BIOEFFICACY OF CHITIN SYNTHESIS INHIBITORS ALONE AND IN COMBINATION WITH CARTAP HYDROCHLORIDE AGAINST LEPIDOPTEROUS PESTS OF CABBAGE

By

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B. Sc. (Ag.)

THESIS SUBMITTED TO THE
ACHARYA N. G. RANGA AGRICULTURAL UNIVERSITY
IN PARTIAL FULFILMENT OF THE REQUIREMENTS
FOR THE AWARD OF THE DEGREE OF

MASTER OF SCIENCE IN AGRICULTURE (ENTOMOLOGY)

DEPARTMENT OF ENTOMOLOGY
COLLEGE OF AGRICULTURE
ACHARYA N. G. RANGA AGRICULTURAL UNIVERSITY
RAJENDRANAGAR, HYDERABAD-500 030, ANDHRA PRADESH

SEPTEMBER, 2004

CERTIFICATE

This is to certify that the thesis entitled **"BIOEFFICACY OF CHITIN SYNTHESIS INHIBITORS ALONE AND IN COMBINATION WITH CARTAP HYDROCHLORIDE AGAINST LEPIDOPTEROUS PESTS OF CABBAGE"** submitted in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE IN AGRICULTURE** of the **Acharya N.G. Ranga Agricultural University,** Hyderabad, is a record of the bonafide research work carried out by **Mr. CH. RAJA GOUD** under our guidance and supervision. The subject of the thesis has been approved by the Student's Advisory Committee.

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

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Place : Hyderabad **MAJOR ADVISOR**

DECLARATION

I, **CH. RAJA GOUD,** hereby declare that the thesis entitled **“BIOEFFICACY OF CHITIN SYNTHESIS INHIBITORS ALONE AND IN COMBINATION WITH CARTAP HYDROCHLORIDE AGAINST LEPIDOPTEROUS PESTS OF CABBAGE”** submitted to Acharya N.G. Ranga Agricultural University for the degree of **'MASTER OF SCIENCE IN AGRICULTURE'** is the result of original research work done by me. I further declare that the thesis or any part thereof has not been published earlier in any manner.

(CH.RAJA GOUD)

CONTENTS

ACKNOWLEDGEMENTS

It is by the unfathomable grace and blessings of **LORD SHIVA** that I have been able to bring out this humble piece of work which I am eternally indebted.

It gives me great pleasure to express unboundful gratitude to Chairman of Advisory Committee, **Dr. S. R. KOTESWARA RAO**, Associate Professor, Department of Entomology, College of Agriculture, Rajendranagar, Hyderabad. I am very lucky to get a chance as a first student of my Chairman. This materialization takes place in correct time is only due to his patience, extraordinary guidance and personal interest on my career development. I am eternally indebted for his advise, guidance during the entire period of my course work. I am thankful for this concrete suggestions that helped me in preparation of this research report.

I deem it my privilege to extol my profound gratitude and sincere thanks to **Dr. (Smt.) CH. CHIRANJEEVI**, Senior Scientist (Entomology), Vegetable Section, Agricultural Research Institute (ARI), Rajendranagar, Hyderabad and member of the Advisory Committee for her guidance during the period of this study. I am thankful for her timely help and suggestions.

I humbly place on record my gratitude to **Sri G. KRISHNA KANTH,** Assistant Professor, College of Agriculture, Department of Statistics and Mathematics, College of Agriculture, Rajendranagar, Hyderabad and member of my Advisory Committee whose constant cooperation and constructive criticism helped me to carry out research effectively.

I extend my deep sense of reverence and profound etiquette to **Dr. G. V. SUBBARATNAM**, Professor and University Head, Department of Entomology, College of Agriculture, Rajendranagar, Hyderabad for his support and encouragement during the progress of work.

I am greatly beholden beyond words to express my graceful thanks and I am splendidly indebted to **Dr. T. V. K. SINGH**, Associate Professor,

Department of Entomology, College of Agriculture, Rajendranagar, Hyderabad for his esteemed suggestions, scientific proficiency, constant encouragement and indebted help during the course of study and interpretation of results and discussion.

It gives me immense pleasure in extending my sincere feelings of gratitude to **Dr. T. B. Gour, Dr. Raman Goud, Dr. Satyanarayana, Dr. Dharma Reddy, Dr. Loka Reddy, Dr. Jagdishwar Reddy, Dr. Ch. Sreenivasa Rao, Dr. K. Vijayalakshmi, Sri Rahman** and **Dr. Swarna Sree** for their transcendent suggestions evincive criticism to embekish the study.

I am in dearth of words to express my sense of gratitude to my beloved parents **Sri. Eedhaiah Goud** and **Smt. Ramulamma** and to my sisters **Saraswathi**, **Sandhya** and **Suvarna** for their unbouding love, unparalled affection and unstinted encouragement throughout my educational career.

I feel an immense pleasure and joy in expressing my profound etiquette and intrinsic affection to my friends, **Chandrasekhar**, **Muthyalu**, **Sudhakar**, **Sadanandam**, **Balaraju**, **Hari**, **Yadagiri**, **Latheef**, **Govardhan**, **China Nag**, **Boddu**, **Venkanna**, **Vittal Rao**, **Rahul**, **Minnaiah**, **H.P.**, **Manda**, **Prabakaran** and colleagues **Nampally**, **Milind Kumar**, **Upender**, **Vasudeva Reddy**, **Abhay**, **Dilin**, **Shahanaz** and **Kavitha** and juniors **Satish Kumar**, **Cheralu** for their help and cooperation rendered to me during the course of my research.

I am grateful to the **Acharya N. G. Ranga Agricultural University** and **Government of Andhra Pradesh** for providing me the financial assistance in the form of fellowship during my post graduation study.

A word of appreciation also goes to **Mr.** and **Mrs. D. Ravi Krishna**, **Krishna Shashank Computers**, Premavathipet, Rajendranagar for their neat and timely computer typesetting in completing my thesis.

(CH. RAJA GOUD)

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Title of the thesis	:	**"BIOEFFICACY OF CHITIN SYNTHESIS INHIBITORS ALONE AND IN COMBINATION WITH CARTAP HYDROCHLORIDE AGAINST LEPIDOPTEROUS PESTS OF CABBAGE"**
Degree to which it is submitted	:	**MASTER OF SCIENCE**
Faculty	:	**AGRICULTURE**
Major field	:	**ENTOMOLOGY**
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University	:	**ACHARYA N.G. RANGA AGRICULTURAL UNIVERSITY**
Year of submission	:	**2004**

ABSTRACT

The efficacy of chitin synthesis inhibitors alone and in combination with cartap hydrochloride against lepidopterous pests of cabbage was studied under field conditions during *rabi*, 2003-2004 at College Farm, College of Agriculture, Rajendranagar, Hyderabad. The ED_{50} and ED_{90} values of selected chitin synthesis inhibitors *viz.*, novaluron, flufenoxuron and lufenuron against diamondback moth were determined in the laboratory of Department of Entomology, College of Agriculture, Rajendranagar, Hyderabad. The weather data was also collected from Agricultural Research Institute, Rajendranagar, Hyderabad for correlating the incidence of lepidopterous pests of cabbage.

Novaluron (0.005%) + cartap hydrochloride (0.025%) treatment exerted superior control of diamondback moth and cabbage leaf webber which was on par with other treatments *viz.*, flufenoxuron (0.005%) + cartap hydrochloride (0.025%), lufenuron (0.005%) + cartap hydrochloride (0.025%) and novaluron (0.01%), flufenoxuron (0.01%). Cartap hydrochloride (0.05%) was moderately effective in controlling diamondback moth and cabbage leaf webber, while neem (2 ml/l) was least

effective as this could not bring out the desirable control of diamondback moth and cabbage leaf webber on cabbage crop.

Bioassay of chitin synthesis inhibitors against third instar larvae of diamondback moth at fifth day after treatment revealed that ED_{50} and ED_{90} values of novaluron were 0.13468 and 0.72506 ng a.i. per larva while flufenoxuron were 0.40773 and 1.03947 ng a.i. per larva, respectively and at ninth day after treatment, the ED_{50} and ED_{90} values of lufenuron were recorded as 0.31999 and 1.33737 ng a.i. per larva, respectively.

Among the weather factors studied, maximum temperature exerted significant negative effect on *P. xylostella* and *C. binotalis* population whereas, minimum temperature, rainfall and sunshine hours shown negative impact and RH I and RH II shown positive impact on *P. xylostella* and *C. binotalis* population, respectively.

CHAPTER – I

INTRODUCTION

Cabbage (*Brassica oleracea* var. *capitata*) is one of the important cole crops commercially grown in India. In India, it is cultivated in an area of 0.27 m. ha. with a production of 5.7 m.t. and the average yield being 21,111 kg ha^{-1}. In Andhra Pradesh, it is cultivated in an area of 0.00155 m.ha. with a production of 0.03883 m.t. and the average yield was 25,000 kg ha^{-1} (Indian Harvest Database, CMIE, 2004).

The cabbage like other cruciferous crops is ravaged by wide array of insect pests, among which diamondback moth, *Plutella xylostella* (Linnaeus), cabbage leaf webber, *Crocidolomia binotalis* Zeller, tobacco caterpillar, *Spodoptera litura* (Fabricius), cabbage head borer, *Hellula undalis* (Fabricius), green peach aphid, *Myzus persicae* (Sulzer), cabbage aphid, *Brevicoryne brassicae* (Linnaeus) and mustard aphid *Liphaphis erysimi* (Kaltenbach) are the most important. The yield loss due to these pests has been estimated to be ranging from 31 (Abraham and Padmanabhan, 1968) to 66 per cent (Srihari and Satyanarayana, 1992). According to Raju (1996), resistance to insecticides by *P. xylostella*, has become a limiting factor in the commercial cultivation of cabbage and cauliflower in India. Among these insect pests of cabbage, diamondback moth and other lepidopterous pests cause extensive damage. Several conventional insecticides are recommended against these pests to

minimize the damage. Many of these insecticides are harmful to consumers and beneficial insects and cause ecological disturbance leading to number of problems such as insecticide resistance in pests, outbreaks of secondary pests and toxic residues. Therefore, a constant search for effective chemicals has become a regular feature of entomological research to offer timely suggestions to the growers. As a consequence there is a great demand for safer and selective insecticides affecting insect pests while sparing non-target insects. To develop ecologically safe Integrated Pest Management (IPM) programme for controlling cabbage pests a constant search of new approaches are made. One of the approaches is use of novel insecticides with different mode of action from the conventional insecticides. Chitin synthesis inhibitors fulfill this criterion.

Insect cuticle, a characteristic of class Insecta, can offer an excellent target for the control of insect pests. Chitin synthesis inhibitors inhibit the enzyme chitin synthetase so that the last polymerisation step in the synthesis of chitin does not take place and consequently the abortive moulting occurs resulting in various sorts of lethal and sub lethal effects and this checks the multiplication of the pest. Chitin synthesis inhibitors are not acutely toxic. The treated larvae apparently are unaffected until their next moult. At the time of moulting they are unable to split the old cuticle and wriggle out resulting in death.

Chitin synthesis inhibitors alone and in combination with cartap hydrochloride are attractive due to better control of pests without affecting non-target insect pests. Hence, the present investigation is taken up with the following objectives:

1. To evaluate the bio-efficacy of certain chitin synthesis inhibitors alone and in combination with cartap hydrochloride against lepidopterous pests of cabbage.

2. To determine the ED_{50} and ED_{90} values of the chitin synthesis inhibitors against diamondback moth, *P. xylostella* in the laboratory.

3. To study the influence of major abiotic factors on the population build up of lepidopterous pests of cabbage.

CHAPTER – II

REVIEW OF LITERATURE

Cabbage is the most important cruciferous vegetable crop, throughout the world. Among the various factors responsible for low productivity in cabbage, one of the major constraints is the damage done by various insect pests starting from transplanting till the harvest. A field experiment with cabbage crop was conducted at College Farm, College of Agriculture, Rajendranagar, Hyderabad during *rabi* 2003-04.

The review pertaining to the bio-efficacy of chitin synthesis inhibitors alone and in combination with cartap hydrochloride against lepidodpterous pests of cabbage, determination of ED_{50} and ED_{90} values against diamondback moth and influence of major abiotic factors on the population build up of lepidopterous pests of cabbage is presented below:

2.1 BIOEFFICACY OF CHITIN SYNTHESIS INHIBITORS ALONE AND IN COMBINATION WITH CARTAP HYDROCHLORIDE AGAINST LEPIDOPTEROUS PESTS OF CABBAGE

Insects are characterized by the presence of a chitin containing exoskeleton, which is incapable of being stretched any further. It is therefore essential that this cuticle must be periodically shed for growth during post embryonic development of insects. Growth is therefore accompanied by moulting, in other words, moulting is essential for growth and development of insects (Metcalf and Flint, 1962;

Wigglesworth, 1972). In recent years attempts have been made to disrupt the moulting by using either juvenile hormone analogues or by inhibiting the synthesis/deposition of chitin during moulting by using benzophenyl urea analogues (Hollingworth, 1975).

The first efforts to interfere with deposition of chitin in cuticle were made by Endo *et al*. (1970), who observed that polyxin-D interfered with the synthesis of chitin. Later Van Daalen *et al*. (1972) described that benzoylphenyl urea compound, 1-(2,6-dichloro benzoyl)-3-(3,4-dichlorophenyl) -urea (DW 19111®) also affected moulting in a number of insect species belonging to various orders which failed to emerge successfully from exuvia at the time of moulting. This failure of insects to moult successfully has been attributed to the reduction of deposition of chitin in cuticle (Mulder and Gijswijt, 1973). These chance observations led to a systematic search for compounds which interfered with moulting process. Wellinga *et al.* (1973a) and Post *et al.* (1974) described the insecticidal properties of diflubenzuron. Wilkinson *et al*. (1978) reported that diflubenzuron is safe to natural enemies and vertebrates and could be used in IPM without any adverse effect on natural enemies.

2.1.1 Novaluron

Novaluron, a novel benzoyl phenyl urea, acts by both ingestion and contact. As such it is active against lepidopterous larvae by ingestion and against nymphs *of Bemesia tabaci* (Gennadius) by contact. The LC_{50} of

novaluron against third instar larvae of beet army worm, *Spodoptera littoralis* (Boisduval) feed on treated castor bean (*Ricinus communis* L.) leaves was -0.1 mg a.i./ larva (Ishaaya *et al*., 1996).

Ishaaya *et al*. (1998) reported that novaluron was a potent larval growth suppresser of the beet army worm. In assays with the green house white fly, novaluron (LC_{90} = 3.28 mg a.i./l) was two fold more potent than lufenuron (LC_{90} = 6.29 mg a.i./l) and about fourteen fold more potent than teflubenzuron (LC_{90} = 47.00 mg a.i./l). Novaluron has been found to be highly effective in management of *P. xylostella* (Khambete *et al*., 1999 and Reddy *et al*., 1999).

Vadodaria *et al.* (2000) indicated that novaluron @ 100 gm a.i./ha. significantly reduced the larval population *H.armigera* (Hubner) on cotton in comparison to other insect growth regulators and untreated control.

Ashok *et al*. (2001) conducted studies on the efficacy of certain insecticides against *P. xylostella*. The results showed that the neem extract 0.5 per cent was observed to be the least effective against *P. xylostella* when compared to other insecticides *viz*., chlorpyriphos 20 EC, cypermethrin 25 EC, abamectin 1.8 EC, novaluron 10 EC, diafenthiuron 50 EC and lufenuron 10 EC but superior over control.

Satpathy and Rai (2002) reported that maximum mortality inflicted by the chitin synthesis inhibitor, novaluron was 96.27 per cent

and 74.05 per cent on two day old and six day old larvae of diamondback moth, respectively. The LC_{50} on six day old larvae (0.00139%) was about four times more than the LC_{50} on two day old larvae (0.00044%).

Novaluron 10 EC @ 300-400 ml in 200 litres of water gave effective control of Bihar hairy caterpillar upto ten days after spraying. It also inhibited the production of chitin synthesis as it was evident from the morphological deformities from fifth instar onwards, resulting in the emergence of malformed pupae and adults (Murthy and Rao, 2002).

Sawant *et al*. (2004) found that novaluron 0.01 per cent effective against brinjal shoot and fruit borer, *Leucinodes orbonalis* Guenee in reducing the infestation.

2.1.2 Lufenuron

Lufenuron is a member of benzophenyl urea class of chitin synthesis inhibitors and these compounds are known to influence the insects by inhibiting or interfering with chitin deposition during and after moult (Wellinga *et al.*, 1973b). Insecticides of this group are very promising for use in IPM because of their safety to vertebrates and selectivity in action (Mass *et al*., 1981).

Follas and Popay (1995) reported that lufenuron at 25g/ha applied at 14 day intervals had lower damage scores of *P. xylostella* in brassicas and higher harvest quality than the standard cyhalothrin (14 day interval) treatment and was comparable to *Bacillus thuringiensis* Berliner, (7 day

interval) treatment. Ranganathan and Govindhan (1996) reported that lufenuron @ 600 ml/ha or 400 ml/ha was effective when compared to diafenthiuron against *P. xylostella* on cauliflower.

Application of lufenuron @ 20 g, 30g and 40 g a.i/ha gave an excellent control of *P. xylostella* on cabbage with good percentage of marketable heads (Sannaveerappanavar *et al*., 1997). Cartap hydrochloride followed by lufenuron and *B. thuringinesis* were found to be the most effective insecticides in controlling the diamondback moth (Nagesh and Shashi Verma, 1997).

Lufenuron (0.05%) was found effective against *P. xylostella* on mustard with a mean reduction of 57.32 per cent over untreated control at seven days after treatment (Sujatha *et al*., 1999). The growth deregulating insecticide, lufenuron was proved to be the most effective (production of marketable cabbages), particularly during the hot season (Daly *et al*., 2000).

The ecofriendly chemicals lufenuron, *B.thuringiensis* and neem were less effective against *H. armigera* on pigeonpea (Rao *et al*., 2001). Application of lufenuron 5 EC @ 60 g a.i./ha was effective in controlling *H. armigera* on chickpea (Biradar and Dhanorkar, 2001). Patil *et al*. (2001) reported that lufenuron (Match 5 EC) @ 60 g a.i./ha, novaluron (Rimon 10 EC) @ 100 g a.i./ha and flufenoxuron (Cascade 10 EC) were effective in reducing *H. armigera* incidence on cotton.

Sudhakaran (2002) reported the mortality of third instar larvae of *S. litura* was 87.5 and 100 per cent at 0.2 and 0.4 ml lufenuron per litre respectively, while that of fourth instar larvae, it was 77.5 and 97.5 per cent at 0.2 and 0.4 ml lufenuron per litre, respectively. The results showed that the dosage of lufenuron had a direct impact on larval moulting.

The toxicity of lufenuron to the second instar diamondback moth larvae was 18.83 times more compared to that of diafenthiuron (Rakesh *et al.*, 2003).

Vastrad *et al*. (2003) reported that thiodicarb, lufenuron, spinosad, *B. thuringiensis* (Biobit®) emerged as the most promising insecticides for managing field population of diamondback moth which were resistant to conventional insecticides. Reduction of larval population in plots treated with these chemicals ranged from 57.13 to 99.99 per cent.

2.1.3 Flufenoxuron

The chitin precursor when injected simultaneously with topically applied diflubenzuron, flufenoxuron or teflubenzuron, all three acyl ureas were found to be equally effective as inhibitors of chitin synthesis when measured after 5 h. (Clark and Jewess, 1990).

Application of teflubenzuron @ 45 g a.i./ha and flufenoxuron @ 20 g a.i./ha resulted in significant yield increase and superior crop quality in

cabbage indicating that these chemicals were effective in controlling diamondback moth (Peter and Sundararajan, 1991).

Sinha (1993) reported that flufenoxuron @ 0.025% reduces the infestation by 40-50 per cent and 77-78 per cent, respectively, on chickpea for the control of *H. armigera*. They also reported that neem seed kernel extract (5%) gave 40 per cent reduction in infestation.

The results of the field experiment revealed that flufenoxuron, diafenthiuron, thiodicarb and polytrin C were highly effective for the control of resistant *S. litura* (Schichang *et al*., 1995).

Tambe *et al*. (1997) reported that higher dose of Cascade (flufenoxuron) i.e. 80g a.i./ha was found to be significantly superior in reducing the infestation of diamondback moth at three, seven and ten days after application and increasing the yield of cabbage.

Naik *et al*. (1998) reported that flufenoxuron used at 80 g a.i./ha emerged as the best treatment by reducing the larval population significantly from 4.39 to 0.75 number of diamondback moth larvae per head in 15 days after spraying and also by recording the highest cabbage yield (17.37 tonnes/ha).

Rao and Subbaratnam (2000) reported that the flufenoxuron initiated mortality of the third instar larvae of *Spodoptera exigua* (Hubner) within 24 h of treatment and brought about appreciable mortality within two days when fed on treated onion leaves.

Rakesh *et al.* (2003) conducted an experiment in which second instar diamondback moth larvae were starved initially and exposed to cabbage leaves dipped in different concentrations of endosulfan (0.07, 0.06, 0.05, 0.04, 0.03 and 0.02%), diafenthiuron (800, 700, 600, 500, 400 and 300 ml/ha), lufenuron (1000, 800, 600, 400, 200 and 100 ml/ha) and NSKE (5.0, 4.0, 3.0, 2.0, 1.0 and 0.5%). The toxicity of lufenuron to the second-instar diamondback moth larvae was 18.83 times more compared to that of endosulfan and 14.83 times more compared to that of diafenthiuron.

2.1.4 Joint toxic action of chitin synthesis inhibitors with other insecticides

Chitin synthesis inhibitors are expected to increase the toxicity of conventional chemicals by disrupting the cuticle formation and there by enhancing the penetration of chemicals through cuticle (Saad *et al.*, 1981). Though chitin synthesis inhibitors are effective in controlling several insect pests, the action is not quick and distinct as conventional chemicals. However, the combinations of the ecofriendly chemicals with insecticides as an effective method in combating insect pests (Salama *et al*., 1984). The potentiation in the toxicity of insecticides when combined with insect growth regulators (IGR's) was also reported by Megeed *et al*. (1986), Pawar *et al*. (1998) and Sujatha *et al*. (1999).

Sudhakaran *et al*. (1995) reported that combination of Match 5 EC (lufenuron) and Polo 50 SC (diafenthiuron) @ 400 + 400 ml/ha was

highly effective in controlling *H. armigera* on cotton. Murthy *et al*. (1997) found that combination of cypermethrin, profenofos, methomyl with diflubenzuron at half of their normal concentration proved highly effective from sixth day of spraying against *C. binotalis*

Flufenoxuron used at 30, 40 g a.i./ha alone and @ 20 g a.i./ha with 100 g a.i./ha of copper oxychloride, flufenoxuron 20 g a.i with 2 per cent urea were found at par with best treatment, i.e. flufenoxuron @ 80 g a.i./ha (Naik *et al*., 1998).

Pawar *et al*. (1998) reported that lufenuron (Match 5 EC) + profenofos (60 + 600 g a.i./ha) proved most effective against bollworm complex recording 18.51 and 10.64 per cent boll and locule damage, respectively. Moreover, the seed cotton yield in this treatment was significantly higher (23.50 q/ha) than in any other insecticidal treatments.

Ramanjaneyulu (1998) reported that lufenuron (0.005%) in combination with deltamethrin (0.01%), triazophos (0.03%) and endosulfan (0.035%) were superior in reducing the larval population of *S. litura* over insecticidal treatments in groundnut.

Papa *et al*. (1999) evaluated lufenuron in combination with methomyl and indoxacarb for the control of *S. frugiperda* on cotton in Brazil. Good control to the tune of 83 and 92 per cent was achieved with indoxacarb at 400 ml per ha and indoxacarb + methomyl at 30 + 800 ml per ha, respectively, after ten days of application.

Sujatha *et al*. (1999) reported that lufenuron (0.025%) + cypermethrin (0.02%) was found to be most effective followed by various combinations with lufenuron.

Combination of lufenuron with conventional insecticides *viz*., thiodicarb (0.037%), lambda cyhalothrin (0.005%) and profenofos (0.05%) was highly effective against *H. armigera* and *Maruca vitrata* (Geyer) in pigeonpea (Rao *et al*., 2001).

Superiority of combination of lufenuron (0.005%) with insecticides *viz*., profenofos (0.025%), methomyl (0.025%), cypermethrin (0.005%) and neem oil (0.5%) against *S. litura* on sunflower was reported by Visalakshi *et al*. (2000)

A combination product of lufenuron + profenofos (60 + 600 g a.i./ha) was proved most effective against *H. armigera* on chickpea (Biradar and Dhanorkar, 2001).

Murthi and Rao (2002) reported that novaluron (0.02%) gave effective control of Bihar hairy caterpillar, *Spilosoma obliqua* Walker after ten days after spraying whereas mixture of novaluron (0.15%) + quinalphos (0.05%) gave 95 per cent kill of second instar larvae five days after spraying.

Radhika (2002) reported that chitin synthesis inhibitors *viz*., flufenoxuron and lufenuron recorded higher mortality when combined with indoxacarb or thiodicarb to *S. litura* at both the levels of testing *viz*.,

LD_{50} + LD_{50} and LD_{50} + LD_{25} by leaf sandwich and topical methods of application.

In a study by Kumar *et al*. (2003) malathion (2 ml/l), carbaryl (2g/l), *B. thuringiensis* (2 g/l), neem (3 ml/l), endosulfan (2 ml/l), diflubenzuron (4 g/l) and fenvalerate (0.5 ml/l) were evaluated alone and in different combinations with novaluron against diamondback moth larvae (third instar) by topical application. Five days after treatment, novaluron alone @ 0.75 ml/l provided 90 per cent mortality of diamondback moth larvae while all the combinations at full doses provided highest (100%) mortality where as novaluron + *B. thuringiensis* var. *kurstaki* (0.375 ml + 1g/l) also gave 100 percent mortality which is a half dose combination.

2.1.5 Cartap hydrochloride

Cartap hydrochloride is a slow acting nereistoxin obtained from the marine annelids *Lumbrineris heteropoda* and *L. brevicirra*. Nagano and Sakai (1974) found that cartap hydrochloride was effective against *P. xylostella* as an ovicide and larvicide. David and Swami (1982) reported that insecticidal activity of cartap hydrochloride is attributed to its blocking action on the central nervous system that leads to paralysis. It acts both as a stomach and contact poison

According to Omoy (1987) dichlorvos (0.2%) and cartap hydrochloride (0.2%) as ineffective treatments in reducing *C. binotalis* on

cabbage. Sumalatha (1990) recorded highest population reduction of *C. binotalis* with 0.1 per cent cartap hydrochloride one day after treatment.

Srinivasan and Krishna Moorthy (1988) found that cartap hydrochloride at 350 g a.i./ha and pyraclophos at 175 and 350 g a.i./ha gave excellent control of *P. xylostella* on cabbage as compared to sprays of cypermethrin (30 g), deltamethrin (10 g) and fenvalerate (50 g) a.i./ha. Peter *et al*. (1987) considered cartap hydrochloride at 200 g a.i./ha to be minimum effective dosage for the control of *P. xylostella* on cabbage.

Rajavel and Babu (1989) observed cartap hydrochloride (100 g a.i./ha) as moderately effective treatment (0.33 to 0.66 larvae/cabbage) in comparison to fenvalerate (75 g a.i./ha) (0 to 0.66 larvae/cabbage) in reducing the larval population of *P. xylostella* on cabbage. Srinivasan and Moorthy (1991) recommended cartap hydrochloride (0.05%) for the control of *P. xylostella* and *C. binotalis* on cabbage.

Rai *et al*. (1992) reported that granular formulation of cartap hydrochloride (Padan 4G) to give highest reduction in the larval population (87%) of *P. xylostella* as against sprayable formulations of flufenoxuron (Cascade 10 EC) and cartap hydrochloride (Padan 50 SP).

Singh *et al*. (1993) reported cartap hydrochloride @ 100 g a.i./ha was the next best treatment after fenvalerate @ 75 g a.i./ha in controlling the larvae of *P. xylostella* on cabbage.

Manmadha Rao (1995) found cartap hydrochloride at 0.25 and 0.05 per cent in bait form to be very effective and recorded 70 and 100 per cent larval mortality of *S. litura*, respectively.

Nagesh and Shashi Verma (1997) reported that cartap hydrochloride followed by diflubenzuron and *B.t.* were effective against *P. xylostella* and suggested that sequential spraying of these chemicals can be recommended to overcome the problem of resistance in *P. xylostella.* Cartap hydrochloride gave moderate control of *P. xylostella* when compared with flufenoxuron @ 37.5 g a.i./ha, teflubenzuron @ 56.25 g a.i./ha, neem seed kernel extract (4%) and *B.t.* products like Biobit®, Dipel® and Delfin® (Sannaveerappanavar and Viraktamath, 1997). Babu and Krishnaiah (1998) reported that individual treatments of cartap hydrochloride, quinalphos and their combinations were highly effective and required only fewer sprays (2-3) at much longer intervals (12-15 days), in comparison to neem oil, *B.t.* sub sp. *kurstaki* and their combinations which were relatively less effective against cauliflower caterpillars in Andhra Pradesh.

Satpathy and Rai (1991) reported that cartap hydrochloride at 500 g a.i./ha recorded significantly lower numbers of diamondback moth larvae/head on cabbage.

Kalra and Sharma (2000) reported that thiodicarb at 1.0 kg/ha, cartap hydrochloride 1.0 kg/ha and *B. thuringiensis* var. *kurstaki* at 1.0 kg/ha gave effective control of *P. xylostella* on cauliflower cv. Snowball-16.

Sharma *et al*. (2000) reported that Bioasp® and Biolep® @ 2 kg/ha gave highest larval mortality i.e. equivalent to cartap hydrochloride 50 WP @ 1 kg/ha.

Rao and Lal (2001) reported that cartap hydrochloride (0.05%), deltamethrin (0.002%), endosulfan (0.07%) and imidacloprid (0.01%) gave maximum larval mortality of diamondback moth, *P. xylostella* on cabbage.

The efficacy of insecticides against diamondback moth in a descending order were cartap hydrochloride (0.05%), lambda-cyhalothrin (0.01%), beta-cyfluthrin (0.00125%), ethofenprox (0.01%), endosulfan (0.07%), imidacloprid (0.01%) (Lal and Meena, 2001). They observed that, cartap hydrochloride recorded the lowest populations of *P. xylostella* in 1998-99 and 1999-2000 cropping seasons of cabbage crop.

Arora *et al*. (2003) made studies on the toxicity of some newly introduced and few commonly used insecticides against third instar larvae of *P. xylostella* collected from cauliflower fields around Hisar. The LC_{50} values of spinosad, *B.thuringiensis* var. *kurstaki*, cartap hydrochloride and cypermethrin were 0.00033, 0.01493, 0.01758 and 0.02502 per cent, respectively.

Malla Reddy (2003) reported that cartap hydrochloride was moderately effective in controlling diamondback moth (47.23%), cabbage leaf webber (43.75%) and tobacco caterpillar (50.27%).

2.1.6 Neem

Joshi and Ram Prasad (1975) reported that the neem seed kernel suspension in water at 3 per cent was effective as antifeedant against the fifth instar larvae of *S. litura*. Mortality was observed only in the first two larval instars.

Neem oil (0.25%) treatment on *P. xylostella* resulted in 30.14 and 77.25 per cent mortality after 24 and 72 h, respectively (Kadam, 1976). On contrary, Chandrasekaran *et al*. (1994) reported poor efficacy of neem oil against *P. xylostella* in cauliflower. Neem oil extract @ 2 ml per lit gave 45 per cent mortality of second instar larvae of *P. xylostella* at 72 hrs after treatment (Raju *et al*., 1994).

Ramachandra Rao *et al*. (1980) tested four neem products *viz*., Biosol®, Neemark®, Repellin® and Neem oil against *S. litura*, and reported that repellency, feeding deterrancy of the insect increased with increase in concentration.

Fagoonee and Large (1981) demonstrated the anti-feedant property of neem kernel extract at the test concentrations (0.001-5.0%) against all instars of *C. binotalis*. Fagoonee (1986) reported that NSKE (5 %) was found to be as effective as deltamethrin against *P. xylostella* and

H. undalis (Drayer, 1987). Patnaik *et al*. (1987) observed higher larval mortality with neem oil at 1.5 per cent concentration.

Improved neem seed kernel extract was observed to give best results in reducing the population of *S. litura* and *P. xylostella* when compared to aqueous neem seed kernel extract (Sombatsine and Temboonkeat, 1987).

Venkateshwarlu *et al*. (1988) reported the loss of antifeedent property of neem oil after five days at 0.5, 1.0 per cent and 60 days at 12 per cent against *S. litura*.

Mani *et al*. (1990) recorded 79.76 per cent larval mortality of *C. binotalis* with neem oil at 1.5 per cent. Neemguard® 0.1 per cent recorded 89.30, 72.25 and 75.33 per cent reduction of *C. binotalis*, *P. xylostella* and *S. litura*, respectively at ten days after application (Sumalatha, 1990).

Repellin® (1%), dichloroethane extract of neem (1%) and neem seed kernel suspension gave the best and significant protection to tobacco seedlings upto nine days after spraying from *S. litura* (Chari *et al*., 1993). Repellin® (1%) caused 84.85 per cent mortality of fifth instar larvae of *S. litura* (Obulapathy, 1994).

Meadow *et al*. (1999) reported that neem extracts sprayed on cabbage at a concentration above 2 ppm prevented larval development

and at a concentration above 8 ppm prevented plant damage for nearly 1-2 weeks from lepidopterous insect pests.

Javaid *et al*. (2000) reported the use of neem extracts as part of IPM for *P. xylostella* control since all the neem treatments recorded significantly higher yield of marketable heads of cabbage and significantly better control of *P. xylostella* than the commonly used mixture of pyrethroids or the untreated control. Manjunatha *et al*. (2000) reported Nivaar®, a neem based pesticide was on par with malathion and monocrotophos after the first and second sprays and superior to above insecticides after the third spraying for two consecutive years and effective for control of *P. xylostella* at 0.2, 0.3 and 0.4 per cent of Nivaar®. But, it was found less effective against aphids.

Moorthy and Kumar (2000) reported that NSKE prepared by grinding (4%) was best alternative to the insecticide against *P. xylostella*. Saucke *et al*. (2000) obtained better results with Neemazal® and aqueous NSKE in comparison to *B. thuringiensis* products (Delfin® and Thuricide®) and insect growth regulator, chlorfluazuron (Atabron®), in field trials for controlling the lepidopterous insect pests among biological methods. Besides its high efficacy against lepidopterous insect pests it also controlled the mustard aphid, *L. erysimi*.

Ghosh *et al*. (2001) reported that azadirachtin (Neemactin®) was relatively less effective than other insecticides tested but gave significant larval control over untreated check against *C. binotalis*.

Rao and Lal (2001) reported that Achook® @ 0.5% was the least effective treatment against larval population of *P. xylostella* on cabbage cv. Golden Acre.

Malla Reddy (2003) reported that neem and *B.t.* formulation (Delfin®) were ineffective as they could not bring the desirable control of lepidopterous pests as well as aphids on cabbage. Among the plant products tested, *Azadirachta indica* recorded the maximum yield of cabbage 31.86 t ha^{-1} which was not only significantly superior over other plant product i.e. hong oil (27.60 t/ha) but also with the standard check malathion (18.70 t/ha) and Colt (15.43 t/ha) (Roopa *et al.,* 2003).

2.2 TOXICITY OF CHITIN SYNTHESIS INHIBITORS TO INSECT PESTS

The embryonic ED_{50} at different periods after 24 h ingestion of diflubenzuron to *Anthonomus grandis* adults was found to be 431 ppm at 3 days, 2797 ppm at 15 days and 11262 ppm at 21 days (McLaughlin, 1976). The ED_{50} to fourth and fifth instar nymphs of *Schistocerca gregaria* (Forskal) was 0.24 and 0.7 µg of diflubenzuron per nymph respectively and ED_{50} for egg hatch inhibition was 0.0008 µg per egg when applied topically (Mariy *et al*., 1981).

An LC_{50} of 1.4 ppm in first instar and 1.5 ppm in fourth instar larvae of spruce bud worm when applied through diet and an ED_{50} of 0.53 µg per larva applied topically was reported by Granette and Retnakaran (1983). The ED_{50} to fifth instar larvae of castor butterfly was 52.56 µg/larva when fed on containing diflubenzuron for 33 h (Chocklingam and Krishnan, 1984). An ED_{50} of 0.043 µg per pupa and ED_{80} of 0.1 µg per pupa of *Coryca cephalonica* (Stainton) was reported by Sriramulu (1984).

Larvae of *S. littoralis* were more susceptible to topical application of insect growth regulator flufenoxuron than to ingestion of treated food. Fecundity and larval emergence was reduced in offspring of parents one or both of which had been orally treated in larval stage (Aldebis *et al*., 1988). Teflubenzuron was more toxic to the larvae of resistant strain of *S. littoralis*. Diflubenzuron was less effective (LC_{50} = 34.9 ppm) as compared to chlorfluazuron (LC_{50} = 0.04 ppm) (Emam and Degheele, 1988). El-Seikh *et al*. (1988) found that LC_{50} value of chlorfluazuron was 20 ppm against *Pthorimae operculella* (Zeller).

Flufenoxuron was equally effective as an insecticide by topical application or ingestion. The enhanced toxicity of flufenoxuron to *S. littoralis* compared with earlier acyl ureas can probably be attributed to its slower metabolism and reduced excretion (Clarke and Jewess, 1990).

Degheele *et al*. (1993) assessed four benzoyl phenyl ureas under laboratory conditions against third instar larvae of *Spodoptera exempta* (Walker). The LC_{50} values were 0.013, 0.035, 0.074 and 0.138 µg/ml 24h after exposure; 0.006, 0.007, 0.0035 and 0.062 µg/ml 48 hours after exposure and 0.001, 0.004, 0.013 and 0.01 µg/ml 72 hours after exposure for teflubenzuron, hexaflumuron, flufenoxuron and diflubenzuron, respectively.

Lyra *et al*. (1994) showed that the larvae of *Agrotis segetum* (Denis and Schiffermuller) were more susceptible to flufenoxuron by ingestion than by topical application. The first application of lufenuron caused greater mortality (70.46%) and lowest level of infestation (13.98%) of *Spodoptera frugiperda* (J.E. Smith). It caused the greatest overall mortality (82.38%) and lowest infestation (15.71%) (Lopez *et al*., 1995).

Lyra *et al*. (1998) studied the action of chitin synthesis inhibitors on reproduction of *S. littoralis*. The third instar larvae treated with lufenuron and flufenoxuron by ingestion and contact. The surviving larvae were observed until adult stage. The percentage of fecundity of females and hatched larvae decreased by 45 and 30 per cent when both sexes were obtained from larvae treated with lufenuron and flufenoxuron, respectively.

Lokare *et al*. (1999) reported that the LC_{50} of lufenuron against *P. xylostella* larvae was 0.0079 per cent. Second, third and fourth instars

of *P. xylostella* were treated at their respective LC_{50} using a standard 'leaf-disc dip' method of bioassay. Sizes and weights of pupae from the treated lots were significantly reduced but larval and pupal durations remained unaffected. All the pupae formed from larvae treated at fourth instars were deformed and produced no adults. Only 38 and 14 per cent of adults emerged from the pupae formed following treatment at the second and third instar, respectively, compared to 88-92 per cent adult emergence in the control (Anureet *et al*., 2000).

Rao and Subbaratnam (2000) reported that flufenoxuron was relatively more toxic than diflubenzuron and lufenuron as indicated by LC_{50} values of 0.0135, 0.0185 and 0.0207 per cent respectively, four days after treatment on ragi cutworm, *S. exigua*.

Tiwari (2000) reported that the chlorfluazuron treatment affected the growth in fifth instar hoppers of *Schistorcerca gregaria* (Forskal). During development, fifth instar- adult intermediates and abnormal adults with twisted wings were observed in treated insects. Chlorfluazuron was found to be very toxic to *S. gregaria* hoppers, its ED_{50} being 0. 2456 μg.

Radhika (2002) reported that chitin synthesis inhibitors *viz*., flufenoxuron and lufenuron were highly toxic when administered to *S. litura* through leaf sandwich than applied topically. The LD_{50} and LD_{90} values of lufenuron to the Guntur population of *S. litura* larvae by leaf sandwich method was 0.509 and 7.010 μg/larva after 48h and 0.191 and

3.553µg/ larva after 72h and 0.114 and 1.299 µg/larva after 96h of treatment, respectively. When the flufenoxuron was administered through leaf sandwich method, the LD_{50} and LD_{90} values were 0.680 and 4.914µg/larva after 72 h and 0.012 and 0.223 µg/larva after 96h of treatment, respectively.

2.3. INFLUENCE OF MAJOR ABIOTIC FACTORS ON THE POPULATION BUILDUP OF LEPIDOPTEROUS PESTS OF CABBAGE

During the period of investigation the lepidopterous pests that occurred on cabbage were the diamondback moth, *P. xylostella*. (Plutellidae, Lepidoptera) and cabbage leaf webber, *C. binotalis* (Pyralidae, Lepidoptera).

2.3.1 Diamondback moth, *P. xylostella*

The development and survival of diamondback moth, *Plutella maculipennis* (Curt.) was slightly influenced by atmospheric humidity but temperature had considerable effect on all its stages (Lal, 1939). The minimum threshold of development was found to be 10^{o}C and the upper vital limit to be 40^{o}C. Abraham and Padmanabhan (1968) found the infestation on cruciferous vegetables in high proportions in Tamil Nadu during the hot weather period, especially in April and May with as many as 32 caterpillars on a plant in which, not a single leaf was left untouched. The population peak continued high till the month of August and was low during the months of November and February.

Sachan and Srivastava (1972) in their studies on seasonal incidence of *P. xylostella* on cabbage in Rajasthan, found seven to eight per cent of the plants infested in September-October initially and 32-100 per cent in January-March at the peak. At Taiwan, Chin (1974) observed that the population of *P. xylosteIla* was highest in March and October and lowest in June-August. He also reported that relative humidity did not affect pest population.

Bindra *et al*. (1977) in their population fluctuation studies on *P. xylosteIla* in cauliflower at Ludhiana, India during 1973-74 and 1974-75 found that the maximum activity of the pest was during August-September months. During January-February reduction in the population buildup was observed as the season became warm.

Babu (1985) reported that diamondback larvae were found damaging the crop at Hyderabad, Andhra Pradesh from early November till end of January with peak activity during late November.

Talekar and Lee (1985) found that heavy infestations of *P. xylosetella* on cabbage occurred mainly in the cool dry months, in Taiwan. Occurrence of population peaks of diamondback moth in February-April and November has been observed in Singapore (Ong and Soon, 1989). Similar results were obtained by Padmavathi (1991) who found high populations in November planted crop at Hyderabad.

Devi and Raj (1991) reported the peak population of *P. xylostella* coincided with the active vegetative/flowering and late growth stages of *rabi* season crops. The most favourable conditions for the yponomeutid were at

maximum and minimum temperatures of 17.9 to 22.8^{o}C and 10.0 to 11.9^{o}C, respectively. Gera and Bhatnagar (1992) observed the maximum population of diamondback moth in first week of February at Jobner, Rajasthan.

Desh *et al*. (1993) observed that a narrow range of maximum and minimum temperatures (17.9 to 19.8^{o}C and 10.0 to 10.8^{o}C, respectively) appeared to have a significant influence on *P. xylostella* activity, but other climatic factors were also affecting seasonal abundance. Relative humidity during this period ranged from 32.3 to 67.0 per cent.

Bioecological studies on the diamondback moth in the mid-hills of Himachal Pradesh conducted during 1991 and 1992 reflected that the pest appeared in the first fortnight of March on cabbage and cauliflower. The peak larval populations were observed in the first week of April during 1991 and in the third week of April during 1992 on cabbage and cauliflower (Chauhan *et al*., 1997).

Chaudhuri *et al*. (2001) reported the larval population of diamondback moth to show positive correlation with average temperature, relative humidity and total rainfall but negative correlation with average sunshine hours per day. Meena and Sharma (2003) reported that the infestation of cabbage started in the last week of November (1.00 larvae/plant) and attained its peak (8.06 larvae/plant) in the fourth week of January. Rao *et al*. (2003) reported that larval population of *P. xylostella* and *S. litura* were negatively correlated with the maximum and minimum temperature.

2.3.2 Cabbage leaf webber, *C. binotalis*

Fagoonee (1980) attributed rainfall as the main factor regulating the populations of *C. binotalis* on cabbage, in Mauritius. He observed that during the periods of low rainfall, populations multiplied rapidly at 20-40^{o}C, but during heavy rainfall, population intensity was very low, *C. binotalis* occurred nearly all the year round, but was numerous from May to December with a peak in November (Lee, 1986).

The cabbage leaf webber population peak occurred during February-April and November on cabbage and *Brassica alboglabra*, respectively (Ong and Soon, 1989). Simple correlations between number of cabbage leaf webbers and weather variables indicated that both morning and evening relative humidity had significant positive association with number of leaf webbers (Ratnamanjula, 1992).

Chaudhuri *et al*. (2001) reported that larval population of cabbage leaf webber showed positive correlation with average temperature, relative humidity and total rainfall, but negative correlation with average sunshine hours per day.

Rao *et al*. (2003) observed that larval populations of *C. binotalis* and *B. brassicae* were positively correlated with the evening relative humidity and minimum temperature respectively, during the first cropping of cauliflower.

CHAPTER III

MATERIALS AND METHODS

Field bioefficacy studies were undertaken with chitin synthesis inhibitors alone and in combination with cartap hydrochloride against lepidopterous pests of cabbage during *rabi*, 2003-04 at College Farm, College of Agriculture, Rajendranagar, Hyderabad. The laboratory experiments were conducted in the Department of Entomology to determine the ED_{50} and ED_{90} values against diamondback moth. For studying the influence of major abiotic factors on the population build up of lepidopterous pests of cabbage, the bulk crop was grown adjacent to the field experiment and weather data was collected from Agricultural Research Institute, Rajendranagar, Hyderabad. The materials used in conducting the experiment and the various methods employed during the course of investigations are given below.

3.1 BIOEFFICACY OF CHITIN SYNTHESIS INHIBITORS ALONE AND IN COMBINATION WITH CARTAP HYDROCHLORIDE AGAINST LEPIDOPTEROUS PESTS OF CABBAGE

3.1.1 Preparatory cultivation

The field was ploughed thrice with a tractor drawn cultivator and evenly leveled after removing all the stubbles and weeds.

3.1.2 Layout of the experiment

The experiment was laid out in a Randomized Block Design (RBD) with nine treatments each replicated thrice (Fig. 1 & Plate 1). Plots

measuring an area of 15 m^2 (5 x 3 m) were laid out by forming the bunds all around with irrigation channels between replications according to the design. The individual plots were divided into ridges and furrows with a distance of 50 cm between adjacent ridges.

3.1.3 Basal application of fertilizers

Basal dose of fertilizers as per recommendation i.e. 20 kg N, 60 kg P_2O_5 and 60 kg K_2O ha^{-1} was applied. Nitrogen in the form of urea was applied as basal and pocket application in three equal splits at different growth stages of the crop.

3.1.4 Variety

A popular short duration hybrid “BC-64” was chosen for the study. Seedlings were raised near Entomology green house, College of Agriculture, Rajendranagar, Hyderabad and were utilized for transplanting in the main field of red loamy soil of fine tilth.

3.1.5 Transplanting

One month old seedlings were transplanted after providing irrigation by adopting an inter row spacing of 45 cm and intra row spacing of 30 cm. This is followed by gap filling after ten days of transplanting.

3.1.6 Irrigation

The experimental plots were adequately irrigated at the time of transplanting followed by irrigation, whenever required throughout the crop period.

3.1.7 Intercultivation

The crop was kept free from weeds by hand weeding whenever needed and was kept well managed throughout the period of experiment by adopting the recommended package of practices.

3.1.8 Top dressing of fertilizers

The recommended dose of fertilizers for top dressing i.e. 60 kg of N ha^{-1} was given in three equal split doses at different growth stages of the crop.

3.1.9 Application of insecticidal treatments

All the test treatments were applied as foliar sprays and details of test insecticides are given in Table 1. The first spray was given soon after the incidence of pest noticed at 30 days after transplanting and thereafter, repeated at ten days interval. A total of three sprays were given during the experimentation.

The measured quantities of test insecticides were mixed with small quantity of water and remaining quantity of water added to it

subsequently to make up the volume. The spray fluid was evenly mixed with a stick before spraying.

3.1.10 Pests observed

The following lepidopterous pests were observed during the crop period.

S.No.	Common name	Scientific name	Family/order
1.	Diamondback moth	*Plutella xylostella* (L.)	Plutellidae : Lepidoptera
2.	Cabbage leaf webber	*Crocidolomia binotalis* Z.	Pyralidae : Lepidoptera

3.1.11 Counting the pests

Lepidopterous insect pests infesting cabbage heads were recorded at frequent intervals during the period of study. The data were recorded from five plants randomly selected from a given plot which was tagged in each treatment and the population counts were recorded. The number of larvae of diamondback moth, *P. xylostella* and leaf webber, *C. binotalis* were recorded from the selected labelled plants. The data on the above pests were recorded one day before spraying and as well as three, seven and ten days after each spray. The counts on tenth day after each spray were taken as a pre-treatment counts for the next spray. The larval counts of diamondback moth and leaf webber were recorded on individual plant basis from five labelled plants.

3.1.12 Statistical analysis

The per cent reduction of lepidopterous pests in different treatments over control was calculated by modified Abbot's formula (Fleming and Retnakaran, 1985) as given below:

$$\text{Population reduction (\%)} = \left[1 - \left\{\frac{\text{Post-treatment population in treatment}}{\text{Pre-treatment population in treatment}}\right\} \times \left\{\frac{\text{Pre-treatment population in control}}{\text{Post-treatment population in control}}\right\}\right] \times 100$$

The per cent reduction at three, seven and ten days after each spraying were pooled and transformed into angular values which were further subjected to statistical analysis. The overall efficacy of treatments by combining the three, seven and ten days observations were also done by analyzing the data through ANOVA.

3.2 DETERMINATION OF THE ED_{50} AND ED_{90} VALUES OF THE SELECTED CHITIN SYNTHESIS INHIBITORS AGAINST DIAMONDBACK MOTH IN THE LABORATORY

3.2.1 Diamondback moth, *P. xylostella* rearing

For rearing *P. xylostella* in *rabi* and summer seasons, cabbage hybrid 'BC-64' were raised near Entomology green house, College of Agriculture, Rajendranagar, Hyderabad by adopting standard package of practices.

The larvae of *P. xylostella* were obtained from cabbage fields of Shamshabad, Hyderabad and were reared in the laboratory under controlled conditions. The larvae were fed with tender leaves in early instars and with matured leaves in the later instars.

To avoid competition, the larval number was reduced in each glass trough from the third instar onwards. Moulting time between two instars was identified by the cast skin and width of the head capsule of the larvae.

Food was changed every day till their pupation. Adults emerged were released in rearing cages and fed on sugar solution in cotton swab. The eggs laid by the adults on the leaves of cabbage in rearing cage were kept for hatching in petri plates (5 cm diameter). The larvae obtained from these eggs were utilized for conducting the experiment.

3.2.2 Determination of ED_{50} and ED_{90} values of chitin synthesis inhibitors to diamondback moth following leaf disc method

To determine ED_{50} and ED_{90} values, third instar larvae of *P. xylostella* was selected and treated with formulation products of chitin synthesis inhibitors. One square cm discs of cabbage leaves were cut and placed in the petri plates. The concentrations of 0.02, 0.015, 0.01, 0.005, 0.001, 0.00075, 0.0005, 0.00025 and 0.0001 per cent of chitin synthesis inhibitors *viz.*, novaluron, flufenoxuron, lufenuron (4µl) were applied with the help of Fixvo micropipette (HiMedia Laboratories Ltd., Mumbai) on one square cm leaf disc and on another leaf disc of same size starch was smeared in each treatment. Thereafter, both the leaf discs were attached together to get a sandwich. Ten larvae were exposed in each concentration constituting one replication. Each concentration was replicated thrice. Larvae applied with distilled water were utilized as untreated control. The treated and untreated larvae kept individual in petri

plates. Before insecticidal application larvae were starved for 2 h as suggested by Singh and Vats (1976).

Deformity and mortality counts were made at 24 h interval in all the treatments till the adult emergence were observed in the pupae formed in untreated control. Deformed larvae/pupae/malformed adult were treated as treatmental effect. Wherever the treated larvae did not develop any deformity during larval period, the deformity and mortality counts were continued in pupal stage as well as during adult emergence. Concentrations of wide range initially and narrow range subsequently were tested till mortality in the range of 5 to 90 per cent was obtained. The amount of insecticide present in four micro litres of test concentration was calculated and expressed as dose in nano grams per larva. Correction for natural mortality was made according to Abbot's (1925). ED_{50} and ED_{90} values of chitin synthesis inhibitors were computed by probit analysis (Finney, 1952).

3.3 INFLUENCE OF MAJOR ABIOTIC FACTORS ON THE POPULATION BUILDUP OF LEPIDOPTEROUS PESTS OF CABBAGE

3.3.1 Raising of bulk plot

The land was ploughed thrice with a tractor drawn cultivator and evenly leveled after removing all the stubbles and weeds and the bulk plots were laid out thereafter one month old seedlings were transplanted

at a spacing of 45 x 30 cm and general package of practices were followed according to the recommendations to maintain a good crop.

3.3.2 Recording of data

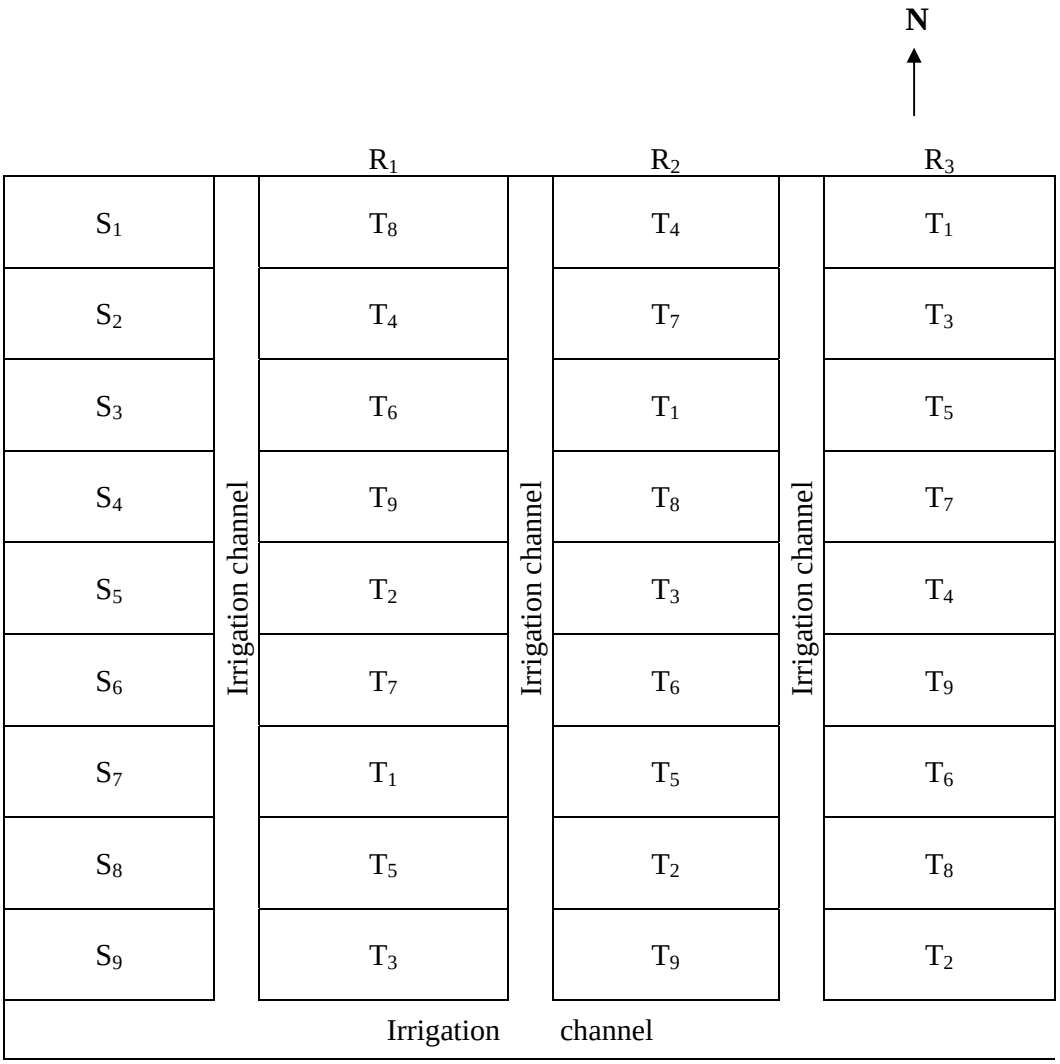
The data in respect to pest incidence was recorded at weekly intervals throughout the crop period on 50 randomly selected labelled cabbage plants in bulk crop. Sprayings were not taken up on the bulk crop throughout the crop period. Weather data was collected from Agricultural Research Institute, Rajendranagar, Hyderabad to correlate with pest incidence of cabbage.

3.3.3 Statistical analysis

Simple correlations, multiple linear regression and step down analysis were worked out between the larval population of lepidopterous pests of cabbage and the weather parameters like maximum temperature, minimum temperature, morning relative humidity, evening relative humidity and sun shine hours. Rainfall received during experimentation was also recorded.

Table 1: Details of the insecticides used in the present experimentation

S.No.	Common name	Dosage (%)	Trade name and formulation	Chemical name	Sources of supply
1.	Novaluron	0.01%	Rimon 10 EC	(±) – 1– [3 – chloro – 4 – (1,1,2 – trifluoro – 2 – trifluoro methoxyethoxy) = phenyl] – 3 – 2 (2,6 – difluorobenzoyl) urea	Indofil Chemicals Company, Mumbai
2.	Lufenuron	0.01%	Match 5 EC	(RS) – 1- [2,5 – dichloro – 4 – (1,1,2,3,3,3 – hexafluoro propoxy) phenyl] - = 3 – (2,6 – difluorobenzoyl) urea	Syngenta India Ltd., Mumbai
3.	Flufenoxuron	0.01%	Cascade 10 DC	1 – [4 – (2 – chloro - α,α,α - trifluoro – P – tolyloxy) – 2 – fluorophenyl] – = 3 – (2,6 – difluorobenzoyl) urea	BASF India Ltd., Mumbai
4.	Cartap hydrochloride	0.05%	Wartap 50 SP	S,S[1] – (2-dimethyl amino trimethylene) bis (thiocarbamate)	Hyderabad Chemical Suppliers Ltd., Hyderabad
5.	Neem	2 ml/lit.	Maha Neem 0.15 EC	Dimethyl [2aR – [2a α, 3β, 4β, 1a R*, 2S*, 3aS*, 6aS*, 7S*, 7aS*], = 4aB, 5α, 7aS*, 8β(E), 10β, 10aα, 10bβ)] – 10 – (acetoxy) octahydro-3,5-dihydroxy-4-=methyl-8-[(2-methyl-1-oxo-2-butenyl) oxy] – 4 – (3a, 6a, 7, 7a-tetrahydro-6a-hydroxy - = 7a – methyl – 2, 7 – methanofuro [2, 3-b], oxireno [e] oxepin – 1a (2H) – yl) – 1H, 7H - = natpho [1, 8-bc : 4, 4a-C[1]] difuran – 5, 10a (8H) - dicarboxylate	Fortune Biotech Ltd., Hyderabad



Design : RBD
Treatments : 9
Replications : 3
Plot size : 5 x 3 m
Spacing : 45 x 30 cm
Cabbage hybrid : BC-64

S_1 -S_9 Bulk plots
T_1 Novaluron @ 0.01 %
T_2 Lufenuron @ 0.01 %
T_3 Flufenoxuron @ 0.01 %
T_4 Novaluron @ 0.005 % Cartap hydrochloride @ 0.025 %
T_5 Lufenuron @ 0.005 % + Cartap hydrochloride @ 0.025 %
T_6 Flufenoxuron @ 0.005 % + Cartap hydrochloride @ 0.025 %
T_7 Neem @ 2 ml/l
T_8 Cartap hydrochloride @ 0.05 %
T_9 Control

Fig. 1: Layout of the experimental site

CHAPTER – IV

RESULTS

4.1 BIOEFFICACY OF CHITIN SYNTHESIS INHIBITORS ALONE AND IN COMBINATION WITH CARTAP HYDROCHLORIDE AGAINST LEPIDOPTEROUS PESTS OF CABBAGE

The efficacy of chitin synthesis inhibitors alone and in combination with cartap hydrochloride against *P. xylostella* and *C. binotalis* on cabbage were tested. A total of three sprays were given at ten days interval commencing from the incidence of pest and the results obtained are presented below:

4.1.1 Efficacy of insecticidal treatments against diamondback moth, *P. xylostella*

The data on reduction of larval population of diamondback moth over the control at three, seven and ten days after first, second and third spraying are presented in Tables 2, 3, 4 and Figs. 2, 3, 4, respectively. The mean per cent reduction of larval population of diamondback moth were calculated over untreated control.

4.1.1.1 First spray

The pretreatment count was taken one day before first spraying. The data pertaining to pretreatment count indicated a larval population range from 3.60 to 4.46 per plant. The post treatment counts were recorded at third, seventh and tenth days after first spraying.

The data recorded on reduction of diamondback moth population three days after first spraying revealed that cartap hydrochloride was significantly superior with 70.08 mean per cent reduction in diamondback moth larval population over untreated control which was on par with novaluron (0.005%) + cartap hydrochloride (0.025%) and flufenoxuron (0.005%) + cartap hydrochloride (0.025%) with 69.53 and 65.04 mean per cent reduction of diamondback moth larval population, respectively. The next best treatments were novaluron (0.01%), lufenuron (0.005%) + cartap hydrochloride (0.025%), flufenoxuron (0.01%) and lufenuron (0.01%) which recorded 56.32, 56.32, 55.16 and 51.76 mean per cent reduction of diamondback moth larval population, respectively and these treatments were on par with each other. The treatment with neem (2 ml/l) was the least effective among the insecticidal treatment with 29.5 mean per cent reduction in larval population of diamondback moth over the control (Table 2 and Fig. 2).

The data on reduction of diamondback moth population at seven days after first spraying indicated that novaluron (0.005%) + cartap hydrochloride (0.025%) was significantly superior with 80.27 mean per cent reduction of diamondback moth larval population over untreated control which was on par with flufenoxuron (0.005%) + cartap hydrochloride (0.025%) with 78.42 mean per cent reduction of diamondback moth larval population over untreated control. The next best treatment was lufenuron (0.05%) + cartap hydrochloride (0.025%)

with 76.10 mean per cent reduction of diamondback moth larval population over the control which was also on par with flufenoxuron (0.005%) + cartap hydrochloride (0.025%) treatment. The next best treatments were flufenoxuron (0.01%), novaluron (0.01%) and lufenuron (0.01%) with 66.82, 66.67 and 65.42 mean per cent reduction of diamondback moth larval population over the control, respectively and these treatments were on par with each other. The cartap hydrochloride (0.05%) was less effective after seven days after spraying in reducing the mean per cent reduction of diamondback moth larval population i.e. 48.33 per cent. The neem (2 ml/l) treatment was least effective with 34.37 mean per cent reduction of diamondback moth larval population over the control among the insecticidal treatments. However, all the insecticidal treatments were significantly superior over the control in reducing the diamondback moth larval population at seven days after spraying.

Observations on reduction of diamondback moth population at ten days after first spraying revealed that novaluron (0.005%) + cartap hydrochloride (0.025%) was significantly superior with 55.69 mean per cent reduction of diamondback moth larval population over the control which was on par with flufenoxuron (0.005%) + cartap hydrochloride (0.025%) with 50.96 mean per cent reduction of larval population over the control. The next best treatment was novaluron (0.01%) with 46.52 mean per cent reduction of diamondback moth larval population

followed by flufenoxuron (0.05%) + cartap hydrochloride (0.025%). flufenoxuron (0.01%) and lufenuron (0.005%) + cartap hydrochloride (0.025%) with 50.96, 44.36 and 44.14 mean per cent, respectively. The cartap hydrochloride (0.05%) was less effective in reducing diamondback moth larval population i.e. 34.05 per cent which was on par with lufenuron (0.01%) with 33.94 mean per cent reduction of diamondback moth larval population over the control. The treatment neem (2 ml/l) was least effective in reducing the larval population i.e., 23.29 mean per cent reduction of diamondback moth larval population over the control.

Overall efficacy of different treatments after first spraying as reported in Table 2 and shown in Fig. 2 revealed that all the treatments were significantly superior over the control in reducing the diamondback moth larval population. Among the treatments, novaluron (0.005%) + cartap hydrochloride (0.025%) constantly proved its efficacy over others by recording 68.49 mean per cent reduction of diamondback moth larval population over the control which was on par with flufenoxuron (0.005%) + cartap hydrochloride (0.025%), lufenuron (0.005%) + cartap hydrochloride (0.025%) and novaluron (0.01%). The treatment flufenoxuron (0.01%) recorded 55.44 mean per cent reduction of larval population of diamondback moth over the control which was on par with flufenoxuron (0.005%) + cartap hydrochloride (0.025%), lufenuron (0.005%) + cartap hydrochloride (0.025%), novaluron (0.01%), cartap

hydrochloride (0.05%) and lufenuron (0.01%) with 64.80, 58.85, 56.51, 50.82 and 50.37 mean percent reduction of diamondback moth larval population, respectively. Among all the treatments, neem (2 ml/l) was the least effective treatment which was recorded 29.05 mean per cent reduction of diamondback moth larval population over the control.

4.1.1.2 Second spray

The second spray was given 10 days after first spraying with same treatments. The pretreatment observations recorded one day before spraying and these were no significant differences among them.

The observations recorded on reduction of diamondback larval population three days after second spraying revealed that cartap hydrochloride (0.05%) was effective in reducing 76.73 mean per cent reduction of the larval population over the control (Table 3 and Fig. 3). The next best treatment was novaluron (0.005%) + cartap hydrochloride (0.025%) with 69.95 mean per cent reduction of larval population. Among the other treatments, lufenuron (0.005%) + cartap hydrochloride (0.025%) with 66.16 mean per cent reduction of diamondback moth larval population, was on par with flufenoxuron (0.005%) + cartap hydrochloride (0.025%) with 66.04 mean per cent reduction over the control. Another treatment novaluron (0.01%) was also effective in reducing the larval population i.e., 54.16 mean per cent which was on par with flufenoxuron (0.01%) with 52.11 mean per cent reduction of

diamondback moth larval population. The lufenuron (0.01%) was less effective with 48.54 mean per cent reduction of diamondback moth larval population over the control. The treatment neem (2 ml/l) was the least effective and recorded 28.68 mean per cent reduction of diamondback moth larval population over the control.

Observations on reduction of diamondback moth larval population at seven days after second spraying revealed that novaluron (0.005%) + cartap hydrochloride (0.025%) was superior with 74.81 mean per cent reduction of diamondback moth larval population, which was on par with flufenoxuron (0.005%) + cartap hydrochloride (0.025%) and novaluron (0.01%) with 71.92 and 71.09 mean per cent reduction of diamondback moth larval population over the control, respectively. The next best treatment was lufenuron (0.005%) + cartap hydrochloride (0.025%) reducing 66.84 mean per cent reduction of diamondback moth larval population, which was on par with novaluron (0.01%) and flufenoxuron (0.01%) with 71.09 and 66.98 mean per cent reduction of diamondback moth larval population, respectively. The remaining treatments *viz*., lufenuron (0.01%), cartap hydrochloride (0.05%) and neem (2 ml/l) recorded 57.94, 49.94 and 27.61 mean per cent reduction of diamondback moth larval population over the control, respectively.

The observations recorded on reduction of diamondback moth larval population at ten days after second spraying revealed that novaluron (0.005%) + cartap hydrochloride (0.025) was very effective

and significantly different from other treatments with 55.85 mean per cent reduction of diamondback moth larval population over the control followed by novaluron (0.01%) which recorded 48.42 mean per cent reduction of diamondback moth larval population and was on par with flufenoxuron (0.05%) + cartap hydrochloride (0.025%) with 47.24 mean per cent reduction of diamondback moth larval population over the control. Among other treatments, lufenuron (0.005%) + cartap hydrochloride (0.025%) recorded 44.43 mean per cent reduction of diamondback moth larval population and was on par with flufenoxuron (0.005%) + cartap hydrochloride (0.025%) with 47.24 mean per cent reduction of diamondback moth larval population over the control. The remaining treatments *viz.,* flufenoxuron (0.01%), lufenuron (0.01%), cartap hydrochloride (0.05%) and neem (2 ml/l) recorded 40.65, 34.19, 29.95 and 20.85 mean per cent reduction of diamondback moth larval population over the control, respectively.

The overall efficacy of different treatments after second spraying showed that all the treatments were significantly superior over the control in reducing the diamondback moth larval population. Among all the treatments novaluron (0.005%) + cartap hydrochloride (0.025%) was very effective with 66.87 mean per cent reduction of diamondback moth larval population, which was on par with other treatments *viz.,* flufenoxuron (0.005%) + cartap hydrochloride (0.025%), lufenuron (0.005%) + cartap hydrochloride (0.025%), novaluron (0.01%),

flufenoxuron (0.01%) and cartap hydrochloride (0.05 %) with 61.73, 59.14, 57.89, 53.24 and 52.20 mean per cent reduction of diamondback moth larval population over the control, respectively. The next best treatment lufenuron (0.01%) was effective with 46.89 mean per cent reduction of diamondback moth larval population which was on par with lufenuron (0.005%) + cartap hydrochloride (0.025%), novaluron (0.01%), flufenoxuron (0.01%) and cartap hydrochloride (0.05%) with 59.14, 57.89, 53.24 and 52.20 mean per cent reduction of diamondback moth larval population over the control, respectively. Among the treatments, the neem (2 ml/l) was least effective with 25.71 mean per cent reduction of diamondback moth larvae over the control, which was significantly differ from all the other treatments.

4.1.1.3 Third spray

The third spray was given at 10 days after second spraying with respective chemicals represented in Table 4 and Fig. 4. The pretreatment observations were recorded one day before spraying which revealed that there is no significant difference among them.

Observations obtained on reduction of diamondback moth larval population at three days after third spraying revealed that the treatment cartap hydrochloride (0.05%) was very effective with 75.99 mean per cent reduction of diamondback moth larval population over the control. The next best treatment was novaluron (0.005%) + cartap hydrochloride

(0.025%) with 65.81 mean per cent reduction of diamondback moth larval population over the control which was on par with flufenoxuron (0.005%) + cartap hydrochloride (0.025%) with 65.31 mean per cent reduction of diamondback moth larval population over the control. Lufenuron (0.005%) + cartap hydrochloride (0.025%) treatment recorded 58.69 mean per cent reduction of diamondback moth larval population which was significantly superior with remaining treatments. In the order of efficacy, novaluron (0.01%), flufenoxuron (0.01%) and lufenuron (0.01%) with 53.48, 52.05 and 49.03 mean per cent reduction of larval population over the control, respectively which were on par with each other. Among the treatments, the neem (2 ml/l) was least effective with 24.47 mean per cent reduction of diamondback moth larval population over the control.

Observations obtained on reduction of diamondback moth larval population at seven days after third spraying revealed that the treatment novaluron (0.005%) + cartap hydrochloride (0.025%) was significantly superior over other treatments with 78.64 mean per cent reduction of diamondback moth larval population over the control. Among the other treatments, flufenoxuron (0.005%) + cartap hydrochloride (0.025%) was found superior with 75.71 mean per cent reduction of diamondback moth larval population over the control. In the remaining treatments, novaluron (0.01%) and flufenoxuron (0.01%) gave 71.64 and 68.98 mean per cent reduction of diamondback moth larval population over the

control and were on par with each other. The treatment lufenuron (0.01%) superior with 67.78 mean per cent reduction of diamondback moth larval population which was also on par with flufenoxuron (0.01%) and lufenuron (0.005%) + cartap hydrochloride (0.025%) with 68.98 and 66.88 mean per cent reduction of diamondback moth larval population over the control, respectively. The treatment cartap hydrochloride (0.05%) recorded 54.71 mean per cent reduction of diamondback moth larval population over the control. Neem (2 ml/l) was the least effective treatment against diamondback moth with 22.20 mean per cent reduction of larval population over the control.

The data recorded at tenth day after third spraying indicated that all the insecticidal treatments were significantly superior over the control in reducing the larval population of diamondback moth. Among the treatments, novaluron (0.005%) + cartap hydrochloride (0.025%) was very effective with 53.41 mean per cent reduction of diamondback moth larval population of diamondback moth which was on par with flufenoxuron (0.005%) + cartap hydrochloride (0.025%) and novaluron (0.01%). The next best treatment lufenuron (0.005%) + cartap hydrochloride (0.025%) has recorded 44.65 mean per cent reduction of larval population which was also on par with flufenoxuron (0.005%) + cartap hydrochloride (0.025%), novaluron (0.01%) and flufenoxuron (0.01%) with 48.42, 46.57 and 39.22 mean per cent reduction of larval population over the control, respectively. The rest of treatments in the

descending order of efficacy were lufenuron (0.01%), cartap hydrochloride (0.05%) and neem (2 ml/l) with 35.13, 27.52 and 22.97 mean per cent reduction of larval population over the control and the last two treatments were on par with each other.

The overall efficacy of the different treatments after third round of spraying revealed that novaluron (0.005%) + cartap hydrochloride (0.025%) was very effective with 65.95 mean per cent reduction of larval population which was on par with the remaining treatments *viz.,* flufenoxuron (0.005%) + cartap hydrochloride (0.025%), novaluron (0.01%), lufenuron (0.005%) + cartap hydrochloride 0.025%), flufenoxuron (0.01%), cartap hydrochloride (0.025%) and lufenuron (0.01%) with 63.14, 57.23, 56.74, 53.42, 52.74 and 50.64 mean per cent reduction of larval population of diamondback moth over the control. Among the treatments, neem (2 ml/l) was least effective with 23.21 mean per cent reduction of diamondback moth larval population over the control. However, all the insecticidal treatments were significantly effective against diamondback moth in decreasing the mean per cent reduction of larval population over the control.

4.1.1.4 Overall efficacy of three rounds of insecticidal sprayings against diamondback moth, *P. xylostella*

The data on overall efficacy of different insecticidal treatments against *P. xylostella* larval population, pooled from the three rounds of insecticidal sprayings are presented in Table 5 and Fig. 5.

The pooled data pertaining to three days after spraying indicated that all the insecticidal treatments were significantly superior over the control in reducing the larval population of diamondback moth. The treatment cartap hydrochloride (0.05%) was very effective and significantly superior over other treatments with 74.26 mean per cent reduction of larval population of diamondback moth over the control. The next best treatments were novaluron (0.005%) + cartap hydrochloride (0.025%) and flufenoxuron (0.005%) + cartap hydrochloride (0.025%) recording 68.43 and 65.59 mean per cent reduction of larval population of diamondback moth over the control, respectively. These chemicals were on par with each other and significantly superior over the remaining treatments. The treatments that followed in descending order of efficacy were lufenuron (0.005%) + cartap hydrochloride (0.025%), novaluron (0.01%), flufenoxuron (0.01%) and lufenuron (0.01%) with 60.39, 54.66, 53.10 and 49.77 mean per cent reduction of larval population of diamondback moth over the control, respectively. Among all the treatments, neem (2 ml/l) was significantly inferior and least effective treatment with 27.55 mean per cent reduction of diamondback moth larval population over the control at three days after spraying.

The pooled data of the three rounds of insecticidal spraying pertaining to seven days after spraying revealed that novaluron (0.005%) + cartap hydrochloride (0.025%) was superior with 77.90 mean per cent

reduction of larval population of diamondback moth over the control and was on par with flufenoxuron (0.005%) + cartap hydrochloride (0.025%) with 75.35 mean per cent reduction of diamondback moth larval population over the control. The next best treatment was lufenuron (0.005%) + cartap hydrochloride (0.025%) with 70.94 mean per cent reduction of diamondback moth larval population and was on par with flufenoxuron (0.005%) + cartap hydrochloride (0.025%), novaluron (0.01%) and flufenoxuron (0.01%) with 75.35, 69.80 and 67.59 mean per cent reduction of diamondback moth larval population over the control, respectively. The decreasing order of efficacy of other treatments were lufenuron (0.01%) and cartap hydrochloride (0.05%) with 69.80 and 50.99 mean per cent reduction of diamondback moth larval population over the control. The treatment neem (2 ml/l) was significantly inferior with 28.06 mean per cent reduction of diamondback moth larval population over the control at seven days after spraying. However, all the insecticidal treatments were significantly superior over the control in reducing the larval population of *P. xylostella*.

At ten days after spraying novaluron (0.005%) + cartap hydrochloride (0.025%) was found to be significantly superior and the most effective treatment in reducing the larval population of diamondback moth i.e. 54.98 mean per cent reduction over the control. The next best treatment was flufenoxuron (0.005%) + cartap

hydrochlodride (0.025%) recorded 48.87 mean per cent reduction of larval population of diamondback moth over the control. Among other treatments, lufenuron (0.005%) + cartap hydrochloride (0.025%) with 44.40 mean per cent reduction of *P. xylostella* larval population which was on par with flufenoxuron (0.005%) + cartap hydrochloride (0.025%) with 48.87 mean per cent reduction of diamondback moth larval population over the control. The other treatments that showed good degree of efficacy in the descending order were flufenoxuron (0.01%), lufenuron (0.01%) and cartap hydrochloride (0.05%) with 41.42, 34.42 and 30.50 mean per cent reduction of diamondback moth larval population over the control, respectively and which were not on par with each other. Neem (2 ml/l) indicated the lowest reduction i.e., 22.37 mean per cent reduction of diamondback moth larval population over the control. However, the pooled data of the three insecticidal sprays indicated that all the treatments were significantly superior over the control in reducing the larval population of *P. xylostella* after ten days of spraying.

The overall efficacy of insecticidal treatments against diamondback moth indicated that all the treatments were significantly superior over the control in reducing the larval population of diamondback moth. Among the treatments, novaluron (0.005%) + cartap hydrochloride (0.025%) was superior with 67.10 mean per cent reduction of diamondback moth larval population over the control,

which was on par with other treatments *viz.,* flufenoxuron (0.005%) + cartap hydrochloride (0.025%), lufenuron (0.005%) + cartap hydrochloride (0.025%), novaluron (0.01%) and flufenoxuron (0.01%) with 63.27, 58.57, 57.21 and 54.03 mean per cent reduction of diamondback moth larval population over the control, respectively. The next best treatment was cartap hydrochloride (0.05%) with 51.91 mean per cent reduction and was also on par with flufenoxuron (0.005%) + cartap hydrochloride (0.025%), lufenuron (0.005%) + cartap hydrochloride (0.025%), novaluron (0.01%), flufenoxuron (0.01%) and lufenuron (0.01%) with 63.27, 58.57, 57.21, 54.03 and 49.30 mean per cent reduction of larval population of diamondback moth over the control. Among all the treatments, neem (2 ml/l) recorded the lowest mean per cent reduction i.e. 25.99 of diamondback moth larval population over the control and was found to be least effective over all the other insecticidal treatments.

4.1.2 Efficacy of insecticidal treatments against cabbage leaf webber, *C. binotalis*

The data on reduction of larval population of *C. binotalis* over the control at three, seven and ten days after first, second and third sprayings were presented in Tables 6, 7, 8 and Figs. 6, 7, 8, respectively. The per cent reduction of larval population of *C. binotalis* in insecticidal treatments were calculated over untreated control.

4.1.2.1 First spray

The pretreatment counts were taken one day before first spraying indicated the uniform distribution of the pest in all treatments with larval population ranging from 4.86 to 6.93 per plant (Table 6 and Fig. 6).

The data pertaining to the mean per cent reduction of larval population of *C. binotalis* at three days after first spraying showed that all the insecticidal treatments were significantly superior over the control. Among all the insecticidal treatments, cartap hydrochloride (0.05%) and novaluron (0.005%) + carap hydrochloride (0.025%) were on par with each other and found to be the most effective treatments by achieving 74.58 and 72.16 mean per cent reduction of larval population of *C. binotalis* over the control, respectively. The next best treatment was flufenoxuron (0.005%) + cartap hydrochloride (0.025%) with 65.01 mean per cent reduction of larval population of *C. binotalis* which was on par with lufenuron (0.005%) + cartap hydrochloride (0.025%) with 64.89 mean per cent reduction of larval population of *C. binotalis* over the control. The treatments that followed in the descending order of efficacy were novaluron (0.01%), flufenoxuron (0.01%) and lufenuron (0.01%) with 59.17, 55.72 and 53.54 mean per cent reduction of larval population of *C. binotalis* over the control, respectively. Among all the treatments, the neem (2 ml/l) was least effective with 50.93 mean per

cent reduction of larval population of *C. binotalis* over the control at three days after first spraying.

The data recorded on seven days after first spraying revealed that novaluron (0.005%) + cartap hydrochloride (0.025%) and flufenoxuron (0.005%) + cartap hydrochloride (0.025%) were on par with each other and significantly superior in reducing the larval population of larval population over the control i.e., 86.93 and 84.92 mean per cent reduction. Then the next best treatment lufenuron (0.005%) + cartap hydrochloride (0.025%) recorded the 79.21 mean per cent reduction of larval population of *C. binotalis* over the control. In the order of efficacy, novaluron (0.01%) and flufenoxuron (0.01%) showed 73.82 and 70.30 mean per cent reduction of larval population of *C. binotalis,* respectively, and these two treatments were on par with each other. The treatment lufenuron (0.01%) recorded 68.51 mean per cent reduction of larval population of *C. binotalis* which was also on par with the treatment flufenoxuron (0.01%) with 70.30 mean per cent reduction of larval population of *C. binotalis* over the control. The cartap hydrochloride (0.05%) recorded 49.79 mean per cent reduction of larval population over the control. Among the insecticidal treatments, neem (2 ml/l) was least effective and recorded the lowest mean per cent reduction i.e. 38.21 in the larval population of *C. binotalis* over the control. However, all the insecticidal treatments were significantly

superior over the control in reducing the larval population of *C. binotalis* at seven days after first spraying.

The data obtained on ten days after first spraying revealed that all the insecticidal treatments were significantly superior over the control in reducing the larval population of *C. binotalis*. The data further indicated that novaluron (0.005%) + cartap hydrochloride (0.025%) was very effective in reducing the larval population of *C. binotalis* over the control i.e. 60.49 mean per cent reduction. The next best treatment was flufenoxuron (0.005%) + cartap hydrochloride (0.025%) recording 54.20 mean per cent reduction of *C. binotalis* which was on par with lufenuron (0.005%) + cartap hydrochloride (0.025%) with 51.58 mean per cent reduction of larval population of *C. binotalis* over the control. The decreasing order of efficacy of treatments were novaluron (0.01%), flufenoxuron (0.01%), lufenuron (0.01%) and cartap hydrochloride (0.05%) with 45.39, 43.15, 37.76 and 28.89 mean per cent reduction of larval population of *C. binotalis* over the control. Among all the treatments, the least effective treatment over untreated control was neem (2 ml/l) with 25.06 mean per cent reduction of larval population of *C. binotalis*.

The overall efficacy of different insecticidal treatments after first round of spraying indicated that all the insecticidal treatments were significantly superior over the control in reducing the larval population of *C. binotalis*. The treatment novaluron (0.005%) + cartap

hydrochloride (0.025%) was significantly superior with 73.22 mean per cent reduction of larval population of *C. binotalis* and was on par with other treatments *viz*., flufenoxuron (0.005%) + cartap hydrochloride (0.025%), lufenuron (0.005%) + cartap hydrochloride (0.025%) and novaluron (0.01%) with 68.04, 65.22 and 59.46 mean per cent reduction of larval population of *C. binotalis* over the control, respectively. The next best treatment flufenoxuron (0.01%) recorded 53.27 mean per cent reduction of larval population which was also on par with other treatments *viz*., flufenoxuron (0.005%) + cartap hydrochloride (0.025%), lufenuron (0.005%) + cartap hydrochloride (0.025%), novaluaron (0.01%) and flufenoxuron (0.01%) with 68.04, 65.22, 59.46 and 56.39 mean per cent reduction of larva population over the control. Among the treatments, neem (2 ml/l) was least effective in reducing the mean per cent reduction i.e. 38.06 of larval population of *C. binotalis* over the control.

4.1.2.2 Second spray

The post-treatmental count at tenth day after first spraying was taken as the pre-treatmental count for the second spraying. The data on the third day after second spraying indicated that all the treatments were significantly superior over the control in reducing the larval population of *C. binotalis* (Table 7 and Fig. 7). The treatment cartap hydrochloride (0.05%) was effective and significantly superior over other treatments in

reducing the larval population of *C. binotalis* i.e. 74.78 mean per cent reduction. The next best treatment was novaluron (0.005%) + cartap hydrochloride (0.025%) which recorded 68.31 mean per cent reduction of larval population of *C. binotalis* over the control. The treatments followed in the descending order of efficacy were flufenoxuron (0.005%) + cartap hydrochloride (0.025%), novaluron (0.01%), flufenoxuron (0.01%), lufenuron (0.005%) + cartap hydrochloride (0.025%) with 63.90, 60.36, 55.48 and 55.12 mean per cent reduction of larval population of *C. binotalis* over the control, respectively and the last two treatments were on par with each other. Among the treatments, neem (2 ml/l) was least effective in reducing the larval population i.e. 49.56 mean per cent which was on par with lufenuron (0.01%) with 51.17 mean per cent reduction of larval population of *C. binotalis* over the control at third day after second spraying.

The data on seventh day after second spraying indicated that all the treatments were effective in reducing the larval population of *C. binotalis* over the control. The treatment novaluron (0.005%) + cartap hydrochloride (0.025%) was very effective and was significantly superior in reducing the larval population over the control i.e. 86.19 mean per cent. The next best treatment flufenoxuron (0.005%) + cartap hydrochloride (0.025%) recorded 81.07 mean per cent reduction of larval population of *C. binotalis* which was on par with lufenuron (0.005%) + cartap hydrochloride (0.025%) with 79.49 mean per cent

reduction of larval population of *C. binotalis* over the control. The order of efficacy among other treatments was novaluron (0.01%), flufenoxuron (0.01%), lufenuron (0.01%) and cartap hydrochloride (0.05%) with 73.34, 66.61, 63.90 and 48.01 mean per cent reduction of larval population of *C. binotalis* over the control, respectively. Among all the treatments, the neem (2 ml/l) was least effective with 38.48 mean per cent reduction of larval population of *C. binotalis* over the control.

The data on ten days after second spraying revealed that novaluron (0.005%) + cartap hydrochloride (0.025%) was very effective and significantly superior over other treatments and recorded 57.09 mean per cent reduction of larval population of *C. binotalis* over the control. The next best treatment flufenoxuron (0.005%) + cartap hydrochloride (0.025%) recorded 49.67 mean per cent reduction of larval population of *C. binotalis* over the control. The descending order of efficacy of the remaining treatments were in the following order *viz*., novaluron (0.01%), lufenuron (0.005%) + cartap hydrochloride (0.025%), flufenoxuron (0.01%), lufenuron (0.01%) and cartap hydrochloride (0.05%) with 43.13, 42.92, 40.20, 38.86 and 29.39 mean per cent reduction of larval population of *C. binotalis* over the control. Among all the treatments, neem (2 ml/l) was least effective and recorded 24.11 mean per cent reduction of larval population of *C. binotalis* over the control.

The data on overall efficacy of insecticidal treatment against *C. binotalis* after second round of spraying revealed that all the insecticidal treatments were effective in reducing the larval population over the control. The treatment novaluron (0.005%) + cartap hydrochloride (0.025%) was effective with 70.53 mean per cent reduction of larval population and it was on par with flufenoxuron (0.005%) + cartap hydrochloride (0.025%), lufenuron (0.005%) + cartap hydrochloride (0.025%) and novaluron (0.01%) with 64.88, 59.17 and 58.94 mean per cent reduction of larval population of *C. binotalis*, over the control, respectively. The next best treatment was flufenoxuron (0.01%) recording 54.09 mean per cent reduction of larval population which was on par with other treatments *viz*., flufenoxuron (0.005%) + cartap hydrochloride (0.025%), lufenuron (0.005%) + cartap hydrochloride (0.025%), novaluron (0.01%), lufenuron (0.01%) and cartap hydrochloride (0.05%) with 64.88, 59.17, 58.94 and 50.72 mean per cent reduction of larval population of *C. binotalis* over the control, respectively. Among the treatments, neem (2 ml/l) was least effective with 37.38 mean per cent reduction of larval population of *C. binotalis* over the control.

4.1.2.3 Third spray

The post treatment count at ten days after second spraying served as the pretreatment count for the third spraying. The data recorded at

third day after spraying suggested that all the insecticidal treatments were significantly superior over the control in reducing the larval population of *C. binotalis* (Table 8 and Fig. 8). The treatment cartap hydrochloride (0.05%) was most effective with 72.30 mean per cent reduction of larval population of *C. binotalis* over the control. The next best treatment novaluron (0.005%) + cartap hydrochloride (0.025%) recorded 65.55 mean per cent reduction of larval population of *C. binotalis* over the control. Among the remaining treatments, flufenoxuron (0.005%) + cartap hydrochloride (0.025%) has recorded 63.31 mean per cent reduction of larval population of *C. binotalis* which was on par with novaluron (0.01%) with 60.24 mean per cent reduction of larval population of *C. binotalis* over the control. In the order of efficacy, novaluron (0.01%), flufenoxuron (0.01%) and lufenuron (0.005%) + carap hydrochloride (0.025%) and lufenuron (0.01%) showed 60.24, 57.67, 56.59 and 54.26 mean per cent reduction of larval population of *C. binotalis* over the control. Among the treatments, neem (2 ml/l) was least effective with 44.26 mean per cent reduction of larval population of *C. binotalis* over the control.

The data recorded on seventh day after third spraying revealed that novaluron (0.005%) + cartap hydrochloride (0.025%) was significantly superior in reducing 81.62 mean per cent reduction of larval population of *C. binotalis* and was also on par with flufenoxuron (0.005%) + cartap hydrochloride (0.025%) with 76.45 mean per cent

reduction of larval population of *C. binotalis* over the control. The next best treatment lufenuron (0.005%) + cartap hydrochloride (0.025%) recorded 71.62 mean per cent reduction of larval population of *C. binotalis* which was also on par with other treatments *viz*., novaluron (0.01%) and flufenoxuron (0.01%) with 70.95 and 68.19 mean per cent reduction of larval population of *C. binotalis* over the control. Cartap hydrochloride (0.05%) showed 41.96 mean per cent reduction of larval population of *C. binotalis* over the control. Among the treatments, neem (2 ml/l) was least effective with 37.83 mean per cent reduction of larval population of *C. binotalis* over the control.

The data recorded at ten days after third spraying over the control indicated that all the insecticidal treatments were significantly superior over the control in reducing the larval population of *C. binotalis*. Among the treatments, novaluron (0.005%) + cartap hydrochloride (0.025%) was very effective and significantly superior to other treatments with 56.51 mean per cent reduction which was also on par with flufenoxuron (0.005%) + cartap hydrochloride (0.025%) with 52.48 mean per cent reduction in larval population of *C. binotalis* over the control. The next best treatments in the descending order of efficacy was lufenuron (0.025%) + cartap hydrochloride (0.025%), novaluron (0.01%), flufenoxuron (0.01%), lufenuron (0.01%) and cartap hydrochloride (0.05%) with 46.48, 39.60, 37.47, 34.74 and 31.02 mean per cent reduction of larval population of *C. binotalis* over the control,

respectively. Among the treatments, neem (2 ml/l) was the least effective with 22.40 mean per cent reduction of larval population of *C. binotalis* over the control.

The overall efficacy of the different insecticidal treatments after third round of spraying revealed that novaluron (0.005%) + cartap hydrochloride (0.025%) was very effective and significantly superior with 68.56 mean per cent population of larval population which was on par with other treatments *viz*., flufenoxuron (0.005%) + cartap hydrochloride (0.025%), lufenuron (0.005%) + cartap hydrochloride (0.025%), novaluron (0.01%) and flufenoxuron (0.01%) with 64.08, 58.22, 56.93 and 54.44 mean per cent reduction of larval population of *C. binotalis* over the control, respectively. The next best treatment lufenuron (0.01%) recorded 50.97 mean per cent reduction of larval population which was on par with flufenoxuron (0.005%) + cartap hydrochloride (0.025%), lufenuron (0.005%) + cartap hydrochloride (0.025%), novaluron (0.01%), flufenoxuron (0.01%) and cartap hydrochloride (0.05%) with 64.08, 58.22, 56.93, 54.44 and 48.42 mean per cent reduction of larval population of *C. binotalis* over the control. Among the treatments, neem was least effective with 34.83 mean per cent reduction which was also on par with cartap hydrochloride with 48.42 mean per cent reduction of larval population of *C. binotalis* over the control. However, all the insecticidal treatments were significantly

superior over the control in reducing the larval population of *C. binotalis* after third spraying.

4.1.2.4 Overall efficacy of three rounds of insecticidal sprayings against cabbage leaf webber, *C. binotalis*

The data on the overall efficacy of different insecticidal treatments against *C. binotalis*, pooled from the three rounds of insecticidal spraying are presented in Table 9 and Fig. 9.

The pooled data pertaining to third day after spraying indicated that all the insecticidal treatments were significantly superior over the control in reducing the larval population of *C. binotalis*. Among the treatments, cartap hydrochloride (0.05%) was significantly superior over other treatments with 73.88 mean per cent reduction of larval population of *C. binotalis* over the control. Novaluron (0.005%) + cartap hydrochloride (0.025%) as next best treatment recorded 69.34 mean per cent reduction of larval population of *C. binotalis* over the control. The treatments in the descending order of efficacy were flufenoxuron (0.005%) + cartap hydrochloride (0.025%), novaluron (0.01%), lufenuron (0.005%) + cartap hydrochloride (0.025%), flufenoxuron (0.01%) and lufenuron (0.01%) with 64.07, 59.92, 58.86, 56.29 and 52.99 mean per cent reduction of larval population of *C. binotalis* over the control, respectively. Among the treatments, neem (2 ml/l) was least effective with 48.25 mean per cent reduction of larval population of *C. binotalis* over the control.

The pooled data of the three rounds of insecticidal spraying pertaining to seventh day after spraying revealed that novaluron (0.005%) + cartap hydrochloride (0.025%) was very effective and significantly superior over other treatments with 84.96 mean per cent reduction of larval population of *C. binotalis* over the control. Flufenoxuron (0.005%) + cartap hydrochloride (0.025%) recorded 80.81 mean per cent reduction of larval population of *C. binotalis* over the control. The treatments that followed in the descending order of efficacy was lufenuron (0.005%) + cartap hydrochloride (0.025%), novaluron (0.01%), flufenoxuron (0.01%), lufenuron (0.01%) and cartap hydrochloride (0.05%) with 76.77, 72.70, 68.36, 65.44 and 46.48 mean per cent reduction of larval population of *C. binotalis* over the control, respectively. Among all the treatments, neem (2 ml/l) was the least effective treatment in reducing the mean per cent reduction of larval population of *C. binotalis* i.e. 38.17 over the control. However, all the insecticidal treatments were significantly superior over the control in reducing the larval population of *C. binotalis*.

The pooled data of three sprays pertaining to tenth day after spraying indicated that, novaluron (0.005%) + cartap hydrochloride (0.025%) was most effective and significantly superior over other treatments in reducing the larval population of *C. binotalis* over the control i.e. 58.03 mean per cent. The next best treatment flufenoxuron (0.005%) + cartap hydrochloride (0.025%) recorded 52.11 mean per cent

reduction of larval population of *C. binotalis* over the control. The order of efficacy of other treatments in descending order was lufenuron (0.005%) + cartap hydrochloride (0.025%), novaluron (0.01%), flufenoxuron (0.01%), lufenuron (0.01%) and cartap hydrochloride (0.05%) with 46.99, 42.70, 40.27, 37.12 and 29.76 mean per cent reduction of larval population of *C. binotalis* over the control, respectively. Among all the treatments, neem (2 ml/l) was least effective and recorded 23.85 mean per cent reduction of larval population of *C. binotalis* over the control.

The overall efficacy of insecticidal treatments against *C. binotalis* larval population, when the entire data of the three rounds of sprays was put together indicated that all the insecticidal treatments were significantly superior over the control. Among the treatments, novaluron (0.005%) + cartap hydrochloride (0.025%) was the most effective with 70.77 mean per cent reduction and significantly superior which was on par with flufenoxuron (0.005%) + cartap hydrochloride (0.025%), lufenuron (0.005%) + cartap hydrochloride (0.025%) and novaluron (0.01%) with 65.66, 60.87, and 58.44 mean per cent reduction of larval population of *C. binotalis* over the control, respectively. The next best treatment flufenoxuron (0.01%) has recorded 54.97 mean per cent reduction and was on par with flufenoxuron (0.005%) + cartap hydrochloride (0.025%), lufenuron (0.005%) + cartap hydrochloride (0.025%), novaluron (0.01%), lufenuron (0.01%) and cartap

hydrochloride (0.05%) with 65.66, 60.87, 58.44, 51.51 and 50.04 mean per cent reduction of larval population of *C. binotalis* over the control, respectively. Among the treatments, neem (2 ml/l) was least effective with 36.75 mean per cent reduction of larval population which was also on par with lufenuron (0.01%) and cartap hydrochloride (0.05%) with 51.51 and 50.04 mean per cent reduction of larval population of *C. binotalis* over the control, respectively.

4.2 DETERMINATION OF ED_{50} AND ED_{90} VALUES OF CHITIN SYNTHESIS INHIBITORS TO *P. xylostella*

The third instar *P. xylostella* larvae were treated with different doses i.e. 0.004, 0.01, 0.02, 0.03, 0.04, 0.2, 0.4, 0.6 and 0.8 ng a.i. per larva of chitin synthesis inhibitors *viz*., novaluron, flufenoxuron and lufenuron and the results are presented in Tables 9, 10 and 11. The criteria of mortality were taken either with deformity in larval-pupal transformation or pupal-adult transformation or death of the larva/pupa.

Chitin synthesis inhibitors have varied affects and could be broadly categorized into the following groups.

a. The affected larvae were sluggish failed to moult and resulted in deformed larvae (Plate 2).
b. During larval-pupal transformation, failure of the larva to shed its cuticle resulted in deformed pupae (Plate 3).
c. The pupae become dark and hard resulting in formation of deformed pupae (Plate 4).
d. Adult insects just broke the pupal case but failed to emerge (Plate 5).

e. The emerged adults had deformed wings and also deformed abdomen (Plate 6).

4.2.1 Effect of novaluron to *P. xylostella* at fifth day after treatment

The affect of novaluron on diamondback moth, *P. xylostella* larva was 27.58, 31.03, 34.48, 37.93, 44.82, 58.62, 68.96, 82.75 and 93.10 per cent mortality for doses of 0.004, 0.01, 0.02, 0.03, 0.04, 0.2, 0.4, 0.6 and 0.8 ng a.i. per larva, respectively. The per cent mortality of larvae and dose applied to *P. xylostella* were directly proportional to each other (Table 13).

The chi-square test indicated that the *P. xylostella* larval population used in this study were homogenous (χ^2 = 7.386). The slope of the log dose probit (ldp) line was 2.17071 (Fig. 10). The ED_{50} and ED_{90} values for novaluron were 0.13468 and 0.72506 ng a.i. per larva of *P. xylostella* at fifth day after treatment.

Table 13 : Effect of novaluron to *P. xylostella* at fifth day after treatment

Dose (ng a.i./larva)	Corrected per cent of mortality	Heteroge-neity (χ^2)	ED_{50} (95 FL)	ED_{90} (95 FL)	Slope b±SE
0.004	27.58				
0.01	31.03				
0.02	34.48				
0.03	37.93				
0.04	44.82	7.386	0.13468 (0.04646-0.21404)	0.72506 (0.57961-0.98247)	2.17071± 2.76463
0.2	58.62				
0.4	68.96				
0.6	82.75				
0.8	93.10				

4.2.2 Effect of flufenoxuron to *P. xylostella* at fifth day after treatment

The larval morality of *P. xylostella* was found to be significantly affected at various doses of flufenoxuron by leaf sandwich method. The per cent larval mortality was dependant and it was 13.79, 17.24, 20.69, 24.14, 27.58, 37.93, 44.82, 55.17 and 89.65 per cent for the doses of 0.004, 0.01, 0.02, 0.03, 0.04, 0.2, 0.4, 0.6 and 0.8 ng a. i. per larva, respectively (Table 14). The ED_{50} and ED_{90} values for larval morality at fifth day after treatment were 0.40773 and 1.03947 ng a.i. per larva, respectively. The slope of the log dose probit line was 2.0286 (Fig. 11).

Table 14 : Effect of flufenoxuron to *P. xylostella* at fifth day after treatment

Dose (ng a.i./larva)	Corrected per cent of mortality	Heterogeneity (χ^2)	ED_{50} (95 FL)	ED_{90} (95 FL)	Slope b±SE
0.004	13.79				
0.01	17.24				
0.02	20.69				
0.03	24.14				
0.04	27.58	6.783	0.40773 (0.31975-0.52596)	1.03947 (0.84479-1.38223)	2.02860± 7.17207
0.2	37.93				
0.4	44.82				
0.6	55.17				
0.8	89.65				

4.2.3 Effect of lufenuron to *P. xylostella* at ninth day after treatment

The mortality of *P. xylostella* at fifth day after treatment of lufenuron was very low. So the mortality at ninth day after treatment were subjected to probit analysis and the results obtained are presented below:

The mortality of *P. xylostella* larvae was 25.00, 28.57, 32.14, 35.71, 39.29, 42.86, 53.57, 71.43 and 82.14 per cent for doses of 0.04, 0.01, 0.02, 0.03, 0.04, 0.2, 0.4, 0.6 and 0.8 ng a.i. per larva, respectively (Table 15). The chi-square test indicated that the *P. xylostella* larval population used in this study was homogenous ($\chi^2 = 4.992$). The slope of the log dose probit line was 1.25966. The ED_{50} and ED_{90} values of lufenuron to *P. xylostella* at ninth day after treatment were 0.31999 and 1.33737 ng a.i. per larva, respectively (Fig. 12).

Table 15 : Effect of lufenuron to *P. xylostella* at ninth day after treatment

Dose (ng a.i./larva)	Corrected per cent of mortality	Heteroge-neity (χ^2)	ED_{50} (95 FL)	ED_{90} (95 FL)	Slope b±SE
0.004	25.00				
0.01	28.57				
0.02	32.14				
0.03	35.71				
0.04	39.29	4.992	0.31999 (0.18927-0.49425)	1.33737 (0.98034-2.32256)	1.25966± 3.79465
0.2	42.86				
0.4	53.57				
0.6	71.43				
0.8	82.14				

4.3 INFLUENCE OF MAJOR ABIOTIC FACTORS ON THE POPULATION BUILD UP OF LEPIDOPTEROUS PESTS

4.3.1 Diamondback moth, *P. xylostella*

The data recorded on the incidence of diamondback moth, *P. xylostella* larval population at weekly intervals revealed that the *P. xylostella* infestation begin during the third week of November with mean population of 0.38 larvae per plant (Table 16). The average maximum and minimum temperatures prevailed during third week of November, 2003 were 29.9^{o}C and 15.3^{o}C, while the average morning and evening relative humidity were 87 and 43 per cent, respectively, with nil rainfall and 7.8 sunshine hours (Figs. 13 and 14).

The highest larval incidence was observed during the last week of January, 2004 i.e. at 85 days after transplanting with 4.85 larvae per plant. During the period of peak incidence the average maximum and minimum temperatures were 29.5^{o}C and 18.9^{o}C, respectively while, the average morning and evening relative humidity were 91 and 52 per cent, respectively along with 2.8 mm of rainfall and 7.2 sun shine hours. The peak larval incidence continued till the end of first week of February. Thereafter there was a sudden decline and a population of 0.4 and 0.1 larvae per plant were recorded during second and third week of February 2004, respectively.

The correlations were worked out to find out the interaction between the number of larvae per plant with major abiotic factors *viz*., maximum and minimum temperatures, morning and evening relative humidities, rainfall and sunshine hours and the results are presented in Table 17.

Table 17 : Simple correlation between weather parameters and the incidence of *P. xylostella* larval population on cabbage during *rabi*, 2003-04

Weather parameters	Correlation coefficient 'r'
Maximum temperature	-0.4855*
Minimum temperature	-0.0504^{NS}
RH I	0.2707^{NS}
RH II	0.0884^{NS}
Rainfall	-0.0293^{NS}
Sunshine hours	-0.3892^{NS}

* : Significant at 5% level

NS : Non significant

A significant negative correlation (r = -0.4855) was found between maximum temperature and diamondback moth larval population. Minimum temperature was also found to exert non significant negative action (r = -0.0504). The morning relative humidity and evening relative humidity were positively correlated with number of larvae per plant but were non-significant with correlation coefficient values of 0.2707 and 0.0884, respectively. The rainfall and sunshine

hours were negatively correlated with pest incidence and were non-significant.

The results of the multiple linear regression on *P. xylostella* population and selected weather parameters showed that the larval population were negatively correlated with maximum temperature, RH II and sunshine hours, whereas larval population was positively correlated with minimum temperature, RH I and rainfall (Table 18).

Neither the simple correlation between each of the factors individually nor the multiple regression have been able to bring out the true significance of the relationship among the different weather parameters studied.

In order to have a clear understanding of the weather factors, which have directly contributed to diamondback moth incidence either individually or in concert, step down regression has been worked out.

The cumulative effect of weather parameters on the population build up of diamondback moth revealed that they effect to an extent of 28.11 per cent (R^2=0.2811). In step down regression analysis, all the parameters except rainfall and minimum temperature have effected the diamondback moth to an extent of 31.18 per cent (R^2=0.3118). Among all the major abiotic factors sunshine hours was the least effective with only 9.42 per cent (R^2=0.0942) impact on diamondback moth (Table 19).

4.3.2 Cabbage leaf webber, *C. binotalis*

The data recorded on the incidence of leaf webber population at weekly intervals revealed that the infestation of *C. binotalis* started during the third week of November i.e. 1.6 mean number of larvae per plant (Table 16). The average maximum and minimum temperatures prevailed during the third week of November, 2003 were 29.9^{o}C and 15.3^{o}C, while the average morning and evening relative humidities were 87 and 43 per cent respectively, with nil rainfall and 7.8 sunshine hours. The peak leaf webber larval population was recorded during the third week of January with 6.20 larvae per plant and the weather parameters *viz*., the average maximum and minimum temperatures were 31.1^{o}C and 11.9^{o}C, respectively while average morning and evening relative humidities were 87 and 27 per cent, respectively along with nil rainfall and 9.8 sunshine hours. The peak larval population of leaf webber continued till the first week of February thereafter there was a gradual decline with 2.30 and 1.30 larva per plant during second and third week of February 2004, respectively (Fig. 15 and 16).

Table 20 : Simple correlation between weather parameters and the incidence of *C. binotalis* larval population on cabbage during *rabi*, 2003-04

Weather parameters	Correlation coefficient 'r'
Maximum temperature	-0.4994*
Minimum temperature	-0.1623^{NS}
RH I	0.1586^{NS}
RH II	0.0268^{NS}
Rainfall	-0.0791^{NS}
Sunshine hours	-0.3707^{NS}

* : Significant at 5% level

NS : Non significant

The correlation coefficients of maximum temperature showed a significant negative correlation (r = -0.4994) with leaf webber larval population (Table 18). Minimum temperature was also found to be negatively correlated but it was non-significant (r = -0.1623). Morning and evening relative humidity were positively correlated with number of cabbage leaf webber larvae, but these were non-significant with 'r' values of 0.1586 and 0.0268, respectively. Rainfall and sunshine hours were negatively correlated with leaf webber population per plant ('r' values -0.0791 and -0.3707) which were also non-significant.

The results of multiple linear regression model revealed that, the cabbage leaf webber population were negatively regressed with maximum temperature, evening relative humidity and sunshine hours and were non significant. The cabbage leaf webber population positively

regressed with minimum temperature, morning relative humidity and rainfall (Table 21).

In order to have a clear cut understanding a step down regression analysis was worked out (Table 22), which revealed that all the selected major abiotic factors have influenced the cabbage leaf webber to an extent of 19.9 per cent (R^2 = 0.1990). All the major abiotic factors except minimum temperature and rainfall have influenced the maximum effect on cabbage leaf webber (R^2 = 0.3039). Sunshine hours was the least influenced parameter on the cabbage leaf webber population to an extent of 7.98 per cent (R^2 = 0.0798).

Table 18 : Multiple linear regression analysis of larval population of *P. xylostella* on selected weather parameters

Variable	Partial regression coefficient	Standard error	t value
X_1 : Max. temp.	-1.0454	0.6917	1.5113^{NS}
X_2 : Min. temp.	0.5317	0.5083	1.0461^{NS}
X_3 : RH I	0.1779	0.1105	1.6105^{NS}
X_4 : RH II	-0.3171	0.1618	1.9591^{NS}
X_5 : Rainfall	0.2100	0.2886	0.7277^{NS}
X_6 : Sunshine hours	-0.6877	0.5602	1.2275^{NS}

NS : Non significant

Multiple Linear Regression equation :

$Y = 27.8086-1.0454X_1 + 0.5317X_2 + 0.1779X_3-0.3171X_4 + 0.2100X_5 - 0.6877X_6$

Intercept = 27.8086 ; F. value = 2.042; R^2 value = 0.2811

Table 19 : Step down regression analysis of larval population of *P. xylostella* on selected weather parameters

S.No.	Weather parameters eliminated	R^2 value
1	None	0.2811
2	Rainfall	0.3118
3	Rainfall, min. temp.	0.3199
4	Rainfall, min. temp., max. temp.	0.2931
5	Rainfall, min. temp., max. temp., RH I	0.1539
6	Rainfall, min. temp., max. temp., RH I, RH II	0.0942

Table 21 : Multiple linear regression analysis of larval population of *C. binotalis* on selected weather parameters

Variable	Partial regression coefficient	Standard error	t value
X_1 : Max. temp.	-0.6078	0.8445	0.7197^{NS}
X_2 : Min. temp.	0.0821	0.6206	0.1324^{NS}
X_3 : RH I	0.1634	0.1348	1.2118^{NS}
X_4 : RH II	-0.2413	0.1976	1.2212^{NS}
X_5 : Rainfall	0.2304	0.3524	0.6537^{NS}
X_6 : Sunshine hours	-1.1242	0.6839	1.6437^{NS}

NS : Non significant

Multiple Linear Regression equation :

$Y = 24.1956-0.6078X_1 + 0.0821X_2 + 0.1634X_3 - 0.2413X_4 + 0.2304X_5 - 1.1242X_6$

Intercept = 24.1956; F. value = -1.6625; R^2 value = 0.1990

Table 22 : Step down regression analysis of larval population of *C. binotalis* on selected weather parameters

S.No.	Weather parameters eliminated	R^2 value
1	None	0.1990
2	Min. temp.	0.2705
3	Min. temp., rainfall	0.3039
4	Min. temp., rainfall, max. temp.	0.2657
5	Min. temp., rainfall, max. temp., RH I	0.1998
6	Min. temp., rainfall, max. temp., RH I, RH II	0.07988

Table : Influence of selected weather parameters on the population build-up of lepidopterous pests of cabbage

Week No.	Period	Temperature (^{o}C)		RH		Rain fall (mm)	Sunshine hours per day	Mean no. of larvae per plant	
		Maximum	Minimum	I	II			Diamond-back moth	Cabbage leaf webber
44	29-04 Nov	30.1	19.3	93	60	8.6	8.0	0.00	0
45	05-11	30.1	16.5	90	40	0.0	8.7	0.00	0.00
46	12-18	29.9	15.3	87	43	0.0	7.8	0.38	1.60
47	19-25	29.1	12.6	89	40	0.0	9.1	0.73	1.56
48	26-02 Dec	29.2	12.7	89	41	0.0	9.0	0.86	2.16
49	03-09	29.3	9.5	80	26	0.0	9.3	1.03	2.60
50	10-16	29.0	11.7	84	36	0.0	8.3	1.31	3.40
51	17-23	28.5	10.0	86	30	0.0	9.2	1.54	2.80
52	24-31	26.8	15.8	83	51	0.0	4.7	3.81	4.50
1	01-07 Jan	28.1	12.5	91	39	0.0	8.3	3.85	4.80
2	08-14	27.7	9.2	87	28	0.0	9.2	4.49	5.20
3	15-21	31.1	11.9	87	27	0.0	9.8	4.12	6.20
4	22-28	29.5	18.9	91	52	2.8	7.2	4.85	5.30
5	29-04 Feb	28.8	18.1	93	55	4.5	5.5	2.85	3.60
6	05-11	29.6	12.7	78	36	0.0	9.3	0.40	2.30
7	12-18	30.5	13.7	80	33	0.0	9.9	0.10	1.30
8	19-25	33.7	14.7	83	26	0.0	9.7	0.00	0.00

Table 2: Efficacy of insecticidal treatments against diamondback moth, *P. xylostella* after first spraying

	Treatment	Mean pre treatment larval population/plant	Mean per cent reduction of larval population over control			
			3 DAS	7 DAS	10 DAS	Overall
T_1	Novaluron @ 0.01%	4.13	56.36 (48.65)^{b}	66.67 (54.74)^{c}	46.52 (42.99)^{b}	56.51 (48.79)^{ab}
T_2	Lufenuron @ 0.01%	3.93	51.76 (46.01)^{b}	65.42 (53.98)^{c}	33.94 (35.33)^{c}	50.37 (45.20)^{b}
T_3	Flufenoxuron @ 0.01%	3.73	55.16 (47.96)^{b}	66.82 (54.83)^{c}	44.36 (41.73)^{b}	55.44 (48.18)^{b}
T_4	Novaluron @ 0.005% + Cartap hydrochloride @ 0.025%	3.80	69.53 (56.55)^{a}	80.27 (63.66)^{a}	55.69 (48.27)^{a}	68.49 (56.13)^{a}
T_5	Lufenuron @ 0.005% + Cartap hydrochloride @ 0.025%	3.86	56.32 (48.66)^{b}	76.10 (60.76)^{b}	44.14 (41.61)^{b}	58.85 (50.33)^{ab}
T_6	Flufenoxuron @ 0.005% + Cartap hydrochloride @ 0.025%	4.00	65.04 (53.77)^{a}	78.42 (62.32)^{ab}	50.96 (45.52)^{ab}	64.80 (53.87)^{ab}
T_7	Neem @ 0.2 %	3.60	29.50 (32.85)^{c}	34.37 (35.89)^{e}	23.29 (28.78)^{d}	29.05 (32.54)^{c}
T_8	Cartap hydrochloride @ 0.05%	4.46	70.08 (56.84)^{a}	48.33 (44.04)^{d}	34.05 (35.70)^{c}	50.82 (45.52)^{b}
	S.Em±		1.75	0.83	2.39	3.72
	C.D. (P=0.05)		3.72	1.77	5.07	7.89

DAS : Days after spraying;
Figures in parenthesis are arc sin transformed values
Means followed by same letters are not significantly differ at 5% level by Dunkun's multiple range test.
C.D. (p=0.05) : Critical difference at 5% level;
S.Em± : Standard error of mean.

Table 3: Efficacy of insecticidal treatments against diamondback moth, *P. xylostella* after second spraying

	Treatment	Mean pre treatment larval population/plant	Mean per cent reduction of larval population over control			
			3 DAS	7 DAS	10 DAS	Overall
T_1	Novaluron @ 0.01%	4.60	54.16 (47.39)^{d}	71.09 (57.48)^{ab}	48.42 (44.09)^{b}	57.89 (49.65)^{ab}
T_2	Lufenuron @ 0.01%	5.86	48.54 (44.16)^{e}	57.94 (49.57)^{c}	34.19 (35.76)^{e}	46.89 (43.17)^{b}
T_3	Flufenoxuron @ 0.01%	4.40	52.11 (46.21)^{d}	66.98 (54.95)^{b}	40.65 (39.60)^{d}	53.24 (46.91)^{ab}
T_4	Novaluron @ 0.005% + Cartap hydrochloride @ 0.025%	5.26	69.95 (56.76)^{b}	74.81 (59.87)^{a}	55.85 (48.36)^{a}	66.87 (54.99)^{a}
T_5	Lufenuron @ 0.005% + Cartap hydrochloride @ 0.025%	4.60	66.16 (54.43)^{c}	66.84 (54.88)^{b}	44.43 (41.79)^{c}	59.14 (50.35)^{ab}
T_6	Flufenoxuron @ 0.005% + Cartap hydrochloride @ 0.025%	4.73	66.04 (54.37)^{c}	71.92 (58.01)^{a}	47.24 (43.41)^{bc}	61.73 (51.92)^{a}
T_7	Neem @ 0.2 %	4.80	28.68 (32.37)^{f}	27.61 (31.69)^{e}	20.85 (27.15)^{g}	25.71 (30.41)^{c}
T_8	Cartap hydrochloride @ 0.05%	5.86	76.73 (61.17)^{a}	49.94 (44.96)^{d}	29.95 (33.14)^{f}	52.20 (46.43)^{ab}
	S.Em±		0.95	1.31	1.00	4.07
	C.D. (P=0.05)		2.02	2.78	2.13	8.62

DAS : Days after spraying;
Figures in parenthesis are arc sin transformed values
Means followed by same letters are not significantly differ at 5% level by Dunkun's multiple range test.
C.D. (p=0.05) : Critical difference at 5% level;
S.Em± : Standard error of mean.

Table 4: Efficacy of insecticidal treatments against diamondback moth, *P. xylostella* after third spraying

	Treatment	Mean pre treatment larval population/plant	Mean per cent reduction of larval population over control			
			3 DAS	7 DAS	10 DAS	Overall
T_1	Novaluron @ 0.01%	2.93	53.48 (46.99)^{d}	71.64 (57.82)^{c}	46.57 (43.03)^{ab}	57.23 (49.28)^{a}
T_2	Lufenuron @ 0.01%	4.60	49.03 (44.44)^{d}	67.78 (55.42)^{d}	35.13 (36.33)^{c}	50.64 (45.40)^{a}
T_3	Flufenoxuron @ 0.01%	4.20	52.05 (46.18)^{d}	68.98 (56.16)^{cd}	39.22 (38.75)^{bc}	53.42 (47.04)^{a}
T_4	Novaluron @ 0.005% + Cartap hydrochloride @ 0.025%	3.00	65.81 (54.23)^{b}	78.64 (62.48)^{a}	53.41 (46.95)^{a}	65.95 (54.54)^{a}
T_5	Lufenuron @ 0.005% + Cartap hydrochloride @ 0.025%	3.13	58.69 (50.03)^{c}	66.88 (54.87)^{d}	44.65 (41.92)^{b}	56.74 (48.93)^{a}
T_6	Flufenoxuron @ 0.005% + Cartap hydrochloride @ 0.025%	3.20	65.31 (53.92)^{b}	75.71 (60.50)^{b}	48.42 (44.09)^{ab}	63.14 (52.82)^{a}
T_7	Neem @ 0.2 %	4.13	24.47 (29.60)^{e}	22.20 (28.09)^{f}	22.97 (28.56)^{d}	23.21 (28.79)^{b}
T_8	Cartap hydrochloride @ 0.05%	4.86	75.99 (60.66)^{a}	54.71 (47.70)^{e}	27.52 (31.56)^{d}	52.74 (46.66)^{a}
	S.Em±		1.42	0.80	1.86	4.56
	C.D. (P=0.05)		3.01	1.71	3.96	9.67

DAS : Days after spraying;
Figures in parenthesis are arc sin transformed values
Means followed by same letters are not significantly differ at 5% level by Dunkun's multiple range test.
C.D. (p=0.05) : Critical difference at 5% level;
S.Em± : Standard error of mean.

Table 5 : Efficacy of insecticidal treatments against diamondback moth, *P. xylostella* after three rounds of spraying

Treatment	Mean per cent reduction of larval population over control			
	3 DAS	7 DAS	10 DAS	Overall
T_1 Novaluron @ 0.01%	54.66 (47.67)^{d}	69.80 (56.67)^{b}	47.17 (43.37)^{c}	57.21 (49.23)^{ab}
T_2 Lufenuron @ 0.01%	49.77 (44.87)^{e}	63.71 (52.98)^{c}	34.42 (35.92)^{e}	49.30 (46.58)^{b}
T_3 Flufenoxuron @ 0.01%	53.10 (46.78)^{de}	67.59 (55.30)^{b}	41.42 (40.05)^{d}	54.03 (47.37)^{ab}
T_4 Novaluron @ 0.005% + Cartap hydrochloride @ 0.025%	68.43 (55.82)^{b}	77.90 (61.92)^{a}	54.98 (47.86)^{a}	67.10 (55.21)^{a}
T_5 Lufenuron @ 0.005% + Cartap hydrochloride @ 0.025%	60.39 (51.02)^{c}	70.94 (57.42)^{b}	44.40 (41.78)^{c}	58.57 (50.05)^{ab}
T_6 Flufenoxuron @ 0.005% + Cartap hydrochloride @ 0.025%	65.59 (54.08)^{b}	75.35 (60.26)^{ab}	48.87 (44.35)^{bc}	63.27 (52.86)^{ab}
T_7 Neem @ 0.2 %	27.55 (31.64)^{f}	28.06 (31.90)^{e}	22.37 (28.22)^{g}	25.99 (30.62)^{c}
T_8 Cartap hydrochloride @ 0.05%	74.26 (59.55)^{a}	50.99 (45.57)^{d}	30.50 (33.50)^{f}	51.91 (46.11)^{b}
S.Em±	1.27	1.79	0.77	3.90
C.D. (P=0.05)	2.70	3.79	1.65	8.27

DAS : Days after spraying;
Figures in parenthesis are arc sin transformed values
Means followed by same letters are not significantly differ at 5% level by Dunkun's multiple range test.
C.D. (p=0.05) : Critical difference at 5% level;
S.Em± : Standard error of mean.

Table 6: Efficacy of insecticidal treatments against cabbage leaf webber, *C. binotalis* after first spraying

	Treatment	Mean pre treatment larval population/plant	Mean per cent reduction of larval population over control			
			3 DAS	7 DAS	10 DAS	Overall
T_1	Novaluron @ 0.01%	5.73	59.17 (50.28)^{c}	73.82 (59.23)^{c}	45.39 (42.35)^{c}	59.46 (50.62)^{ab}
T_2	Lufenuron @ 0.01%	6.93	53.54 (47.03)^{d}	68.51 (55.89)^{d}	37.76 (37.91)^{d}	53.27 (46.93)^{b}
T_3	Flufenoxuron @ 0.01%	4.86	55.72 (48.28)^{d}	70.30 (56.99)^{cd}	43.15 (41.05)^{c}	56.39 (48.77)^{b}
T_4	Novaluron @ 0.005% + Cartap hydrochloride @ 0.025%	4.86	72.16 (58.15)^{a}	86.93 (68.85)^{a}	60.49 (51.07)^{a}	73.22 (59.36)^{a}
T_5	Lufenuron @ 0.005% + Cartap hydrochloride @ 0.025%	6.53	64.89 (53.67)^{b}	79.21 (62.92)^{b}	51.58 (45.90)^{b}	65.22 (54.14)^{ab}
T_6	Flufenoxuron @ 0.005% + Cartap hydrochloride @ 0.025%	5.26	65.01 (53.74)^{b}	84.92 (67.15)^{a}	54.20 (47.41)^{b}	68.04 (56.09)^{ab}
T_7	Neem @ 0.2 %	6.26	50.93 (45.53)^{e}	38.21 (38.18)^{f}	25.06 (30.01)^{f}	38.06 (37.91)^{c}
T_8	Cartap hydrochloride @ 0.05%	6.06	74.58 (59.73)^{a}	49.79 (44.71)^{e}	28.89 (32.51)^{e}	50.98 (45.64)^{b}
	S.Em±		0.87	1.06	1.01	4.59
	C.D. (P=0.05)		1.84	2.25	2.16	9.74

DAS : Days after spraying;
Figures in parenthesis are arc sin transformed values
Means followed by same letters are not significantly differ at 5% level by Dunkun's multiple range test.
C.D. (p=0.05) : Critical difference at 5% level;
S.Em± : Standard error of mean.

Table 7: Efficacy of insecticidal treatments against cabbage leaf webber, *C. binotalis* after second spraying

	Treatment	Mean pre treatment larval population/plant	Mean per cent reduction of larval population over control			
			3 DAS	7 DAS	10 DAS	Overall
T_1	Novaluron @ 0.01%	5.73	60.36 (50.98)^{d}	73.34 (58.92)^{c}	43.13 (41.04)^{c}	58.94 (50.31)^{ab}
T_2	Lufenuron @ 0.01%	6.60	51.17 (45.67)^{f}	63.90 (53.07)^{d}	38.86 (38.56)^{d}	51.31 (45.76)^{b}
T_3	Flufenoxuron @ 0.01%	4.40	55.48 (48.14)^{e}	66.61 (54.70)^{d}	40.20 (39.34)^{cd}	54.09 (47.39)^{b}
T_4	Novaluron @ 0.005% + Cartap hydrochloride @ 0.025%	3.20	68.31 (55.75)^{b}	86.19 (68.19)^{a}	57.09 (49.08)^{a}	70.53 (57.66)^{a}
T_5	Lufenuron @ 0.005% + Cartap hydrochloride @ 0.025%	3.40	55.12 (47.94)^{e}	79.49 (63.09)^{b}	42.92 (40.92)^{c}	59.17 (50.64)^{ab}
T_6	Flufenoxuron @ 0.005% + Cartap hydrochloride @ 0.025%	3.86	63.90 (53.08)^{c}	81.07 (64.29)^{b}	49.67 (44.81)^{b}	64.88 (54.03)^{ab}
T_7	Neem @ 0.2 %	6.26	49.56 (44.75)^{f}	38.48 (38.48)^{f}	24.11 (29.40)^{f}	37.38 (37.49)^{c}
T_8	Cartap hydrochloride @ 0.05%	6.00	74.78 (59.86)^{a}	48.01 (43.86)^{e}	29.39 (32.82)^{ef}	50.72 (45.51)^{b}
	S.Em±		0.82	1.19	0.73	4.74
	C.D. (P=0.05)		1.74	2.53	1.56	10.06

DAS : Days after spraying;
Figures in parenthesis are arc sin transformed values
Means followed by same letters are not significantly differ at 5% level by Dunkun's multiple range test.
C.D. (p=0.05) : Critical difference at 5% level;
S.Em± : Standard error of mean.

Table 8: Efficacy of insecticidal treatments against cabbage leaf webber, *C. binotalis* after third spraying

	Treatment	Mean pre treatment larval population/plant	Mean per cent reduction of larval population over control			
			3 DAS	7 DAS	10 DAS	Overall
T_1	Novaluron @ 0.01%	3.93	60.24 (50.91)^{cd}	70.95 (57.39)^{b}	39.60 (38.99)^{c}	56.93 (49.09)^{ab}
T_2	Lufenuron @ 0.01%	5.13	54.26 (47.44)^{d}	63.92 (53.09)^{c}	34.74 (36.10)^{cd}	50.97 (45.54)^{b}
T_3	Flufenoxuron @ 0.01%	4.00	57.67 (49.41)^{d}	68.19 (55.67)^{bc}	37.47 (37.73)^{c}	54.44 (47.60)^{ab}
T_4	Novaluron @ 0.005% + Cartap hydrochloride @ 0.025%	1.40	65.55 (55.31)^{b}	81.62 (64.92)^{a}	56.51 (48.74)^{a}	68.56 (56.20)^{a}
T_5	Lufenuron @ 0.005% + Cartap hydrochloride @ 0.025%	2.26	56.59 (48.73)^{d}	71.61 (57.82)^{b}	46.48 (42.98)^{b}	58.22 (49.85)^{ab}
T_6	Flufenoxuron @ 0.005% + Cartap hydrochloride @ 0.025%	1.80	63.31 (52.74)^{c}	76.45 (61.09)^{ab}	52.48 (46.43)^{a}	64.08 (53.08)^{ab}
T_7	Neem @ 0.2 %	5.73	44.26 (41.70)^{e}	37.83 (37.95)^{e}	22.40 (28.24)^{e}	34.83 (35.96)^{c}
T_8	Cartap hydrochloride @ 0.05%	4.93	72.30 (58.24)^{a}	41.96 (40.37)^{d}	31.02 (33.81)^{d}	48.42 (44.15)^{bc}
	S.Em±		1.18	1.88	1.49	4.24
	C.D. (P=0.05)		2.50	3.99	3.16	8.99

DAS : Days after spraying;
Figures in parenthesis are arc sin transformed values
Means followed by same letters are not significantly differ at 5% level by Dunkun's multiple range test.
C.D. (p=0.05) : Critical difference at 5% level;
S.Em± : Standard error of mean.

Table 9: Efficacy of insecticidal treatments against cabbage leaf webber, *C. binotalis* after three rounds spraying

Treatment	Mean per cent reduction of larval population over control			
	3 DAS	7 DAS	10 DAS	Overall
T_1 Novaluron @ 0.01%	59.92 (50.72)^{d}	72.70 (58.50)^{d}	42.70 (40.80)^{d}	58.44 (50.00)^{ab}
T_2 Lufenuron @ 0.01%	52.99 (46.71)^{f}	65.44 (54.00)^{e}	37.12 (37.53)^{e}	51.51 (45.88)^{bc}
T_3 Flufenoxuron @ 0.01%	56.29 (48.61)^{e}	68.36 (55.78)^{e}	40.27 (39.38)^{de}	54.97 (47.92)^{b}
T_4 Novaluron @ 0.005% + Cartap hydrochloride @ 0.025%	69.34 (56.38)^{b}	84.96 (67.22)^{a}	58.03 (49.62)^{a}	70.77 (57.72)^{a}
T_5 Lufenuron @ 0.005% + Cartap hydrochloride @ 0.025%	58.86 (50.12)^{d}	76.77 (61.24)^{c}	46.99 (43.27)^{c}	60.87 (51.52)^{ab}
T_6 Flufenoxuron @ 0.005% + Cartap hydrochloride @ 0.025%	64.07 (53.17)^{c}	80.81 (64.10)^{b}	52.11 (46.21)^{b}	65.66 (54.46)^{ab}
T_7 Neem @ 0.2 %	48.25 (43.99)^{g}	38.17 (38.15)^{g}	23.85 (29.23)^{g}	36.75 (37.12)^{c}
T_8 Cartap hydrochloride @ 0.05%	73.88 (59.27)^{a}	46.48 (42.98)^{f}	29.76 (33.06)^{f}	50.04 (45.10)^{bc}
S.Em±	1.07	1.10	0.95	4.54
C.D. (P=0.05)	2.28	2.34	2.01	9.63

DAS : Days after spraying;
Figures in parenthesis are arc sin transformed values
Means followed by same letters are not significantly differ at 5% level by Dunkun's multiple range test.
C.D. (p=0.05) : Critical difference at 5% level;
S.Em± : Standard error of mean.

Table 10 : Effect of novaluron at different doses against third instar larvae of *P. xylostella*

Per cent concentration	Dose ng a.i./larva	Corrected per cent of mortality								
		1st DAT	2nd DAT	3rd DAT	4th DAT	5th DAT	6th DAT	7th DAT	8th DAT	9th DAT
0.02	0.8	26.66	50.00	66.66	80.00	93.10	93.10	96.54	100.00	100.00
0.015	0.6	23.33	43.33	60.00	76.66	82.75	86.20	89.65	89.28	93.10
0.01	0.4	20.00	40.00	53.33	63.33	68.96	68.92	68.96	72.41	72.41
0.005	0.2	20.00	26.66	43.33	50.00	58.62	62.07	65.51	67.85	67.85
0.001	0.04	16.66	23.33	30.00	40.00	44.82	55.16	58.62	62.07	62.07
0.00075	0.03	16.66	23.33	30.00	33.33	37.93	44.82	48.27	48.27	48.27
0.0005	0.02	13.33	16.66	26.66	30.00	34.48	34.47	41.37	44.82	44.82
0.00025	0.01	10.00	13.33	20.00	26.66	31.03	34.47	37.93	37.92	37.92
0.0001	0.004	3.33	10.00	16.66	23.33	27.58	31.03	34.47	34.48	34.48

DAT : Day(s) after treatment

Table 11 : Effect of flufenoxuron at different doses against third instar larvae of *P. xylostella*

Per cent concentration	Dose ng a.i./larva	Corrected per cent of mortality								
		1st DAT	2nd DAT	3rd DAT	4th DAT	5th DAT	6th DAT	7th DAT	8th DAT	9th DAT
0.02	0.8	23.33	36.66	62.06	82.75	89.65	93.10	96.42	96.42	96.42
0.015	0.6	13.33	20.00	27.58	48.27	55.17	75.85	82.14	89.28	92.85
0.01	0.4	10.00	13.33	24.13	41.37	44.82	51.72	60.71	67.85	78.57
0.005	0.2	10.00	13.33	20.68	34.47	37.93	44.82	53.56	64.28	64.28
0.001	0.04	3.33	10.00	17.24	24.13	27.58	37.93	42.85	46.43	46.43
0.00075	0.03	3.33	6.66	13.78	20.68	24.14	31.03	32.14	39.29	39.29
0.0005	0.02	3.33	6.66	10.34	17.24	20.69	27.58	32.14	35.71	35.71
0.00025	0.01	0.00	3.33	6.89	13.78	17.24	24.14	25.00	32.14	32.14
0.0001	0.004	0.00	0.00	0.00	6.89	13.79	24.14	25.00	25.00	25.00

DAT : Day(s) after treatment

Table 12: Effect of lufenuron at different doses against third instar larvae of *P. xylostella*

Per cent concentration	Dose ng a.i./larva	Corrected per cent of mortality								
		1st DAT	2nd DAT	3rd DAT	4th DAT	5th DAT	6th DAT	7th DAT	8th DAT	9th DAT
0.02	0.8	13.33	20.00	24.13	31.03	44.82	58.62	67.85	74.99	82.14
0.015	0.6	10.00	16.66	20.68	27.58	37.93	48.27	60.71	71.42	71.43
0.01	0.4	6.66	13.33	17.24	24.13	34.48	44.82	50.00	50.00	53.57
0.005	0.2	6.66	10.00	13.78	20.68	24.14	37.93	39.28	40.86	42.86
0.001	0.04	6.66	10.00	10.34	17.24	20.68	27.58	28.57	39.29	37.29
0.00075	0.03	3.33	6.66	10.34	13.78	17.24	24.13	25.00	28.57	35.71
0.0005	0.02	0.00	6.66	6.89	10.34	13.79	20.68	25.00	28.57	32.14
0.00025	0.01	0.00	3.33	3.44	10.34	10.34	13.78	21.42	28.57	28.57
0.0001	0.004	0.00	0.00	0.00	3.44	6.89	13.78	17.85	25.00	25.00

DAT : Day(s) after treatment

Plate 1: Field view of the experimental site

Plate 2: Effect of novaluron on larvae of *P. xylostella*

Plate 3: Larval-pupal intermediates of *P. xylostella* due to novaluron

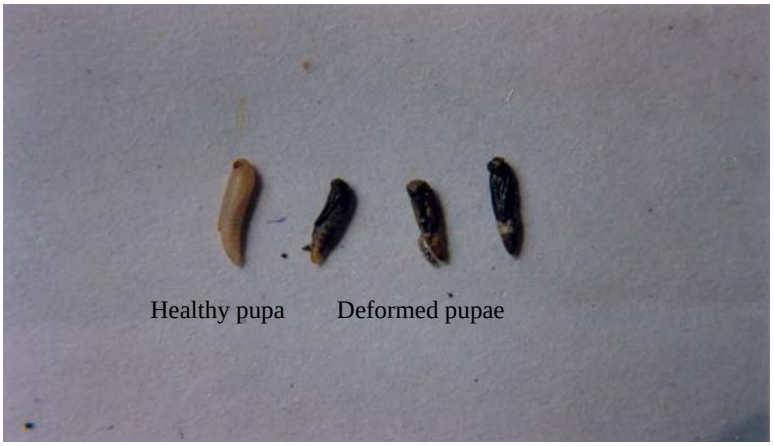


Plate 4: Deformed pupae of *P. xylostella* due to novaluron

Plate 5 : Pupal-adult intermediates of *P. xylostella* due to novaluron

Plate 6 : Deformed adult of *P. xylostella* due to novaluron

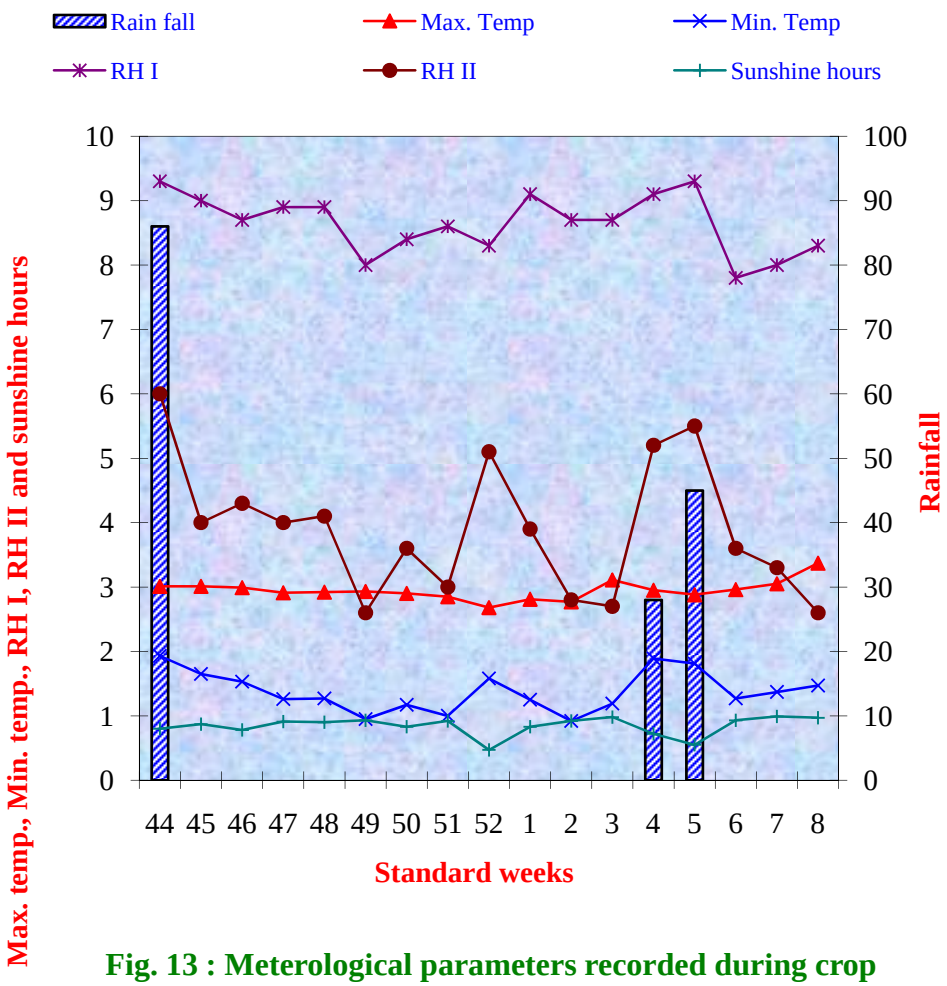


Fig. 13 : Meterological parameters recorded during crop period

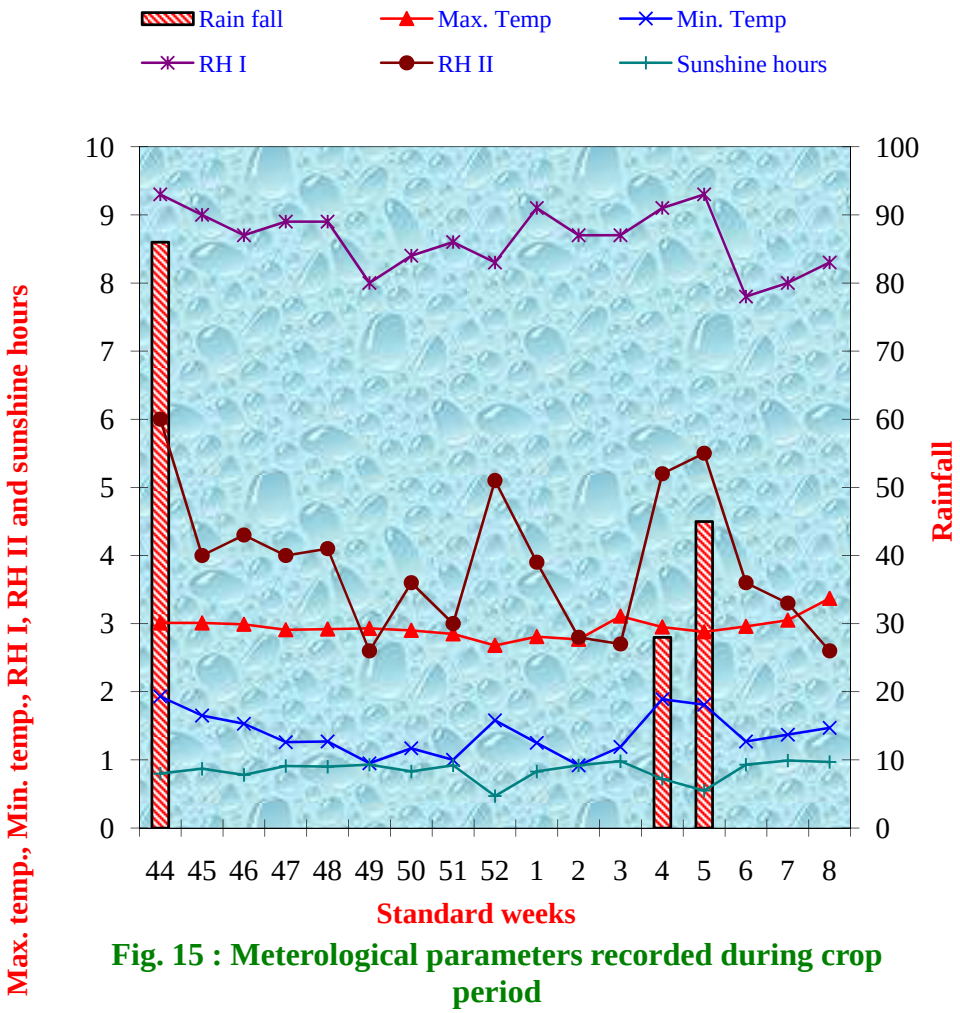


Fig. 15 : Meterological parameters recorded during crop period

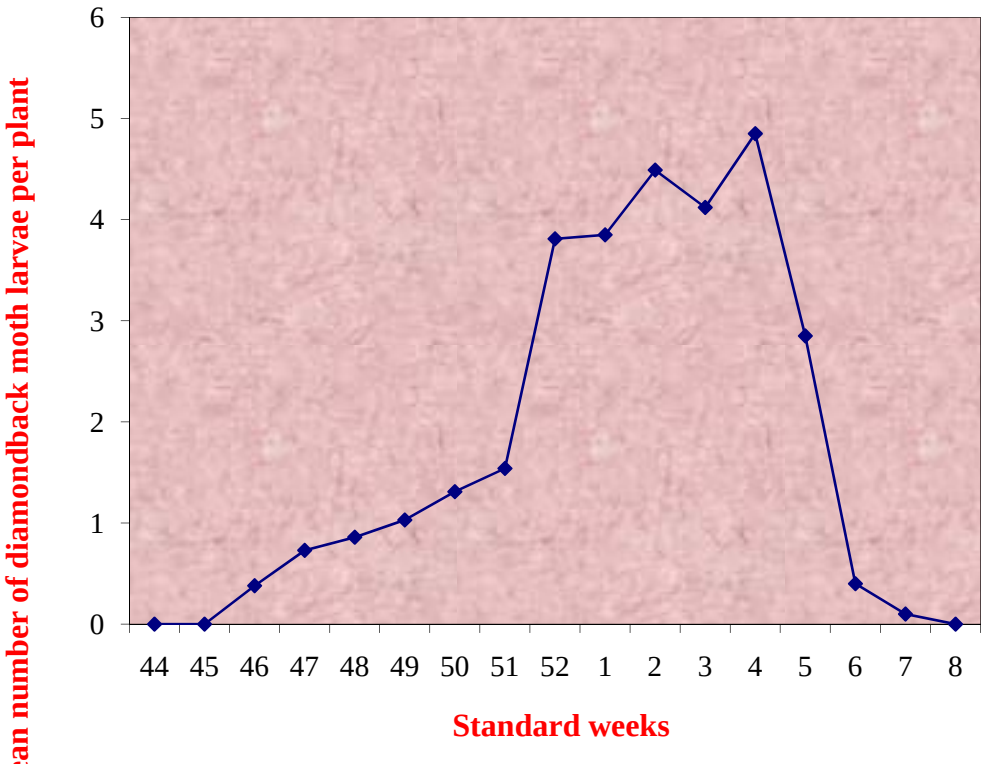


Fig. 14 : Diamondback moth larval population during crop period

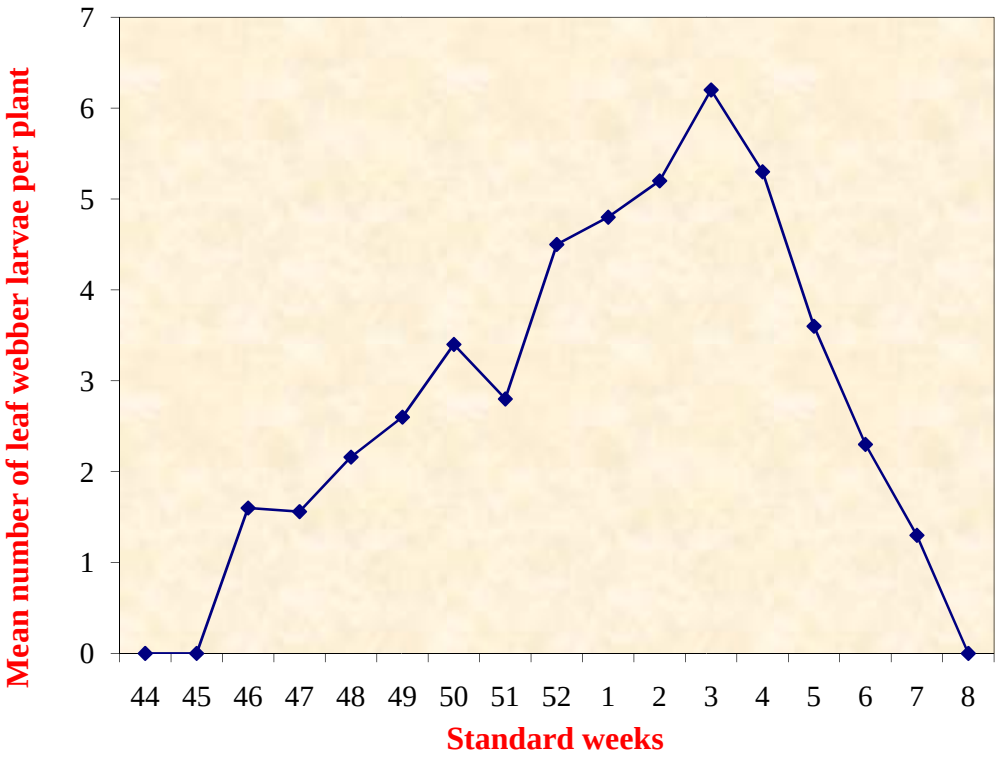


Fig. 16 : Cabbage leaf webber larval population during crop period

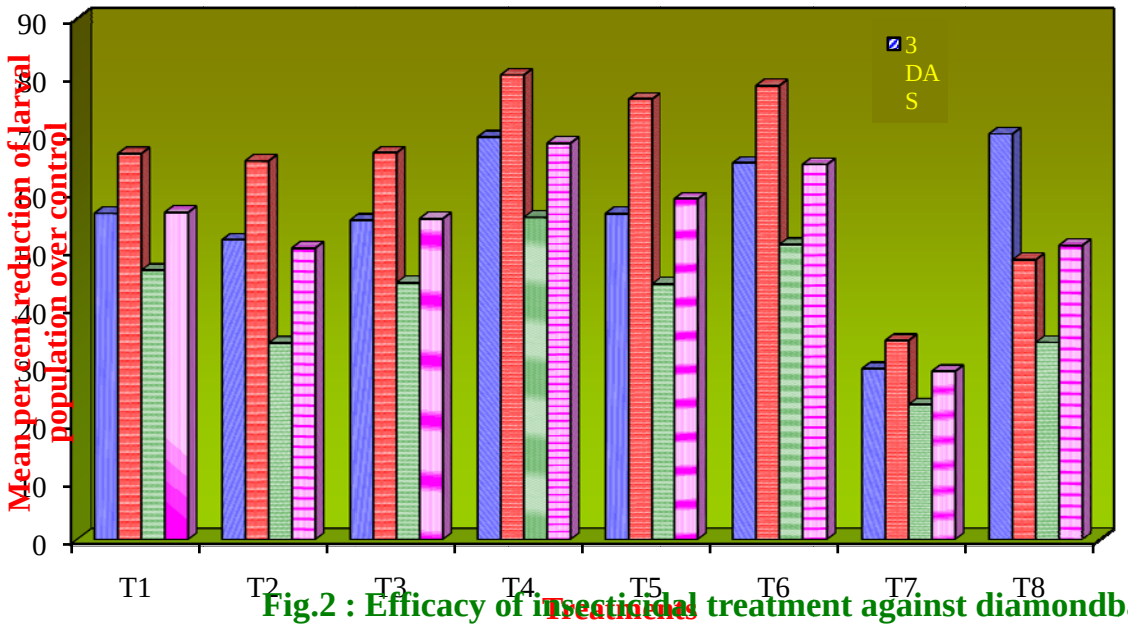


Fig.2 : Efficacy of insecticidal treatment against diamondback moth, *P. xylostella* after first spraying

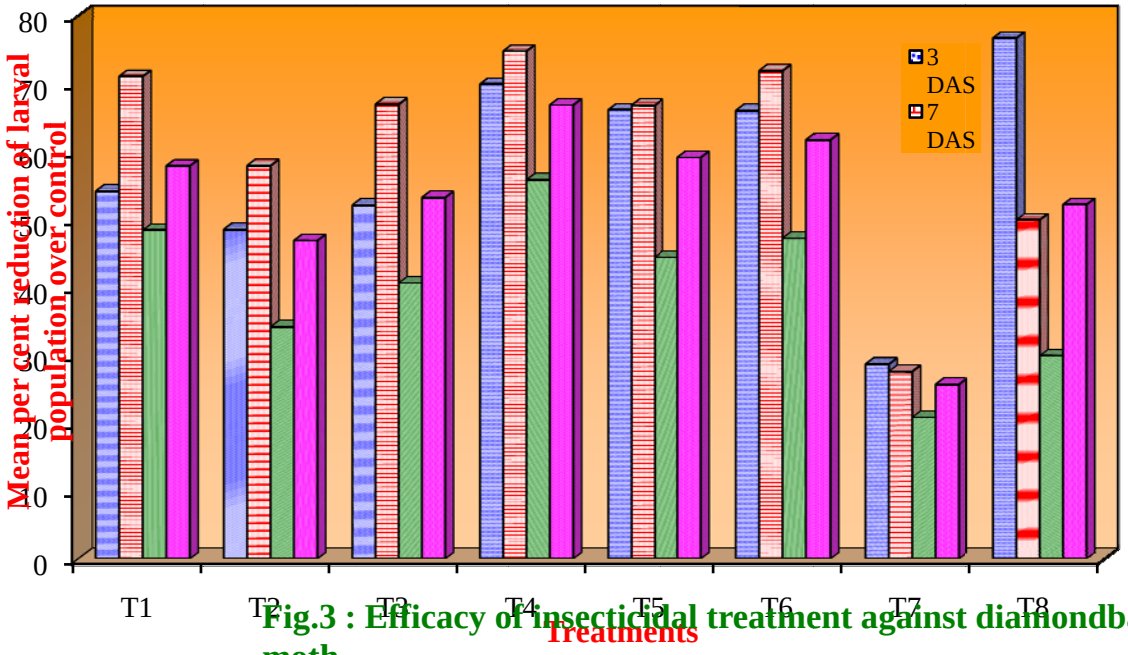


Fig.3 : Efficacy of insecticidal treatment against diamondback moth, *P. xylostella* after second spraying

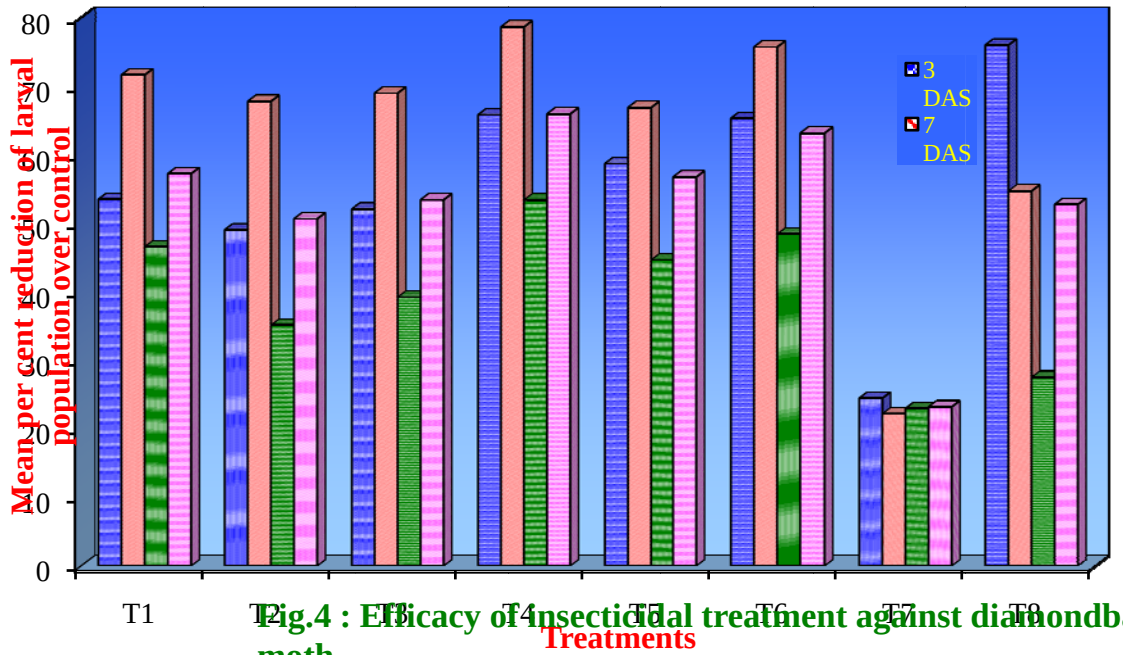


Fig.4 : Efficacy of insecticidal treatment against diamondback moth, *P. xylostella* after third spraying

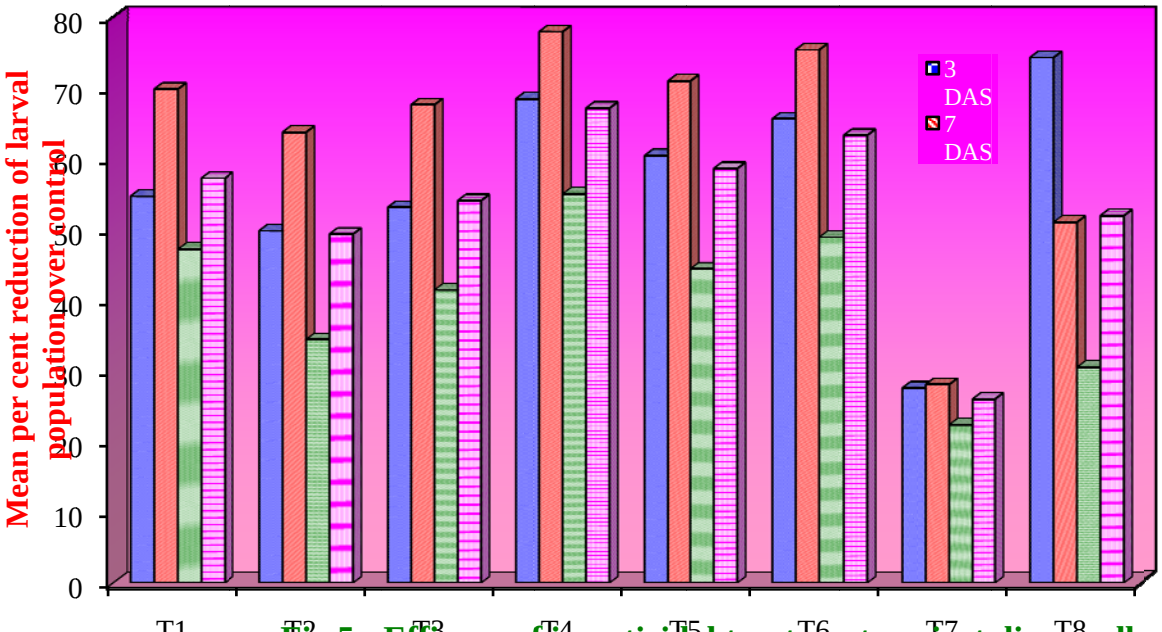


Fig.5 : Efficacy of insecticidal treatment against diamondback moth, *P. xylostella* after three rounds of spraying

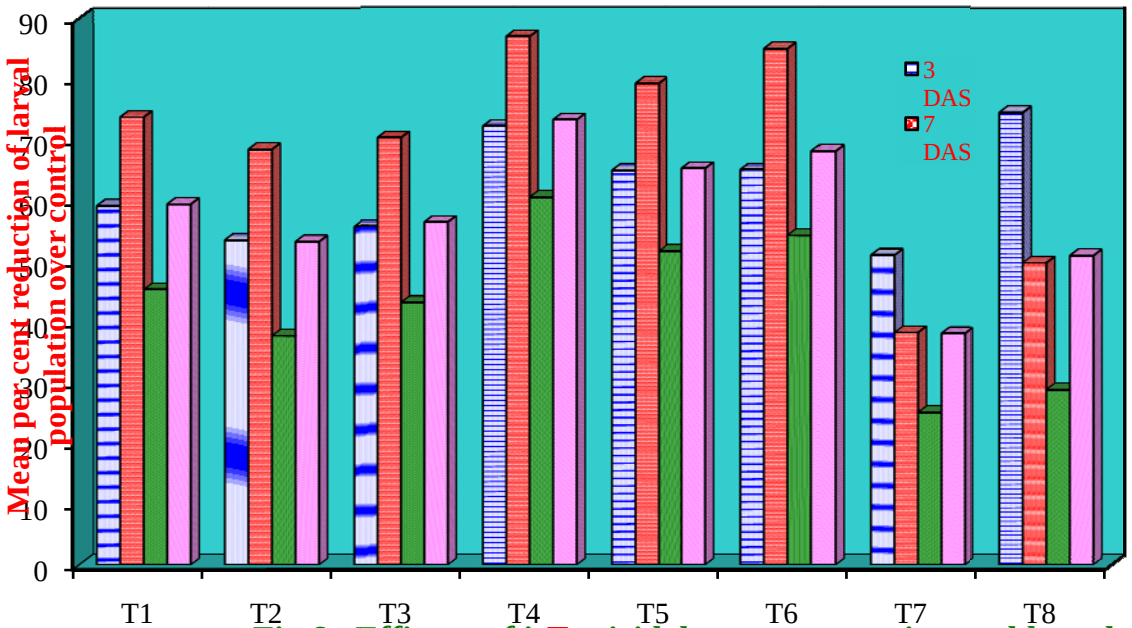


Fig.6 : Efficacy of insecticidal treatment against cabbage leaf webber, *C. binotalis* after first spraying

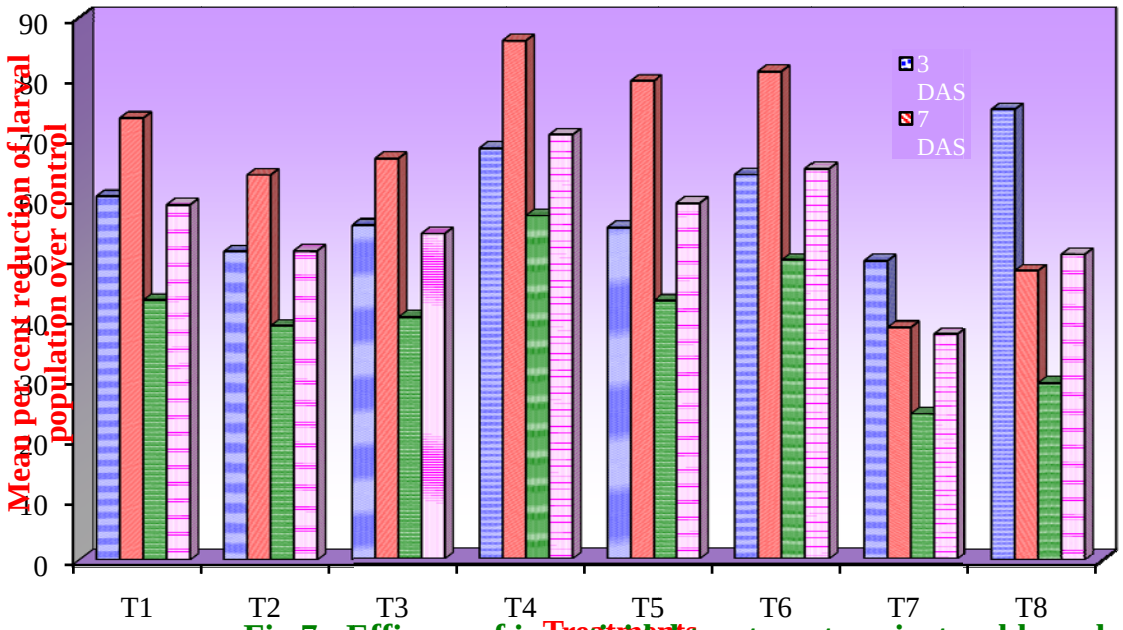


Fig.7 : Efficacy of insecticidal treatment against cabbage leaf webber, *C. binotalis* after second spraying

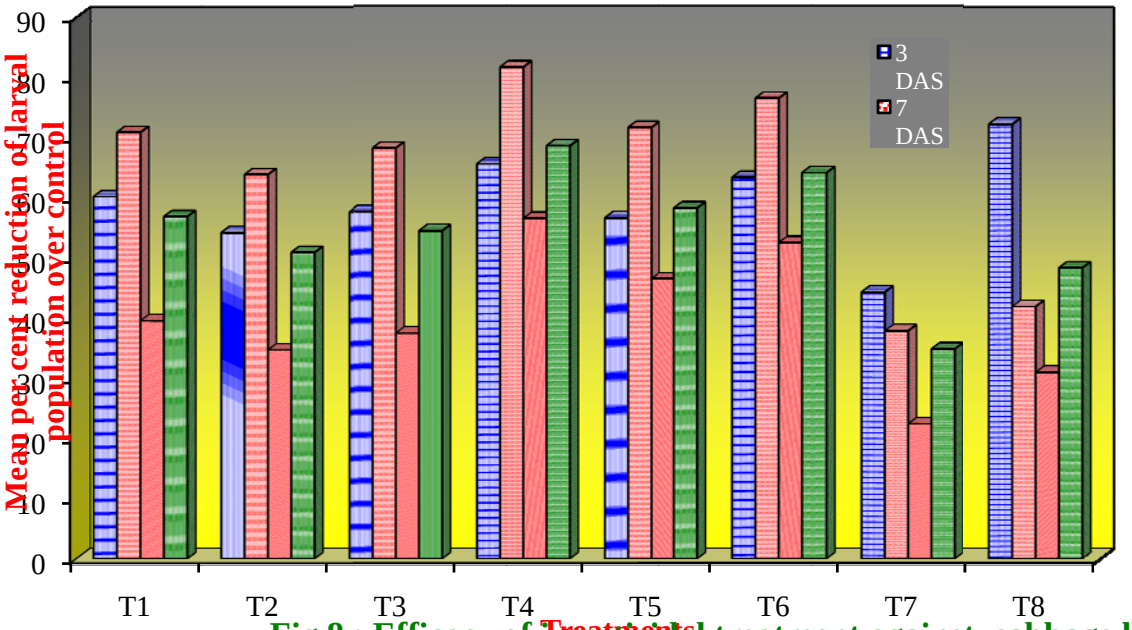


Fig.8 : Efficacy of insecticidal treatment against cabbage leaf webber, *C. binotalis* after third spraying

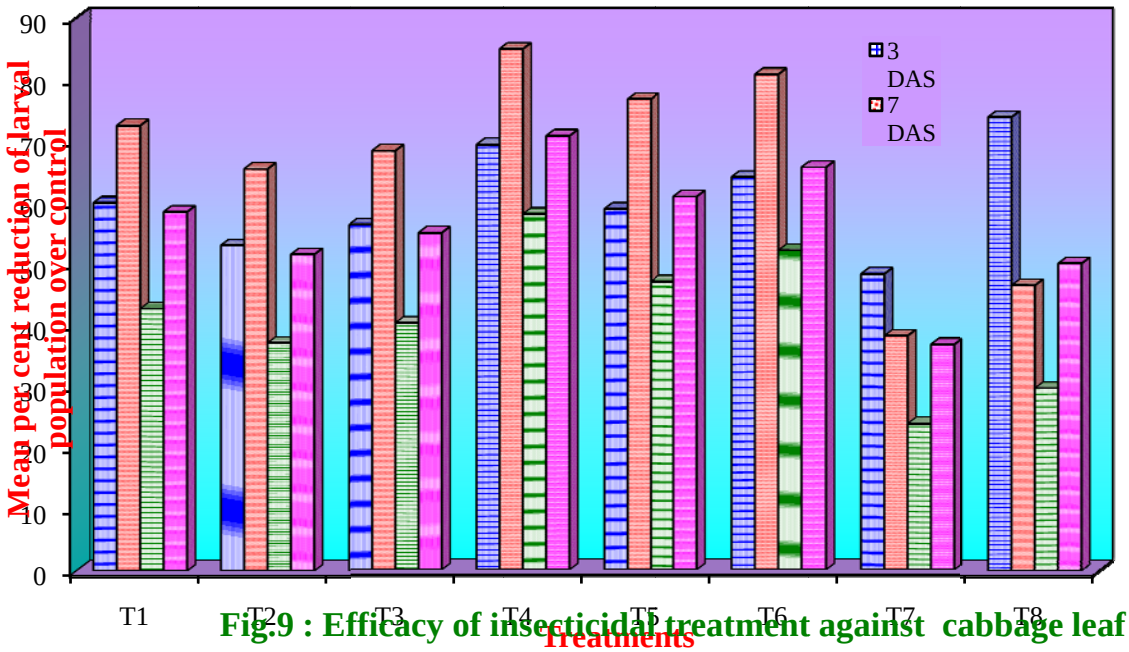


Fig.9 : Efficacy of insecticidal treatment against cabbage leaf webber,

C. binotalis after three rounds of spraying

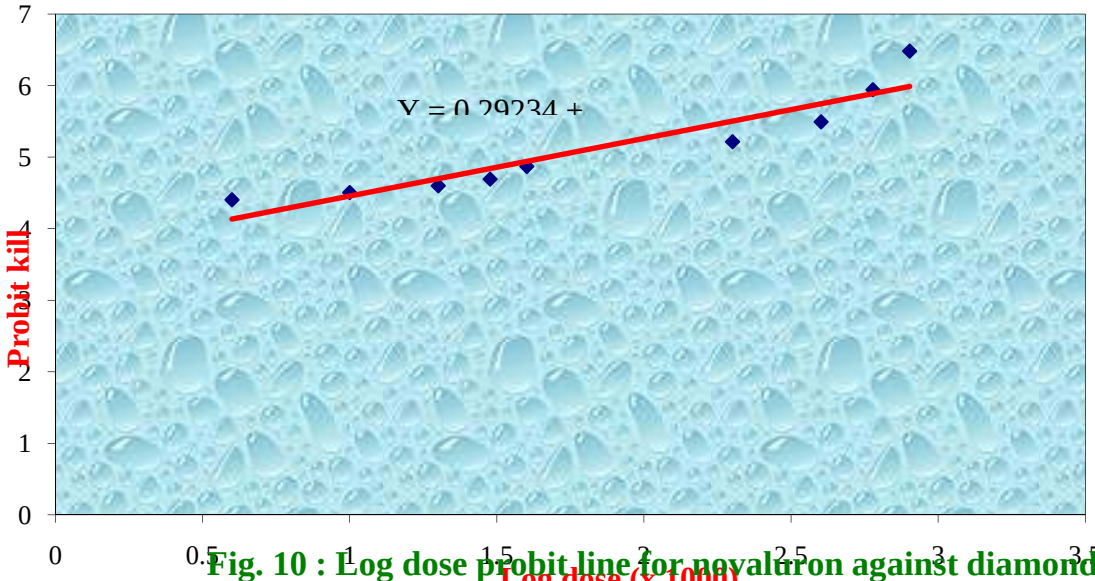


Fig. 10 : Log dose probit line for novaluron against diamondback moth after fifth day of treatment

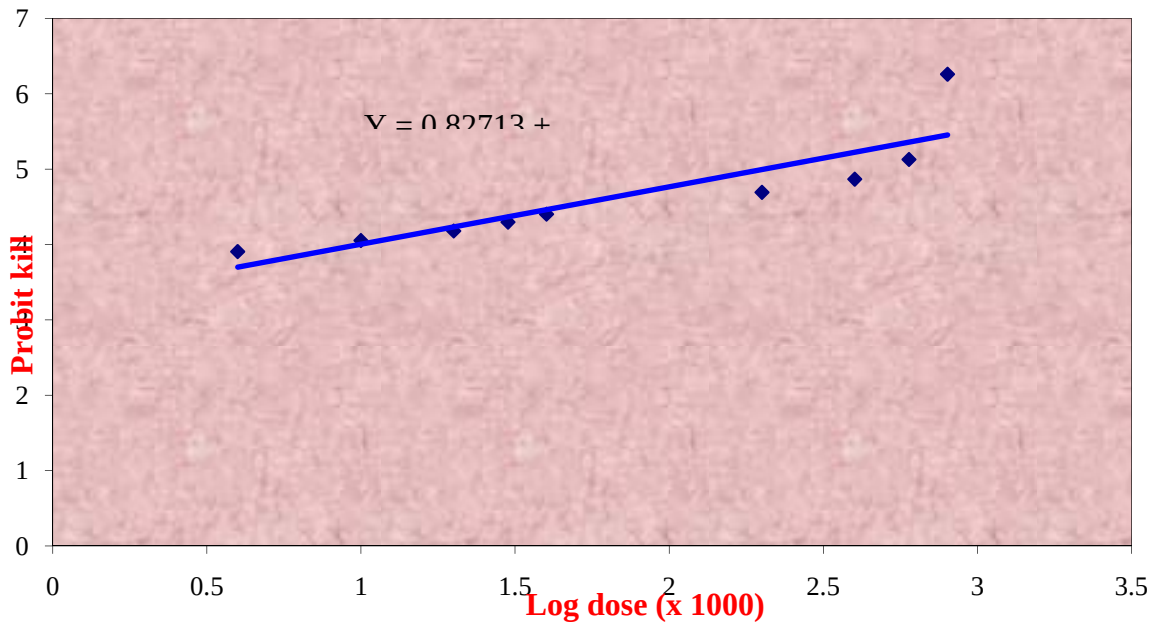


Fig. 11 : Log dose probit line for flufenoxuron against diamondback moth after fifth day of treatment

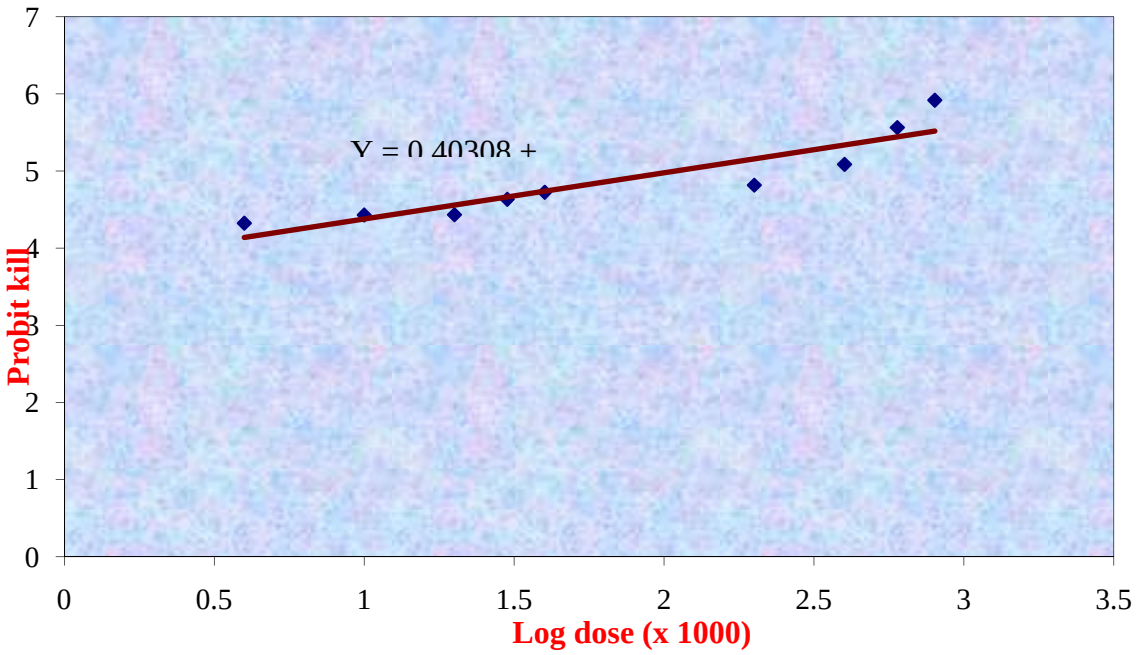


Fig. 12 : Log dose probit line for lufenuron against diamondback moth after ninth day of treatment

CHAPTER – V

DISCUSSION

A field experiment was conducted with cabbage hybrid "BC-64" at College Farm, College of agriculture, Rajendranagar, Hyderabad during *rabi*, 2003-04 to study the "Bioefficacy of chitin synthesis inhibitors alone and in combination with cartap hydrochloride against lepidopterous pests of cabbage". The laboratory experiments were conducted to determine ED_{50} and ED_{90} values of chitin synthesis inhibitors *viz*., novaluron, flufenoxuron and lufenuron against *P. xylostella*. The results obtained in the present studies are discussed in the light of available literature and are presented below.

5.1 BIOEFFICACY OF CHITIN SYNTHESIS INHIBITORS ALONE AND IN COMBINATION WITH CARTAP HYDROCHLORIDE AGAINST LEPIDOPTEROUS PESTS OF CABBAGE

5.1.1 Diamondback moth, *P. xylostella*

The pooled overall efficacy of three rounds of insecticidal application showed that all the insecticidal treatments were effective in minimising the larval population of diamondback moth over the control. Among all the treatments, novaluron (0.005%) + cartap hydrochloride (0.025%) were superior with 67.10 mean per cent reduction of larval population of *P. xylostella* which was on par with flufenoxuron (0.005%) + cartap hydrochloride (0.025%), novaluron (0.01%) and

flufenoxuron (0.01%) with 63.27, 58.57, 57.21 and 54.03 mean per cent reduction of larval population of *P. xylostella* over the control, respectively. The higher efficiency of novaluron (0.005%) + cartap hydrochloride (0.025%) in the present studies is in agreement with the findings of Saad *et al*. (1981), Megeed *et al*. (1986), Pawar *et al*. (1998) and Sujatha *et al*. (1999) who reported that chitin synthesis inhibitors are expected to increase the toxicity of conventional insecticides by disrupting the cuticle formation and their by enhancing the penetration of chemicals through cuticle. The potentiation in the toxicity of insecticides when combined with insect growth regulators was also reported by Megeed *et al*. (1986), Pawar *et al*. (1998) and Sujatha *et al*. (1999).

The efficacy of novaluron on diamondback moth in the present studies is supported by the work of Satpathy and Rai (2002), who reported that maximum mortality was inflicted by novaluron to a tune of 96.27 and 74.05 per cent on two day old and six day old larva of diamondback moth, respectively. Ashok *et al*. (2001) also reported the novaluron to be effective in controlling the larval population of diamondback moth when compared to other insecticides *viz*., diafenthiuron, lufenuron and neem.

The performance of flufenoxuron against diamondback moth gains support to the present studies from the findings of Tambe *et al*.

(1997) who reported that higher dose of flufenoxuron i.e. 80 g a.i./ha was found to be significantly superior in reducing the infestation of diamondback moth at three, seven and ten days after application and increasing the yield of cabbage. Naik *et al*. (1998) also reported flufenoxuron at 80 g a.i./ha as the best treatment by reducing the larval population significantly from 4.39 to 0.75 number of diamondback moth larvae per head in 15 days after spraying and also by recording the highest cabbage yield and the results are also in accordance to the present findings.

The next best treatment was cartap hydrochloride (0.05%) with 51.91 mean per cent reduction and was on par with flufenoxuron (0.005%) + cartap hydrochloride (0.025%), lufenuron (0.005%) + cartap hydrochloride (0.025%), novaluron (0.01%), flufenoxuron (0.01%) and lufenuron (0.01%) with 63.27, 58.57, 57.21, 54.03 and 49.30 mean per cent reduction of larval population of *P. xylostella,* respectively. The superior performance of cartap hydrochloride against diamondback moth supported by Rai *et al*. (1992) who reported that granular formulation of cartap hydrochloride to offer highest reduction in the larval population (87%) of *P. xylostella*. The report of Lal and Meena (2001) are also in accordance with the present findings. Among all the treatments neem (2 ml/l) recorded the lower reduction of (25.99%) larval population of *P. xylostella*. This may be due to photodegradation of neem at faster rate resulting in low efficacy. Similar results were reported by

Chandrasekharan *et al*. (1994) for neem. Contradictory results were obtained by Manjunatha (2000) who reported high efficacy of neem against *P. xylostella*, whereas, Kadam (1976), Fagoonee (1986) and Sombatsine and Temboonkeat (1987) who reported that NSKE (5%) and neem oil (0.25%) are highly effective in controlling *P. xylostella*.

5.1.2 Cabbage leaf webber, *C. binotalis*

The results revealed that novaluron (0.005%) + cartap hydrochloride (0.025%) to be the most effective treatment by recording 70.77 mean per cent reduction of larval population and was on par with flufenoxuron (0.005%) + cartap hydrochloride (0.025%), lufenuron (0.005%) + cartap hydrochloride (0.025%), and novaluron (0.01%) with 65.66, 60.87, and 58.44 mean per cent reduction of *C. binotalis* over the control, respectively. The literature pertaining to efficacy of combination of half of the recommended dose of novaluron, flufenoxuron, lufenuron with cartap hydrochloride against *C. binotalis* is scanty. Hence, chitin synthesis inhibitors with other insecticides were discussed here. Murthy and Rao (2002) found that mixture of novaluron (0.005%) + quinalphos (0.05%) gave 95 per cent kill of second instar larvae of Bihar hairy caterpillar at five days after spraying. Rao *et al*. (2001) also reported that combination of lufenuron (0.005%) with thidiocarb (0.037%), lambda cyhalothrin (0.005%) and profenophos (0.05%) was highly effective against *Helicoverpa armigera* (Hubner) and *Maruca vitrata*

(Geyer) in pigeonpea. These results are in conformity with present findings.

The flufenoxuron recorded 54.97 mean per cent reduction which was also on par with flufenoxuron (0.005%) + cartap hydrochloride (0.025%), lufenuron (0.005%) + cartap hydrochloride (0.025%), novaluron (0.01%), lufenuron (0.01%) and cartap hydrochloride (0.05%) with 65.66, 60.87, 58.44, 51.51 and 50.04 mean per cent reduction of *C. binotalis* over the untreated control, respectively. These results are in accordance with the findings of Peter and Sundararajan (1991) who found that flufenoxuron was highly effective against diamondback moth and significantly more effective than diflubenzuron. These results are also supported by Tambe *et al*. (1997).

The efficacy of novaluron @ 0.0075 per cent and lufenuron @ 0.012 per cent against *P. xylostella* was reported by Ashok *et al*. (2001) are in accordance with present findings.

Sumalatha (1990) and Srinivasan and Moorthy (1991) who reported cartap hydrochloride (0.05%) to be effective in controlling *C. binotalis*, whereas, Omoy (1987) reported the least efficacy of cartap hydrochloride against *C. binotalis*.

Among all the treatments, neem (2 ml/l) was least effective with 36.75 mean per cent reduction of larval population. The similar results are also reported by Ghosh *et al*. (2001) who found that azadirachtin

(Neemacitin®) was relatively less effective than other insecticides tested against *C. binotalis*. Malla Reddy (2002) also reported that neem was least effective treatment which recorded 39.38 mean per cent reduction of *C. binotalis* larval population and these are in conformity with the present findings.

5.2 DETERMINATION OF ED_{50} AND ED_{90} VALUES OF CHITIN SYNTHESIS INHIBITORS AGAINST THIRD INSTAR LARVAE OF *P. xylostella*

The results on the determination of ED_{50} and ED_{90} values of chitin synthesis inhibitors *viz*., novaluron, flufenoxuron and lufenuron against third instar larvae of *P. xylostella* are discussed here under.

The ED_{50} and ED_{90} values for novaluron to third instar larvae of *P. xylostella* were 0.13468 and 0.72506 ng a.i. per larva at fifth day after treatment. Satpathy and Rai (2002) reported the LC_{50} values of novaluron on two day old and six day old larvae of diamondback moth as 0.00044 and 0.00139 per cent, respectively. The literature on ED_{50} and ED_{90} to diamondback moth is scanty, hence ED_{50} and ED_{90} values of other pests are discussed in relation to related pests. Mariy *et al*. (1981) reported that the ED_{50} to fourth and fifth instar *Schistocerca gregaria* (Forskal) was 0.24 and 0.70 µg of diflubenzuron per nymph, respectively.

The ED_{50} and ED_{90} values of flufenoxuron to *P. xylostella* are 0.4073 and 1.03947 ng a.i. per larva, respectively are recorded in the

present study. Degheele *et al*. (1993) reported the LC_{50} values of flufenoxuron against third instar larvae of *Spodoptera exempta* (Walker) as 0.0740, 0.0035 and 0.0130 µg/ml at 24, 48 and 72 h after exposure, respectively. Rao and Subbaratnam (2000) reported that flufenoxuron was relatively more toxic than diflubenzuron and lufenuron as indicated by LC_{50} values of 0.0135, 0.0185 and 0.0207 per cent respectively to four days after treatment on ragi cutworm.

The ED_{50} and ED_{90} values of lufenuron to *P. xylostella* were 0.31999 and 1.33737 ng per larva at ninth day after treatment, respectively. Lokare *et al*. (1999) reported the LC_{50} value of lufenuron against *P. xylostella* as 0.0079 per cent. Rao and Subbaratnam (2000) also reported that lufenuron LC_{50} value as 0.0207 per cent at four days after treatment against ragi cutworm.

5.3 INFLUENCE OF MAJOR ABOITIC FACTORS ON THE POPULATION BUILDUP OF LEPIDOPTEROUS PESTS ON CABBAGE

5.3.1 Diamondback moth

In the field experiments conducted on cabbage during *rabi*, 2003-04, the peak larval population of diamondback moth was observed during the last week of January. These results coincide with the findings of Babu (1985), Meena and Sharma (2003) who reported the diamondback moth larvae found damaging the cabbage from early November till the end of January with peak activity. The peak larval

incidence continued till the end of first week of February, and thereafter sudden decline was recorded. These results confirmed the work of Bindra *et al*. (1977), who reported the reduction in the population during January-February as the season become warm.

The simple correlation between weather parameters and diamondback moth revealed that maximum temperature, rainfall, sunshine hours were negatively correlated with diamondback moth population and positively correlated with morning and evening relative humidity.

The results of multiple linear regression on diamondback moth population and weather parameters showed that the larval population were negatively correlated with maximum temperature, evening relative humidity and sunshine hours, whereas, positively correlated with minimum temperature, morning relative humidity and rainfall. These results are in agreement with the findings of Anil *et al*. (1997), who reported that the population of *P. xylostella* to have significant negative and positive correlation with minimum temperature and rainfall, respectively.

The step down regression analysis revealed that all the selected weather parameters except rainfall and minimum temperature have effected diamondback moth to an extent of 31per cent.

5.3.2 Cabbage leaf webber

In the present study the peak larval population was observed during third week of January, 2004 when average maximum and minimum temperature were 31.1^{o}C and 11.9^{o}C along with zero mm rainfall. These results are in conformity with Fagoone (1980), who observed that during the periods of low rainfall and at a temperature range of 20-40^{o}C, the population of leaf webber multiplied rapidly but during heavy rainfall, population intensity was very low.

Simple correlations between selected weather parameters and leaf webber population revealed that maximum temperature, minimum temperature, rainfall and sunshine hours were negatively correlated with leaf webber, whereas, morning relative humidity was positively correlated. Ratnamanjula (1992) also reported that both morning and evening relative humidity had significant positive association with the number of leaf Webbers and these results are in accordance with the present findings.

The results of multiple linear regression analysis revealed that, the cabbage leaf webber population was negatively associated with maximum temperature, evening relative humidity and sunshine hours and were non-significant, whereas, positively associated with minimum temperature, morning relative humidity and rainfall. Chauduri *et al.* (2001) also reported that the larval population of cabbage leaf webber to

exhibit positively associated with average temperature, relative humidity and total rainfall but negatively associated with sunshine hours per day.

In step down regression analysis, all the selected parameters except minimum temperature and rainfall were influenced maximum per cent i.e. 30 on the population buildup of cabbage leaf webber.

CHAPTER – VI

SUMMARY

Field experiments were carried out during *rabi* 2003-04 to study the "Bioefficacy of chitin synthesis inhibitors alone and in combination with cartap hydrochloride against lepidopterous pests of cabbage" at College Farm, College of Agriculture, Rajendranagar, Hyderabad. In addition, ED_{50} and ED_{90} values of chitin synthesis inhibitors were determined against *P. xylostella* in the laboratory at Department of Entomology, College of Agriculture, Rajendranagar, Hyderabad. The weather data was collected from Agricultural Research Institute, Rajendranagar, Hyderabad for correlating lepidopterous pest incidence with major abiotic factors.

Among the eight treatments against lepidopterous pests of cabbage, novaluron (0.005%) + cartap hydroclhloride (0.025%) was found to be superior with 67.10 mean per cent reduction of *P. xylostella* which was on par with other treatments *viz*., flufenoxuron (0.005%) + cartap hydrochloride (0.025%), lufenuron (0.005%) + cartap hydrochloride (0.025%), novaluron (0.01%) and flufenoxuron (0.01%) with 63.27, 58.27, 57.21 and 54.03 mean percentage reduction, respectively. Next best treatment was cartap hydrochloride (0.05%) which was also on par with flufenoxuron (0.005%) + cartap hydrochloride (0.025%), lufenuron (0.005%) + cartap hydrochloride

(0.025%) novaluron (0.01%), flufenoxuron (0.01%) and lufenuron (0.01%) against *P. xylostella*. Among the treatments, neem (2 ml/l) recorded the lowest mean per cent reduction i.e. 25.99 of larval population of *P. xylostella*.

The study indicated that novaluron (0.005%) + cartap hydrochloride (0.025%) was the most effective in reducing the *C. binotalis* population which was on par with flufenoxuron (0.005%) + cartap hydrochloride (0.025%), lufenuron (0.005%) + cartap hydrochloride (0.025%) and novaluron (0.01%) treatments. The next best treatment was flufenoxuron, which was also on par with flufenoxuron, (0.005%) + cartap hydrochloride (0.025%), lufenuron (0.005%) + cartap hydrochloride (0.025%), novaluron (0.01%), lufenuron (0.01%) and cartap hydrochloride (0.05%) treatments. Neem (2 ml/l) was least effective against *C. binotalis* larval population.

The ED_{50} and ED_{90} values of chitin synthesis inhibitor, novalauron, against third instar larva of *P. xylostella* were 0.13468 and 0.72506 ng a.i. per larva at fifth day after treatment respectively and for flufenoxuron, the ED_{50} and ED_{90} values were 0.40773 and 1.0947 ng a.i. per larva, respectively. The ED_{50} and ED_{90} values of lufenuron to *P. xylostella* at ninth day after treatment were 0.31999 and 1.33737 ng a.i. per larva, respectively.

All the selected weather parameters except rainfall and minimum temperature have exerted maximum effect on the population buildup of diamondback moth and cabbage leaf webber larval population.

Conclusion

From the results obtained the following conclusions can be drawn.

- The combination of half of the recommended dose of novaluron (0.005%), flufenoxuron (0.005%) and lufenuron (0.005%) with cartap hydrochloride (0.025%) and recommended dose of novaluron (0.01%) and flufenoxuron (0.01%) were found effective against diamondback moth and cabbage leaf webber on cabbage.
- The toxicity of novaluron and flufenoxuron is relatively high when compared to lufenuron against third instar larvae of diamondback moth.
- Significant negative correlations were found between the maximum temperature and larval population of *P. xylostella* and *C. binotalis*.
- Non significant positive correlations to RH I and RH II and negative correlations to rainfall and sunshine hours were recorded.

All the selected weather parameters except rainfall and minimum temperature have exerted maximum effect on the population buildup of diamondback moth and cabbage leaf webber larval population.

Conclusion

From the results obtained the following conclusions can be drawn.

- The combination of half of the recommended dose of novaluron (0.005%), flufenoxuron (0.005%) and lufenuron (0.005%) with cartap hydrochloride (0.025%) and recommended dose of novaluron (0.01%) and flufenoxuron (0.01%) were found effective against diamondback moth and cabbage leaf webber on cabbage.
- The toxicity of novaluron and flufenoxuron is relatively high when compared to lufenuron against third instar larvae of diamondback moth.
- Significant negative correlations were found between the maximum temperature and larval population of *P. xylostella* and *C. binotalis*.

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