POPULATION DYNAMICS IN RELATION TO WEATHER PARAMETERS AND MANAGEMENT OF CITRUS LEAF ROLLER, Psorosticha zizyphi Stainton (OECOPHORIDAE : LEPIDOPTERA) ON KAGZILIME Citrus aurantifolia Swingle

A THESIS SUBMITTED TO THE GUJARAT AGRICULTURAL UNIVERSITY IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE AWARD OF THE DEGREE OF Master of Science (AGRICULTURE) IN AGRICULTURAL ENTOMOLOGY

BY

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1994
DEDICATED
TO MY
BELOVED
PARENTS
ABSTRACT
Investigation on population dynamics of citrus leaf roller, *Psorosticha zizyphi* Stainton and their parasitoids in relation to different weather parameters, screening of different acidlime varieties for their resistance against *P. zizyphi* and bio-efficacy of different insecticides against *P. zizyphi* were carried out at B.A. College of Agriculture, Gujarat Agricultural University, Anand during the year 1992-93.

Higher activity of the pest (more than 25 larvae/250 twigs) was found in October, from third week of June till July end, in fifth week of August and in third and fourth weeks of September. The pest has been observed to remain at highest level during monsoon. The pest population was found to have significant positive correlation with minimum temperature, average vapour pressure and relative humidity.
While significant negative correlation with sunshine hours. Based on step regression analysis the most influencing factor was relative humidity on the population of _P. zizyphi_

Two parasites, _Pristomeres marginicollis_ Cameron (an Ichneumonidae) and _Apanteles_ sp. (Braconidae) were found to parasitise the larvae of pest. Higher activity of _P. marginicollis_ (more than 50% parasitism) was found in month of October and in fourth week of September while higher activity of _Apanteles_ sp. (more than 20% parasitism) was recorded in July and in fifth week of August. Higher total per cent parasitism (more than 50% parasitism) was found in month of October, in July and second half month of September. Maximum temperature had significant negative correlation with per cent parasitism by _P. marginicollis_ while sunshine hours had significant negative correlation with per cent parasitism by _Apanteles_ sp. and total per cent parasitisation. Minimum temperature, average vapour pressure, relative humidity, total rainfall and host population had significant positive effect on per cent parasitism by _Apanteles_ sp. and relative humidity had significant positive effect on total per cent parasitisation. Based on the step regression analysis maximum temperature and relative humidity were found most influencing factors on the per cent parasitism by _P. marginicollis_ and total per cent parasitisation, respectively. Minimum temperature, average vapour pressure and total rainfall were found most influencing factors on per cent parasitism by _Apanteles_ sp.
Among the eight varieties of Acidlime, Seedless lime and Adinima lime were less susceptible while Pariya-culum and Jumakhiya lime were comparatively more susceptible.

Among the synthetic insecticides (dimethoate @ 0.03%, chlorpyriphos @ 0.05%, endosulfan @ 0.07%, fluvalinate @ 0.005%, acephate @ 0.075%, fenvalerate @ 0.01%, triazophos @ 0.1%, butacarboxim @ 0.005%, quinalphos @ 0.05% and carbaryl @ 0.2%) tested for their larvicidal action in laboratory, all the insecticides gave 99.00% larval mortality of *P. zizyphi* except etrafolan 0.05% and proved effective.

Among the botanical materials evaluated in laboratory for their larvicidal action repel in 1.0%, nicotine sulphate 0.05%, neem oil 1.0% and NSKS 2.0% were found better (gave more than 40% larval mortality) than rest of the treatments (acheok 1.0%, nimbicidine 0.2%, parshmani 0.2% and azadirchitin 0.4% (NTGCF product), MLDPS 2.0%, FLE 3.0%, NLE 5.0% and ALE 5.0%).

The synthetic insecticides were found better than botanical insecticides as far as their ovicidal action is concerned against *P. zizyphi* in laboratory. Among the synthetic insecticides, quinalphos 0.05%, fenvalerate 0.01% and acephate 0.075% were found better (gave more than 70% egg mortality) than rest of the treatments (dimethoate 0.03%, chlorpyriphos 0.05%, endosulfan 0.07%, triazophos 0.1%, butacarboxim 0.005% and carbaryl 0.2%). Among the botanical insecticides repel in 1.0% and NSKS 2.0% were found
better (gave < 30% egg mortality) than rest of the treatments (nicotine sulphate 0.05% and neem oil 1.0%).

The results of larvicidal action of different insecticides in field indicated that the synthetic insecticides were found better than botanical insecticides. Among the synthetic insecticides quinalphos and chlorpyriphos at 0.05% concentration were found better (gave more than 99.00% larval mortality) than rest of the treatments (dimethoate 0.03%, endosulfan 0.07%, fluvalinate 0.005%, acephate 0.075%, fenvalerate 0.01%, triazophos 0.1%, butacarboxim 0.005% and carbaryl 0.2%). Among the botanical insecticides repelin 1.0% was found better (gave 70.00% of larval mortality) than rest of the treatments (nicotine sulphate 0.05%, NSKS 2.0% and neem oil 1.0%).
Dr. V.M. Valand
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CERTIFICATE

This is to certify that the thesis entitled, "Population dynamics in relation to weather parameters and management of citrus leaf roller, Psorosticha zizyphi Stainton (Oecophoridae : Lepidoptera) on Kagzilime, Citrus aurantifolia Swingle" submitted by Shri C.P. Patel in partial fulfilment of the requirements for the degree of Master of Science in Agricultural Entomology of the Gujarat Agricultural University is a record of bonafide research work carried out by him under my guidance and supervision and the thesis has not previously formed the basis for the award of any degree, diploma or other similar title.

Anand
Date: May, 17th, 1994

(J. M. VALAND)
Major Advisor
ACKNOWLEDGEMENT

With immense pleasure and great privilege I pickup this opportunity to express my deep sense of gratitudeness to my Major Advisor Dr. V.M. Valand, Associate Research Scientist (Entomology), Department of Entomology, B.A.College of Agriculture, Gujarat Agricultural University, Anand for his valuable guidance and his keen interest throughout the investigation and also for painstaking assistance in preparing manuscript of this thesis.

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Thanks are also due to Shri N.C. Patel and other staff members of the Department of Entomology, B.A. College of Agriculture, Anand for their direct or indirect help.

I express my cordial thanks to my friends for their sincere co-operation during the course of investigation.

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ANAND

Date: May $^{31}$th, 1994

( C. P. PATEL )
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INTRODUCTION
CHAPTER - I
INTRODUCTION

Citrus spp. occupy commercially a very important place among fruit crops. Southern Asia, especially South Vietnam and the Southern regions of nearby China are commonly regarded as native countries of the citrus species and cultivation in these regions probably dates back as far as 2400 B.C. (Marloth, 1949 as quoted by Shah, 1983).

Early records indicate that the citrus fruits such as orange, limes and lemons were being cultivated in South China, Malaya and Sub-Himalayan parts of Assam and spread to tropical and sub-tropical parts of the world. Latter on U.S.A. is the leading citrus growing country in the world with 40 per cent of the world total acreage under citrus. The citrus fruits of different varieties produced in U.S.A. is about 16,274 million pounds, out of which lime fruit production is about 26 million pounds (Ziegler and Wolfe, 1960). Spain, Italy, Mexico, India, Japan, South Africa and Brazil are the other important citrus growing countries.

In India, after mango and banana, citrus is one of the important fruit crop and it is cultivated in almost all the states of India. Out of many citrus species grown in different parts of the country, orange (Citrus sinensis Linnaeus), mandarin (Citrus reticulata Blanco) and acidlime (Citrus aurantifolia Swingle) are the most common. Andhra Pradesh, Karnataka, Punjab, Madhya Pradesh, Maharashtra, Bihar and Gujarat are the states of India with more than 1
Bihar and Gujarat are the states of India with more than 1 lakh metric tone production of citrus fruits per year (Anonymous, 1990). The cultivation of acidlime locally known as Kagzilime is popular in Gujarat state and the area under its cultivation has increased from 2700 hectares in the year 1975-76 to 5100 hectares in the year 1980-81 and majority of the area lies in Kheda and Mehsana district of the state (Table 1).

Such a valuable perennial fruit crop is found to be attacked by several insect pests during its growth. Clausen (1933) listed about 200 insect species attacking citrus trees in tropical Asia, of which 96 are found in India. About 160 pests are reported on citrus trees in India which include 49 species of Coccidae, 39 of Lepidoptera, 12 of Aleurodidae and 12 of Coleoptera (Pruthi and Mani, 1945).

Ebling (1959) has listed as many as 823 species of insects and mites reported on citrus trees around the world and of which 20% are found in India. In Gujarat 11 species of insect pests has been reported to be serious (Patel et al., 1970).

1. Citrus leafminer  **Phyllocnistis citrella** Stainton
   (Phyllocnistidae : Lepidoptera)

2. Lemon butterfly  **Papilio demoleus** Linnaeus
   (Padilionidae : Lepidoptera)
Table 1: Districtwise area under Kaghilime cultivation in Gujarat state from the year 1975-76 to the year 1980-81

<table>
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<th>Sr. No.</th>
<th>District</th>
<th>Area in hectares during different year</th>
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<td>1.</td>
<td>Kheda</td>
<td>1700</td>
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<tr>
<td>2.</td>
<td>Mehsana</td>
<td>500</td>
</tr>
<tr>
<td>3.</td>
<td>Ahmedabad</td>
<td>200</td>
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<td>4.</td>
<td>Gandhinagar</td>
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</tr>
<tr>
<td>5.</td>
<td>Baroda</td>
<td>100</td>
</tr>
<tr>
<td>6.</td>
<td>Sabarkantha</td>
<td>-</td>
</tr>
<tr>
<td>7.</td>
<td>Banaskantha</td>
<td>100</td>
</tr>
<tr>
<td>8.</td>
<td>Bhavnagar</td>
<td>100</td>
</tr>
<tr>
<td>9.</td>
<td>Rajkot</td>
<td>-</td>
</tr>
<tr>
<td>TOTAL</td>
<td></td>
<td>2700</td>
</tr>
</tbody>
</table>

Source: Season and crop report of Gujarat State, Directorate of Agriculture, Ahmedabad.
3. Citrus psylla  
   Diaphorina citri Kuwayma  
   (Psyllidae : Homoptera)

4. Citrus leaf roller  
   Psorosticha zizyphi Stainton  
   (Oecophoridae : Lepidoptera)

5. Citrus whitefly  
   Dialeurodes citri Ashmead  
   (Aleyrodidae : Homoptera)

6. Citrus fruit sucking moth  
   Ophideres fullonica Linnaeus  
   O. Materna Linnaeus  
   (Noctuidae : Lepidoptera)

7. Mealy bug  
   Planococcus citri Risso  
   (Pseudococcidae : Homoptera)

8. Citrus mites  
   Paratetranychus citri Meckregor  
   (Tetranychidae : Acarina)

9. Citrus aphid  
   Toxoptera aurantii Boy  
   (Aphididae : Homoptera)

10. Red ants  
    Oecophylla smaragdina Fabricius  
    (Formicidae : Hymenoptera)

11. White ants  
    Termes Sp.  
    (Termitidae : Isoptera)

The citrus leaf roller, Psorosticha zizyphi Stainton  
(Syn. Tonica zizyphi Stainton) though a minor pest causes  
serious damage to Kagzilime in nursery as well as in field  
during new flush. The larvae webs young developing leaves,  
enclosing and damaging the growing bud and thus seriously  
hampers new flush. The infestation in nurseries as well as  
field retards the growth and development of the Kagzilime  
saplings.
Detailed information regarding the population dynamics, natural enemies, susceptibility and management of this pest is not available in light of its occurrence in Gujarat. It was therefore, planned to carry out investigation on above aspects of *P. zizyphi* at B.A. College of Agriculture, Gujarat Agricultural University, Anand Campus, Anand during 1992-93.

Thus results obtained from the investigation during the year 1992-93 form the subject matter of this thesis.
REVIEW
OF
LITERATURE
CHAPTER - II
REVIEW OF LITERATURE

Among the minor pest, the citrus leaf roller, P. zizyphi is a serious pest in Gujarat and other states of India in the nursery as well as in field.

From the available literature, it was found that very limited work had been done on this pest. However, efforts had been made to review the published literature on P. zizyphi and presented hereafter under the following headings.

2.1 DISTRIBUTION

The citrus leaf folder, P. zizyphi has been reported as sporadic pest in India (Fletcher, 1914), Sri Lanka (Hutson and Pinto, 1934), Pakistan (Ghani, 1941), Queensland (Australia) (Davis, 1965), Java, Philippines and New Guinea (Mishra et al., 1989).

In India, it was first reported from Madras (Fletcher, 1914) and subsequently from Maharashtra (Khare, 1921), Madhya Pradesh (Gupta, 1954) and Punjab (Batra and Sandhu, 1979). Recently, it was reported as a serious pest in the Punjab (Batra and Sharma, 1987). It's occurrence was also noted in Kerala, Tamilnadu, Uttar Pradesh and Bihar (Mishra et al., 1989).

2.2 HOST

Citrus leaf folder, P. zizyphi has been reported to attack various citrus species such as grape fruit, lemon, limes, orange, mandarin etc. and its allied genera viz.,
Poncirus trifoliata Rafinesque, Feronia limonia Swingle, Feronia elephantum Correa and bael (Aegle marmelos Linnaeus) as well as on other plants such as Zizyphus sp., curry leaf plant (Murraya koenigii Spreng.) and Murraya exotica Linnaeus (Fletcher, 1914; Khare, 1921; Margabandhu, 1933; Gupta, 1954 and Pruthi and Batra, 1960).

In Punjab, Sharma and Batra (1987) reported that during active period, it feeds on the citrus (April to October), ber and bael (June to August) but the population on ber, bael and old citrus plants was almost negligible.

Mishra et al. (1989) recorded it on four year old plants of Ailanthus excelsa Roxburgh, locally known as Maharukh, a nutritious fodder tree, in the Satyanarayan Research Nursery, Ranipur Research Range, Dehradun, Uttar Pradesh. This was a new record for this host.

2.3 NATURE OF DAMAGE

Fletcher (1914) reported it to be a minor pest in Coimbatore, Palni Hills and Madras, occasionally becoming injurious and eating tender shoots of young plants.

According to Margabandhu (1933), serious injury caused to seedling by the larvae of *P. zizyphi* which fold tender leaves and feed on them in Maharashtra. In the early stages they scrape the leaves while in the later stages, they bite holes in the leaves. In case of severe infestation, the growing shoots are defoliated.
In Sri Lanka, Hutson and Pinto (1934) have mentioned the pest to be less injurious damaging the growing shoots by webbing together or rolling the leaves.

In Punjab, Batra and Sharma (1987 and 1990) have reported that the larvae of citrus leaf folder were destructive under nursery conditions and feed on the apical/lateral buds from tip downwards. After eating \(\frac{3}{4}\)th or more portion of the leaf/leaves, the larvae migrated to fresh leaves of the same or another plant. During day time the larvae remained in rolled leaves and became active in the evening and caused maximum damage at night. In case of severe infestation, apical bud withered off which sometimes caused initiation of growth of lateral buds. The growth of attacked plants was reduced considerably as compared to unattacked plants constituting a proportion of increase in height \(1:2.88\) in attacked Vs unattacked plants.

2.4 SEASONAL INCIDENCE

According to Margabandhu (1933) the pest was observed on seedlings almost throughout year in Maharashtra but the degree of incidence was very high during monsoon from August to January and pest disappeared in February.

In Madhya Pradesh, Gupta (1954) recorded incidence of this pest to be usually high during rainy season from July to September, after which it slowly declined and disappeared completely during hot summer months.

Davis (1965) reported incidence of the pest to be most severe during November to March in Queensland.
According to Batra and Sandhu (1979), the pest was active from April to August with peak period in May and June at Ludhiana in Punjab.

In Punjab, it has been reported that the pest was active from April to October. Maximum infestation of the pest was noticed during monsoon season from June to August when there was moderate temperature (29.50+2.31 to 33.0+2.63°C), high relative humidity (47.93 + 9.38 to 78.74 + 14.07 per cent) and high rainfall (49.50 to 367.50 mm). The population of pest decreased from September onwards and was negligible in the 4th week of October with decrease in temperature and rainfall. The low temperature and rainfall were observed to have a direct effect on population of citrus leaf roller (Batra and Sharma, 1987 and Sharma and Batra, 1987, 1988 and 1989a).

In Punjab, Sharma and Batra (1989a) have also studied the effect of various abiotic (temperature and relative humidity) and biotic factors (parasitoids) on the population of P. zizyphi through simple, partial and multiple correlations. They reported that the larval population was positively correlated with mean temperature and per cent parasitization. While, they found non-significant correlation between the pest population and relative humidity. Further, regression analysis indicated that mean temperature and parasitoids independently, resulted in 40.25 and 77.54 per cent variation in larval population respectively.
The incidence of citrus leaf roller has been observed during September to December at Rahuri (Maharashtra) with maximum built up in month of October. While, at Ludhiana (Punjab) higher incidence of the pest was registered during June to August and no incidence during December to February (Anonymous, 1991).

2.5 NATURAL ENEMIES

Ghani (1941) reared two hymenopterous parasites from the larvae in Punjab but he has not reported their names.

Gupta (1954) has reported three parasites viz., Apanteles sp. (Braconidae), Pristomerus sp. (Ichneumonidae) and Brachymeria euploeae Westwood (Chalcidoidea) from the larvae of P. zizyphi in Madhya Pradesh. In Queensland, Davis (1965) has reported an Ichneumonidae parasite (Pristomerus sp.) from the larvae.

It has been reported by Batra and Sandhu (1979) at Ludhiana in Punjab that the caterpillars were parasitised upto 30 per cent by several parasites. Three parasites viz., Apanteles sp., Pristomerus sp. and B. euploeae were recorded by them. They also found number of spiders preying upon larvae.

In Punjab, Sharma and Batra (1989b) noted an increased in parasitism with an increase in larval population of host and it was maximum during July. Three different hymenopterous parasitoids viz., Pristomerus sp., Mesochorus sp. and Apanteles machaeralis Wilkinson parasitising the larvae of
P. zizyphi were observed by them. Extent of parasitism by Pristomerus sp. and Mesochorus sp. was higher during July and by A. machaeralis during June. Mesochorus sp. was reported for the first time to parasitise citrus leaf roller. However, no parasitization of eggs and pupae was observed.

Batra and Sharma (1990) reported that main contributive factors for the maximum parasitization were high host population, a moderate temperature (30°C) and high relative humidity in Punjab.

In Bangalore (Andhra Pradesh), Nagalingam (1991) reported three parasitoids viz., Ophion triangularemaculatus (Family : Ichneumonidae) a major/exercising 48 per cent parasitism followed by Apanteles sp. causing 6-11 per cent parasitism and Goniozus sp. an occasional and minor parasitoid causing only a 4 per cent parasitism. This report on parasitisation due to O. triangularemaculatus and Goniozus sp. on citrus leaf roller constituted the first record from India.

It has been noted that citrus leaf roller population was maximum (85%) during monsoon and correspondingly the parasitisation by different parasitoids (Apanteles sp., Mesochorus sp. and Pristomerus sp.) was also maximum (26.9%) when the mean temperature and relative humidity were 30.5 ± 2.7°C and 73.0 ± 16.9 per cent, respectively at Ludhiana. High temperature (30°C) and high relative humidity (73.0%)
were favourable for high parasitisation of citrus leaf roller. In total 81 per cent variation in parasitisation was being controlled by the combined effect of two variables viz., mean temperature and relative humidity, which independently had no significant effect on parasitisation (Anonymous, 1991).

2.6 CONTROL MEASURES

Margabandhu (1933) had recommended hand picking of eggs and larvae and spraying with lead arsenate against this pest in Maharashtra.

In Sri Lanka, Hutson and Pinto (1934) have reported that regular application of sprays against Phylloclisstis should control Psorosticha but if attack persists, lead arsenate (1 oz. to 2 gal. water) should be applied two or three times at short intervals.

In Madhya Pradesh, Gupta (1954) had obtained significant results with fish oil rosin soap which was applied at the rate of 1 oz. per gallon of water.

At Anand, Patel (1977) has concluded that leptophos (0.05%) and dimethoate (0.03%) were suitable and effective insecticides in the laboratory experiment.

Sandhu and Batra (1978) have indicated that chlorpyriphos, leptophos and monocrotophos at 0.05 per cent concentrations was giving complete control of leaf roller larvae whereas, dicrotophos, dimethoate and endosulfan were moderately effective at 0.05 per cent concentration at Ludhiana (Punjab).
Batra et al. (1983), have found chorpyrophos, monocrotophos and quinalphos @ 0.05 per cent to be very effective against *P. zizyphi* infesting citrus in Punjab. Permethrin and fenvalerate were mediocre while, DDT and phosalone were least effective at 0.05 per cent.

In Punjab, Sharma and Batra (1987) have indicated that monocrotophos, quinalphos and methyl parathion @ 0.05% gave the best result for the control of citrus leaf roller. The pyrethroids viz., cypermethrin, deltamethrin and fenvalerate @ 0.01 per cent were mediocre in action whereas, carbaryl @ 0.2 per cent proved least effective for its control.

At Dehradun in Uttar Pradesh, Mishra et al. (1989) have found that a foliar spray of 0.25% malathion in April/May was effective in field trial while 0.005% fenvalerate was effective in laboratory trial carried out for the control of *P. zizyphi*.

At Ludhiana, spray with monocrotophos @ 0.05% alone and monocrotophos @ 0.05% alternated with neem oil 1% gave the best results for the control of this pest. This was closely followed by acephate 0.05%. Fenvlalrate (0.005%) and neem oil (1%) did not prove effective for the control of this pest (Anonymous, 1991).

Thus, it is evident from the above review that a very little information is available on the larvicidal and ovicidal efficacy of various botanical insecticides in comparison to synthetic insecticides against *P. zizyphi*.
infesting citrus tree. Information is also not available on relative susceptibility of various varieties of citrus against this pest.
MATERIALS
&
METHODS
CHAPTER - III
MATERIALS AND METHODS

The materials and methods used for various investigations on different aspects of P. zizyphi are described below.

3.1 POPULATION DYNAMICS

In order to study the population dynamics of P. zizyphi, ten trees of citrus trees in an orchard at Horticulture Farm, B.A.College of Agriculture, Gujarat Agricultural University, Anand were selected and kept unsprayed. For determination of the pest population, 25 newly emerged or fresh tender twigs with 4 to 8 leaves were selected randomly on each tree and total number of larvae were counted by observing all the leaves critically. Such observations were recorded at weekly interval as per meteorological standard weeks, starting from October, 1992 and continued upto September, 1993.

With a view to know the effect of weather parameters viz., temperature (maximum, minimum and average), mean vapour pressure, relative humidity, sunshine hours and rainfall on the population fluctuation of P. zizyphi, correlation coefficient and step regressions were worked out. Weekly meteorological data recorded by the Meteorological Department of Agriculture College, Gujarat Agricultural University, Anand for the period of October, 1992 to September, 1993 were used for this purpose.
3.2 ESTIMATION OF NATURAL PARASITISM

In order to estimate the extent of natural parasitism by different parasites, the larvae of *P. zizyphi* were collected from orchard at weekly interval and reared in the laboratory till the larvae completed the development or yielded parasite. Parasitised larvae which could be easily identified by their dark brown colour were counted and per cent parasitism was worked out. Correlation coefficient and step regressions between the per cent parasitism and different weather parameters were also worked out.

3.3 VARIETAL SCREENING

Eight varieties/germplasms of acidlime (*C. auranti-folia*) viz., Maxican lime, Coorglime, Pariya-culum lime, Tirupatti lime, Seedless lime, Jumakhiya lime, Adinima lime and Kagzilime available at Horticulture Farm, Gujarat Agricultural University, Anand were studied to screen out the tolerant/resistant variety against *P. zizyphi*. For the purpose, single tree of each variety was selected and was kept unsprayed with insecticides. Total number of larvae were counted on a group of five newly emerged or fresh tender twigs having 4 to 8 leaves. Such five groups were selected randomly covering the whole canopy of the tree and each group was considered as one replication. Thus, 25 twigs were selected on each tree for recording observations. Observations were recorded at weekly interval following meteorological standard weeks starting from October, 1992 and continued upto September, 1993.
Here, one tree of each variety was considered as a one treatment. The data on number of larvae per five twigs obtained at different time interval for different varieties were subjected to ANOVA after $\sqrt{x + 1}$ transformation and following split plot over time design.

3.4 CONTROL MEASURES

3.4.1 Laboratory experiments

With a view to evaluate the bio-efficacy of various synthetic insecticides and botanical materials against the citrus leaf roller, *P. zizyphi*, experiments were conducted in the laboratory of the Department of Entomology, B.A. College of Agriculture, Gujarat Agricultural University, Anand Campus, Anand during the year 1992-93.

3.4.1.1 Maintenance of laboratory culture:

Initial laboratory culture of citrus leaf roller, *P. zizyphi* was raised by collecting large number of larvae from nurseries and orchard of Gujarat Agricultural University, Anand Campus, Anand. These field collected larvae were reared on fresh tender twigs with fresh leaves of Kagzilime which was kept in plastic containers measuring 10 cm in diameter and 5 cm in height. The twigs were replaced everyday and excreta as well as other rubbish in the container were removed regularly for cleanliness. When the larvae pupated, they were sexed by examining the relative positions of the anal and gential slits under a stereoscopic binocular microscope. The male and female pupae were then kept separately in suitable plastic containers.
Plate I: A. Female pupa with longer distance between anal and genital slits
B. Male pupa with shorter distance between anal and genital slits

Plate: Adults of P. zizyphi
The freshly emerged moths were paired and each pair was introduced in a glass chimney placed on a petridish measuring 10 cm in diameter and 2 cm in depth. Moist soil was kept in the petridish over which a blotting paper was placed so that high humidity is maintained in the chimney. A tender Kagzilime twig with fresh leaves was also provided in the chimney so that moths can rest and lay their eggs on it. The cut end of the twig was wrapped in cotton wool and dipped in water to maintain turgidity of the leaves on the twig and then placed in a specimen tube. The top of the chimney was covered with a piece of fine nylon cloth held in place by a rubber band. A cotton swab containing five percent honey solution was placed on the chimney to provide food for the moths. The cotton swab was covered with a plastic lid (2.5 cm diameter) so as to prevent drying and feeding by other insects. The twigs and cotton swabs were replaced everyday in the morning. The eggs laid on the leaves/twig were separated and kept in plastic tubes. Required number of eggs were used for ovicidal study while rest were reared further for studying the larvicidal properties of various synthetic insecticides as well as botanical materials.

3.4.1.2 Preparation of plant extracts:

Various locally available plants having insecticidal properties were collected (Table 2). Required quantity of leaves/seeds of the plant was weighted by using a top pan
balance and ground in an electrical grinder with 100 ml water for two minutes at high speed. It was then filtered with fine muslin cloth and remanent from the cloth was again ground with 100 ml water. Finally the volume was made upto 1 litre by adding required quantity of additional water.

The suspension of each of the botanical material was prepared individually as described above and used individually to study their larvicidal and ovicidal actions against P. zizyphi.

3.4.1.3 Larvicidal action:

Two separate experiments, one to evaluate various synthetic insecticides and another to evaluate botanical materials were carried out in the laboratory condition following completely randomized design (CRD) with twelve treatments of synthetic insecticides and thirteen treatments of botanical materials including control. Each treatment in both the experiments was replicated three times. The details of treatments are given in Table 2.

The required concentration of various synthetic insecticides and botanical materials was prepared in 1 litre of water using glass jar. 1 ml teepol as sticker was also added per litre solution. Each suspension of respective treatments was uniformly sprayed with the help of potter's tower at a constant air pressure (2.5 kg/sq. cm) on fresh tender twigs and then dried under fan. The treated twigs were transferred to separate plastic containers. 3 to 4
Table 2: Details of the synthetic insecticides and botanical materials tested for their bio-efficacy against *P. zizyphi* on Kagzilime

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Technical name</th>
<th>Conc. (%)</th>
<th>Quantity used/litre water</th>
<th>Trade name</th>
<th>Source of supplier</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Etrafolan</td>
<td>0.05</td>
<td>1 gm</td>
<td>Mipcin 50 WP</td>
<td>Mitsubishi Chemical Industries Ltd., Bombay, India.</td>
</tr>
<tr>
<td>2</td>
<td>Dimethoate</td>
<td>0.03</td>
<td>1 ml</td>
<td>Rogor 30 EC</td>
<td>Rallis India Ltd., Bombay, India.</td>
</tr>
<tr>
<td>3</td>
<td>Chlorpyrifos</td>
<td>0.05</td>
<td>2.5 ml</td>
<td>Durmet 20 EC</td>
<td>Cynamide India Ltd., Bombay, India.</td>
</tr>
<tr>
<td>4</td>
<td>Endosulfan</td>
<td>0.07</td>
<td>2 ml</td>
<td>Endocel 35 EC</td>
<td>Excel Industries Ltd., Bombay, India.</td>
</tr>
<tr>
<td>5</td>
<td>Fluvalinate</td>
<td>0.005</td>
<td>0.2 ml</td>
<td>Mavrik 25 EC</td>
<td>Sandoz India Ltd., Bombay, India.</td>
</tr>
<tr>
<td>6</td>
<td>Acephate</td>
<td>0.075</td>
<td>1 gm</td>
<td>Asataf 75 SP</td>
<td>Rallis India Ltd., Bombay, India.</td>
</tr>
<tr>
<td>7</td>
<td>Fenvalerate</td>
<td>0.01</td>
<td>0.5 ml</td>
<td>Fenval 20 EC</td>
<td>Searle India Ltd., Bombay, India.</td>
</tr>
<tr>
<td>8</td>
<td>Triazophos</td>
<td>0.1</td>
<td>2.5 ml</td>
<td>Hostathion 40 EC</td>
<td>Hoechst India Ltd., Bombay, India.</td>
</tr>
<tr>
<td>9</td>
<td>Butacarboxim</td>
<td>0.005</td>
<td>0.1 ml</td>
<td>Drawin 50 EC</td>
<td>Bharal Pulverising Mills Ltd., Bombay, India.</td>
</tr>
<tr>
<td>10</td>
<td>Quinalphos</td>
<td>0.05</td>
<td>2 ml</td>
<td>Ekalux 25 EC</td>
<td>Sandoz India Ltd., Bombay, India.</td>
</tr>
<tr>
<td>11</td>
<td>Carbaryl</td>
<td>0.2</td>
<td>4 gm</td>
<td>Kilex carbaryl 50 WP</td>
<td>Paushak Ltd. Baroda, Gujarat, India.</td>
</tr>
</tbody>
</table>

Contd...
<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Treatments</th>
<th>Conc. (%)</th>
<th>Quantity used/litre water</th>
<th>Source of supplier</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td><strong>Experiment - II</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.</td>
<td>Repelin 'RD-9(100 EC)</td>
<td>1.0</td>
<td>10 ml</td>
<td>ITC Ltd. (ILTD division Research Deptt., Rajahmundry (Andhra Pradesh), India.</td>
</tr>
<tr>
<td>2.</td>
<td>Nicotine sulphate (50%)</td>
<td>0.05</td>
<td>1.25 ml</td>
<td>Gujarat Tobacco, Bhadaran, Kaira, Gujarat, India.</td>
</tr>
<tr>
<td>3.</td>
<td>Nimbicidine 100 EC (Neem based product)</td>
<td>0.2</td>
<td>2 ml</td>
<td>T. Stanes &amp; Co. Ltd., Coimbatore, India.</td>
</tr>
<tr>
<td>4.</td>
<td>Acheok CK 100 EC (Neem based product)</td>
<td>1.0</td>
<td>10 gm</td>
<td>Godrej Agrovet Ltd., Bombay, India.</td>
</tr>
<tr>
<td>5.</td>
<td>Parshmani 100 EC (Neem based product)</td>
<td>0.2</td>
<td>2 ml</td>
<td>Suraj Agro Industries, Kathalal, Gujarat, India.</td>
</tr>
<tr>
<td>6.</td>
<td>Azadirechtin (NTGCF product)</td>
<td>0.4</td>
<td>4 ml</td>
<td>N.T.G.C.F., Anand, Gujarat, India.</td>
</tr>
<tr>
<td>8.</td>
<td>Neem leaf extract (NLE) (Azadirachta indica A. Juss.)</td>
<td>5.0</td>
<td>50 gm</td>
<td>-Do-</td>
</tr>
<tr>
<td>9.</td>
<td>Neem oil</td>
<td>1.0</td>
<td>10 ml</td>
<td>Dhanvantri Ayurved Bhavan, G.I.D.C. Estate, V.V.Nagar, Anand, Gujarat, India.</td>
</tr>
<tr>
<td>10.</td>
<td>Fudina leaf extract (FLE) (Mentha piperata L.)</td>
<td>3.0</td>
<td>30 gm</td>
<td>Prepared in laboratory.</td>
</tr>
<tr>
<td>11.</td>
<td>Mint leaf dry powder suspension (MLDPS) (Mentha piperata L.)</td>
<td>2.0</td>
<td>20 gm</td>
<td>-Do-</td>
</tr>
<tr>
<td>12.</td>
<td>Ardusa leaf extract (ALE) (Ailanthus excelsa Roxb.)</td>
<td>5.0</td>
<td>50 gm</td>
<td>-Do-</td>
</tr>
</tbody>
</table>
twigs were placed in one plastic container and such one plastic container was considered as one replication.

The third instar larvae to be used for testing were starved for 12 hours. Such starved larvae of similar size in group of ten were released on treated twigs in each plastic container i.e. in each replication. In the first experiment, observations were recorded for the larval mortality after 6, 18 and 36 hrs. of treatments and corrected percentage mortality was worked out by using the Abott's formula (Abott, 1925) mentioned below:

\[
\text{% mortality} = \left(1 - \frac{T_a \times C_b}{T_b \times C_a}\right) \times 100
\]

Where,
- \( T_a \) = Nos. of living larvae in treatment after application
- \( T_b \) = Nos. of living larvae in treatment before application
- \( C_a \) = Nos. of living larvae in check after application
- \( C_b \) = Nos. of living larvae in check before application

In the second experiment, observations were recorded for the larval mortality after 6, 24 and 48 hrs. of treatments and the per cent larval mortality was worked out. The data on corrected per cent mortality of experiment No. 1 and the data on per cent larval mortality of experiment No. 2 obtained at different time interval were subjected to ANOVA (Completely Randomized Design) after following arcsin transformation.
3.4.1.4 Ovicidal action:

The synthetic insecticides and botanical materials found effective for their larvicidal action were further tested for ovicidal action. For the purpose, an experiment was conducted in completely randomized design (CRD) with fourteen treatments viz., dimethoate, chlorpyriphos, endosulfan, acephate, fenvalerate, triazophos, butacarboxim, quinalphos, carbaryl, repelin, nicotine sulphate, neem seed kernel suspension, neem oil and control. Each treatment was replicated three times. Details of the treatments are given in Table 2.

For the studies on ovicidal action, 24 to 36 hrs. old eggs were used. The eggs in group of ten were transferred with utmost care on the glass slides measuring 7.5 cm x 2.5 cm with the help of fine camel hair brush and such one slide was considered as one replication. The spray suspension of respective treatments was applied with the help of Potter's tower at a constant air pressure (2.5 kg/sq. cm). Water spray was given in the control treatment. Glass slides were thoroughly dried and placed in a glass petri dish.

The eggs were observed everyday under bionocular stereoscopic microscope and from observations on egg hatching for each treatment were recorded for one week. Eggs which did not hatch during this period were considered to be toxified i.e. dead. The per cent egg mortality was worked out after 1 week. The data on per cent egg mortality were
subjected to ANOVA (Completely Randomized Design) after following arcsin transformation.

3.4.2 Field experiment

The treatments, both of synthetic insecticides and botanical materials found effective in laboratory condition were further tested in the field. The trial was conducted at the Horticulture Farm, B.A.College of Agriculture, Gujarat Agricultural University, Anand Campus, Anand during the year 1992-93. The experiment was carried out following randomized block design (RBD) with fifteen treatments viz., dimethoate, chlorpyriphos, endosulfan, fluvalinate, acephate, fenvalerate, triazophos, butacarboxim, quinalphos, carbaryl, repelin, nicotine sulphate, neem seed kernel suspension, neem oil and control. Each treatment was replicated three times considering one tree as one replication. Details of the treatments are given in Table 2.

With the appearance of pest population in field, ten randomly selected twigs per tree each twig with one larva were tagged for observation on larval mortality after spray. The spray suspension of respective treatments was made as per required concentration in 5 litre of water per tree. The application of suspension was made with the help of knapsack sprayer on each tree. Observations on larval mortality were recorded one, two, three and seven days after spray and percent larval mortality was calculated for different time interval. The data so obtained were subjected to ANOVA (Randomized Block Design) after following arcsin transformation.
RESULTS
&
DISCUSSION
CHAPTER - IV

RESULTS AND DISCUSSION

The results of the investigations on various aspects of citrus leaf roller, *P. zizyphi* carried out in the laboratory as well as in the field are presented and discussed in this chapter.

4.1 STUDIES ON POPULATION DYNAMICS OF *P. ZIZYPHI* ON KAGZILIME

The present investigation was conducted at Horticulture Farm, B.A. College of Agriculture, Anand to study the population dynamics of *P. zizyphi* on Kagzilime in relation to weather parameters.

The data on incidence of pest was recorded at weekly intervals on ten trees of Kagzilime starting from October, 1992 to September, 1993 and they are presented in Table 3 and depicted in Fig. 1.

Correlation studies and step regression studies between weather parameters and incidence of pest was also worked out. The correlation matrixs of pest incidence with respect to weather parameters are given in Table 4 and Fig.1, while step regression equations and $R^2$ values to predict pest incidence on the basis of weather parameters having significant correlation are given in Table 5.

4.1.1 Seasonal incidence

It can be seen from the data presented in Table 3 and depicted in Fig. 1 that the larval population of *P. zizyphi* was found fluctuating during different months and ranged
<table>
<thead>
<tr>
<th>Month Year</th>
<th>Std. week</th>
<th>No. of larvae per 250 twigs per 10 trees</th>
<th>Temperature °C</th>
<th>Average vapour pressure (mm)</th>
<th>Relative humidity (%)</th>
<th>Sun shine hours</th>
<th>Total rainfall (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Max.</td>
<td>Min.</td>
<td>Av.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Oct.'92</td>
<td>40</td>
<td>27</td>
<td>36.43</td>
<td>23.43</td>
<td>29.92</td>
<td>18.19</td>
<td>57.52</td>
</tr>
<tr>
<td></td>
<td>41</td>
<td>51</td>
<td>32.53</td>
<td>22.19</td>
<td>27.29</td>
<td>17.95</td>
<td>70.53</td>
</tr>
<tr>
<td></td>
<td>42</td>
<td>41</td>
<td>33.70</td>
<td>19.60</td>
<td>28.08</td>
<td>18.12</td>
<td>65.54</td>
</tr>
<tr>
<td></td>
<td>43</td>
<td>38</td>
<td>33.36</td>
<td>17.56</td>
<td>25.46</td>
<td>12.34</td>
<td>53.40</td>
</tr>
<tr>
<td>Nov.'92</td>
<td>44</td>
<td>12</td>
<td>33.41</td>
<td>16.47</td>
<td>24.94</td>
<td>10.82</td>
<td>48.00</td>
</tr>
<tr>
<td></td>
<td>45</td>
<td>07</td>
<td>32.87</td>
<td>14.00</td>
<td>23.43</td>
<td>8.59</td>
<td>42.30</td>
</tr>
<tr>
<td></td>
<td>46</td>
<td>09</td>
<td>32.33</td>
<td>18.31</td>
<td>25.32</td>
<td>13.89</td>
<td>58.34</td>
</tr>
<tr>
<td></td>
<td>47</td>
<td>06</td>
<td>29.94</td>
<td>13.21</td>
<td>21.58</td>
<td>10.06</td>
<td>55.52</td>
</tr>
<tr>
<td>Dec.'92</td>
<td>48</td>
<td>14</td>
<td>30.97</td>
<td>13.40</td>
<td>22.18</td>
<td>10.35</td>
<td>56.73</td>
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Fig. 1 Weekly incidence of P. zizyphi in relation to different weather parameters
between 00.00 and 83.00 larvae per 250 twigs per 10 trees in different weeks. The pest did not remain active throughout the year. The population of the pest was found absent or negligible after second week of March till May. While, higher activity of the pest i.e., more than 25 larvae per 250 twigs was found in October, from third week of June till July end, in fifth week of August and in third and fourth weeks of September. There were four higher peaks i.e., more than 50 larvae per 250 twigs, first in second week of October (51 larvae), second in fourth week of June (83 larvae), third in third week of July (62 larvae) and fourth in fifth week of August (64 larvae). During remaining periods, the pest was found to remain at lower level i.e., less than 25 larvae per 250 twigs. Thus, the pest has been observed to remain at higher level during monsoon.

The population of P. zizyphi has been reported to remain higher during monsoon season from August to January in Maharashtra (Margabandhu, 1933), from July to September in Madhya Pradesh (Gupta, 1954) and from June to August and May to June in Punjab (Batra and Sandhu, 1979; Batra and Sharma, 1987; Sharma and Batra, 1987, 1988 and 1989a and Anonymous, 1991). The above reports on higher activity of the pest during monsoon almost tally with present findings. However, Davis (1965) has reported the higher infestation of P. zizyphi during November to March in Queensland, which differed from the present findings. This might be due to different climatic/ecological factors prevailing in the area.
4.1.2 Correlation with weather parameters

It is evident from the data presented in Table 4 that the pest population had exhibited significant positive correlation at 5 per cent level of significance with minimum temperature ($X_2$), average vapour pressure ($X_4$) and relative humidity ($X_5$) indicating that an increase in above weather parameters tend to increase the infestation of the pest significantly and vice versa. Highly significant negative correlation was observed between the pest incidence and sunshine hours ($X_6$) indicating that an increase in sunshine hours tend to decrease the incidence of the pest significantly and vice versa (Fig. 1). The correlation with maximum temperature ($X_1$), average temperature ($X_3$) and total rainfall ($X_7$) was non-significant indicating that there was no significant effect of these parameters on the fluctuation of the pest.

A very little work has been done elsewhere on the correlation among P. zizyphi and weather parameters as evident from the review of literature. However, at Ludhiana in Punjab, Sharma and Batra (1989a) have reported positive correlation between mean temperature and citrus leaf roller population. Relative humidity had no significant effect on pest population. During present investigation, a positive correlation between the pest and relative humidity as well as minimum temperature and average vapour pressure has been observed, while negative correlation has been found with
Table 4: Correlation matrix of \textit{P. zizyphi} population with respect to weather parameters

<table>
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<tr>
<th>Pest population</th>
<th>(X_1)</th>
<th>(X_2)</th>
<th>(X_3)</th>
<th>(X_4)</th>
<th>(X_5)</th>
<th>(X_6)</th>
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<td>Citrus leaf roller (Y)</td>
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<td>0.0328</td>
<td>0.4379*</td>
<td>0.4562*</td>
<td>-0.3177*</td>
<td>0.2266</td>
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</table>

* Significant at 5 per cent level.

Legend:

\(Y\) = Larval population/250 twigs.
\(X_1\) = Maximum temperature
\(X_2\) = Minimum temperature
\(X_3\) = Average temperature
\(X_4\) = Average vapour pressure
\(X_5\) = Relative humidity
\(X_6\) = Sunshine hours
\(X_7\) = Total rainfall
sunshine hours. Thus, present results differed from above report might be due to different interaction between weather parameters and pest population at different place.

4.1.3 Regression with weather parameters

The result of the step regression analysis presented in Table 5 indicated that out of all abiotic factors, relative humidity was found most influencing factor with coefficient of determination ($R^2$) 0.2081 showing that 20.81 per cent variation in the population of P. zizyphi was contributed by this factor. The prediction equation for pest incidence in respect of most influential factor was:

$$Y = -51.61 + 1.34 X_5$$

Where, $Y$ = larval population per 250 twigs per 10 trees and $X_5$ = relative humidity.

Sharma and Batra (1989a) reported 40.25 per cent variation in larval population due to mean temperature. However, in present investigation relative humidity is found to be the most influencing factor for variation in pest population.

4.2 STUDIES ON LARVAL PARASITOIDS OF P. ZIZYPHI

During present investigation the larvae were found parasitised by an Ichneumonid, Pristomerus marginicollis Cameron and Braconid, Apanteles sp. In Queensland, Davis (1965) has reported an Ichneumonidae parasite (Pristomerus sp.) from the larvae of P. zizyphi. At Ludhiana, in Punjab, Batra and Sandhu (1979) have noted Apanteles sp.,
Table 5: Stepwise regression analysis and $R^2$ value between citrus leaf roller and weather parameters

<table>
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<th>Multiple regression equation</th>
<th>Multiple correlation coefficient (r)</th>
<th>$R^2$</th>
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<tr>
<td>$Y = -51.61 + 1.34 X_5$</td>
<td>0.46</td>
<td>0.2081</td>
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Legend: $Y = \text{Larval population}/250 \text{ twigs}$

$X_5 = \text{Relative humidity}$
Plate III: Pupae and adults of *P. marginicollis*

Plate IV: Adults and pupae of *Apanteles sp.*
Pristomerus sp. and Brachymeria euploeae Westwood (Chalcidoidea) parasitising the pest. Moreover, in Punjab, Sharma and Batra (1989b) reported three parasites viz., Pristomerus sp., Mesochorus sp. and Apanteles machaeralis Wilkinson parasitising the larvae. Nagalingam (1991) has reported Ophion triangularemaculatus (Ichneumonidae), Goniozus sp. and Apanteles sp. parasitising *P. zizyphi* in Andhra Pradesh. While, during present investigation at Anand in Gujarat, *P. zizyphi* was found parasitised by *P. marginicollis* and Apanteles sp. The parasites viz., *B. euploeae* reported by Batra and Sandhu (1979) in Punjab, Mesochorus sp. reported by Sharma and Batra (1989b) in Punjab and O. triangularemaculatus and Goniozus sp. reported by Nagalingam (1991) in Andhra Pradesh have not been reported at Anand in Gujarat.

In order to estimate the extent of natural parasitism caused by these two parasites a survey was carried out at Horticulture Farm, G.A.U., Anand. The larvae of *P. zizyphi* were collected at weekly interval from the field and reared till the larvae completed the development or yielded parasites. The extent of natural parasitism by these two parasites and total per cent parasitism were assessed and result obtained are presented in Table 6 and graphically depicted in Fig. 2, 3 and 4.
Correlation studies and step regression studies among weather parameters, host population and parasitoids was also worked out. The correlation matrix of parasitoids with respect to weather parameters and host population are given in Table 7 and depicted in Fig. 2, 3, 4 and 5, while step regression equations and \( R^2 \) values to predict parasitoids activity on the basis of weather parameters having significant correlation are given in Table 8.

4.2.1 Seasonal activity of larval parasitoids

The data on per cent parasitism by parasitoids during study period indicated that the larval mortality due to natural parasitism by *P. marginicollis* ranged between 00.00 to 60.27 per cent in different weeks. The per cent parasitism by *P. marginicollis* was found absent in fifth week of December, second week of February and from third week of March till May. Higher activity of this parasite i.e., more than 50 per cent parasitism was found in month of October and in fourth week of September. The per cent parasitism ranged between 10 to 30 per cent during June (except second week of June) and in fourth and fifth week of August. During remaining periods per cent parasitism ranged between 30 to 50 per cent (Table 6 and Fig. 2).

The per cent parasitism due to the parasite, *Apanteles* sp. ranged between 00.00 to 30.00 per cent during different weeks. It was found absent in second and fourth week of November, from the month of December upto May, in second
Table 6: Percentage parasitism on *P. zizyphi* larvae by different parasites in Kagzilime

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<th>Month Year</th>
<th>Std. No. of larvae observed</th>
<th>Month</th>
<th>Per cent parasitism by <em>Pristomerus marginicollis</em></th>
<th>Month</th>
<th>Per cent parasitism by <em>Apanteles sp.</em></th>
<th>Total per cent parasitism</th>
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week of June, in first week of August and in second week of September. Higher activity of the parasite i.e., more than 20 per cent parasitism was found during July and in fifth week of August. During remaining periods the per cent parasitism ranged between 1.00 to 20.00 per cent (Table 6 and Fig. 3).

The data on total per cent parasitism during different periods (Table 6 and Fig. 4) indicated that the larval mortality due to parasitoids ranged between 00.00 to 66.67 per cent. The activity of both the parasitoids was found absent in fifth week of December, second week of February and from third week of March till May. Higher total per cent parasitism i.e., more than 50 per cent parasitism was found in month of October, in July and in third and fourth week of September. The total per cent parasitism ranged between 10 to 30 per cent in first and third week of June. During remaining periods, the total per cent parasitism ranged between 30 to 50 per cent.

Thus, from the result, it is clear that the activity of the parasites was observed with the appearance of host population. The seasonal activity of the parasitoids was found maximum during monsoon season. It was due to the fact that parasitisation depended upon the pest population and it was higher during this period. It is also inferred from the result that P. marginicollis was found as major larval parasite while, Apanteles sp. was major larval parasite and these parasitoids exercised considerable natural check on the population build up of the pest.
Fig. 3 Per cent parasitism by *Apanteles* sp. during different months (1992-93) in relation to weather parameters.
Fig. 4 Total per cent parasitisation by parasitoids in relation to weather parameters
In Punjab, it has been reported that the parasitisation was increased with an increase in larval population and it was maximum during monsoon (Sharma and Batra, 1989b and Anonymous, 1991). These reports are in close confirmation with present findings.

4.2.2 Correlation with weather parameters and host population

It is evident from the data presented in Table 7 that the per cent parasitism due to P. marginicollis had exhibited significant negative correlation with maximum temperature ($X_1$) at 5 per cent level of significance. This revealed that as the maximum temperature increased, the activity of the P. marginicollis decreased significantly and vice versa (Fig. 2). The correlation with minimum temperature ($X_2$), average temperature ($X_3$), average vapour pressure ($X_4$), relative humidity ($X_5$), sunshine hours ($X_6$) and total rainfall ($X_7$) was non-significant.

The correlation of per cent parasitism by Apanteles sp. with minimum temperature ($X_2$), average vapour pressure ($X_4$), relative humidity ($X_5$) and total rainfall ($X_7$) was positive and significant at 5 per cent level of significance indicating that as the above variables ($X_2$, $X_4$, $X_5$ and $X_7$) increased the activity of the Apanteles sp. also increased and vice versa. A significant negative correlation was observed between sunshine hours ($X_6$) and the per cent parasitism due to Apanteles sp. indicating that as sunshine hours increased, the activity of the Apanteles sp. decreased.
Table 7: Correlation matrix of parasitoids with respect to weather parameters and host population

<table>
<thead>
<tr>
<th>Parasite incidence</th>
<th>Temperature °C</th>
<th>Average vapour pressure</th>
<th>Relative humidity (%)</th>
<th>Sun shine hours</th>
<th>Total rainfall (mm)</th>
<th>Host population</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Max.</td>
<td>Min.</td>
<td>Av.</td>
<td>X4</td>
<td>X5</td>
<td>X6</td>
</tr>
<tr>
<td>Pristomerus marginicollis</td>
<td>Y1</td>
<td>-0.2713*</td>
<td>-0.1091</td>
<td>-0.1028</td>
<td>-0.0611</td>
<td>0.1317</td>
</tr>
<tr>
<td>Apanteles sp.</td>
<td>Y2</td>
<td>0.0689</td>
<td>0.5751*</td>
<td>0.2084</td>
<td>0.6490*</td>
<td>0.5972*</td>
</tr>
<tr>
<td>Total per cent parasitism</td>
<td>Y3</td>
<td>-0.2207</td>
<td>0.1212</td>
<td>-0.0164</td>
<td>0.1931</td>
<td>0.3488*</td>
</tr>
</tbody>
</table>

* Significant at 5 per cent level.
and vice versa (Fig. 3). The correlation of the per cent parasitism by *Apanteles* sp. with maximum temperature \( (X_1) \) and average temperature \( (X_3) \) was non-significant.

Total per cent parasitisation had significant positive correlation with relative humidity \( (X_5) \) at 5 per cent level of significance indicating that as the above weather parameter increased, total per cent parasitism also increased and vice versa. Sunshine hours \( (X_6) \) had significant negative correlation with total per cent parasitism, which revealed that as the sunshine hours increased, the total per cent parasitisation decreased and vice versa (Fig. 4). The correlation of total per cent parasitism with maximum temperature \( (X_1) \), minimum temperature \( (X_2) \), average temperature \( (X_3) \), average vapour pressure \( (X_4) \) and total rainfall \( (X_7) \) was non-significant.

The per cent parasitism by *Apanteles* sp. had significantly positive correlation with host population at 5 per cent level of significance. This revealed that as the population of pest increased, the parasitism by the *Apanteles* sp. was increased and vice versa (Fig. 5). While, correlation of host population with the per cent parasitism by *P. marginicollis* as well as with total per cent parasitism was non-significant.

As per available literature, a very little work has been done on correlation of per cent parasitisation with respect to weather parameters and host population. At
Fig. 5 Population fluctuation of _P. zizyphi_ in relation to parasitoids
Ludhiana (Punjab), it has been reported that mean temperature (30°C) and relative humidity (73.0 per cent) were favourable for high parasitisation of pest but these two factors independently had no significant effect on parasitisation (Anonymous, 1991). During present investigation, relative humidity has been found to have significant positive effect on total parasitisation. Sharma and Batra (1989a) have reported significant positive correlation between pest population and per cent parasitisation. During present investigation a significant positive correlation has been observed between pest population and the per cent parasitism by *Apanteles* sp. The pest population had also positive correlation with the per cent parasitism by *P. marginicollis* and with total per cent parasitism but it was non-significant. Thus, the present results on correlation of pest population with parasitoids more or less tally with the above report.

4.2.3 Regression with weather parameters

The results of step regression analysis presented in Table 8 indicated that out of all abiotic factors, maximum temperature (*X*_1) was found most influential factor with coefficient of determination *R*^2_ = 0.0736 showing that 7.36 per cent variation in *P. marginicollis* activity was due to variation in maximum temperature. The prediction equation obtained in relation to weather parameter was:

\[ Y_1 = 0.99 - 0.02 X_1 \]
Table 8: Stepwise regression analysis and $R^2$ values between parasitoids and weather parameters

<table>
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<tr>
<th>Multiple regression equation</th>
<th>Multiple correlation coefficient $(r)$</th>
<th>$R^2$</th>
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</thead>
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<tr>
<td>$Y_1 = 0.99 - 0.02 X_1$</td>
<td>- 0.27</td>
<td>0.0736</td>
</tr>
<tr>
<td>$Y_2 = -0.02 + 0.01 X_2 - 0.01 X_4 + 0.001 X_7$</td>
<td>0.79</td>
<td>0.6282</td>
</tr>
<tr>
<td>$Y_3 = -0.01 + 0.01 X_5$</td>
<td>0.35</td>
<td>0.1217</td>
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</table>

Legend:
- $Y_1$ = % parasitism by *Pristomeres marginicollis* Cameron
- $Y_2$ = % parasitism by *Apanteles* sp.
- $Y_3$ = Total per cent parasitisation
- $X_1$ = Maximum temperature
- $X_2$ = Minimum temperature
- $X_4$ = Average vapour pressure
- $X_5$ = Relative humidity
- $X_7$ = Total rainfall
Where, $Y_1$ = per cent parasitism due to *P. marginicollis* and $X_1 =$ maximum temperature.

In case of *Apanteles* sp., minimum temperature ($X_2$), average vapour pressure ($X_4$) and total rainfall ($X_7$) were found most influencing factors and they collectively contributed 62.82 per cent variation ($R^2 = 0.6282$) in per cent parasitism by *Apanteles* sp. The prediction equation worked out in relation to weather parameters for per cent parasitism by *Apanteles* sp. was:

$$Y = -0.02 + 0.01 X - 0.01 X + 0.001 X$$

Where, $Y_2$ = per cent parasitism due to *Apanteles* sp., $X_2$ = minimum temperature, $X_4$ = average vapour pressure and $X_7$ = total rainfall.

As regard the relation of total per cent parasitism with weather parameters, only relative humidity ($X_5$) was found most influencing factor and it was responsible for variation in total per cent parasitism to the extent of 12.17 per cent ($R^2 = 0.1217$). The prediction equation for the total per cent parasitism in respect to most influencing factor was:

$$Y_3 = -0.01 + 0.01 X_5$$

Where, $Y_3$ = total per cent parasitism and $X_5$ = relative humidity.

It has been reported that a total of 81 per cent variation in parasitisation was being controlled by the combined effect of two variables viz., mean temperature and
relative humidity, which independently had no significant effect on parasitisation (Anonymous, 1991). During present investigation only relative humidity has been found influencing factor and it contributed 12.17 per cent variation in total per cent parasitisation.

4.3 SCREENING OF ACIDLIME (C. AURANTIFOLIA) VARIETIES/GERMPLASMS FOR THEIR RESISTANCE TO P. ZIZYPHI

To determine the varietal resistance/tolerance ability among the available cultivars/varieties of Acidlime (C. aurantifolia) a survey on population of P. zizyphi infesting eight different Acidlime varieties (Maxican lime, Coorglime; Pariyaculum lime; Tirupatti lime, Seedless lime; Jumakhiya lime; Adinima lime and Kagzilime) was conducted at Horticulture Farm, B.A. College of Agriculture, Anand Campus, Anand and the data generated are presented in Table 9 and depicted in Fig. 6.

It is evident from the ANOVA (Table 9) that the interaction: variety (V) x period (P) was significant indicating that the different varieties of Acidlime did not performed consistently at different period of observation. The infestation of P. zizyphi did not remain at same level at different period of observation as the source, period (P) was significant. Further, it is clear from the ANOVA that the source variety (V) was significant indicating that all the varieties showed varying degree of susceptibility against the pest. The data on mean larval population over 52
Table 9: Periodical population of *P. zizyphi* per 5 twigs per tree in different varieties of Acidlime (1992-93)

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<th>Coorg lime</th>
<th>Pariyaculum lime</th>
<th>Tirupatti lime</th>
<th>Seedless lime</th>
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(0.25) (0.25) (0.32) (0.28) (0.04) (0.30) (0.10) (0.21)

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**Figures in parentheses are retransformed values while those outside are \(\sqrt{x+1}\) transformed values.
Fig. 6 Incidence of *P. zizyphi* in different varieties of acidlime.

The bar chart shows the mean larval number per tree for different varieties of lime. The varieties listed from left to right are: Seedless lime, Adinima lime, Kaggilime, Mexican lime, Coorglime, Tirupatti lime, Jumakhiya lime, and Parlya-culum lime. The vertical axis represents the mean larval number per tree, ranging from 0 to 0.35.
periods showed that Seedless lime recorded the lowest mean larval number (0.04 larvae per 5 twigs) and it was statistically at par with Adinima lime which recorded 0.10 larvae per 5 twigs. These two varieties were significantly less infested than rest of the varieties. Pariyaculum lime recorded maximum mean larval population (0.32 larvae per 5 twigs) indicating its higher susceptibility to the pest. However, it was statistically at par with Jumakhiya lime (0.30 larvae per 5 twigs), Tirupatti lime (0.28 larvae per 5 twigs), Maxican lime (0.25 larvae per 5 twigs) and Coorglime (0.25 larvae per 5 twigs) but differed significantly from Seedless lime and Adinima lime. Kagzilime recorded 0.21 larvae per 5 twigs which was significantly more susceptible to the pest than varieties Seedless lime and Adinima lime but was at par with Coorglime, Maxican lime and Tirupatti lime while significantly less susceptible than varieties Jumakhiya lime and Pariyaculum lime. The order of susceptibility of different varieties was Pariyaculum lime > Jumakhiya lime > Tirupatti lime > Maxican lime = Coorglime < Kagzilime > Adinima lime > Seedless lime.

Thus, from the result it is clear that Seedless lime and Adinima lime were comparatively less susceptible while Pariyaculum lime and Jumakhiya lime were comparatively more susceptible to the pest. The varieties Kagzilime, Coorglime, Maxican lime and Tirupatti lime were mediocre in their susceptibility to *P. zizyphi*. 
4.4 BIO-EFFICACY OF DIFFERENT INSECTICIDES AGAINST P. ZIZYPHI

To evaluate various insecticides for their larvicidal efficacy against P. zizyphi, two separate experiments, one with synthetic insecticides and second with botanical materials were conducted in the laboratory at Department of Entomology, B.A. College of Agriculture.

The synthetic insecticides and botanical materials found effective in laboratory conditions against the larvae of P. zizyphi were further evaluated in the laboratory for their ovicidal action as well as against the larvae of P. zizyphi in field at Horticulture Farm, Anand during the year 1992-93.

4.4.1 Evaluation of synthetic insecticides in laboratory

Eleven conventional synthetic insecticides viz., etrafolan @ 0.05%, dimethoate @ 0.03%, chlorpyrifos @ 0.05%, endosulfan @ 0.07%, fluvalinate @ 0.005%, acephate @ 0.075%, fenvalerate @ 0.01%, triazophos @ 0.1%, butacarboxim @ 0.005%, quinalphos @ 0.05% and carbaryl @ 0.2% along with control (water spray) were evaluated against the larvae of P. zizyphi. The data on corrected percentage mortality of larvae obtained in various treatments after 6, 18 and 36 hrs. of spray application are presented in Table 10.

It can be seen from the data (Table 10) that there was significant difference among various treatments after 6 hours of their application. The order of their effectiveness
Table 10: Laboratory assessment of various insecticides against the larvae of *P. zizyphi*

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<th>Converted percentage mortality of larva after indicated hours of treatment</th>
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<td>(49.96)</td>
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<td>(64.48)</td>
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<td>(99.97)</td>
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<td>(79.13)</td>
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<td>(64.40)</td>
</tr>
<tr>
<td>9.</td>
<td>Butacarboxim</td>
<td>0.005</td>
<td>77.04ab</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(94.97)</td>
</tr>
<tr>
<td>10.</td>
<td>Quinalphos</td>
<td>0.05</td>
<td>57.89d</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(71.74)</td>
</tr>
<tr>
<td>11.</td>
<td>Carbaryl</td>
<td>0.2</td>
<td>53.53ed</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(64.67)</td>
</tr>
</tbody>
</table>

S.Em. + 4.11  3.13  1.65  
C.D. at 5% 11.99  9.13  4.82  
C.V. % 12.67  7.23  3.68

* /Arcsin√percentage transformed values.  
** Figures in parentheses are retransformed values. 
Figures with same letters are at par at 5% level of significance.
was fluvalinate 0.005% > fenvalerate 0.01% > butacarboxim 0.005% > endosulfan 0.07% > acephate 0.075% > quinalphos 0.05% > carbaryl 0.2% > chlorpyriphos 0.05% > triazophos 0.1% > dimethoate 0.03% > etrafolan 0.05%. The treatment of fluvalinate 0.005% recording maximum larval mortality (99.97 per cent) was statistically at par with fenvalerate 0.01% and butacarboxim 0.005% but it was significantly superior over rest of the insecticides. Etrafolan 0.05% recording lowest larval mortality (17.86 per cent) was significantly inferior to other insecticides. The treatments of triazophos 0.1%, chlorpyriphos 0.05% and carbaryl 0.2% were at par with each other as well as with dimethoate 0.03%, quinalphos 0.05% and acephate 0.075%. Endosulfan 0.07% was at par with acephate 0.075%, butacarboxim 0.005% and fenvalerate 0.01%.

After 18 hours of treatment, the order of effectiveness was fluvalinate 0.005% = fenvalerate 0.01% = butacarboxim 0.005% = endosulfan 0.07% = acephate 0.075% = quinalphos 0.05% = carbaryl 0.2% = chlorpyriphos 0.05% > triazophos 0.1% > dimethoate 0.03% > etrafolan 0.05%. Etrafolan 0.05% recording lowest larval mortality (27.56 per cent) was significantly inferior to rest of the insecticides. Dimethoate 0.03% was next least effective but was significantly superior than etrafolan 0.05% while inferior to rest of the insecticides. Chlorpyriphos 0.05%, carbaryl 0.2%, quinalphos 0.05%, acephate 0.075%, endosulfan 0.07%, butacarboxim 0.005%, fenvalerate 0.01% and fluvalinate 0.005%
recording equal larval mortality (99.97 per cent) were at par with each other as well as with triazophos 0.1% recording 98.25 per cent mortality.

After 36 hours of spray application, all the treatments except etrafolan 0.05% were found equally effective recording 99.97 per cent mortality. Etrafolan 0.05% recording lowest larval mortality (47.33 per cent) was significantly inferior to rest of the insecticides.

4.4.2 Evaluation of botanical materials in laboratory

Twelve botanical materials viz., repelin @ 1.0%, nicotine sulphate @ 0.05%, nimbicidine @ 0.2%, acheok @ 1.0%, parshmani @ 0.2%, azadirechtin @ 0.4% (NTGCF product), neem seed kernel suspension (NSKS) @ 2.0%, neem leaf extract (NLE) @ 5.0%, neem oil @ 1.0%, fudina leaf extract (FLE) @ 3.0%, mint leaf dry powder suspension (MLDPS) @ 0.2% and ardusa leaf extract (ALE) @ 5.0% were evaluated alongwith control (water spray) for their larvicidal action against P. zizyphi. The data on per cent mortality of larvae obtained after 6, 24 and 48 hours of treatment are presented in Table 11.

It is evident from the data (Table 11) that the results were non-significant at 6 hours after application and there was no significant difference among various treatments. However, the different treatments were significantly differing at 24 hours and 48 hours of application.
<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Treatments</th>
<th>Conc. (%)</th>
<th>Percentage mortality of larva after indicated hours of treatment</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Repelin</td>
<td>1.0</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>15.32* (6.98)** (39.13) (%) (39.83)</td>
</tr>
<tr>
<td>2.</td>
<td>Nicotine sulphate</td>
<td>0.05</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>15.32 (6.98) (34.91) a (32.75)</td>
</tr>
<tr>
<td>3.</td>
<td>Nimbicidine</td>
<td>0.2</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>8.60 (1.40) (15.32) bcde (6.98)</td>
</tr>
<tr>
<td>4.</td>
<td>Acheok</td>
<td>1.0</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>0.99 (0.03) (18.03) bcd (9.58)</td>
</tr>
<tr>
<td>5.</td>
<td>Parshmani</td>
<td>0.2</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>0.99 (0.03) (15.32) bcde (6.98)</td>
</tr>
<tr>
<td>6.</td>
<td>Azadirachtin NTGCF product</td>
<td>0.4</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>0.99 (0.03) (15.32) bcde (6.98)</td>
</tr>
<tr>
<td>7.</td>
<td>Neem seed kernel susp NSKS</td>
<td>2.0</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>6.80 (1.40) (23.84) ab (16.34)</td>
</tr>
<tr>
<td>8.</td>
<td>Neem leaf extract NLE</td>
<td>5.0</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>0.99 (0.03) (0.99) e (0.03)</td>
</tr>
<tr>
<td>9.</td>
<td>Neem oil</td>
<td>1.0</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>6.80 (1.40) (28.77) ab (23.16)</td>
</tr>
<tr>
<td>10.</td>
<td>Fudina leaf extract FLE</td>
<td>3.0</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>0.99 (0.03) (12.61) bcde (4.77)</td>
</tr>
<tr>
<td>11.</td>
<td>Mint leaf dry powder susp ML DPS</td>
<td>2.0</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>0.99 (0.03) (9.51) cde (2.73)</td>
</tr>
<tr>
<td>12.</td>
<td>Arduza leaf extract ALE</td>
<td>5.0</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>0.99 (0.03) (6.80) de (1.40)</td>
</tr>
<tr>
<td>13.</td>
<td>Control</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>0.99 (0.03) (0.99) e (0.03)</td>
</tr>
</tbody>
</table>

S.E.m. + C.D. a b e 5% C.V. %
4.07 16.84 155.23
5.79 14.49 58.86
9.51 16.49 58.86
4.98 14.49 58.25

* Arcsine transformed values.
** Figures in parentheses are retransformed values.
Figures with same letters are at par at 5% level of significance.
After 24 hours of treatment, the order of effectiveness of various treatments was repelin 1.0% > nicotine sulphate 0.05% > neem oil 1.0% > NSKS 2.0% > acheok 1.0% > nimbicidine 0.2% = parshmani 0.2% = azadirechtin 0.4% (NTGCF product) > FLE 3.0% > MLDPS 2.0% > ALE 5.0% > NLE 5.0% = control. The treatment of repelin 1.0% recording maximum larval mortality (39.83 per cent) was statistically at par with the treatments of nicotine sulphate 0.05%, neem oil 1.0% and NSKS 2.0% but significantly superior over rest of the treatments. The treatment of NLE 5.0% recording lowest per cent mortality (0.03 per cent) was not effective as it was at par with control. The treatments, nimbicidine 0.2%, parshmani 0.2%, azadirechtin 0.4% (NTGCF product), FLE 3.0%, MLDPS 2.0%, ALE 5.0% and NLE 5.0% were also not effective as they were at par with control. The treatment of acheok 1.0% was at par with NSKS 2.0%, neem oil 1.0%, nimbicidine 0.2%, parshmani 0.2%, azadirechtin 0.4% (NTGCF product) and FLE 3.0%.

After 48 hours of spray application, the order of effectiveness of various treatments was repelin 1.0% > nicotine sulphate 0.05% > neem oil 1.0% > NSKS 2.0% > nimbicidine 0.2% = acheok 1.0% = parshmani 0.2% = azadirechtin 0.4% (NTGCF product) > FLE 3.0% = MLDPS 2.0% = NLE 5.0% = ALE 5.0% = control. The treatment of repelin 1.0% recording maximum larval mortality (70.29 per cent) was statistically at par with nicotine sulphate 0.05% and neem oil 1.0% but
was significantly superior over rest of the treatments. The treatments of ALE 5.0%, NLE 5.0%, MLDPS 2.0% and FLE 3.0% were less effective as they were at par with control. Nimbicidine 0.2% and acheok 1.0% recording equal per cent mortality (19.30 per cent) were at par with NSKS 2.0%, parshmani 0.2%, azadirechtin 0.4% (NTGCF product), MLDPS 2.0%, FLE 3.0% and NLE 5.0%. NSKS 2.0% and neem oil 1.0% were at par with each other as well as with nicotine sulphate 0.05%.

Thus, among the different readymade botanical formulations, repelin 1.0%, nicotine sulphate 0.05% and neem oil 1.0% were comparatively better insecticides than acheok 1.0%, nimbicidine 0.2%, parshmani 0.2% and azadirechtin 0.4% (NTGCF product). Among the different treatments of botanical extracts NSKS 2.0% was better than MLDPS 2.0%, FLE 3.0%, NLE 5.0% and ALE 5.0%. Further, it was found that the treatments of different readymade botanical formulations were better than the treatments of different botanical extracts prepared in laboratory except NSKS 2.0%.

4.4.3 Ovicidal action of synthetic insecticides and botanical materials in laboratory

It can be seen from the data on per cent egg mortality (Table 12) that the order of effectiveness of various treatments was quinalphos 0.05% > fenvalerate 0.01% > acephate 0.075% > triazophos 0.1% > chlorpyriphos 0.05% > dimethoate 0.03% = carbaryl 0.2% > endosulfan 0.07% > buta-
Table 12: Ovicidal effect of various synthetic insecticides and botanical materials on eggs of *P. zizyphi* under laboratory condition

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Treatments</th>
<th>Conc. (%)</th>
<th>Percentage mortality after one week</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Dimethoate</td>
<td>0.03</td>
<td>48.83* (56.66)**</td>
</tr>
<tr>
<td>2.</td>
<td>Chlorpyrifos</td>
<td>0.05</td>
<td>52.75 (63.36)de</td>
</tr>
<tr>
<td>3.</td>
<td>Endosulfan</td>
<td>0.07</td>
<td>41.14 (43.28)e</td>
</tr>
<tr>
<td>4.</td>
<td>Acephate</td>
<td>0.075</td>
<td>58.98 (73.44)bc</td>
</tr>
<tr>
<td>5.</td>
<td>Fenvalerate</td>
<td>0.01</td>
<td>63.41 (79.96)b</td>
</tr>
<tr>
<td>6.</td>
<td>Triazophos</td>
<td>0.1</td>
<td>56.77 (69.97)cd</td>
</tr>
<tr>
<td>7.</td>
<td>Butacarboxim</td>
<td>0.005</td>
<td>37.21 (36.57)fg</td>
</tr>
<tr>
<td>8.</td>
<td>Quinalphos</td>
<td>0.05</td>
<td>71.54 (89.97)a</td>
</tr>
<tr>
<td>9.</td>
<td>Carbaryl</td>
<td>0.2</td>
<td>48.83 (56.66)e</td>
</tr>
<tr>
<td>10.</td>
<td>Repelin</td>
<td>1.0</td>
<td>37.21 (36.57)fg</td>
</tr>
<tr>
<td>11.</td>
<td>Nicotine sulphate</td>
<td>0.05</td>
<td>32.99 (29.65)gh</td>
</tr>
<tr>
<td>12.</td>
<td>NSKS</td>
<td>2.0</td>
<td>33.20 (29.98)gh</td>
</tr>
<tr>
<td>13.</td>
<td>Neem oil</td>
<td>1.0</td>
<td>30.98 (26.49)h</td>
</tr>
<tr>
<td>14.</td>
<td>Control</td>
<td></td>
<td>0.99 (0.03)i</td>
</tr>
</tbody>
</table>

*S.Em.* +
C.D. a± 5%
C.V. %

* /Arcsin√percentage transformed values.
** Figures in parentheses are retransformed values. Figures with same letters are at par at 5% level of significance.
carboxim 0.005% = repelin 1.0% > NSKS 2.0% > nicotine sulphate 0.05% > neem oil 1.0% > control.

All the insecticidal treatments were significantly differing from each other and were superior over control. Quinalphos 0.05% recording highest egg mortality (89.97 per cent) showed its significant superiority over rest of the treatments. Neem oil 1.0% recording lowest egg mortality (26.49 per cent) was statistically at par with nicotine sulphate 0.05% and NSKS 2.0% but significantly superior over control. The treatments of butacarboxim 0.005% and repelin 1.0% were equally effective and were at par with endosulfan 0.07%, NSKS 2.0% and nicotine sulphate 0.05%. No significant difference was found in ovicidal action between fenvalerate 0.01% and acephate 0.075% and were next in effectiveness to quinalphos 0.05%. The treatment of triazophos 0.1% was at par with acephate 0.075% and chlorpyriphos 0.05%. Dimethoate 0.03% and carbaryl 0.2% were equally effective and were at par with chlorpyriphos 0.05%.

Thus, among the synthetic insecticides, quinalphos 0.05%, fenvalerate 0.01% and acephate 0.075% recording more than 70 per cent egg mortality were found to have better ovicidal action on P. zizyphi. Among botanical insecticides repelin 1.0% and NSKS 2.0% were better in their ovicidal action. Further, synthetic insecticides were found better than botanical insecticides so far their ovicidal action is concerned.
4.4.4 Evaluation of synthetic insecticides and botanical materials in field

Ten synthetic insecticides (dimethoate 0.03%, chlorpyriphos @ 0.05%, endosulfan @ 0.07%, fluvalinate @ 0.005%, acephate @ 0.075%, fenvalerate @ 0.01%, triazophos @ 0.1%, butacarboxim @ 0.005%, quinalphos @ 0.05% and carbaryl @ 0.2%) and four botanical materials (repen @ 1.0%, nicotine sulphate @ 0.05%, NSKS @ 2.0% and neem oil @ 1.0%) were evaluated for their field efficacy against *P. zizyphi*. The data obtained on percentage mortality of larvae after 1, 2, 3 and 7 days of spray application are presented in Table 13.

Looking to the results (Table 13), it is evident that all the treatments remained significantly superior over control after 1, 2, 3 and 7 days of spray application. After 1 day of treatment, the order of effectiveness of various treatments was quinalphos 0.05% > endosulfan 0.07% > acephate 0.075% > chlorpyriphos 0.05% > fluvalinate 0.005% > fenvalerate 0.01% = triazophos 0.1% > dimethoate 0.03% = butacarboxim 0.005% > carbaryl 0.2% > repelin 1.0% > nicotine sulphate 0.05% > neem oil 1.0% > NSKS 2.0% > control. Quinalphos 0.05% recording the maximum larval mortality (89.97 per cent) was statistically at par with endosulfan 0.07%, acephate 0.075% and chlorpyriphos 0.05% but differed significantly from rest of the treatments. NSKS 2.0% recording lowest larval mortality (4.77 per cent) was
Table 13: Bio-efficacy of various synthetic insecticides and botanical materials against the larva of citrus leaf roller, *P. zizyphi* in field condition

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Treatments</th>
<th>Conc. (%)</th>
<th>% mortality of larva after indicated days</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>1 day</td>
</tr>
<tr>
<td>1</td>
<td>Dimethoate</td>
<td>0.03</td>
<td>56.98* (70.30)**</td>
</tr>
<tr>
<td>2</td>
<td>Chlorpyrifos</td>
<td>0.05</td>
<td>63.90 (80.64)abc</td>
</tr>
<tr>
<td>3</td>
<td>Endosulfan</td>
<td>0.07</td>
<td>68.83 (86.96)ab</td>
</tr>
<tr>
<td>4</td>
<td>Fluvalinate</td>
<td>0.005</td>
<td>61.69 (77.51)bc</td>
</tr>
<tr>
<td>5</td>
<td>Acephate</td>
<td>0.075</td>
<td>66.12 (83.61)abc</td>
</tr>
<tr>
<td>6</td>
<td>Fenvalerate</td>
<td>0.01</td>
<td>58.98 (73.44)c</td>
</tr>
<tr>
<td>7</td>
<td>Triazophos</td>
<td>0.1</td>
<td>58.98 (73.44)c</td>
</tr>
<tr>
<td>8</td>
<td>Butachlor</td>
<td>0.005</td>
<td>56.98 (70.30)c</td>
</tr>
<tr>
<td>9</td>
<td>Quinalphos</td>
<td>0.05</td>
<td>71.54 (89.97)a</td>
</tr>
<tr>
<td>10</td>
<td>Carbaryl</td>
<td>0.2</td>
<td>56.77 (69.97)c</td>
</tr>
<tr>
<td>11</td>
<td>Repelin</td>
<td>1.0</td>
<td>28.77 (23.16)d</td>
</tr>
</tbody>
</table>

Contd...
Table 13 Contd...

<table>
<thead>
<tr>
<th></th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
</tr>
</thead>
<tbody>
<tr>
<td>12. Nicotine sulphate</td>
<td>0.05</td>
<td>26.06</td>
<td>(19.30)</td>
<td>30.98</td>
<td>f</td>
<td>(49.96)</td>
<td>g</td>
</tr>
<tr>
<td>13. NSKS</td>
<td>2.0</td>
<td>12.62</td>
<td>(4.77)</td>
<td>e</td>
<td>23.85</td>
<td>(16.35)</td>
<td>f</td>
</tr>
<tr>
<td>14. Neem oil</td>
<td>1.0</td>
<td>23.85</td>
<td>(16.35)</td>
<td>d</td>
<td>26.55</td>
<td>(19.99)</td>
<td>f</td>
</tr>
<tr>
<td>15. Control</td>
<td></td>
<td>0.99</td>
<td>(0.03)</td>
<td>f</td>
<td>0.99</td>
<td>(0.03)</td>
<td>g</td>
</tr>
<tr>
<td>S. Em. +</td>
<td></td>
<td>3.24</td>
<td></td>
<td></td>
<td>2.81</td>
<td></td>
<td></td>
</tr>
<tr>
<td>C.D. at 5%</td>
<td></td>
<td>9.37</td>
<td></td>
<td></td>
<td>8.12</td>
<td></td>
<td></td>
</tr>
<tr>
<td>C.V. %</td>
<td></td>
<td>11.78</td>
<td></td>
<td></td>
<td>9.43</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* /Arcsin√percentage transformed values.
** Figures in parentheses are retransformed values.

Figures with same letters are at par at 5% level of significance.
statistically superior over control but inferior than rest of the treatments. Neem oil 1.0% was next least effective and was at par with nicotine sulphate 0.05% and repelin 1.0%. The treatments viz., chlorpyriphos 0.05%, acephate 0.075% and fluvalinate 0.005% were at par with each other as well as with endosulfan 0.07%, fenvalerate 0.01%, triazophos 0.1%, dimethoate 0.03%, butacarboxim 0.005% and carbaryl 0.2%.

After 2 days of spraying, the order of effectiveness of various treatments was quinalphos 0.05% > acephate 0.075% > endosulfan 0.07% = chlorpyriphos 0.05% > fluvalinate 0.005% > dimethoate 0.03% > fenvalerate 0.01% = triazophos 0.1% = carbaryl 0.2% > butacarboxim 0.005% > repelin 1.0% > nicotine sulphate 0.05% > neem oil 1.0% > NSKS 2.0% > control. The treatment of quinalphos 0.05% recording maximum larval mortality (98.58 per cent) remained significantly superior over all the treatments. NSKS 2.0% recording lowest larval mortality (16.35 per cent) was least effective and was statistically at par with neem oil 1.0% and nicotine sulphate 0.05% but superior over control. The treatment of repelin 1.0% was statistically superior to NSKS 2.0%, neem oil 1.0% and nicotine sulphate 0.05% but inferior than rest of the treatment. Fluvalinate 0.005%, endosulfan 0.07% and chlorpyriphos 0.05% were at par with each other as well as with dimethoate 0.03% and acephate 0.075%. The treatments viz., carbaryl 0.2%, triazophos 0.1% and fenvalerate 0.01%
were equally effective and were at par with fluvalinate 0.005%, dimethoate 0.03% and butacarboxim 0.005%.

After 3 days of treatment, the order of effectiveness of various treatments was quinalphos 0.05% > chlorpyriphos 0.05% > acephate 0.075% > endosulfan 0.07% > fluvalinate 0.005% = dimethoate 0.03% > triazophos 0.1% > fenvalerate 0.01% = carbaryl 0.2% > butacarboxim 0.005% > repelin 1.0% = nicotine sulphate 0.05% > neem oil 1.0% > NSKS 2.0% > control. The treatment of quinalphos 0.05% recording maximum larval mortality (99.97 per cent) was statistically at par with chlorpyriphos 0.05% but significantly superior over rest of the treatments. NSKS 2.0% recording the lowest larval mortality (39.83 per cent) was statistically at par with neem oil 1.0%, nicotine sulphate 0.05% and repelin 1.0% but superior over control and inferior to rest of the treatments. Dimethoate 0.03% and fluvalinate 0.005% were equally effective and were at par with endosulfan 0.07%, acephate 0.075% and triazophos 0.1%. The treatment of acephate 0.075% was statistically at par with chlorpyriphos 0.05%, endosulfan 0.07%, dimethoate 0.03% and fluvalinate 0.005%. The treatments of fenvalerate 0.01% and carbaryl 0.2% were equally effective and were at par with triazophos 0.1% and butacarboxim 0.005%.

After 7 days of spraying, the order of effectiveness of various treatments was quinalphos 0.05% = chlorpyriphos 0.05% > acephate 0.075% > endosulfan 0.07% = dimethoate
0.03% > fluvalinate 0.005% > triazophos 0.1% > fenvalerate 0.01% = carbaryl 0.2% > butacarboxim 0.005% > repelin 1.0% > neem oil 1.0% > nicotine sulphate 0.05% > NSKS 2.0% > control. Quinalphos 0.05% and chlorpyriphos 0.05% recording maximum larval mortality (99.97 per cent) were equally effective and significantly superior over rest of the treatments. NSKS 2.0% recording the lowest larval mortality (53.47 per cent) was at par with nicotine sulphate 0.05% and neem oil 1.0% but significantly superior over control. Acephate 0.075% remained next to quinalphos 0.05% and chlorpyriphos 0.05% in its effectiveness but was at par with endosulfan 0.07% and dimethoate 0.03%. The treatments of triazophos 0.1% and fluvalinate 0.005% were at par with each other as well as with dimethoate 0.03%, endosulfan 0.07%, fenvalerate 0.01% and carbaryl 0.2% whereas, butacarboxim 0.005% was at par with fenvalerate 0.01%, carbaryl 0.2%, triazophos 0.1% and repelin 1.0%.

Thus, the data of the field experiment revealed that all the treatments were significantly superior over control. Further, it was found that botanical materials were comparatively less effective than synthetic insecticides. Among the synthetic insecticides quinalphos 0.05% and chlorpyriphos 0.05% were found better insecticides while, among botanical insecticides repelin 1.0% was comparatively better against _P. zizyphi_. 
Sandhu and Batra (1978) indicated that chlorpyriphos and monocrotophos at 0.05 per cent concentration gave complete control of *P. zizyphi* whereas, dimethoate and endosulfan were moderately effective at 0.05 per cent concentration. Batra et al. (1983) have found chlorpyriphos, monocrotophos and quinalphos @ 0.05 per cent to be very effective while fenvalerate @ 0.05 per cent was mediocre in their performance against *P. zizyphi*. Sharma and Batra (1987) have reported quinalphos 0.05% one of the best insecticide while fenvalerate 0.01% as mediocre in action against *P. zizyphi*. The above reports on chemical control more or less tally with the present results. Published information on effectiveness of botanical insecticides is scanty therefore, it could not be compared with results obtained during present investigation.
Plate V: A, B: Damaged shoots by *P. zizyphi*
   C: Healthy shoots

Plate VI: Larvae of *P. zizyphi*
SUMMARY
&
CONCLUSIONS
Investigations were carried out at Gujarat Agricultural University, Anand Campus, Anand on following aspects of citrus leaf roller, *P. zizyphi* during the year 1992-93.

1. Population dynamics of *P. zizyphi* on Kagzilime.
2. Studies on larval parasitoids of *P. zizyphi*.
3. Screening of Acidlime (C. aurantifolia) varieties/germplasms for their resistance to *P. zizyphi*.
4. Bio-efficacy of different insecticides against *P. zizyphi*.

The results derived from these investigations are summarized as under:

5.1 POPULATION DYNAMICS OF *P. ZIZYPHI* ON KAGZILIME

The larval population of *P. zizyphi* was found fluctuating during different months and ranged between 00.00 and 83.00 larvae per 250 twigs per 10 trees in different weeks. The population of pest was found absent or negligible after second week of March till May. Higher activity of the pest (more than 25 larvae per 250 twigs) was found in October, from third week of June till July end, in fifth week of August and in third and fourth weeks of September. During remaining periods, the pest was found comparatively at lower level. The pest has been observed to remain at higher level during monsoon.

The pest population had significant positive correlation with minimum temperature \( (X_2) \), average vapour pressure
(X_4) and relative humidity (X_5) while negative correlation with sunshine hours (X_6). There was no correlation between pest population and other weather parameters under study.

The step regression analysis indicated that out of all abiotic factors, only relative humidity was found most influencing factor and it contributed 20.81 per cent variation (R^2 = 0.2081) in pest population.

5.2 STUDIES ON LARVAL PARASITOIDS OF P. ZIZYPHI

The larvae of P. zizyphi were found parasitised by an Ichneumonid, Pristomerus marginicollis Cameron and Braconid, Apanteles sp. P. marginicollis was observed to be a major parasite. The per cent parasitism by P. marginicollis ranged between 00.00 to 60.27 per cent in different weeks. Its activity was found absent in fifth week of December, second week of February and from third week of March till May. Higher activity of this parasite (more than 50% parasitism) was recorded in month of October and in fourth week of September while, it was comparatively at low level (between 10 to 30 per cent) during June (except second week of June) and in fourth and fifth week of August.

The per cent parasitism by Apanteles sp. a minor parasite ranged between 00.00 to 30.00 per cent during different weeks. It was found absent in second and fourth week of November, from month of December till May, in second week of June, in first week of August and in second week of September. Higher activity of this parasite (more than 20%
parasitism) was recorded during July and in fifth week of August. During remaining periods the per cent parasitism was found comparatively low (between 1.00 to 20.00 per cent).

The total per cent parasitism due to parasitoids ranged between 00.00 to 66.67 per cent. Higher total per cent parasitism (more than 50% parasitism) was found in month of October, in July and in third and fourth week of September and found comparatively low (between 10 to 30 per cent) in first and third week of June. The parasitoids were found more active during monsoon season and per cent parasitisation increased with increase in host population.

The correlation studies with respect to weather parameters and host population indicated that per cent parasitism by *P. marginicollis* and per cent parasitism by *Apanteles* sp. had significant negative correlation with maximum temperature \((X_1)\) and sunshine hours \((X_6)\) respectively. While, per cent parasitism by *Apanteles* sp. had significant positive correlation with minimum temperature \((X_2)\), average vapour pressure \((X_4)\), relative humidity \((X_3)\) and total rainfall \((X_7)\). Total per cent parasitisation had significant positive correlation with relative humidity \((X_3)\) and significant negative correlation with sunshine hours \((X_6)\). The correlation between host population and per cent parasitism by *Apanteles* sp. was also significant. The other correlation coefficient values were non-significant.
Step regression analysis indicated that out of all abiotic factors, maximum temperature \( (X_1) \) was found most influencing factor and it contributed 7.36 per cent variation \( (R^2 = 0.0736) \) in per cent parasitism by _P. marginicollis_. In case of Apanteles sp. activity, minimum temperature \( (X_2) \), average vapour pressure \( (X_4) \) and total rainfall \( (X_7) \) were found most influencing factors and they collectively contributed 62.82 per cent variation \( (R^2 = 0.6282) \) in per cent parasitism. Only relative humidity was found most influencing factor to total per cent parasitisation and it contributed 12.17 per cent variation \( (R^2 = 0.1217) \).

5.3 SCREENING OF ACIDLIME (C. AURANTIFOLIA) VARIETIES/GERM-PLASMS FOR THEIR RESISTANCE TO _P. ZIZYPHI_

Out of eight varieties of Acidlime, Seedless lime and Adinima lime were comparatively less susceptible while, Pariya-culum lime and Jumakhiya lime were comparatively more susceptible to the pest. The varieties Kagzilime, Coorglime, Maxican lime and Tirupatti lime were mediocre in their susceptibility to _P. zizyphi_.

5.4 BIO-EFFICACY OF DIFFERENT INSECTICIDES AGAINST _P. ZIZYPHI_

Among the eleven synthetic insecticides evaluated in laboratory for larvicidal action all the insecticides (dimethoate @ 0.03%, chlorpyriphos @ 0.05%, endosulfan @ 0.07%, fluvalinate @ 0.005%, acephate @ 0.075%, fenvalerate
@ 0.01%, triazophos @ 0.1%, butacarboxim @ 0.005%, quinalphos @ 0.05% and carbaryl @ 0.2%) except etrafolan 0.05% were found significantly effective giving more than 99.00% larval mortality of *P. zizyphi* after 36 hrs. of spray application.

Among the botanical materials tested in laboratory for their larvicidal action, different readymade botanical formulations were found better than different botanical extracts except NSKS 2.0%. Among the readymade botanical formulations repelin 1.0%, nicotine sulphate 0.05% and neem oil 1.0% were found comparatively better insecticides than acheok 1.0%, nimbidicine 0.2%, parshmani 0.2% and azadirchitin 0.4% (NTGCF product). Among the botanical extracts NSKS 2.0% was found better than MLDPS 2.0%, FLE 3.0%, NLE 5.0% and ALE 5.0%.

The synthetic insecticides were found better than botanical insecticides tested for their ovicidal action against *P. zizyphi* in laboratory. Among the synthetic insecticides, quinalphos 0.05%, fenvalerate 0.01% and acephate 0.075% showed good ovicidal action than dimethoate 0.03%, chlorpyriphos 0.05%, endosulfan 0.07%, triazophos 0.1%, butacarboxim 0.005% and carbaryl 0.2%. Among the botanical insecticides repelin 1.0% and NSKS 2.0% showed good ovicidal action than nicotine sulphate 0.05% and neem oil 1.0%.

In field condition, all the insecticidal treatments were found significantly superior over control. Botanical
materials were comparatively less effective than synthetic insecticides. Among the synthetic insecticides quinalphos 0.05% and chlorpyriphos 0.05% were found better insecticides than dimethoate 0.03%, endosulfan 0.07%, fluvalinate 0.005%, acephate 0.075%, fenvalerate 0.01%, triazophos 0.1%, butacarboxim 0.005% and carbaryl 0.2%. Among the botanical insecticides repelin 1.0% was found comparatively better than nicotine sulphate 0.05%, NSKS 2.0% and neem oil 1.0%. 
REFERENCES
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* Original not seen.