

SEASONAL ABUNDANCE AND MANAGEMENT OF MAJOR CITRUS PESTS OF SOUTH ZONE

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**THESIS SUBMITTED TO THE
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CERTIFICATE

This is to certify that **Mr. P. KOTESWARA RAO**, has satisfactorily prosecuted the course of research and that the thesis entitled "**SEASONAL ABUNDANCE AND MANAGEMENT OF MAJOR CITRUS PESTS OF SOUTH ZONE**" submitted is the result of original research work and is of sufficiently high standard to warrant its presentation to the examination. I also certify that the thesis or part there of has not been previously submitted by him for a degree of any University.

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Place :

CERTIFICATE

This is to certify that the thesis entitled "**SEASONAL ABUNDANCE AND MANAGEMENT OF MAJOR CITRUS PESTS OF SOUTH ZONE**" submitted in partial fulfilment of the requirements for the degree of '**Master of Science in Agriculture**' of the Acharya N.G. Ranga Agricultural University, Hyderabad, is a record of the bonafide research work carried out by **Mr. P. KOTESWARA RAO** under our guidance and supervision. The subject of the thesis has been approved by the Student's Advisory Committee.

No part of the thesis has been submitted by the student for any other degree or diploma. The published part has been fully acknowledged. All assistance and help received during the course of the investigations have been duly acknowledged by the author of the thesis.

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DECLARATION

I, **Mr. P. KOTESWARA RAO**, here by declare that the thesis entitled "**SEASONAL ABUNDANCE AND MANAGEMENT OF MAJOR CITRUS PESTS OF SOUTH ZONE**" submitted to Acharya N.G. Ranga Agricultural University, Hyderabad for the degree of **Master of Science in Agriculture** is the result of original research work done by me. I also declare that the materials contained in this thesis has not been published earlier.

Date :

(P. KOTESWARA RAO)

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ABSTRACT

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Studies on seasonal abundance of major pests of citrus were undertaken on Sathgudi sweet orange and Balaji acid lime during June 2003 to May 2004. On sweet orange incidence of leaf miner *Phyllocnistis citrella* Stainton was peak during January and was negligible during April to July whereas on acid lime, peak incidence was noticed during December and negligible from April to June. Larval population of citrus butterfly *Papilio demoleus* Linnaeus was high during December and November and there was negligible during summer period (April and May) on both hosts viz., sweet orange and acid lime respectively. The incidence of citrus psylla *Diaphorina citri* Kuwayama was moderate during November and December on sweet orange and acid lime respectively, and incidence was recorded little during the months of July to October and February to April on both hosts. In case of weevil *Mylloceris* sp. population, peak occurrence recorded during October. No incidence of weevil was recorded during April and May on sweet orange and during May and June on acid lime. High incidence of leaf folder *Psorosticha zizyphi* St. was recorded during February on sweet orange whereas on acid lime it was high during February and December. There was no activity of black fly *Aleurocanthus woglumi* Ashby. throughout the year.

In case of green mite *Schizotetranychus hindustanicus* Hirst. the incidence was more during November on sweet orange while on acid lime peak population was noticed during March. Rust mite *Phyllocoptruta oleivora*

Ash. attained peak during March and January on sweet orange and acid lime respectively.

During the study of seasonal occurrence of various pests some of the insects like psychids, *Clania crameri*, *W. chaliella vitrea*, *Pteroma* sp., loopers, *Gonodontis clelia*, *Somatina purpurescens*, and semi looper *Paralellia palunba* L. were also recorded as pests of citrus, which is first record in this region.

During the period of study a larval parasitoid, *Tetrastichus* sp. on the larvae of leaf miner, *P. citrella*, two braconid parasitoids viz., *Apanteles papilionis* Viereck, *Bracon hebetor* S. and one predator *Rhynocoris marginatus* Fab. were found to be associated with a larval population of citrus butterfly, *P. demoleus*. Four coccinellid predators viz., *Coccinella septumpunctata* L., *Chilonemus sexmaculata* F., and *Brumus suturalis* F. and *Chilochorus nigrinus* F., one lace wing *Chrysopa* sp. and an unidentified preying mantid as well as a parasite *Tetrastichus* sp. were found associated with nymphs of psylla, *D. citri*. A pentatomid bug, *Amyotea malabarica* Fab. was identified as predator of adult weevil, *Myloccerus discolor* Boh.

Natural and synthetic insecticides were evaluated against citrus leaf miner, *P. citrella* under field conditions both as prophylactic and curative control measures. In the prophylactic control of leaf miner with natural products, all the treatments viz., NSKE, azadirachtin, neem soap, pongamia oil, pongamia soap, garlic extract, *Bacillus thuringiensis* (0.005% and 0.0025%) offered total initial protection keeping the citrus plants free from leaf miner attack upto three days. However NSKE, azadirachtin and *Bt.* (0.005%) effectively checked the incidence even upto five days. In curative method of leaf miner control *Bt* at both concentrations (0.005 and 0.0025%) found highly effective upto 10 days recording 100 per cent reduction. This was followed by azadirachtin and NSKE. Among synthetic insecticides, profenophos, lambda cyhalothrin and fenvalerate were the most effective as prophylactic treatments which checked the leaf miner incidence upto seven days. Cartap hydrochloride was comparatively less effective as it lost its efficacy in three days after spraying. As curative method of evaluation by synthetic insecticides, thiodicarb, lambda cyhalothrin and fenvalerate offered effective control by offering cent per cent mortality by third day. Cartap hydrochloride and chlorpyrifos were comparatively less effective treatments.

Against larval population of citrus butterfly, *P. demoleus* both concentrations of *Bt.* (0.005 and 0.0025%) were to be as the most effective treatments showing cent per cent mortality at five days after spraying. All the synthetic insecticides offered cent per cent larval mortality at five days after spraying.

CHAPTER - I

INTRODUCTION

Citrus industry is the third largest fruit industry in the world occupying about six per cent of the total area under fruit production. It occupies a place of considerable importance in the fruit economy of our country next to mango and banana.

The genus "citrus" is unique in its diversity possessing greater adaptability to different climatic conditions, hence are grown with equal success in tropical and sub tropical conditions and even in some favourable parts of the temperate regions of the world. This genus covers a wide range of fruit varieties including limes, lemons, oranges, pummelos, mandarins etc. These are highly regarded for their nutritive value and economic significance. They provide minerals, vitamins and other essential elements which are required for human health, besides being a rich source of vitamin 'C'.

India is one of the principal citrus producing country in the world having an area of 0.45 m.ha with annual production of 3.79 m.tonnes. In India, Andhra Pradesh is prominent for citrus cultivation occupying a majestic position with an area of 0.84 lakh ha having an annual production of 7.83 lakh tonnes of fruits. (Anonymous, 2002). The other important states for citrus cultivation are Maharashtra, Karnataka, Tamil Nadu and Punjab. In Andhra Pradesh the leading districts growing citrus are Nellore, Chittoor, Anantapur, Kadapa, Prakasam, East Godavari, West Godavari, Nalgonda, Karimnagar and Guntur. Sathgudi sweet orange and acid lime are the important citrus fruits grown in Andhra Pradesh.

Around 823 species of different insect and mite pests were know to be associated with citrus in various citrus grown areas of the world. (Ebeling, 1959). Out of these, 165 species are important in India causing an estimated loss of 30 per cent in yields (Pruthi and Mani, 1945). Many of these pests damage the crop at all stages of crop growth i.e. from nursery stage to bearing trees (Butani, 1979). About 55 species of insect and mite pests were reported feeding on citrus in south zone of Andhra Pradesh (Rama Subba Reddy *et al.*, 1989).

Although a large number of pests attack citrus, the citrus leaf miner (*Phyllocnistis citrella* Stainton), citrus butterfly (*Papilio demoleus* Linnaeus), citrus psylla (*Diaphorina citri* Kuwayama), weevils (*Mylocerus discolor* Boheman), leaf folder (*Psorosticha zizyphi* Stainton), blackfly (*Aleurocanthus woglumi* Ashby), green mite (*Schizotetranychus hindustanicus* Hirst) and rust mite (*Phyllocoptruta oleivora* Ashmead) are economically important (Rao and Raju, 1975). However in the altered scenario of orchard management in south zone of Andhra Pradesh, there is a need to understand the comprehensive information regarding the pest complex and their seasonal abundance. Hence in the present study, investigations were undertaken to document the seasonal activity of pests in the citrus ecosystem.

Among the various mortality factors, natural enemies play major role in the suppression of insect and non insect pests and support the grower in avoiding indiscriminate use of synthetic pesticides and pave way for developing a sustainable pest management strategy at ecosystem level. Hence, in the present study efforts were also made to study the different bioagents associated with citrus pests by making field observations and by

maintaining the pest material collected from the field to know the emergence of parasitoids.

For a long time, control of insect and mite pests could be done through chemical insecticides with the sole aim of getting quick results. This indiscriminate use of insecticides caused adverse effects, like resurgence, outbreak of minor pests by way of destroying the useful fauna besides increasing the cost involved in plant protection. The changed situations of aiming for environmental safety and replacement of chemical molecules with natural ones that preserve the activity of natural enemies of pests demand some close study on identification of better formulation. Hence, studies were also oriented to evaluate the efficacy of plant and animal origin formulations against pests of citrus.

These studies were conveniently divided in the following way with specific objectives.

1. Seasonal abundance of major pests of sweet orange and acid lime.
2. Identification of new pests of citrus under south zone environment.
3. Record of natural enemies associated with major pests of citrus.
4. Management of important citrus pests by involving natural and synthetic products as prophylactic and curative control measures.

CHAPTER-II

REVIEW OF LITERATURE

2.1 DISTRIBUTION, HOST PREFERENCE AND NATURE OF DAMAGE :

2.1.1 Citrus leaf miner (*Phyllocnistis citrella* Stainton)

The citrus leafminer, *P. citrella* had been recorded in Japan, China, Formosa, Siam, Malaya, Phillippines, East India and North Australia. It was prevalent in India, being more common in Madras, Madhya Pradesh, Assam, Western Uttar Pradesh and Punjab (Atwal, 1964).

Uygen *et al.* (1995) reported that the pest was originated in South and East Asia and spread to Turkey. Michelakis and Vacante (1997) reported that it was widely distributed throughout the citrus growing regions of Crete and Greece.

P. citrella was reported as one of the major pests of citrus in India, especially in Uttar Pradesh and Punjab (Singh 1984).

He reported that the citrus leafminer attacked only the younger and tender leaves, which become distorted and curled. The typical injury caused to tender leaves was reported as irregular twisted galleries or zigzag glistering tunnels in the leaves.

A survey of citrus orchards of Chittoor and Cuddapah districts in Andhra Pradesh revealed moderate to severe infestation of leafminer (Anonymous 1987).

Bhatia and Joshi (1991) reported that the budded seedlings of Kinnow orange were severely attacked by leafminer at nursery stage. At times, the attack of the pest was so serious, causing death of the new sprouts of grafted buds, thus resulting in a total loss of the budded plants.

Garijo and Garcia (1994) reported that the larva caused galleries on both sides of leaves and also frequently affected the stems resulting in reduced vigour.

Garrido-Vivas and Gascon-Lopez (1995) reported that eggs were laid both on upper and lower surfaces of the leaves. However, ovipositional preference was on the lower surface when leaves were less than 10mm in length. Larvae were abundant on the lower surface of leaves.

Grande (1995) recorded the occurrence of leaf miner on sweet orange, mandarin, clementine, sour orange, lemon and grapefruit.

Caleca *et al.* (1996) reported that greatest number of early instar larvae were recorded on leaves of 1-3 cm long, 85 per cent of eggs found on leaves upto 3 cm long, where as 78 per cent of pupae were on leaves more than 5 cm long.

Quilici *et. al* (1997) reported that the pest was present from sea level upto an altitude of 1250 meters.

2.1.2 Citrus butterfly : (*Papilio demoleus* Linnaeus)

The citrus caterpillar, *Papilio demoleus* L. was reported as a serious defoliator and widely distributed throughout the citrus growing areas. Besides citrus, it was also recorded on various species of plants belonging to family Rutaceae (Fletcher, 1914; Ayyar, 1940; Jandu, 1942; Bindra, 1957 and Atwal, 1964).

Jandu (1942) reported a number of alternate host plants for citrus caterpillars viz. *Trichodesma indicum*, *Feronia elephantum*, *Glycosmis pentaphylla*, *Zizyphus jujuba*, *Ruta graveolens*, *Citrus decimana*, *Chloroxylon sweitenia*, *Murraya koenigii* and *Aegle marmelos* were the most preferable food plants for this pest.

Sontakay (1943) reported serious out break of *P. demoleus* in Madya Pradesh during July, 1940 and again in the year 1943 in which caterpillars defoliated the entire orchards of Nagpur, and also caused flower and fruit drop from tender twigs.

Atwal (1964) reported that the genus *Papilio* was widely distributed all over the world. *Papilio demoleus* was found in Africa,

greater parts of Asia, Formosa and Japan. It has been reported as a pest throughout India but not in the U.S.A, Canada, Europe and the U.S.S.R.

Atwal (1964) stated that particularly the nurseries were more devastated by the pest and in cases of severe damage, the entire plant may be defoliated.

Purohit *et al.* (1966) recorded a weed, *Psoralea corylifolia* as an alternate host plant of the lemon butterfly *P. demoleus*.

Basu *et al.* (1969) reported that the pest was particularly serious in nursery plants and caused a great loss to seedlings and young saplings in Darjeeling district, West Bengal.

Thakare and Borle (1969) stated that the caterpillars of *P. demoleus* besides citrus, damaged bael (*Aegle marmelos*), Kadhu limb (*Murraya koenigii*), bawachi (*Psoralea corylifolia*) and bhira (*Chloroxylon sweitenia*) and further reported that the pest caused 100 percent defoliation in Maharashtra.

Butani and Jotwani (1975) reported that severe infestation of *P. demoleus* resulted in total defoliation of the infested tree.

Resham *et al.* (1986) reported that the caterpillars were voracious feeders and defoliated the entire seedlings within no time. Damage resulted

in death of the seedlings whereas young trees suffered to a greater extent with retarded growth.

Solomon Raju and Appala Naidu (2000) revealed that *Citrus aurantium* Weight was preferred by *P. demoleus* for egg laying.

Mahesh pathak and Pizvi (2003) found that, lemon was the most preferred and suitable food for the development of *P. demoleus*.

2.1.3 Citrus psylla (*Diaphorina citri* Kuwayama)

Citrus psylla *Diaphorina citri* Kuwayama was widely distributed throughout tropical and subtropical Asia and Far-east. In India it was most serious in North India. (Bindra 1969).

Raju and Reddy (1975) recorded the pest in low populations in Andhra Pradesh, but not as a serious pest.

Chakraborty *et al.* (1977) stated that *Murraya koenigii* Spreng and *M. paniculata* L. were the most preferred hosts than *Citrus* species.

Hill (1983) reported that the pest distributed from Pakistan and India through South East Asia to South China, Phillippines and Indonesia. There was one report about the pest occurrence from Saudi Arabia, also from Mauritius, Reunion and South America (Brazil).

Lim and Shamsudin (1990) recorded that *Murraya Koenigii*, *M. paniculata*, *Citrus sp* and *Clausena excavata* Burm are important natural hosts of *D. citri*.

Bap Reddy and Joshi (1991) reported the distribution of the pest in Bihar, Delhi, Himachal Pradesh, Kerala, Madhya Pradesh, Tamil Nadu, Maharashtra, Punjab, Rajasthan, Tripura and Uttar Pradesh and particularly serious in Punjab and Maharashtra.

2.1.4 Weevils (*Mylocerus sp.*)

A comparative treatise on citrus pests of the world (Jeppin and Carman, 1960) and detailed lists of pest complex in India (Pruthi and Mani, 1945; Bindra, 1957; Ayyar, 1963; Wadhi and Batra, 1954; and Bindra, 1969) do not show any record of *Mylocerus sp* as pest of Citrus.

In Andhra Pradesh these weevil pests were noticed to be of common occurrence causing considerable damage to the foliage of sathgudi orange at fruit Research station, Anantharajupet, Kodur, Kadapa districts for the first time in 1972. (Ramachander Rao *et al.* 1976).

Ramachander Rao *et al.* 1976 reported that they congregate in large numbers at nights and feed on the foliage from the margins. Damage was more and serious on the new flushes (or) tender foliage.

Mukhtar-Ahmed and Ahmed (1989) reported that *Mylocerus viridanus* as a common defoliator of teak (*Tactona grandis*) in the forests of Southern India. It is a potential pest with a distinct polyphagous nature.

Sasmal and Pradhan (1991) reported that *Mylocerus discolor* was a pest of Jute in the fields of West Bengal, India in 1990. Negative binomial and poisson distributions fitted most of the data on damage caused by the pest.

2.1.5 Citrus leaf folder : (*Psorosticha zizyphi* Stainton)

Sharma and Batra (1987) reported that, the larvae of citrus leaf roller were found feeding on ber (*Ziziphus mauritiana*) bael (*Aegle marmelos*), mandarins, oranges and lemons.

2.1.6 Citrus blackfly (*Aleurocanthus woglumi* Ashby)

The citrus blackfly *Aleurocanthus woglumi* Ashby was introduced from South America into the Indian subcontinent and was first recorded as

pest of citrus in Jamaica in 1913. It was subsequently reported from the Bahama Islands, Cuba, Panama and Costa Rica (Dietz and Zetek 1920).

Dowell *et al.* (1981) reported that blackfly infested trees were blackened with sooty mold and caused 50-70% yield loss.

2.1.7 Mites

Green and rust mite (*Schizotetranychus hindustanicus* Hirst and *Phyllocoptruta oleivora* Ashmead)

Ranga Rao *et al.* (1957) reported rust mite (*Phyllocoptruta oleivora* Ash) as an important pest of sweet orange in Andhra Pradesh.

Sadana and Kanta (1972) observed that citrus green mite (*Schizotetranychus hindustanicus*) as a pest on different varieties of Citrus in India, and lemon (*C. limon*) being highly susceptible.

Sadana and Kanta (1972) also reported that the green mite particularly the nymphal and adult females deprived the chlorophyll content of leaves and the damage resulted into small yellow brown specks on it and later on premature shedding of infesting leaves.

Huang (1974) recorded *Phyllocoptruta oleivora* feeding on *C. reticulata* in Taiwan.

Sanchez *et al.* (1985) studied the populations of the citrus rust mite, *P. oleivora* and their relation to the damage caused to orange, *C. cinensis*. They reported that a single mite damaged 0.048% of the fruit surface per day.

Savithri and Rama subba Reddy (1988) observed that low initial rust mite population on the marble sized Rangapur lime fruits caused slight rusty blotches on the rind over a period of 25-30 days, which gradually increased to light dirty white patches with disappearance of green colour. The fruits developed completely dirty white colour after 30-45 days of appearance of rusty blotches.

Achor *et al.* (1991) observed that the upper surface lesions on “Sunburst” mandarin due to the damage of *P. oleivora* were more severe than on other citrus cultivars. The development of lesions was examined in mandarins, treating damaged leaves with a fungicide confirmed that the anatomical changes were an enhanced wound periderm response to feeding injury and not the result to fungal invasion.

Yang *et al.* (1994) studied the effects of early season damage by *P.oleivora* on orange fruit growth and drop. Fruit drop increased with increasing fruit surface damage by citrus rust mite. Data revealed that with increase in mite damage and time, fruit drop also slightly increased.

According to Yang *et al.* (1994) increasing fruit maturity increased susceptibility to *P. oleivora* feeding. This was indicated by a decline in the number of days required to cause a given percentage of damage as fruit maturity increased. Tree location and age did not seem to have an obvious effect on the general trend in damage rate.

2.2 SEASONAL ABUNDANCE :

2.2.1 Citrus leaf miner (*Phyllocnistis citrella* Stainton)

Lal (1949) observed that the activity of the pest reached its peak between July to August and decreased incidence from May to June in Uttar Pradesh.

Atwal (1964) observed that the pest was known to breed from December to May and September to November during the year. Further, in summer months the development was 5-6 times faster compared to that in autumn or early spring.

Sachan *et al.* (1982) recorded that the peak activity of the pest on Khasi mandarin in Meghalaya was during July-January.

Studies made by Lin *et al.* (1985) in China revealed that the pest infestation increased from spring to autumn with 1 percent of leaves infested

on spring shoots, 5 per cent on early summer shoots, 40 to 50 percent on late summer shoots and 52 to 84 per cent on autumn shoots.

Maheswari and Sharma (1986) reported that high population densities were observed in September, November and April reaching approximately 6.1, 11.0 and 10.4 larvae per twig respectively.

Singh and Azam (1986) observed that the pest remained active throughout the year on sweet orange with severe infestation during February and March.

Huang *et al.* (1989) reported that water deficiency in citrus leaves was the main mortality factor for the winter and early spring generations.

You-Min Sheng *et al.* (1995) observed that egg hatching rate, larval survival rate, adult fecundity and population increased with temperature.

Berkani *et al.* (1996) observed that many eggs were recorded in May and 5 generations in a year. The length of each generation was depended on the prevailing temperature and humidity conditions. A temperature of 24-26°C favoured population increase.

The density of population *P. citrella* increased from spring to autumn and declined during winter in South Florida (Pena *et al.* 1996).

Costa Comelles *et al.* (1997) stated that leaf miner larval population were very low in spring and reached high levels (3-4 per leaf) between June and October in Valencia, Spain.

Lara-Guerra *et al.* (1998) stated that weekly irrigation of the nursery provided constant tree growth and ensured appropriate conditions for the development of *P. citrella* and generation overlap.

Alkhateeb *et al.* (1999) observed highest infestation level in July but infestation was low on fall flush.

Sarvanan (2000) observed that peak infestation was recorded during January, February, August and third, fourth and fifth weeks of November. During January and February it caused 92 and 94 per cent of infestation.

Patel and Patel (2001) reported that, the leaf miner activity was high during July, August and September months was higher in compared to January, February and March. The infestation on Kagzi lime was found higher in February and July to November months.

Garcia Mari *et al.* (2002) revealed that leaf miner population was maximum when there was new flush during months of February to March and July to September.

2.2.2 Citrus butterfly (*Papilio demoleus* Linnaeus)

Sontakay (1943) recorded breeding of *P. demoleus* throughout the year in Vidharbha region of Maharashtra.

Ganguli and Ghosh (1967) reported that the occurrence of butterflies was noticed in the months of June, August and November when there were low temperature and high relative humidity prevailed.

Bindra (1969) and Nair (1975) observed the butterfly population being peak in the months of April and July-October.

Ramasubba Reddy (1984) recorded more number of caterpillars of *P. demoleus* during January-February and the population declined during hot summer months and again increase of population was noticed during June and July, then the population declined during winter months.

Resham *et al.* (1986) reported that the pest was found throughout the year but rare in winter months with 4 to 5 five overlapping generations in a year.

Maheswara Babu (1988) reported that the population of *P. demoleus* was present in June-July and reached its maximum in the months of August and September, from October onwards the pest population declined and no population from second fortnight of November to the end of December.

Yadav and Rizvis (1995) reported that the lemon butterfly, *Papilio demoleus* was active during February-June months at Faizabad, Uttar Pradesh.

Ram Pratap *et al.* (2000) reported that maximum damage by *P. demoleus* on lime in the Bundelkhand region of Uttar Pradesh was occurred from August to September.

Lakshmi Narayanamma (2001) reported that peak pest population was observed during months of November and December on sweet orange and acid lime.

2.2.3 Citrus psylla (*Diaphorina citri* Kuwayama)

Hussain and Nath (1927) reported that during December to January the population of citrus psylla dwindled, but again increased from middle of February with peak activity during March-April.

Nair (1975) recorded that pest activity was observed from January to November in Punjab, but the adults appeared from November to January with decreased population in winter months.

Koli *et al.* (1981) recorded that peak periods of the pest coincided with the emergence of new flushes, during months of August and March.

Around Nagpur, the pest activity was found to be very high during June-July when ample shoots were available for oviposition. Activity declined thereafter till the end of October. The population increased by the end of December and high populations were maintained until the end of February (Khan *et al.*, 1984).

Huang *et al.* (1990) reported that the psyllid population increased from late February and reached peak in late April and early May both under green house and field conditions.

Tarlok Singh *et al.* (1990) observed that in Punjab maximum populations of citrus psylla were recorded on sweet orange in September and November. The population declined from December to February.

Bap Reddy and Joshi (1991) observed that citrus psylla was most active during spring and early summer and again during and after the rains.

Gangwar and Singh (1992) recorded that psylla was active from March to September with peak abundance in June.

Chakravarthi (1997) reported that maximum population was recorded during months of February to April on sweet orange and acid lime.

Rajasekhara Rao and Pathak (2001) observed that maximum number of psylla adult population were recorded in June and citrus species

Sohjora and Khasi mandarin (*C. reticulata*) recorded very high population ranging from 16.66 to 19.33 adults per leaf on under surface.

2.2.4 Weevils (*Myloccerus* sp.)

Ramachander Rao *et al.* (1976) reported that damage was observed throughout the year with heavy damage during October to December which ranged from 20.5 percent to 83.1 percent on leaf basis.

Rama subba reddy (1984) revealed that the population of *M. discolor* was observed throughout the year but maximum population was recorded during months of September to October.

2.2.5 Citrus leaf folder (*Psorosticha zizyphi* Stainton)

Sharma and Batra (1987) reported that, the pest was active from April to October, with infestation peaks occurring in June to August.

Sharma and Batra (1989a) observed that the leaf roller adults were emerged from overwintering pupae during first week of April. The larval population was low during April but increased during May. The population ranged from 81.80 to 88.26 larvae / 100 plants during June to August and declined thereafter.

Chatterjee *et al.* (2000) observed the influence of weather parameters on population fluctuation of citrus leaf roller and reported a significant negative correlation with rainfall and positive correlation with relative humidity.

2.2.6 Citrus black fly (*Aleurocanthus woglumi* Ashby)

Kuchanwar *et al.* (1989) Reported that the peak adult population of citrus black fly was recorded during March, July and November in Ambia, Mriga and Hasta Bahar respectively.

Koli *et al.* (1981) observed that the incidence of white fly was at rock bottom level during December and January when cold weather prevailed, but the incidence was high during July and maximum incidence was observed in August.

Kuchanwar *et al.* (1986) reported that peak population of citrus black fly was observed during July-September months, whereas low population was recorded during December-February months.

Chatterjee *et al.* (2000) revealed that the citrus black fly *A. woglumi* population significantly increased with the increase in relative humidity and rainfall during the months of July to September.

2.2.7 Mites

Green and Rust mite (*Schizotetranychus hindustanicus* Hirst) and *Phyllocoptruta oleivora* Ashmead)

Bindra and Bakhettia (1969) observed the highest population of *Aceria mangifera* on mango during the month of February, there after showed gradual decrease till May.

Matsumoto *et al.* (1983) studied that the biology of *P. oleivora* was closely linked with the phenology of its food-plant 'Valencia late' orange trees. This citrus variety exhibited three distinct periods of foliage production each year, and these foliage periods affected the population dynamics of the mite.

Kumar and Sharma (1993) reported that there was highly significant positive correlation between rust mite population and predatory mites.

Allen *et al.* (1995) observed that the optimal temperature for *P.oleivora* population growth was 25°C.

2.3 IDENTIFICATION OF NEW PESTS OF CITRUS UNDER SOUTH ZONE ECOSYSTEM

Nair (1975) revealed that the grub stage of *Autoserica insanabilis* damaged the roots of sugarcane.

Thangavelu *et al.* (1985) reported that *Clania crameri*, the most common of the bag worms found in India, where it infests tea and other ornamental plants.

Clania crameri found to feeds on castor leaves and bark of tea plants (Kakoty *et al.*, 1993).

2.4 NATURAL ENEMIES :

2.4.1 Citrus leaf miner (*Phyllocnistis citrella* Stainton)

Narayan *et al.* (1957) recorded three larval parasitoids *Amatellon* sp, *Tetrastichus* sp and *Elasmus* sp which caused 33 per cent parasitization.

Leaf miner larvae were found parasitized by *Tetrastichus* sp (Anonymous, 1983)

Chen and Le (1986) reported that the larval ectoparasitoids, *Elachertus* sp, (Eulopidae) mainly attacked second and third instar larvae of citrus leaf miner causing 40.28 and 54.38 percent parasitization in May-October and August respectively.

Chen *et al.* (1989) reported that the predator *Chrysopa boninensis* on an average, each individual consumed 149.1 larvae of *P. citrella*.

Liotta and Vacante (1997) reported that the pest was parasitized by polyphagous species *Pnigalio* sp and *Citrospilus pictus*, the later record the highest percentage parasitisation reaching 60 per cent in some areas.

Raga *et al* (1998) reported that the level of parasitism by larval parasitoid *Galeopsomya* sp ranged from 4.1 to 34.7 percent in control.

2.4.2 Citrus butterfly (*Papilio demoleus* Linnaeus)

Atwal (1964) reported that young caterpillars of *P. demoleus* were attacked by yellow wasp (*Polistes hebreus* F.), preying mantids (*Creobrator gemmatus* Soll) and spiders. The pupae were parasitised by the *Pteromalus* species and the eggs by another minute hymenopterous parasite.

Yeshbir singh (1967) recorded two hymenopterous parasites *Charcops* sp. and *Brachymeria* sp on larvae of *Papilio demoleus* Linn.

Ramzan and Darshan Singh (1979) recorded 124 pupae of *Pteromalus puparum* from a single pupa of *P. demoleus*.

Balraj Singh and Anand (1982) reported that high temperature (35°C) and low relative humidity (60%) acted as limiting factors in the development and survival of the parasite. A combination of (30°C) and 60-75 percent relative humidity were found optimum for the development, survival and parasitising efficiency of *Apanteles flavipes* on *Chilo partellus*.

Narayanan and Gopalakrishnan (1984) reported that cytoplasmic polyhydrosis virus caused death of *Papilio demoleus* larvae in 9-16days. The dead larvae infected with CPV were bent backwards dorsally. They also observed that the CPV infection was associated with natural parasitisation by the internal, gregarious parasite *Apanteles papilionis* Viereck.

Krishnamoorthy and Singh (1986) reported two species of egg parasitoids viz., *Trichogramma chilonis* and a scelionid, *Telenomus* sp, on *P. demoleus* and *P. polytes*. They reported that *T. chilonis* parasitised 1-2 day old eggs of *Papilio* sp and the rate of parasitism was as high as 75.9 percent.

Resham *et al.* (1986) reported *Apanteles lunatus* and *Pteromalus puparum* as natural enemies of *P. demoleus* in Nepal citrus orchards.

Krishnamoorthy and Singh (1988) recorded two egg parasitoids, *Trichogramma chilonis* and *Telenomus* sp. and one larval parasitoid, *Apanteles papilionis* on citrus pests of *P. demoleus* and *P. polytes*. Percentage parasitism by *T. chilonis*, *Telenomus* sp. and *O. papilionis*, was 0-65, 10-78 and 1-73 per cent respectively.

Maheswara Babu (1988) reported two parasites viz., *Apanteles papilionis* Viereck, a larval parasite and *Pteromalus puparum*, a pupal parasite on *P. demoleus*.

Jalali and Singh (1990) recorded a new hymenopteran parasitoid *Ooencyrtus papilionis* in addition to *Telenomus* sp and *Trichogramma* sp. on eggs of *P. demoleus*. A single egg produced 3-7 adults of *O. papilionis*, which lived for 5 days.

Singh (1991) reported the natural enemies viz., *Apanteles papilionis*, *Holcojoppa coelopyga*, *Melalophacharops* sp, *Brachymeria Jambolana* and *Pteromalus puparum* on four species of Papilio viz, *P. demoleus*, *P. polytes*, *P. polymnestor* and *P. helenus*.

Garraway and Bailey (1992) recorded of 87.4 per cent mortality of eggs by *O. encyrtus* the egg parasitoid in the population of *P. homerus* in Jamaica during July-October.

Zitani *et al.* (1997) reported a gregarious endoparasitoid of papilionid larvae *Meteorus papiliovorus* from Costarica in addition to *P. anchisiadesidaeus* on citrus.

Singh and Singh (1998) reported the Coccinellids *Coccinella septempunctata*, *Chilomenes sexmaculata*, *Anegleis cardoni* and *Brumoides suturalis* the salticid, *Carrhotus* sp, the vespid *Vespa orientalis* and an

unidentified species of preying mantid preying on different species of insect pests. Coccinellids, vespids and the preying mantid were reported for the first time as predators of the lemon shoot butterfly and citrus butterfly, *Papilio demoleus*.

Sahayaraj *et al.* (2002) reported that *Rhynocoris marginatus* a reduviid, was a predator on *P. polytes* and observed that within 24 hours a predator killed 2 preys.

2.4.3 Citrus psylla (*Diaphorina citri* kuwayama)

Bindra (1970) and Nair (1975) recorded five species of ladybird beetles viz., *Coccinella septempunctata* L., *C. repanda*, *Chilomenes sexmaculata* F., *Chilocorus nigritus* F. and *Brumus suturalis* F. a syrphid fly and a *Chrysopa* sp. preying on the young nymphs. *Tetrastichus radiatus* parasitises the nymphs.

In Reunion, populations of the psylla were controlled by *Tetrastichus radiatus* introduced from India and by *Diaphorencyrtus aligharhensis* which parasitises the nymphs (Aubert and Quilici, 1983).

Citrus psylla population was effectively reduced in Taiwan by introduction of an eulophid parasite *Tamarixia radiata* waterston from Reunion islands (Chein *et al.*, 1988).

Batra *et al.* (1990) and Tandon (1991) recorded five species of coccinellids viz. *Coccinella septumpunctata*, *Menochilus sexmaculata*, *Brumus suturalis* and *Chilocorus nigritus* were main predators of citrus psylla and checked its population from 20-50 percent during the spring flush.

Sanda (1991) suggested that a spider *Marpissa tigrina* was a highly efficient predator of citrus psylla.

Some of the predators noticed on psylla at IIHR, Chettalli were lady bird beetles viz. *Coccinella septumpunctata*, *Chilomenes sexmaculata*, *Chilocorus nigritus*, Chrysopa and some unidentified syrphids (AICRPTF Research report, 1993).

2.4.4 Weevil (*Myloccerus* sp.)

Pati and Mathu (1986) found that *Amyotea malabarica* was predator on leaf feeding insects of rice.

2.4.5 Citrus leaf roller (*Psorosticha zizyphi* Stainton)

Sharma and Batra (1989b) revealed that *Pristomerus* sp., *Mesochorus* sp. and *Apanteles machaeralles* parasitized the larvae of the citrus pest *Psorosticha zizyphi* in Punjab in India.

Nagalingam (1990) reported three parasitoids of *Psorosticha zizyphi*, the ichneumonid, *Ophion triangularemaculatus*, the bethylid *Goniozus* sp. and the braconid *Apanteles* sp. Among them, the *O. triangularemaculatus* caused 48 per cent parasitism, followed by *Apanteles* sp. with 6-11 per cent and *Goniozus* sp. with 4 per cent parasitism.

2.4.6 Citrus black fly (*Aleurocanthus woglumi* Ashby)

Cherry and Dowell (1979) reported that spiders and the coccinellid, *Delphastes pusillus* were the most abundant predators of citrus black fly.

Robert *et al.* (1986) found that *Delphastus pallidus* Lec., *D. pusillus* Lec and *Chrysopa* sp were the primary predator of citrus black fly.

Thomson *et al.*(1987) reported that *Encarsia opulenta* and *Amitus hesperidum* were major parasites of citrus black fly. They caused 80.9 and 61.4 per cent parasitization on nymphs of black fly respectively.

2.4.7 Mites

Green and Rust mite (*Schizotetranychus hindustanicus* Hirst) and *Phyllocoptruta oleivora* Ashmead)

Mc Murtry (1977) stated that the phytoseiid mites such as *Amblyseius stipulatus* Athias, *A. californicus* (Mc Gregot) and *A. potentillae* (German) were found to feed on citrus mite pests.

Tna (1986) described the integrated control of mite pests of citrus. *Agistermus exsertus* (a predaceous stigmatid mite) was used against *P. oleivora* and other mites.

Chen *et al.* (1988) reported that a predatory mite, *Tydeus* sp. feeding on *P. oleivora*.

Allen *et al.* (1994) assessed the role of the fungus *Hirsutella thompsonii* as natural control agent of citrus mites.

2.5 EFFICACY OF INSECTICIDES :

2.5.1 Leaf miner (*Phyllocnistis citrella* Stainton)

Nagalingam and Savithri (1980) reported that fenvalerate 0.02 percent, monocrotophos 0.05 percent and methyldemeton 0.05 percent were the most effective in killing the larvae and in reducing the leaf damage when applied twice at 10 days interval starting from the new flush initiation on Sathgudi sweet orange and Acid lime.

Vikekanandan and Naganathan (1983) reported that fenvalerate, fenprothrin and permethrin at 0.01 per cent were found most promising in reducing the pest population on mandarin orange and acid lime followed by methyl demeton and monocrotophos each at 0.05 percent.

Batra and Sandhu (1986) stated that effective control of citrus leaf miner was obtained with fenvalerate or cypermethrin each at 0.01 percent or with decamethrin (deltamethrin) at 0.005 percent.

Two sprays of monocrotophos 0.05 percent (or) fenvalerate 0.01 per cent at weekly interval from the initiation of new flush effectively controlled leaf miner and other leaf eating insect pests. (*Anonymous 1986*)

Singh and Azam (1986) reported that neem cake extract at the rate of 1kg / 10 litres of water was the most effective insecticidal treatment causing 95.26 percent mortality after 3days of spraying followed by 0.05 demeton-S-methyl (89.09%).

Bhumannavar (1987) reported that synthetic pyrethroids (cypermethrin and fenvalerate) were most effective than quinalphos and monocrotophos and controlled the citrus leaf miner at the concentration of 0.001 percent.

The greatest reduction in the larval population was observed with 0.01 percent cypermethrin which resulted in 64.46 per cent mortality after 24 hours of spraying. (Radke and Kandalkar, 1988)

Bhatia and Joshi (1991) reported that fenvalerate, deltamethrin, cypermethrin were the most effective against leaf miner.

Chari *et al.* (1996) reported that neem seed kernal extract (NSKE) and *Spodoptera litura* NPV were safe and compatible with parasitoids and 24 hours after spraying they did not interfere with parasitising ability.

Chakravarthi (1997) reported that triazophos was the most effective treatment recording 97.11 per cent population reduction against citrus psylla *Diaphorina citri* Kuwayama. It was followed by imadacloprid and profenophos both at 0.025 percent with 96.29 and 96.17 percent reduction. Neem oil (1.0 %) and azadirachtin (0.0003%) offered effective control with 89.51 and 86.65 per cent reduction respectively.

Kalaisekar (1999) reported that triazophos, profenophos, neem formulation (azadirachtin) and anona formulation showed 74.91, 73.91, 60.21 and 54.56 per cent mortality respectively against citrus mungumite *Phyllocoptruta oleivora* (Ashmed).

Saravanan (2000) reported that profenophos (0.05%) thiodicarb (0.1%) azadirachtin (5ml/lt), Neem Seed Kernal Extract (NSKE 5 %) showed 84.08, 85.61, 70.45 and 73.06 per cent mortality 24 hours after spraying against citrus leaf miner.

Jorge *et al.* (2000) reported that methomil @ 0.45 Kg a.i / ha and imidacloprid 0.5 Kg a.i/ha controlled citrus leafminer effectively and increased the ultimate yield.

2.5.2 Citrus butterfly (*Papilio demoleus* Linnaeus)

Sharma and Srivastava (1970) reported that 0.2 percent carbaryl was the most effective treatment among different insecticides tested when the treated foliage of citrus was subjected to artificial infestation of *P. demoleus* caterpillars.

Resham *et al.* (1986) reported that *Bacillus thuringiensis* Berliner was highly effective in the control of citrus butterfly larvae.

Nandihalli *et al.* (1991) found that 0.08 per cent acephate had caused the greatest reduction (95.1%) after 72 hours of spray.

Solunke and Deshpande (1991) stated that plant extracts i.e., pimpal (*Ficus religiosa*), beshram (*Manchoria hastaeifolia*), neem (*Azadirachta indica*) and datura (*Datura stramonium*) significantly reduced the pest population of *Papilio demoleus*.

Balagangadhar Tilak (1992) reported that among the plant products, allitin (1.0%) gave highest per cent reduction over control (94.56%) followed by repelin (81.05%) margosol (80.13%), neem guard (78.75%) necknool (77.05%), vepanic (76.71%), karrich (65.07%), annmet (63.77%), sitapal (60.96%) and wellgro (21.16%) at 1.0 per cent.

Jhonson *et al.* (1995) reported that *Bacillus thuringiensis* applied at the rate of 40 BIU/ha was found toxic to early and later (4th) instar larvae

of *Papilio glaucus* and *P. canadensis*. Toxicity to early instar of *P. glaucus* persisted upto 30 days. Studies indicated that *B. thuringiensis* sprays were also toxic to some non-target lepidopterans for atleast 30 days after the spray.

Ranjeet Singh *et al.* (1996) reported that spraying of an aqueous extract of neem seed kernal at 0.5 per cent twice with an interval of 8 days was effective in providing protection against *Papilio demoleus*.

Chauke *et al.* (1999) reported that among the plant products azadirachtin (0.3%) was found significantly superior over neem seed kernal extract (5%) and Neem Leaf Extract (NLE) 5 per cent against the lemon butter fly (*Papilio demoleus*).

Deepak *et al.* (2001) reported that 0.015 per cent fenvalerate gave cent percent mortality one day after spraying.

CHAPTER-III

MATERIALS AND METHODS

Field studies on seasonal occurrence of major pests of citrus were carried out in citrus orchard of AICRP on Tropical Fruits, Tirupati. The experiments on management of citrus leaf miner and citrus butterfly were carried out in the citrus orchard of AICRP on Tropical fruits, Tirupati. The studies were conducted during June 2003 - May 2004. The materials used and the methods employed in these investigations are presented below.

3.1 SEASONAL OCCURRENCE OF MAJOR PESTS OF CITRUS:

Studies were made on Balaji acid lime and Sathgudi sweet orange plants maintained under intensive input management orchards of Tirupati, from June 2003 to May 2004. The data were recorded from the plants selected for study, which were not sprayed with any insecticide during the period of study. Methods adopted for assessing per cent infestation and population density of important citrus pests are detailed below.

3.1.1 Leaf miner (*Phyllocnistis citrella* Stainton)

Seasonal occurrence of leaf miner was studied in two citrus cultivars viz., sathgudi sweet orange and acid lime trees of ten year old, each maintained unprotected. From each tree, observations were made on number of leaf miner infested leaves and total leaves from ten randomly selected tender twigs. Mean per cent of leaf miner infestation was computed from the following formula.

$$\text{Per cent leaf miner infestation} = \frac{\text{Number of leaves infested with leaf miner larvae}}{\text{Total number of leaves in the twig}} \times 100$$

3.1.2 Citrus butterfly (*Papilio demoleus* Linnaeus)

Observations were recorded on twenty unprotected trees of ten years old each of sweet orange and acid lime to know the population fluctuations in relation to climatic variations from June 2003 to May 2004. From each tree, larval population was recorded from randomly selected tender twigs at fortnightly interval. Sampling was done on ten randomly selected tender twigs of 10-15 cm length covering the four sides. These studies also provide information about the conducive periods for pest build up which help in effective management of the pest.

3.1.3 Psylla (*Diaphorina citri* Kuwayama)

Psyllid population was counted on 20 trees each of acid lime and sweet orange that were maintained under normal agronomic practices. The population was recorded on 10 randomly selected twigs covering the four sides of each tree.

3.1.4 Weevils (*Mylocerus* sp.)

Data was recorded on the total adult weevil population and damaged leaves from 20 trees of each of sweet orange and acid lime. In each tree observations were made on ten randomly selected twigs.

3.1.5 Leaf folder (*Psorosticha zizyphi* Stainton)

The leaf folder larval population was counted on 20 trees of each sweet orange and acid lime. The larval population was recorded on 10 randomly selected leaves of each covering the four sides of tree.

3.1.6 Black fly (*Aleurocanthus woglumi* Ashby)

The black fly population in terms of both nymphs and pupae were counted on 20 trees each of sweet orange and acid lime and in each tree,

population was recorded on 10 randomly selected leaves covering the four sides of the tree.

3.1.7 Green mite (*Schizotetranychus hindustanicus* Hirst)

Observations were recorded on 20 trees each of Sathgudi sweet orange and acid lime trees. In each tree nymphal and adult population were counted from 10 randomly selected leaves from each variety. The average number of mites present on each leaf at fortnightly intervals were recorded.

3.1.8 Rust mite (*Phyllocoptruta oleivora* Ashmead)

The mite population (nymph and adults) were counted on 20 trees each of sweet orange and acid lime that were maintained unsprayed with insecticides. The population of mite was counted on 0.5 cm² area, on each of 10 randomly selected fruits covering four sides of each tree.

3.1.9 Survey and surveillance of major pests of citrus in Chittoor and Nellore districts during June 2003 to May 2004

In the major citrus growing regions of Nellore and Chittoor Districts, roving survey was conducted once in three months i.e. October - December, January - March, April- June and July - September in about 10 per cent

orchards (at least 25-50 orchards) in specified villages, to know the distribution and intensity of major citrus pests. Details about the villages selected and numbers of citrus orchards surveyed are furnished below.

Table 1 : No. of citrus orchards surveyed in Chittoor and Nellore districts during June 2003 - May 2004.

S. No.	Name of the district	Name of the village	Total number of citrus orchards surveyed
1.	Chittoor	Buchinaidu Kandriga, Bopporaju Palem, Vadamalapeta	26
2.	Nellore	Rapur, Podalkur, Petlur Balaiahpalli and Singavaram	19
	Total		45

3.2 IDENTIFICATION OF NEW PESTS OF CITRUS UNDER SOUTH ZONE ECOSYSTEM

During the periods of understanding the seasonal incidence and making roving survey studies, some of the new pests were collected and preserved. These preserved specimens were sent for identification to Division of Entomology, IARI, New Delhi

3.3 NATURAL ENEMIES OF MAJOR PESTS OF CITRUS

While taking observations on seasonal occurrence of major pests of citrus, different pests were collected from field at every fortnightly interval and maintained in the laboratory to know the natural enemy occurrence. The parasitoids and predators, collected were preserved and got them identified.

3.4 EVALUATION OF THE EFFICACY OF CERTAIN NATURAL AND SYNTHETIC CHEMICAL PESTICIDES AGAINST CITRUS LEAF MINER, *P. citrella* AND BUTTERFLY, *P. demoleus*

Field trials were conducted separately to evaluate the efficacy of different insecticides, that included synthetic and natural products, against major pests of citrus (citrus leaf miner and citrus butterfly) during the year 2003-04. The chemicals included in the experiment were evaluated separately both as prophylactic and curative control. Prophylactic and curative method of leaf miner control trial was carried out at AICRP on Tropical fruits (citrus), Tirupati. Both the experiments were carried out on sweet orange trees of 10 years old with nine treatments of synthetic

products and nine treatments of natural products in a randomized block design with three replications.

To evaluate the efficacy of synthetic and natural products as prophylactic and curative treatments against citrus butterfly, a field experiment was conducted at AICRP on Tropical Fruits (citrus), Tirupati, on one and half year old sathgudi sweet orange nursery plants. The experiment was conducted with nine treatments of synthetic products and nine treatments of natural products in a randomized block design with three replications in plot size of 2 x 6 m for each treatment. An untreated check was maintained for comparative studies. Each treatment was introduced with three litres of spray solution using knap - sack sprayer.

Details of the insecticides included in the two experiments viz., natural and synthetic chemicals in relation to formulation, concentration, dosage, trade name, common name and source of supply of the insecticides were furnished in the tables 2 and 3.

3.4.1 Preparation of insecticidal solution

The quantity of the chemical required was calculated as per the formula given below.

$$V_1 = \frac{V_2 S_2}{S_1}$$

Where,

V_1 = Volume of the concentrated spray material

S_1 = Strength of the concentrated spray material

V_2 = Volume of the diluted spray material

S_2 = Strength of the diluted spray material

Thiovit was added @ 1 ml/lit for each treatment. Care is taken for proper mixing of the insecticide with water.

3.4.2 Recording of data in prophylactic control trial

In this experiment the treatments were imposed synchronizing with emergence of 50 per cent of new foliage. In each tree, 10 emerging tender twigs were tagged. Total number of leaves and number of infested leaves were recorded to assess the per cent leaf miner incidence.

3.4.3 Recording of data in curative control trial

In case of leaf miner, in each tree 10 tender twigs were tagged randomly covering four sides. In the tagged twigs larval population was recorded one day before spraying, post treatment counts at 1, 3, 5, 7, 10 and 14 days after spraying.

In case of butterfly, larval population was recorded one day before spraying and at 1,3,5,7 10 and 14 days after spraying as post treatment counts.

3.4.4 Statistical analysis

In case of leaf miner prophylactic control experiment, the per cent incidence was calculated for all the treatments by using the following formula.

$$\text{Per cent incidence} = \frac{\text{Number of infested leaves}}{\text{Total number of leaves in twigs}} \times 100$$

In case of curative experiment, per cent mortality was calculated for leaf miner and butterfly for all the treatments by using the following formula.

$$\text{Per cent mortality} = \frac{\text{Number of larvae dead}}{\text{Initial larval count}} \times 100$$

The percentages thus obtained were transformed into angular values and analysed statistically. The data were analysed by Fischer's analysis of variance in Randomised Block Design. Significance of different treatments was tested by 'F' test at five per cent and one per cent probability. The critical difference worked out was utilised for comparing the treatment means to know the significant differences among the various treatments in efficacy.

Table 3 : Insecticides of Synthetic Origin

S.No.	Common Name	Formulation	Trade Name	Concentration / Dose (%)	Source of Supply
1.	Thiodicarb	75% WP	Larvin	0.075%	Rhone - Poulenc Agrochemicals (Ind.) Ltd., Mumbai, 29,
2.	Profenophos	50% EC	Carina	0.1%	PI industries Ltd., 237, G.I. D.C. Panoli, Bharush (Dist.) Gujarat
3.	Lambda cyhalothrin	2.5% EC	Deva	0.0025%	Northern Minerals Ltd., Daulatbad Road, Gurgaon 122 001
4.	Cartaphydrochloride	50% SP	Caldran	0.1%	Dhanuka Pesticides Ltd., Attai Village, Sohna - rankola road Tehsil, Nuh District Gurgaon (Haryana) 122 103
5.	Fenvalerate	20% EC	Hyfen	0.02%	Hyderabad chemicals Supplies Limited. A-24/25, APIE, Balanagar, Hyderabad, 500 017
6.	Methomyl	40% SP	Dunet	0.08%	Dhanuka Pesticides Ltd.,
7.	Acephate	75% WP	Aphansaan	0.075%	Vantech chemicals Industrial Limited, Medak (Dist.) A.P.
8.	Chlorpyriphos	20% EC	Durmet	0.05%	BASF India Ltd., Regd. Office, Mahindra Towers, A wing first floor, Dr. G.M. Bhosale Marg, Mumbai 400 018
9.	Control	-	-	-	-

Table 2 : DETAILS OF THE INSECTICIDES USED IN THE EXPERIMENTS

Insecticides of Natural Origin

S. No.	Common Name	Formulation	Trade Name	Concentration / Dose	Source of Supply
1.	Neem seed kernal extract (NSKE)	5%	-	5 %	Local made
2.	Azadirachtin	0.03%	Neemazal	0.0001 %	EID Parry (IND) Ltd., Dare House, Chennai-1
3.	Neem soap	-	-	10 g/lt	IIHR, Hessaragatta lake Bangalore
4.	Pongamia oil	100% EC	Pongamia oil	0.5 %	Locally purchased
5.	Pongamia soap	-	-	10 g/lt	IIHR, Hessaragatta lake, Banglaore
6.	Garlic extract	-	-	20 g/lt	Locally purchased
7.	<i>Bacillus thuringiensis</i> (Bt)	5% WP	Halt	0.0025 %	Wockhardt Limited, Mumbai
8.	<i>Bacillus thuringiensis</i> (Bt)	5% WP	Halt	0.005 %	Wockhardt Limited, Mumbai.
9.	Control (Water spray)	-	-	-	-

CHAPTER - IV

RESULTS

4.1 SEASONAL OCCURRENCE OF MAJOR PESTS OF CITRUS ON SATHGUDI SWEET ORANGE AND BALAJI ACID LIME

4.1.1 Seasonal Abundance of Major Pests of Citrus on Sathgudi Sweet orange

Studies on seasonal abundance of major citrus pests viz., citrus leaf miner (*Phyllocnistis citrella* Stainton), butterfly (*Papilio demoleus* Linnaeus), psylla (*Diaphorina citri* Kuwayama), weevils (*Myloccerus* sp.), leaf folder (*Psorosticha zizyphi* Stainton), green mite (*Schizotetranychus hindustanicus* Hirst) and rust mite (*Phyllocoptruta oleivora* Ashmead) were carried out during June 2003 to May 2004 to know about the population fluctuations and also to understand the favourable periods for pest build up so as to synchronise the management strategies against the pest.

4.1.1.1 Citrus leaf miner (*Phyllocnistis citrella* Stainton)

The data regarding leaf miner infestation, temperature, (both maximum and minimum), relative humidity (I and II) and rainfall are presented in Table 4.

The incidence of the pest started from the second fortnight of July. The leaf miner, *P. citrella* infestation was more from second fortnight of September 2003 to second fortnight of February 2004. The infestation of leaf miner increased from first fortnight of September 2003 to first fortnight of January 2004. High incidence was noticed from first fortnight of November 2003 till first fortnight of February 2004 ranging from 35.18 to 29.63 per cent infestation. The peak incidence (40.84%) of citrus leaf miner was noticed during first fortnight of January at maximum temperature, minimum temperature, relative humidity-I and II and rainfall of 29.92°C, 16.45°C, 73.93 per cent, 41.06 per cent and 0.27 mm respectively. However, the incidence of citrus leaf miner tended to dwindle from first fortnight of March and it was low during second fortnight of July and August 2003. No incidence was observed from April first fortnight to July first fortnight.

Correlation between leaf miner incidence and climatic factors viz., maximum temperature, minimum temperature, relative humidity-I, relative humidity-II and rainfall were worked out and co-efficient were given in Table 5, Figure 5.

The correlation of leaf miner incidence, with maximum temperature ($r = -0.751$) and minimum temperature ($r = -0.770$) was negative and significant. The correlation between leaf miner incidence and relative humidity I ($r = 0.432$) and relative humidity-II ($r = 0.282$) were positive and non significant, and with rainfall ($r = 0.629$) the correlation was positive and significant.

4.1.1.2 Citrus butterfly (*Papilio demoleus* Linnaeus).

The larval population of *P. demoleus* was recorded at fortnightly starting from the appearance of the pest. The data regarding larval population, temperatures (both maximum and minimum), relative humidity (I and II) and rainfall were presented in Table 4.

The incidence of pest started from second fortnight of June 2003. The population increased gradually from first fortnight of October 2003 to first fortnight of January 2004. Highest larval population was recorded during second fortnight of December 2003 by recording the highest number of 67.5 larvae per 20 twigs at maximum temperature 29.05°C, minimum temperature 18.12°C, relative humidity-I 80.12 per cent, relative humidity-II 58.87 per cent and rain fall 0.66 mm respectively. Peak period of pest

population was synchronized with the emergence of new flush. The activity of pest decreased slowly from first fortnight of February onwards and least incidence was observed during March and nil population recorded during the months of April, May 2004 and first fortnight of June 2003.

Correlation between butterfly larval population and climatic factors *viz.*, maximum temperature, minimum temperature, relative humidity-I, relative humidity-II and rainfall were worked out and coefficients were given in Table 6, Figure 3.

The correlation of butterfly larval population with maximum and minimum temperature ($r = -0.729$ and -0.589) were negative and significant. The correlation between larval population and relative humidity-I ($r = 0.581$) and relative humidity-II ($r = 0.475$) were positive and significant. Butterfly population with rainfall ($r = -0.421$) showed negative and non significant correlation.

4.1.1.3 Citrus psylla (*Diaphorina citri* Kuwayana).

The data regarding psylla, *D. citri* population, temperature (both maximum and minimum), relative humidity (I and II) and rainfall were presented in Table 4.

The incidence of pest started from the second fortnight of October 2003. Peak population (19.9 psyllids per ten twigs) was recorded during second fortnight of November at maximum temperature, minimum temperature, relative humidity-I, relative humidity-II and rainfall of 27.73°C, 18.32°C, 71.92 per cent, 49.94 per cent and 0.00 mm respectively. However the population tended to decline from second fortnight of December 2003 and it was remained low upto first February 2004. Psyllid population was not observed during first fortnight of July 2003 to first fortnight of October 2003 and second fortnight of February 2004 to first fortnight of April 2004.

Correlation between psyllid population and climatic factors viz., maximum temperature, minimum temperature, relative humidity (I and II) and rainfall were worked out and co-efficients were given in Table 7 and Fig. 4.

The correlation between psyllid population and maximum temperature ($r = -0.563$) was negative and significant. The correlation between psyllid population and minimum temperature ($r = -0.163$) was negative and non significant. Relative humidity I ($r = -0.126$) showed positive and non significant correlation with population of psyllid whereas

relative humidity II ($r=-0.599$) showed negative and significant relationship. There was a positive and non significant correlation between rainfall ($r = 0.127$) and psyllid population.

4.1.1.4 Weevils : (*Myllocerus* sp.)

Data on the population of weevils was furnished in Table 4. Incidence of weevils was observed throughout the year except during second fortnight of April and May 2004. High weevil incidence (20.6 weevils / 10 twigs) was noticed during first fortnight of October 2003 at maximum temperature, minimum temperature, relative humidity (I & II) and rainfall of 33.01°C, 23.76°C, 79.07 per cent, 53.33 per cent and 5.82 mm. Low level of weevil population (1.4 to 6.4 weevils / 10 twigs) was observed during months of January to first fortnight of April 2004.

The correlation between weevil population and climatic factors viz., maximum temperature, minimum temperature, relative humidity (I & II) and rain fall was worked out and results were given in Table 8, Figure 5.

The correlation between weevil population and maximum temperature ($r = -0.639$) was negative and significant but it was found to be

negative and non significant relationship with minimum temperature ($r = -0.118$). Positive and significant correlation was existed between relative humidity I ($r = 0.586$), relative humidity II ($r = 0.582$) and weevil population. Population showed positive and non-significant correlation with rainfall ($r = 0.090$).

4.1.1.5 Leaf folder (*Psorosticha zizyphi* Stainton)

High incidence of leaf folder *P. zizyphi* was noticed during second fortnight of February (21.4 larvae / 10 twigs) and first fortnight of March (14.7 larvae / 10 twigs). A moderate level of pest population was noticed during the months of June, November and December 2003.

4.1.1.6 Blackfly (*Aleurocanthus woglumi* Ashby)

No pest incidence was observed during whole period of study i.e. June 2003 to May 2004.

4.1.1.7 Green mite (*Schizotetranychus hindustanicus* Hirst)

Observations recorded on seasonal incidence of green mite, *S. hindustanicus* on Sathgudi sweet orange trees are presented in Table 4. Incidence of green mite was recorded throughout the year on Sathgudi

sweet orange except during June, July 2003 and second fortnight of May 2004. The population (23.7 mites/ leaf) was first started in first fortnight of August 2003. Thereafter it started to decline upto first fortnight of October. From second fortnight of October, population again raised and attained peak level during November, moderate incidence was recorded during December and low during January. The peak population of the green mite was noticed during second fortnight of November (24.4mites/leaf) at maximum temperature, minimum temperature, relative humidity-I, relative humidity-II and rainfall of 27.73°C, 18.32°C, 71.92 per cent , 49.94 per cent and 0.00 mm.

Correlation between green mite population and climatic factors viz., maximum temperature, minimum temperature, relative humidity(I and II) and rainfall were worked out and results were given in Table 9, Figure 6.

The correlation between green mite population and maximum temperature ($r = -0.448$) was negative and significant but with minimum temperature ($r = -0.038$), it was negative and non-significant. There was positive and significant relationship between relative humidity I and II ($r =$

0.233 and 0.213) and mite population. The correlation between green mite population and rainfall ($r=-0.259$) was negative and non significant.

4.1.1.8 Rust mite (*Phyllocoptruta oleivora* Ashmead)

The data regarding rust mite population, temperature (both maximum and minimum), relative humidity (I and II) and rainfall are presented in Table 4.

Rust mite, *P. oleivora* was recorded from second fortnight of November 2003 to first fortnight of May 2004. Peak incidence (60.25 mites / 0.5 cm² of fruit) was recorded during first fortnight of March 2004 at maximum temperature, minimum temperature, relative humidity-I, relative humidity-II and rainfall of 35.82°C, 18.90°C, 58.26 per cent, 22.33 per cent and 0.00 mm. Thereafter the population of mites tended to decrease and the population reached zero level from second fortnight of May 2003 to second fortnight of November 2003. Moderate incidence was observed during the months of December 2003 and January 2004.

Correlation between rust mite population and climatic factors viz., maximum temperature, minimum temperature, relative humidity (I & II) and rainfall were worked out and results were given in Table 10 Fig. 7.

The correlation between rust mite population and maximum temperature ($r=0.145$) was positive and non significant whereas with minimum temperature ($r=-0.597$) that was negative and significant. The correlation between rust mite population and relative humidity I and II ($r = -0.525$ and -0.719) and rain fall ($r=-0.556$) was negative and significant.

4.1.2 Seasonal Occurrence of Major Pests of Citrus on Balaji Acid lime

4.1.2.1 Citrus leaf miner : (*Phyllocnistis citrella* Stainton)

Investigations on seasonal incidence of *P. citrella* were carried out during June 2003 to May 2004 in relation to the weather parameters. Observation on leaf miner *P. citrella* infestation was recorded at fortnightly intervals. The data regarding leaf miner infestation, temperature (both maximum and minimum) relative humidity I and II and rainfall are presented in Table 11.

The incidence of the pest started from the first fortnight of July 2003. The leaf miner infestation was more (31.25 to 36.33%) during the months of November and December. The peak incidence (36.33%) of citrus leaf

miner was noticed during second fortnight of December 2003 at maximum temperature, minimum temperature, relative humidity-I, relative humidity-II and rainfall of 29.05°C, 18.12°C, 80.12 per cent, 58.87 per cent and 0.66 mm respectively. However the incidence of citrus leaf miner tended to decline from February and it was continued to be low upto April first fortnight. No infestation was recorded from second fortnight of April to May 2004 and June 2003.

Correlation between leaf miner and climatic factors *viz.*, maximum temperature minimum temperature, relative humidity I, relative humidity-II and rainfall were worked out and co-efficient were given in Table 12, Figure 9.

The correlation of leaf miner incidence and maximum temperature ($r=-0.906$) and minimum temperature ($r = -0.502$) was negative and significant. Relative humidity I ($r =0.655$) and II ($r = 0.552$) showed positive and significant relation with leaf miner incidence, whereas with rainfall ($r = -0.299$) it was negative and non significant.

4.1.2.2 Citrus butterfly (*Papilio demoleus* Linnaeus)

The data regarding *P. demoleus* caterpillar population, temperature (both maximum and minimum), relative humidity (I and II) and rainfall were presented, in Table 11.

The incidence of pest commenced from June first fortnight. The population increased gradually from first fortnight of September to January. Highest larval population was recorded during second fortnight of November by recording 64.3 larvae / 20 twigs at maximum temperature 27.73°C, minimum temperature 18.32°C, relative humidity (I and II) 71.92 per cent and 49.94 per cent and rain fall 0.00 mm respectively. Peak period of pest population was synchronized with the emergence of new flush. The activity of the pest decreased slowly from February onwards and it reached to 0.00 population during the months of April and May 2004.

Correlation between larval population and various climatic factors viz., maximum temperature, minimum temperature, relative humidity-I, relative humidity-II and rainfall were worked out and co-efficient were given in Table 13, Figure 10.

The correlation between larval population and maximum temperature ($r=-0.508$), minimum temperature ($r=-0.552$) was negative and significant. Relative humidity I ($r = 0.342$) and relative humidity II ($r=0.054$) showed positive and non-significant correlation with larval population. The rainfall ($r= -0.521$) was showed negative and significant correlation.

4.1.2.3 Citrus psylla (*Diaphorina citri* Kuwayama)

The data regarding psylla, *D. citri* population, temperature (both maximum and minimum), relative humidity (I and II) and rainfall were presented in Table 11.

The incidence started from first fortnight of November 2003. The highest population (16.7 psyllids / 10 twigs) was recorded during first fortnight of December at maximum temperature, minimum temperature, relative humidity-I, relative humidity-II, and rainfall of 28.98°C, 16.27°C, 71.67 per cent, 43.33 per cent and 2.23 mm. The pest population dwindled from second fortnight of January 2004. Nil population was observed from second fortnight of February 2004 to first fortnight of April 2004 and second fortnight of July 2003 to second fortnight of October 2003.

Correlation between psyllid population and climatic factors viz., maximum temperature, minimum temperature, relative humidity (I & II) and rainfall were worked out and results were given in Table 14, Figure 11.

The correlation between psyllid population and maximum temperature ($r=-0.207$) and minimum temperature ($r = -0.143$) were negative and non significant. Relative humidity I ($r = 0.101$), II ($r = 0.198$) and rainfall($r=0.234$) were showed positive and non significant correlation.

4.1.2.4 Weevils (*Myloccerus* sp.)

During the period of seasonal occurrence studies, two weevil species were observed. The population data in respect of weevil population have been furnished in Table 11.

Weevil population was observed throughout the year except May and first fortnight of June. The highest population (18.4 weevils / 10 twigs) was recorded during second fortnight of October 2003 at maximum temperature, minimum temperature, relative humidity I and II and rainfall of 30.68°C, 21.97°C, 81.37 per cent, 61.69 per cent and 6.88 mm respectively. High level (4.1 - 18.4 weevils / 10 twigs) of weevil population

was observed during first fortnight of July to second fortnight of November.

The correlation between weevil population and climatic factors *viz.* maximum temperature, minimum temperature, relative humidity (I and II) and rainfall were worked out and results were given in Table 15, Figure 12.

The correlation between weevil population and maximum temperature ($r = -0.466$) was negative and significant, with minimum temperature ($r = 0.031$) it was positive and non significant, whereas relative humidity-I ($r = 0.587$) and relative humidity II ($r = 0.522$) showed positive and significant correlation. It was positive and significant with rainfall ($r = 0.092$).

4.1.2.5 Leaf folder (*Psorosticha zizyphi* Stainton)

Incidence of leaf folder in large number was noticed during months of February and December. Leaf folder larval population was also observed during the months of January, March, July, first fortnight of August and second fortnight of November.

4.1.2.6 Blackfly : (*Aleurocanthus woglumi* Ashby)

No pest incidence was observed during whole period of study i.e. June 2003 to May 2004.

4.1.2.7 Green mite (*Schizotetranychus hindustanicus* Hirst)

Observations recorded on seasonal occurrence of green mite, *S. hindustanicus* on Balaji acid lime are presented in Table 11. Except June to July 2003 and April to May 2004 its incidence was observed throughout the year. It's incidence started from first fortnight of August, thereafter it was decreased upto September. Again it was increased upto November. Low population levels (4.0 to 8.0 mites / leaf) were recorded during second fortnight of December 2003 to January 2004. The peak population (43.4 mites/ leaf) of green mite was noticed during first fortnight of March 2004 at maximum temperature, minimum temperature, relative humidity I, relative humidity II and rainfall of 35.82°C, 18.90°C, 58.26 per cent, 22.33 per cent and 0.00 mm respectively.

Correlation between green mite population and climatic factors viz., maximum temperature, minimum temperature, relative humidity

(I and II) and rainfall were worked out and results were given in Table 16, Figure 13.

The correlation between green mite population and maximum temperature ($r=-0.128$) was negative and non significant, with minimum temperature ($r= 0.506$) it was positive and significant. Relative humidity I ($r= 0.307$) showed positive and non significant relation with green mite population whereas relative humidity II ($r =-0.441$) was showed negative and non significant relationship with the mite population. Rainfall ($r = -0.619$) showed negative and significant correlation.

4.1.2.8 Rust mite (*Phyllocoptruta oleivora* Ashmead).

The data regarding the population counts of rust mite, temperature (both maximum and minimum), relative humidity-I, relative humidity-II and rainfall are presented in Table 11.

Rust mite population was observed from first fortnight of November 2003. Peak population (59.75 mites / 0.5 cm² fruit) was recorded during second fortnight of January 2004 at maximum temperature, minimum temperature, relative humidity (I & II) and rainfall of 30.76°C, 17.88°C,

72.87 per cent 44.12 per cent and 0.00 mm respectively. Thereafter the population of mites tended to decrease. Nil population was observed during months of May to October. Low population levels were recorded during April and November and moderate level (18.5-33.5 mites / 0.5 cm² fruit) population were recorded from December to first fortnight of January.

Correlation between rust mite population and climatic factors *viz.*, maximum temperature, minimum temperature, relative humidity (I & II) and rainfall were worked out and results were given in Table 17, Figure 14.

The correlation between rust mite population and maximum temperature ($r=-0.227$) was negative and non significant, whereas minimum temperature ($r= -0.757$) showed negative and significant relationship. Relative humidity I ($r= 0.130$) was positive and non significant, but relative humidity II ($r= - 0.379$) was showed negative and non-significant relationship. Rainfall ($r= -0.679$) was negative and significantly correlated with rust mite population.

4.1.2.9 Survey and Surveillance of Citrus Pests in Chittoor and Nellore Districts During June 2003 to May 2004

During June 2003 to May 2004 a roving survey was undertaken in 18 orchards of Nellore district and 27 orchards of Chittoor district with a view to assess the distribution pattern of various pests, new introduction of pests and problematic pests of the region.

It was revealed that snow scale *P. aspidistrae* problem was more during summer months in Nellore district, where 22.22 per cent gardens showed very severe infestation. Very severe leafminer, *P. citrella* incidence was recorded 16.66 per cent of garden during November to December months. Green mite, *S. hindustanicus* and rust mite, *P. oleivora* incidence was observed in 11.1 per cent of the citrus gardens. Among other recorded pests butterfly, *P. demoleus* was very severe in 5.55 per cent, severe in 38.82 per cent, moderate infestation in 27.77 per cent, low in 11.11 per cent and nil in 16.66 per cent of gardens (Table 18). Majority of the gardens surveyed showed zero to low incidence of psylla, *D. citri* and aphids *Toxoptera* sp..

In Chittoor district roving survey was conducted in 27 orchards covering four villages. The data revealed that citrus leaf miner, *P. citrella* was the predominant pest during winter months which recorded very severe and severe infestation in 18.50 per cent of gardens and severe infestation in 48.16 per cent of gardens (Table 19). Green mite, *S. hindustanicus* and rust mites, *P. oleivora* were also observed as major pests in Chittoor district. They are very severe and severe in 14.8 and 14.1 per cent of gardens. Citrus butterfly, *P. demoleus* was also major pest in this district. Very severe and severe infestation of citrus butterfly was observed in 7.40 and 33.3 per cent of gardens respectively. Snow scale, *P. aspidistrae* were observed as serious pest in some of the gardens of Chittoor district where 3.75 per cent of gardens having very severe infestation and 22.22 per cent gardens showed severe infestation. In majority for the gardens surveyed of psylla, *D. citri* and fruit sucking moth, *Othreis* sp. were appeared to be of minor importance recording low level of pest damage.

Table 18 : Observations recorded on the various citrus pests and their intensity during the roving survey in Nellore district.

S. No.	Name of the Pest	No. of Citrus Orchards Surveyed	Level of incidence				
			Nil	Low	Moderate	Severe	Very Severe
1.	Citrus leaf miner, <i>P. citrella</i>	18	-	2 (11.11)	4 (22.22)	9 (50)	3 (16.66)
2.	Citrus butterfly, <i>P. demoleus</i>	18	3 (16.66)	2 (11.11)	5 (27.77)	7 (36.88)	1 (5.55)
3.	Rust mite, <i>P. oleivora</i>	18	1 (5.55)	4 (22.2)	5 (27.77)	5 (33.33)	2 (11.11)
4.	Green mite, <i>S. hindustanicus</i>	18	2 (11.11)	5 (27.77)	6 (33.33)	3 (16.66)	2 (11.11)
5.	Psylla, <i>D. citri</i>	18	10 (55.55)	6 (33.33)	2 (11.11)	- (0.00)	- (0.00)
6.	Snow scales, <i>P. aspidistrae</i>	18	1 (5.55)	2 (11.11)	3 (16.66)	8 (44.44)	4 (22.22)
7.	Aphids, <i>Toxoptera</i> sp.	18	12 (66.66)	4 (22.22)	2 (11.11)	- (0.00)	- (0.00)

Figures in parentheses are per cent of infested gardens.

Table 19 : Observations recorded on the various citrus pests and their intensity during the roving survey in Chittoor district.

S. No.	Name of the Pest	No. of citrus Orchards Surveyed	Level of incidence				
			Nil	Low	Moderate	Severe	Very Severe
1.	Citrus leaf miner, <i>P. citrella</i>	27	1 (3.70)	2 (7.42)	6 (22.22)	13 (48.16)	5 (18.50)
2.	Citrus butterfly, <i>P. demoleus</i>	27	3 (11.11)	6 (22.22)	7 (25.92)	9 (33.33)	2 (7.40)
3.	Rust mite, <i>P. oleivora</i>	27	2 (7.40)	5 (10.50)	9 (3.23)	8 (29.60)	3 (11.11)
4.	Green mite, <i>S. hindustanicus</i>	27	2 (7.40)	4 (14.86)	8 (29.60)	9 (33.33)	4 (14.86)
5.	Psylla, <i>D. citri</i>	27	3 (11.11)	21 (77.77)	3 (11.11)	- (0.00)	- (0.00)
6.	Snow scales, <i>P. aspidistrae</i>	27	6 (22.22)	7 (25.92)	7 (25.92)	6 (22.22)	1 (3.75)
7.	Fruit sucking moth, <i>Othreis</i> sp.	27	22 (81.48)	4 (14.86)	1 (3.75)	-	-

* Figures presented in paranthesis are per cent of infested gardens.

Table 20 : Categorisation of citrus pests based on their infestation

S.No	Rating	Percent infestation				
		Nil	Low	Moderate	Severe	Very severe
1.	Leaf miner	<1%	1-5%	6-15%	16-30%	>30%
2.	Rust mite	<1%	1-10%	11-30%	31-40%	>50%
3.	Butterfly	<1%	1-5%	6-10%	11-15%	>15%

4.2 IDENTIFICATION OF NEW PESTS OF CITRUS UNDER SOUTHZONE ECOSYSTEM

During the period of seasonal incidence and roving survey studies following insect pests were identified first time on citrus under south zone of Andhra Pradesh

Table 21 : New pests of citrus

S.No.	Common Name	Scientific Name	Family/Order	Nature of Damage
1	Psychids	<i>Clania crameri</i>	Psychidae/ Lepidoptera	Foliage feeder
2.	Chaffer beetle	<i>Autoserica insanabilis</i>	Melonthidae / Coleoptera	Foliage feeder

4.3 NATURAL ENEMIES :

4.3.1 Citrus leaf miner (*Phyllocnistis citrella* Stainton).

During the period of study of seasonal abundance of citrus leaf miner, the occurrence of natural parasitisation was observed. It was found that some of the larvae have been parasitised by larval parasitoid, *Tetrastichus* sp.

4.3.2 Citrus butterfly (*Papilio demoleus* Linnaeus)

During seasonal abundance studies following natural enemies were observed on citrus butterfly.

4.3.2.1 Braconid parasite : *Apanteles papilionis* Viereck.

Family : Braconidae

Order : Hymenoptera.

A braconid parasitoid *A. papilionis* V. was recorded as an endoparasitoid of *P. demoleus* caterpillars. Parasitoid larvae after becoming full grown in the host body, came out of the body of caterpillar by making small punctures and pupated in small silken cocoons. Adults emerged from the pupae after one week. It's peak parasitisation was observed during November and December months.

4.3.2.2 Braconid parasite :

Bracon hebetor

Family : Braconidae

Order : Hymenoptera.

B. hebetor also an endoparasite of *P. demoleus* caterpillars. It resembled the *Apanteles papilionis*, but the cocoons formed after pupation were smaller and compact when compared to the *Apanteles* sp.

4.3.2.3 Reduviid predator :

Rhynocoris marginatus Fab.

Family : Reduviidae

Order : Hemiptera.

A reduviid bug *Rhynocoris marginatus* was observed as predator on caterpillars of *Papilio polytes*. The predator hold the prey by rostral tip and prefer to suck the contents from the ventral side. After approaching the caterpillar, it captured the caterpillar at it's dorsal side, then it was rotated to ventral side for sucking the contents. The predator pierced and sucked the prey content in various parts. After sucking the contents of the prey the predator dropped the empty skin of the prey. Within 24 hours the predator killed two preys.

4.3.3 Citrus psylla (*Diaphorina citri* Kuwayama)

During the period of study of seasonal abundance of citrus psylla, *D. citri* the occurrence of certain natural enemies were observed. Among the predators observed on psyllid population, four coccinellids, one lace wing and one preying mantid found feeding on the population. One parasitoid of eulophid origin was recovered from psyllid population.

Coccinellid predators include *Chilonemus sexmaculata* F., *Coccinella septumpunctata* L., *Brumus suturalis* F. and *Chilocorus nigritus* F. One lace wing, *Chrysopa* sp, and an unidentified preying mantid were found predating upon citrus psylla nymph. An eulophid parasite *Tetrastichus* sp, was found parasitising the nymphs of citrus psylla. All these natural enemies were found prevalent during peak activity of the pest i.e. February and April months.

4.3.4 Weevil (*Myllocerus discolor* Boh)

During the period of study one pentatomid bug *Amyotea malabarica* Fab was identified as a predator of adult weevil.

4.4 EVALUATION OF THE EFFICACY OF NATURAL AND SYNTHETIC INSECTICIDES AGAINST CITRUS LEAFMINER, *Phyllocnistis citrella* Stainton AND CITRUS BUTTERFLY, *Papilio demoleus* Linnaeus AS PROPHYLACTIC AND CURATIVE CONTROL

4.4.1 Prophylactic Control of Citrus Leafminer With Natural Insecticides

Treatments were imposed as prophylactic measure with the initiation of new flush before commencement of leafminer damage. Data on the leafminer infestation were recorded on 1, 3, 5, 7, 10 and 14 days after application of treatments and the results are presented in the Table 23.

4.4.1.1 One day after spraying

Since, all the new flushes were in budding stage and did not open fully, observations were made only in opened leaves. There was no incidence of leafminer infestation on one day after spraying.

4.4.1.2 Three days after spraying

All the treatments were superior in keeping the citrus plants free from leafminer infestation at three days after spraying.

4.4.1.3 Five days after spraying

All the treatments were significantly superior to untreated check. Among the different treatments, NSKE, azadirachtin, Bt (0.005%) offered complete protection from leafminer infestation by recording zero incidence. Among the rest of the treatments, neem soap (5.33%), Bt 0.0025 per cent (7.17%) and pongamia oil (9.09%) offered superior protection by recording less infestation and these were superior to pongamia soap (13.65%) and garlic extract (17.97%) .

The efficacy of various treatments at five days after spraying were in the descending order and be depicted in the following way.

$$T_1 = T_2 = T_8 > T_3 > T_7 > T_4 > T_5 > T_6$$

4.4.1.4 Seven days after spraying

All the insecticidal treatments were significantly superior to untreated check at seven days after spraying. NSKE showed lowest per cent incidence of 12.24 per cent. In the order of efficacy, the next best treatments were Bt 0.005 per cent (16.26%) and azadirachtin (19.11%) which were followed by neem soap (20.72%), Bt 0.0025 per cent (21.05%). Neem formulations were found significantly superior to pongamia oil, pongamia soap and garlic extract recording 25.74, 29.71 and 31.52 per cent

pest incidence respectively. However, even on seven days after application all these natural treatments were superior to untreated check.

The efficacy of insecticides at seven days after spraying was found to be in the following order.

$$T_1 > T_8 > T_2 > T_3 > T_7 > T_4 > T_5 > T_6$$

4.4.1.5 Ten days after spraying

All the insecticides were significantly superior over untreated check at ten days. Out of all the treatments, NSKE was significantly superior to all the rest of the treatments by recording least per cent infestation (20.67%) and was superior to Bt (0.005%), azadirachtin and neem soap which were in the second order in efficacy recording 22.06, 22.83 and 23.34 per cent damage respectively. However, neem formulations azadirachtin and neem soap did not show any significant difference in the efficacy. In the order of efficacy next superior treatments were Bt (0.0025%), pongamia oil and pongamia soap with 25.41, 27.65 and 31.13 per cent of infestation. Among all the treatments garlic extract was found less effective recording high infestation of 37.06 per cent.

The efficacy of insecticides at ten days after spraying was found to be in the following order.

$$T_1 > T_8 = \overline{T_2} > T_3 > T_7 > T_4 > T_5 > T_6$$

4.4.1.6 Fourteen days after spraying:

Fourteen days after spraying, all the treatments were significantly superior over untreated check. The order of efficacy of treatments were NSKE (25.31%), Bt 0.005 per cent (26.74%) azadirachtin (30.42%), Bt 0.0025 per cent (32.38%), neem soap (34.84%). Pongamia oil (37.21%), pongamia soap (38.50%) and garlic extract (40.81%) were proved inferior to neem formulations and Bt at both concentrations by recording high infestation. Similar to the earlier observations made on tenth day, NSKE showed its superior efficacy to all other treatments by recording least damage. Garlic extract was less effective compared to all other insecticidal treatments, while in untreated check 61.33 per cent of damage was recorded.

The order of efficacy of various treatments at fourteen days after spraying were in the following order.

$$T_1 > T_8 > T_2 > T_7 > T_3 > T_4 > T_5 > T_6$$

4.4.2 Prophylactic Control of Citrus Leafminer With Synthetic Insecticides

4.4.2.1 One day after spraying

There was no incidence of leafminer at one day after spraying. because all the new flushes were in unopened condition (Table 24).

4.4.2.2 Three days after spraying

Except in untreated check all treatments offered complete protection from leafminer infestation. In control treatment 37.05 per cent infestation was recorded.

4.4.2.3 Five days after spraying

All the treatments were significantly superior to untreated check. Except cartap hydrochloride which recorded low infestation (7.32%), all other insecticidal treatments offered complete protection from the pest, whereas in untreated check 40.81 per cent infestation was recorded.

4.4.2.4 Seven days after spraying

All the insecticides were significantly superior to untreated check at seven days after spraying. Treatments viz., profenophos, lambda cyhalothrin and fenvalerate were significantly superior to all other insecticides and offered complete protection by recording zero per cent infestation followed by acephate which recorded least per cent incidence of

4.86 per cent. Among the other insecticides, thiodicarb also offered good protection as it recorded only 9.81 per cent of incidence and found superior to chlorpyrifos and methomyl with 12.23 and 13.10 per cent of incidence respectively and these were found to be on par with each other. Cartap hydrochloride showed least efficacy by recording 20.69 per cent of pest incidence. In untreated check 43.22 per cent incidence was observed (Table 20).

The order of efficacy of various treatments at seven days after spraying were in the following order.

$$T_5 = T_3 = T_2 > T_7 > T_1 > \underline{T_8} > T_6 > T_4$$

4.4.2.5 Ten days after spraying

All the insecticides were significantly superior over untreated check at ten days after spraying. In all the insecticidal treatments the infestation increased compared to seventh day observations (Table 24). Fenvalerate and lambda cyhalothrin were highly effective and proved significantly superior to all other insecticides recording 4.78 and 6.49 per cent incidence respectively. Profenophos and acephate were the next superior treatments recording less infestation of 16.8 and 22.04 per cent respectively. Thiodicarb and chlorpyrifos were on par offering less protection by

recording 26.13 and 26.28 per cent damage respectively and these were superior to methomyl (27.42%) and cartap hydrochloride (29.89%).

The order of efficacy of various treatments at 10 days after spraying were as follows.

$$\underline{T_5} > T_3 > T_2 > T_7 > T_1 > T > T_8 > T_6 > T_4$$

4.4.2.6 Fourteen days after spraying

All the treatments were significantly superior to untreated check. Insecticides fenvalerate and lambda cyhalothrin showed least infestation at fourteen days after spraying with the incidence of 20.83 and 23.25 per cent followed by profenophos (25.82%) and acephate (26.13%). However, profenophos and acephate were superior to thiodicarb (30.96%), chlorpyriphos (31.07%) and methomyl (33.19%) were on par with cartap hydrochloride (34.95%) at fourteen days after spraying.

The order of efficacy of various treatments at fourteen days after spraying were in the following order.

$$T_5 > T_3 > T_2 > T_7 > T_1 > T_8 > T_6 > T_4$$

4.4.3 Evaluation of Efficacy of Natural Insecticides Against Leafminer (Curative Control)

The efficacy of insecticides on leafminer larval population was evaluated by imposing the treatments after noticing leafminer damage. The results were presented in the Table 25. Observations were made on larval population one day before insecticidal treatments and 1, 3, 5, 7, 10 and 14 days after spraying to assess the larval mortality.

4.4.3.1 One day after spraying

Observations recorded on the larval population at one day after insecticidal application showed that all the insecticidal treatments were significantly superior to untreated check. The maximum population reduction was obtained from treatments Bt 0.005 per cent (69.87%), Bt 0.0025 per cent (60.28%) and NSKE (58.67%). Bt 0.0025 per cent was found to be on par with NSKE, however these treatments found superior to all other treatments. Azadirachtin was in the next order in its efficacy resulting in 51.34 per cent mortality. Treatments neem soap (37.63%), pongamia oil (36.74%) and pongamia soap (31.77%) were found less effective initially. Garlic extract showed least efficacy with 29.11 per cent of larval mortality. Neem formulations NSKE and azadirachtin showed

their significant superiority over neem soap. Pongamia oil was superior to pongamia soap.

The efficacy of the insecticidal treatments against citrus leafminer were found to be in the following order.

$$T_8 > \underline{T_7} > T_1 > T_2 > \overline{T_3} > T_4 > T_5 > T_6$$

4.4.3.2 Three days after spraying

In all the treatments toxicity was enhanced compared to the observations at one day after application of insecticides. All the insecticides were significantly superior over untreated check. The per cent larval mortality at three days after spraying revealed that Bt 0.005 per cent was the most effective treatment causing 87.63 per cent mortality. The next superior treatments were Bt 0.0025 (75.02%), neem seed kernal extract (73.35%) and azadirachtin (70.25%). Neem soap recorded low mortality of 46.4 per cent, however it was superior to pongamia oil , pongamia soap and garlic extract recording in 41.75, 40.96 and 39.19 per cent larval mortality. No significant difference was found between pongamia soap, pongamia oil and garlic extract.

The efficacy of the insecticidal treatments at three days after spraying were found to be in the following order.

$$T_8 > T_7 > T_1 > T_2 > T_3 > T_4 > T_5 > T_6$$

4.4.3.3 Five days after spraying

Similar results were obtained on fifth day after spraying indicating increased efficacy over third day observations in all the insecticidal treatments. All the treatments were superior to untreated check. Bt (0.005%) was the most effective treatment with highest mortality of 100 per cent and found significantly superior to all other treatments. In the order of efficacy next best treatments were Bt 0.0025 per cent, azadirachtin and NSKE which attributed 82.93, 79.97 and 78.39 per cent larval mortality. Neem soap occupied third position in its efficacy (57.77%) but superior to the rest of the treatments *viz.*, pongamia oil, pongamia soap and garlic extract resulting in 50.61, 47.06 and 41.87 per cent larval mortality respectively.

The efficacy of the insecticides at five days after spraying were found to be in the following order.

$$T_8 > T_7 > T_2 > T_1 > T_3 > T_4 > T_5 > T_6$$

4.4.3.4 Seven days after spraying

Bt at both concentrations (0.005 and 0.0025 %) exhibited its superior efficacy over all the rest of the treatments by recording 100 per cent larval mortality. Reinfestation of leafminer was noticed in all other treatments indicating that they lost their residual toxicity gradually.

4.4.3.5 Ten days after spraying

Except in Bt 0.005 and 0.0025 per cent treatments, remaining all other treatments reinfestation was observed indicating the loss in their toxic effect.

4.4.3.6 Fourteen days after spraying

All insecticidal treatments lost their residual toxicity hence reinfestation was noticed.

4.4.4 Evaluation of Efficacy of Synthetic Insecticides Against Citrus Leaf miner (Curative Control)

4.4.4.1 One day after spraying

Observations recorded on the larval population at one day after insecticidal application showed that all the insecticidal treatments were significantly superior to untreated check (Table 26).

Fenvalerate (94.38%), lambda cyhalothrin (92.52%) and thiodicarb (90.28%) recorded high per cent mortality and were superior to all the remaining treatments. The next best effective treatment was profenophos with 85.90 per cent population reduction, however this was on par with acephate (84.17%). The rest of the treatments *viz.*, methomyl, chlorpyrifos and cartap hydrochloride were also effective recording 81.68, 80.86 and 78.07 per cent population reduction. Among all the treatments cartap hydrochloride was found less effective compared to all other treatments.

The efficacy of the insecticidal treatments against *P. citrella* was found to be in the following order.

$$T_5 > T_3 > T_1 > T_2 > T_7 > \overline{T_6} > T_8 > T_4$$

4.4.4.2 Three days after spraying

Observations recorded on larval population at three days after insecticidal application showed that all treatments were significantly superior to untreated check. The treatments *viz.*, thiodicarb, lambda cyhalothrin and fenvalerate were highly effective by recording 100 per cent mortality. In the order of efficacy the next superior treatments were profenophos (95.15%), acephate (95.20%) and methomyl (93.06%) with no

significant difference among them. Out of all the treatments low population reduction was obtained in chlorpyrifos (88.31%) and cartap hydrochloride (85.35%).

The efficacy of the insecticidal treatments at three days after spraying was found to be in the following order.

$$\overline{T_1 = T_3 = T_5} > \underline{T_7 = T_2} > T_6 > T_8 > T_4$$

4.4.4.3 Five days after spraying

Similar results were obtained on fifth day after spraying indicating an increase in their efficacy over third day observations in all the treatments. All the insecticidal treatments were superior to untreated check at five days after insecticidal application. Except chlorpyrifos (89.76%) and cartap hydrochloride (88.20%) all the rest of the treatments *viz.*, thiodicarb, profenophos, lambda cyhalothrin, fenvalerate, methomyl and acephate gave cent per cent mortality.

The efficacy of the insecticides at five days after spraying were found to be in the following order.

$$T_1 = T_2 = T_3 = T_5 = T_6 = T_7 > \underline{T_8} > T_4$$

4.4.4.4 Seven days after spraying

All the treatments *viz.*, thiodicarb, profenophos, lambda cyhalothrin, fenvalerate, methomyl and acephate consistently maintained their efficacy by recording 100 per cent larval mortality showing similar performance as on fifth day after insecticidal application. In the treatments cartap hydrochloride and chlorpyriphos there was no increase in per cent mortality compared to the previous observation of five days after spraying.

4.4.4.5 Ten days after spraying

Insecticides fenvalerate and lambda cyhalothrin continued to exhibit their persistent toxicity proving their superiority over all other treatments recording 100 per cent larval reduction even ten days after spraying without recording any reinfestation in these treatments. In all other treatments fresh infestation was recorded.

4.4.4.6 Fourteen days after spraying

All insecticidal treatments lost their residual toxicity hence reinfestation was noticed in all the treatments.

4.4.5 Evaluation of Efficacy of Natural Insecticides Against Citrus Butterfly (Curative Control)

The efficacy of insecticides on citrus butterfly larval population was evaluated by imposing the treatments after noticing butterfly larval damage. The results were presented in the Table 27. Observations were made on larval population one day before insecticidal treatments and 1, 3, 5, 7, 10 and 14 days after spraying to assess the per cent population reduction.

4.4.5.1 One day after spraying

Observations recorded on the larval population at one day after insecticidal application revealed that all the insecticidal treatments were significantly superior to untreated check. The maximum population reduction was obtained in treatment Bt 0.005 per cent, which offered 61.46 per cent mortality. Next best treatment was Bt 0.0025 per cent which showed 46.80 per cent mortality. The treatments in the order of efficacy were NSKE (25.66%), azadirachtin (22.29%), neem soap (16.47%), pongamia oil (13.27%) and garlic extract (8.88%). Observation recorded after one day of spraying revealed that except Bt, all the other treatments did not cause significant population reduction

The efficacy of the insecticidal treatments against citrus butterfly were found to be in the following order.

$$T_8 > T_7 > \underline{T_1 > T_2} > T_3 > \underline{T_5 > T_4} > T_6$$

4.4.5.2 Three days after spraying

In all the treatments, their efficacy was enhanced compared to earlier observations. The treatments Bt 0.005 per cent (90.71%) and Bt 0.0025 per cent (85.88%) offered higher per cent reduction and found superior to all other treatments. NSKE (55.41%), azadirachtin (46.25%), neem soap (42.47%) were second in the order of efficacy. However, azadirachtin and neem soap did not differ significantly in their efficacy. Next to azadirachtin and neem soap, pongamia soap recorded the least (33.81%) reduction, but superior to pongamia oil and garlic extract. Among all the treatments pongamia oil and garlic extract offered less protection by recording only 26.83 and 23.61 per cent larval mortality.

The efficacy of the insecticidal treatments at three days after spraying were found to be in the following order.

$$T_8 > T_7 > T_1 > \underline{T_2} > T_3 > T_5 > \underline{T_4} > T_6$$

4.4.5.3 Five days after spraying

Five days after spraying similar results were obtained as in earlier observation of third day recording increased efficacy in controlling the pest in all the treatments. All the insecticidal treatments were superior to untreated check at five days after insecticidal application. Bt 0.005 per cent and Bt 0.0025 per cent recorded highest (100%) per cent reduction in population. The order of efficacy of other treatments were NSKE (81.08%), azadirachtin (76.03%), neem soap (69.87%), pongamia oil (66.17%), pongamia soap (56.61%) and garlic extract(41.10%). Though the efficacy of NSKE was on par with azadirachtin, it was significantly superior to rest of the treatments, and was followed by azadirachtin. Neem soap and pongamia soap were superior to pongamia oil (56.61%). Out of all the treatments garlic extract offered less protection from citrus butterfly larvae.

The efficacy of the insecticides at five days after spraying were found to be in the following order.

$$T_8 = T_7 > \overline{T_1} > \overline{T_2} > T_3 > T_5 > T_4 > T_6$$

4.4.5.4 Seven days after spraying

Except garlic extract, all other treatments showed enhanced efficacy. The two Bt treatments proved to be highly effective over all other treatments recording cent per cent mortality. NSKE (95.92%), azadirachtin (90.92%) and neem soap (83.51%) were the next superior treatments in offering effective control against the pest and these were significantly superior to pongamia soap and pongamia oil which recorded 70.60 per cent and 61.14 per cent larval mortality respectively. Garlic extract toxicity was lost at five days after spraying and no further increase in mortality recorded.

4.4.5.5 Ten days after spraying

Except Bt 0.005 per cent and 0.0025 per cent treatments, all other treatments lost their efficacy.

4.4.5.6 Fourteen days after spraying

All insecticidal treatments lost their residual toxicity hence reinfestation could be noticed in all the treatments.

4.4.6 Evaluation of Efficacy of Synthetic Insecticides Against Citrus Butterfly Larvae (Curative Control)

4.4.6.1 One day after spraying

Observations recorded on the larval population at one day after insecticidal application showed that all the insecticidal treatments were significantly superior to untreated check (Table 28). The maximum population reduction was obtained in the treatment fenvalerate (98.41%) showing its superior efficacy over all other treatments *viz.*, lambda cyhalothrin, thiodicarb, profenophos and acephate which also exercised effective control by recording high per cent reduction of 96.94, 95.29, 94.59 and 93.83 per cent respectively. Among the treatments thiodicarb, lambda cyhalothrin and profenophos no significant difference was found in their efficacy and stood closely followed by acephate. Order of the treatments in their decreasing order of efficacy were methomil (89.02%), chlorpyriphos (87.93%) and cartap hydrochloride (86.83%).

The efficacy of insecticidal treatments against citrus butterfly were found to be in the following order.

$$T_5 > T_3 > T_1 > T_2 > T_7 > T_6 > T_8 > T_4$$

4.4.6.2 Three days after Spraying

In all the treatments mortality was increased compared to the observations at one day after application of insecticides. All the insecticides were significantly superior over untreated check. Cent per cent population reduction was observed in thiodicarb, profenophos, lambda cyhalothrin, fenvalerate, methomyl and acephate. The treatments chlorpyriphos and cartap hydrochloride reduced the pest population to 89.48 and 88.88 per cent respectively and these were found to be on par with each other.

4.4.6.3 Five days after spraying

All the treatments were superior to untreated check at five days after spraying. All the treatments showed 100 per cent population reduction revealing their enhanced efficacy.

4.4.6.4 Seven days after spraying

Except in the cartap hydrochloride treatment, all other treatments *viz.*, thiodicarb, profenophos, lambda cyhalothrin, fenvalerate, methomyl, acephate and chlorpyriphos consistently maintained their efficacy by recording 100 per cent larval reduction showing similar performance as in fifth day after insecticidal application. Reinfestation was noticed in treatment cartap hydrochloride, indicating that the residual toxicity was lost gradually.

4.4.6.5 Ten days after spraying

Insecticides fenvalerate and lambda cyhalothrin continued to exhibit their persistent toxicity proving their superiority over all other treatments recording 100 per cent larval reduction even at ten days after sprayings. Reinfestation observed in all other treatments.

4.4.6.6 Fourteen days after spraying

All insecticidal treatments lost their residual toxicity hence reinfestation was noticed in all the treatments.

4.4.7 Overall Performance of Natural and Synthetic Insecticides Against Citrus Leafminer *P. citrella* and Citrus Butterfly *p. demoleus*

Natural insecticides were evaluated as prophylactic and curative methods of control against citrus leaf miner. Against citrus butterfly the above products were evaluated as curative method of control. In prophylactic method of control, NSKE, azadirachtin and Bt (0.005%) were proved effective insecticides followed by neem soap and Bt (0.0025%). Garlic extract was the least effective among all the natural insecticides. The performance of natural insecticides in curative method of control revealed the superiority of Bt (0.005% and 0.0025%) among all the

insecticides tested against both citrus butterfly and leaf miner. Among the botanicals azadirachtin was the effective insecticide against leaf miner whereas NSKE was proved as best treatment against butterfly. Garlic extract was least effective in both cases.

Synthetic chemicals were evaluated both as prophylactic and curative methods of control against leaf miner only as curative control against the citrus butterfly.

Among all the insecticides synthetic pyrethroids were proved as superior chemicals both as prophylactic as well as curative methods against leaf miner and as curative method of control against butterfly. Though profenophos was proved as better insecticide as prophylactic treatment, but as curative treatment, it was losing its residual toxicity earlier than synthetic pyrethroids. Thiodicarb and acephate losing their toxicity on seventh day in prophylactic control, whereas in curative control they are retaining their efficacy upto seven days by causing cent per cent larval mortality of butterfly and leaf miner. Cartap hydrochloride was found to be comparatively least effective chemical both as prophylactic and curative treatment against both pests.

Fig.2 : Relationship between citrus leaf miner, *P. citrella* infestation on Sathgudi sweet orange and weather factors

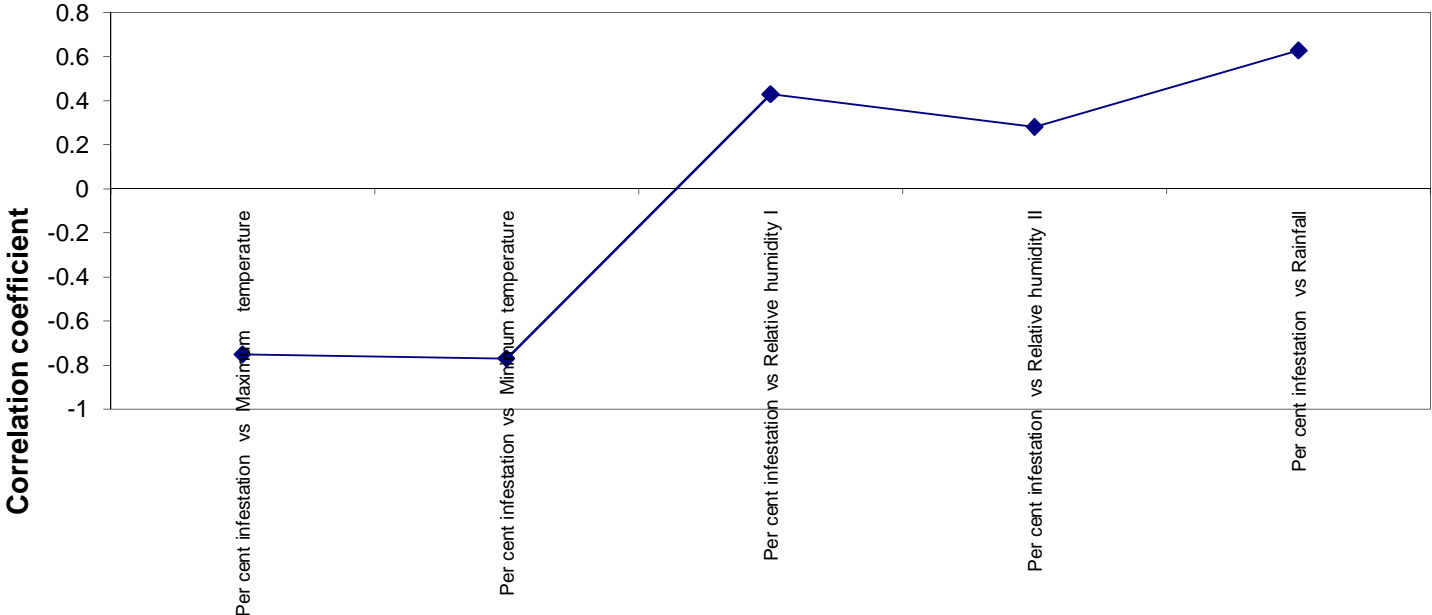


Fig.3 : Relationship between citrus butterfly, *P. demoleus* larval population on Sathgudi sweet orange and weather factors

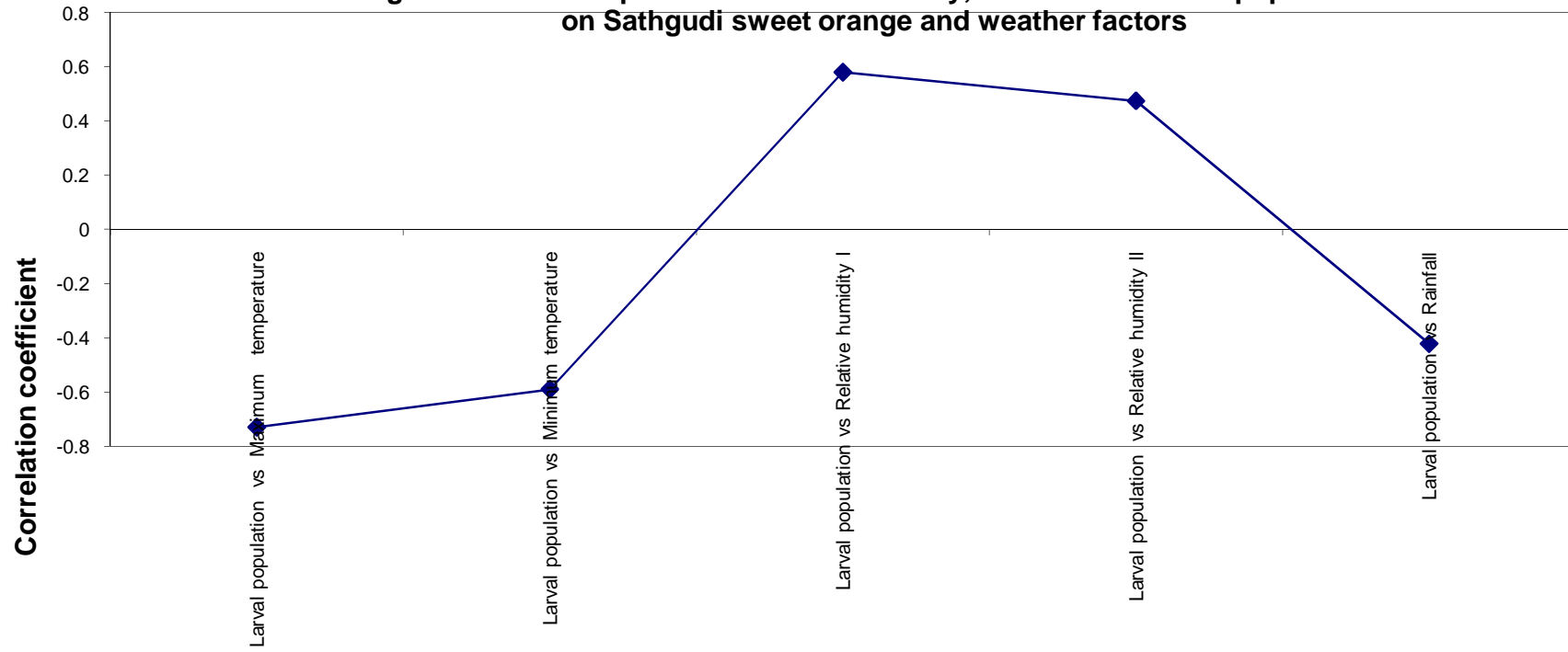


Fig.4 : Relationship between citrus psylla, *D. citri* population on Sathgudi sweet orange and weather factors

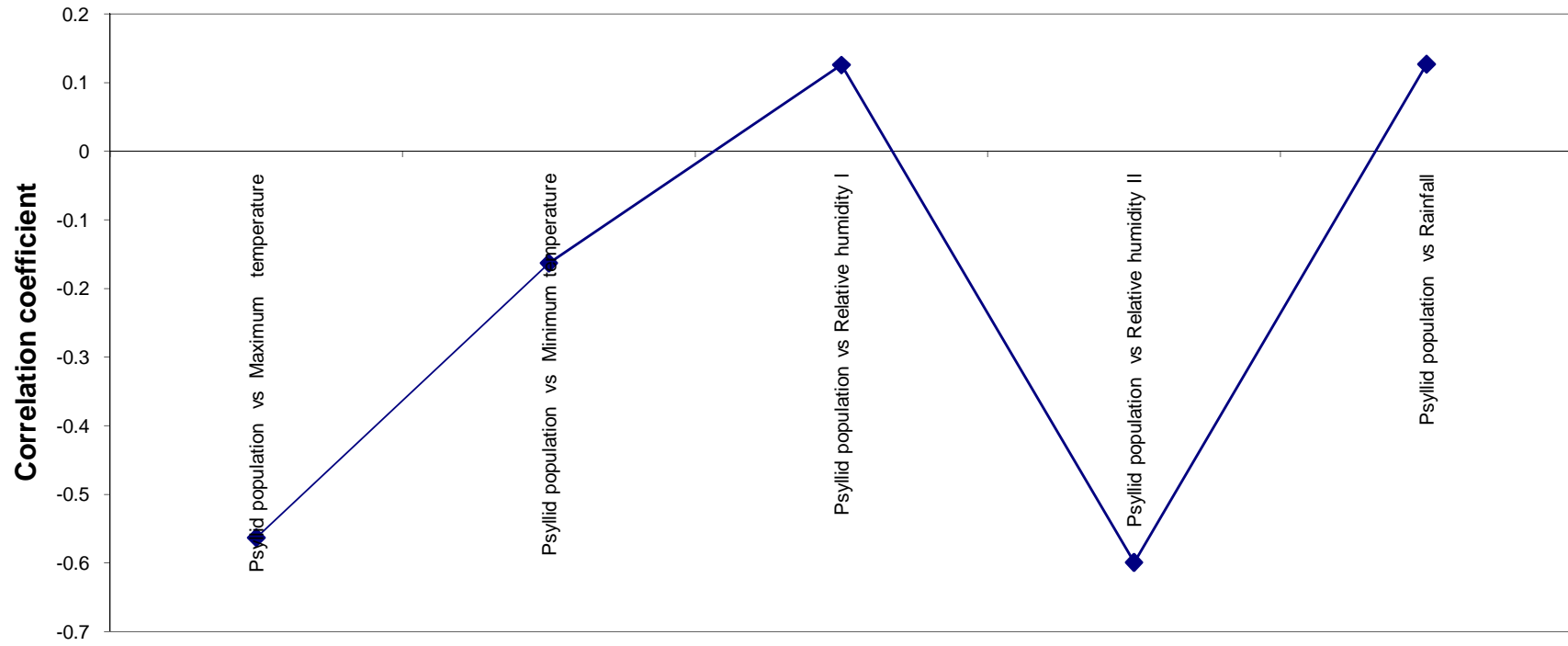


Fig.7 : Relationship between rust mite, *P. oleivora* population on Sathgudi sweet orange and weather factors

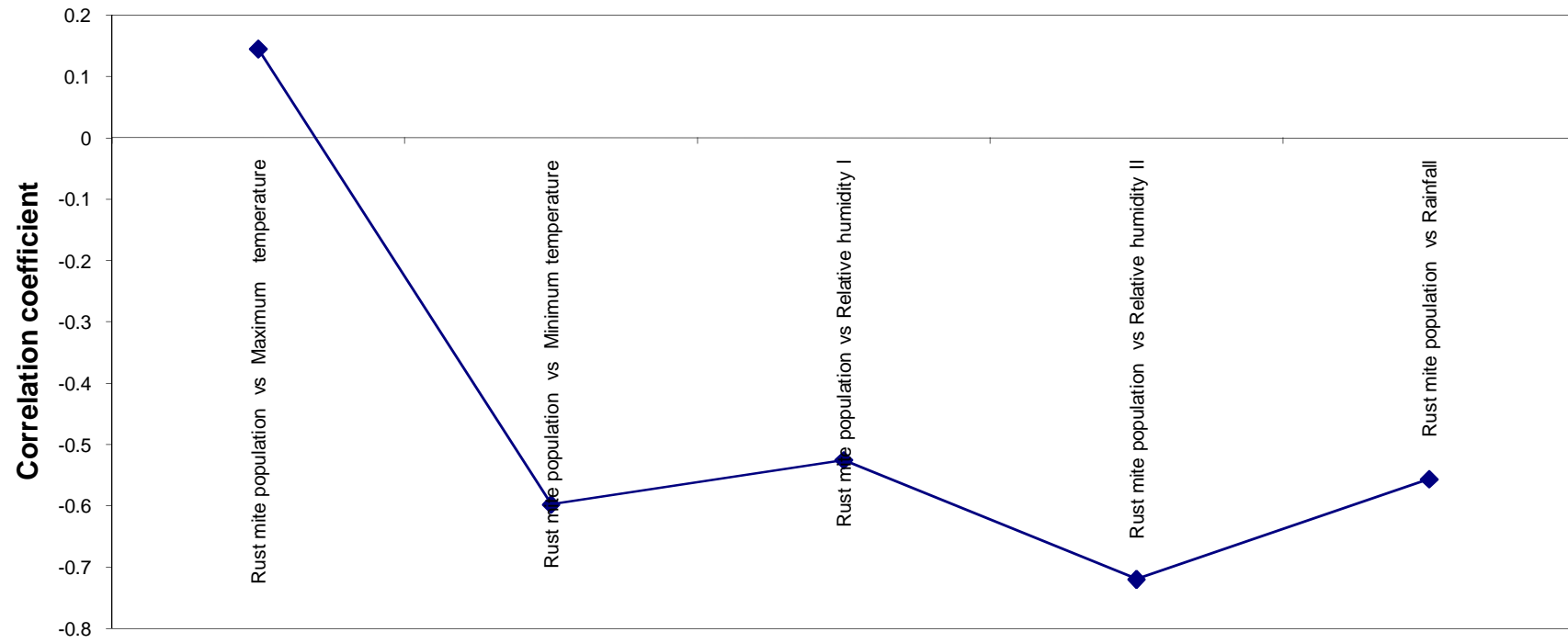


Fig.6 : Relationship between green mite, *S. hindustanicus* population on Sathgudi sweet orange and weather factors

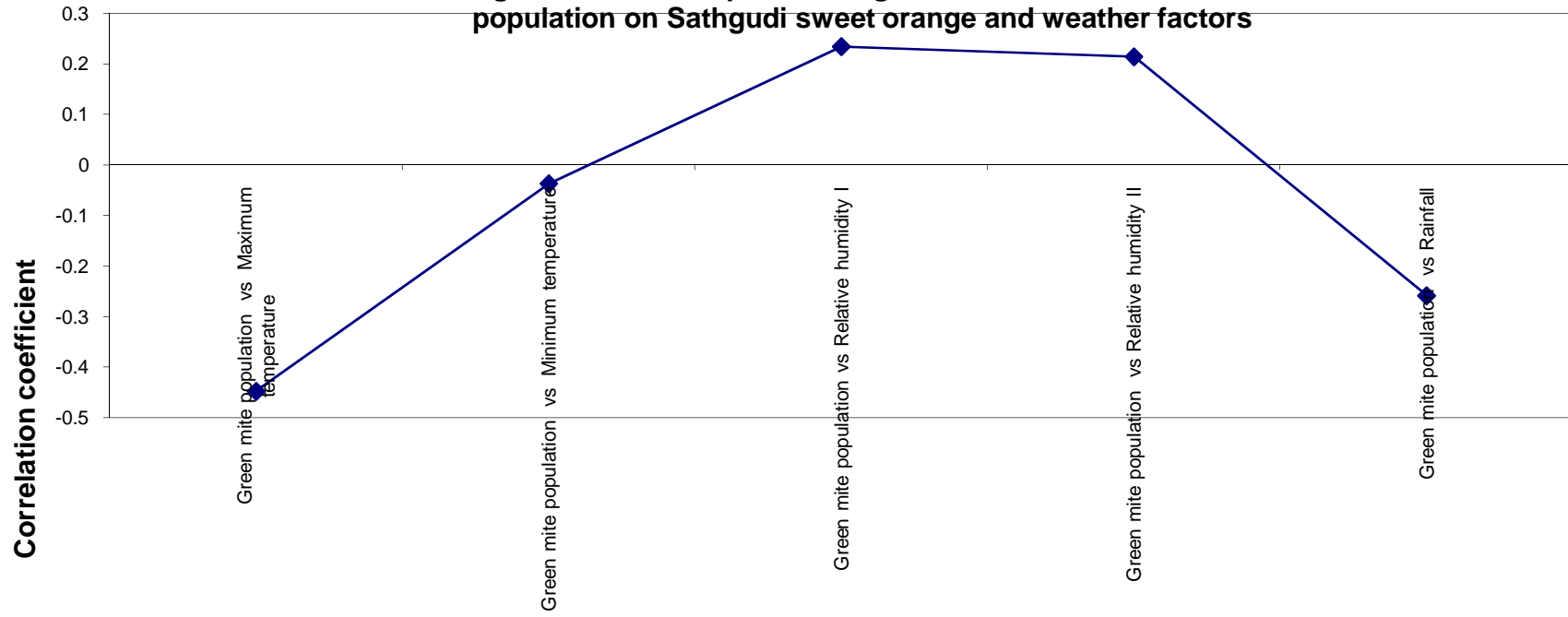


Fig.5 : Relationship between weevil, *Myllocerus* sp. population on Sathgudi sweet orange and weather factors

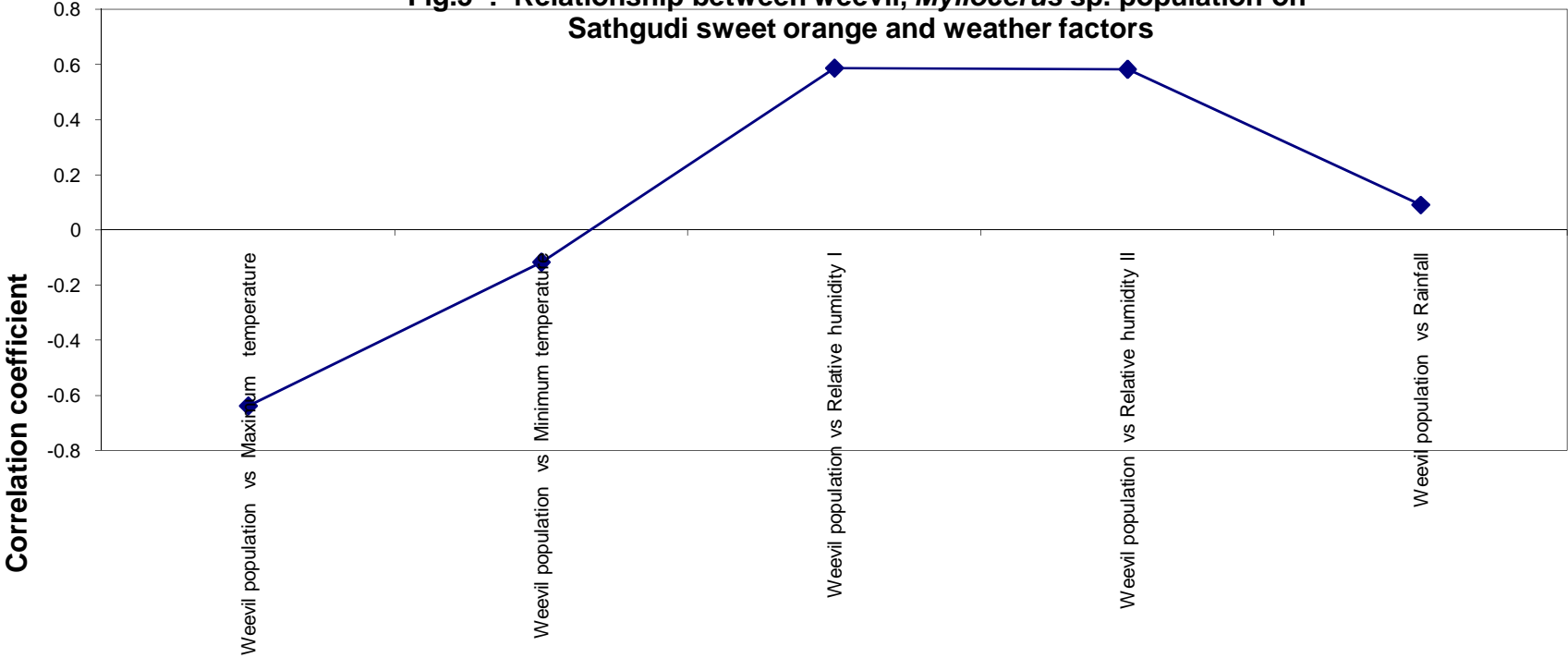


Fig. 9 : Relationship between citrus leaf miner, *P. citrella* incidence on Balaji acid lime and weather factors

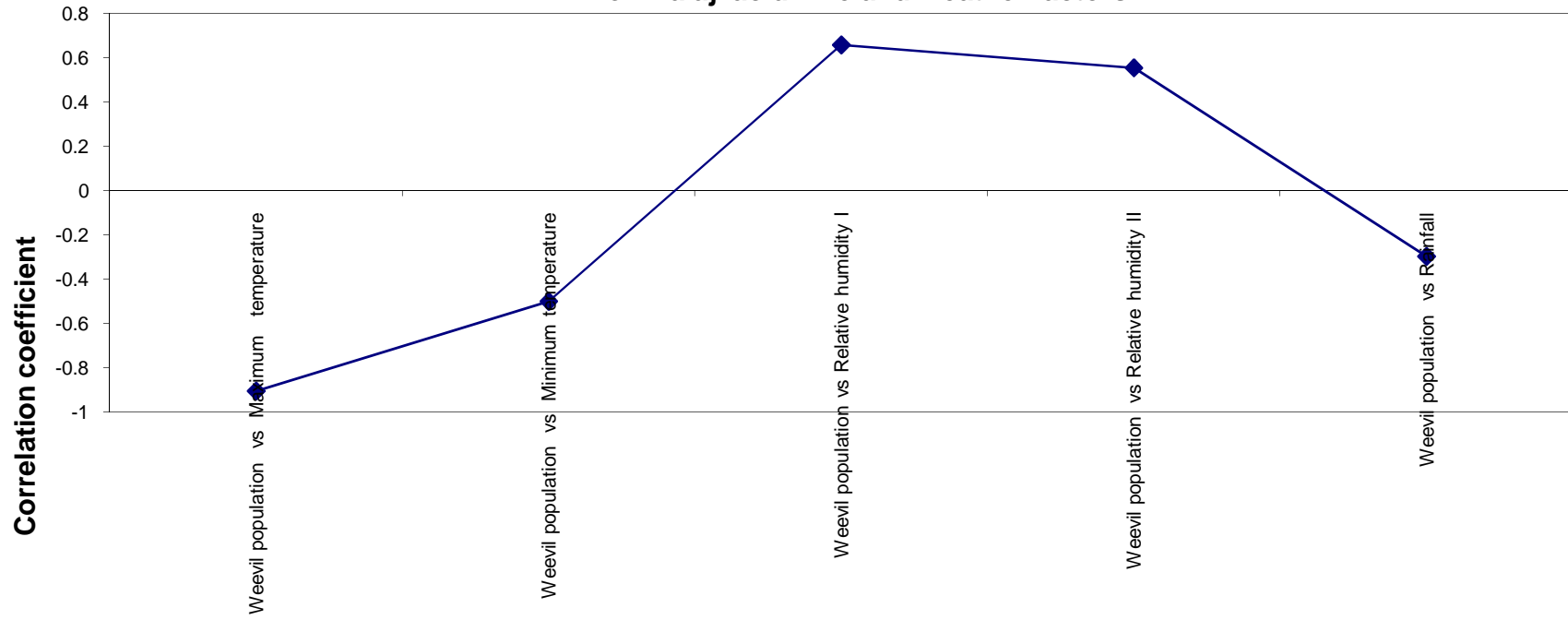


Fig. 10 : Relationship between citrus butterfly, *P. demoleus* larval population on Balaji acid lime and weather factors

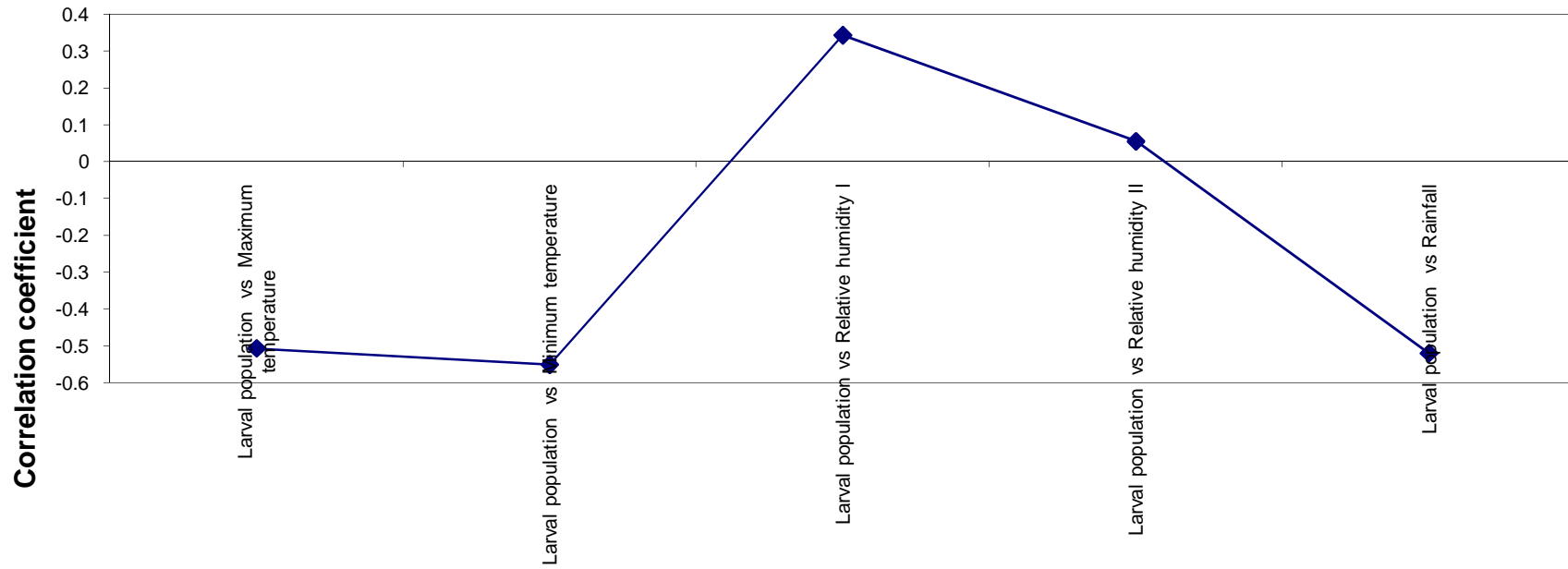


Fig. 11 : Relationship between psylla, *D. citri* population on Balaji acid lime and weather factors

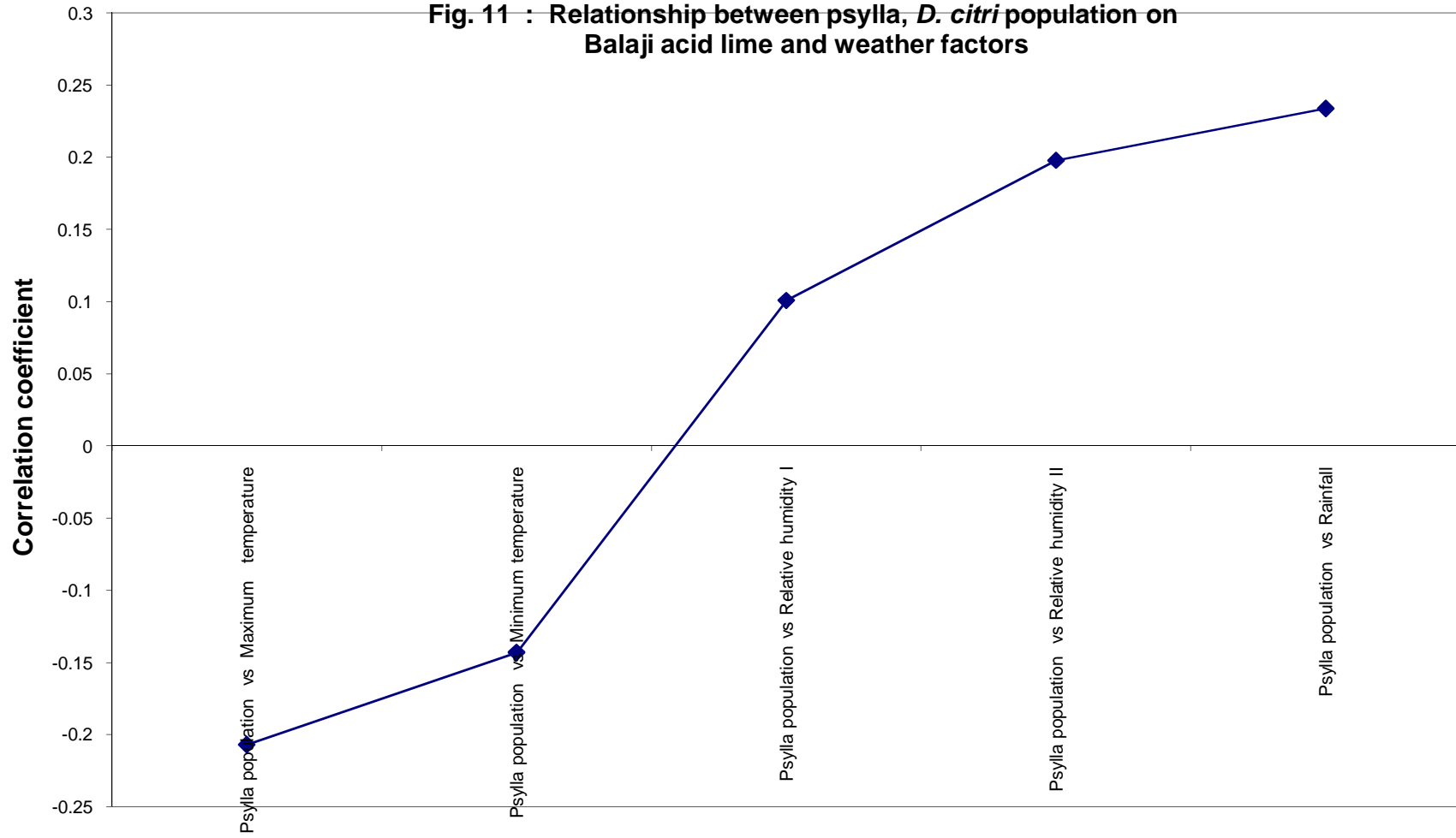
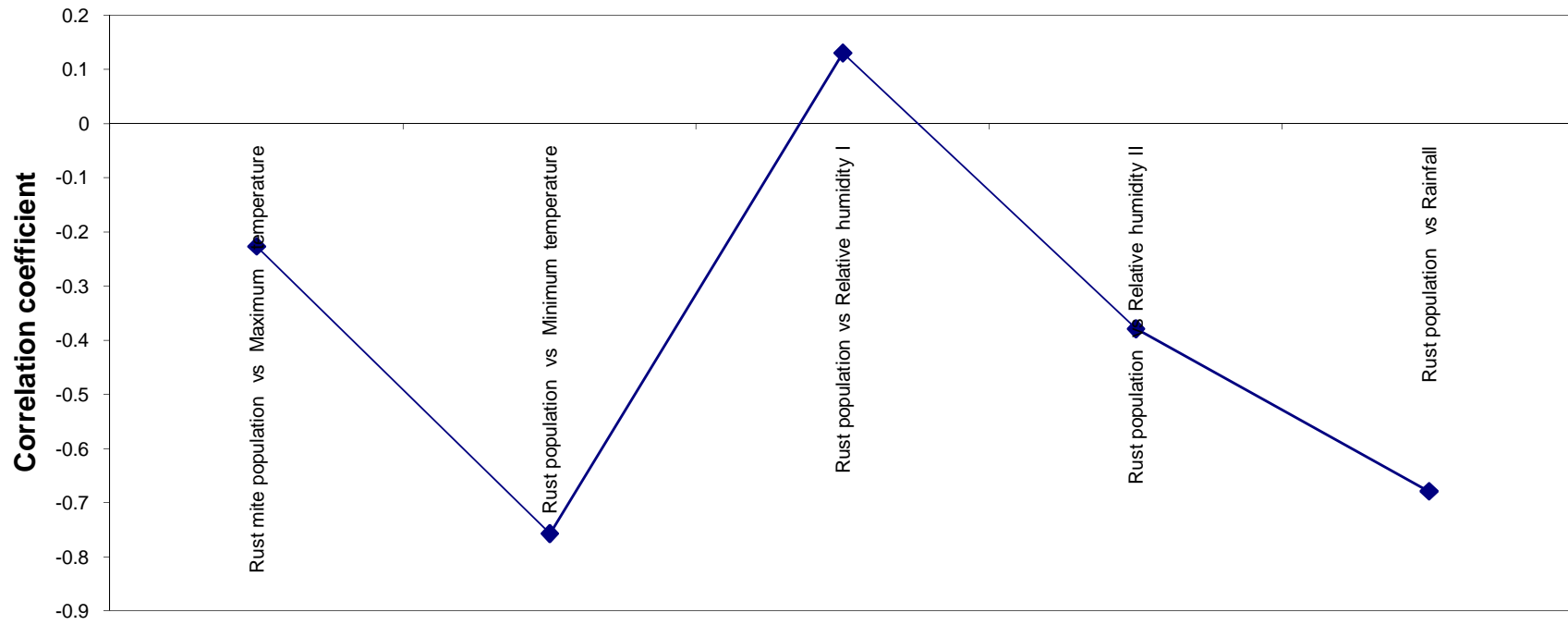


Fig. 14 : Relationship between rust mite, *P. oleivora* population on Balaji acid lime and weather factors



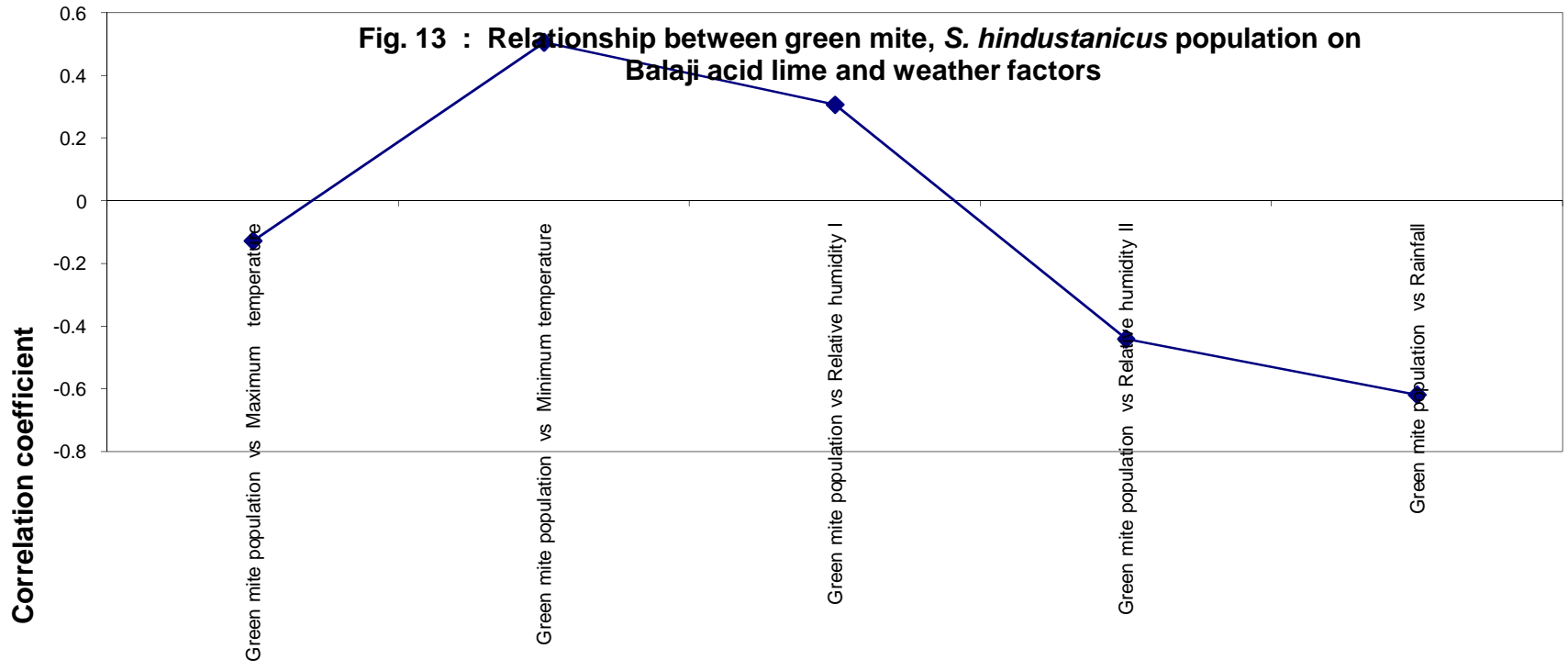


Fig. 12 : Relationship between weevil, *Mylocerus* sp. population on Balaji acid lime and weather factors

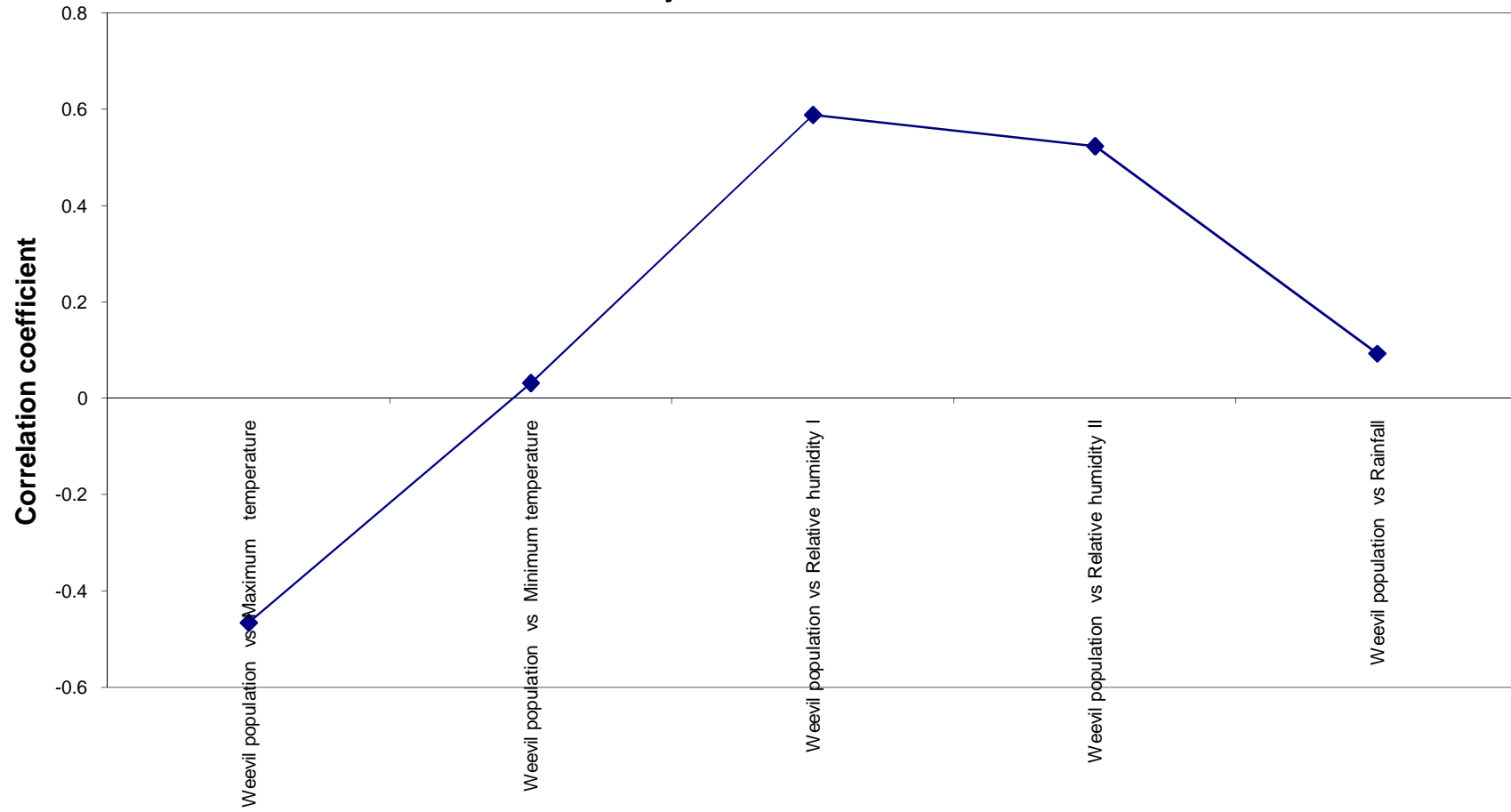


Fig. 8 : Seasonal occurrence of major pests of citrus on Balaji acid lime during June 2003 to May 2004

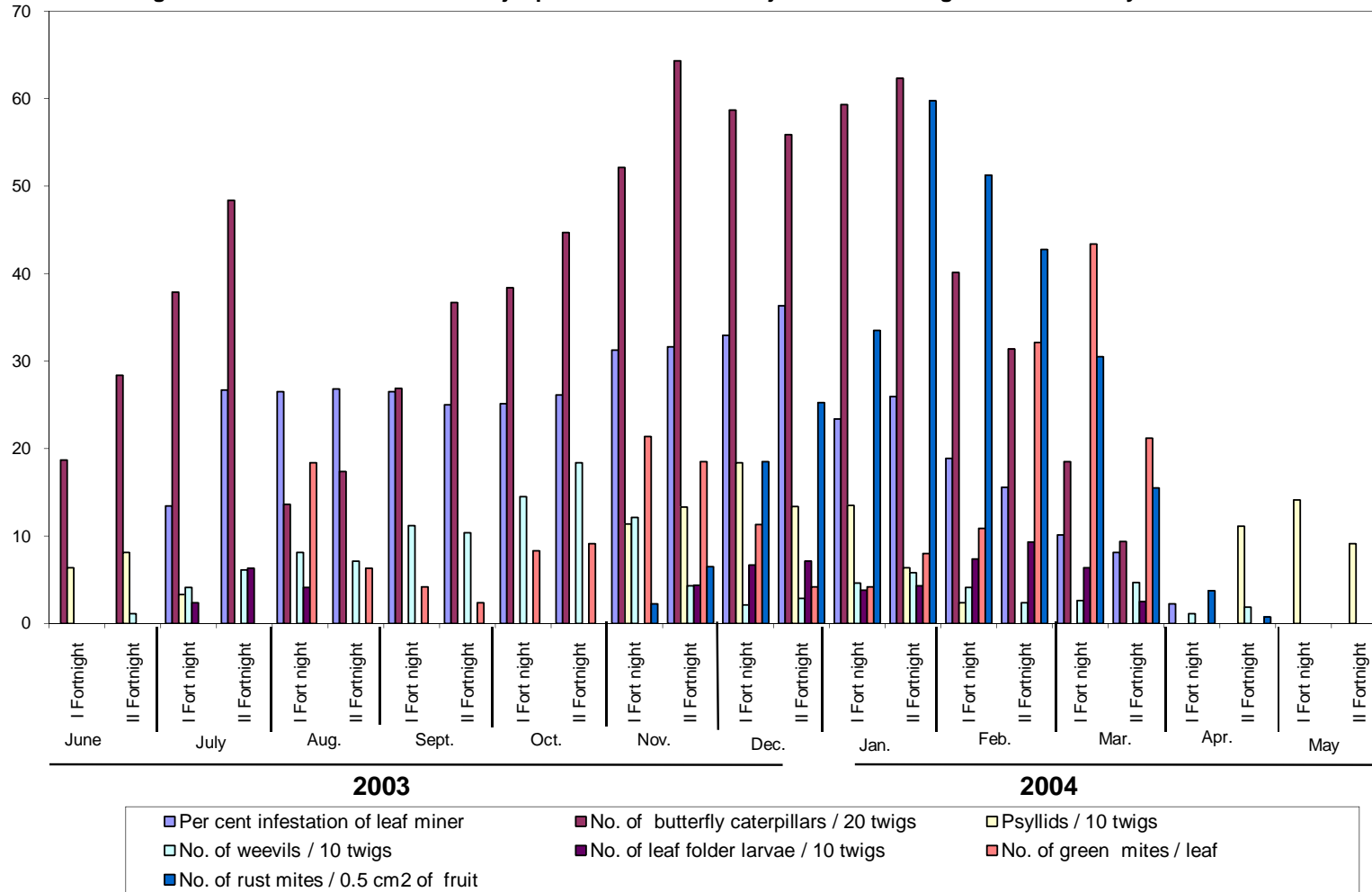


Fig. 1 : Seasonal occurrence of major pests of citrus on Sathgudi sweet orange during June 2003 to May 2004

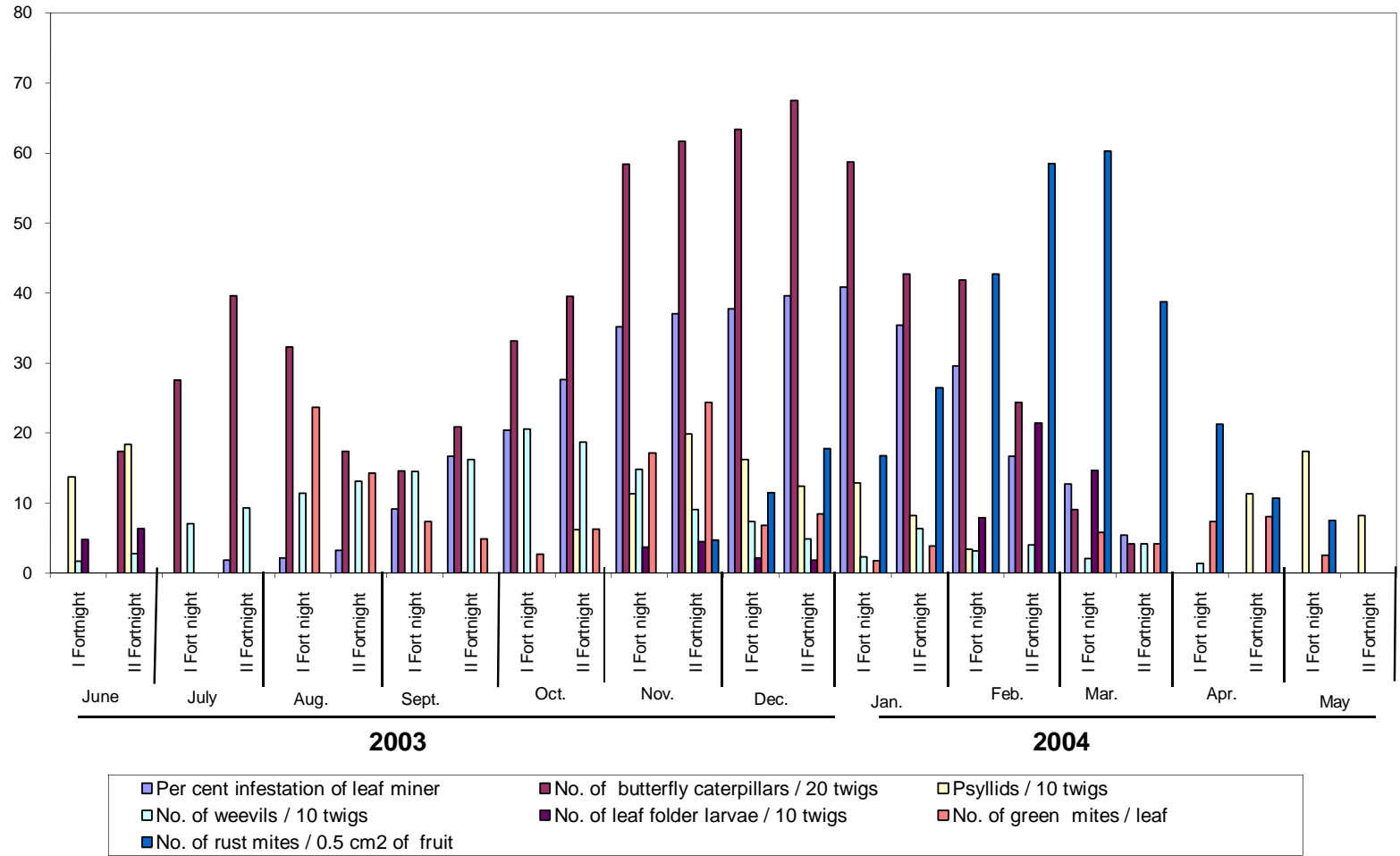




Plate 1 : Leaf miner, *P. citrella* infested twig

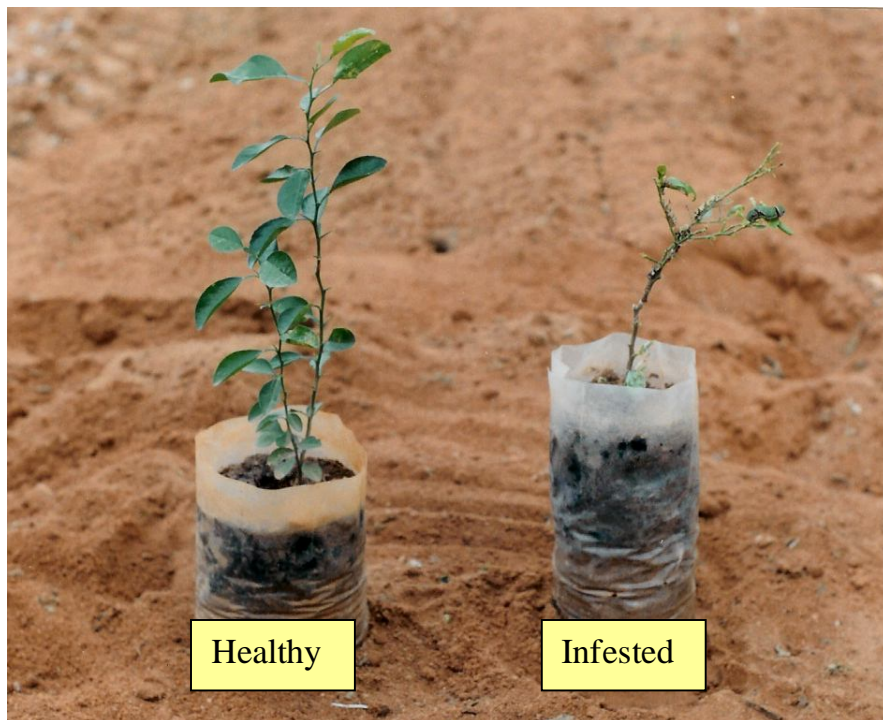


Plate 2 : Damage of citrus butterfly, *P. demoleus* larvae



Plate 3 : An adult of citrus psylla, *D. citri*



Plate 4 : Damage of weevil *Mylocerus* sp.



Plate 5 : Damage of green mite, *S. hindustanicus* on sathgudi leaves



Plate 6 : Larvae of leaf folder, *P. zizyphi*



Plate 7 : Snow scale *P. aspidistrae* infestation on trunk of acid lime



Plate 8 : Population of aphid, *Toxoptera* sp.



Plate 9 : Host larvae with cocoons of *Apanteles* sp.



Plate 10 : An adult of *Apanteles papilionis*



Plate 11 : An adult of *Bracon hebetor*



Plate 12 : A reduviid predator *Rhynocoris marginatus* Fab. on caterpillar of citrus butterfly, *P. demoleus*

Table 5 : Relationship between *Phyllocnistis citrella* Stainton infestation on Sathgudi sweet orange and weather factors

S.No.	Particulars	Correlation coefficient
1.	Per cent infestation Vs Maximum temperature	-0.751**
2.	Per cent infestation Vs Minimum temperature	-0.770**
3.	Per cent infestation Vs Relative humidity I	0.432 ^{NS}
4.	Per cent infestation Vs Relative humidity II	0.282 ^{NS}
5.	Per cent infestation Vs Rainfall	0.629**

* Significant at 1% probability

** Significant at 5% probability

NS - Non significant

Table 6 : Relationship between *Papilio demoleus* L. larval population on Sathgudi sweet orange and weather factors

S.No.	Particulars	Correlation coefficient
1.	Mean larval population Vs Maximum temperature	-0.729**
2.	Mean larval Population Vs Minimum temperature	-0.589**
3.	Mean larval population Vs Relative humidity - I	0.581**
4.	Mean larval population Vs Relative humidity-II	0.475*
5.	Mean larval population Vs Rainfall	-0.421 ^{NS}

* Significant at 1% probability

** Significant at 5% probability

^{NS} Non significant

Table 7 : Relationship between *Diaphorina citri* K. population on Sathgudi sweet orange and weather factors

S.No.	Particulars	Correlation coefficient
1.	Psyllid population Vs Maximum temperature	-0.563*
2.	Psyllid population Vs Minimum temperature	-0.163 ^{NS}
3.	Psyllid population Vs Relative humidity - I	0.126 ^{NS}
4.	Psyllid population Vs Relative humidity- II	-0.599**
5.	Psyllid population Vs Rainfall	0.127 ^{NS}

* Significant at 1% probability

** Significant at 5% probability

NS - Non significant

Table 10 : Relationship between rust mite *Phyllocoptruta oleivora* Ash. population on Sathgudi sweet orange and weather factors

S.No.	Particulars	Correlation coefficient
1.	Rust mite population Vs Maximum temperature	0.145 ^{NS}
2.	Rust mite population Vs Minimum temperature	-0.597**
3.	Rust mite population Vs Relative humidity - I	-0.525*
4.	Rust mite population Vs Relative humidity-II	-0.719**
5.	Rust mite population Vs Rainfall	-0.556*

* Significant at 1% probability

** Significant at 5% probability

NS - Non significant

Table 9 : Relationship between green mite *Schizotetranychus hindustanicus* Hirst. population on Sathgudi sweet orange and weather factors

S.No.	Particulars	Correlation coefficient
1.	Green mite population Vs Maximum temperature	-0.448*
2.	Green mite population Vs Minimum temperature	-0.038 ^{NS}
3.	Green mite population Vs Relative humidity - I	0.233 ^{NS}
4.	Green mite population Vs Relative humidity-II	0.213 ^{NS}
5.	Green mite population Vs Rainfall	-0.259 ^{NS}

* Significant at 1% probability

** Significant at 5% probability

NS - Non significant

Table 8 : Relationship between weevil *Myllocerus* sp. population on Sathgudi sweet orange and weather factors

S.No.	Particulars	Correlation coefficient
1.	Weevil population Vs Maximum temperature	-0.639**
2.	Weevil population Vs Minimum temperature	-0.118 ^{NS}
3.	Weevil population Vs Relative humidity - I	0.586**
4.	Weevil population Vs Relative humidity-II	0.582**
5.	Weevil population Vs Rainfall	0.090 ^{NS}

* Significant at 1% probability

** Significant at 5% probability

NS - Non significant

Table 12 : Relationship between citrus leaf miner *P. citrella* incidence on Balaji acid lime and weather factors

S.No.	Particulars	Correlation coefficient
1.	Leaf miner population Vs Maximum temperature	-0.906**
2.	Leaf miner population Vs Minimum temperature	-0.502**
3.	Leaf miner population Vs Relative humidity - I	0.655**
4.	Leaf miner population Vs Relative humidity-II	0.552*
5.	Leaf miner population Vs Rainfall	-0.299 ^{NS}

* Significant at 1% probability

** Significant at 5% probability

NS - Non significant

Table 13 : Relationship between *P. demoleus* larval population on Balaji acid lime and weather factors

S.No.	Particulars	Correlation coefficient
1.	Mean larval population Vs Maximum temperature	-0.508*
2.	Mean larval population Vs Minimum temperature	-0.552*
3.	Mean larval population Vs Relative humidity - I	0.342 ^{NS}
4.	Mean larval population Vs Relative Humidity-II	0.054 ^{NS}
5.	Mean larval population Vs Rainfall	-0.521*

* Significant at 1% probability

** Significant at 5% probability

NS - Non significant

Table 14 : Relationship between psylla *D. citri* population on Balaji acid lime and weather factors

Sl.No.	Particulars	Correlation coefficient
1.	Psylla population Vs Maximum temperature	-0.207 ^{NS}
2.	Psylla population Vs Minimum temperature	-0.143 ^{NS}
3.	Psylla population Vs Relative humidity - I	0.101 ^{NS}
4.	Psylla population Vs Relative Humidity-II	0.198 ^{NS}
5.	Psylla population Vs Rainfall	0.234 ^{NS}

* Significant at 1% probability

** Significant at 5% probability

NS - Non significant

Table 17 : Relationship between rust mite *P. oleivora* population on Balaji acid lime and weather factors

Sl.No.	Particulars	Correlation coefficient
1.	Rust mite population Vs Maximum temperature	-0.227 ^{NS}
2.	Rust mite population Vs Minimum temperature	-0.757**
3.	Rust mite population Vs Relative humidity - I	0.130 ^{NS}
4.	Rust mite population Vs Relative humidity-II	-0.379 ^{NS}
5.	Rust mite population Vs Rainfall	-0.679**

* Significant at 1% probability

** Significant at 5% probability

NS - Non significant

Table 16 : Relationship between green mite *S. hindustanicus* population on Balaji acid lime and weather factors

S.No.	Particulars	Correlation coefficient
1.	Green mite population Vs Maximum temperature	-0.128 ^{NS}
2.	Green mite population Vs Minimum temperature	0.506*
3.	Green mite population Vs Relative humidity - I	0.307 ^{NS}
4.	Green mite population Vs Relative humidity-II	-0.441 ^{NS}
5.	Green mite population Vs Rainfall	-0.619**

* Significant at 1% probability

** Significant at 5% probability

NS - Non significant

Table 15 : Relationship between weevil *Myloccerus* sp. population on Balaji acid lime and weather factors

Sl.No.	Particulars	Correlation coefficient
1.	Weevil population Vs Maximum temperature	-0.466*
2.	Weevil population Vs Minimum temperature	0.031 ^{NS}
3.	Weevil population Vs Relative humidity - I	0.587**
4.	Weevil population Vs Relative humidity-II	0.522*
5.	Weevil population Vs Rainfall	0.092 ^{NS}

* Significant at 1% probability

** Significant at 5% probability

NS - Non significant

Table 4 : Seasonal occurrence of major pests of citrus on Sathgudi sweet orange during June 2003 to May 2004

S.No.	Period of observation	Per cent infestation of leaf miner	No. of butterfly caterpillar / 20 twigs	Psyllid / 10 twigs	No. of weevils / 10 twigs	No. of leaf folder larvae / 10 twigs	No. of green mites / leaf	No. of rust mite / 0.5 cm ² of fruit	Mean maximum temperature (°C)	Mean minimum temperature (°C)	Relative humidity (%)		Rainfall (mm)
											I	II	
1	June 2003												
	I Fortnight	0.00	0.00	13.7	1.7	4.8	0.00	0.00	39.36	26.48	64.26	38.86	5.69
	II Fortnight	0.00	17.4	18.4	2.8	6.4	0.00	0.00	36.40	26.22	65.86	39.80	3.43
2	July												
	I Fort night	0.00	27.6	0.00	7.1	0.00	0.00	0.00	32.73	23.23	78.86	56.73	12.35
	II Fortnight	1.85	39.6	0.00	9.3	0.00	0.00	0.00	33.20	23.85	76.30	49.56	6.88
3	August												
	I Fort night	2.17	32.3	0.00	11.4	0.00	23.7	0.00	31.17	24.69	75.00	56.13	3.04
	II Fortnight	3.27	17.4	0.00	13.1	0.00	14.3	0.00	30.42	24.18	74.25	57.56	3.77
4.	September												
	I Fort night	9.15	14.6	0.00	14.5	0.00	7.4	0.00	33.85	24.74	65.53	44.93	4.48
	II Fortnight	16.67	20.9	0.06	16.2	0.00	4.9	0.00	31.07	23.00	81.30	54.27	5.89
5.	October												
	I Fort night	20.40	33.2	0.00	20.6	0.00	2.7	0.00	33.01	23.76	79.07	53.33	5.82
	II Fortnight	27.63	39.5	6.2	18.7	0.00	6.3	0.00	30.68	21.97	81.37	61.69	6.88
6.	November												
	I Fort night	35.18	58.4	11.3	14.8	3.7	17.2	0.00	30.50	21.29	84.20	57.00	0.00
	II Fortnight	37.04	61.7	19.9	9.1	4.5	24.4	4.75	27.73	18.32	71.92	49.94	0.00
7.	December												
	I Fort night	37.73	63.4	16.2	7.4	2.2	6.8	11.50	28.98	16.27	71.47	43.33	0.00
	II Fortnight	39.61	67.5	12.4	4.9	1.9	8.5	17.75	29.05	18.12	80.12	58.87	0.66
8.	January 2004												
	I Fort night	40.84	58.7	12.9	2.3	0.00	1.8	16.75	29.92	16.45	73.93	41.06	0.27
	II Fortnight	35.44	42.7	8.2	6.4	0.00	3.9	26.50	30.76	17.88	72.87	44.12	0.00
9.	February												
	I Fort night	29.63	41.9	3.4	3.2	7.9	2.8	42.75	31.26	18.14	73.80	37.40	0.00
	II Fortnight	16.67	24.4	0.00	4.0	21.4	1.9	58.50	33.64	15.65	53.92	28.00	0.00
10.	March												
	I Fort night	12.73	9.1	0.00	2.1	14.7	5.8	60.25	35.82	18.90	58.26	22.33	0.00
	II Fortnight	5.45	4.2	0.00	4.2	0.00	4.2	38.75	35.61	29.30	64.00	21.25	0.95
11.	April												
	I Fort night	0.00	0.00	0.00	1.4	0.00	7.4	21.25	37.30	21.04	65.60	35.00	8.50
	II Fortnight	0.00	0.00	11.3	0.00	0.00	8.1	10.75	38.56	29.20	61.40	30.53	5.41
12.	May												
	I Fort night	0.00	0.00	17.4	0.00	0.00	2.6	7.50	34.06	25.64	71.26	52.93	8.36
	II Fortnight	0.00	0.00	8.2	0.00	0.00	0.00	0.00	35.32	25.71	65.37	44.75	5.8

Table 11 : Seasonal occurrence of major pests of citrus on Balaji acid lime during June 2003 to May 2004

S.No.	Period of observation	Per cent infestation of miner	No. of butterfly caterpillar / 20 twigs	Psyllids / 10 twigs	No. of weevils / 10 twigs	No. of leaf folder larvae / 10 twigs	No. of green mites / leaf	No. of rust mites / 0.5 cm ² of fruit	Mean maximum temperature (°C)	Mean minimum temperature (°C)	Relative humidity (%)		Rainfall (mm)
											I	II	
1	June 2003												
	I Fort night	0.00	18.7	6.4	0.00	0.00	0.00	0.00	39.36	26.48	64.26	38.86	5.69
	II Fortnight	0.00	28.4	8.1	1.1	0.00	0.00	0.00	36.40	26.22	65.86	39.80	3.43
2	July												
	I Fort night	13.45	37.9	3.3	4.1	2.4	0.00	0.00	32.73	23.23	78.86	56.73	12.35
	II Fortnight	26.67	48.4	0.0	6.1	6.3	0.00	0.00	33.20	23.85	76.30	49.56	6.88
3	August												
	I Fort night	26.51	13.6	0.00	8.1	4.1	18.4	0.00	31.17	24.69	75.00	56.13	3.04
	II Fortnight	26.83	17.4	0.00	7.1	0.00	6.3	0.00	30.42	24.18	74.25	57.56	3.77
4.	September												
	I Fort night	26.53	26.9	0.00	11.2	0.0	4.2	0.00	33.85	24.74	65.53	44.93	4.48
	II Fortnight	25.00	36.7	0.00	10.4	0.00	2.4	0.00	31.07	31.07	81.30	54.27	5.89
5.	October												
	I Fort night	25.14	38.4	0.00	14.5	0.00	8.3	0.00	33.01	23.76	79.07	53.33	5.82
	II Fortnight	26.10	44.7	0.00	18.4	0.00	9.1	0.00	30.68	21.97	81.37	61.69	6.88
6.	November												
	I Fort night	31.25	52.1	11.4	12.1	0.00	21.4	2.25	30.50	21.29	84.20	57.00	0.00
	II Fortnight	31.65	64.3	13.3	4.3	4.4	18.5	6.50	27.73	18.32	71.92	49.94	0.00
7.	December												
	I Fort night	32.92	58.7	16.7	2.1	6.7	11.3	18.50	28.98	16.27	71.47	43.33	2.23
	II Fortnight	36.33	55.9	13.4	2.9	7.1	4.2	25.25	29.05	18.12	80.12	58.87	0.66
8.	January 2004												
	I Fort night	23.40	59.3	13.5	4.6	3.8	4.2	33.50	29.92	16.45	73.93	41.06	0.27
	II Fortnight	25.92	62.3	6.4	5.8	4.3	8.0	59.75	30.76	17.88	72.87	44.12	0.00
9.	February												
	I Fort night	18.90	40.1	2.4	4.1	7.4	10.9	51.25	31.26	18.14	73.80	37.40	0.00
	II Fortnight	15.55	31.4	0.00	2.4	9.3	32.1	42.75	33.64	15.65	53.92	28.00	0.00
10.	March												
	I Fort night	10.10	18.5	0.00	2.6	6.4	43.4	30.5	35.82	18.90	58.26	22.33	0.00
	II Fortnight	8.11	9.4	0.00	4.7	2.5	21.2	15.50	35.61	29.30	64.00	21.25	0.95
11.	April												
	I Fort night	2.22	0.00	0.00	1.1	0.00	0.00	3.75	37.30	21.04	65.60	35.00	8.50
	II Fortnight	0.00	0.00	11.1	1.9	0.00	0.00	0.75	38.56	29.20	61.40	30.53	5.41
12.	May												
	I Fort night	0.00	0.00	14.14	0.00	0.00	0.00	0.00	34.06	25.64	71.26	52.93	8.36
	II Fortnight	0.00	0.00	9.12	0.00	0.00	0.00	0.00	35.32	25.71	65.37	44.75	5.80

**Table 22 : Some of the minor insect pests associated with citrus
(sweet orange and acid lime)**

S. No.	Common name	Scientific name	Family / order	Plant parts damaged
1.	Leaf webber	<i>Archips micaceana</i> Walker	Tortricidae / Lepidoptera	Tender to semi mature flush
2.	Hairy caterpillar	<i>Dasychira mendosa</i> Hubner	Lymantriidae / Lepidoptera	Tender to semi mature flush
3.	Tobacco caterpillar	<i>Spodoptera litura</i> Fabricius	Noctudae / Lepidoptera	Tender to semi mature flush
4.	Slug caterpillar	<i>Parasa lepida</i> Cramer	Limacodidae / Lepidoptera	Tender to mature flush
5.	Flower beetle	<i>Mylabris pustulata</i> Thunb.	Meloidae / Coleoptera	Flowers
6.	Mealy bugs	<i>Planococcus citri</i> Risso	Pseudococcidae / Homoptera	Small tender twigs / mature twigs
77.	Snow scales	<i>Pinnaspis aspidistrae</i> Signoret	Diaspididae / Homoptera	Trunks and Branches
8.	Bark eating caterpillar	<i>Indarbela quadrinotata</i> Walker	Metarbelidae / Lepidoptera	On small twigs and branches
9.	Aphids	<i>Toxoptera auranti</i> Bay.	Aphididae / Homoptera	Tender leaves/ Tenders twigs
10.	Grass hopper	<i>Orthacris simulans</i> Bol.	Acrididae / Orthoptera	Semi mature to mature leaves
11.	Fruit sucking moth	<i>Othreis materna</i> Lin. <i>O. fullonica</i> Cl. <i>O. ancilla</i> Cl.	Noctudae / Lepidoptera Noctudae/ Lepidoptera Noctudae/ Lepidoptera	Ripened fruits

Table 23 : Effect of Natural Insecticides on Leafminer Incidence on Sathgudi Sweet Orange(prophylactic control)

S. No.	Name of the Insecticide	Concentration / dose (%)	Per cent leaf miner incidence(days after spraying)*					
			1	3	5	7	10	14
1.	Neem seed kernal extract (NSKE)	5	00.00 (0.00)	00.00 (0.00)	00.00 (0.00)	12.24 (20.44)	20.67 (27.06)	25.31 (30.20)
2.	Azadirachtin	0.0001	00.00 (0.00)	00.00 (0.00)	00.00 (0.00)	19.11 (25.91)	22.83 (28.52)	30.42 (33.46)
3.	Neem soap	10 g/ lit	00.00 (0.00)	00.00 (0.00)	5.33 (13.31)	20.72 (25.91)	23.34 (28.86)	34.84 (36.15)
4.	Pongamia oil	0.5	00.00 (0.00)	00.00 (0.00)	9.09 (17.56)	25.74 (30.46)	27.65 (31.69)	37.21 (37.58)
5.	Pongamia soap	10 g/lit	00.00 (0.00)	00.00 (0.00)	13.65 (21.64)	29.71 (33.02)	31.13 (33.90)	38.50 (38.75)
6.	Garlic extract	20 g/lit	00.00 (0.00)	00.00 (0.00)	17.97 (25.03)	31.52 (34.14)	37.06 (37.52)	40.81 (39.70)
7.	<i>Bacillus thuringiensis</i>	0.0025 (2.09 x 10 ⁷)	00.00 (0.00)	00.00 (0.00)	7.17 (15.56)	21.05 (27.27)	25.41 (30.26)	32.38 (34.08)
8.	<i>Bacillus thuringiensis</i>	0.005 (4.23 x 10 ⁷)	00.00 (0.00)	00.00 (0.00)	00.00 (0.00)	16.26 (23.81)	22.06 (28.04)	26.74 (31.11)
9.	Untreated check	-	00.00 (0.00)	39.10 (38.70)	40.19 (39.35)	47.16 (43.39)	54.19 (47.41)	61.33 (51.33)
	CD at 5%	-	-	-	1.19	0.99	0.94	1.35

*Average of 3 replications

Figures in the parenthesis are angular transformations

Table 24 : Effect of Synthetic Insecticides on Leafminer Incidence on Sathgudi Sweet Orange(prophylactic control)

S. No.	Name of the Insecticide	Concentration / dose (%)	Per cent leafminer incidence(days after spraying)*					
			1	3	5	7	10	14
1.	Thiodicarb	0.075	00.00 (0.00)	00.00 (0.00)	00.00 (0.00)	9.81 (18.24)	26.13 (30.72)	30.96 (33.77)
2.	Profenophos	0.1	00.00 (0.00)	00.00 (0.00)	00.00 (0.00)	00.00 (0.00)	16.80 (24.20)	25.82 (30.53)
3.	Lambda cyhalothrin	0.0025	00.00 (0.00)	00.00 (0.00)	00.00 (0.00)	00.00 (0.00)	6.49 (14.77)	23.25 (28.79)
4.	Cartap hydrochloride	0.1	00.00 (0.00)	00.00 (0.00)	7.32 (15.77)	20.69 (27.06)	29.89 (33.15)	34.95 (26.21)
5.	Fenvalerate	0.02	00.00 (0.00)	00.00 (0.00)	00.00 (0.00)	00.00 (0.00)	4.78 (12.11)	20.83 (27.13)
6.	Methomyl	0.08	00.00 (0.00)	00.00 (0.00)	00.00 (0.00)	13.10 (21.22)	27.42 (31.56)	33.19 (35.18)
7.	Acephate	0.075	00.00 (0.00)	00.00 (0.00)	00.00 (0.00)	4.86 (12.66)	22.04 (28.25)	26.13 (30.72)
8.	Chlorpyrifos	0.05	00.00 (0.00)	00.00 (0.00)	00.00 (0.00)	12.23 (20.44)	26.28 (30.85)	31.07 (34.27)
9.	Untreated check	-	-	37.05 (36.93)	40.81 (39.70)	43.22 (41.09)	49.79 (44.89)	54.61 (47.64)
	CD at 5%	-	-	-	6.82	2.56	1.91	1.86

*Average of 3 replications

Figures in the parenthesis are angular transformations

Table 25 : Effect of Natural Insecticides on Leafminer on Sathgudi Sweet Orange(Curative Control)

S. No.	Name of the Insecticide	Concentration / dose (%)	Pre count population	Per cent larval mortality (Days after spraying)*					
				1	3	5	7	10	14
1.	Neem seed kernal extract (NSKE)	5	25.00	58.67 (50.01)	73.35 (58.95)	78.39 (62.31)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
2.	Azadirachtin	0.0001	24.66	51.34 (45.74)	70.25 (56.91)	79.97 (63.36)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
3.	Neem soap	10 g/ lit	23.00	37.63 (37.82)	46.40 (42.94)	57.77 (48.97)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
4.	Pongamia oil	0.5	26.33	36.74 (37.29)	41.75 (40.22)	50.61 (45.41)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
5.	Pongamia soap	10 g/lit	22.00	31.77 (34.27)	40.96 (39.76)	47.06 (43.34)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
6.	Garlic extract	20 g/lit	23.00	29.11 (32.65)	39.19 (38.70)	41.87 (40.28)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
7.	<i>Bacillus thuringiensis</i>	0.0025 (2.09 x 10 ⁷)	25.33	60.28 (50.94)	75.02 (60.00)	82.93 (65.59)	100 (0.00)	100 (0.00)	<input type="checkbox"/>
8.	<i>Bacillus thuringiensis</i>	0.005 (4.23 x 10 ⁷)	24.33	69.87 (56.37)	87.63 (69.38)	100 (0.00)	100.0 (0.00)	100.0 (0.00)	<input type="checkbox"/>
9.	Untreated check		27.00	-	-	-	-	-	-
	CD at 5%		-	1.64	1.10	4.88	-	-	-

* Average of 3 replications

Reinfestation started

Figures in the parenthesis are angular transformations

Table 26 : Effect of Synthetic Insecticides on Leafminer on Sathgudi Sweet Orange (Curative Control)

S. No.	Name of the Insecticide	Concentration / dose (%)	Pre count population	Per cent larval mortality(Days after spraying)*					
				1	3	5	7	10	14
1.	Thiodicarb	0.075	20.66	90.28 (71.85)	100 (0.00)	100 (0.00)	100 (0.00)	<input type="checkbox"/>	<input type="checkbox"/>
2.	Profenophos	0.1	21.33	85.90 (67.94)	95.15 (77.21)	100 (0.00)	100 (0.00)	<input type="checkbox"/>	<input type="checkbox"/>
3.	Lambda cyhalothrin	0.0025	22.33	92.52 (74.11)	100 (0.00)	100 (0.00)	100 (0.00)	100 (0.00)	<input type="checkbox"/>
4.	Cartap hydrochloride	0.1	22.66	78.07 (62.10)	85.35 (67.46)	88.20 (69.91)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
5.	Fenvalerate	0.02	23.66	94.38 (76.31)	100 (0.00)	100 (0.00)	100 (0.00)	100 (0.00)	<input type="checkbox"/>
6.	Methomyl	0.08	23.66	81.68 (64.67)	93.06 (74.66)	100 (0.00)	100 (0.00)	<input type="checkbox"/>	<input type="checkbox"/>
7.	Acephate	0.075	21.00	84.17 (66.58)	95.20 (77.34)	100 (0.00)	100 (0.00)	<input type="checkbox"/>	<input type="checkbox"/>
8.	Chlorpyriphos	0.05	22.66	80.86 (64.09)	88.31 (70.00)	89.76 (71.37)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
9.	Untreated check	-	23.00	-	-	-	-	-	-
	CD at 5%			1.25	4.67	3.71	-	-	-

* Average of 3 replications

Reinfestation started

Figures in the parenthesis are angular transformations

Table 27 : Effect of Natural Insecticides on Larval Population of Citrus Butterfly on Sathgudi Sweet Orange (Curative Control)

S. No.	Name of the Insecticide	Concentration / dose (%)	Pre count population	Per cent larval mortality(Days after spraying)*					
				1	3	5	7	10	14
1.	Neem seed kernal extract (NSKE)	5	24.66	25.66 (30.40)	55.41 (48.10)	81.08 (63.51)	95.92 (78.32)	<input type="checkbox"/>	<input type="checkbox"/>
2.	Azadirachtin	0.0001	22.33	22.29 (28.18)	46.25 (42.82)	76.03 (60.67)	90.92 (72.44)	<input type="checkbox"/>	<input type="checkbox"/>
3.	Neem soap	10 g/lit	24.33	16.47 (23.97)	42.47 (40.69)	69.87 (56.37)	83.51 (66.03)	<input type="checkbox"/>	<input type="checkbox"/>
4.	Pongamia oil	0.5	23.00	10.35 (18.72)	26.83 (31.18)	56.61 (48.79)	61.14 (54.39)	<input type="checkbox"/>	<input type="checkbox"/>
5.	Pongamia soap	10 g/ lit	22.66	13.27 (21.39)	33.81 (35.55)	66.17 (54.45)	70.60 (57.17)	<input type="checkbox"/>	<input type="checkbox"/>
6.	Garlic extract	20 g/lit	23.00	8.88 (17.36)	23.61 (29.06)	41.10 (39.87)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
7.	<i>Bacillus thuringiensis</i>	0.0025 (2.09 x 10 ⁷)	21.33	46.80 (43.17)	85.88 (67.86)	100 (0.00)	100 (0.00)	100 (0.00)	<input type="checkbox"/>
8.	<i>Bacillus thuringiensis</i>	0.005 (4.23 x 10 ⁷)	23.00	61.46 (51.65)	90.71 (72.24)	100 (0.00)	100 (0.00)	100 (0.00)	<input type="checkbox"/>
9.	Untreated check		21.66	-	-	-	-	-	-
	CD at 5%		10.08	5.86	4.62	7.81	1.12	-	-

* Average of 3 replications

Reinfestation started

Figures in the parenthesis are angular transformations

Table 28 : Effect of Synthetic Insecticides on Citrus Butterfly Larval Population on Sathgudi Sweet Orange(Curative Control)

S. No.	Name of the Insecticide	Concentration / dose (%)	Per count population	Per cent larval mortality(Days after spraying)*					
				1	3	5	7	10	14
1.	Thiodicarb	0.075	21.66	95.29 (77.48)	100 (0.00)	100 (0.00)	100 (0.00)	<input type="checkbox"/>	<input type="checkbox"/>
2.	Profenophos	0.1	23.00	94.59 (76.56)	100 (0.00)	100 (0.00)	100 (0.00)	<input type="checkbox"/>	<input type="checkbox"/>
3.	Lambda cyhalothrin	0.0025	21.33	96.94 (79.86)	100 (0.00)	100 (0.00)	100 (0.00)	100 (0.00)	<input type="checkbox"/>
4.	Cartap hydrochloride	0.1	23.00	86.83 (68.70)	88.88 (70.54)	100 (0.00)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
5.	Fenvalerate	0.02	22.66	98.41 (70.63)	100 (0.00)	100 (0.00)	100 (0.00)	100 (0.00)	<input type="checkbox"/>
6.	Methomyl	0.08	23.00	89.02 (70.63)	100 (0.00)	100 (0.00)	100 (0.00)	<input type="checkbox"/>	<input type="checkbox"/>
7.	Acephate	0.075	24.33	93.83 (75.58)	100 (0.00)	100 (0.00)	100 (0.00)	<input type="checkbox"/>	<input type="checkbox"/>
8.	Chlorpyriphos	0.06	22.33	87.93 (69.64)	89.48 (71.09)	100 (0.00)	100 (0.00)	<input type="checkbox"/>	<input type="checkbox"/>
9.	Untreated check		24.66	-	-	-	-	-	-
	CD at 5%	-	-	0.98	4.67	-	-	-	-

* Average of 3 replications

Reinfestation started

Figures in the parenthesis are angular transformations

CHAPTER - V

DISCUSSION

5.1 SEASONAL ABUNDANCE OF MAJOR PESTS OF CITRUS ON SATHGUDI SWEET ORANGE AND BALAJI ACID LIME

To plan appropriate intervention techniques including application of chemicals, for managing pests, there is a need of understanding the seasonal activity of the pests. Hence, the studies in that direction made in South zone on citrus viz., acid lime and sweet orange are discussed in the light of results documented by other workers of this line.

5.1.1 Citrus leaf miner

The activity of the pest started from second fortnight of July and it showed peak infestation (40.84%) during first fortnight of January and thereafter slowly leaf miner, *P. citrella* infestation decreased during September. Second peak incidence was noticed during December second fortnight (39.67%) and its peak activity extended upto January. From first fortnight of March onwards leafminer incidence began to dwindle and it was negligible during first fortnight of April to first fortnight of July. Maximum and minimum temperatures and rainfall showed significantly

negative correlation with leaf miner population. However, relative humidity (I & II) showed positive correlation.

On Balaji acid lime, infestation first initiated from first fortnight of July and it was gradually increased reaching peak infestation (36.33%) during December month when plants put forth the new foliage. After that miner activity slowly decreased. No infestation of leaf miner was observed from second fortnight of April to second fortnight of June. Maximum and minimum temperatures and rainfall showed negative correlation with leaf miner incidence. However, relative humidity showed positive correlation. Significant negative correlation of temperature with leaf miner incidence might be the reason for absence of pest during summer months on both the hosts. This indicates that high temperature during summer period was not conducive for pest buildup. These results were supported by Anonymous (1987) and Saravanan (2000). Contrary to these findings, Bhumanavar and Singh (1983) stated that the availability of tender flushes appeared to be most important factors affecting pest incidence, rather than climatic factors of the region. Sidharan *et al.* (1989) recorded the peak population of the pest in late April and May. Singh (1984) and Singh and Azam (1986)

recorded severe infestation of leaf miner during February and March months.

5.1.2 Citrus butterfly

The incidence of citrus butterfly, *P. demoleus* was prominent on two hosts viz., sweet orange and acid lime. On sweet orange the incidence started from second fortnight of June 2003. From the first fortnight of October the population on sweet orange increased gradually and attained peak level during November, December and first fortnight of January, recording highest number of 58.4, 61.7, 63.4, 67.5 and 58.7 larvae per 20 twigs. Pest activity declined from second fortnight of February. The population was negligible during April and May and first fortnight of June.

On acid lime, larval population increased gradually from first fortnight of September, with peak activity during second fortnight of November to January recording 64.3, 58.4, 55.9, 59.3 and 62.3 larvae per 20 twigs. Population was found declining subsequently in February and March months.

There was negative correlation between the population of *P. demoleus* and maximum and minimum temperatures and rainfall and positive correlation with relative humidity.

Peak activity was found during September by Ray and Deering (1959), during August-November according to Bindra (1969), during October - December and first fortnight of January according to Lakshmi Narayanamma (2001). All these results supported the present findings. Pest infestation was negligible during April to first fortnight of July according to Lakshmi Narayanamma (2001) and during April and May according to research reports of AICRPTF (Citrus) (2003). These findings are more or less similar to present findings. However, according to Hayes (1957) and Resham *et al.* (1986) the population was negligible in winter months. According to Maheswara babu (1988), pest population declined during October and there was no population from second fortnight of November to the end of December. The difference in the occurrence of pest activity was due to the major variations in the weather factors from one region to another region where wide variations exist in the climatic conditions especially with reference to the temperature and humidity factors.

It was also seen that inspite of new foliages during April and May months, no butterfly infestation was noticed on both the hosts because of maximum temperatures prevailed during these months i.e 34.01°C and 38.56°C respectively. This indicated that presence of tender foliage may be of secondary importance whereas weather factors play major role in the incidence of citrus butterfly.

5.1.3 Citrus psylla

On both the hosts *viz.*, sweet orange and acid lime, the psyllid *D. citri* infestation was negligible during July to October months. Pest incidence started from second fortnight of October on sweet orange and first fortnight of November on acid lime. The population of psyllid on sweet orange attained peak level (19.9 psyllids / 10 twigs) during second fortnight of November. There after the population declined. During the studies the psyllid population on sweet range showed significant and non significant negative correlation with maximum, minimum temperatures and relative humidity II and non-significant positive correlation with relative humidity-I and rainfall. On acid lime the peak population recorded during first fortnight of December and there after the population declined. Maximum and minimum temperatures showed negative correlation whereas relative

humidity and rainfall showed positive correlation. All the weather factors showed non significant influence on psylla population. Though there was high relative humidity during September and October months the population of psylla was negligible due to lack of tender twigs on the host plant.

The peak activity of the insect was found during November to January according to Nair (1975) December to March according to Tandon (1991). Results of these studies are more or less similar to the present findings with slight variations. The peak activity of the pest was found March to April by Hussain and Nath (1927), during March according to Koli *et al.* (1981) and during April according to Chakravarthy (1997). The variations in the activity periods might be due to changes in climatic conditions and available of tender twigs. During February and March months the population of psyllids was negligible on acid lime. New foliage was also absent on acid lime at that time i.e. during February. This indicated that the presence of new foliage was another factor that influence the pest build up besides conducive weather factors. This might be the main reason for non significant correlation of weather parameters with psyllid

population on acid lime in contrast to the significant correlation of psyllid population with the weather parameters, on sweet orange.

5.1.4 Weevils :

The weevil, *Myloccerus sp.* population was recorded through out the year. The highest population was recorded during October (20.6 and 18.7 weevils / 10 twigs) on sweet orange, (14.5 and 18.4 weevils / 10 twigs) on acid lime, it was decreased from December onwards and became the least during summer months on sweet orange. The weevil population showed significant negative correlation with maximum temperature and non significant negative relation with minimum temperature. It was positively correlated with all other weather parameter, i.e. relative humidity (I) and (II) and rainfall. But on acid lime the weevil population showed negative significant correlation with maximum temperature and positive correlation with all other weather parameters. The population showed negative significant correlation on both hosts with maximum temperature (34.06 to 38.55°C). This might be the reason for low incidence during summer months. Earlier Ramachander Rao *et al.* (1976) and Rama subba Reddy (1984) also reported similar observations recording the incidence of

weevils, which caused heavy damage during October and November months.

5.1.5 Leaf folder :

The incidence of leaf folder, *P. zizyphi* was observed during June, November, December and February to first fortnight of March, on sweet orange with peak incidence (21.4 larvae / 10 twigs) in second fortnight of February and first fortnight of March. But on acid lime its maximum population was recorded during February (7.4 and 9.3 larvae / 10 twigs).

These findings were more (or) less similar with observation of Rama Subbareddy (1989). But these are deviated with the findings of Sharma and Batra (1989a) due to changes in weather factors from region to region.

5.1.6 Citrus blackfly

The incidence of citrus blackfly, *A. woglumi* was almost negligible in this area during June 2003 to May 2004. This deviation may be due to abnormal changes in the climatic factors i.e. almost prolonged dry spells coincided with intermittent rains that arrested the build up of the pest. In addition the change in the farmer's practice in terms of fertilizer

management and insecticide usage might be the reason behind the decline of this pest. However its build up in serious proportions were recorded in some pockets of the region as per research reports of AICRTF (Citrus), (2001, 2002).

5.1.7 Greenmite :

Incidence of green mite, *S. hindustanicus* was recorded throughout the year on Sathgudi sweet orange except during second fortnight of May to July. The peak population (24.4 mites / leaf) of green mite was noticed during November second fortnight. On acid lime, the incidence of green mite was recorded throughout the year except during April to July months. The peak population (43.4 mites / leaf) of green mite was noticed during first fortnight of March. On sweet orange the green mite population showed negative correlation with temperature (maximum and minimum) and rainfall, but with relative humidity (I and II) it showed positive correlation. On acid lime the green mite population showed negative correlation with all weather parameters except with minimum temperature and relative humidity I. Significant and negative correlation of rainfall might be the reason for absence of mite population during summer months, even it was negatively correlated with maximum temperature

which was non significant. All these results are more (or) less similar with findings of Rama Subba Reddy (1984).

5.1.8 Rust mite:

On sweet orange, they appeared first during second fortnight of November on fruits, when the fruits were in marble size, and reached its peak (60.25 mites / 0.5cm²) during first fortnight of March.

On acid lime, first appearance of rust mite coincided with marble size of the fruit development during November first fortnight and reached its peak (59.75 mites / 0.5 cm²), during January second fortnight, when the fruits develop sufficiently i.e. around 4.0 cm in diameter.

After the peak activity there was decrease in population culminating in negligible number during April and disappear totally between second fortnight of May to first fortnight of November on sweet orange, and May to October on acid lime.

According to Yang *et. al* (1994) the population growth of *P. oleivora* was single peaked, more (or) less symmetrically shaped. This is in support of present findings that the peak activity was observed only once on both

the hosts. Only maximum temperature was showing non significant positive correlation with rust mite population on sweet orange remaining all weather factors were negatively correlated. On acid lime only relative humidity-I was showing non significant and positive correlation.

In general the maximum mite activity was observed during first fortnight of March and January to March on both the hosts viz., sweet orange and acid lime. This is in conformity with the observations made by Rama Subba Reddy (1984) and Kalaisekhar (1999) and AICRPTF research reports (2002).

5.1.9 Survey and surveillance of citrus pests in Chittoor and Nellore districts

The results of roving survey during June 2003 to May 2004 in Nellore and Chittoor districts, revealed that snow scale problem was more in Nellore district whereas leaf miner problem is predominant in Chittoor district. Psylla was recorded as minor pest in both districts. Aphid was recorded as minor pest in Nellore district where as fruit sucking moth was identified as minor pest in Chittoor. The variation in climatic factors and agronomic practices of farmers might be the reason for variation in

abundance of major pests in both districts. These findings were in agreement with results of AICRTF (2003) research reports.

5.2 IDENTIFICATION OF NEW PESTS ON CITRUS UNDER SOUTH ZONE

During period of seasonal incidence and roving survey studies, a psychid *Clania crameri* and a chaffer beetle, *Autoserica insanabilis*, were identified as foliage feeders of citrus. These findings are in agreement with Thangavelu (1985) and Kakotyl *et al.* (1993) who reported the *Clania crameri* as pest of tea and other ornamental plants. Nair (1975) identified the *Autoserica insanabilis* as pest of sugar cane. These findings supported the present results.

5.3 NATURAL ENEMIES

During the period of study *Tetrastichus* sp has been observed as larval parasitoid of leafminer, *P. citrella*. This finding was in agreement with Narayan *et al.* (1957) and Anonymous (1983).

Two braconid parasitoids *viz.*, *Apanteles papilionis* Viereck, and *Bracon hebetor* were observed as larval parasitoids of citrus butterfly, *P. demoleus*. These observations were in agreement with the findings of

Narayan and Gopalakrishnan (1984), Krishnamoorthy (1987), Krishnamoorthy and Singh (1988), Balagangadara Tilak (1992) and Lakshmi Narayanamma (2001). A reduviid bug, *Rhynocoris marginatus* Fab. was identified as predator on citrus butterfly larvae. This was supported by the findings of Sahayaraj *et al.* (2002).

Four species of coccinellids *viz.*, *coccinella septumpunctata*, *Chilomenus sexmaculata*, *Brumus suturalis* and *Chilocorus nigritus* were observed as predators of *D. citri*. One lace wing predator *Chrysopa* sp and an unidentified preying mantid were found to predate upon nymphs of citrus psylla, *D. citri*. One nymphal parasitoid of eulophid origin (*Tetrastichus* sp.) was recovered from the population of psyllids. These observations are in agreement with the findings of Bindra (1970), Nair (1975), Batra *et al.* (1990) and Tandon (1991) and AICRPTF Research Report (1993).

A pentatomid bug *Amyotea malabarica* Fab was identified as a predator of adult ash weevil, *Myloccerus* sp. This was in agreement with findings of Pati and Mathur (1986).

5.4 EVALUATION OF EFFICACY OF NATURAL AND SYNTHETIC INSECTICIDES

5.4.1 Efficacy of Natural Insecticides Against Citrus Leafminer

Two field experiments were conducted to evaluate their efficacy as prophylactic and curative control measures against citrus leafminer, *P. citrella*. In the field experiment conducted as prophylactic method of chemical control, data were recorded on leafminer damage at 1, 3, 5, 7, 10 and 14 days after spraying. All the insecticidal treatments were significantly superior to untreated check. The treatments *viz.*, NSKE, azadirachtin and Bt (0.005%) offered complete protection upto five days after spray keeping the citrus plants free from leafminer infestation. Rest of all the treatments lost their efficacy on fifth day itself and showed incidence of pest.

On seventh day all the treatments showed infestation of citrus leafminer indicating that there was decrease in their toxicity. Among all the treatments NSKE offered effective protection from the pest, followed by Bt (0.005%) and azadirachtin. Bt might have worked on neonate larval stage of leaf miner to keep the citrus plants free from pest. This might be the reason to consider Bt as effective prophylactic treatment against leaf miner. Pongamia soap and garlic extract were found less effective compared to

other insecticidal treatments as they showed a maximum leafminer incidence indicating less persistence nature of the compounds. On tenth and fourteenth day results depicted the reduced efficacy of all the treatments. Hence during new flush periods to protect the citrus plants from leaf miner attack second spraying should be given at seven days interval.

In curative type of chemical control leaf miner larval population was recorded at one day before spraying and post treatment counts were recorded at 1, 3, 5, 7, 10 and 14 days after spraying. On first day after spraying maximum larval mortality was recorded in Bt at both the concentrations (0.005 and 0.0025 per cent), NSKE and azadirachtin, which were followed by neem soap and pongamia oil. On third and fifth day also all the treatments showed enhanced efficacy while Bt (0.005%) gave 100 per cent mortality. On seventh day reinfestation was recorded in all the treatments except Bt 0.005 and 0.0025 per cent treatments. They continued their residual action upto ten days, hence, no reinfestation was recorded. Rest of all other treatments showed reinfestation from seventh day itself, which indicated their decreased residual action. Hence, it is suggested that second spraying should be given at ten days interval during new flush period to check the leafminer damage effectively. On fourteenth day all the

treatments showed reinfestation of citrus leafminer revealed their dissipation of toxicity.

NSKE and azadirachtin sprayed during new flush period offered effective control of leafminer. Similar observations were made by Pandao *et al.* (1992), Raveendran *et al.* (1998) and Ukey *et al.* (1999). Chakravarthi (1997) reported the effectiveness of NSKE and azadirachtin against citrus psylla, *D. citri* Shivasankar (1999) and Lakshmi Narayanamma (2001) reported that Bt at both concentrations (0.005 and 0.0025%) gave cent per cent mortality against citrus butterfly, *P. demoleus*.

5.4.2 Efficacy of Synthetic Insecticides Against Citrus Leafminer,

P. citrella

Field experiments were conducted as prophylactic and curative measures with synthetic insecticides to know their efficacy against leaf miner, *P. citrella*.

In prophylactic method of control, data were recorded on leafminer damage at 1, 3, 5, 7, 10 and 14 days after spraying. All the insecticidal treatments were significantly superior to untreated check. Upto fifth day all the treatments except cartap hydrochloride, protected the citrus plants from leafminer infestation. Insecticides *viz.*, profenophos, lambda cyhalothrin and fenvalerate continued their persistence to check the pest even upto seven days after spraying. However in all other treatments toxicity decreased gradually. Cartap hydrochloride was found less effective compared to other insecticidal treatments as it showed leaf miner incidence even at five days after spraying indicating less persistent nature of the compound.

In curative type of chemical control larval population of leafminer, *P. citrella* was recorded at one day before spraying and post treatment counts were recorded at 1, 3, 5, 7, 10 and 14 days after spraying. Maximum per cent larval mortality was obtained in treatments fenvalerate, lambda cyhalothrin and thiodicarb followed by profenophos and acephate.

On third day thiodicarb, lambda cyhalothrin and fenvalerate showed cent per cent larval mortality. On fifth day thiodicarb, profenophos, lambda

cyhalothrin, fenvalerate, methomyl, acephate and chlorpyrifos offered maximum larval mortality (100%). On seventh day cartap hydrochloride and chlorpyrifos lost their efficacy and reinfestation was observed. Lambda cyhalothrin and fenvalerate retained their residual action upto ten days, and no reinfestation was recorded. On fourteenth day all the treatments showed reinfestation of citrus leafminer indicating that there was decrease in residual action.

Synthetic pyrethroids viz., lambda cyhalothrin and fenvalerate effectively controlled the citrus leafminer upto ten days. Similar findings were made by Bhumannavar (1987), Bhatia and Joshi (1991), Sarvanan (2000) and AICRPTF research reports (2002, 2003) Thiodicarb and profenophos also effectively controlled the citrus leafminer upto seven days. These results are more (or) less similar to finding of Sarvanan (2002) and AICRPTF research reports (2002, 2003).

5.4.3 Evaluation of Efficacy of Natural Insecticides Against Citrus Butterfly

In field experiment the data recorded larval population of butterfly, *P. demoleus* at different days after insecticidal application revealed that all the insecticidal treatments were significantly superior to untreated check in

causing larval mortality. In all the insecticidal treatments, the percentage of larval reduction increased gradually upto seven days, except in garlic extract, which lost its efficacy after five days of spraying. The bacterial insecticide *Bacillus thuringiensis* (Bt) tested in two different concentrations recorded highest per cent larval mortality (100%) at five days after spraying and these treatments showed their persistent efficacy upto ten days after application by maintaining the same trend of population reduction. But in case of botanical insecticides viz., NSKE, azadirachtin, neem soap, pongamia oil and pongamia soap, the efficacy increased slightly from fifth to seventh day after application, later their persistence action decreased at ten days after spraying. Although low mortality was reported initially, the botanicals like NSKE and azadirachtin had strong antifeedant and repellent effects and were effective as moulting inhibitors.

The superiority of *Bacillus thuringiensis* in the control of citrus butterfly, *P. demoleus* in the present study was in agreement with the findings of Resham *et al.* (1986) and Johnson *et al.* (1995), who recorded its toxicity to early and later instar larvae citrus butterfly *Papilio glaucus* and *P. canadensis*. Shivasankar (1999) reported that Bt at 0.005 per cent concentration was effective against lemon butterfly, *P. demoleus*.

Venkadasubramanyam and David (1999) also gave similar findings of present study that Bt and botanicals gave effective results against *Spodoptera litura* and *Helicoverpa armigera*. Lakshminarayananamma (2001) and research reports of AICRPTF (Citrus) (2002, 2003) also supported the results of present studies in which Bt at both concentrations (0.005 and 0.0025%) was most effective in controlling the citrus butterfly. Next effective treatments were botanicals *viz.*, NSKE and azadirachtin. The effectiveness of neem products in controlling citrus butterfly was reported by Solunke and Deshpande (1991), Balagangadhar Tilak (1992), Ranjeet Singh *et al.* (1996) and Chauke *et al.* (1999).

5.4.4 Efficacy of Synthetic Insecticides Against Citrus Butterfly,

P. demoleus

A field experiment was conducted with synthetic insecticides, to evaluate their efficacy against the larvae of citrus butterfly, *P. demoleus*. In this curative type of experiment, larval population of citrus butterfly was recorded before 24 hrs of spraying and post treatment counts were recorded at 1,3,5, 7, 10 and 14 days after spraying. The data recorded on butterfly larval population at different days after insecticidal application revealed that all the insecticidal treatments were significantly superior to untreated

check in reducing the larval population of citrus butterfly. All the insecticidal treatments except cartap hydrochloride and chlorpyrifos resulted in cent per cent larval mortality on third day after spraying. Cent per cent was recorded in all the treatments *viz.*, thiodicarde, fenvalerate, methomyl, acephate and chlorpyrifos. All the treatments showed their persistent efficacy upto seven days while cartap hydrochloride, lost its efficacy on seventh day by recording reinfestation of pest. Synthetic pyrethroids (lambda cyhalothrin and fenvalerate) retained their residual action even upto ten days after spraying. Hence, the results indicated the necessity of giving a second spray after week days so as to check the new growth of pest. On fourteenth day all the treatments showed reoccurrence of population, indicating the decrease in residual action of insecticides subjected.

Synthetic pyrethroids were the most effective insecticides, that controlled the citrus butterfly upto ten days after application. These findings are in agreement with Deepak Tripathi (2001) who reported that 0.015 per cent, fenvalerate gave cent per cent mortality and retained their toxicity upto ten days. Next to synthetic pyrethroids, thiodicarb, profenophos recorded cent per cent mortality and retained their toxicity upto seven days. These

findings similar to the results of AICRPTF research reports (2003). Chakravarthi (1997) and Saravanan (2000) who have concluded the effectiveness of thiodicarb and profenophos both on citrus psylla, *D. citri* and leafminer, *P. citrella* respectively.

CHAPTER-IV

SUMMARY

Studies were made on the seasonal abundance of major citrus pests on sweet orange and acid lime during June 2003 to May 2004. On sweet orange the leaf miner infestation was more from second fortnight of September 2003 to second fortnight of February 2004. The infestation of leaf miner increased from first fortnight of September 2003 to first fortnight of January 2004. The peak incidence of leaf miner was noticed during first fortnight of January (40.84%) at maximum temperature, minimum temperature, relative humidity (I and II) and rainfall of 29.92°C, 16.45°C, 73.93 per cent, 41.06 per cent and 0.27 mm respectively. Negligible incidence was observed from April first fortnight to July first fortnight. On acid lime the incidence of leaf miner started from first fortnight of July 2003. Leaf miner activity was peak during second fortnight of December 2003 (36.33%) at maximum temperature, minimum temperature, relative humidity (I and II) and rainfall of 29.05°C, 18.12°C, 80.12 per cent, 58.87 per cent and 0.66 mm respectively. Very low infestation was recorded during June 2003 and second fortnight of April to May 2004. On both hosts the leafminer incidence showed negative correlation with maximum,

minimum temperatures and rainfall and positive correlation with relative humidity.

On sweet orange the larval population of butterfly started from second fortnight of June 2003. Butterfly activity reached its peak during second fortnight of December 2003 by recording highest larval population of 67.5 larvae per 20 twigs at maximum temperature, minimum temperature, relative humidity (I and II) and rainfall of 29.05°C, 18.12°C, 80.12 per cent, 58.87 per cent and 0.66 mm respectively. Peak period of pest population synchronized with the emergence of new flush. Zero population was recorded during first fortnight of June 2003 and April to May 2004. On acid lime the larval population of citrus butterfly was commenced from June first fortnight, reaching highest population during second fortnight of November by recording 64.3 larvae per 20 twigs. Negligible population was recorded during the months of April and May 2004 when hot period was prevailed. The butterfly larval population showed negative correlation with both temperatures (maximum and minimum) and rainfall where as it was positively correlated with relative humidity (I and II) on sweet orange and acid lime respectively.

The incidence of psylla started from second fortnight of October 2003 on sweet orange, and the pest population attained the peak. (19.9 psyllids / 10 twigs) during second fortnight of November 2003, when weather factors like maximum temperature (27.73°C), minimum temperature (18.32°C), relative humidity II (71.92%), relative humidity I (49.94%) and rainfall 0 mm were prevailed. However the population tended to decline from first fortnight of December 2003 and remained low upto first fortnight of February 2004. There was no population from first fortnight of July 2003 to first fortnight of October 2003 and second fortnight of February to first fortnight of April, 2004. The population was negatively correlated with maximum temperature, and minimum temperature and relative humidity II and it was positively correlated with relative humidity I and rainfall. On acid lime the peak population was recorded (16.7 psyllids / 10twigs) during first fortnight of December at maximum temperature, minimum temperature, relative humidity I, relative humidity II and rainfall of 28.98°C, 16.27°C, 71.47 per cent, 43.33 per cent and 0 mm respectively. Zero population was recorded from second fortnight of February to first fortnight of April 2004 and second fortnight of July 2003 to second fortnight of October 2003. The correlation between

psyllid population and temperatures (maximum and minimum) was negative whereas it was positive with relative humidity (I & II) and rainfall.

On sweet orange weevil population was noticed throughout the year except second fortnight of April to May 2004. The peak population (20.6 weevils / 10twigs) was noticed during first fortnight of October 2003 at maximum temperature, minimum temperature, relative humidity (I & II) and rain fall of 33.01°C, 23.76°C, 79.07%, 53.33% and 5.82 mm respectively. On acid lime the peak population (18.4 weevils / 10 twigs) was recorded during second fortnight of October 2003 at temperatures (maximum and minimum), relative humidity (I and II) and rainfall of 30.68°C, 21.97°C, 81.37 per cent, 61.69 per cent and 6.88 mm respectively. The correlation between weevil population and temperatures (maximum and minimum) was negative on sweet orange, where as in acid lime population showed positive correlation with minimum temperature. Positive correlation was existed between weevil population and relative humidity (I and II) and rainfall on both hosts viz., sweet orange and acid lime respectively.

High incidence of leaf roller was noticed during second fortnight of February on sweet orange, while it was peak during February, December months on acid lime

Blackfly incidence was not observed throughout the study.

The green mite showed the peak population (24.4 mites / leaf) during second fortnight of November 2003 on Sweet orange at maximum temperature, minimum temperature, relative humidity (I and II) and rainfall were 27.73°C, 18.32°C, 71.90 per cent, 49.94 per cent and 0.00 mm respectively. Incidence of green mite was recorded throughout the year on Sathgudi sweet orange except during months of June and July 2003 and second fortnight of May 2004. On acid lime its peak population (43.4 mites / leaf) was noticed during first fortnight of March 2004 at maximum temperature, minimum temperature, relative humidity (I & II) and rainfall of 35.82°C, 18.90°C, 58.26 per cent, 22.33 per cent and 0.00 mm respectively. The mite population showed negative correlation with temperatures (maximum and minimum) and rainfall, but it was positively correlated with relative humidity (I and II) sweet orange. On acid lime the

green mite population showed negative correlation with all weather parameters except with minimum temperature and relative humidity I.

The data of rust mite on Sathgudi sweet orange indicated that rust mite population was observed from second fortnight of November 2003, attaining peak population (60.25 mites / 0.5mm² fruit) during first fortnight of March 2004 at maximum temperature, minimum temperature, relative humidity (I and II) and rainfall of 35.82°C, 18.90°C, 58.26 per cent, 22.33 per cent and 0.00 mm respectively. Thereafter the population of mites tended to decline, very negligible population was observed during second fortnight of May to first fortnight of November. The correlation between rust mite population and maximum temperature was positive and it showed negative correlation with all other weather factors viz., minimum temperature, relative humidity (I ad II) and rainfall respectively.

The rust mite population on acid lime was high (59.75mites / 0.5cm²) during second fortnight of January 2004 at maximum temperature, minimum temperature, relative humidity (I and II) and rainfall 30.76°C, 17.88°C, 77.87 per cent, 44.12 per cent and 0.00 mm respectively. Thereafter the population of mites tended to decrease. Nil population was

observed during months of May to October. The population of rust mite showed positive correlation with relative humidity I and it was negatively correlated with all other weather factor viz., maximum temperature, minimum temperature II and rainfall.

During period of study, a psychid *Clania crameri* and a chaffer beetle, *Autoserica insanabilis* were identified as foliage feeders of citrus.

During period of the study larval parasitoid *Tetrastichus* sp. was recorded on larvae of leaf miner. On citrus butterfly two braconid larval parasitoids viz. *Apanteles papilionis* and *Bracon hebetor* and a reduviid predator *Rhynocoris marginatus* were recorded. On psylla four species of coccinellids viz., *Coccinella septumpunctata*, *Chilomenus sexmaculata*, *Brumus suturalis* and *Chilocorus nigritus*, one lace wing predator *Chrysopa* sp and an unidentified preying mantid were found preying upon nymphs of citrus psylla. One nymphal parasitoid of eulophid (*Tetrastichus* sp) was recovered from the population of psyllids. A pentatomid bug *Amotys malabarica* Fab. was identified as predator of adult weevil.

Field experiments were conducted to evaluate the efficacy of natural and synthetic insecticides on incidence and larval mortality of citrus leaf miner *P. citrella*. In prophylactic method of leaf miner control all natural insecticides kept the citrus plants completely free from pest attack upto three days, but insecticides viz. NSKE, azadirachtin and Bt. (0.005%) effectively checked the incidence even upto five days. On seventh day onwards, leaf miner fresh incidence was observed in all the treatments indicating their loss of efficacy.

In curative control of leaf miner by using natural products, Bt at both concentrations (0.005 and 0.0025 %) showed 100 percent mortality and their residual action remained for even upto 10 days. In the order of efficacy the next best treatments were azadirachtin and NSKE which offered 79.97 and 78.39 per cent larval mortality at five days after spraying. After five days treatments, neem seed kernel extract, azadirachtin, neem soap, pongamia oil, pongamia soap and garlic extract lost their efficacy by recording reinfestation of leaf miner.

In prophylactic control of leaf miner with synthetic products, insecticides profenophos, lambda cyhalothrin and fenvalerate checked the

leaf miner incidence upto seven days offering complete protection. The rest of treatments thiodicarb, methomyl, acephate and chlorpyriphos prevented the incidence of leaf miner up to five days. Among all the treatments cartap hydrochloride was least effective which lost it's efficacy at three days after spraying.

In curative control of leaf miner with synthetic insecticides, all the treatments were superior over control. Insecticides viz., thiodicarb, lambda cyhalothrin and fenvalerate showed 100 percent mortality on third day itself. Among rest of insecticides profenophos, methomil and acephate were offered 100 percent mortality at five days after spraying. Cartap hydrochloride and chlorpyriphos were showed least efficacy and lost their efficacy at five days after spraying. At fourteen days after spraying fresh miner incidence was recorded in all the treatments, which indicating their decrease in residual action.

Field experiments were conducted to evaluate the efficiency of natural and synthetic insecticides against citrus butterfly *P.demoleus*. Data recorded on larval mortality of citrus butterfly at different periods after insecticidal application revealed that all the insecticidal treatments were

significantly superior to untreated check. The overall efficacy of field trial after insecticidal application revealed that Bt tested in two different concentrations (0.0025% and 0.005%) was the most effective treatment showing cent per cent mortality at five days after spraying. Bt was followed by botanical insecticides NSKE, azadirachtin, neem soap, pongamia soap and pongamia oil which exhibited maximum larval mortality of 95.92, 90.92, 83.51, 70.60 and 61.14 percent respectively. Garlic extract was least effective treatment showing only 41.10 percent larval mortality.

However, the citrus plants sprayed with NSKE, azadirachtin, neem soap, pongamia oil and Pongamia soap showed reinfestation after 10 days of treatment application whereas in the Bt treated plants, no fresh damage was noticed.

All the treatments *viz.*, thiodicarb, profenophos, lambda cyhalothrin, cartap hydrochloride, fenvalerate, methomil, acephate and chlorpyriphos resulted in cent percent larval mortality at five days after spraying. Among these treatments, synthetic pyrethroids retained their residual effect for longer time than rest of the treatments without recording any fresh incidence. At fourteenth day after spraying reoccurrence of larval population of *P. demoleus* was observed indicating decline in the residual action of all the insecticides.

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To
The Associate Dean
S.V. Agril. College
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Sir,

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A copy of the thesis entitled "**SEASONAL ABUNDANCE AND MANAGEMENT OF MAJOR CITRUS PESTS OF SOUTH ZONE**" submitted by Mr. P. Koteswara Rao, TAM-02-14 M.Sc. (Ag.) student majoring in Entomology of 2002 admitted batch is herewith enclosed along with the following enclosures for favour of onward transmission of the same to the Dean, PG Studies, ANGRAU, Hyderabad for further action.

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