (2.80)	15.34 (4.04)	26.11 (5.21)	16.69 (4.21)	12.05 (3.61)	21.64 (4.76)	34.08 (5.92)	17.46 (4.30)
Acetamiprid 0.002%	5.18 (2.49)	2.51 (1.87)	6.00 (2.65)	19.79 (4.56)	6.89 (2.81)	0.89 (1.37)	7.89 (2.98)	26.18 (5.21)	7.96 (2.99)
Imidacloprid 0.003%	8.48 (3.08)	3.17 (2.04)	7.00 (2.83)	23.24 (4.92)	5.95 (2.64)	2.13 (1.77)	8.99 (3.16)	27.64 (5.35)	9.39 (3.22)
Dimethoate 0.05%	7.33 (2.89)	2.78 (1.94)	9.00 (3.16)	21.94 (4.79)	6.93 (2.82)	1.96 (1.72)	12.34 (3.65)	24.20 (5.02)	9.55 (3.25)
Untreated control	24.18 (5.02)	24.84 (5.08)	27.75 (5.36)	29.87 (5.56)	30.29 (5.59)	32.79 (5.81)	35.17 (6.01)	35.21 (6.02)	29.88 (5.56)

CD (0.05) Treatment : 0.08 Figures in parentheses are $\sqrt{(x+1)}$ transformed values

CD (0.05) Treatment × Interval: 0.23 DAS-Days after spraying recorded significantly lower population over untreated plots (27.75) on the seventh day after spraying. Acetamiprid (6.00) and imidacloprid (7.00) were on par. Dimethoate recorded 9.00 aphids per 15 cm shoot. The population of the pest was 12.59 and 15.34 per 15 cm shoot in plots sprayed with NeemAzal T/S and neem oil + garlic emulsion, respectively. On the fifteenth day, acetamiprid (19.79) and dimethoate (21.94) were on par in their effect, recording significantly low population of the pest and it was followed by imidacloprid (23.24). NeemAzal T/S (25.64) and neem oil + garlic emulsion (26.11) were on par in their effect and differed significantly from control (29.87).

Second spray: Significant reduction in the population of the aphid was recorded in imidacloprid (5.95), acetamiprid (6.89), and dimethoate (6.93) sprayed plots when observed one day after the spray and the treatments were on par. Compared to the unsprayed plot (30.29), incidence of the aphid was significantly lower in plots sprayed with NeemAzal T/S (11.84) and neem oil + garlic emulsion (16.69). On the third day too, significant reduction in the aphid population was noticed in all the treatments. The lowest population of the aphid was recorded in acetamiprid (0.89) treated plots. It was followed by dimethoate (1.96) and imidacloprid (2.13) treatments and both the insecticides were on par. Though, significantly low aphid population was observed in the plots sprayed with NeemAzal T/S (9.09) and neem oil + garlic emulsion (12.05) when compared to the untreated plot (32.79), both the botanicals differed significantly in their effect. On the seventh day, all the treatments reduced the aphid population significantly. Acetamiprid (7.89) and imidacloprid (8.99) recorded low population and were on par. The insecticides were followed by dimethoate (12.34). Neem oil + garlic emulsion (21.64) and NeemAzal T/S (22.45) too recorded low population of the aphid and differed significantly between themselves and from the untreated plot (35.17). On the fifteenth day also, significantly lower population of the aphid was observed in dimethoate (24.20), acetamiprid (26.18) and imidacloprid (27.64) treated plots. While the population of the pest recorded in NeemAzal T/S (30.04) treated plot was on par with that in imidacloprid sprayed plot, the population in neem oil + garlic emulsion (34.08) treated plots was on par with that in control plot (35.21).

Pooled analysis of the data indicated that acetamiprid (7.96) was superior in reducing the aphid population. It was followed by imidacloprid (9.39) and dimethoate (9.55). The botanicals, NeemAzal T/S (15.66) and neem oil + garlic emulsion (17.46) too reduced the population of the aphid significantly when compared to control (29.88).

Considering the persistent toxicity of the botanicals and synthetic insecticides, appreciably low population of the aphid was seen in acetamiprid, dimethoate and imidacloprid treated plots upto seven days after spraying. Efficacy of the botanicals, Neemazal T/S and neem oil + garlic emulsion persisted upto three days.

4.3.2.2.2. Effect on other pests

During the cropping season ten sap feeders, five borers, ten leaf feeders and one flower feeder were recorded from the crop (Table 66). The sap feeders included the spiraling white fly (*A. dispersus*), white fly (*B. tabaci*), soft scale (*Ceroplastes* sp.), lab lab bug (*C. cribraria*), striped mealy bug (*F. virgata*), green stink bug (*N. viridula*), blacked wing bug (*P. moesta*), pod bug (*R. pedestris*), cow bug (*Tricentrus bicolor)* and red spider mite (*Tetranychus* sp.).The borers noted were the gram pod borer (*H. armigera*) blue butterfly (*L. boeticus*), spotted pod borer (*M. vitrata*), stem griddler (*Oberea* sp.) and stem fly (*O. phaseoli*).Sphingid caterpillar (*A. styx* and *H. convolvuli*), Green leaf caterpillar (*A. irrorata*), Hairy caterpillar (*D. oblicua* and *P. scintillans*), Serpentine leaf miner (*L. trifolii*), Leaf cutter bee (*M. anthracina*), Ash weevil (*Myllocerus* spp.), Leaf roller (*N. vulgalis*), Wingless grasshopper (*O. simulans*) were the leaf feaders observed in the field (Plate 27, 28 and 29). Among the pests, *A. disperses, R. pedestris, M.vitrata* were observed to cause perceptible damage to the crop. The results

Table 66. Pests infesting *Psophocarpus tetragonolobus*

Sl.No.	Species	Common name	Family	Order	Site of damage	Pest status
	A. Sap feeders					
1	*Aphis craccivora* Koch	Cowpea aphid	Aphididae	Hemiptera	Shoots, buds, pods & leaves	Major
2	*Aphis fabae* Scopoli	Bean aphid	Aphididae	Hemiptera	Young pods	Minor
3	*Aphis gossypii* Glover	Cotton aphid	Aphididae	Hemiptera	Older leaves	Minor
4	*Aphis spiraecola* Patch	Spirea aphid	Aphididae	Hemiptera	Young pods & leaves	Minor
5	*Aleurodicus dispersus* Russell	Spiralling whitefly	Aleyrodidae	Hemiptera	Leaves	Major
6	*Bemisia tabaci* (Gennadius)	whitefly	Aleyrodidae	Hemiptera	Leaves	Minor
7	*Ceroplastes* spp.	Soft scale	Coccidae	Hemiptera	Older leaves	Minor
8	*Coptosoma cribraria* F.	Lab Lab bug	Corimelaenidae	Hemiptera	Shoots & leaves	Minor
9	*Ferrisia virgata* (Ckll.)	Striped mealybug	Pseudococcidae	Hemiptera	Older leaves	Minor
10	*Nezara viridula* Linn.	Green stink bug	Petatomidae	Hemiptera	Shoots, buds, pods & leaves	Minor
11	*Proutista moesta* (Westwood)	Black winged bug	Derbidae	Hemiptera	Shoots & leaves	Minor
12	*Riptortus pedestris* F.	Pod bug	Coreidae	Hemiptera	Developing pods	Major
13	*Tricentrus bicolor* Dist.	Cow bug	Membracidae	Hemiptera	Shoots & leaves	Minor
14	*Tetranychus* sp.	Red spider mite	Tetranychidae	Acarina	Leaves	Minor
	B. Borers					
15	*Heliothis armigera* (Hb.)	Gram pod borer	Noctuidae	Lepidoptera	Young pods & leaves	Minor
16	*Lampides boeticus* L.	Blue butterfly	Lycaenidae	Lepidoptera	Young pods	Minor
17	*Maruca vitrata* (Fab.)	Spotted pod borer	Pyraustidae	Lepidoptera	Flower buds & pods	Major
18	*Oberea* sp.	Stem griddler	Cerambycidae	Coleoptera	Stem	Minor
19	*Ophiomyia phaseoli* Coq.	Stem fly	Agromyzidae	Diptera	Stem	Minor
	C. Leaf feeders					
20	*Acherontia styx* Westw.	Sphingid caterpillar	Sphingidae	Lepidoptera	Leaves	Minor
21	*Anticarsia irrorata* F.	Green leaf caterpillar	Noctuidae	Lepidoptera	Leaves	Minor
22	*Diacrisia obliqua* Wlk.	Hairy caterpillar	Arctiidae	Lepidoptera	Leaves	Minor
23	*Herse convolvuli* Linn.	Sphingid caterpillar	Sphingidae	Lepidoptera	Leaves	Minor
24	*Liriomyza trifolii* (Burgess)	Serpentine leaf miner	Agromyzidae	Diptera	Leaves	Minor
25	*Megachile anthracina* S.	Leaf cutter bee	Megachilidae	Hymenoptera	Leaves	Minor
26	*Myllocerus* spp.	Ash weevil	Curculionidae	Coleoptera	Leaves	Minor
27	*Nacoleia vulgalis* Guen.	Leaf roller	Pyralidae	Lepidoptera	Leaves	Minor
28	*Porthesia scintillans* W.	Hairy caterpillar	Lymantriidae	Lepidoptera	Leaves & flower	Minor
29	*Orthacris simulans* B.	Wingless grasshopper	Acrididae	Orthoptera	Leaves	Minor
	D. Flower feeder					
30	*Mylabris pustulata* Thunberg	Blister beetle	Meloidae	Coleoptera	Flower buds & flower	Minor

Aphis craccivora

Aphis fabae

Aphis gossypii

Aphis spiraecola

Aleurodicus dispersus

Coptosoma cribraria

Plate 27. Sucking pests of winged bean

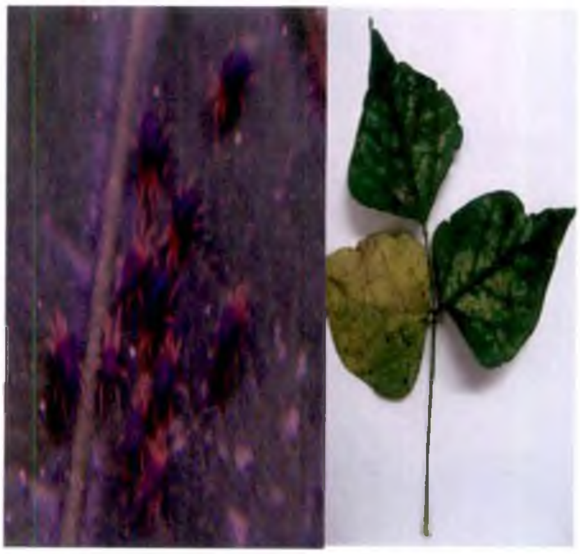
Ferrisia virgata

Nezara viridula

Riptortus pedestris

Proutista moesta

Tricentrus bicolor



Tetranychus sp.

Plate 27 (continued). Sucking pests of winged bean

Fruit damaged by *Lampides boeticus*

Fruit damaged by *Maruca vitrata*

Oberea sp.

Stem damaged by *Oberea* sp.

Plate 28. Borers of winged bean

Acherontia styx

Herse convolvuli

Leaf damaged by *Megachile anthracina*

Nacoleia vulgalis

Leaf damaged by *Porthesia scintillans*

Leaf damaged by *Orthacris simulans*

Plate 29. Leaf feeders of winged bean and their damage

on the effect of the different insecticides on the pests expressed as number per plant are presented in Tables 67 to 83.

Spiralling white fly (*A. dispersus*)

First spray: Significantly low population of whitefies was recorded in the plots sprayed with acetamiprid 0.002% (1.93) and imidacloprid 0.003% (2.23), both the treatments being on par, one day after the spray (Table 67). The population of the pest in plots sprayed with dimethoate 0.05 %(2.73) was on par with that in imidacloprid 0.003% (2.23) and NeemAzal T/S 4ml/l (2.88) treatments. Significant reduction in the pest population was also noted in the plots sprayed with neem oil + garlic emulsion 2% (3.75) when compared to the unsprayed plot (8.03). On the third day, acetamiprid (0.15) and imidacloprid (0.30) again decreased the population of the pest significantly and was superior to all other treatments. The population of the pest in plots treated with dimethoate (1.13) too was significantly low and it was on par with NeemAzal T/S (1.45). Neem oil + garlic emulsion (2.58) treated plots too recorded low population of whiteflies in comparison with the unsprayed plot (8.18). On the seventh day, significant reduction in the number of the aleyrodid was seen in all the treated plots when compared to the unsprayed plot (8.20). Low population was observed in acetamiprid (1.60) and imidacloprid (2.43) even though the treatments differed significantly. Dimethoate (3.85) again was on par with NeemAzal T/S (3.95) which in turn was at par with neem oil + garlic emulsion (4.23). While 9.05 white flies were recorded in the unsprayed plots on the fifteenth day after spraying, significantly lower population of the pest was seen in acetamiprid (4.13) followed by imidacloprid (5.03) and neem oil + garlic emulsion (5.90). Dimethoate (6.63) treated plots were on par with NeemAzal T/S (6.60).

Significant decline in the population of the pest was noticed in acetamiprid (1.50), imidacloprid (1.98) and NeemAzal T/S (1.80) treated plots when observed one day after the second spray and the treatments were on par. This was followed by neem oil + garlic emulsion (2.75) and dimethoate ([illegible].80) which recorded significantly lower numbers of whiteflies when com[illegible]red to the untreated plot (9.30). Very low population of the pest was recorded in all the treated plots on the third day after spraying, compared to 9.85 white flies per plant seen in the control plots. With the exception of acetamiprid (0.05), all the other treatments viz., neem oil + garlic emulsion (0.90), imidacloprid (0.10), dimethoate (1.00) and NeemAzal T/S (1.00) were on par. On the seventh day, the population of the pest was negligible in acetamiprid (0.20) and imidacloprid (0.60) sprayed plots as against the high population in the untreated plots (10.78). Plots sprayed with dimethoate (2.78) too recorded significantly low population. This was followed by neem oil + garlic emulsion (4.05) and NeemAzal T/S (5.08). On the fifteenth day, acetamiprid (3.23) recorded the lowest population and was superior to all other treatments. It was followed by imidacloprid (4.33), NeemAzal T/S (7.10) and dimethoate (7.35) treatments. Though, comparatively higher population of the pest was noted in neem oil + garlic emulsion (9.53) it was superior to control (12.10).

Analysis of the cumulative data revealed that acetamiprid significantly reduced the population of white flies (1.60) followed by imidacloprid (2.12). Dimethoate (3.53) and NeemAzal T/S (3.73) were on par in their effect. Neem oil + garlic emulsion (4.21) too reduced the population of the pest significantly when compared to the untreated plot (9.43).

Regarding the persistent toxicity of the different botanicals and synthetic insecticides, the neonicotinods persisted in their effect upto 15 days after spraying. Appreciable effect of dimethoate was observed upto seven days. The pest regulatory effect of NeemAzal T/S and neem oil garlic emulsion too persisted upto seven days after spraying.

Table 67. Effect of botanicals and chemical insecticides on *Aleurodicus dispersus* in winged bean

Treatments	Number per plant								Pooled mean
	I spray				II spray				
	1 DAS	3 DAS	7 DAS	15 DAS	1 DAS	3 DAS	7 DAS	15 DAS	
NeemAzal T/S 4 ml/l	2.88	1.45	3.95	6.60	1.80	1.00	5.08	7.10	3.73
Neem oil + garlic 2%	3.75	2.58	4.23	5.90	2.75	0.90	4.05	9.53	4.21
Acetamiprid 0.002%	1.93	0.15	1.60	4.13	1.50	0.05	0.20	3.23	1.60
Imidacloprid 0.003%	2.23	0.30	2.43	5.03	1.98	0.10	0.60	4.33	2.12
Dimethoate 0.05%	2.73	1.13	3.85	6.63	2.80	1.00	2.78	7.35	3.53
Untreated control	8.03	8.18	8.20	9.05	9.30	9.85	10.78	12.10	9.43

CD (0.05) Treatment : 0.22 DAS-Days after spraying

CD (0.05) Treatment × Interval : 0.62

The efficiency of the insecticides, acetamiprid and imidacloprid persisted upto seven days after treatment while that of dimethoate, NeemAzal and neem oil garlic emulsion only upto three days after treatment.

Pod borer (*M. vitrata*)

Compared to the unsprayed plot (10.95), significant decrease in the number of the pod borer was observed in dimethoate 0.05% (1.35), acetamiprid 0.002% (1.40) and imidacloprid 0.003% (1.55) treated plots one day after spraying and the treatments were on par (Table 69). Similarly, NeemAzal T/S 4ml/l (2.60) and neem oil + garlic emulsion 2% (3.15) too reduced the pest incidence and were on par in their effect. On the third day after spraying too, significant reduction in the number of the pod borers was recorded in dimethoate (1.80), imidacloprid (2.10) and acetamiprid (2.70) treated plots. NeemAzal T/S (3.15) and neem oil + garlic emulsion (3.20) also reduced the pest population significantly when compared to the unsprayed plots (11.05). Again, on the seventh day after spraying, acetamiprid (5.75) dimethoate (6.20) and imidacloprid (6.30) sprayed plots showed significant reduction in the population of the pest and were on par in their effect. This was followed by NeemAzal T/S (7.15) and neem oil + garlic emulsion (8.10), which also recorded significantly low population of the borer when compared to the control plot (11.70). On the fifteenth day, significantly low population of the pod borer was seen in dimethoate (7.90) sprayed plots followed by imidacloprid (8.95) and acetamiprid (9.25) treated plots. The number of borers recorded in neem oil + garlic emulsion and NeemAzal T/S treatments were10.50 and 11.15, respectively as against 12.95 in the control plot.

Scrutiny of the cumulative data indicated that dimethoate (4.31) imidacloprid (4.73) and acetamiprid (4.78) were equally effective against *M. vitrata*. NeemAzal T/S (6.01) and neem oil + garlic emulsion (6.24) too decreased the population of the pest significantly when compared to the unsprayed plot (11.66).

Table 68. Effect of botanicals and chemical insecticides on *Riptortus pedestris* in winged bean

Treatments	Number per plant				Pooled mean
	II spray				
	1 DAS	3 DAS	7 DAS	15 DAS	
NeemAzal T/S 4 ml/l	0.55	0.18	1.38	2.58	1.17
Neem oil + garlic 2%	0.58	0.28	1.80	1.85	1.13
Acetamiprid 0.002%	0.38	0.10	1.05	1.48	0.75
Imidacloprid 0.003%	0.60	0.25	0.95	1.63	0.86
Dimethoate 0.05%	0.60	0.55	1.55	1.73	1.11
Untreated control	1.95	2.30	2.58	2.70	2.38

CD (0.05) Treatment : 0.15
CD (0.05) Treatment × Interval : 0.30

DAS-Days after spraying

Table 69. Effect of botanicals and chemical insecticides on *Maruca vitrata* in winged bean

Treatments	Number per plant				Pooled mean
	II spray				
	1 DAS	3 DAS	7 DAS	15 DAS	
NeemAzal T/S 4 ml/l	2.60	3.15	7.15	11.15	6.01
Neem oil + garlic 2%	3.15	3.20	8.10	10.50	6.24
Acetamiprid 0.002%	1.40	2.70	5.75	9.25	4.78
Imidacloprid 0.003%	1.55	2.10	6.30	8.95	4.73
Dimethoate 0.05%	1.35	1.80	6.20	7.90	4.31
Untreated control	10.95	11.05	11.70	12.95	11.66

CD (0.05) Treatment : 0.34
CD (0.05) Treatment × Interval : 0.68

DAS-Days after spraying

Appreciable toxicity of acetamiprid and imidacloprid was noted upto seven days after spraying while that of dimethoate, NeemAzal T/S and neem oil garlic emulsion upto three days after treatment.

4. 3.2.2.3 Effect on natural enemies

The effect of the various treatments on the natural enemies of the aphid presented as number per 10 plants is depicted in Tables 70 to 75.

Coccinellid Predators

First spray: The population of coccinellids was significantly reduced in all the treatments when compared to control (11.24) on the first day after spraying (Table 70). Acetamiprid 0.002% (1.73) and dimethoate 0.05% (2.48) were highly toxic to the coccinellids followed by imidacloprid 0.003% (4.13). NeemAzal T/S 4 ml/l (6.46) and neem oil + garlic emulsion 2% (6.98) were significantly less toxic and were on par. On the third day after spraying, the lowest population of the predator was seen in dimethoate (0.22) treated plots followed by acetamiprid (2.24) and imidacloprid (2.48) sprayed plots which were on par. NeemAzal T/S (6.73) and neem oil + garlic emulsion (7.23) were significantly less toxic to the coccinellids. Dimethoate (1.23) was significantly the most toxic followed by acetamiprid (2.97) and imidacloprid (2.97) on the seventh day. NeemAzal T/S (9.75) and neem oil + garlic emulsion (8.73) recorded comparatively higher coccinellid population and were on par, though they were inferior to untreated control (12.50). On the fifteenth day, dimethoate (3.72), acetamiprid (7.23) and imidacloprid (9.23) recorded significantly lower population of coccinellds. Neem oil + garlic emulsion (13.50) and NeemAzal T/S (13.75) treated plots recorded high population and were on par with the control plots (13.75).

Second spray: A significant reduction of coccinelld population was observed in all the treatments one day after the second spray when compared to control (14.50). Least number of coccinellids was recorded in dimethoate (0.72) followed by acetamiprid (3.43) and imidacloprid (4.22) treated plots.

NeemAzal T/S (8.22) and neem oil + garlic emulsion (9.99) were on par in their effect. A similar trend was seen on the third after spraying too. Again significant reduction in the population of coccinellids was seen in the plots sprayed with dimethoate (0.46) followed by acetamiprid (2.71) and imidacloprid (3.15) which were on par. Though, compared to the insecticides higher population of coccinellids was observed in NeemAzal T/S (8.98) and neem oil + garlic emulsion (10.50) treatments, the population was significantly low compared to that in the unsprayed plots (15.50). On the seventh day too, dimethoate sprayed plots (3.98) had significantly lower number of coccinellids. Acetamiprid (9.23) and imidacloprid (10.99) were on par in their effect. No significant difference was discerned in the population of the predator in the NeemAzal T/S (11.97) and neem oil + garlic emulsion (11.99) treated and control plot (11.99). On the fifteenth day, significantly low population of the predator was seen in dimethoate sprayed plots (9.95). Imidacloprid (12.35) and acetamiprid (14.50) were on par in their effect. Population of the coccinellid in plots treated with NeemAzal T/S (15.74) and neem oil + garlic emulsion (16.50) did not differ significantly from that in the untreated plots (16.50).

The pooled data on the efficacy of the treatments indicated that dimethoate (2.37) was the most toxic to the coccinellid followed by acetamiprid (4.93) and imidacloprid (5.73). Compared to the insecticides, NeemAzal T/S (9.96) and neem oil + garlic emulsion (10.52) treated plots supported significantly higher population of the predator though it was significantly less than that in the unsprayed plots (13.22).

Noticeable toxic effect of the insecticides to the predator persisted upto seven days after spraying and thereafter a significant increase in the population of the coccinellids was observed. On the other hand, slight toxicity of the botanicals was seen upto three days after which the population of the predator increased and came on par with control by the fifteenth day.

Syrphid Predators

First spray: Among the treatments, dimethoate 0.05% (0.00), acetamiprid 0.002% (0.25), imidacloprid 0.003% (0.50) and NeemAzal T/S 4 ml/l (0.75) treated plots recorded negligible population of the predator one day after the first spraying and were on par (Table 71). Neem oil + garlic emulsion 2% (1.25) sprayed plots too recorded significantly low population of the syrphid when compared to the untreated plots (4.50). On the third day, while 5.00 syrphids were recorded per ten plants in the control plot, no syrphids were observed in dimethoate sprayed plots. Acetamiprid (0.75) and imidacloprid (1.25) too recorded low population. The population of the predator in NeemAzal T/S (2.00) and neem oil + garlic emulsion (2.25) treated plots did not differ significantly. On the seventh day also, dimethoate (1.25) recorded the least number of syrphids. Acetamiprid (2.25) and imidacloprid (3.00) treated plots too recorded low population of the predator when compared to the conrol plot (5.75). NeemAzal T/S (4.25) and neem oil + garlic emulsion (4.50) recorded significantly higher population than the insecticides. On the fifteenth day too, significantly low number of syrphids was recorded in dimethoate (2.50) sprayed plots followed by acetamiprid (4.25) and imidacloprid (5.00). However, the population of the predator in NeemAzal T/S (5.50) and neem oil + garlic emulsion (6.00) treated plots was on par with that in unsprayed plots (6.25).

A more or less same trend was observed following the second round of spraying. The population of the syrphid was negligible in dimethoate (0.00), acetamiprid (0.25) and imidacloprid (0.50) treated plots one day after the spray. Though a significantly low population of the syrphid was seen in NeemAzal T/S 4 ml/l (2.50) and neem oil + garlic emulsion 2%(2.25) treated plots when compared to the unsprayed plot(7.25), it was significantly higher than that in the insecticide treated plots. A similar trend was observed on the third day after spraying. Negligible population of the syrphids was observed

Table 70. Effect of botanicals and chemical insecticides on coccinellids in winged bean

Treatments	Number per 10 plants								Pooled mean
	I spray				II spray				
	1 DAS	3 DAS	7 DAS	15 DAS	1 DAS	3 DAS	7 DAS	15 DAS	
NeemAzal T/S 4 ml/l	6.46 (2.73)	6.73 (2.78)	9.75 (3.28)	13.50 (3.81)	8.22 (3.04)	8.98 (3.16)	11.97 (3.60)	15.74 (4.09)	9.96 (3.31)
Neem oil + garlic 2%	6.98 (2.83)	7.23 (2.87)	8.73 (3.12)	13.75 (3.84)	9.99 (3.32)	10.50 (3.39)	11.99 (3.60)	16.50 (4.18)	10.52 (3.39)
Acetamiprid 0.002%	1.73 (1.65)	2.24 (1.80)	2.97 (1.99)	7.23 (2.87)	3.43 (2.10)	2.71 (1.93)	9.23 (3.20)	14.50 (3.94)	4.93 (2.44)
Imidacloprid 0.003%	4.13 (2.27)	2.48 (1.87)	2.97 (1.99)	9.23 (3.20)	4.22 (2.28)	3.15 (2.04)	10.99 (3.46)	12.35 (3.65)	5.73 (2.60)
Dimethoate 0.05%	2.48 (1.87)	0.22 (1.10)	1.23 (1.49)	3.72 (2.17)	0.72 (1.31)	0.46 (1.21)	3.98 (2.23)	9.95 (3.31)	2.37 (1.84)
Untreated control	11.24 (3.50)	11.48 (3.53)	12.50 (3.67)	13.75 (3.84)	14.50 (3.94)	15.50 (4.06)	11.99 (3.60)	16.50 (4.18)	13.22 (3.77)

CD (0.05) Treatment : 0.10

CD (0.05) Treatment × Interval : 0.29

Figures in parentheses are $\sqrt{(x+1)}$ transformed values

DAS-Days after spraying

Table 71. Effect of botanicals and chemical insecticides on syrphids in winged bean

Treatments	Number per 10 plants								Pooled mean
	I spray				II spray				
	1 DAS	3 DAS	7 DAS	15 DAS	1 DAS	3 DAS	7 DAS	15 DAS	
NeemAzal T/S 4 ml/l	0.75	2.00	4.25	5.50	2.50	4.25	7.50	9.00	4.47
Neem oil + garlic emulsion 2%	1.25	2.25	4.50	6.00	2.25	4.25	8.50	9.75	4.84
Acetamiprid 0.002%	0.25	0.75	2.25	4.25	0.25	0.50	2.50	5.25	2.00
Imidacloprid 0.003%	0.50	1.25	3.00	5.00	0.50	0.75	3.00	6.50	2.56
Dimethoate 0.05%	0.00	0.00	1.25	2.50	0.00	0.00	1.25	4.00	1.13
Untreated control	4.50	5.00	5.75	6.25	7.25	7.75	8.50	9.25	7.00

CD (0.05) Treatment : 0.29

CD (0.05) Treatment × Interval : 0.82

DAS-Days after spraying

in dimethoate (0.00), acetamiprid (0.50) and imidacloprid (0.75) treated plots. Comparatively, the botanicals viz., NeemAzal T/S (4.25) and neem oil + garlic emulsion (4.25) recorded higher population of the predator though the number seen were significantly lower than that in the unsprayed plots (7.50). On the seventh day too, the syrphid population was significantly reduced in dimethoate (1.25), acetamiprid (2.50) and imidacloprid (3.00) treated plots. NeemAzal T/S (7.50) and neem oil + garlic emulsion (8.50) were on par with control (8.50). On the fifteenth day, the population of the syrphids was significantly low in dimethoate (4.00), acetamiprid (5.25) and imidacloprid (6.50) treated plots when compared to the untreated plots (9.25). Contrarily, NeemAzal T/S (9.00) and neem oil + garlic emulsion (9.75) did not affect the syrphids adversely.

The cumulative data on the efficacy of the treatments indicated the toxicity of dimethoate (1.13) followed by acetamiprid (2.00) and imidacloprid (2.56) to the syrphid. Comparatively, NeemAzal T/S (4.47) and neem oil + garlic emulsion (4.84) treated plots recorded significantly higher population of the predator though it was significantly less than that in the unsprayed plots (7.00).

Though toxicity of dimethoate continued upto 15 days after treatment, the discernible toxicity of acetamiprid and imidacloprid persisted upto seven days only. Appreciable adverse effect of the botanicals persisted upto three days. Thereafter, an increase in the population of the predator was observed which came on par with control by the fifteenth day

Chamaemyiids (*Leucopis* sp.)

One day after the first spraying, significant reduction in the number of *Leucopis sp.* was seen in dimethoate 0.05% (0.25) treated plots followed by acetamiprid 0.002% (1.50) and imidacloprid 0.003% (1.75) which were on par (Table 72). NeemAzal T/S 4 ml/l (6.00) and neem oil + garlic emulsion 2% (7.00) sprayed plots too recorded significantly low population of the predator when compared to the untreated plots (12.50). A similar trend was seen on the third day after spraying too. The population of *Leucopis* sp. was significantly low in dimethoate (0.00), acetamiprid (1.50) and imidacloprid (2.25) sprayed plots. Though significant reduction in the population of the predator was also noted in NeemAzal T/S (7.00) and neem oil + garlic emulsion (8.00) treated plots when compared to the untreated plots (13.50), it was significantly higher than that in the insecticide treated plots. On the seventh day dimethoate (4.75) again recorded the least number of the predator followed by acetamiprid (6.50) and imidacloprid (9.00). NeemAzal T/S (12.75) and neem oil + garlic emulsion (11.75) recorded significantly higher population than the insecticides. On the fifteenth day too, significantly lower number of the predator was recorded in dimethoate (11.00) treatment followed by acetamiprid (12.25) and imidacloprid (15.00) treatments. However, the population of the predator in NeemAzal T/S (14.50) and neem oil + garlic emulsion (14.25) treated plots was on par with that in unsprayed plot (14.50).

A comparable trend was observed after the second spray. The population of the *Leucopis* sp. was significantly reduced in dimethoate (0.50) treated plots one day after the spray followed by acetamiprid (2.50) and imidacloprid (3.25) which were on par. Though a significantly low population of the *Leucopis* sp. was seen the NeemAzal T/S 4 ml/l (6.50) and neem oil + garlic emulsion 2% (7.50) treated plots when compared to the unsprayed plots(16.00), it was significantly higher than that in the insecticide treated plots. No *Leucopis* sp was recorded in dimethoate treated plots on the third day. Low population of the predator was noticed in acetamiprid (3.00) and imidacloprid (4.50) sprayed plots. On the other hand, NeemAzal T/S (10.00) and neem oil + garlic emulsion (8.50) recorded higher population of the predator though it was significantly lower than that in unsprayed plots (17.00). On the seventh day too, the population of the predator was significantly reduced in dimethoate (2.50) treated plots. Comparatively, acetamiprid (8.50) and imidacloprid (9.50) treated plots recorded higher number of the predator. Even though inferior to control

(18.50), NeemAzal T/S (14.50) and neem oil + garlic emulsion (14.50) recorded significantly higher population of the predator than the insecticides. On the fifteenth day, the population of *Leucopsis* sp. was significantly low in dimethoate (8.50). Though inferior to the untreated plots (18.25), acetamiprid (14.50) and imidacloprid (14.75) recorded higher number of the predator and were on par. No reduction in the predator population was seen in NeemAzal T/S (18.00) and neem oil + garlic emulsion (18.50) sprayed plots.

Considering the overall effect of the botanicals and insecticides, the lowest population of the predator was recorded in dimethoate (3.44) treated plot followed by acetamiprid (6.28) and imidacloprid (7.50). Compared to the insecticides significantly higher number of the predator was recorded in NeemAzal T/S (11.03) and neem oil + garlic emulsion sprayed plots (11.25).

Regarding the persistent efficacy, while the toxicity of the insecticides dimethoate, acetamiprid and imidacloprid persisted upto seven days after spraying, the effect of the botanicals persisted only upto three days.

Hemerobiids

No hemerobiids were observed in the plots sprayed with dimethoate 0.05% on one day after treatment and the insecticide was on par with acetamiprid 0.002% (0.50) and imidacloprid 0.003% (0.75) (Table 73). Significantly lower number of the predator was recorded from NeemAzal T/S 4 ml/l (2.00) and neem oil + garlic emulsion 2% (1.75) sprayed plots compared to the untreated plot (6.25). After three days too, no hemerobiids were detected in the plots sprayed with dimethoate. Only very low population of the predator was noted in the plots sprayed with acetamiprid (1.25) and imidacloprid (1.75). NeemAzal T/S (2.50) and neem oil + garlic emulsion (2.25) treated plots were on par in their effect on the predators though inferior to control (6.50). On the seventh day, dimethoate (1.25) sprayed plots again recorded very low number of hemerobiids. However,

Table 72. Effect of botanicals and chemical insecticides on *Leucopis* sp in winged bean

Treatments	Number of per 10 plants								Pooled mean
	I spray				II spray				
	1 DAS	3 DAS	7 DAS	15 DAS	1 DAS	3 DAS	7 DAS	15 DAS	
NeemAzal T/S 4 ml/l	6.00	7.00	12.75	14.50	6.50	10.00	14.50	18.00	11.03
Neem oil + garlic 2%	7.00	8.00	11.75	14.25	7.50	8.50	14.00	18.50	11.25
Acetamiprid 0.002%	1.50	1.50	6.50	12.25	2.50	3.00	8.50	14.50	6.28
Imidacloprid 0.003%	1.75	2.25	9.00	15.00	3.25	4.50	9.50	14.75	7.50
Dimethoate 0.05%	0.25	0.00	4.75	11.00	0.50	0.00	2.50	8.50	3.44
Untreated control	12.50	13.50	14.50	14.50	16.00	17.00	18.50	18.25	15.88

CD (0.05) Treatment : 0.34 DAS-Days after spraying
CD (0.05) Treatment × Interval : 0.96

Table 73. Effect of botanicals and chemical insecticides on hemerobiids in winged bean

Treatments	Number of per 10 plants								Pooled mean
	I spray				II spray				
	1 DAS	3 DAS	7 DAS	15 DAS	1 DAS	3 DAS	7 DAS	15 DAS	
NeemAzal T/S 4 ml/l	2.00	2.50	4.50	9.50	4.25	5.50	10.75	12.50	6.44
Neem oil + garlic 2%	1.75	2.25	5.00	9.25	3.50	5.50	11.25	13.00	6.28
Acetamiprid 0.002%	0.50	1.25	2.50	5.50	1.50	1.75	6.75	11.00	3.84
Imidacloprid 0.003%	0.75	1.75	3.50	6.50	1.75	2.50	8.75	12.25	4.72
Dimethoate 0.05%	0.00	0.00	1.25	4.25	0.00	0.25	1.00	3.50	1.28
Untreated control	6.25	6.50	8.75	9.50	10.75	12.25	13.75	12.75	10.28

CD (0.05) Treatment : 0.31 DAS-Days after spraying
CD (0.05) Treatment × Interval : 0.89

acetamiprid (2.50) and imidacloprid (3.50) registered significantly higher population. Similarly, higher population of the predator was observed in NeemAzal T/S (4.50) and neem oil + garlic emulsion (5.00) treated plots when compared to the control plot (8.75). On the fifteenth day too significantly low population of hemerobiids was seen in dimethoate (4.25) treated plots. Comparatively, higher population of the predator was observed in acetamiprid (5.50) and imidacloprid (6.50) sprayed plots, though the populatin was significantly less than that recorded in the unsprayed plots. The hemerobiid population in NeemAzal T/S (9.50) and neem oil + garlic emulsion (9.25) treated plots were on par with that of the control (9.50).

One day after the second spraying, no hemerobiids were seen in dimethoate treated plots. Significant reduction in the number of the predator was observed in acetamiprid (1.50) and imidacloprid (1.75) treatments, which were on par. NeemAzal T/S (4.25) and neem oil + garlic emulsion (3.50) sprayed plots too recorded significantly low population of the predator when compared to the untreated plot (10.75). A similar trend was seen on the third day. The population of the predator was significantly low in dimethoate (0.25), acetamiprid (1.75) and imidacloprid (2.50) sprayed plots. The population of the predator in NeemAzal T/S (5.50) and neem oil + garlic emulsion (5.50) treated plots was reduced significantly when compared to the untreated plot (12.25). On the seventh day after spraying also, dimethoate (1.00) recorded the least number of the predator followed by acetamiprid (6.75) and imidacloprid (8.75). NeemAzal T/S (10.75) and neem oil + garlic emulsion (11.25) recorded significantly higher population than the insecticides. On the fifteenth day, significantly low number of the predator was recorded in dimethoate (3.50) sprayed plots. Though inferior to control (12.75), acetamiprid (11.00) and imidacloprid (12.25) treated plots recorded higher population than in dimethoate treatment. However, the population of the predator in NeemAzal T/S (12.50) and neem oil + garlic emulsion (13.00) treated plots was on par with that in unsprayed plot (12.75).

The cumulative data on the effect of the different treatments showed significant reduction of hemerobiid population in dimethoate (1.28) treated plots. Acetamiprid (3.84) and imidacloprid (4.72) also showed significant reduction of the predator. Despite being inferior to control, NeemAzal T/S (6.44) and neem oil + garlic emulsion (6.28) recorded higher population than the insecticide treated plots.

Considering the persistent toxicity, dimethoate showed high toxicity upto fifteen days. Acetamiprid and imidacloprid showed appreciable toxicity only upto seven days. NeemAzal T/S and neem oil + garlic emulsion showed adverse effect only when observed on the first day after spraying.

Spiders

The insecticides, dimethoate 0.05% (0.50), acetamiprid 0.002% (0.50) and imidacloprid 0.003% (1.25) were highly toxic to spiders reducing the population significantly one day after the first spraying (Table 74). NeemAzal T/S 4 ml/l (2.25) and neem oil + garlic emulsion 2% (2.50) sprayed plots too recorded significantly low population of the predator when compared to the untreated plot (5.50). On the third day, no spiders were seen in dimethoate treated plot. Significantly low population was also recorded in acetamiprid (2.25) and imidacloprid (1.75) sprayed plots. The population of the predator in NeemAzal T/S (3.00) and neem oil + garlic emulsion (2.75) treated plots was significantly low when compared to the untreated plot (5.75). On the seventh day after spraying, the lowest number of spiders was observed in dimethoate (1.75) sprayed plots followed by acetamiprid (3.75) and imidacloprid (3.50). NeemAzal T/S (4.50) and neem oil + garlic emulsion (5.00) recorded significantly higher population than the insecticides. On the fifteenth day too, significantly low number of the predator was recorded in dimethoate (4.00) sprayed plots followed by acetamiprid (5.50) and imidacloprid (6.75). However, the population of the predator in NeemAzal T/S (7.50) and neem oil + garlic emulsion (8.00) treated plots were on par with that in the unsprayed plot (7.75).

After the second spray, significant reduction in the population of spiders was noticed in dimethoate (0.25) treated plots one day after the spray followed by acetamiprid (1.25) and imidacloprid (1.50) which were on par. Similarly, significantly low population of the araneae was seen in the NeemAzal T/S (1.75) and neem oil + garlic emulsion (2.25) treated plots when compared to the unsprayed plot (8.25). No spiders were recorded in dimethoate treated plots on the third day. Low population of the predator was noticed in acetamiprid (1.00) and imidacloprid (2.00) sprayed plots. Contrarily, NeemAzal T/S (3.50) and neem oil + garlic emulsion (3.75) which were on par recorded higher population of the predator though it was significantly lower than that in unsprayed plot (8.50). On the seventh day too the spider population was significantly reduced in dimethoate (3.25). Comparatively, acetamiprid (5.50) and imidacloprid (6.00) treated plots recorded higher number of the predator. Even though inferior to control (9.50), NeemAzal T/S (7.75) and neem oil + garlic emulsion (8.00) recorded significantly higher population of the predator than the insecticides. On the fifteenth day, the population of spiders was significantly low in dimethoate (7.00), acetamiprid (7.25) and imidacloprid (7.50) treated plots when compared to the untreated plot (10.25) and the treatments were on par. No significant reduction in the predator population was seen in NeemAzal T/S (10.00) and neem oil + garlic emulsion (10.25) sprayed plots.

Considering the overall effect of the botanicals and insecticides, dimethoate (2.09) was the most toxic, recording the lowest population of the predator. It was followed by acetamiprid (3.38) and imidacloprid (3.78). Compared to the insecticides, significantly higher number of the predator was recorded in NeemAzal T/S (4.78) and neem oil + garlic emulsion (5.19) sprayed plots though it was significantly less than that in control (7.88).

Regarding the persistent toxicity, while the effect of dimethoate persisted upto fifteen days, acetamiprid and imidacloprid persisted upto 7 days. The adverse effect of the botanicals persisted only upto three days.

Parasitoids

No parasitoids were seen in dimethoate 0.05% treated plots, one day after the first spray. Acetamiprid 0.002% (1.00) and imidacloprid 0.003% (1.75) too were highly toxic to the parasitoids, reducing the population significantly (Table 75). NeemAzal T/S 4 ml/l (3.00) and neem oil + garlic emulsion 2% (3.00) sprayed plots too recorded significantly low population of the predator when compared to the untreated plot (7.75). On the third day also, the population of parasitoids was significantly low in dimethoate (0.25), acetamiprid (1.75) and imidacloprid (2.25) sprayed plots. The population of the predator in NeemAzal T/S (3.75) and neem oil + garlic emulsion (4.25) treated plots was significantly low when compared to the untreated plot (8.00). On the seventh day after spraying, dimethoate (2.75) sprayed plots again recorded the lowest number of parasitoids. Significant reduction in the parasitoid population was also seen in imidacloprid (4.50) and acetamiprid (5.25) treatments. Neem oil + garlic emulsion (9.50) and NeemAzal T/S (9.75) recorded significantly higher population than the insecticides and was on par with control (9.75). With the exception of dimethoate (9.50) which recorded significantly lower number of parasitoids, the population of the natural enemy in all the other treatments viz., acetamiprid (11.00), imidacloprid (11.25), NeemAzal T/S (10.75) and neem oil + garlic emulsion (11.00) was at par with that in the unsprayed plots (11.00) on the fifteenth day.

No parasitoids were observed in dimethoate treated plots one day after the second spray. Acetamiprid (1.25) and imidacloprid (1.25) recorded significant reduction in the population of parasitoids and were on par. Comparatively, higher population was seen in NeemAzal T/S (6.25) and neem oil + garlic emulsion (7.75) treated plots though it was significantly lower than that in the unsprayed plot (12.25). Low population of the parasitoids was noticed in dimethoate (0.25), imidacloprid (1.00) and acetamiprid (2.50) sprayed plots on the third day after spraying. NeemAzal T/S (7.25) and neem oil + garlic emulsion (9.75) recorded higher population

Table 74. Effect of botanicals and chemical insecticides on spiders in winged bean

Treatments	Number per 10 plants								Pooled mean
	I spray				II spray				
	1 DAS	3 DAS	7 DAS	15 DAS	1 DAS	3 DAS	7 DAS	15 DAS	
NeemAzal T/S 4ml/l	2.25	3.00	4.50	7.50	1.75	3.50	7.75	10.00	4.78
Neem oil + garlic 2%	2.50	2.75	5.00	8.00	2.25	3.75	8.00	10.25	5.19
Acetamiprid 0.002%	0.50	2.25	3.75	5.50	1.25	1.00	5.50	7.25	3.38
Imidacloprid 0.003%	1.25	1.75	3.50	6.75	1.50	2.00	6.00	7.50	3.78
Dimethoate 0.05%	0.50	0.00	1.75	4.00	0.25	0.00	3.25	7.00	2.09
Untreated control	5.50	5.75	7.50	7.75	8.25	8.50	9.50	10.25	7.88

CD (0.05) Treatment : 0.32 DAS-Days after spraying
CD (0.05) Treatment × Interval : 0.90

Table 75. Effect of botanicals and chemical insecticides on parasitoids in winged bean

Treatments	Number per 10 sweeps								Pooled mean
	I spray				II spray				
	1 DAS	3 DAS	7 DAS	15 DAS	1 DAS	3 DAS	7 DAS	15 DAS	
NeemAzal T/S 4 ml/l	3.00	3.75	9.75	10.75	6.25	7.25	13.25	14.25	8.50
Neem oil + garlic 2%	3.00	4.25	9.50	11.00	7.75	9.75	13.75	14.75	9.22
Acetamiprid 0.002%	1.00	1.75	5.25	11.00	1.25	2.50	9.00	14.50	5.78
Imidacloprid 0.003%	1.75	2.25	4.50	11.25	1.25	1.00	8.25	14.50	5.59
Dimethoate 0.05%	0.00	0.25	2.75	9.50	0.00	0.25	3.75	11.00	3.44
Untreated control	7.75	8.00	9.75	11.00	12.25	13.25	13.50	14.50	11.44

CD (0.05) Treatment : 0.35 DAS-Days after spraying
CD (0.05) Treatment × Interval : 0.99

of the parasitoids than the insecticides, though it was significantly lower than that in unsprayed plots (13.25). On the seventh day too the population of the bioagent was significantly reduced in dimethoate (3.75). Comparatively, imidacloprid (8.25) and acetamiprid (9.00) treated plots recorded higher number of parasitoids. The population in NeemAzal T/S (13.25) and neem oil + garlic emulsion (13.75) treated plots was on par with that of the control plot (13.50). Excepting in dimethoate (11.00) treatment, no significant reduction in the number of parasitoids was seen in NeemAzal T/S (14.25), acetamiprid (14.50), imidacloprid (14.50) and neem oil + garlic emulsion (14.75) sprayed plots when compared to the untreated plots (14.50) on the fifteenth day.

Considering the overall effect, dimethoate (3.44) was most toxic, to the parasitoid. It was followed by imidacloprid (5.59) and acetamiprid (5.78). Compared to the insecticides, NeemAzal T/S (8.5) and neem oil + garlic (9.22) were significantly less toxic.

The toxicity of dimethoate persisted upto fifteen days, while that of acetamiprid and imidacloprid persisted only upto seven days. The adverse effect of the botanicals was seen only upto three days after spraying.

4.3.2.2.4 Effect on soil invertebartes

Earthworm

The results on the influence of various treatments on earthworm assessed as number per 30 cm^3 are presented in Table 76.

Significant reduction in the number of earthworms was noticed on one day after the first spraying in dimethoate 0.05% (1.50) sprayed plots. Acetamiprid 0.002% (2.25) and imidacloprid 0.003% (2.50) too recorded a significant reduction when compared to the unsprayed plots (3.50). NeemAzal T/S 4 ml/l (3.25) and neem oil + garlic emulsion 2% (3.50) were not toxic to the earthworm .On the third day, the population of the invertebrate was significantly low in dimethoate (1.00) and acetamiprid (2.50) treatments. The population of earthworm in imidacloprid (3.50), NeemAzal T/S (3.25) and neem oil + garlic emulsion (3.50) treated plots was on par with that of the untreated plot (3.50). On the seventh and fifteenth day after spraying, no significant difference was observed in the population of the earthworm in the different treatments, the number of earthworms ranging from 3.50 to 3.75 and 3.75 to 4.25 per 30 cm^3 pit on these days, respectively.

After the second spray, significant reduction in the population of earthworm was noticed in dimethoate (1.25) treated plots one day after the spray followed by acetamiprid (2.50) and imidacloprid (2.50) which were on par. The population of the worm in neemAzal T/S (4.25) and neem oil + garlic emulsion (4.50) did not differ significantly from that in the unsprayed plots (4.25). On the third day too, low population of earthworm was noticed in dimethoate (0.50) and acetamiprid (3.00) sprayed plots. Imidacloprid (3.50) was on par with NeemAzal T/S (4.25) and neem oil + garlic emulsion (4.25) which were on par with the unsprayed plot (4.50). On the seventh day, with the exception of dimethoate (3.00) which recorded significantly low population of earthworm, all the other treatments were on par with control. On the fifteenth and twenty first days, there was no significant difference between the population in the other treatments and control. The population of earthworm on these days ranged from 4.5 to 5.00 and 5.00 to 5.25 per cm^3 pit respectively.

Considering the overall effect of the botanicals and insecticides, dimethoate (2.47) was the most toxic, recording the lowest population of earthworm as against 4.25 per cm^3 pit in the control plot. It was followed by acetamiprid (3.61) and imidacloprid (3.81) which were on par. NeemAzal T/S (4.14) and neem oil + garlic emulsion (4.14) did not affect the earthworm significantly.

The toxicity of dimethoate and acetamiprid to earthworm persisted upto seven days, while adverse effect of imidacloprid and the botanicals was seen only for one day.

Soil coleopterans

The population of soil coleopterans observed per kg soil at different intervals after spraying are given in Table 77.

No coleopterans were obtained from dimethoate 0.05% treated plots one day after the first spray and the insecticide was on par with the neonicotinoids, imidacloprid 0.003% (0.25), acetamiprid 0.002% (0.50) and the botanical, NeemAzal T/S 4 ml/l (0.50), all of which recorded negligible population when compared to the control plot (1.50). Application of neem oil + garlic emulsion 2% (1.00) did not result in any significant reduction in the population of the soil coleopterans. Significant reduction in the number of soil coleopterans was observed in dimethoate (0.25), imidacloprid (0.50) and acetamiprid (0.50), sprayed plots on the third day after spraying. However, NeemAzal T/S (1.25) and neem oil + garlic emulsion (1.25) were on par with untreated control (1.50). On the seventh day, compared to the untreated plots (1.75), only dimethoate (0.75) recorded significantly low population of the soil coleopterans. All the other treatments viz., acetamiprid (1.25), imidacloprid (1.25), NeemAzal T/S (1.50) and neem oil + garlic emulsion (1.75) did not affect the soil coleopterans adversely. There was no significant difference in the population of coleopterans in the treated and untreated plots on the fifteenth day, the population ranging from 2.00 to 2.50 in the different plots.

Significant decrease in the population of soil coleopterans was seen in dimethoate (0.25), acetamiprid (0.25) imidacloprid (0.50) treated plots on one day after the spray. No significant reduction was observed in NeemAzal T/S (1.50) and neem oil + garlic emulsion (1.75) sprayed plots when compared to the untreated plot (2.25). Three and seven days after the second spray too significant reduction of the coleopteran population was noted in dimethoate (0.00, 1.75), acetamiprid (0.75, 1.50) and imidacloprid (1.00, 1.75). NeemAzal T/S (2.00, 3.25) and neem oil + garlic emulsion (2.00, 3.00) were on par with control (2.25, 3.00). The population of the soil

Table 76. Population of earthworm in winged bean plots sprayed with botanicals and chemical insecticides

Treatments	Number per pit (30 cm^3)									Pooled mean
	I spray				II spray					
	1 DAS	3 DAS	7 DAS	15 DAS	1 DAS	3 DAS	7 DAS	15 DAS	21 DAS	
NeemAzal T/S 4 ml/l	3.25	3.25	3.75	3.75	4.25	4.25	4.75	5.00	5.25	4.14
Neem oil + garlic 2%	3.50	3.50	3.50	3.75	4.50	4.25	4.50	4.50	5.25	4.14
Acetamiprid 0.002%	2.25	2.50	3.75	4.25	2.50	3.00	4.25	4.75	5.25	3.61
Imidacloprid 0.003%	2.50	3.50	3.50	4.25	2.50	3.50	4.25	4.75	5.00	3.81
Dimethoate 0.05%	1.50	1.00	3.50	3.75	1.25	0.50	3.00	4.50	5.00	2.47
Untreated control	3.50	3.50	3.75	4.00	4.25	4.50	4.75	4.75	5.00	4.25

CD (0.05) Treatment : 0.32

CD (0.05) Treatment × Interval : 0.96

DAS-Days after spraying

Table 77. Population of soil coleopteran in winged bean plots sprayed with botanicals and chemical insecticides

Treatments	Number of coleopteran observed per kg soil									Pooled mean
	I spray				II spray					
	1 DAS	3 DAS	7 DAS	15 DAS	1 DAS	3 DAS	7 DAS	15 DAS	21 DAS	
NeemAzal T/S 4 ml/l	0.50	1.25	1.50	2.00	1.50	2.00	3.25	3.50	4.75	2.25
Neem oil + garlic 2%	1.00	1.25	1.75	2.50	1.75	2.00	3.00	3.50	4.75	2.39
Acetamiprid 0.002%	0.50	0.50	1.25	2.25	0.25	0.75	1.50	3.25	5.25	1.72
Imidacloprid 0.003%	0.25	0.50	1.25	2.00	0.50	1.00	1.75	3.50	5.00	1.75
Dimethoate 0.05%	0.00	0.25	0.75	2.00	0.25	0.00	1.00	3.25	5.25	1.31
Untreated control	1.50	1.50	1.75	2.25	2.25	2.25	3.00	3.50	4.75	2.61

CD (0.05) Treatment : 0.29

CD (0.05) Treatment X Interval : 0.87

DAS-Days after spraying

coleopterans in the treated plots did not vary significantly from that in the unsprayed plots when observed on the fifteenth and twenty first day after spraying. The mean population ranged from 3.25 to 3.50 and 4.75 to 5.25 on these days, respectively.

An overall analysis of the data indicated that dimethoate (1.31), acetamiprid (1.72) and imidacloprid (1.75) decreased the soil coleopteran population significantly. NeemAzal T/S and neem oil + garlic emulsion did not affect the soil coleopterans significantly, recording 2.25 and 2.39 coleopterans per kg soil respectively as against 2.61 coleopterans per kg soil in the untreated plots.

The toxic effect of dimethoate persisted upto seven days. The neonicotinoids, acetamiprid and imidacloprid showed a drop in the population after three days. NeemAzal T/S and neem oil + garlic emulsion did not show any adverse effect on the soil coleopterans.

Termites

Significant reduction in the population of termites was observed in the insecticide sprayed plots one, three and seven days after spraying (Table 78). While the population of termites was 0.46, 0.00 and 1.48 per kg soil in dimethoate 0.05% treated plots on these days respectively, it was 0.46, 0.46 and 1.23 and 0.46, 0.46 and 1.23 in imidacloprid 0.003% and acetamiprid 0.002% treated plots, respectively. NeemAzal T/S 4 ml/l and neem oil + garlic emulsion 2% which recorded 1.73, 2.24 and 3.49 and 1.73,1.96 and 3.24 per kg soil on one, three and seven days after spraying were on par with control (2.24, 2.24 and 3.49 per kg soil on one, three and seven days after spraying) in their effect. The population of the isopteran recorded in all the treatments was on par with untreated control (3.57) on the fifteenth day, the population ranging from 3.24 to 3.74 per kg soil.

A trend similar to that observed in the first spray was seen after the second spray too. Again, significant reduction in the population of termite was observed in the insecticide sprayed plots one, three and seven days after treatment. The population of termites was0.46, 0.46 and 3.49 in acetamiprid, 0.72, 0.00 and 2.48 in dimethoate and 0.72, 0.22 and 2.97 per kg soil in imidacloprid treated plots on these days respectively as against 4.49, 5.24 and 5.49 per kg soil respectively in the unsprayed plot. No significant reduction was noted in the population of the termites in NeemAzal T/S and neem oil + garlic emulsion sprayed plots which recorded 3.49, 5.24 and 5.22 and 3.98, 5.49 and 5.49 per kg soil respectively on one, three and seven days after spraying. The population of the isopteran recorded in all treatments was on par with untreated control (3.57) on the fifteenth day, the population ranging from 3.24 to 3.74 per kg soil.

Analysis of the pooled data revealed that dimethoate (1.54), imidacloprid (1.72) and acetamiprid (1.75) were equally toxic to the termites. Neem oil + garlic emulsion (3.07) and NeemAzal T/S (3.05) were non toxic and at par with untreated control (3.24).

Considering the persistent effect of the insecticides viz., imidacloprid, dimethoate, and acetamiprid showed significant toxicity upto seven days. NeemAzal T/S and neem oil + garlic emulsion did not show any toxicity to the termite.

Ants

Significant reduction in the population of ants was observed in dimethoate 0.05% (5.25) and acetamiprid 0.002% (6.00) followed by imidacloprid 0.003% (7.00) sprayed plots one day after treatment (Table 79). Neem oil + garlic emulsion 2% (12.75) and NeemAzal T/S 4 ml/l (13.25) did not significantly affect the ant population when compared to control (13.00). On the third day after spraying, the lowest population of ants was seen in dimethoate (4.50) followed by acetamiprid (7.25) and imidacloprid (11.75) treatments. NeemAzal T/S (13.50) and neem oil + garlic emulsion (12.75) were on par with control (13.25). On the seventh day, significant reduction of population was observed only in dimethoate (7.25) sprayed plot. All the other treatments viz., acetamiprid (13.50) and imidacloprid (14.50), NeemAzal T/S (13.25) and neem oil + garlic emulsion (13.25) were on par with control (13.50). No reduction in the population of ants was observed on

Table 78. Population of termites in winged bean plots sprayed with botanicals and chemical insecticides

Treatments	Number per kg soil									Pooled mean
	I spray				II spray					
	1 DAS	3 DAS	7 DAS	15 DAS	1 DAS	3 DAS	7 DAS	15 DAS	21 DAS	
NeemAzal T/S 4 ml/l	1.73 (1.65)	2.24 (1.80)	3.49 (2.12)	3.49 (2.12)	3.49 (2.12)	5.24 (2.50)	5.22 (2.49)	6.24 (2.69)	6.73 (2.78)	4.07 (2.25)
Neem oil + garlic 2%	1.73 (1.65)	1.96 (1.72)	3.24 (2.06)	3.74 (2.18)	3.98 (2.23)	5.49 (2.55)	5.49 (2.55)	6.49 (2.74)	6.74 (2.78)	4.17 (2.27)
Acetamiprid 0.002%	0.46 (1.21)	0.46 (1.21)	1.23 (1.49)	3.49 (2.12)	0.46 (1.21)	0.46 (1.21)	3.47 (2.12)	6.24 (2.69)	6.73 (2.78)	1.75 (1.66)
Imidacloprid 0.003%	0.46 (1.21)	0.46 (1.21)	1.23 (1.49)	3.49 (2.12)	0.72 (1.31)	0.22 (1.10)	2.97 (1.99)	6.49 (2.74)	6.98 (2.83)	1.72 (1.65)
Dimethoate 0.05%	0.46 (1.21)	0.00 (1.00)	1.48 (1.57)	3.24 (2.06)	0.72 (1.31)	0.00 (1.00)	2.48 (1.87)	6.24 (2.69)	6.98 (2.83)	1.54 (1.59)
Untreated control	2.24 (1.80)	2.24 (1.80)	3.49 (2.12)	3.57 (2.14)	4.49 (2.34)	5.24 (2.50)	5.49 (2.55)	6.49 (2.74)	6.73 (2.78)	4.37 (2.32)

CD (0.05) Treatment : 0.07
CD (0.05) Treatment × Interval : 0.23

Figures in parentheses are $\sqrt{(x+1)}$ transformed values

Table 79. Population of ant in winged bean plots sprayed with botanicals and chemical insecticides

Treatments	Number of ant observed per kg soil									Pooled mean
	I spray				II spray					
	1 DAS	3 DAS	7 DAS	15 DAS	1 DAS	3 DAS	7 DAS	15 DAS	21 DAS	
NeemAzal T/S 4 ml/l	13.25	13.50	13.25	13.75	15.50	14.75	16.25	15.50	14.25	14.31
Neem oil + garlic 2%	12.75	12.75	13.25	14.25	13.50	12.75	15.25	15.75	14.25	13.83
Acetamiprid 0.002%	6.00	7.25	13.50	14.75	6.25	7.00	13.50	15.50	14.75	10.78
Imidacloprid 0.003%	7.00	11.75	14.50	15.25	8.50	9.00	14.00	15.50	15.00	12.28
Dimethoate 0.05%	5.25	4.50	7.25	13.75	3.25	2.00	7.50	15.00	14.25	7.78
Untreated control	13.00	13.25	13.50	14.00	15.75	16.50	15.50	15.75	14.50	14.64

CD (0.05) Treatment : 0.45
CD (0.05) Treatment X Interval : 1.35

DAS-Days after spraying

the fifteenth day, the population of the ants in the different treatments ranging from 13.75 to 15.25 as against 14.00 in the unsprayed plot.

Again one day after the second spray, significant reduction in ant population was recorded in dimethoate (3.25) followed by acetamiprid (6.25), imidacloprid (8.50) and neem oil + garlic emulsion (13.50). NeemAzal T/S (15.50) was on par with control (15.75). On the third day again significantly low population was seen in dimethoate (2.00), acetamiprid (7.00) and imidacloprid (9.00) treatments. Neem oil + garlic emulsion and NeemAzal T/S recorded 12.75 and 14.75 ants per kg soil as against 16.50 ants per kg soil in control. On the seventh day, dimethoate (7.50) recorded significantly the lowest number of ants followed by acetamiprid (13.50) and imidacloprid (14.00). NeemAzal T/S (16.25) and neem oil + garlic emulsion (15.25) did not differ significantly from control (15.50). The ant population recorded in all the treatments on the fifteenth and twenty first days was on par with untreated control, the population ranging from 15.00 to 15.75 and 14.25 to 15.00 on these days.

Analysis of the pooled data indicated that, dimethoate (7.78) was most toxic to the ants. Comparatively, imidacloprid (10.78), acetamiprid (12.28) and neem oil + garlic emulsion (13.83) were less toxic. NeemAzal T/S (14.31) was non toxic and at par with untreated control (14.64).

The toxicity of dimethoate persisted upto seven days while imidacloprid and acetamiprid exhibited appreciable toxicity only upto three days. Neem oil + garlic emulsion and NeemAzal T/S did not show any persistent toxicity to the ants.

Collembolans

The data on one day after first spraying revealed significant reduction of collembolan population in all the treatments over control (Table 80) and the treatments varied significantly among themselves too. As against 18.74 collembolans per kg soil in the unsprayed plots, 5.98, 8.49, 10.74, 10.99 and 14.24 collembolans per kg soil were recorded in dimethoate 0.05%, acetamiprid 0.002%, imidacloprid 0.003%, NeemAzal T/S 4 ml/l and neem oil + garlic emulsion 2% treated plots, respectively. On the third day too, all the treatments differed significantly over control and among themselves in their effect on the collembolans. While 7.49 collembolans per kg soil was seen in dimethoate sprayed plots, 8.73, 12.50, 14.49 and16.49 collembolans per kg soil were recorded in acetamiprid, imidacloprid, NeemAzal T/S and neem oil + garlic emulsion treated plots as against 19.74 collembolans per kg soil in the unsprayed plots. On the seventh day after spraying ,significantly lower population was observed in dimethoate (12.74), acetamiprid (19.99) and imidacloprid (20.74) treated plots. NeemAzal T/S (21.47) and neem oil + garlic emulsion (20.99) were on par with control (21.74). On the fifteenth day, the collembolans recorded in all treatments were on par with control plot, the number ranging from 22.24 to 22.75.

A similar trend was observed following the second round of spraying. One day after the spray, the population of collembola was significantly decreased in all the treatments when compared to control and the treatments differed significantly among themselves. While only 2.48 (dimethoate), 10.49 (acetamiprid), 13.49 (imidacloprid), 12.99 (NeemAzal T/S) and 15.25 (neem oil + garlic emulsion) were recorded in the various treatments, 23.25 collembolans per kg soil were seen in the unsprayed plots. On the third day too, significantly low population was recorded in dimethoate (4.74), acetamiprid (11.50), imidacloprid (16.50), NeemAzal T/S (15.50) and neem oil + garlic emulsion (17.50) treated plots, contrary to that in the unsprayed plot (24.00).On the seventh day, the lowest population of 14.99 was recorded in dimethoate treatment. Acetamiprid (24.25) and imidacloprid (24.50) were on par. NeemAzal T/S (24.23) and neem oil + garlic emulsion (24.23) were on par with control (24.50). No significant reduction in the population of the collembolans was seen on the fifteenth and twenty first day in the various treatments. The population ranged from 27.25 to 27.50 and 27.00 to 27.49 on these days.

Overall analysis of the data revealed significant reduction of collembolans in dimethoate (11.63) treated plot followed by acetamiprid (17.00) and imidacloprid (19.10) sprayed plots. NeemAzal T/S and neem oil + garlic emulsion registered 19.21 and 20.55 collembolans per kg soil as against 23.38 in the control plots.

Toxicity of dimethoate to collembola was seen upto seven days after spraying. Appreciable toxicity of the neonicotinoids was seen only upto three days. The botanicals did not show any persistent toxic effect.

Soil mite

One day after the first spraying, the lowest population of the mite was observed in dimethoate 0.05% (3.00) sprayed plot and the insecticide differed significantly from other treatments (Table 81). When compared to the untreated plots (8.50) significant reduction of the soil mite was seen in NeemAzal T/S 4 ml/lit (7.00) sprayed plots. No significant decrease in the number of mite was noted in acetamiprid 0.002% (7.50), imidacloprid 0.003% (7.50) and neem oil + garlic emulsion 2% (8.00) treated plots. On the third day also, significant reduction of population was observed in plots receiving dimethoate (3.75) spray. With the exception of the low population seen in NeemAzal T/S (7.50) and imidacloprid (8.00) treated plots, all the other treatments viz., acetamiprid (8.25) and neem oil + garlic emulsion 2% (9.00) were on par with control(9.50). Significantly low population of the mite was observed in dimethoate (8.25) treatment on the seventh day. All the other treatments were on par with control (10.25), the population in the treatments ranging from10.00 to 11.00 per kg soil. There was no significant reduction of population on the fifteenth day, the population in the treatments ranging from 11.00 to 11.50 per kg soil as against 11.25 per kg soil in the control plot.

One day after the second spraying, dimethoate (5.50) recorded the lowest population. Compared to the control plot (11.50) significant reduction of population was observed in acetamiprid (9.25), imidacloprid (9.25) and neem oil + garlic emulsion (10.00) treated plots. NeemAzal T/S

Table 80. Population of collembola in winged bean plots sprayed with botanicals and chemical insecticides

Treatments	Number per kg soil									Pooled mean
	I spray				II spray					
	1 DAS	3 DAS	7 DAS	15 DAS	1 DAS	3 DAS	7 DAS	15 DAS	21 DAS	
NeemAzal T/S 4 ml/l	10.99 (3.46)	14.50 (3.940)	21.47 (4.74)	22.24 (4.82)	12.99 (3.74)	15.50 (4.06)	24.24 (5.02)	27.25 (5.32)	26.94 (5.29)	19.21 (4.50)
Neem oil + garlic 2%	14.24 (3.90)	16.50 (4.18)	20.99 (4.69)	23.24 (4.92)	15.25 (4.03)	17.50 (4.30)	24.24 (5.02)	27.50 (5.34)	27.25 (5.32)	20.55 (4.64)
Acetamiprid 0.002%	8.49 (3.08)	8.73 (3.12)	19.99 (4.58)	22.50 (4.85)	10.50 (3.39)	11.50 (3.54)	24.25 (5.03)	27.25 (5.32)	27.50 (5.34)	17.00 (4.24)
Imidacloprid 0.003%	10.74 (3.43)	12.50 (3.67)	20.74 (4.66)	22.75 (4.87)	13.50 (3.81)	16.50 (4.18)	24.50 (5.05)	27.50 (5.34)	27.50 (5.34)	19.10 (4.48)
Dimethoate 0.05%	5.98 (2.64)	7.49 (2.91)	12.74 (3.71)	23.24 (4.92)	2.48 (1.87)	4.74 (2.40)	14.99 (4.00)	27.25 (5.32)	27.00 (5.29)	11.63 (3.54)
Untreated control	18.74 (4.44)	19.74 (4.55)	21.74 (4.77)	22.50 (4.85)	23.25 (4.92)	24.00 (5.00)	24.50 (5.05)	27.50 (5.34)	27.25 (5.34)	23.38 (4.94)

CD (0.05) Treatment : 0.04

CD (0.05) Treatment × Interval : 0.12

Figures in parentheses are √(x+1) transformed values

DAS-Days after spraying

Table 81. Population of soil mite in winged bean plots sprayed with botanicals and chemical insecticides

Treatments	Number per kg soil									Pooled mean
	I spray				II spray					
	1 DAS	3 DAS	7 DAS	15 DAS	1 DAS	3 DAS	7 DAS	15 DAS	21 DAS	
NeemAzal T/S 4 ml/l	7.00	7.50	11.00	11.25	10.25	12.50	13.50	15.00	16.75	11.72
Neem oil + garlic 2%	8.00	9.00	10.00	11.50	10.00	12.25	14.00	15.50	16.50	11.94
Acetamiprid 0.002%	7.50	8.25	10.25	11.50	9.25	10.75	13.25	15.50	16.75	11.33
Imidacloprid 0.003%	7.50	8.00	10.75	11.00	9.25	11.00	13.00	15.50	16.25	11.17
Dimethoate 0.05%	3.00	3.75	8.25	11.25	5.50	6.50	13.25	15.25	15.75	9.17
Untreated control	8.50	9.50	10.25	11.25	11.50	12.25	13.25	15.25	16.50	12.03

CD (0.05) Treatment : 0.43

CD (0.05) Treatment × Interval : 1.27

DAS-Days after spraying

(10.25) was on par with control. On the third day, while dimethoate (6.50) and acetamiprid (10.75) recorded significantly low population, imidacloprid (11.00) and neem oil + garlic emulsion (12.25) and NeemAzal T/S (12.50) treated plots were on par with control (12.25). On the seventh, fifteenth and twenty first days, no significant difference was noticed in the population of the mite in the sprayed and unsprayed plots. The population on these days ranged from 13.00 to 14.00, 15.00 to 15.50 and 15.75 to 16.75 in the different treatments as against 13.25, 15.25 and 16.50 respectively in the untreated plot.

An overall analysis of the data indicated that dimethoate (9.17) significantly reduced the population of the soil mite followed by imidacloprid (11.33) and acetamiprid (11.17) which were on par. NeemAzal T/S (11.72) and neem oil + garlic emulsion (11.94) did not affect the soil mite and were on par with untreated control (12.03) in their effect.

With the exception of dimethoate whose toxicity persisted upto three days, all the other treatments did not show any appreciable persistent toxicity.

4.3.2.2.5 Effect on soil microflora

Fungi

A significant reduction in the fungal population was noticed in dimethoate 0.05% (4.50) followed by acetamiprid 0.002% (9.50) and imidacloprid 0.003% (10.75) one day after the first spray (Table 82). NeemAzal T/S 4 ml/l (12.00) and neem oil + garlic emulsion 2% (12.25) recorded high population and were on par with control (12.00). On the third day, the population of soil fungi was significantly low in dimethoate (4.50) followed by acetamiprid (11.00) treated plots. No significant reduction of the fungi was seen in imidacloprid (12.50), NeemAzal T/S (12.50) and neem oil + garlic emulsion (13.50) sprayed plots. On the seventh day again significant population reduction was noted in dimethoate (10.75) treated plots. Acetamiprid (13.75), imidacloprid (14.00), NeemAzal T/S (13.50) and neem oil + garlic emulsion (14.25) were on par with control (14.50). No reduction in the fungal population was recorded in the treatments on the fifteenth day, the population in the various treatments ranging from 15.00 to 15.50 x 10^4 cfu g^{-1} as against 15.25 x 10^4 cfu g^{-1} in the untreated plot.

One day after the second spray too, significant reduction in the fungal population was noted in dimethoate (7.50) treatment. The fungal population in acetamiprid (14.25), imidacloprid (14.25), NeemAzal T/S (14.75) and neem oil + garlic emulsion (15.00) sprayed plots did not differ significantly from the unsprayed plot (15.50). On the third day, with the exception of dimethoate (9.50) which recorded significantly low population of the fungi all the other treatments (14.00 to 15.75) were on par in their effect though they differed significantly from that of control (17.00). The data on seventh, fifteenth and twenty first days indicated no significant reduction of fungal population in all the treatments. The population ranged from 16.25 to 17.00, 17.50 to 18.00 and 19.75 to 20.50 x 10^4 cfu g^{-1} soil as against 17.50, 17.75 and 20.00 x 10^4 cfu g^{-1} soil in the control plot on seventh, fifteenth and twenty first days respectively.

Overall analysis of the data indicated that among the insecticides dimethoate (11.81) was most toxic to fungi. This was followed by acetamiprid (14.56) and imidacloprid (15.06). NeemAzal T/S (15.36) and neem oil + garlic emulsion (15.72) recorded higher fungal population.

With the exception of dimethoate which showed significant inhibition of soil fungi upto three days , all the other treatments did not show any appreciable persistent inhibition of the fungal population.

Bacteria

The plot treated with dimethoate 0.05% (8.75) recorded significantly the lowest population of bacteria on day after the first spraying (Table 83). Compared to the control plot (19.00), significantly lower population of bacteria was recorded in acetamiprid 0.002% (16.50) and imidacloprid 0.003% (16.75) sprayed plots. No significant reduction in the bacterial population was noted in NeemAzal T/S 4 ml/l (18.25) and neem oil + garlic emulsion 2% (19.50) sprayed plots. Similarly on the third day, dimethoate (12.00) treated plot registered significantly low soil bacterial population followed by acetamiprid (17.50) and imidacloprid (18.50) as against 20.50 in the untreated plot. No significant reduction was noted in NeemAzal T/S (19.75) and neem oil + garlic emulsion (20.00) treatments. The bacterial population in all the treatments was on par with untreated control on seven and 15 days after spraying. The population of bacteria in the treatments on these days ranged from 19.50 to 20.25 and 20.75 to 21.75 as against 20.50 and 21.25 respectively in the control plot.

Similarly one day after second spraying, dimethoate (13.50) recorded significantly low population of soil bacteria as against 23.75 in the control plot. The bacterial population in acetamiprid (22.25) ,imidacloprid (22.75), NeemAzal T/S (22.25) and neem oil + garlic emulsion (23.25) did not differ significantly. On the third day too dimethoate (18.00) recorded low population of soil bacteria when compared to control (23.50). However, acetamiprid (22.75), imidacloprid (23.25), NeemAzal T/S (23.50) and neem oil + garlic emulsion (22.75) were on par. From the seventh day onwards no significant reduction was observed in the population of bacteria in the various treatments. The population ranged from 18.00 to 19.25 x 10^4 cfu g^{-1}, 18.25 to 18.75 x 10^4 cfu g^{-1} and 18.75 to 19.75 x 10^4 cfu g^{-1} respectively on seven ,fifteen twenty first day as against 19.00, 18.50 and 18.75 x 10^4 cfu g^{-1} in control.

The cumulative effect of the treatments indicated that dimethoate (16.56) was toxic to the bacteria. Acetamiprid (19.53), imidacloprid (19.92) and NeemAzal T/S (20.28) too was harmful to the bacteria when compared to control (20.63). Neem oil + garlic emulsion (20.44) did not hamper the bacterial population.

With the exception of dimethoate which showed significant inhibition of soil bacteria upto three days, all the other treatments did not show any appreciable inhibition of the bacterial population.

Actinomycete

The data on the first and third day after first spraying showed that there was no significant reduction in the population of actinomycetes in all treatments except dimethoate 0.05% which recorded 3.00 and 2.25 x 10^4 cfu g^{-1} on these days respectively (Table 84). The population of actinomycete in the other treatments ranged from 4.75 to 5.50 x 10^4 cfu g^{-1} and 4.25 to 4.75 x 10^4 cfu g^{-1} as against 5.50 and 4.50 x 10^4 cfu g^{-1} in control. All the treatments did not reduce the population of actinomycetes significantly on seven and fifteen days after spraying.

One day after second spraying low population was recorded in the dimethoate (1.75) treated plot. All the other treatments were on par with control plot (3.50), the population in the various treatments ranging from 3.50 to 4.00 x 10^4 cfu g^{-1}. Three days after the second spraying, with the exception of dimethoate treatment which recorded low population (1.75) all the other treatments were on par with control. The population of actinomycetes ranged from 3.00 to 3.50, 2.50 to 3.00 and 2.25 to 3.00 on 7, 15 and 21 days aftyer spraying respectively and was on par with untreated control (3.25, 2.75 and 2.50)

The data on overall mean revealed that dimethoate treated plot recorded significantly low population of 2.72 as against 3.64 in control. Acetamiprid (3.58), imidacloprid (3.53), neemAzal T/S (3.47) and neem oil + garlic emulsion (3.69) recorded high population and were on par with control (3.64).

With the exception of dimethoate which showed significant inhibition of soil actinomycete upto three days, all the other treatments did not show any appreciable inhibition of the actinomycete population.

Table 82. Fungal population in winged bean plots sprayed with botanicals and chemical insecticides

Treatments	Population of soil fungi (x 10^4 cfu g^{-1} soil)									Pooled mean
	I spray				II spray					
	1 DAS	3 DAS	7 DAS	15 DAS	1 DAS	3 DAS	7 DAS	15 DAS	21 DAS	
NeemAzal T/S 4 ml/l	12.00	12.50	13.50	15.25	14.75	14.75	17.00	18.00	20.50	15.36
Neem oil + garlic emulsion 2%	12.25	13.50	14.25	15.25	15.00	15.75	16.50	17.75	20.25	15.72
Acetamiprid 0.002%	9.50	11.00	13.75	15.00	14.25	14.00	16.25	17.50	19.75	14.56
Imidacloprid 0.003%	10.75	12.50	14.00	15.50	14.25	14.00	17.00	17.50	20.25	15.06
Dimethoate 0.05%	4.50	4.50	10.75	15.00	7.50	9.50	16.75	17.75	20.00	11.81
Untreated control	12.00	13.25	14.50	15.25	15.50	17.00	17.50	17.75	20.00	15.86

CD (0.05) Treatment : 0.35
CD (0.05) Treatment × Interval : 1.07

Table 83. Bacterial population in winged bean plots sprayed with botanicals and chemical insecticides

Treatments	Population of soil bacteria (x 10^6 cfu g^{-1} soil)									Pooled mean
	I spray				II spray					
	1 DAS	3 DAS	7 DAS	15 DAS	1 DAS	3 DAS	7 DAS	15 DAS	21 DAS	
NeemAzal T/S 4 ml/l	18.25	19.75	20.25	21.50	22.25	23.50	19.00	18.50	19.50	20.28
Neem oil + garlic emulsion 2%	19.50	20.00	20.25	21.25	23.25	22.75	19.25	18.25	19.75	20.44
Acetamiprid 0.002%	16.50	17.50	19.50	21.00	22.25	22.75	18.25	18.75	19.25	19.53
Imidacloprid 0.003%	16.75	18.50	20.25	20.75	22.75	23.25	18.75	18.25	19.25	19.92
Dimethoate 0.05%	8.75	12.00	19.50	21.75	13.50	18.00	18.00	18.75	18.75	16.56
Untreated control	19.00	20.50	20.50	21.25	23.75	23.50	19.00	18.50	18.75	20.63

CD (0.05) Treatment : 0.35
CD (0.05) Treatment × Interval : 1.06

Table 84. Actinomycetes population in winged bean plots sprayed with botanicals and chemical insecticides

Treatments	Population of soil actinomycetes (x 10^4 cfu g^{-1} soil)									Pooled mean
	I spray				II spray					
	1 DAS	3 DAS	7 DAS	15 DAS	1 DAS	3 DAS	7 DAS	15 DAS	21 DAS	
NeemAzal T/S 4 ml/l	5.25	4.50	3.50	3.50	3.50	3.25	3.50	2.50	2.25	3.47
Neem oil + garlic emulsion 2%	5.50	4.25	3.00	3.50	4.00	3.50	3.50	3.00	3.00	3.69
Acetamiprid 0.002%	5.25	4.25	3.00	3.50	4.00	3.75	3.00	2.75	2.75	3.58
Imidacloprid 0.003%	4.75	4.75	3.75	3.50	3.75	3.25	3.25	2.50	2.25	3.53
Dimethoate 0.05%	3.00	2.25	3.50	3.75	1.75	1.75	3.25	2.75	2.50	2.72
Untreated control	5.50	4.50	3.25	3.75	3.50	3.50	3.25	2.75	2.50	3.64

CD (0.05) Treatment : 0.29
CD (0.05) Treatment × Interval : 0.89

DAS-Days after spraying

4.3.2.2.6 Yield and Benefit- Cost Ratio

The data on the yield of winged bean are furnished in Table 85.

All the treatments resulted in significantly higher yield when compared to the control plot (11.27 kg). The yield obtained from the insecticide treated plots was on par being 19.93,18.28 and 18.12 kg fruits per plot in acetamiprid 0.002%, imidacloprid 0.003% and dimethoate 0.05% sprayed plots, respectively. Significantly higher yield was also obtained from the plots treated with NemAzal T/S 4ml/l (15.42 kg) fruit and neem oil + garlic emulsion 2% (14.57 kg).

The data on benefit-cost revealed that acetamiprid gave Rs.1.80 in return for every one rupee invested as against control which gave only 1.10. The next best return was from imidacloprid 0.003% which gave Rs.1.65. Benefit: cost ratio of dimethoate 0.05%, neemAzal T/S 0.4%, and neem oil + garlic emulsion 2% were 1.63, 1.39 and 1.28 respectively.

4.3.2.2.7 Residues of insecticides in winged bean fruit

Residues of 0.709, 0.494 and 1.203 ppm were detected in pods of winged bean sprayed with acetamiprid, imidacloprid and dimethoate respectively five days after spraying (Table 86). On the tenth day 0.042 ppm residue of acetamiprid was recorded from the pods while imidacloprid and dimethoate were below detectable level (BDL). Residues of all the insecticides were below detectable level on the fifteenth day after spraying.

Table 85. Effect of botanicals and synthetic insecticides on yield of winged bean and the resultant BC ratio

Treatments	Yield (kg / 20 m^2 plot)	Yield (kg ha^{-1})	Cost of cultivation (Rs ha^{-1})	Expense for insecticides (Rs ha^{-1})	Total expense (Rs ha^{-1})	Gross income (Rs ha^{-1})	Net income (Rs ha^{-1})	B:C ratio
NeemAzal T/S 4 ml/l	15.42	7710	65435	910	66345	92520	26175	1.39
Neem oil + garlic 2%	14.57	7285	65435	2800	68235	87420	19185	1.28
Acetamiprid 0.002%	19.93	9965	65435	782	66217	119580	53363	1.80
Imidacloprid 0.003%	18.28	9140	65435	744	66179	109680	43501	1.65
Dimethoate 0.05%	18.12	9060	65435	972	66407	108720	42313	1.63
Untreated control	11.72	5862	65435	0	65435	70344	4909	1.10
CD (0.05%)	1.95							

Table 86. Harvest time residues of insecticides in winged bean

Treatments	Mean residues (ppm) at intervals (days)		
	5	10	15
Acetamiprid 0.002%	0.709	0.042	BDL
Imidacloprid 0.003%	0.494	BDL	BDL
Dimethoate 0.05%	1.203	BDL	BDL

BDL-Below detectable level

Discussion

5. DISCUSSION

Pests are an integral part of agroecosystems. Consequently, the changes in their densities in time and space and the forces effecting the variations are important. Several factors contribute to the numerical changes in a population. Both density dependant and independent factors are indicted in this phenomenon. In ecosystems with low biological diversity, which are subjected to irregular extrinsic perturbations, populations are regulated by physical environmental factors. But in ecosystems with high biological diversity which are not physically stressed, populations are usually controlled biologically. Thus, understanding the intricacies involved is of prime importance in designing sustainable pest management strategies.

Aphids, which damage plants through direct feeding and as vectors of plant pathogenic viruses are a menace in vegetable cultivation. Different species of the pest predominate on different host plants and locations. Identification of the species involved is vital since each species is a part of a complex system of interacting factors. A hierarchy of different processes control population growth of aphids at various levels of abundance. Host attributes influence the in population dynamics to a large extent, while extreme climatic conditions may periodically suppress populations of aphids to very low levels. Again, factor reducing parasitoids and predators could result in economic damage to the crop (Kaplan and Eubank, 2002). Apparently estimates of population density taking into account the ecosystem may provide the most appropriate approach to unravel processes affecting the population dynamics of aphids. Comprehensive studies should be undertaken in each location to unveil the interactions of the pest with the natural enemies, host plants and weather. These studies give a good understanding of the system and could establish a basis for the development of future aphid management. Often, effortless control measures would suffice in checking the pest. The present study provides an insight into the aphid species associated with different vegetables, their natural enemies and factors influencing their possible outbreak and measures to tackle them.

5.1. Aphid fauna in vegetables

Exploratory studies on the aphid fauna associated with various vegetables in Thiruvananthapuram district of Kerala revealed the prevalence of eight species under the sub family Aphidinae. The species recorded were melon aphid, *A. gossypii*; the cowpea aphid, *A. craccivora*; the spirea aphid, *A. spiraecola*; the oleander aphid, *A. nerii*, the bean aphid, *A. fabae;* the rusty plum aphid *H. setariae;* the mustard aphid, *L. erysimi* and the green peach aphid, *M. persicae*. Since the species encountered were well described, the important external characters of the species aiding in their tentative identification in the field were alone elaborated. A key which would aid in confirming the identity of these common aphid species of vegetables is also provided. Tender leaves and shoots, buds, flowers and young fruits of the plants were vulnerable to the attack of the homopteran. Despite an array of aphids like *A. gossypii* (okra, tomato, chilli, brinjal, and cucurbits); *A. malvae* (okra and bittergourd); *M. persicae* (chilli), *Aulacorthum solani* (Kaltenbach), *A. nastrutii*, *M. euphorbiae* and *M. ornatus* (tomato); *L. erysimi* and *B. brassicae* (crucifers) and *A. craccivora* (cowpea) infesting vegetables (Nasir and Yousuf 1995; Nair, 1995), only *A. gossypii*, *A. malvae* and *A. craccivora* (Nair, 1995) and *A. spiraecola* (Vijayasree, 2006) have been documented in Kerala. More species of aphids were observed infesting various vegetables in the present study. Infestation of *A. gossypii* on *C. grandis*, *M. oleifera* and *P. tetragonolobus*; *A. craccivora* on *C. gladiata*, *P. tetragonolobus* and *S. grandiflora* ; *A. spiraecola* on *A. tricolor, C. sativus, C. tetragonoloba, M. oleifera, M. charantia, M. koeingii, P. tetragonolobus* and *S. androgynus* ; *M. persicae* on *A. tricolor* and *R. sativus*, *A. nerii on C. annuum* and *C. frutescens* observed in the study were first records from the State. The vegetable host plants of *H. setariae* viz., *A. tricolor* and *A. dubius* were first records from South India.

Besides vegetables, several weeds in the plots and other plants on the bunds and nearby areas were recorded as hosts of the aphids. Interestingly, of the one hundred and fifty four host plants documented, vegetables constituted only 20.78 per cent of the plant assemblage with weeds and other plants forming 79.22 per cent (Fig.1a). Of the other host plants recorded, 43, 20, 25, 2, 8, 1, 1 and 14, respectively of *A. gossypii, A. craccivora, A. spiraecola, L. erysimi, M. persicae, A. nerii, A. fabae* and *H. setariae* were first records from South India. Likewise, 11, 2, 1, 3, 3, 1 and 5 other host plants, respectively of *A. gossypii, A. craccivora, A. spiraecola, L. erysimi, A. nerii, A. fabae* and *H. setariae* were first records from Kerala. The host plants belonged to a wide range of plant families. While the vegetables were from only 22 per cent of the plant families (Fig.1b), the weeds and other plants belonged to a wider range of plant families (78 per cent). Evidently, a number of unimportant plants are acting as reservoirs of the pest in the vegetable ecosystem. Since infestation on crops start when a few winged aphids fly into the crop from elsewhere, the proper management of these sources is imminent.

Among the aphids recorded, *A. gossypii* was the most dominant aphid pest of vegetables, infesting 39.03 per cent of the crops surveyed, closely followed by *A. craccivora* (16.66 per cent) and *A. spiraecola* (16.66 per cent). While *Myzus persicae* and *L. erysimi* each infested 9.25 per cent vegetables, *A. nerii, A. fabae* and *H. setariae* each attacked 3.70 per cent vegetables (Fig.1c). Fifty per cent of the host vegetables of *A. gossypii* were from the plant family Cucurbitaceae, 20 per cent from Solanaceae, 10 per cent from Fabaceae and 5 per cent each from Moringaceae, Malvaceae, Amaranthaceae and Umbelliferae (Fig. 2a). The other host plants of the pest including weeds were from a diverse range of

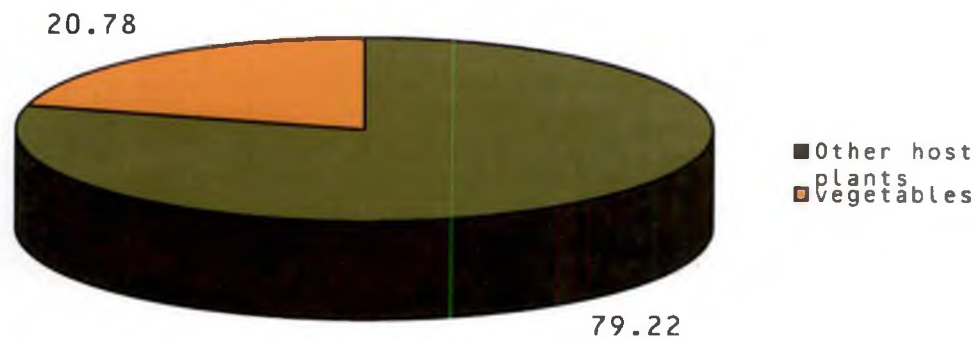


Fig 1a. Occurrence of aphids on vegetables and other host plants

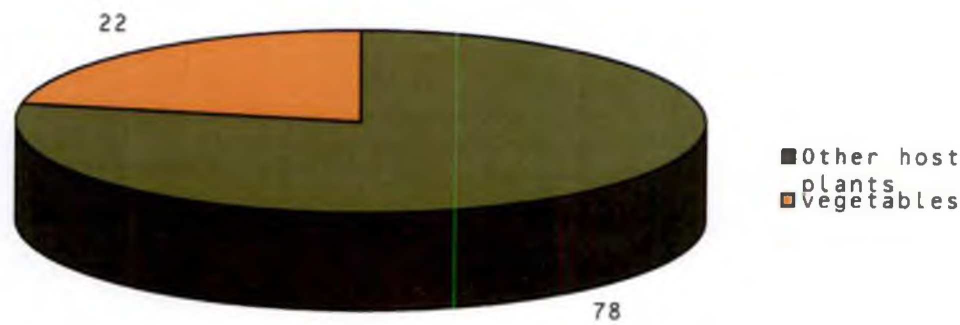


Fig 1b. Plant taxa of vegetables and other host host plants of aphids

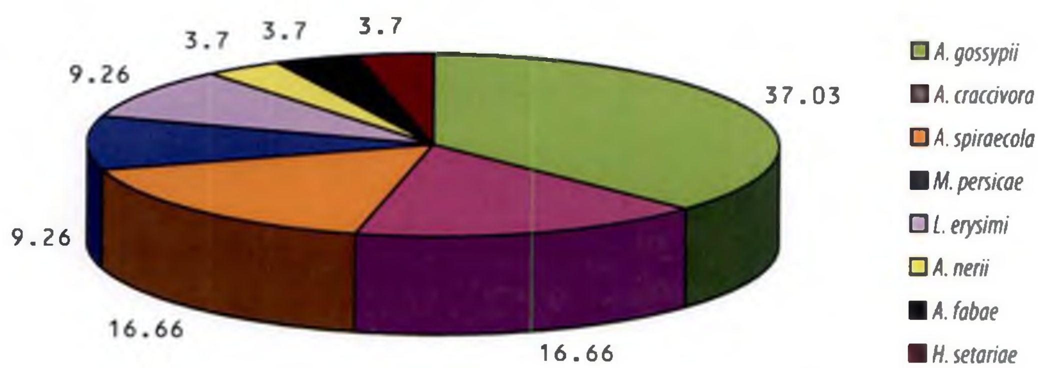


Fig 1c. Extent of infestation of different aphids in vegetables

families (30).The results are in consonance with earlier reports on the highly polyphagous nature of the aphid, occurring on numerous plant families (Raychaudhuri, 1980; Joshi, 2005).

Seventy eight per cent of the vegetable host plants of *A. craccivora* belonged to the plant family Fabaceae while only 11 per cent plants were recorded each from Amaranthaceae and Moringaceae (Fig. 2b). The weed and other host plants too were mostly of Fabaceae family (23). This clearly indicated the preference of the aphids for plants in the family Fabaceae. Though the aphid occurs most commonly on legumes, it is also known to attack more than 50 other crops in more than 19 different plant families (Emden and Harrington, 2007). However, in the present study, only crops in a few other plant families were noted to host the aphid.

While 33.32 per cent of the vegetable hosts of *A. spiraecola* were from Cucurbitaceae and 22.22 per cent from Fabaceae, the plant families viz., Amaranthaceae, Moringaceae, Rutaceae and Euphorbiaceae each contributed 11.11% of vegetables (Fig. 2c). However, the weeds and other plants belonged to a wide range of families. The results of the study corroborate with earlier findings on the polyphagous nature of the pest (Raychaudhuri et al, 1981; Joshi, 2005).

M. persicae was mainly recorded from vegetables in Solanaceous family (60 per cent) followed by Amaranthaceae (20 per cent) and Brassicaceae (20 per cent) (Fig. 2d). Very few weeds in the vegetable plots harboured the pest. Though reported to be extremely polyphagous (Chakrabarti and Sarkar, 2001; Joshi, 2005), it could be recorded only from a few plants in the study conducted. *L. erysimi* was mostly recorded from vegetables in Brassicaceae (80 per cent) agreeing with earlier reports (George, 1927; Joshi, 2005). Only 20 per cent of vegetables were from Umbelliferae (Fig. 2e). Contrarily, the weed host plants belonged to a wide

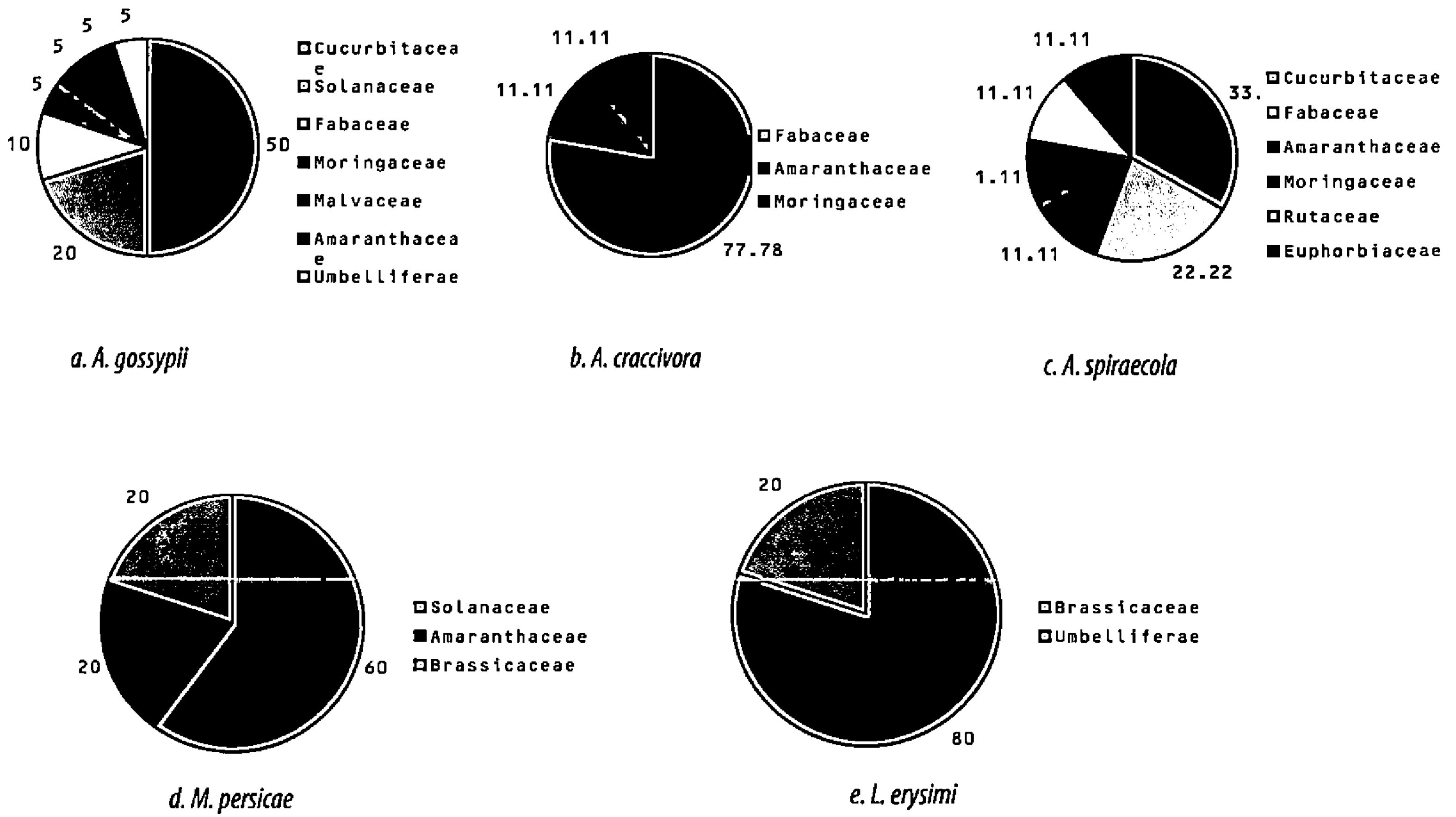


Fig 2. Plant taxa of vegetable host plants of aphids recorded from Thiruvananthapuram district

range of families, the 12 plants identified belonging to 8 families. While *A. nerii* was recorded solely from Solanaceaous vegetables, the weed host plants belonged to unrelated families viz. Ascelepiadaceae and Apocynaceae. The observations were in agreement with earlier findings (David, 1958b; Raychaudhuri et al, 1981; Joshi, 2005). Though *A. fabae* was recorded from vegetables of Fabaceaeous family, it was also recorded from weeds in the Solanaceous family. Similarly *H. setariae* was noted only on Amaranthaceaous vegetables. However, of the 20 weed hosts only two were from Amaranthaceae, 15 from Poaceae, 2 from Cyperaceae and one from Asteraceae. The preference of the aphid for plants in Poaceae has been observed earlier (Gadiyappanavar, 1970; Raychaudhuri et al, 1981; Joshi, 2005).

Among the vegetables surveyed, maximum species (5) were recorded on amaranthus, the aphids recorded being *A. gossypii, A. craccivora, A. spiraecola, Myzus persicae* and *H. setariae.* This was followed by winged bean which supported *A. craccivora, A. gossypii, A. fabae* and *A. spireacola.* Three aphid species were recorded on chilli (*A. gossypii, A. nerii, Myzus persicae*), cowpea (*A. craccivora, A. gossypii, A. fabae*) and drumstick (*A. craccivora, A. gossypii* and *A. spiraecola*). Only one species of aphid attacked the other vegetables.

5.1.1 Natural Enemies

Natural enemies can reduce the rate of increase of herbivores radically. Various studies have demonstrated the explosive reproductive potential of aphids in the absence of biological control agents. Identification of the key natural enemies is of paramount importance in designing practical management strategies. Between predators (92.85 per cent) and parasitoids (7.15 per cent), predators were the dominant group of natural enemies encountered in the vegetable fields of Thiruvananthapuram district (Fig. 3a). The predatory fauna comprised of coccinellids, syrphids, chamaemyiids chrysopids, hemerobiids and spiders. The aphidophagous coccinellids constituted the major predatory fauna (51.30 per cent) followed by the spiders (28.20 per cent). While the syrphids formed 10.25 per cent of the fauna, the chrysopids contributed 5.13 per cent and hemerobiids and chamaemyiids 2.56 per cent each (Fig. 3b). As aphids are early colonizers in crop fields and prevail in large numbers, they form an excellent source of food for predators. This verity might have accounted for the predominance of the predatory fauna in the vegetable fields. Moreover, a few of the predators like syrphids, chrysopids, hemerobiids and chamaemyiids specialize on aphids.

Among the coccinellids, *M. sexmaculatus* (22.45 per cent) was the dominant species followed by *C. transversalis* (20.92 per cent) and *S. latemaculatus* (15.82 per cent). *C. septempunctata, P. trinotatus, H. octomaculata, B. suturalis, M. discolor, P. japonica, Nephus* sp. and *P. flaviceps* contributed to 6.12, 5.61, 4.59, 4.02, 3.06, 3.06, 2.55 and 2.55 per cent of the coccinellid population, respectively. The other coccinellids together constituted 9.18 per cent of the population (Fig. 3c). Of the 20 coccinellids recorded, 13 species viz., *S. latemaculatus, P. trinotatus, P. japonica, P. flaviceps, S. obscurella, S. o-nigrum, C. orbiculus, S. castaneus, S. coccivora, S. rougeti, P. perrotteti, Sticholotis* sp. and *Telsimia* sp. were new reports from Kerala. Coccinellids are potential predators of small and soft bodied insect pests like aphids, mealy bugs, scales etc of agricultural crops. A number of the coleopteran predators have been reported feeding on aphids (Behura, 1965; Agarwal and Gosh, 1988; Suja, 2003; Joshi, 2005). Within the prey group too, they show distinct preference. *M. discolor* preferred *A. gossypii* the most followed by *A. craccivora* and *A. nerii* the least. *C. punctata* had a high preference for *M. persicae* (Omkar et al, 1997), *C. transversalis* for *A. craccivora* (Omkar et al, 1999) and *Cheilomenes sexmaculatus* for *A. gossypii* (Omkar and Bind, 1998). *A. nerii* was least preferred by all the lady beetles (Omkar et al, 1999). The results of the study are in consonance with previous observations on the divergent penchant of the predators for different aphid prey. Excepting *P. trinotatus*, the major prey of all the coccinellids was *A. gossypii* followed by *A. craccivora*. *P. trinotatus* preferred *A. craccivora* over *A. gossypii*. Of the 20 species of coccinellids recorded 17 species were associated with *A. gossypii*, 14 with *A. craccivora*, 4 with *H. setariae* and 2 each with *M. persicae*, *A. nerii*, *L. erysimi* and *A. fabae* respectively. Preference of the lady beetles for certain aphid species might be due to variation in food quality caused by difference in the chemical constituents present in aphid infested host plants (Omkar et al, 1999).

Among the four syrphids recorded, *I. scutellaris* was the predominant species contributing to 52.38 per cent of the aphidophagous syrphid population. *P. yerburiensis*, *P. serratus* and *D. aegrota* contributed to 19.04, 15.48 and 13.10 per cent of the population, respectively (Fig.3c). All the syrphids predated on *A. gossypii* and *A. craccivora*. While *I. scutellaris*, *P. serratus* and *P. yerburiensis* were associated with *A. spiraecola*, *H. setariae*, *I. scutellaris* and *P. serratus* preyed on *A. nerii* and *L. erysimi* too. Two syrphid predators viz. *P. yerburiensis* and *D. aegrota* were recorded for the first time from Kerala. *Leucopis* sp. was the only chamaemyiid species recorded from the vegetable fields. The predator was noted preying on *A. gossypii*, *A. craccivora*, *H. setariae* and *M. persicae* and was found more associated with *A. gossypii* and *A. craccivora*. Aphidophagous syrphids play an important role in the suppression of many aphid hosts of economic importance (Verma, 2003) since a single syrphid larva is deemed to destroy 484 aphids in four hours (Lefroy, 1909). Though several species of syrphids were recorded from different parts of India (Rao, 1969; Gosh, 1974; Ghorpadae, 1981; Joshi, 2005), only four species could be recorded in the present study.

The chrysopids, *C. carneae* and *A. octopunctata* and the hemerobiid, *Micromus* sp. were the Neuropteran predators recorded. *Micromus* sp. was dominant (53.85 per cent) in the vegetable fields and was recorded preying on three aphid spp. viz. *A. gossypii, A. craccivora* and *A. spiraecola* followed by *C. carneae* (26.42 per cent) and *A. octopunctata* (19.23 per cent) (Fig.3c). *A. octopunctata* was recorded for the first time from Kerala. Over 60 species of chrysopids have been recorded in India of which *C. carnea, A. crassinervis, M. boninensis* and *M. astur* were reported to be common predators of pests (Singh and Narasimham, 1992).

Among the eleven species of spiders observed, *O. javanus* (19 per cent), *T. mandibulata* (16.46 per cent), *O. quadridentatus* (13.92 per cent), *O. shweta* (13.42 per cent) and *Phidippus* sp. (11.39 per cent) were the frequently encountered species in the vegetable fields (Fig.4a). *A. gossypii* and *A. craccivora* were the most commonly preyed aphid species. Earlier, thirty species of spiders were documented from various vegetable fields of Trivandrum district of Kerala (Manu and Hebsy Bai, 2006). Spiders are the most familiar, efficient and ubiquitous obligate predators, which feed on different types of prey. Though the araneae have no discriminatory reaction and consume whatever prey is offered, they do show preference for soft bodied insects like aphids (Mathirajan and Regupathy, 2003; Manu, 2005). Since they abound in agricultural fields and being an important part of natural control mechanism the carnivore could contribute enormously to stabilize the holistic pest population if conserved or augmented.

Of the three species of parasitoids recorded, *Aphidius* sp. (50 per cent) was the most dominant (Fig.4b) in the vegetable fields followed by *Aphelinus* sp. (34.62 per cent) and *D. rapae* (15.38 per cent). Parasitisation of *A. gossypii* and *Myzus persicae* by *Aphidius* sp. and

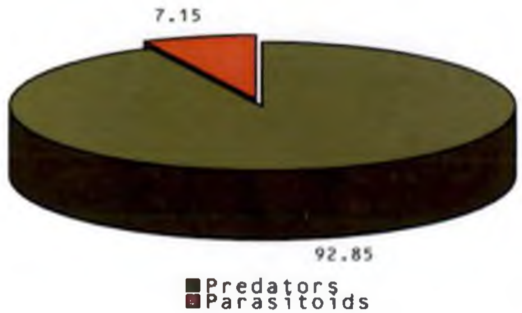


Fig 3a. Relative abundance of predators and parasitoids of aphids in vegetable fields

Fig 3b. Relative abundance of predatory fauna in vegetable fields

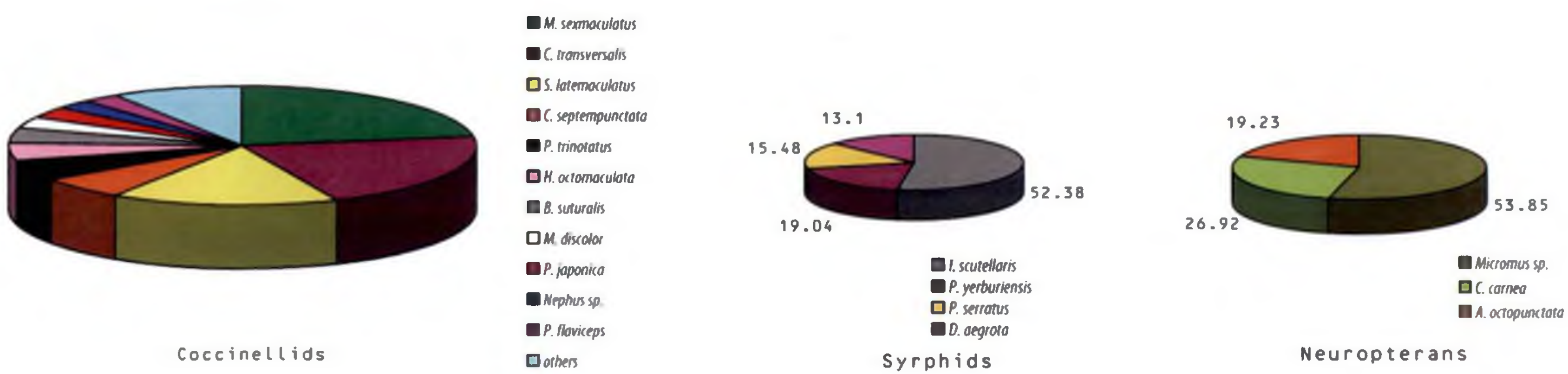


Fig 3c. Species richness of different predators in vegetable fields

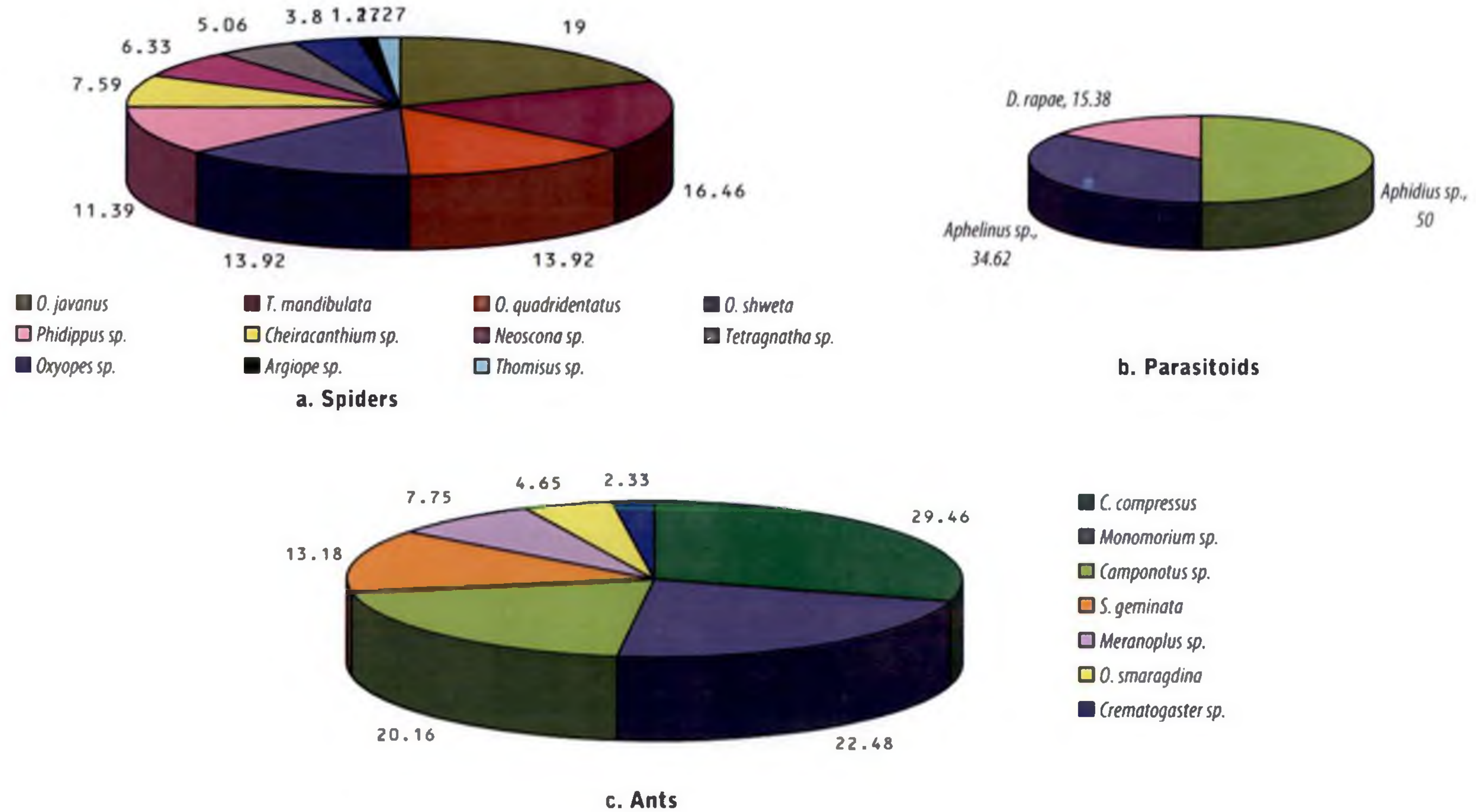


Fig 4. Relative abundance of different species of spiders, parasitoids and ants in vegetable fields

Aphelinus sp. was observed in unsprayed chilli fields in Karnataka (Mani and Krishnamoorthy, 1994). Fourteen species of aphidiid parasitoids and two species of aphelinid parasitoids parasitising seventeen species of aphids in different host plants too were recorded (Joshi, 2005)

Several ants were recorded attending the aphids of which *C. compressus* (38 per cent) associated with six aphid species was the most dominant followed by *Monomorium* sp. (22.48 per cent) associated with five aphid species and *Campontus* sp.(22.16 per cent) with six aphid species (Fig.4c). *O. smaragdina* and *Crematogaster* sp. were related exclusively with *A. spiraecola*. Aphids exude honey dew which attracts ants. The pest benefits from ant-tending because the presence of ants deter insect predators, thus increasing their feeding rate and also transport them to new plants when resources are depleted. The protection that ants give the aphids varies depending on the type of predator. Generally, they are better in dealing with lady bird larvae. The number of ants associated with a given species of aphid and the number of aphid species associated with a given species of ants varies from place to place. Understanding the interaction between species or populations is a prerequisite for predicting ecological phenomena at all levels of biological organization.

Considering the intensity of infestation of *A. gossypii* and *A. craccivora* in the different vegetables in the various locations, more incidence of *A. gossypii* was observed in chilli and coccinia as indicated by the population of the aphid and damage index recorded (Fig.5). Okra, brinjal and bittergourd too showed appreciable level of infestation. Incidence of *A. craccivora* was the highest in winged bean followed by cowpea (Fig.6). Mosaic disease incidence was noted in 10 vegetables, the percentage of infected plants being high in bittergourd (22.7), coccinia (20.23), cucumber (16.06), cowpea (14.53) and amaranthus (10.43). Aphids damage crops not only through direct feeding but also vectors

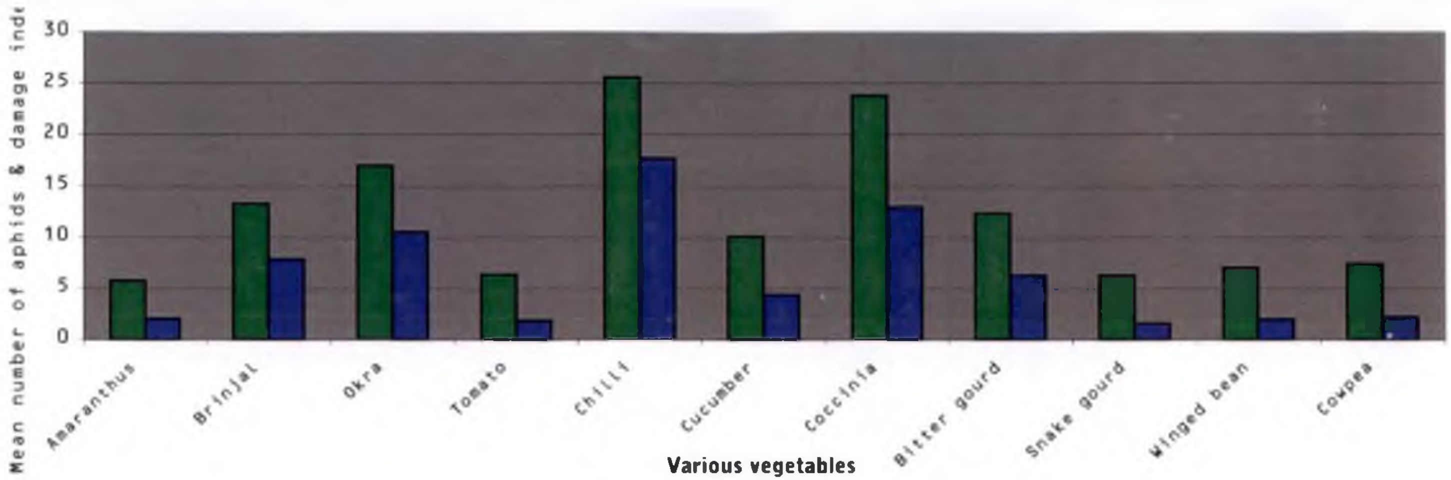


Fig 5. Incidence of *Aphis gossypii* in different vegetables in Thiruvananthapuram district

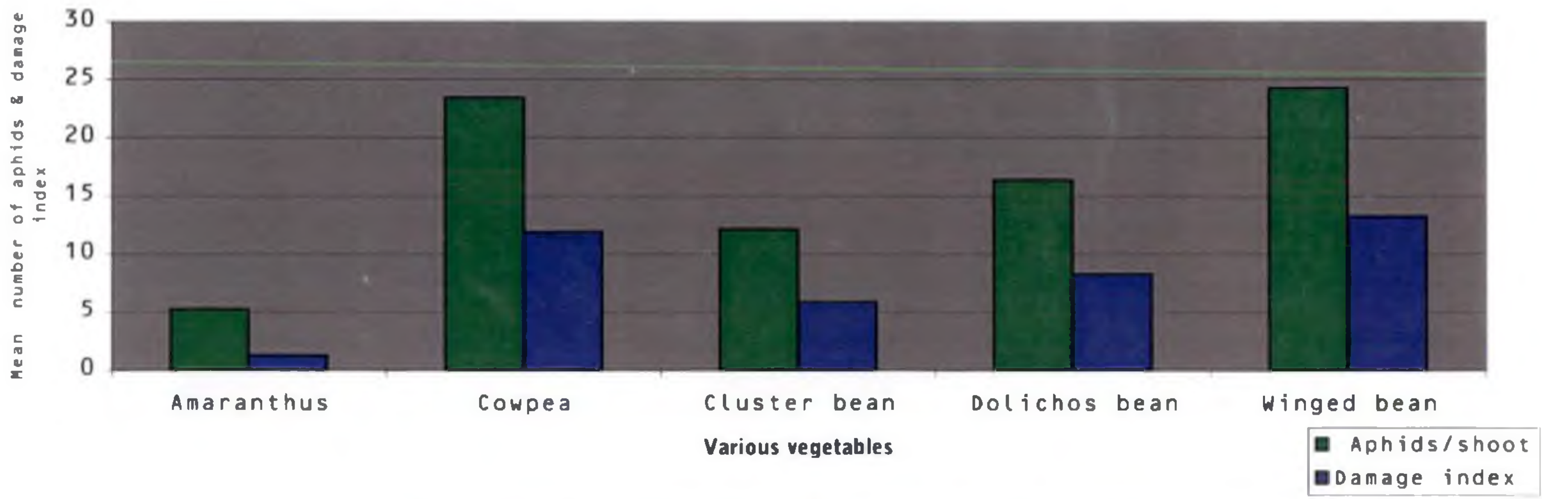


Fig 6. Incidence of *Aphis craccivora* in different vegetables in Thiruvananthapuram district

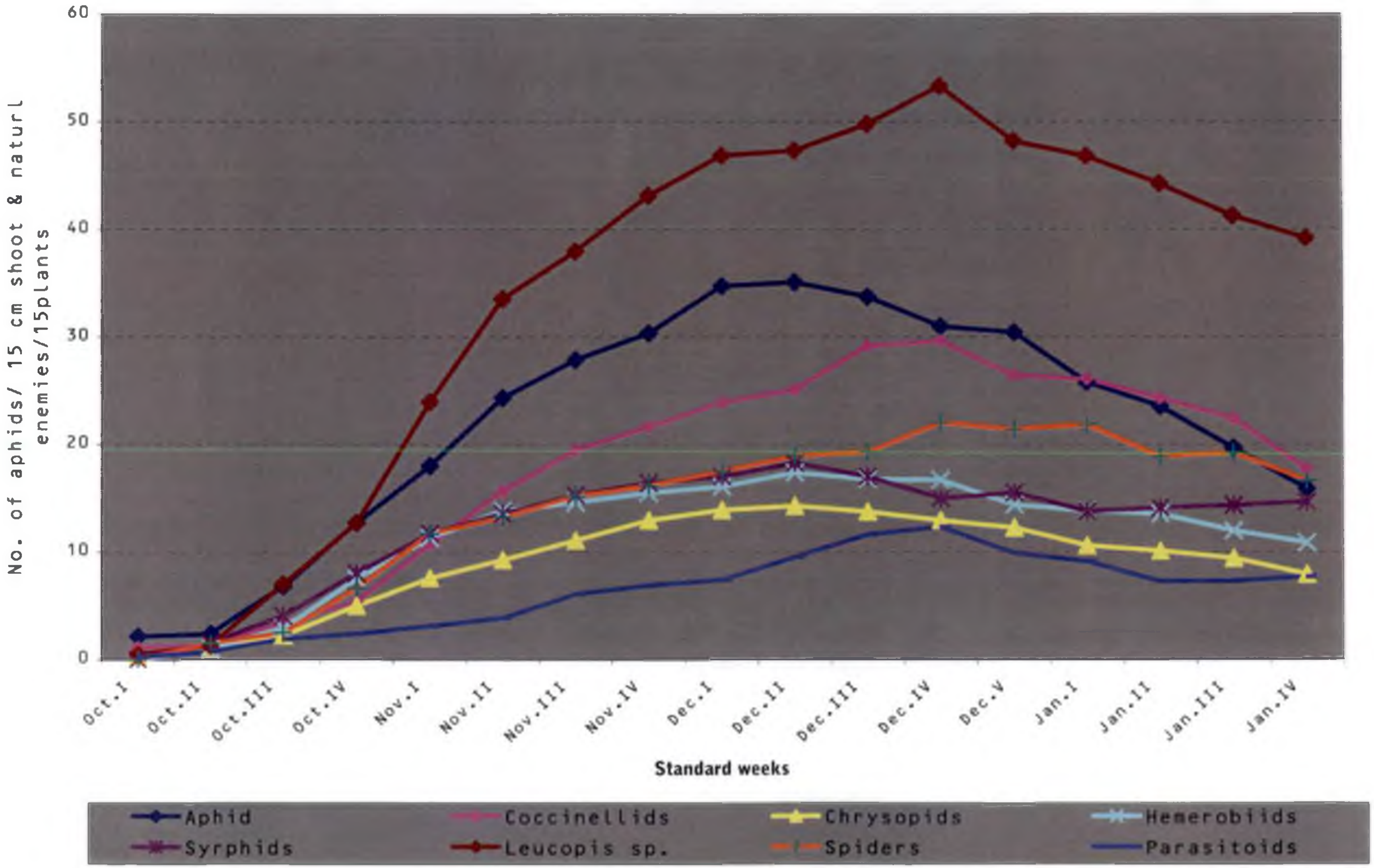


Fig 7. Population fluctuation of *Aphis gossypii* and their natural enemies in chilli

numerous devastating viral diseases. More than 50 plant viruses are transmitted by *A. gossypii* and 30 by *A. craccivora* (Embden and Harrington, 2007). Hence, the role if any of these aphid pests in the diseases observed need to be established.

5.2 POPULATION DYNAMICS

Studies on the population fluctuation of *A. gossypii* in chilli (Fig.7) and *A. craccivora* in winged bean (Fig.8) within their optimum/preferable cropping season indicated that both the aphids prevailed in the crop throughout the cropping period in varying densities. Population of both the aphids was very low during the early phase of the crop. This was due to the rains received during the period, signifying that aphid populations were negatively influenced by the weather parameter. After the rains, appreciable population was seen and the population showed an increasing trend hence forth. High population was seen during November and December coinciding with the active vegetative stage of the crops. Thereafter, a decrease was recorded in the population of the pests. With regard to the natural enemies, comparatively, more predators prevailed in the field than the parasitoids. Among the predators, *Leucopis* sp. was seen to dominate in both the crops followed by the coccinellids and spiders. Higher population of the predators coincided with that of the aphids.

Correlation studies revealed a significant and positive correlation between the population of both the aphids with the insect predators, spiders and parasitoids. None of the climatic parameters prevailing during the period had any significant influence on the aphid population. In general, with the exception of maximum temperature which had a positive influence, all the other weather parameters viz., minimum temperature, relative humidity, rainfall and wind velocity had a negative influence on the population of the predators and parasitoids. These results suggested that host attributes and natural enemies influenced the population dynamics

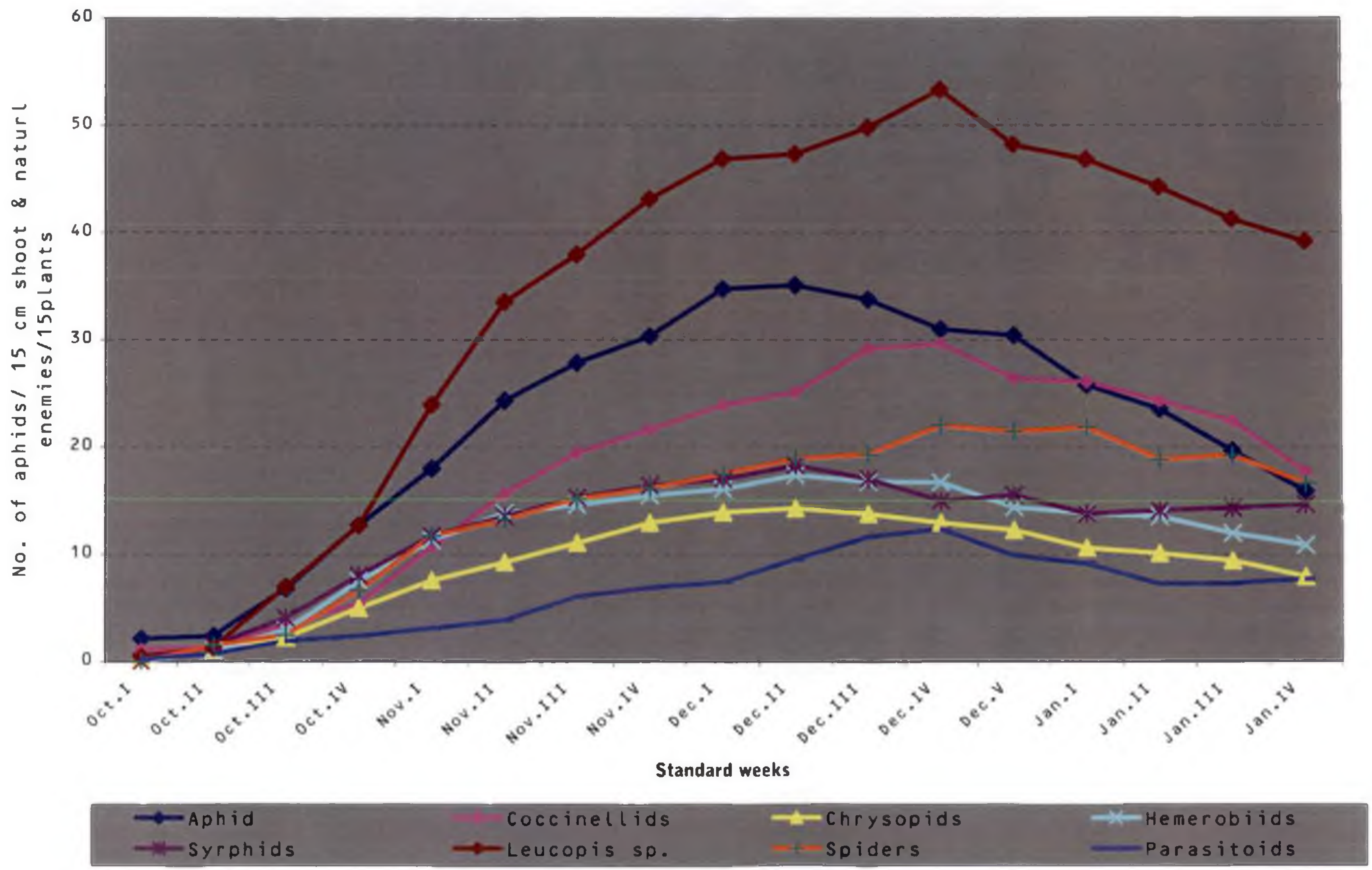


Fig 7. Population fluctuation of *Aphis gossypii* and their natural enemies in chilli

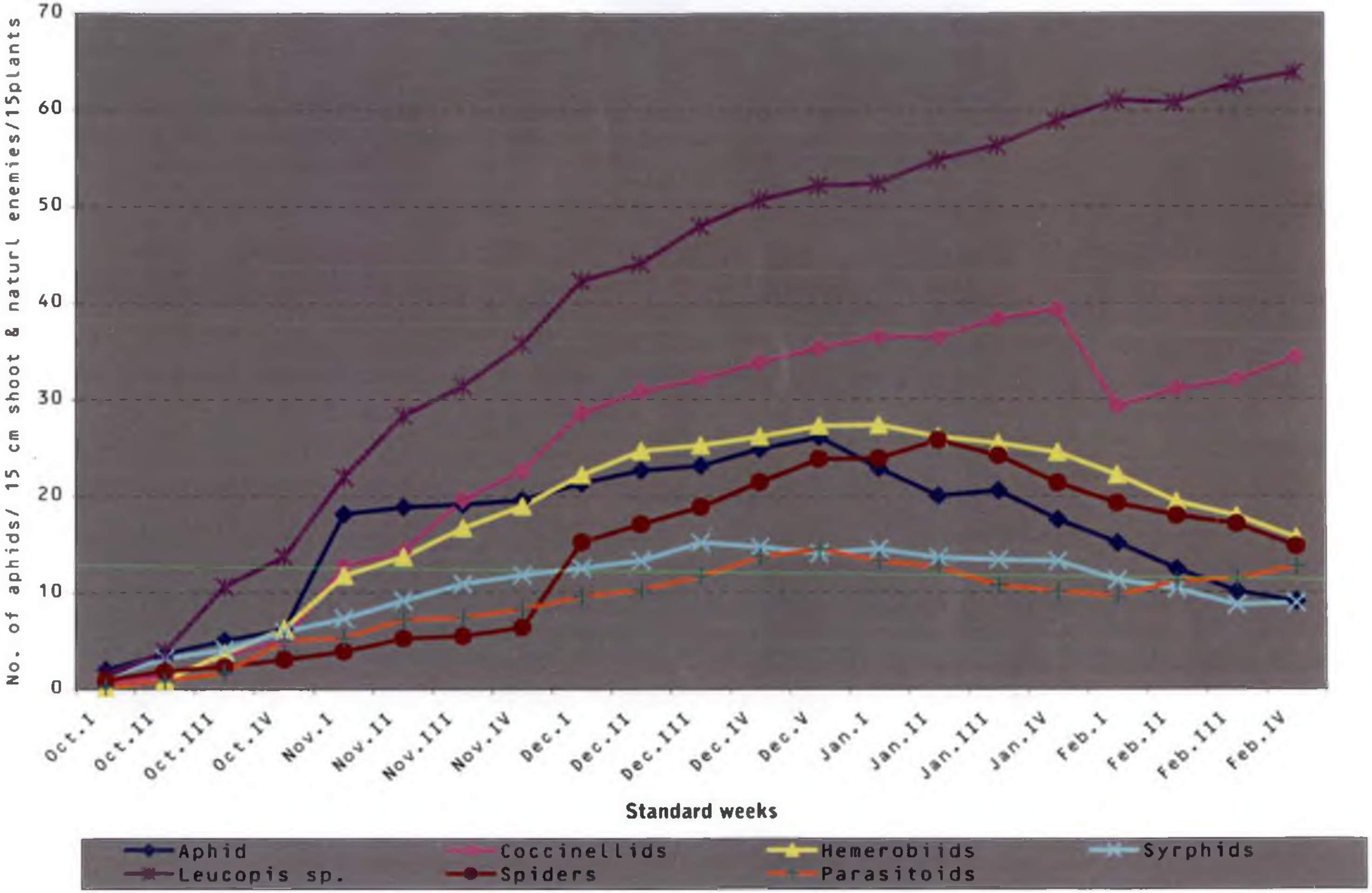


Fig 8. Population fluctuation of Aphis craccivora and their natural enemies in chilli

of the aphids to a larger extent with extreme climatic conditions like rain periodically suppressing populations of aphids to low levels.

Aphids have complex population dynamics often characterized by wide variations of population density, both on a temporal and spatial scale. Several factors including weather, natural enemies and intrinsic quality of host plants have been attributed to this phenomenon. Many workers have reported rainfall as the major factor reducing aphid population (Koul and Desh Raj. 1999 and Purohit et al, 2006). Analyses of long time –series data revealed that density dependent processes commonly regulate populations of aphids (Sequeira and Dixon, 1997; Jarosik and Dixon, 1999). Interactions among aphids and their host-plant largely contribute to the regulation of aphid populations through the intrinsic quality of host plants (Karley et. al., 2003). Within – year seasonal declines of aphid abundance are often correlated with a high level of predation, parasitism or fungal disease (Karley et. al., 2003). However, populations of aphids sometimes exhibit similar variations in abundance over time in the presence or absence of natural enemies (Kidd, 1990), suggesting that host plant attributes influence the population dynamics of aphids to a larger extent than natural enemies because density- dependence is more frequently induced by bottom–up (host plant attributes) than top down forces (biocontrol agents) (Stiling, 1988; Harrison and Cappuccino,1995). In a study on the population dynamics of *A. gossypii* on cotton in Brazil, increase in the population of the pest was favoured by the presence of flower buds (Araujo and Sales, 1985). The results of the present investigation indicated that probably both the natural enemies along with the host attributes influenced the pest population. However, since the study was conducted during only the optimum season of the crops, the processes underlying variations of population density cannot be stated unequivocally. Further studies are needed in order to establish an useful extension of this prediction.

5.3 MANAGEMENT

Different methods have been employed to keep the population of aphids below economic injury level. Chemical control with the conventional insecticides is losing in effectiveness, paving the way for alternate technologies. Suitable measures based on agroecological techniques are the need of the hour to save vegetables from the noxious pest. In this context, plant products exhibiting diverse biological activities and newer insecticide molecules with high efficacy, low dose requirement and low toxicity proffer to be a preferable option.

Among the plant oils, plant extracts and a commercial formulation screened in the laboratory for their pest control efficiency, only neem oil+ garlic emulsion 2 per cent and NeemAzal T/S 4 ml/l recorded 50 per cent mortality against *A. gossypii* and *A. craccivora.* Among the insecticides, the neonicotinoids viz., acetamiprid 0.002%, imidacloprid, 0.003%, and dimethoate 0.05% proved superior to all other treatments. While the effect of the insecticides persisted against *A. gossypii* upto 12 DAT, against *A. craccivora*, it was seen upto 9 DAT.

Insecticides used to control insect pests often affect the non- target biocontrol agents. Information on their toxicity is essential to choose the bioagent- friendly- insecticide in integrated pest management. Evaluation of the relative toxicity of NeemAzal T/S, neem oil + garlic emulsion, acetamiprid, imidacloprid and dimethoate against the coccinellid predators in the laboratory, revealed that the botanicals were safe to the various coccinellids, the extent of mortality recorded for neem oil + garlic emulsion ranging from 14.10 to 33.30 per cent and for NeemAzal T/S from 17.45 to 36.62 per cent. Among the insecticides, dimethoate was highly toxic, the extent of mortality ranging from 90.17 to 99.58 per cent. Between the two neonicotinods, acetamiprid registered higher mortality ranging from 56.67 to 77.13 per cent (Fig.9). Comparatively, imidacloprid recorded lower mortality (42.48 to 58.76 per cent). Among the dipterans,

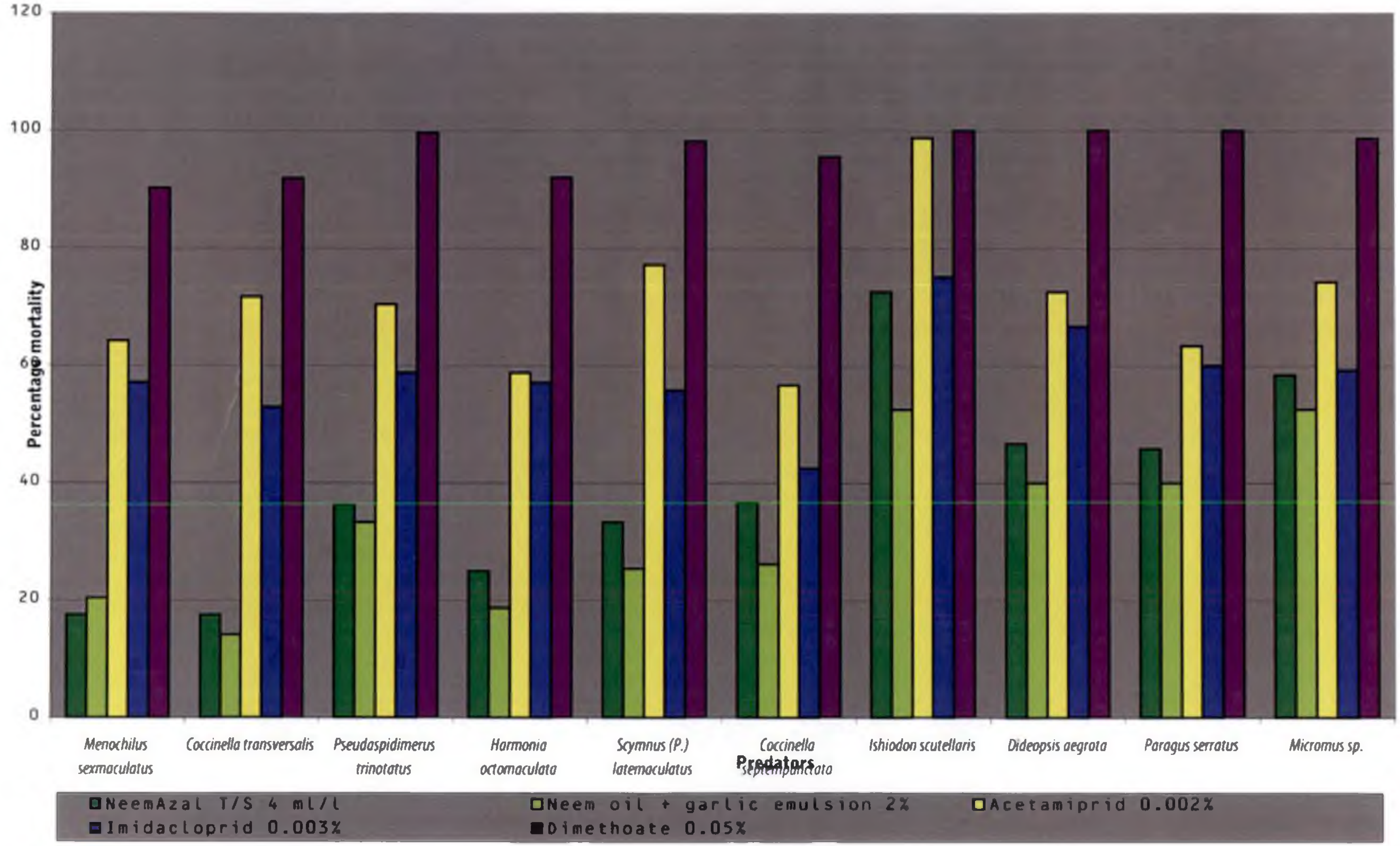


Fig 9. Relative toxicity of botanicals and synthetic insecticides to various predators

both the botanicals and the insecticides were more toxic to *I. scutellaris*, the mortality being 52.50, 72.54, 98.77, 75.09 and 100 per cent to neem oil +garlic emulsion, NeemAzal T/S, acetamiprid, imidacloprid and dimethoate respectively. While the botanicals showed lesser toxicity to *D. aegrota* and *P. serrata*, appreciable toxicity was exhibited towards *Micromus* sp. Dimethoate was extremely toxic (100 per cent mortality) to all the dipteran predators. Between the neonicotinoids, imidacloprid (60.01 to 75.09 per cent) was less toxic than acetamiprid (63.35 to 98.77 per cent).

When the botanicals and newer molecules of insecticides were tested in the field on chill, dimethote and acetamiprid recorded high reduction of *A. gossypii* population being 82.85 and 81.84 per cent, respectively followed by imidacloprid (75.4). The extent of reduction of the pest was only 42.74 and 38.14 per cent, respectively for NeemAzal and neem oil-garlic emulsion. A similar trend was seen in the effect of the treatments on the other sucking pests viz *S. dorsalis, A. biguttula biguttula* and *A. dispersus*, the percentage reduction in the different treatments ranging from 66.76 to 74.89 in the insecticide treated plots and 38.12 to 50.22 in botanical treated plots (Fig.10). Significantly higher yield was also obtained from all the treated plots. There was no significant difference in the yield obtained from dimethoate 0.05% (16.44 kg), acetamiprid 0.002% (15.75 kg) and imidacloprid 0.003% (15.47 kg) treated plots. NeemAzal T/S 4ml/l and neem oil + garlic emulsion 2% recorded 13.89 kg and 13.54 kg of chilli per plot.

In winged bean, acetamiprid 0.002% was the most effective insecticide against *A. craccivora* registering 73.36 per cent reduction in the population of the pest (Fig.11). Both imidacloprid (68.57 per cent) and dimethoate (68.03 per cent) resulted in equal suppression of the pest. The extent of population reduction in the botanicals ranged from 41.57 to 47.59 per cent.

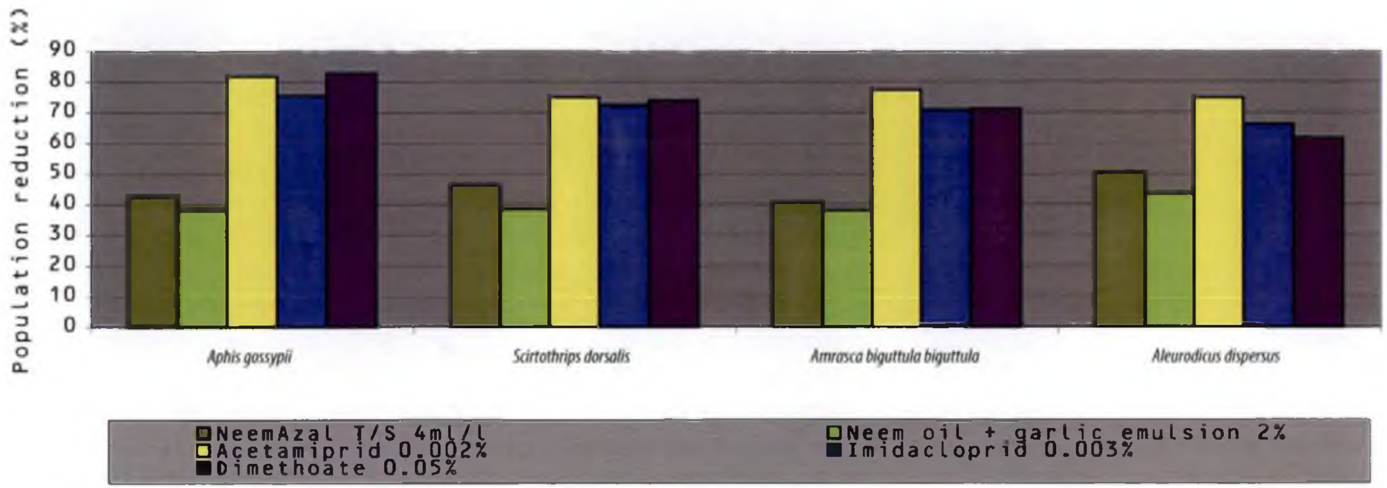


Fig 10. Effect of botanicals and synthetic insecticides on various pests infesting in chilli

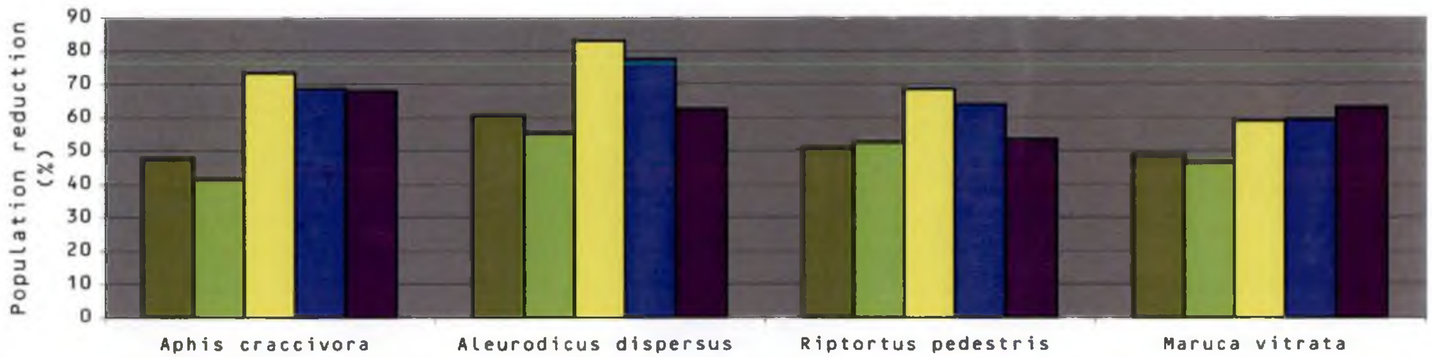


Fig 11. Effect of botanicals and synthetic insecticides on various pests infesting in winged bean

Similarly, acetamiprid gave maximum reduction of the white fly (83.03 per cent) and pod bugs (68.49 per cent) followed by imidacloprid (77.51 and 63.87 per cent), respectively. Dimethoate resulted only in 62.57 and 53.36 per cent reduction of the pest populations, respectively. Contrarily, dimethoate was most effective against the pod borer *M. vitrata* followed by imidacloprid (59.43) and acetamiprid (59.00). The botanicals too gave significant reduction of the pest (55.36 to 60.45 per cent). Efficacy of the insecticides persisted upto 7 DAS and botanicals 3 DAS. All the treatments resulted in significantly higher yields, the yield obtained from the insecticide treated plots being at par. Significantly higher yield was also obtained from the plots treated with NeemAzal T/S 4ml/l and neem oil + garlic emulsion 2%.

The results are in agreement with earlier findings. The efficacy of neem products like neem oil, neem oil -garlic emulsion, NeemAzal and Econeem against aphids and other pests of vegetables has been reported (Chandrasekaran, 2001; Sivakumar, 2001; Hebsy Bai et al., 2002 and Thilagam et al. 2008). Similarly, the effectiveness of imidacloprid (Patil et al., 2002), acetamiprid (Jayewar et al., 2003) against sucking pest complex of chilli and dimethoate against various pests (Nagia et al., 1990; Borach and Nath, 1996) were documented. Few reports are there on the effectiveness of these botanicals and insecticides against pests of winged bean. The winged bean is a high protein crop. Usually, the crop is free of pests, especially when grown in mixed garden. Nonetheless, the plant is known to be susceptible to a number of pests, particularly when raised as a single crop in large areas. Few detailed studies have been conducted on the pest complex of the crop and their management. The information gathered on the pests infesting the crop in the present study could act as an early warning of the impending danger for the prospective cultivators.

With respect to the effect of the tested products on the natural enemies, dimethoate was highly toxic to the different groups in chilli, the extent of toxicity ranging from 67.09 to 81.51 per cent, respectively (Fig.12). The extent of toxicity in acetamiprid ranged from 48.40 to 64.38 per cent. Toxicity of imidacloprid to the predators was less ranging from 39.31 to 53.45 per cent. Both the botanicals were relatively safe, the extent of toxicity ranging from 17.20 to 31.19 in neem oil + garlic emulsion and 19.10 to 38.58 in NeemAzal. In winged bean, again dimethoate was the most toxic resulting in 73.48 to 87.55 per cent and 69.93 per cent reduction in the predator and parasitoid populations respectively (Fig.13). Between the nicotinoids acetamiprid caused 57.11 to 71.43 per cent and 49.48 per cent reduction in the population of predators and parasitoids, respectively. Imidacloprid exhibited 52.03 to 63.43 per cent and 51.14 per cent reduction in the natural enemy populations, respectively. Compared to the insecticides, the botanicals were safer to the natural enemies, the extent of population reduction ranging from 20.42 to 38.91 per cent and 19.41 to 25.70 per cent respectively. Safety of neem based pesticides to coccinellid predators of okra pest complex (Gowri et al., 2002; Thamilvel, 2004), predatory fauna of *A. gossypii* (Patel et al., 2003), *C. carnea* (Vogt et al., 1996), parasitoids in bittergourd field (Nandakumar and Saradamma, 1996) and spiders (Manu, 2005; Vijayasree, 2006) have been reported. Acetamiprid was safe to majority of natural enemies including coccinellids, *Chrysopa* spp., syrphids, and spiders (Yequming et al., 1996) and *C. carnea, M. sexmaculata.* and *C. transversalis* (Varghese, 2003). However, the reports on the toxicity of imidacloprid to natural enemies are contradictory. While Duffle et al. (1997) and Smith and Krischik (1999) reported toxicity of the neonicotinoid to coccinellids in cotton ecosystem Chandrasekaran (2001) and Varghese (2003) opined that it was safe to coccinellids, spiders and chrysopids. Dimethoate was recorded to be highly toxic to natural enemies (Nurindah and Bondra, 1988; George and Ambrose, 1998; Thamilvel, 2004).

Considering the effect on soil fauna, with the exception of termites, there was no appreciable reduction in the population of other non- target

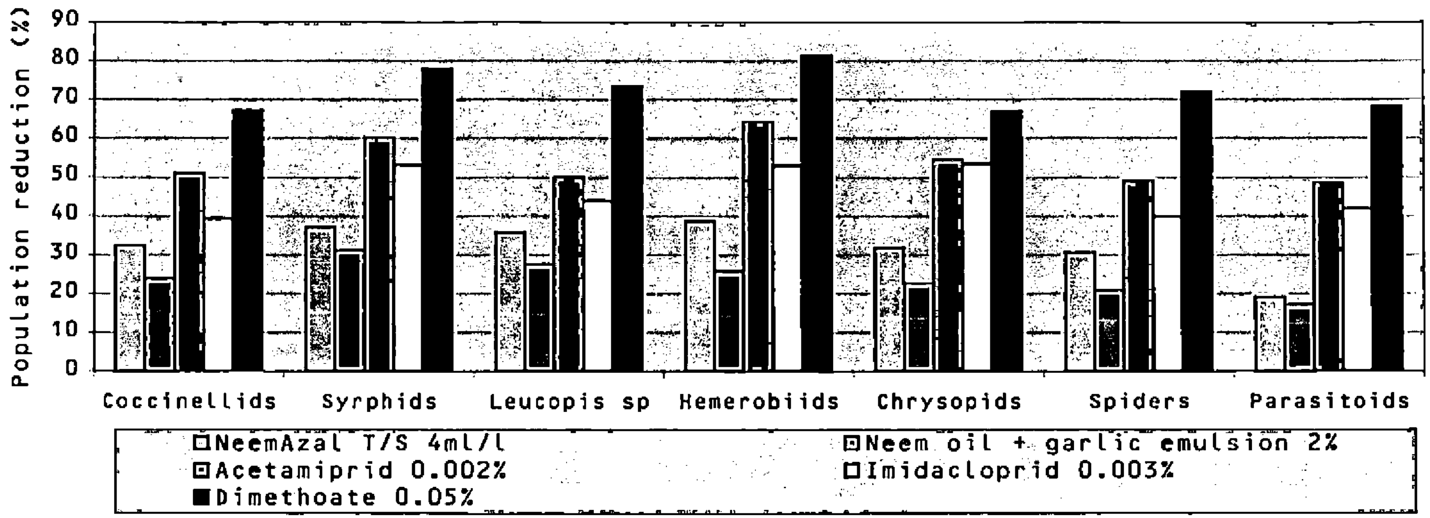


Fig 12. Effect of botanicals and synthetic insecticides on natural enemies in chilli

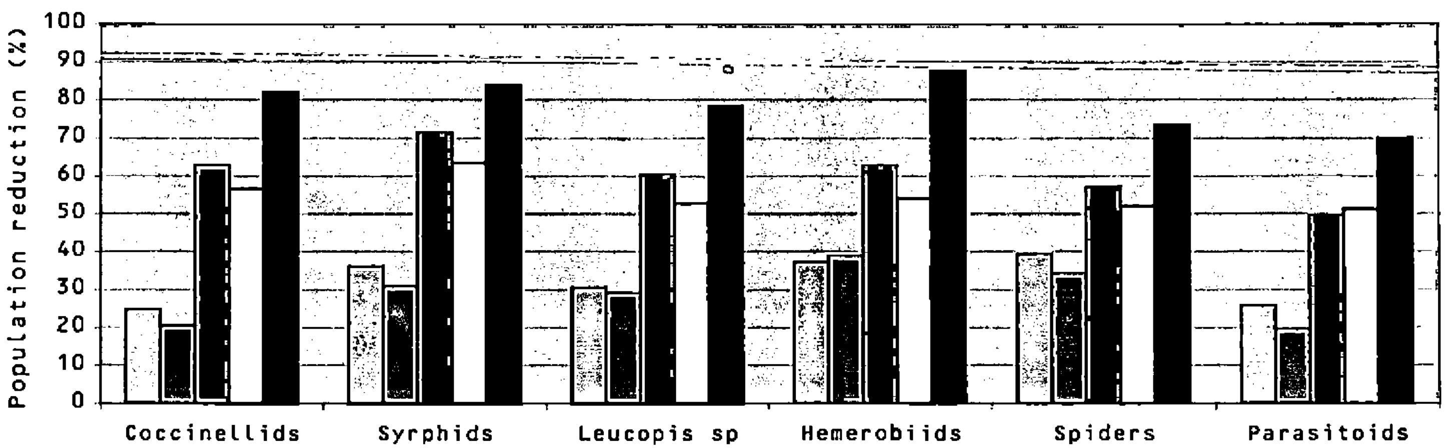


Fig 13. Effect of botanicals and synthetic insecticides on natural enemies in winged bean

organisms in soil like earthworm, soil coleopterans, ants, mite and collembolans. While 27.15 to 49.71 and 41.88 to69.93 per cent reduction in the population of these organisms was seen in dimethoate sprayed chilli (Fig.14) and winged bean plots (Fig.15), respectively, the reduction in the neonicotinoid treated plots ranged from 20.46 to 30.76 per cent and 10.35 to34.10, respectively. The reduction in the population of the organisms in the plots treated with botanicals was negligible ranging from 1.29 to 14.92 per cent and 0.75 to 17.84 per cent in chilli and winged bean plots, respectively. The results conform to earlier findings. Dimethoate was observed be toxic to soil invertebrate species (Martikainen, 1996). Foliar application of imidacloprid showed only a transient effect on the population of earthworms and had no adverse effect on diplopoda and spiders such as Linyphiidae, Araneidae and carabid beetle *Philonthus* sp (Pfluger and schmuck, 1991). Though Margosan-O (MO) containing azadirachtin at 3.0 g a.i was less detrimental to most of the invertebrate's species inhabiting a turf grass system, oribatid mites and non-collembolans were susceptible to MO (Stark, 1992).

With the exception of the slight reduction noted in the soil microflora viz, fungi, bacteria and actinomycetes population in the dimethoate sprayed plots (17.10 to 25.80 per cent in chilli and 19.73 to 25.54 per cent in winged bean), all the other treatments did not adversely affect the microbial population (0 to 7.12 per cent in chilli and 0 to 8.20 per cent in winged bean) (Fig.16 and Fig.17). The effect of dimethoate was seen upto three days after spraying. Toxicity and safety of various insecticides to soil flora has been reported. While phorate applied at 2 kg a.i ha around brinjal seedlings showed moderate antifungal action and less toxicity to soil bacteria (Satpathy, 1974), it reduced the population of actinomycete and bacteria significantly up to seven days in rice (Beevi, 1987). Contrarily, imidacloprid had no significant effect on activity of soil microorganisms even at high dose of 2000 g a.i ha^{-1}(Pfluger and Schmuck,

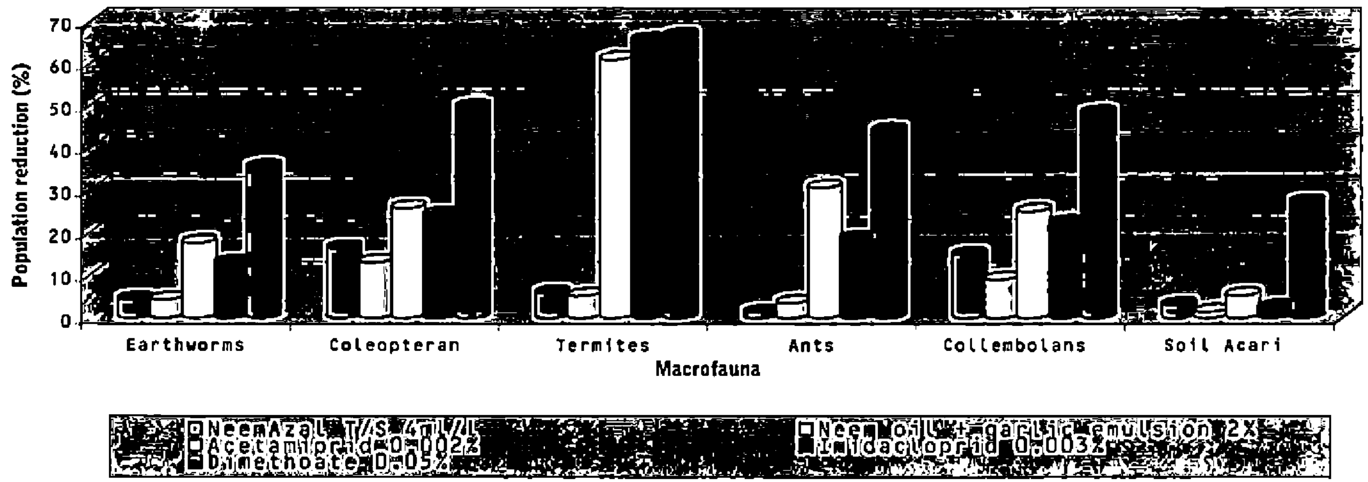


Fig 14. Effect of botanicals and synthetic insecticides on soil macrofauna in chilli

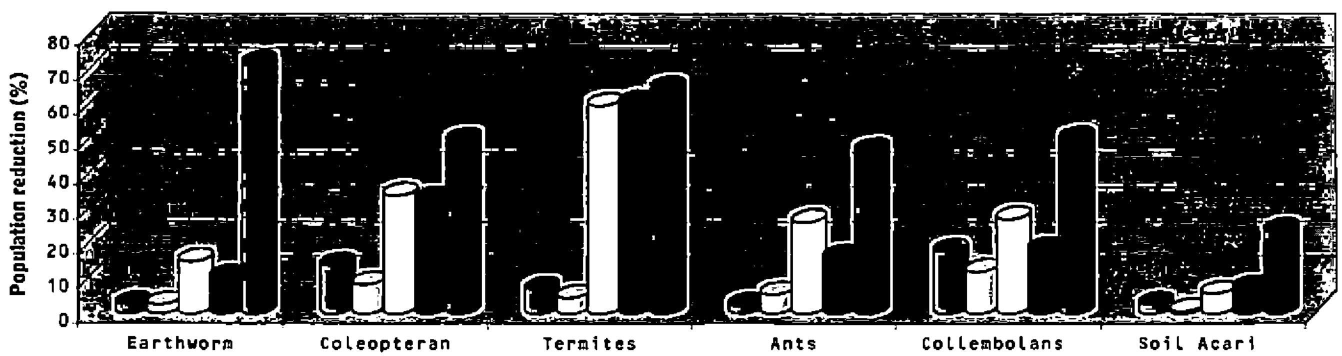


Fig 15. Effect of botanicals and synthetic insecticides on soil macrofauna in winged bean

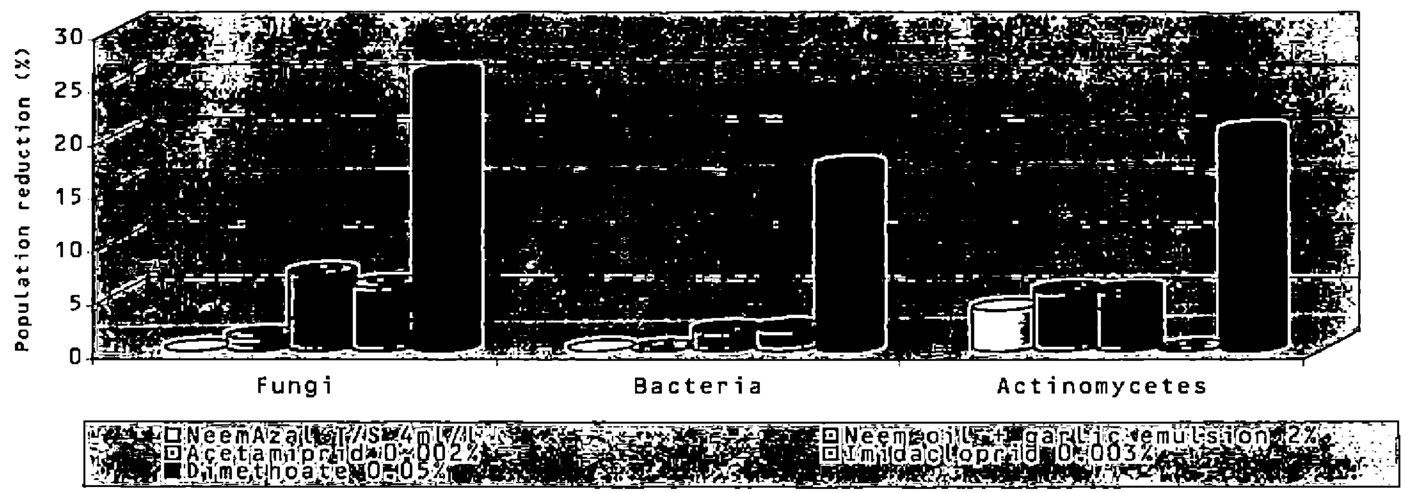


Fig 16. Effect of botanicals and synthetic insecticides on soil microflora in chilli

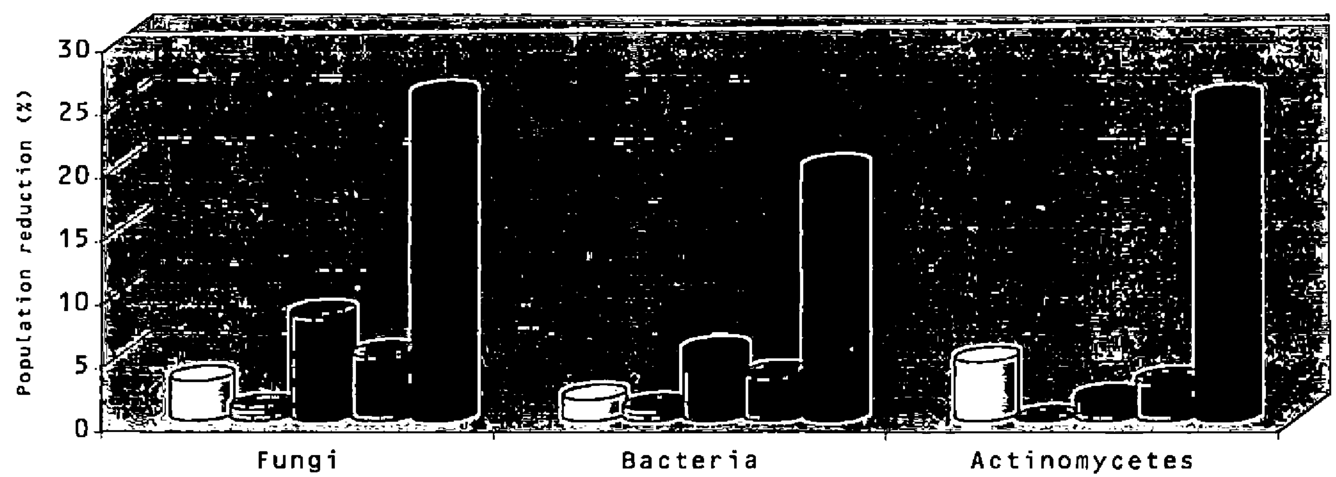


Fig 17. Effect of botanicals and synthetic insecticides on soil microflora in winged bean

1991). Soil microorganisms play a significant role in the degradation of organic wastes.

Residues of acetamiprid, imidacloprid and dimethoate were detected both in chilli fruit and winged bean pods five days after spraying. While on the tenth day after spraying, residues of acetamiprid, and dimethoate were detected in chilli fruits, only residues of acetamiprid was recorded from winged bean pods. Imidacloprid was below detectable level (BDL). Residues of all the three insecticides were below detectable level when estimated fifteen days after spraying. Earlier reports indicated that the half-life values of acetamiprid in chilli were in the range of 2.24 to 4.84 days (Sanyal et al., 2008). The imidacloprid residues progressively reduced with time and on the seventh day the concentration was reported to be 0.08 and 0.18 mg Kg^{-1} from respective treatments and became non detectable on the tenth day from normal dose (20 g a.i. ha^{-1}) and the safe waiting period was seven days after treatment Dikshit and Pachauri (2000).

The residue of imidacloprid was detected only up to 3, 5, 3 and 3 days after treatment in bhendi, chilli, radish and mango, respectively (Suganthy, 2003). Kharbade et al. (2003) evaluated the dissipation of imidacloprid residues in chilli fruits and found that in green chillies, initial residues were 0.38 and 0.56 ppm in spray treatment of 100 and 150 ml ha^{-1} respectively and these residues reached below detectable limit (BDL) of more than 0.05 ppm in 4.19 to 5.48 days. Reddy et al (2007) reported that the initial deposits of dimethoate @ 300 g on green chilli was 0.331 mg which dissipated to below maximum residue level after 24 h. No reports are there on the residues of the insecticides in winged bean. Chilli is one of the most important spice crop of India with immense commercial value. Insecticides are invariably used for the control of an array of sucking pests like aphids, thrips and mites attacking the crop. Many farm gate samples show the presence of insecticide residue which poses a problem in its export. Pesticide free produce could bolster the export of the spice. Hence, there is a need to prescribe the waiting periods of insecticides which will lead to the production of safe produce.

Succinctly, the study revealed that almost all the vegetables were attacked by at least one aphid species. Of the eight species identified, the highly polyphagous, *A. gossypii*, *A. craccivora* and *A. spiraecola* were the important ones with *A. gossypii* and *A. spiraecola* exhibiting more diverse selection of host plants in terms of plant- taxa. Despite being recorded on a large number of plants, *A. craccivora*, restricted itself more to Fabaceae indicating its selectivity of hosts. Similarly, *H. setariae* too occurred mostly on Poaceae. Even though the crucifer feeding aphid *L. erysimi* was recorded from cruciferous vegetables, it was noticed infesting weeds in diverse plant families too. Only very few host plants were recorded for *A. nerii* and *A. fabae*. Nevertheless, the study clearly indicated that the weeds and other host plants in the vegetable ecosystem could act as potential sources of pest inoculum. The best pest control program being one which takes preventive action well before problem pests actually infest the field, checking the surrounding areas for aphid sources prior to the cultivation of vegetables is of extreme importance, since it could provide early warning of aphid invasion to crop areas. Moreover, after the crop is raised, it should be monitored regularly, to check the infestation early since it is difficult to control the pest once the aphid numbers are high.

The large number of specialist and generalist predators encountered clearly established the predatory group as the primary regulating force in the dynamics of aphid population and the crucial role the predators could play in aphid management if this often neglected natural enemy group is properly exploited. Studies on the population dynamics of the melon aphid in chilli and pea aphid in winged bean too confirmed the observation. The generalist predators could check not only the population of aphids but also that of other pests. Although effective in large numbers, the high cost of large scale production of the potential predators precludes its economic use in biological control. Hence, conservation rather than augmentation should be the motto in utilization of the bioagent. Increasing predator abundance through reduced pesticide application and adoption of cropping practices that encourage their activity is to be thought of. The best way to attract natural enemies is to have a wide diversity of flowering plants since many beneficials rely on pollen and nectar from flowers to supplement their diet. Tolerating a few aphid –infested weeds could encourage the beneficials. Their presence will attract the predators early in the season so that they will be available for the later arriving aphids on the crop plants. Management of ants is another key component of aphid management. Ant baits can be used on the ground without harming the natural enemies.

Despite the numerous management options available, at times use of chemicals cannot be totally avoided in cropping systems. Increased restraint on insecticide use has revived the use of plant products. Plant products have multi-action principles and exhibit diverse biological activity such as phagodeterance and repellence, growth retardant and abnormal development and ovipositional suppression that act on behaviour and physiological process of the pest. Moreover, extracts of leaves and seeds, oils and commercial formulations can be effectively used in combination with insecticides and biocontrol agents and can be an important component of other pest management strategies that provide stability to crop ecosystem. Long term suppression of complex pest species is unlikely to be achieved in agro-ecosystems unless natural enemies are made the primary agent. Many natural enemies of aphids like coccinellids, lacewings rarely appear on the scene until aphids have begun attacking plants. Since control by natural enemies improves as the season progresses it is important to maintain the pest population at moderate levels during this "lag period". Here in comes the importance of plant products. In concert with other non chemical methods this could be the remedy in situations where aphids predominate in the pest fauna. In situations warranting insecticide applications, a predator benign insecticide like imidacloprid would be the best option. Based on the results, the following pest management options are suggested for aphid management in vegetables.

1. Early detection of aphids on weeds and other hosts
2. Proper weed management.
3. Regular monitoring of vegetables especially during the active growth stage to spot infestation early.
4. Determination of the status of the beneficials and their conservation
5. Management of ants
6. Application of neem oil + garlic emulsion 2% or NeemAzal T/S 4ml/l in early stages of infestation
7. Use of insecticides like imidacloprid 0.003% with minimum adverse effects on beneficials when needed

Summary

6. SUMMARY

Aphids constitute a major threat to the production of vegetables. Negligence of the pest in endemic areas could lead to complete crop destruction. Since, different species predominate on different hosts in various locations, detection of the species involved and appraisal of their population dynamics is imminent for their timely management. With this view, a survey was conducted in the four taluks of Thiruvananthapuram district of Kerala to document the aphids infesting various vegetables. The studies on fluctuation in the population of the two dominant aphids identified in the survey were carried out in farmers' fields in Kalliyoor panchayat of the district. Laboratory and field trials were done to identify effective botanicals and newer molecules of synthetic insecticides for the management of the aphids. The results of the studies are summarized here under.

1. Eight species of aphids viz., *A. gossypii, A. craccivora, A. spiraecola, A. fabae, A. nerii, H. setariae, M. persicae* and *L. erysimi* belonging to four genera and two tribes under the sub family Aphidinae were documented from 32 vegetables in Thiruvananthapuram district. The important external characters of the species aiding in their tentative identification in the field were described. Tender leaves and shoots, buds, flowers and young fruits were vulnerable to the attack of the aphids.

2. Occurrence of *A. gossypii* on *C. grandis*, *M. oleifera* and *P. tetragonolobus; A. craccivora* on *C. gladiata*, *P. tetragonolobus* and *S. grandiflora* ; *A. spiraecola* on *A. tricolor, C. sativus, C. tetragonoloba, M. oleifera, M. charantia, M. koeingii, P. tetragonolobus* and *S. androgynus* ; *M. persicae* on *A. tricolor* and *R. sativus* and *A. nerii on C. annuum* and *C. frutescens* was recorded for

the first time from Kerala and that of *H. setariae* on *A. tricolor* and *A. dubius* from South India.

3. One hundred and twenty two other plants including common weeds in the vegetable fields were identified as host plants of the different aphids. Among these, 43, 20, 25, 2, 8, 1, 1 and 14 plants, respectively of *A. gossypii, A. craccivora, A. spiraecola, L. erysimi, M. persicae, A. nerii, A. fabae* and *H. setariae* were first records from South India. Likewise, 11, 2, 1, 3, 3, 1 and 5 other host plants, respectively of *A. gossypii, A. craccivora, A. spireacola, L. erysimi, A. nerii, A. fabae* and *H. setariae* were first records from Kerala.

4. Among the aphids recorded, *A. gossypii* was the dominant aphid pest of vegetables closely followed by *A. craccivora,* and *A. spiraecola. M. persicae, L. erysimi, A. nerii, A. fabae* and *H. setariae* were noted to infest a few vegetables.

5. *A. gossypii* (80 host plants), *A. craccivora* (37 host plants), *A. spiraecola* (36 host plants) and *H. setariae* (22 host plants) were observed to be highly polyphagous. Based on plant-family specificity, *A. gossypii* and *A. spiraecola* exhibited more diverse selection. While *A. craccivora* was recorded frequently from Fabaceae, *H. setariae* occurred mostly on Poaceae. *L. erysimi,* the specialist crucifer feeding aphid was recorded from cruciferous vegetables and from weeds in diverse plant families. Only very few plants hosted *A. nerii* and *A. fabae.*

6. Among the vegetables surveyed, maximum species of aphids were recorded on amaranthus (*A. gossypii, A. craccivora, A. spiraecola, M. persicae* and *H. setariae*). This was followed by winged bean (*A. craccivora, A. gossypii, A. fabae* and *A. spiraecola*). Three aphid species were recorded on chilli (*A. gossypii, A. nerii, M. persicae*),

cowpea (*A. craccivora, A. gossypii, A. fabae*) and drumstick (*A. craccivora, A. gossypii* and *A. spiraecola*). Only one species of aphid attacked the other vegetables.

7. Chilli and coccinia were highly susceptible to *A. gossypii* as indicated by the population of the aphid and damage index recorded in the different taluks. Okra, brinjal and bittergourd too showed appreciable level of infestation. Incidence of *A. craccivora* was the highest in winged bean followed by cowpea. Mosaic disease incidence was noted in 10 vegetables, the extent of infection being high in bittergourd, coccinia, cucumber, cowpea and amaranthus.

8. Predators comprising of coccinellids, syrphids, chamaemyiids, chrysopids, hemerobiids and spiders were the predominant group of natural enemies associated with the aphids. The aphidophagous coccinellids constituted the major predatory fauna followed by the spiders and syrphids.

9. Twenty species of coccinellids were recorded from different species of aphids on various host plants. Among them, 13 species viz., *C. orbiculus, P. perrotteti, P. japonica, P. flaviceps, P. trinotatus, S. (Pullus) castaneus, S. (Pullus) coccivora, S. (Pullus) latemaculatus, S. (Pullus) o-nigrum, S. obscurella, Sticholotis* sp., *S. rougeti* and *Telsimia* sp. were first records from Kerala. Among the coccinellids, *M. sexmaculatus* was the dominant species followed by *C. transversalis, S. latemaculatus* and *C. septempunctata,*

10. Four species of aphidophagous syrphids were recorded of which *I. scutellaris* was the predominant. Two syrphids viz. *P. yerburiensis* and *D. aegrota* were recorded for the first time from Kerala. *Leucopis* sp. was the only Chamaemyiid species recorded from the vegetable fields.

11. The chrysopids, *C. carneae* and *A. octopunctata* and the hemerobiid, *Micromus* sp. were the Neuropteran predators of the aphids recorded. *Micromus* sp. was dominant in the vegetable fields followed by *C. carneae* and *A. octopunctata*. *A. octopunctata* was recorded for the first time from Kerala.

12. Among the eleven species of spiders observed, *O. javanus*, *T. mandibulata*, *O. quadridentatus*, *O. shweta* and *Phidippus* sp. were the frequently encountered species in the vegetable fields.

13 *Aphidius* sp. was the most dominant parasitoid in the vegetable ecosystem. *Aphelinus* sp. and *D. rapae* were the other parasitoids recorded.

14. Seven species of ants were recorded attending the aphids of which *C. compressus* was the most dominant followed by *Monomorium* sp. and *Campontus* sp. *O. smaragdina* and *Crematogaster* sp. were associated exclusively with *A. spiraecola*.

15. Studies on the population fluctuation of *A. gossypii* in chilli and *A. craccivora* in winged bean during a cropping season indicated that both the aphids prevailed in the crops throughout the cropping period in varying densities. High population was seen during November and December coinciding with the active vegetative stage of the crops.

16. Comparatively, more predators prevailed in the field than the parasitoids. Among the predators, *Leucopis* sp. dominated in both the crops followed by the coccinellids and spiders. Higher population of the predators coincided with that of the aphids.

17. Correlation studies revealed a significant and positive correlation between the population of both the aphids with the insect predators, spiders and parasitoids. None of the climatic parameters prevailing during

the period had any significant influence on the aphid population. With the exception of maximum temperature which had a positive influence, all the other weather parameters viz., minimum temperature, relative humidity, rainfall and wind velocity had a negative influence on the population of the predators and parasitoids.

18. Among the plant oils, plant extracts and a commercial formulation screened in the laboratory for their pest control efficiency, only neem oil-garlic emulsion 2% and NeemAzal T/S 4 ml/l recorded more than 50 per cent mortality of *A. gossypii* and *A. craccivora.* Among the insecticides, the neonicotinoids viz., acetamiprid 0.002% imidacloprid, 0.003%, and dimethoate 0.05% proved superior to all other treatments.

19. Dimethoate 0.05% was highly toxic to the coccinellids (*Menochilus sexmaculatus, Coccinella transversalis, Pseudaspidimerus trinotatus, Hormonia octomaculata, Scymnus latemaculatus, Coccinella septempunctata*), syrphids (*Ishiodon scutellaris, Dideopsis aegrota and Paragus serratus*) and a hemerobiid (*Micromus* sp.) predator under laboratory condition. Between the two neonicotinoids, acetamiprid 0.002% registered higher mortality than imidacloprid 0.003% whereas NeemAzal T/S 4 ml/l and neem oil + garlic emulsion 2% were safe to the predators.

20. Foliar application of dimethoate 0.05%, acetamiprid 0.002% and imidacloprid 0.003% gave good control of aphid (*A. gossypii*), leafhopper (*A. biguttula biguttula*), thrips (*S. dorsalis*) and whitefly (*A. dispersus*) population in chilli and pea aphid (*A. craccivora*), spiralling whitefly (*A. dispersus*), pod bug (*R. pedestris*) and pod borer (*M. vitrata*) population in winged bean in the field. Compared to control, NeemAzal T/S 4ml/l and neem oil garlic emulsion 2% too checked the population of the pests appreciably.

21. Among the synthetic insecticides, dimethoate 0.05% proved highly toxic to the predators and parasitoids followed by acetamiprid 0.002% both in the chilli and winged bean fields. Comparatively, imidacloprid 0.003% was less toxic. The botanicals were safer to the natural enemies.

22. Dimethoate 0.05% was highly toxic to soil macro faunal (earthworm, soil coleopteran, ant, termite, collembolan and soil Acari) and micro faunal (fungi, bacteria and actinomycetes) populations whereas acetamiprid and imidacloprid were less toxic. The botanicals viz., NeemAzal T/S and neem oil + garlic emulsion were non toxic in both the field trials.

23. Significantly higher yield was obtained from all the treatments. No significant difference was noted in the yields obtained from acetamiprid 0.002%, imidacloprid0.003% and dimethoate 0.05% treated plots.

24. Residues of imidacloprid were detected in chilli and winged bean fruits five days after spraying. While on the tenth day after spraying, residues of acetamiprid, and dimethoate were detected in chilli fruits, only residues of acetamiprid was recorded from winged bean pods. Imidacloprid was below detectable level (BDL). Residues of all the three insecticides were below detectable level when estimated fifteen days after spraying.

Based on the results of the study, early detection and destruction of aphids on weeds and other hosts through regular monitoring, proper weed and ant management, conservation of the beneficials, application of neem oil garlic emulsion 2% or NeemAzal T/S 4ml/l during the early stages of infestation and use of imidacloprid 0.003% when pest density is high are suggested for aphid management in vegetables.

References

7. REFERENCES

Abbott, W.S. 1972. A method of computing the effectiveness of an insecticide. J. Econ.Ent. 18:265-267.

Acharya, S., Mishra H. P. and Dash, D. 2002. Efficacy of insecticides against okra jassid, *Amrasca biguttula biguttula* Ishida. Ann. Pl. Prot. Sci. 10(2): 230-232.

Addicott, J. F.1978. Competition for mutualists: aphids and ants. Can. J. Zool. 56: 2093-2096

Agarwala, B. K. and Ghosh, A. K.1984. A checklist of Aphididae of India. Rec. Zool. Surv. India. Occ. Paper No. 50: 1-71

Agarwala, B. K. 1983. Parasites and predators of rose- infesting aphids (Homoptera: Aphididae) in India. Entomon 8: 391-392

Agarwala, B. K. and Ghosh, A. K. 1988. Prey records of aphidophagous Coccinellidae in India. A review and bibliography. Trop. Pest Mgmt. 34(1): 1-14

Agarwala, B. K. and Saha, J. L. 1986. Larval voracity, development and relative abundance of predators of *Aphis gossypii* on cotton in India. Pp. 339-344. In *Ecology of Aphidophaga*.(Ed. Hodek, I) Dordrencht, Academia Prague and Dr W. Junk.

Agarwala, B.K. Das, S. and Saha, S. 1983. New host and prey records of some aphidophagous insects from India. Entomon 8:391-392

Agarwala, B. K., Ghosh, D., Das, S. K, Poddar, S. C. and Raychaudhuri, D. N. 1981. Parasites and predators of aphids (Homoptera: Aphididae) from India V. New records of two aphidiid parasites, nine arachnids and one dipteran predators of from Sikkim. Entomon 6:207- 209

Agarwala, B. K., Raychaudhuri, D. and Raychaudhuri, D.N.1980. Parasites and predators of aphids in northeast India III. Entomon 5: 39-42

Akol, A. M., Sithanantham, S., Njagi, P. G. N., Varela, A. and Mulke, J. M. 2001. Relative safety of sprays of two neem insecticides to *Diadegma mollipla* (Holmgren), a parasitoid of the diamondback moth effects on adult longevity and foraging behaviour. Crop Prot. 21: 853-859

Anard, R. K. 1984. Predation by *Coccinella septempunctata* Linn. and *Menochilus sexmaculatus* Fab. on five species of aphids.pp.234-237. In *The Aphids*, (ed. Behura, B.K) Bhubneswar, Zoological Socity of Orissa.

Ansari, R and Pawar, S. 1980. Role of coccinellid and syrphid predators in biological control of groundnut aphid *Aphis craccivora* Koch. Indian Oilseeds J.9:67-70

*Araujo, P. A.C.B and Sales , F.J.M. 1985. Influence of climate and of the phenology of cotton aphid population dynamics. Fitossanidade 6 : 57-72

Awaknavar, J. S. and S. S. Karabhantanai. 2004. Effect of pesticides on biomass, survival and reproduction of earthworms, *Polypheritima elondata* (Mich.). Indian J. Ecol. 31(2): 112-115

Ayyar, T. V. R. 1940. *Handbook of Economic Entomology for South India*. First edition, Madras (Govt. Press). India 528pp.

Bakhetia, 1989. Comparative efficacy of some insecticides against the aphid, *Lipaphis erysimi* Kalt. on cabbage crop. Indian J. Entomol. 50 (1): 61-68

Bambaradeniya, C. N. B. 2006. The fauna of Sri Lanka, Current status of aphid taxonomy in Sri Lanka (ed. Edirisighe, J.P. and wijerathna, M.A.P) IUCN- The world conservation union, 35-42

Baneerjee, T.K. and Raychaudhuri, D. 1986. Analysis of niche selection of Aphis gossypii Glover on okra, brinjal and chilli. Aphidology in India:5-12

Banks, C. J. 1958. Effects of the ants, *Lasius niger* (L.) on the behaviour and reproduction of the black bean aphid, *Aphis fabae* Scopoli. Bull. Ent. Res. 49:707-714

Banks, C. J. and Macaulay, E. D. M. 1967. Effects of *Aphis fabae* Scopoli and its attendant ants and insect predators on yields of field bean (*Vicia faba* L.). Ann. Appl. Biol. 60: 445-453

Beevi, N. S.1987. Persistence and metabolism of phorate in rice plants and in different soil types of Kerala and its effect on non target organisms. Ph. D thesis. Kerala Agricultural University, Thrissur, 148 p.

Behura, B. K.1963. Aphids of India: A survey of published information. J. Utkal Univ., Bhubneswar 1: 25-78

Behura, B.K.1965. Supplement to "Aphids of India-A survey of published information- I". J. Utkal Univ.,Bhubneswar 3: 40-65

*Bellettini, S., Bellettini, N. M. T., Fontes, A. R. and Sanches, V. 1999. Efficiency of insecticides as sprays for the control of aphid (*Aphis gossypii* Glover) on cotton. Empresa Brasileira de Pesquisa Agropecuaia, Embrapa Algodao, 9: 293-295.

Bhatia, R. and Verma, A. 1994 . Seasonal incidence of major insect pests associated with winter crop of cabbage in Himachal Pradesh. Ann. Agric. Res. 15: 222-225

Biradar, A. P., Singh, P. K. and Balikai, R. A. 2007. Studies on effect of pesticides to earthworms. Int. J. agric. Sci. 3: 116-119

Bisht, R.S., Rana, D. S. and Katoch, A.R. 2002. Records of aphidocolus ants (Hymenoptera: Formicidae) from Garhwal hills, Uttranchal. J.Aphidol. 16:15-19

Blackman, R. L. and Eastop, V. F. 2000. *Aphids on the World's Crops: An Identification and Information Guide.* Second edition. John Wiley and Sons, New York, 466 pp.

Borach, R. K. 1994. Evaluation of an insecticide schedule against jassid, *Amrasca biguttula biguttula* Ishida on okra. Indian J. Ent. 56: 196-198

Borach, R. K. and Nath, P. D. 1996. Evaluation of an insecticide schedule on the incidence of whitefly *B. tabaci* in okra. Indian J. Vir. 11: 65-67

Bose, K. C. and Ray, N. K. 1975. Influence of ants on the predators and parasites of aphids. Indian J. Ani. Res. 89:63-67

Broadbent, L. 1951. Aphid excretion. Proc. Res. Ent. Soc. London 29:97-103

Butani, D.G. and Bharodia, R. K. 1984. Relation of groundnut aphid population with the natural predator, ladybird beetles. Gujarat agric. Univ. Res. J. 9:72-74

Chakrabarti, S. and Sarkar, A. 2001. A supplement to the food-plant catalogue of Indian Aphididae. J. Aphidol. 15:9-62

Chandrasekaran, M. 2001. Development of integrated pest management on bhindi. Ph.D thesis, Tamil Nadu Agricultural University, Coimbatore, 175 p.

*Chao, S. L., Dennehy, T. J. and Casida, J. E. 1997. Whitefly (Hemiptera: Aleyrodidae) binding site for imidacloprid and related insecticides : A putative nicotine acetylecholine receptor. J. Econ. Ent. 90: 879-882

*Chien, C.C., Chou, L.Y. and Chiu, S.C. 1984. Biology and natural enemies of Hedylepta indicata in Taiwan. J. agric. Res. China 33:181-189

Clausen, C. P. 1940. *Entomophagous insects.* First edition. McGraw-Hill, New York. 688 p.

*Curtright, C. R. 1965. Subterranean aphids of Ohio. Bull. Ohio agric. Expt. Stn. 387:175-233.

Daraghmeh, A., Shraim, A., Abulhaj, S., Sansour, R. and Nig J.C. 2007. Imidacloprid residues in fruits, vegetables and water samples from Palestine. Environ. Geochem. Health 29(1): 45-50.

Datta, S. K., Raychaudhuri, D. and Agarwala, B. K. 1982. Study on aphid tending ants in India-I. New records of aphid and ant species in their association. Entomon 7:327-328

Datta, S. K., Raychaudhuri, D. and Agarwala, B. K. 1983. Study on aphid tending ants in India-II. New records of aphid and ant species in their association. Entomon 8:23-23

David, S. K. 1956. Notes on south Indian aphids I. Indian J. Ent.18:1-9

David, S. K. 1958a. Notes on South Indian aphids III. Lachninae to Aphidinae. Indian J.Ent.19:171-180

David, S. K. 1958b. Notes on South Indian aphids IV. Aphidinae. Indian J. Ent. 19: 289-299

David, S. K. 1967. The rusty plum aphid, *Hysteroneura setariae* (Thomas) in southern India. J. Bombay nat. Hist. Soc. 64:380-381

Deka, S. and Borach, B. 1998. Field efficacy of some insecticides against cowpea aphid (*Aphis craccivora* Koch). J. agric. Sci. Soc. N. E. India 11: 111-114

Deoras, P. J. 1942. Description and biological notes on a few species of syrphidae from India. Indian J. Ent. 4:217-219

Deshpande. 1937. A preliminary account of the aphididae of Poona. J. Bombay nat. Hist. Soc. 39:740-744

Devi, C. M. and Singh, T. K. 1986. Aphidocolous ants (Hymenoptera: Formicidae) in Manipur. Entomon 12:309-313

Devi, C. M., Paonam, M. S. and Singh, T. K. 1987. Aphids (Homoptera: Aphididae) and their associated ants (Hymenoptera: Formicidae) of fruit trees in Manipur. J.Aphidol.1:102-104

Devi, C. M., Singh, T. K. and Nilamani, L. 2001. New aphidocolous ants (Hymenoptera: Formicidae) from India. J.Aphidol.15:107-112

Dhawan, A. K. and Simwat, G. S. 1992. Field evaluation of Neemrich 20 EC for management of insect pests on cotton during reproductive phase. *First National Symposium on Allelopahty in Agroecosystems* (Agriculture and Forestry) (eds. Tauro, P. and Narwal, S.S.). Indian Society of Allelopathy, Haryana Agricultural University, Hisar, pp. 152-153

Dhawan, A. K. and Simwat, G. S. 1994. Field evaluation of botanical insecticides for bollworm control in cotton. *International Symposium on Allelopathy in Sustainable Agriculture, Forestry and Environment* (eds. Tauro, P., Narwal, S.S., Dhaliwal, G.S. and Ramprakash,S). Indian Society of Allelopathy, Haryana Agricultural University, Hisar, 101 p.

Dhawan, A. K., Mohindru, B., Saini, S. and Singh, K. 2008. Comparative toxicity of selected insecticides against cotton aphid, *Aphis gossypii* Glover. Pesticide Res. J. 20 (1):89-91

Dhingra, S. Kodandaram, M. H, Hegde, R. S. and Srivastava, C. 2003. Evaluation of different insecticide mixtures against third instar larvae of *Helicoverpa armigera* (Hubner) . Ann. Pl. Prot. Sci. 11: 274-276

Dikshit, A. K. and D. C. Pachauri. 2000. Persistance and bioefficacy of beta-cyfluthrin and imidacloprid on tomato fruits. Pl. Prot. Bull. 52(3): 1-3

Dikshit, A. K., Lal, O. P. and Srivastava Y. N. 2000. Persistence of pyrethroid and nicotinyl insecticides on okra fruits. Pesticide Res. J. 12(2): 227-231.

Dixon, A.F.G. 1998. *Aphid Ecology*. Chapman and Hall, London. 312pp

*Duffle, W., Sullivan, M. J. and Turnipseed, S.G. 1997. Survival of beneficial arthropods following the application of various insecticides. *Proceedings of Beltwide Cotton Conference, 6-10 January, 1997* (eds. Dugger, P. and Richter, D.). National Cotton Council, Memphis, USA, pp. 1120-1121

Duffield, S.J.1995. Crop specific differences in the seasonal abundance of four major predatory groups on sorghum and short duration pigeon pea. International chickpea and pigeon pea newsletter 2:74-76.

Eastop, V. F. and van Emden, H. F. 1972. The insect material1-31. In *Aphid Technology* (ed. H.F. van Emden). Academic Press, New York.682p.

Emden, H. F. and Harrington,R. 2007. Aphids as crop pests. CABI International, Wallingford, London. 752p.

*Figuls, M., Castane, C. and Gabarra, R.1999. Residual toxicity of some insecticides on the predatory bugs *Dicyphus tamanini* and *Macolophus caliginosus*. J. Biocontrol 44 :89-98

Finlayson, D. G., Cambell, C. J. and Roberts, H. A. 1975. Herbicides and insecticides: their compatibility and effects on weeds, insects and earthworms in the minicauliflower crop. Ann. Appl. Biol. 79: 95-108

Frampton, G. K. 1997. Species spectrum, severity and persistence of pesticide side effects on UK arable springtail populations. In: Fourth International Conference on Pest in Agriculture ANPP, Paris, France 129-136pp

*Frechette, B., Larouche, F. and Lucas.E. 2008. *Leucopis annulipes* larvae (Diptera:Chamaemyiidae) use a furtive predation strategy within aphid colonies. Eur. J. Ent.105:399-403

Gadiyappanavar, R. D.1970. Study of aphid pests of crops of Mysore State and the biology of ragi root aphid, Tetraneura nigriabdominalis (Homoptera: Aphididae). M.Sc. (Ag.) thesis, University of Agricultural Sciences, Bangalore, 95 p.

George, C. J.1927. South Indian Aphididae. J. Asiatic Soc.Bengal.20:308-311

George, P.J.E. and Ambrose, D.P. 1998. Relative toxicity of five insecticides to *Rhynocoris marginatus* (Fabricicus) a potential predator of insect pests (Insecta: Heteroptera: Reduviidae). Fresenius – Environ. Bull. 7: 396-402

Ghorpade, D. K. 1981. Insect prey of Syrphidae (Diptera) from India and neighbouring countries: a review and Bibliography. Trop. pest Mgmt. 27:62-82

Ghosh, A. K. 1974. A list of aphids (Homoptera: Aphididae) from India and adjacent countries. J.Bombay nat. Hist. Soc. 71: 201-225

Ghosh, D., Poddar, S.C. and Raychaudhuri, D.N. 1981. Natural enemy complex of *Aphis craccivora* Koch and *Lipaphis erysimi* (Kalt) in and around Calcutta. Science and Culture 47:58-60

Ghosh, L. K. and Singh, R. 2000. Biodiversity of Indian Insects with special reference to aphids (Homoptera: Aphididae). J. Aphidol. 14:113-123

Gowda, K. T. P. and Reddy, H. R. 1982. Population fluctuations of aphids in chilli field in relation to some meteorological factors. Mysore J. agric. Sci. 16 (2): 160-165

Gowri, S., Ramachandra Rao, G. and Nagalingam, B. 2002. Impact of neem formulations on coccinellid predators of okra pest complex. Pesticide Res. J. 14: 242-243

Gundannavar,K.P., Giraddi, R.S., Kulkarni, K.A. and Awaknavar, J.S. 2007. Development of integrated pest management modules for chilli pests. Karnataka J. agric. Sci. 20: 757-760

Harrison, S. and Cappuccino, N. 1995. Using density-manipulation experiments to study population regulation. In *Population Dynamics: New Approaches and Syntheses* (eds Cappuccino, N. and Price, P.W.) Academic Press, San Diego, California,131-147p

Hebsy Bai, Amritha, V. S., Reji, G.V. and Saradamma, K. 2002. Neem products for management of pests of vegetables Neem-2002. World Neem Conference. Souvenir Vol. I., Nov 27-30, Mumbai, 88 p.

*Horowitz, A.R., Mendelson, Z., Weintraub, P.G. and Ishaaya, I. 1998. Comparative toxicity of foliar systemic applications of acetamiprid and imidacloprid against cotton whitefly, *Bemisia tabaci* (Hemiptera: Aleyrodidae). Bull. Ent. Res. 88: 437-442

*Howard, S., Junior, J.A. and Papa, G. 1999. Effect of insecticide Afitrix (benfuracarb) for the control of aphid, *Aphis gossypii* (Homoptera: Aphididae), on cotton. Empresca Brasileira de Pesquisa Agropecuaia, Embrapa Algodao 9: 279-281

Indumathi, H. R., Sharma, D., Awasthi, M. D. and Siddaramappa, R. 2001. Uptake and dissipation of imidacloprid residues in okra. Pest Mgmt Hort. Ecosyst. 7(2): 124-129

*Ishaaya, I. and A.R. Horowitz. 1995. Insecticides with novel modes of action: an overview. In: *Insecticides with novel models of action: Mechanisms and application,* (eds.) I. Ishaaya and D. Degheela, Narosa Publishing House, New Delhi. pp. 1-18.

Irulandi, S and Balasubramanians, G. 2000. Reported on the effect of botanicals against *Megalurothrips distalis* (Karny) (Thripidae:Thysanoptera)and *Lampides boeticus* Linn. (Lycaenidae: Lepidoptera) on greengram. Insect Environ.5: 175-176

Jayaprabhavathi, S. 2005. Bioefficacy and determination of residues of acetamiprid 20 SP in cotton. Ph.D. Thesis, Tamil Nadu Agricultural University, Coimbatore, India, 150p.

Jayaraj, S. and Rangarajan, A.V. 1987. Trend in insect control – post pyrethroids. Pestology 20 (5): 39-51

Jayewar, N. E., Mundhe D. R., Wadnerkar, D.W., Zanwar, P.R. and Narwade, B.P. 2003. Evaluation of acetamiprid 20 SP against sucking pests of chilli. Pestology, 27(11): 17-20.

Jeger, S. R., Dhalival, G. and Dhawan, A.K. 2004. Effect of alternate application of neem products and insecticides on population of *Bemisia tabaci* Gennadius and its impact on bollworm damage in upland cotton. Ann.Pl. Prot. Sci. 9: 22-25

Johnson, J. 1984. A note on some common aphidovorous insects of Kerala.pp. 415-418. In *The Aphids*, (ed. Behura, B.K.) Bhubneswar, Zoological Socity of Orissa.

Johnson, L.F and Curl, E.A. 1972. Methods for Research in the ecology of soil-borne plant pathogen. Burgers Publication Co., Minneapolis, 247p.

Jarosik, V. and Dixion, A.F.G. 1999. Population dynamics of a tree dwelling aphid: regulation and density independent processes. J. Anim. Ecol. 68: 726-732.

Joshi, S. Balla, R .C and Rao, N. S. 1999. Species complex, population density and dominance structure of aphidophagous syrphids in cowpea ecosystem. Entomon 24:203-213

Joshi, S.2005. Faunistic studies on aphididae (Hemiptera) of Karnataka and Bioecology of the aphid parasitoid, *Diaeretiella rapae* (McIntosh) (Hymenoptera: Braconidae) Ph.D thesis, University of Agricultural Sciences, Bangalore, 210 pp.

Joshi, S. 2008. Records of aphids and aphidocolous ants (Hymenoptera: Formicidae) from Karnataka. Entomon 33 (1): 15-23

Joy, P. J., Lyla, K. R., Abraham, C. C. and Venkataram, C. S. 1983. Preliminary studies on the aphid pests of *Eupatorium odoratum* L. an important weed in plantations of Kerala. Proceedings of the Second Annual Symposium on Plantation crops. (PLACROSYM II) 272-274

Kalra, V. K. 1988. Population dynamics of various predators associated with mustard aphid, *Lipaphis* erysimi (Kalt.). J. Biol. Control. 2 (2):77-79

Kalushkov, P.K., Donchev, K.D. and Dimova, V.I 1990. Ecofaunistic studies on the coccinellids (Coleoptera: Coccinellidae) in Lucerne. Ecologia 23: 57-66

Kalyanam, N.P. 1970. Occurrence of the aphidophagous syrphid fly *Syrphus latifasciatus* Macq.(Syrphidae: Diptera) in south India. Current Sci. 39:66-67

Kaplan, I. and Eubank, M. D. 2002. Disruption of cotton aphid (Homoptera: Aphididae) natural enemy dynamics by red imported fire ants (Hymenoptera: Formicidae). Environ. Entomol. 31: 1175-1183

Kapur, A. P.1942. Bionomics of some Coccinellids predaceous on aphids and coccids in north India. Indian J.Ent.4:49-66

Karim, H. I, Singh, K.M. and Singh, R. N. 2004. Influence of abiotic factors in the population build up of important insect pests of cowpea (*Vigna unguiculata* (L.) Walp.) and their biotic agents recorded at IARI, New Delhi. Indian J.Ent.52: 675-680

Kennedy, J. S., Day, M. R. and Eastop, V.F. 1962. A conspectus of aphids as vectors of plant viruses. Commonwealth Institute of Entomology. London, 114p.

Karley, A.J., Pitchford, J.W., Douglas, A.E., Parker, W.E. and Howard, J.J. 2003. The causes and processes of the mid-summer population crash of the potato aphids *Macrosiphum euphorbiae* and *Myzus persicae* (Hemiptera: Aphididae). Bull. Entomol.Res. 93:425-437.

KAU. 2007. *Package of Practices Recommendations 'Crops'*. Thirteenth edition. Directorate of Extension, Kerala Agricultural University, Thrissur, 334 p.

KAU.1996. KHDP (R&D) Reoprt on –farm identification of problems of vegetables grown in KHDP pilot project areas, Thiruvananthapuram.

Kendappa, G. N., Mallikarjunappa S., Shankar, G. and Mithyantha, M.S. 2004. Evaluation of certain insecticides against spiralling whitefly, *Aleurodicus dispersus* Russell (Aleyrodidae: Homoptera) on cotton. Pestology 28(3): 32-33.

Khan, O. and Hussain, M.1965. Role of coccinellid and syrphid predators in biological control of groundnut aphid. Indian oil-seeds J. 9: 67-70

Kharbade, S. B., Kale, V. D. and Dethe, M.D. 2003. Residues of imidacloprid on chillies. Pestology 27(1): 18-19.

*Kidd, N.A.C. 1990. The population dynamics of the large pine aphid, *Cinara pinea* (Mordov). Res. Pop. Ecol.32:209-226.

Kotwal, D.R., Bhalla, O.P. and Verma, A.K. 1984. Natural enemies of cabbage aphid, Brevicoryne brassicae (Linn.) in the mid-hill regions of Himachal Pradesh. Indian J. Agrl.Sci. 54: 1011-1012

Koul, V.K. and Desh Raj.1999 . Population dynamics of *Brevicoryne brassicae* L. infesting cauliflower, Brassica oleracea L. var. botrytis

L. in mid-hill sub humid zone of Himachal Pradesh. J. Aphidology 13: 67- 74

*Kring, J.B. 1969. Mortality of earthworms *Lumbricus terrestris* following soil application of insecticides in a tobacco field. J. Econ. Ent. 62: 963 - 965.

Krishnamoorthy, A. and Rajagopal, D. 1998. Effect of insecticides on the California red scale, *Aonidiella aurantii* (Maskell) and its natural enemies. Pest Mgmt hort. Ecosystems 4: 83-88

Krishnamurti, B. and Usman, B.1955. Some insect parasites of economic importance in Mysor state. Indian J. Ent. 16: 327-344

Krishnamurti, B.1950. Aphididae of Mysore, II. J. Bombay nat. Hist. Soc. 34:411-419

Kumar, A., Ramkishore and Parihar, S. B. S.2004. Population build up of *Aphis gossypii* Glover on different crops. Insect Environ.10(1):6-7

Kumar, N. K. K., Moorthi, P. N. K. and Reddy, E. S. G. 2001. Imidacloprid and thiamethoxam for the control of okra leafhopper, *Amrasca biguttula biguttula* Ishida. Pest Mgmt hort. Ecosystems 7: 117-126

Kumar, V.D.V.N.H., R. Subramanian and P. Natarasan. 1999. Evaluation of acetamiprid, a new insecticidal compound against cotton aphids, *Aphis gossypii* and jassids, *Amrasca biguttula biguttula*. *Pestology,* 23(3): 28-33.

Kunkel, B. A., Held, D.W. and Potter, D. A. 1999. Impact of halofenozide, imidacloprid and bediocarb on beneficial invertebrates and predatory activity in turf grass. J. Econ. Ent. 92: 922-930

Kurl, S. P. and Misra, S. D.1980.Interaction between the aphids and their attented ants. J.Environ.Res.1: 1-6

Lakshmi, P. S. P., Sekhar, P. R. and Rao, V. R. 2002. Bioefficacy of certain insecticides against spotted pod borer on urd bean. Indian J. Pulses Res.15: 201-202

Lakshmi, V. J., Katti, G., Krishnaiah, N. V. and Lingaiah, T. 1997. Laboratory evaluation of commercial neem formulations and insecticides against egg parasitoid, *Trichogramma japonicum* Ashmead (Hymenoptera: Trichogrammatidae). J. Biol. Control 11: 29-32

Lebrun, P., De Medts, A.and Wauthy, G. 1981. Comparative ecotoxicology and bioactivity of three carbamate insecticides on an experimental population of the earthworm *Lumbricus herculeus*. Pedobiologia, 21: 225-235.

Lefroy, H.M. 1909. *Indian Insect life today and tomorrow*. Printers and Publishers, New Delhi 764pp.

Lyla, K. R, Joy, P. J. and Abraham,C. C.1987. Insect pests of *Chromolaena odorata*(= *Eupatorium odoratum*) Agrl. Res. J. Kerala 25:302-304

Macfadyne, A. 1961. Improved funnel type extractors for soil arthropods. J. Ani. Ecol.30:171-184.

Mackaur, M. and Chow, F. J. 1986. Parasites and parasite impact on aphid populations. In: *Plant virusepidemics: Monitoring, Modelling and Predicting outbreaks*. (Eds. McLean, G. D.,Garret, R. G., Ruesink, W.G.) Sydney, Academic Press PP 95-118

Madan, V. K. Beenakumari. S. 1996. Monitoring of pesticides from farm gate samples of vegetables in Hariana. Pesticide Res. J. 8(1):56-60

*Maiti, M.L., Banerjee, T.K. and Raychudhuri, D. 1989. Population dynamics of *Aphis gossypii* Glover on okra in West Bengal: Key factor analysis. Sci. and Cult.55:499-502.

Malini, N. 2007. Pests of tulsi (*Ocimum tenuiflorum*L.) and their management. M.Sc. (Ag.) thesis, Kerala Agricultural University, Thrissur, 127p.

Mani, M. and Kishnamoorthy, A. 1994. Selectivity of pesticides to the parasitoid *Aphelinus* sp. of the green peach aphid, *Myzus persicae* infesting sweet pepper. J. Aphidol. 8:79-87

Mantur, G. S. 1998. Toxic effect of insecticides on growth and development of earthworms Edrilus eugemiae (Kingberg). M. Sc. (Ag.) Thesis, U.A.S., Dharwad, India, 126p.

Manu, P.M. 2005. Major spiders in vegetable ecosystem and their predatory potential. M.Sc. (Ag.) thesis, Kerala Agricultural University, Thrissur, 105 p.

Manu, P. M. and Hebsy Bai. 2006. Spider fauna in a vegetable ecosystem. Insect Environ. 11 (4): 180-181

Mariam, M. A. and Chandramohan, N. 2000. Evaluation of chemical insecticides and botanicals against various stages of spiraling white fly, *Aleurodicus dispersus* Russell. Madras Agric.J.87:379-381

Martikainen, E. 1996. Toxicity of dimethoate to some soil animal species in different soil types. Ecotoxicology and Environmental safety 33(2):128-136

Martin, J. H.1983. The identification of common aphid pests of tropical agriculture. Trop. Pest Mgmt 29: 395-411

Martin, N. A. 1976. Effect of four insecticides on the pasture ecosystem: V. Earthworms (Oligochaeta: Lumbricidae) and arthropoda extracted by wet sieving and salt floatation. *New Zealand. J. Agric. Res.*, 19: 111-115.

Masoodkhan, M. A., Reddy, J. D. and Rao, V. 2001. Efficacy of selected insecticides against pest complex in okra, *Abelmoschus esculentus* Linn. Pestology 25 (9):44-48

Mathew, P. K., Thomas, M. J. and Nair, M. R. G. K. 1971. Population fluctuations of the pea aphid in relation to climate and predators. Agric.Res.J.Kerala 9:23-26

Mathirajan, V.G. and Regupathy, A. 2003. Prey preference and predatory potential of spiders in cotton ecosystem. Entomon 28: 9-14

Medts, A. D. 1981. Effects de residues de pesticides surles lombriciens en terre de culture. Pedobiologia 21: 439-445.

Misra, H. P. 2002. Field evaluation of some newer insecticides against aphids (*Aphis gossypii*) and jassid (*Amrasca biguttula biguttula*) on okra. Indian J. Ent. 64: 80-84

Misra, H. P. 2003. Efficacy of combination insecticides against til leaf webber and pod borer, *Antigastra catalaunalis* (Dupon.)and phyllody. Ann. Pl. Prot. Sci. 11: 277-280

Mohan, M. and Katiyar, K. N. 2000. Impact of different insecticides used for bollworm control on the population of jassid and whitefly in cotton. Pestic. Res. J. 12: 99-102

Mote, U. N., Dathkhil, R. V. and Pawar, S. A. 1994. Imidacloprid as seed dresser against sucking pests of okra. Pestology 18 (3): 5-9

Mukherjee, I. and M. Gopal. 2000. Environmental behaviour and translocation of imidacloprid in eggplant, cabbage and mustard. Pest Mgmt Sci. 56(10): 932-936.

Nagia, D.K., Kumar, S. and Saini, M.L. 1990. Effectiveness of some insecticides to Bihar hairy caterpillar, *Spilosoma obliqua* (Walker) on cabbage. Pl. Prot. Bull. 42: 17-18

Nair, M. R. G. K. 1995. *Insects and Mites of Crops in India*. Third edition, Indian Council of Agricultural Research, New Delhi, 408 p.

Nair, M. R. G. K. 1999. *A monograph on crop pests of kerala and their control.* Third revised edition, Kerala Agricultural University, Thrissur, 162p.

Nandakumar, C. and Saradamma, K. 1996. Botanical pesticides are benign to the natural enemies of Epilachna beetle. Insect Environ. 2 (1): 27

Nasir, A. and Yousf, M. 1995. Aphids and their host plants in the province of Punjab. Pakistan J. Zool. 27 (3) : 282-284

Natarajan, K. and Sundaramurthy, V.T. 1990. Effect of neem oil on cotton whitefly, *Bemisia tabaci*. Indian J. agric. Sci. 60: 290-291

Nath, D. K. and Sen, B. 1976. Some observations on aphidophagous coccinellid beetles in mustard cultivation. Science and Culture 42:288-290

Nayak, M. R. L., Basu, M. and Raychaudhuri, D. N.1981. Parasites and Predators of aphids (Homoptera : Aphididae) from India V. Seven coleopteran and four dipteran predators from Orissa. Pranikee 3: 7-14

Nayak, R. N. and Behura, B. K.1969. Studies on the Aphididae of India II. Observations on the biology of the common chrysanthemum aphid *Macrosiphoniella sanborni* (Gillette). Prakruti-Utkal University J. Sci. 6: 1-6

Nayar, K. K., Ananthakrishnan,T. N. and David, B.V. 1976. General and applied entomology. First edition. Tata McGraw-Hill Publishing Company Ltd. New Delhi: 589p.

Nurindah, S. and Bondra, O.S. 1988. Studies on biological control of cotton pests. Industrial Crop Res. J. 1: 59-83

Omkar and Bind, R. B. 1998. Prey preference of a ladybird beetle, *Cheilomenes sexmaculata* (Fab.). J. Aphidology 12: 63-66

Omkar, James, B.E and Srivastava, S. 1999. Prey preference of a ladybeetly, *Coccinella transversalis* Fabricius (Coleoptera: Coccinellidae). Adv. Bios. 18 (2): 117-122

Omkar, Srivastava, S. and James, B.E. 1997. Prey preference of a ladybeetle, *Coccinella septempunctata* Linn. (Coleoptera: Coccinellidae). J. Adv. Zool. 18 (2): 96-97

Panickar, B.K. and Patel, J.R. 2001. Leaf curl in chilli protected against thrips, *Scirtothrips dorsalis* with synthetic insecticides. Indian J. Ent. 63: 104-107

Panse, V.G. and Sukhatme, P.V. 1978. *Statistical Methods for Agricultural Workers*. Fourth edition. Indian Council of Agricultural Research, New Delhi, 381 p.

Patel, H.M., Borad, P.K. and Korat, D.M. 2003. Toxicity of biocides and synthetic insecticides on predatory fauna of *Aphis gossypii* infesting plantago. Proceedings of the National Symposium on Frontier areas of Entomological Research, 5-7 November 2003. Indian Agricultural Research Institute, New Delhi. *Abstract*: 267

Patel, J. R. and Patel, H. K. 1969. Some syrphids of Gujarat and their hymenopterous parasites. Indian J. Ent. 31:86-98

Patel, J. J., Patel, N. C., Patel, B. H. and Patel, J. R. 1999. Bioefficacy of different spray schedules against thrips, *Scirtothrips dorsalis* infesting chilli. Indian J. Ent. 61: 345-350

Patel, Z.P. and Patel, J.R. 1996. Effect of botanicals on behavioural response and on growth of the jassid, *Amrasca biguttula biguttula* Ishida. Pestology 24(5): 28-32

Patil, A.S., Patil, P.D., and Patil, R.S. 2002. Efficacy of different schedule doses of imidacloprid against sucking pest complex of chilli (*Capsicum annuum* L.). Pestology 26 (12): 31-34

Patil, B.V. and R. Rajanikantha. 2004. New class of insecticides, mode of action and their bioefficacy. In: *Int. Symposium on strategies for sustainable cotton production – a global vision -3 Crop protection.* (eds.) B.M. Kadhi, H.M. Vamadevaiah, I.S. Katageri, S.N. Chaltan, S.S. Udikeri and S.B. Patil, 23-25 Nov, UAS, Dharwad, Karnataka. pp. 77-85.

Patil, B.V., Bheemanna, M., Badari prasad, S.B., Gowdar S. B. and Kumar, V. D. V. N. H. 2001. Bioefficacy of acetamiprid 20 SP against early sucking pests in irrigated cotton. Pestology 25(9): 29-33.

Patil, B.V., Nandihalli, B.S., Hugar, P., Thimmanagoud, B.R. and Lingappa, S. 1993. Bioefficacy of newer insecticides against cotton whitefly *Bemisia tabaci* (Gennadius). Karnataka J. agric. Sci. 6(4): 20-24

Patil, C.S. and Lingappa, S. 2000. Selective toxicity of some insecticides against tobacco aphid, *Myzus nicotinae* Blackmann and its predator *Cheilomenus sexmaculata* (Fabricious). J. Biol. Control 14: 41-44

*Pfluger, W. and Schmuck, R. 1991. Ecotoxicological profile of imidacloprid. Pflanzenschutz- Nachrichten Bayer, 44: 145-158.

Phadke, A.P., Khandal, V.S. and Rahalkar, S.R. 1988. Use of neem products in insecticide resistant management in cotton. Pesticides 22 (4): 36-37

*Pollini, A. and Bariselli, M. 1997. .Activity of new insecticides used in fruit growing. Pest Mgmt Sci. 53: 3-8

Prasad, R.T., Reddy, G.P.V., Murthy, M.M.K. and Prasad, V.D. 1993. Efficacy of residues of certain new insecticides on okra. Indian J. Pl. Prot. 21: 47-50

Premsagar, J.1992. Disruptive sublethal effects of insecticides on biological control altered foraging ability and life span on a parasitoid after feeding on extra-floral nectar on cotton treated with systemic insecticides. Biological Control. 17: 234-249

Purohit, D., Ameta, O.P. and Sarangdevot, S.S. 2006. Seasonal incidence of major insect pests of cotton and their natural enemies. Pestology 30 (12) : 24- 29

Rahman, K.A. and Khan, A.U. 1941. Biology and control of wooly aphids Eriosoma lanigerum Haussmann (Aphididae: Rhynchota) in Punjab. Indian J. agric.Sci. 11: 265-278

Rai, B. K. 1976. Pests of oilseed crops in India and their control. First edition. Indian Council of Agricultural Research, New Delhi 121pp

Raj, S.M. and Punnaiah, K.C. 2003. Efficacy of insecticides by stem application against *Aphis gossypii* on okra. Proceedings of the National Symposium on Frontier areas of Entomolgical Research, 5-7 November 2003. Indian Agricultural Research Institute, New Delhi. *Abstract* : 67

Ramnathsubramanian and P. Natarajan. 1998. Acetamiprid and spinosad – Two new ecofriendly pest control products for cotton. *Workshop on Ecofriendlycotton,* pp. 26-28.

Rani, B. J. and Sridhar, V. 2005. Record of aphids (Homoptera: Aphididae) and their natural enemies on some medicinal and aromatic plants. Pest Mgmt hort. Ecosystems 11: 71-73

Rani, O.P.R. 1995. Bioecology and life-tables of the pea aphid *Aphis craccivora* Koch. and its natural enemies: M.Sc. (Ag.) thesis, Kerala Agricultural University, Thrissur, 121p.

Rani, J. 2004. Bioecology and management of spiralling whitefly *Aleurodicus dispersus* Russell (Homoptera: Aleyrodidae). M.Sc. (Ag.) thesis, Kerala Agricultural University, Thrissur, 86p.

Rao, N.V., Rajasekhar, P. and Venkataiah, N. and Reddy, A.S. 1996. Performance of few plant products as additives to insecticides against *Heliothis armigera* Hubner. *Neem and Environment* (eds. Singh, R.P., Chari, M.S., Raheja, A.K. and Kraus, W.). Oxford and IBH Publishing Co. Pvt. Ltd., New Delhi, pp. 1109-1115

Rao, V. P. 1969. Survey for natural enemies of aphids in India (U.S. PL-480 Project). CIBC Indian Station, Bangalore.93pp.

Ravikumar, S.S., Chhillar, B.S. and Rohilla, H.R. 2003. Toxicity of Nitroguanidines / Neonicotinoids and conventional insecticides against leafhopper, *Amrasca biguttula biguttula* on okra under green-house. Indian J. Ent. 65: 268-272

Raychaudhuri, D. N., Ghosh, D, Raychaudhuri, D. and Agarwala, B. K. 1981. Studies on the aphids (Homoptera: Aphididae) from South India. Insecta Matsumurana 23: 1-20

Raychaudhuri, D. N 1980. Aphids of North-east Indiaand Bhutan. The Zoologica Society, Calcutta

Raychaudhuri, D. N.1983. Food plant- cataloque of Indian Aphididae. Aphidological Socity of India.pp 202

Reddy, K. M. S., Rajagopal, B. K., Reddy, R. N. S. and Reddy, N. S. 2002. Effect of botanicla insecticides against rose aphid (Microsiphum rosae L.) J.Ornm. Hort. 5(1): 84-85

Reddy, K. N., Satyanarayana, S. and Reddy, K. D. 2007. Persistence of some insecticides in chillies. Pesticide Res. J. 19 (2):234-236

Reddy, M. V. and V. R. Reddy. 1992. Effect of organochlorine, organophosphorous and carbamate insecticide on the population structure and biomass of earthworms in a semiarid tropical grassland. Soil Biol. Biochem. 24: 1733 -1738.

Remaudière, G. and Remaudière, M.1997. Catalogue of World's Aphididae, Paris 426 p.

*Rogers,V and Horner, R. 1977. Toxicity of insecticides to predators of rice plant hoppers : Spider, Mirid bugs and dryinid wasps. *Appl. Ent. Zool.* 35: 177-187

Rosaiah, B. and Reddy, A.S. 1996. Utility of botanicals and biocides as additive to insecticides in *Helicoverpa armigera* management in cotton. *Neem and Environment* (eds. Singh, R.P., Chari, M.S., Raheja, A.K. and Kraus, W.). Oxford and IBH Publishing Co. Pvt. Ltd., New Delhi, pp. 485-491

Roy, P. and Basu, S. K. 1978. Bionomics of aphidophagous syrphid flies. Indian J. Ent. 39:165-174

*Ruiz, V.J. and Medina, Z.J. 2001. Advances in the integrated management of *Bemisia tabaci* on tomato and pepper. Pest Mgmt Sci. 57: 978-985

Salguero, V. and Morales, J. 1994. Efficacy of insecticides for the control of *Bemisia tabaci* (Gennadius) of tomato. J. Econ. Ent. 87: 341-348

Sandeepkaur, R. 2002. Management of cotton jassid, *Amrasca biguttula biguttula* Ishida and spotted bollworm, *Earias* spp. in okra. Vegetable Sci. 29 (2): 172-175

Sandhya, S. B. and Dethe, M. D. 1991. Toxicity of acephate to brinjal aphid, *Myzus persicae* (Sulz.). J. Insect Sci. 4: 203-204

Santhoshkumar, S. N.1997. Insecticide residues in market samples of vegetables and methods of their decontamination. M.Sc. (Ag.) thesis, Kerala Agricultural University, Thrissur, 78 p.

Sanyal, D., Chakma, D. and Alam.S. 2008. Persistence of a neonicotinoid insecticide, Acetamiprid on Chilli (Capsicum annuum L.) Bull. Envirn. Contam. Toxicol. 78: 256-260

Sarangdevot, S. S., Kumar, A. and Chundawat, S.G. 2006. Field bioefficacy of some newer insecticides against aphids infesting tomato crop. Pestology 30 (3): 20-22

Sarode, S.V., Patil, P.P. and Borkar, S.L. 1995. Evaluation of neem seed kernel extract in combination with Heliothis nuclear polyhedrosis virus against cotton bollworm. *J. Ent. Res.* 19 (3): 219-222

Satpathy, J.M.1974. Effect of soil treatment with granular insecticides on soil microorganisms. Indian J. Ent. 36: 139- 141

Schmutterer, H. 1990. Properties and potential of natural pesticides from the neem tree *Azadirachta indica.* Ann.Rev. Ent. 35: 271-297.

Sequeira and Dixon, 1997. Population dynamics of tree- dwelling aphids: the importance of seasonality and time scale. Ecology 78: 2603-2610

Singh. D. 2000. Influence of varieties and dates of planting of radish stecklings on infestation by mustard aphid. *Lipaphis crysimi* (Kaltenback). J. Res. Punjab agric. Univ. 24 (3): 396-398

Singh, R. 2004. *Elements of Entomology.* First edition. Rastogi Publications, Meerut, 564, p.

Singh, S. R. and Allen, D.J. 1980. Pest and disease resistance and protection in cowpea. Advances in Legume Sci. 24: 419-443

Singh, S. P. and Narasimham, A. U. 1992. Indian Chrysopidae. Biological control centre (NCIPM) Bangalore, Technical Bulletin No.5.34pp.

Singh, S. P. and Rao, N. S.1978. Occurrence of *Aphis citricola* van der Goot in India. Sci. Cult.44:330-331

Singh, J.G.S., Simwat, G.S., Brar, K.S. and Sohi, A.S. 2002. Efficacy of Acetamiprid (N125) against cotton jassid on American cotton. Insect Environ. 8: 100

Singh, S. S. ,Tiwari, B. C. and Rao, V. K. 2003.Comparative efficacy of some modern insecticides and neem based formulations against cabbage butterfly, *Pieris brassicae.* Indian J. Ent.65: 264-267

Sivakumar, R., Nachiappan, R.M. and Selvanarayanan, V. 2003. Field evaluation of profenofos (Curacuron) against selected pests of okra. Pestology 27 (1): 7-11

Sivakumar,T. 2001. Ecofriendly pest management in snake gourd (Trichosanthes anguina L.) M.Sc. (Ag.) thesis, Kerala Agricultural University, Thrissur, 85 p.

Sivaveerapandian, D. 2000. Bioefficacy of imidacloprid against sucking pests on bhendi and determination of half-life. M.Sc. (Ag.), Thesis, Tamil Nadu Agricultural University, Coimbatore, India, 111p.

Sivaveerapandian, D., G. Santharam, S. Kuttalam and S. Chandrasekaran. 2002. Harvest time residues and dissipation of imidacloprid on bhendi fruits, *Abelmoschus esculentus*. Pestic. Res. J. 14(1): 191-194.

Skinner, G.J.and Whittaker, J. E. 1981. An experimental investigation of inter-relationships between the wood ant (*Formica rufa* Dact) and some tree-canopy herbivores. J. Ani. Ecol. 50: 313-326

Smith, S.F. and Krischik, V.A. 1999. Effects of systemic imidacloprid on *Coleomegilla maculata* (Coleoptera, Coccinellidae). Environmental Ent. 28:11891195

Srikanth, J. and Lakkundi, N. H. 1990. Seasonal population fluctuations of cowpea aphid A.craccivora Koch. And its predatory coccinellids. Appl. Insect Sci.11:21-26

Srinivasan, G. and Babu, P.C.S. 2001. Field evaluation of neem products against whitefly, *Bemisia tabaci* Gennadius on brinjal. Ann. Pl. Prot. Sci. 9: 19-21

Stark, J. D. 1993. Comparison of the impact of a neem seed-kernel extract formulation, Margosan-O and chlorpyrifos on non-target invertebrates inhabiting turf grass. Pesticide Sci. 36: 293-299

Stary, P. 1988. Aphidiidae. In: *World crop pests: Aphids. Their biology, natural enemies and control* (Eds. Minks, A. K. and Harrewinj, P) pp 171-184

*Stiling, P. 1988. Density- dependent processes and key factors in insect populations. J. Anim. Ecol. 57: 581- 593

Suganthy, M. 2003. Bioefficacy and residues of Confidor® (Imidacloprid 17.8% SL) on cotton, vegetables and mango. Ph.D. Thesis. Tamil Nadu Agric. Univ., Coimbatore, India, 197p.

Suja, G. 2003. Integrated pest management in grain and vegetable cowpea *Vigna unguiculata* (L.) Walp. Ph.D thesis, Kerala Agricultural University, Thrissur, 211 p.

Sujeetha, A.J., Mammen, K.V.,Vishalakshy, A. and Mohan Das, N. 1999. Insecticides interaction on the useful soil organisms in banana plantation. Entomon 24 (2): 185-190

Sundari, M. S. M. 1998. Residual toxicity of insecticides against *Cryptolaemus montrouzieri* Mulsant (Coleoptera : Coccinellidae). Insect Environ. 4: 45

Surekha, J. and Rao, A. P. 2001. Management of applied on bhindi with organic sources of NPK and certain insecticides. Andhra agric. J. 48: 56-60

Sweeden, M. B., Mcleod, P. J. and Russel, W. R. 1994. Acephate : Effect on dryland and irrigated cowpeas when applied for thrips (Thysanoptera: Thripidae) and corn earworm (Lepidoptera: Noctuidae) control. J. Econ. Ent. 87: 1627-1631

Thamilvel, D. 2004. Management of insect pest complex in okra (*Abelmoschus esculentus* Linn.). M.Sc. (Ag.) thesis, Kerala Agricultural University, Thrissur, 107p.

Thayaalini, S. and Raveendranath, S. 1998. Effect of *Gardenia cramerii* Ait and dimethoate on the aphid predator, *Cheilomenus sexmaculata* Fabr. (Coleoptera: Coccinellidae). Pest Mgmt hort. Ecosystems 4: 49-50

Thilagam, P., Sivasubramanian, P. and Vishnupriya, M.2008. Efficacy of neemazal formulations against cotton aphid, *Aphis gossypii* Glover. J. Ecotoxicol. Environ. Monit. 18 (1): 91-92

Tolman, J.H., Chapman, R.A., Moy, P. and Henning, K.V. 2000. Persistence of early-season treatments for control of Colorado potato beetle, *Leptinotarsa decemlineata* (Say), attacking field tomato. J. Veg. Crop Prod. 6(1): 3-16

Tonet, G.L., Fiuza, L.M., Santana, J. and Silva, R.F.P. 1997. Toxicological evaluation of insecticides to *Aphidius* spp. (Hymenoptera; Apidoidea). J. Biol. Control 11: 136-141

Trumble, J. T., Bernardo, U.B. and Giorgini, M. 1983. Aphid (Homoptera: Aphididae) population dynamics on broccoli in an interior valley of California. J.Econ. Entomol. 75: 841-847

Umoru, P.A. and Powell, W. 2002. Sublethal effects of the insecticides primicarb and dimethoate on the aphid parasitoid *Diacretiella rapae* (Hymenoptera: Braconidae) was attacking and developing in insecticide resistant hosts. Biocontrol Sci. Tehnol. 12: 605-614

Upadhyay, V.R., Kaul, C.C. and Talati, G.M.1980. Seasonal incidence of aphid *Dactynotus carthami* and coccinellids in relation to weather conditions. Indian J.Pl. Prot.8:117-121

*Van Driesche and Bellows,G. 1996. Identification of TMV and CMV in pepper in Chongqing area. China Vegetables, 3: 13-15

Varghese, B. 2003. Evaluation of newer insecticides against major pests of cowpea, *Vigna unguiculata* (L.) Walp. and their effect on natural enemies. M.Sc. (Ag.) thesis, Kerala Agricultural University, Thrissur, 78 p.

Veeravel, R. and Bhaskaran, P. 1996. Temperature dependent development, adult longevity, fecundity and feeding potential of two coccinellid predators under laboratory conditions. Entomon 21:13-18

Veeresh, G.K. and Musthak Ali, T.M.1990. The present satatus of our knowledge on Indian ants.In Social insects perspective (eds. Veeresh, G.K., Kumar, A.R.V. and Shivashankar, T) IUSSI-Indian Chapter, Bangalore- India.

Verghese, A. and Tandon, P. L.1987. Interspecific associations among *Aphis gossypii*, *Menochilus sexmaculatus* and *Camponotus compressus* in a guava ecosystem. Phytoparasitica 5:289-297

Verma, A. K. 2003. Some observations on oviposition behaviour of aphidophagous syrphids. Proceedings of the National Symposium on Frontier areas of Entomolgical Research, 5-7 November 2003. Indian Agricultural Research Institute, New Delhi. *Abstract* : 214

Viggiani, G. Bernardo, U.B. and Giorgini, M. 1999. Contact effect of pesticides on some entomophagous insects. Biocontrol News and Information 20 (2): 150

Vijayasree, V. 2006. Pests of coccinia (*Coccinia grandis*(L.) Voigt.) and their management. M.Sc. (Ag.) thesis, Kerala Agricultural University, Thrissur, 106p.

Vogt, H., Handel, U., Vinuela, E. and Kleeberg, H. 1996. Field investigations on efficacy of NeemAzal T/S against *Dysaphis plantaginea* (Passerini) (Homoptera: Aphididae) and its effects on larvae on *Chrysoperla carnea* Stephens (Neuroptera: Chrysopidae). *Proceedings of practice oriented results on use and production of neem ingredients and pheromones, 22-25 January 1996* (ed. Zebitz, C.P.W.). Druck and Graphic, Germany, pp. 141-145

*Xin and Xi. 1995. An evaluation of the effect of imidacloprid on rice plant hopper and its natural enemies. Pl. Prot. 21: 42-44

Yequming, B., Yu, H., Lizhen, Z., Yahong, Y., Xiang, X., Lifen, J. and Ye, Z. 1996. Population dynamics and chemical control of citrus aphids in Zhejiang. Acta Agriculturae Zhejiangensis, 8(5): 281-286.

*Zaki, F. N. 1987. Larval duration and food consumption for the predator *Chrysoperla carnea* Steph. Under different constant regimes. Ann. Agric. Sci. Ani. Shams Univ. Egypt 32:1827-1836

---

* Original not seen

POPULATION DYNAMICS AND MANAGEMENT OF APHIDS IN VEGETABLE ECOSYSTEM

D. THAMILVEL

Abstract of the
thesis submitted in partial fulfilment of the requirement
for the degree of

Doctor of Philosophy in Agriculture

Faculty of Agriculture
Kerala Agricultural University, Thrissur

2009

Department of Agricultural Entomology
COLLEGE OF AGRICULTURE
VELLAYANI, THIRUVANANTHAPURAM 695 522

ABSTRACT

Eight species of aphids viz., *A. gossypii, A. craccivora, A. spiraecola, A. fabae, A. nerii, H. setariae, M. persicae* and *L. erysimi* were recorded from 32 vegetables in a survey conducted in the four taluks of Thiruvananthapuram district of Kerala. Occurrence of *A. gossypii* on *C. grandis, M. oleifera* and *P. tetragonolobus; A. craccivora* on *C. gladiata, P. tetragonolobus* and *S. grandiflora* ; *A. spiraecola* on *A. tricolor, C. sativus, C. tetragonoloba, M. oleifera, M. charantia, M. koeingii, P. tetragonolobus* and *S. androgynus* ; *M. persicae* on *A. tricolor* and *R. sativu*; *A. nerii on C. annuum* and *C. frutescens* was recorded for the first time from the State and *H. setariae* on *A. tricolor* and *A. dubius* from South India. One hundred and twenty two other plants were identified as host plants of the different aphids. *A. gossypii* was the dominant species noted, closely followed by *A. craccivora,* and *A. spiraecola.* Maximum species of aphids were recorded on amaranthus followed by winged bean. Among the vegetables surveyed, chilli and coccinia were highly susceptible to *A. gossypii* and winged bean and cowpea to *A. craccivora.* Mosaic disease incidence was noted in 10 vegetables.

Predators were the predominant group of natural enemies associated with the aphids with the coccinellids constituting the major predatory fauna. Twenty species of coccinellids were recorded from different species of aphids on various host plants of which 13 species were new records from Kerala. *M. sexmaculatus* was the dominant species followed by *C. transversalis, S. latemaculatus* and *C. septempunctata,* Four species of syrphids were recorded of which *I. scutellaris* was predominant. *P. yerburiensis* and *D. aegrota* were recorded for the first time from Kerala. *Leucopis* sp. was the only Chamaemyiid species recorded from the vegetable fields. The chrysopids, *C. carneae* and

A. octopunctata and the hemerobiid, *Micromus* sp. were the Neuropteran predators of the aphids recorded of which *Micromus* sp. was dominant. *A. octopunctata* was recorded for the first time from Kerala.

Eleven species of spiders were observed in the vegetable fields among which, *O. javanus*, *T.mandibulata*, *O. quadridentatus*, *O. shweta* and *Phidippus* sp. were the frequently encountered species. *Aphidius* sp. was the most dominant parasitoid in the vegetable ecosystem. *Aphelinus* sp. and *D. rapae* were the other parasitoids recorded. Seven species of ants were observed attending the aphids.

Studies on the population fluctuation of *A. gossypii* in chilli and *A. craccivora* in winged bean during a cropping season indicated that high population was seen during November and December. Correlation studies revealed a significant and positive correlation between the population of both the aphids with the insect predators, spiders and parasitoids. None of the climatic parameters had any significant influence on the aphid population. Excepting, maximum temperature which had a positive influence, all the other weather parameters viz., minimum temperature, relative humidity, rainfall and wind velocity had a negative influence on the population of the predators and parasitoids.

Among the botanicals screened in the laboratory, only neem oil-garlic emulsion 2% and NeemAzal T/S 4 ml/l recorded more than 50 per cent mortality of *A. gossypii* and *A. craccivora.* Among the insecticides, the neonicotinoids viz., acetamiprid 0.002% imidacloprid, 0.003%, and dimethoate 0.05% proved superior to all other treatments. Dimethoate 0.05% was highly toxic to the coccinellids, syrphids and a hemerobiid (*Micromus* sp.) predator under laboratory condition. Between the two neonicotinods, acetamiprid 0.002% registered higher mortality than imidacloprid 0.003% whereas NeemAzal T/S 4 ml/l and neem oil + garlic emulsion 2% were safe to the predators.

Foliar application of dimethoate 0.05%, acetamiprid 0.002% and imidacloprid 0.003% gave good control of *A. gossypii*, *A. biguttula biguttula*, *S. dorsalis* and *A. dispersus* in chilli and *A. craccivora*, *A. dispersus*, *R. pedestris* and *M. vitrata* in winged bean. NeemAzal T/S 4ml/l and neem oil garlic emulsion 2% too checked the population of the pests appreciably. Dimethoate 0.05% was highly toxic to the predators and parasitoids followed by acetamiprid 0.002% both in the chilli and winged bean fields. Comparatively, imidacloprid 0.003% was less toxic. The botanicals were safer to the natural enemies. Dimethoate 0.05% was highly toxic to soil fauna and flora whereas acetamiprid and imidacloprid were less toxic while NeemAzal T/S 4ml/l and neem oil + garlic emulsion 2% were non toxic.

In both the trials, significantly higher yield was obtained from all the treatments. However, no significant difference was noted in the yields obtained from acetamiprid 0.002%, imidacloprid 0.003% and dimethoate 0.05% treated plots. Residues of imidacloprid were detected in chilli and winged bean fruits five days after spraying. While on the tenth day after spraying, residues of acetamiprid, and dimethoate were detected in chilli fruits, only residue of acetamiprid was recorded from winged bean pods. Imidacloprid was below detectable level (BDL). Residues of all the three insecticides were below detectable level when estimated fifteen days after spraying.

Based on the results of the study, early detection of aphids on weeds and other host through regular monitoring, proper weed and ant management, conservation of the beneficials, application of neem oil + garlic emulsion 2% or NeemAzal T/S 4ml/l during the early stage of infestation and use of imidacloprid 0.003% when needed are suggested for aphid management in vegetables.

APPENDIX-I

The composition of media used for the study of microflora

1. Martins Rose Bengal Agar for Fungi

Dextrose	- 10 g
Peptone	- 5 g
KH_2PO_4	- 1 g
$MgSO_4.7H_2O$	- 0.5 g
Rose Bengal	- 33 mg
Agar	- 20 g
Distilled water	- 1000 ml
Streptomycin	- 30 mg

2. Soil extract Agar for Bacteria

Soil extract	- 100 ml
Glucose	- 1g
KH_2PO_4	- 0.5 g
Agar	- 15 g
Tap water	- 900 ml
pH	- 6.8

3. Glycerol Asparagine Agar for Actinomycetes

Glycerol	- 10 ml
Asparagine	- 1g
KH_2PO_4	- 1 g
Agar	- 20 g
Distilled water	- 1000 ml
pH	- 7.0