BIO EFFICACY OF NEWER INSECTICIDES AGAINST LEAF HOPPER, *Empoasca motti* Pruthi IN BITTER GOURD

By

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THESIS

Submitted in partial fulfilment of the requirement for the degree of

Master of Science in Agriculture

Faculty of Agriculture
Kerala Agricultural University

DEPARTMENT OF AGRICULTURAL ENTOMOLOGY
COLLEGE OF HORTICULTURE
KAU P. O., THRISSUR - 680656
KERALA, INDIA

2003

DECLARATION

I hereby declare that this thesis entitled "**Bio efficacy of newer insecticides against leaf hopper, *Empoasca motti* Pruthi in bitter gourd**" is a bonafide record of research work done by me during the course of research and that this thesis has not been previously formed the basis for the award to me of any degree, diploma, fellowship or other similar title, of any other University or Society.

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CERTIFICATE

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ACKNOWLEDGEMENT

It is with great pleasure I place here on record my heartfelt gratitude and sincere thanks to Dr. Mani chellappan, Assistant Professor, Department of Entomology and Chairman of my advisory committee for his expert guidance, valuable suggestions, constant encouragement and above all, the extreme patience, understanding and wholehearted co-operation rendered throughout the course of my study. I consider myself very fortunate in having the privilege of being guided by him.

No words can truly express my profound gratitude and indebtedness to Dr. Jim Thomas, Associate Professor and Head, Department of Entomology and member of my advisory committee for his ardent interest, valuable suggestions and every willing help which has helped a lot for the improvement of this work.

I deem it a privilege to thank Dr. Maicykutty P. Mathew, Associate Professor, Department of Entomology, College of Horticulture, Vellanikkara for her valuable suggestions and guidance during the period of research.

It is my pleasant privilege to acknowledge Dr. Samuel mathew, Associate Professor, Department of soil science and member of my advisory committee for his expert counsel, sharp and constructive criticism.

I take this opportunity to express my gratitude to Dr. A.M. Ranjith, Dr. Haseena baskar and Dr. Usha kumari for their unbounded support sustained encouragement, kind help and moral support offered at different stages of the study.

Words cannot express my gratitude to Dr Krishnan, Assistant Professor, Department of Agriculture Statistics for his whole hearted support and help given in times of need.

I find it difficult to translate into words the love, affection, constant prayers and moral support of my whole hearted friends Boopathy, Vezhavendan, Ponnaiyan, Shankar, Ramesh and Selvam during this endeavor.

I duly acknowledge the valuable help rendered by, Manimala, Rameash, Sheena, Sumitha, Rajesh, Murugan, Vidya, Rajan, Queeno, Arjitha Deepthi, Jinnappa, Mahadev.

Word cannot express my gratitude to other friends Arul, Ganapathy, Muthukannan, Venkatesh, Pradeep, Kamalakannan, Sambasivam, Nagarajan, Manikandan, Bhavani, Arunachalam, Karuppaiyan, Dineshbabu for their whole hearted support and help given in times of need.

I am extremely thankful to Santhosh, Computer club, College of Horticulture, Vellanikkara for printing of the manuscript.

The award of junior fellowship of the KAU is thankfully acknowledged.

I am forever beholden to my family for their constant prayers, personal sacrifices, affection and tolerance throughout the period of my course.

GOD ALMIGHTY has bestowed me the opportunity, health and confidence to undertake the work successfully . I bow my head before HIM.

(Karthikeyan.R)

Dedicated to

My

Beloved Brother Saravanan. R

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Introduction

1. INTRODUCTION

India is one of the first countries in the developing world to start large scale use of pesticides for the management of insects pests of agricultural importance and third largest consumer of pesticides in the world and the highest among the south Asian countries (Agnihotri, 2000). There are 155 pesticides registered under the Insecticide Act of 1968, which meets the pesticide demand of nearly 100,000 metric tonnes per year (Dhaliwal and Arora, 2001). Large scale and indiscriminate use of these conventional insecticides accumulate the pesticide load on the environment leading to pesticide tread mill syndrome (Altieri, 1995).

This necessitated the use of insecticides with newer site of action and in relatively low dosages, which achieve the desirable pest management and to reduce the harmful effects of the pesticides in the environment (Diehr *et al.*, 1991). Sloway *et al.* (1978) first discovered the insecticidal properties of nitromethylene compound and chloropyridyl substituted heterocycles. The chemist of Nihon Bayer in Japan took up this lead and synthesised imidacloprid (NTN33893), a novel chloronocotinyl insecticide(Appendix-I) with a different molecular mode of action (Tomizawa and Yamamoto,1993), The biochemical target of imidacloprid is the post synaptic acetylecholine receptors, where they cause complete and irreversible blockade and interfere with the chemical signal transmission (Abbinik, 1991).

Acetamiprid (Appendix-II) is a cyanomidine compound that provides excellent control of sucking pests and has systemic and translaminar activities (Yamamota, 1996). Ethofenprox (Appendix III)is yet another new insecticide, which is composed exclusively of carbon, hydrogen and oxygen. This insecticide has a wide spectrum of activity, interfering with the nervous system of insects by inhibiting the transport of sodium along the nerve endings (Capella, 1996).

In Kerala, bitter gourd (*Momordica charantia* L) is one of the major vegetable crops grown owing to perennial demand for all sections of people. Nath and Agnihotri (1984) reported that the major pests limiting the profitable cultivation of bittergourd in India are leaf hopper (***Amrasca biguttula biguttula*** Ishida), fruitfly (***Bactrocera cucurbitae*** Coq.), aphids (*Aphis gossypii* Glover), red pumpkin beetle (***Aulocophora foveicollis*** Lucas) and epilachna beetle (*Henosepilachna vigintioctopunctata* Fabricius). Mathew *et al.* (1996) reported the leafhopper, *Empoasca (Empoasca) motti* Pruthi as a new pest of bittergourd from Kerala. It is a polyphagous pest, also occurring on okra, brinjal, beans, potato, etc. Both the nymphs and adults suck the sap from ventral surface of leaves and inject their saliva into plant tissues. As a result, the feeding spot turns yellowish and the leaves start curling from margins inwardly, gradually the entire leaf shows yellow patch, which turned dark brick-red or brown and ultimately dry and crumble. The incidence of the leafhopper and other insect pests have acquired serious dimensions now and needs the chemical interference to manage the pests. Long persistent insecticides are now being used.

To reduce the increasing pesticide load on the environment and other harmful effects, these newer insecticides have been evaluated for their efficacy in the management of bitter gourd pests with the following objectives *viz.*,

1. To study the bio efficacy and persistence of newer insecticides *viz.*,

   a. acetamiprid

   b. ethofenprox

   c. imidacloprid

and the management of bitter gourd leaf hopper *E. motti* and other major pests of bitter gourd.

2. To study the effect of newer insecticides on the

   a. Natural enemy complex of bitter gourd pests

   b. Soil micro flora

3. To study the residue of selected newer insecticide in the harvested produce.

Review of Literature

2. REVIEW OF LITERATURE

Broad spectrum insecticides and their indiscriminate use in the modern agriculture have resulted in numerous ill effects. This has necessitated the search for molecules with newer chemistry, site and mode of action with the major emphasis to reduce the pesticide load on the environment by their faster biodegradability. Acetamiprid, ethofenprox and imidacloprid are such insecticides and an attempt has been made in the present study to compile the information on their relative performance on insects and other organisms.

2.1. BIO EFFICACY OF CONVENTIONAL INSECTICIDES ON BITTER GOURD

2.1.1. Leafhopper

Many insects pest *viz.*, leafhopper, aphid, fruit fly and epilachna beetle attack cucurbitaceous crops. *Amrasca bigutulla bigututla* and *Empoasca (Empoasca) motti* is the two leaf hopper attacking bittergourd. Nymphs and adults remain on the lower surface of leaves and suck the cell sap coupled with injection of toxic saliva into the tissues result in typical hopper burn symptoms. Pareek and Noor (1980) recommended spraying of endosulfan (0.05 %) or carbaryl (0.2 %) for effective control of leafhoppers attacking ridge gourd. Relative toxicity of five insecticides *viz.*, endosulfan, monocrotophos, carbaryl, quinalphos and phosalone against different populations of *Amrasca biguttula biguttala* were studied and found that carbaryl (0.2 %) was the most effective and persistant insecticide against leaf hopper on bittergourd at Vellanikkara (Sabitha and Jacob, 1994).

Reddy and Rao (1998) tested the field efficacy of eight insecticides against leafhopper infesting bitter gourd in Andhra Pradesh, and found that among the test insecticides fenvalerate followed by monocrotophos and acephate were effective against leaf hopper.

2.1.2. Fruit fly

Fruit fly, *Bactrocera cucurbitae* is a major pest of bittergourd. The maggots feed on the pulp of the fruits resulting in distorted and rotten fruits. Three to five spray applications of malathion (0.1%) or fenthion (0.1 %) at fortnightly intervals for effective control of fruit flies (David and Kumarasamy, 1975). Mote (1975) obtained best results with tetrachlorvinphos (0.1%) followed by fenthion (0.3%) and carbaryl (0.1%) in controlling fruit fly on bittergourd. Several workers have reported the effectiveness of bait spraying in controlling fruifly. Spraying of one percent malathion containing sugar at fortnightly interval was effective for the control of melon fruit fly, *Dacus cucurbitae* (Narayan and Batra, 1960) and bait sprays containing yeast protein (1.0 %) and malathion (0.1%) was effective (Dale and Nair, 1966). Application of carbaryl (0.2%) malathion (0.2%) containing sugar or jaggary at fortnightly interval after fruit set initiation was found to be effective against fruit fly, *B. cucurbitae* on bittergourd (KAU, 1996).

2.1.3. Epilachna beetle

Spraying of deltamethrin (1.5%) or cypermethrin (100 g a.i. ha^{-1}) was found to be effective against spotted epilachna beetle attacking bittergourd crop (Kosavaraju, 1982). The bioefficacy of carbofuran against epilachna beetle infesting bittergourd was studied at Vellanikkara (Thomas , 1989). They observed that application of carbofuran granules (1.5 kg a.i. ha^{-1}) at all the three stage of sowing, vining and flowering gave 95.79 per cent reduction of epilachna beetle even after 80 days of sowing. Spraying of Carbaryl (0.2%) is recommended for controlling the grubs and adults of epilachna beetle attacking bittergourd (KAU, 1996)

2.1.4. Aphids

The aphid, *A. gossypii* is another sucking pest infesting bittergourd at early growth stages. Nymphs and adults of *A. gossypii* desap the plant juice by remaining on the lower surface of leaves. This results in yellowing, drying of leaves and stunting of plants.

Champ (1966) reported that spraying dimethoate (0.05 %) gave significant control of *A. gossypii* attacking gourds and spraying permethrin (100 g a.i. ha^{-1}) or fenvalerate (100 g a.i. ha^{-1}) were found to be effective against on bittergourd aphids (Kosavaraju, 1982). Wen and Lee (1983) reported that Carbofuran 3G was effective against aphid, *A. gossypii* on watermelon. Application of dimethoate (0.05%), phosphamidon (0.05%) or monocrotophos (0.05%) is recommended against aphids on bittergourd (KAU, 1996)

2.1.5. Red pumpkin beetle

The red pumpkin beetle, *A. foveicollis* attack the crop mainly at the seedling stage and also cause damage to the leaves during the later period of growth. The grubs feed on the roots and also fruits touching the ground.

Panji (1965) noted 48.3 per cent mortality of the adults of *A. foveicollis* by application of a dust formulation prepared from dried fruits of *Melia azadirach* and ethanol extract (4 %)of the fruit.

Butani and Verma (1977) reported that dusting carbaryl (4 %) or spraying carbaryl (0.2%) was effective in controlling severe infestation of red pumpkin beetle. Sinha and Chakrabarti (1983) found that soil application of carbofuran 3G (0.5 kg a.i. ha^{-1}) was very effective in controlling the red pumpkin beetle in cucurbitaceous crops like muskmelon and bottle gourd. Singh *et al.* (1984) reported that a single application of carbofuran granules (200-500 g a.i ha^{-1}) at the time of germination was effective against red pumpkin beetle, *A. foveicollis* on watermelon. According to Thomas and Jacob (1994) when carbofuran 3G granules were applied thrice (1.5 kg a.i ha^{-1}) during sowing, vining and flowering stage, the infestation of *A. foveicollis* was reduced by 58.7 per cent over control after 80 days of sowing.

2.1.6. Pumpkin caterpillar

Pumpkin caterpillar *Diaphania indica* was once considered as a minor pest of cucurbits. But during recent years it assumed the status of a major pest. The young caterpillars lacerate and feed on chlorophyll of foliage. During flowering stage, it damages the ovaries of flower and bores in to young developing fruits making it unfit for human consumption.

2.1.7. Fruit borer

Mathew *et al.* (1996) reported the infestation of *Helicoverpa armigera* (Hubner) on bittergourd for the first time in Kerala. It caused about 10 per cent loss of bittergourd fruits. The young larvae initially feed on tender foliage and at later stage attack the fruits. They bore circular holes and thrust only a part of their body inside the fruit and feed the internal contents.

2.2. BIO EFFICACY OF NEWER INSECTICIDES

2.2.1. Hoppers

Ethofenprox (12.5 to 25 g a.i ha^{-1}) was effective against brown plant hopper (BPH) *Nilaparvatha lugens* without causing resurgence and was found to be safer to spiders, *Tetragnatha andamanensis* associated with BPH (Peter *et al.*, 1989). Krishnaiah and Kalode (1993) found a dosage of (100 g a.i.ha^{-1}) gave effective control of *N. lugens, Nephotettix virescens and Sogatella furcifera* without causing detrimental effect on the predatory mirid bug (*Cyrtorhinus lividipennis*) in rice. Dosage of 0.075 kg a.i. ha^{-1} gave good effect on BPH and showed higher grain yield (68.35 q ha^{-1}) in rice (Panda *et al.*, 1995). So it could be preferred for integrated pest management programmes.

Imidacloprid (10g kg^{-1}) seed treatment recorded the leafhopper and whitefly below ETL (Economic threshold level) upto 35 days on cotton and gave enhanced growth (Phytotonic effect) on cotton seedlings (Patil *et al.*, 1999; Vadodaria *et al.*, 2001). Imidacloprid (5g kg^{-1}) gave significant result as a seed dresser on bhendi (Mote et al., 1994) and cotton (3g kg^{-1}) for early stage sucking pests. (Gupta *et al.*, 1998). A lower dosage of 0.2-1.6 ml l^{-1} could also effect 100 per cent control in 24 hours and the efficacy up to three weeks on mango leaf hopper, *Idioscopus* spp (Verghese, 1998) and it (100 and 150 ml ha^{-1}) persisted for 29 and 31 days against the groundnut leafhopper, *Empoasca kerri* (Babu and Santharam, 2000).

Imidacloprid (0.25 ml l^{-1}) showed least population (0.03) on mango leaf hoppers *Idioscopus* spp upto 21 days after spray (Kumar and Giraddi, 2001) and upto 40 days after sowing (20 g a.i. ha^{-1}) on cotton leaf hopper A. *devastans* (Tanal *et al.*, 2001). Ashok *et al.* (2002) found imidacloprid

(20 g a.i. ha^{-1}) in cotton showed equally compared with thiamethoxam (25 g a.i. ha^{-1}) for the control of cotton jassid, *A. devastans* and the same compound at 0.5% used as a seed dressing agent gave effective control of early stage sucking pests in green gram (Nakat *et al.*, 2002).

Acetamiprid gave superior control of cotton leaf hopper (10 g a.i. ha^{-1}) whereas for whitefly control, the dose has to be increased anywhere between 20 and 40 a.i. ha^{-1}. (Subramanian and Natarajan, 1998). Seed treatment of acetamiprid (26.25 g kg^{-1}) protected the cotton crop upto 39 days against early sucking pests, whereas two time application of acetamiprid 20 SP as foliar spray (15 g a.i.ha^{-1}) protected the crop up to 60 days (Patil et al., 2001). Mathew (2000) reported that the acetamiprid at the two doses of 15 and 20 g a.i.ha^{-1} gave the superior control of leaf hoppers (*E .motti and A. biguttula*) in bhendi, brinjal and bitter gourd.

2.2.2.Aphids

Imidacloprid (10g a.i. kg^{-1}) seed treatment plus root dip (0.04%) gave the highest protection of sucking pests and yield of tomato (Walung and Mote, 1995). Imidacloprid 200SL (500ml / ha) was effective against grey aphids *Dysaphis planginea* in apple at petal fall stage (Barbieri and Cavallini, 1997). Imidacloprid (50g a.i.ha^{-1}) as foliar spray effectively controlled the aphids *Myzus nicotianae* Blackman on Virginia tobacco and recorded better yield of cured leaf, bright leaf and grade index (Ramaprasad *et al.*, 1998). Acetamiprid (10 g a.i. ha^{-1}) control the main aphids present on pome fruits, stone fruits and citrus (in particular *D.plantaginea, Apis pomi, Myzus persicae*) effectively (Lacombe, 1999). It (10 g a.i.ha^{-1}) provided consistent control of the target pests for an extended period (up to 10 days) in cotton (Kumar, 1999). Acetamiprid (0.15 kg ha^{-1}) gave effective control of potato aphid and in limiting tuber infection of potato leaf roll leuteo virus (PLRV) (Turska and Wrobel, 2000).

2.2.3. Borer pests

Ethofenprox (100 a.i. ha^{-1}) found significantly superior effects on brinjal shoot and fruit borer (*Leucinodes orbonalis* Guen) compared to conventional insecticides (Srinivas and Peter, 1993).

Seed treatment with imidacloprid (3 %) on sorghum seed showed most effective control for shoot fly (Mote *et al.*, 1995). Beet leaf miner *(Pegomya cunicularia* Kieffer) and beet flea beetle (*Chaetocnema concinna)* were effectively controlled by imidacloprid (10 %) dust (Sato *et al.*, 1995). In citrus orchard, the efficacy of acetamiprid (6-10g a.i ha^{-1}) was compared with imidacloprid (12 g a.i ha^{-1}) for control of *P. citrella* in a five year old orchard. It was concluded both the doses of acetamiprid were as effective as imidacloprid for initial knockdown. Observation made over the succeeding months indicated that acetamiprid had a greater residual effect than imidacloprid (Jerraya *et al.*, 1997) and imidacloprid (35%) gave more than 90 per cent control of *P. citrella* in trials with lemon (Salas *et al.*, 1997). Imidacloprid 200 SL (25 g a.i. ha^{-1}) was found effective against rice yellow stem borers (*Scirpophaga incertulus* Wlk) and produced (19.29 %) increased grain yield (Patel *et al.*, 1999).

2.2.4. Defoliators

Ethofenprox (0.1 kg a.i.ha^{-1}) gave effective control in reducing the population of rice leaf folder, *Cnaphalocrosis medinalis* Guen (Mishra *et al.*, 1998). Mohapatra (2001) evaluated the efficacy of some synthetic insecticides and neem products against cashew leaf folder *Caloptilia tiselaea*, and found ethofenprox (0.015 %) was the least effective (42.2%

reduction only), where as neem guard, profenophos and chlorpyrifos were moderately effective.

2.2.5. Other pests

The newer insecticides are not only effective for crop pests, but also used to control many household pests.

Ethofenprox (0.5%) showed rapid knockdown effect on house fly, *Musca domestica* Linn. with in 20-25 minutes, reducing the population by 98 per cent and the residual action of the chemical was noticed for a period of one week (Kannabyran *et al.*, 1993). Imidacloprid was tested at the minimum therapeutic dosage (10 mg kg^{-1} of body weight) to remove and prevent fleas, *Ctenocephalides* infestation on dogs and cats and it provided a higher level of control for five weeks (Hopkin *et al.*, 1996; Romano *et al.*, 1996). It also gave good control for the soil insects like termites in sugarcane (200 g ha^{-1}) and have no residues in any samples of sugarcane juice, leaf and soil (Gajbhiye *et al.*, 1997). It can be used for the household pest like cockroach as cockroach gel in a typical Indian fast food centre at the rate of 1-2 spots (0.1g) per linear metre of crack and crevice or square metre of surface area reduced the population (87 %) with in one week and practically got eliminated by these cockroaches two months (Kamath *et al.*, 2002).

2.3. SAFETY OF NEWER INSECTICIDES TO NATURAL ENEMIES

Most of the popular insecticides used in agriculture are neurotoxicants, which affect all living organisms in a similar manner. The whole range of living organisms including natural enemies, pollinators, domestic and wild animals, birds, fish and other aquatic organisms and even soil fauna are affected by the use of insecticides in agriculture.

Hence the safety of newer insecticides to natural enemies and other non target organisms is reviewed here.

Acetamiprid (10 g a.i. ha $^{-1}$) was safe to majority of natural enemies including Coccinellidae, *Chrysopa* spp, Syrphidae, *Aphidoletes* spp and spiders (Yeqming *et al.*, 1996) and ethofenprox (0.05 kg ha $^{-1}$) showed lesser toxicity to *Tetragnatha jawana* than other insecticides (Kumar and Velusamy, 1996).

Imidacloprid (200 g a.i. ha^{-1}) showed harmful effects on parasitoids *Encarsia transvena* Timerlake and *Chales noacki* at the higher dosage (Dhoubi, 1992).

Imidacloprid and acetamiprid were relatively safe and did not prevent the emergence of braconids from mummies of *Aphis* spp on mandarins (Viggiani *et al.*, 1998).

Imidacloprid (0.006%) had no significant adverse effect on adult emergence and percent parasitisation of *Trichogramma chilonis* and percent hatchability of *Chrysoperla carnea* (Kumar and Santharam, 1999).

2.4. EFFECTS OF PESTICIDES ON SOIL MICRO FLORA

A number of microorganisms, insects, other arthropods, nematodes and annelids inhabit the soils. These small organisms are essential to the proper functioning of all ecosystems since they break down wastes permitting the vital element to be recycled in the life system. Bacteria and blue green algae make atmospheric nitrogen available to the plants. Earthworms and insects aid in turning over the soil (Dhaliwal and Arora, 2001). Only scanty information is available regarding the impact of pesticides on these soil organisms.

High concentrations of DDT (Dichloro Diphenyl Trichloroethane), HCH (Hexachloro Cyclo Hexane) and carbaryl in the soil inhibit the nitrogen fixing activity of *Rhizhobium* spp, azotobactor and blue green algae (Dhaliwal and Arora, 2001). Chandrasekaran and Regupathy (1993) concluded that the dissipation of carbosulfan was relatively faster under flooded condition than under field capacity. The environmental parameters like moisture and temperature also responsible for the degradation of pesticides (Parkin and Shelton, 1994). Application of herbicide fluchloralin in the soil significantly reduced the bacterial and fungal population at both recommended (1.5 kg ha^{-1}) and double recommended (3.0 kg ha^{-1}) but the effect lasted only up to 10 days after application (Patel and Patel, 1998).

Herbicides generally appear to have no adverse effects on the population of total bacteria in soil except at concentrations exceeding recommended rates (Anderson, 1978).

2.5. RESIDUE ESTIMATION

Only a small amount of the pesticide (< 1%) applied to a crop reaches the target pests and the remaining (>99%) enters into the different components of the environment to contaminate the soil, water, air, food, feed, forage and other commodities. Nearly 100 per cent of human population has been found to contain some residues of pesticides like DDT and HCH. Twenty per cent of the market samples of non-fatty commodities were found to have residues above MRL (Maximum Residue Limit) (Dhaliwal and Arora, 2001).

So in this situation it is necessary to study the full toxicological consequences of pesticide residue on the products.

2.5.1. Analytical methods for identification and estimation of imidacloprid

Imidacloprid being a recent introduction, very few reports are only available on the residue analysis of this insecticide on the crops. High Pressure Liquid Chromatographic (HPLC) and Gas Liquid Chromatographic (GLC) methods are reported on the determination of imidacloprid residues and its metabolites.

2.5.1.1. High Pressure Liquid Chromatographic method (HPLC)

Bachlechner (1989) described a method, which allows the determination of active ingredient (a.i) of NTN-33893 (imidacloprid) in soil. The method consisted of extracting the soil with acetonitrile – water (80:20, v/v). The extracts were cleaned up by liquid-liquid partitioning on ex tube columns, eluting the a.i with dichloromethane. The mean recoveries of the method were 82 per cent. Blab (1990) reported HPLC method for determination of imidacloprid residues in apple, potatoes, sugar beet (including leaves), corn and barley. Alba *et al.* (1996) described a HPLC method with diode array detection (DAD) for determination of imidacloprid residues in vegetables at levels ranging from 0.01- 0.60-mg kg^{-1}. Tokeida *et al.* (1997) found a method to determine the acetamiprid residue by HPLC with UV detector and found the maximum limit of detection (0.005 ppm) for fruits and vegetables.

The method of Kumar (1999) involved the extraction of a.i. by acetone or acetone-water. The aqueous extracts were cleaned by liquid-

liquid partitioning with hexane, hexane-ethyl acetate and washing with K_2CO_3 followed by silica gel cleanup and determination on reverse phase column on HPLC.

2.5.1.2. Gas Liquid Chromatographic (GLC) method

Placke and Weber (1993) reported a GLC method for determination of imidacloprid in crops. In this method the compound was oxidised to 6-chloronicotinic acids, which was then silicated with N-methyl trimethyl siliyl trifluoroacetamide. Total residues (imidacloprid and its degradation products) were estimated as imidacloprid and analysed on GLC using electron capture detector. Roucho ud *et al.* (1994) reported a method to estimate of imidacloprid in soil and plant samples where it was extracted in acetonitrile-water (80:20) and cleaned up by silica gel TLC (Thin Layer Chromatography). The sensitivity was 0.01 mg kg^{-1} for dried and finished sugar beet leaves. Navalon *et al.* (1997) reported a method involving hydrolysis in basic medium followed by gel chromatography-mass spectrometry and selected ion monitoring. It was applicable in vegetables (tomato, cucumber, capsicum and green beans). Recoveries ranged from 94.3 to 105.8 percent.

Acetamiprid was extracted in vegetables with methanol, purified by liquid-liquid partition and column chromatography and then determined by electron capture detector in gas chromatography (Tokeida *et al.*, 1997)

2.5.2. Residues in plant products

Imidacloprid has good mobility in plant system, which makes it especially suitable for seed treatment and soil application (Elbert *et al.*, 1991). Gajbhiye *et al.* (1997) found no residue of imidacloprid in the harvest time samples of sugarcane juice, leaf and soil and the residue of imidacloprid were at below detectable limit in black gram (*Vigna mungo* L) and soyabean (*Glycine max* L) at the rate of 10 g kg^{-1} of seed (Gopal *et al.*, 1997). Cotton showed no residues in the samples of lint, seed and soil at harvest time (Gupta *et al.*, 1998; Kumar, 1998). In okra fruits there was no detectable level of residue collected after 50 Days of sowing (Dikshit *et al.*, 2000)

Materials and Methods

3. MATERIALS AND METHODS

Investigations were carried out to evaluate the bio efficacy of newer insecticides against bitter gourd pests *viz.*, leafhopper, aphid, epilachna beetle, fruit fly and fruitborer. The details of the experiment were as follows.

3.1. EVALUATION OF THE BIO-EFFICACY OF INSECTICIDES (ACETAMIPRID, ETHOFENPROX AND IMIDACLOPRID) AGAINST KEY PESTS OF BITTER GOURD

A field experiment was laid out in randomized block design with three replications and thirteen treatments in the research farm of College of Horticulture, Kerala Agricultural University at Vellanikkara during October 2001 to January 2002 for the first crop and February 2002 to April 2002 for the second crop. Preethi, a high yielding variety of bittergourd was grown at a spacing of 2m x 2m. The plot size was $8m^2$ per treatment per replication. All agronomic practices as per the package of practices recommendations (KAU, 1996) were followed.

Table. 1 Details of treatments

S. N.	Treatments	Stage	Dose
1. •	Imidacloprid-Seed treatment	Sowing	2 g a. i. kg^{-1}
2.	Imidacloprid-Foliar spray	Early vegetative (36 DAS)	20 g a.i.ha^{-1}
3.	Imidacloprid -Foliar spray	Pre flowering (50 DAS)	20 g a.i.ha^{-1}
4.	Imidacloprid -Foliar spray	Fruiting (64 DAS)	20 g a.i.ha^{-1}
5.	Acetamiprid –Seed treatment	Sowing	1.5 g a.i.kg^{-1}
6.	Acetamiprid-Foliar spray	Early vegetative (36 DAS)	10 g a.i ha^{-1}
7.	Acetamiprid- Foliar spray	Pre flowering (50 DAS)	10 g a.i ha^{-1}
8.	Acetamiprid -Foliar spray	Fruiting (64 DAS)	10 g a.i ha^{-1}
9.	Ethofenprox -Foliar spray	Early vegetative (36 DAS)	50 g a.i ha^{-1}
10.	Ethofenprox Foliar spray	Pre flowering (50 DAS)	50 g a.i ha^{-1}
11.	Ethofenprox Foliar spray	Fruiting (64 DAS)	50 g a.i ha^{-1}
12.	Acephate- Foliar spray	Pre flowering (50 DAS)	0.1 per cent
13.	Absolute control	No spray	Nil

3.1.1. Field Observation

Observations on pest incidence and intensity were recorded right from the germination to the final harvest of the crop. The pest surveillance by pre treatment and post treatment counts were carried out regularly at the scheduled treatment applications.

3.1.2. Sucking pests and foliage feeders

The population of sucking insects and foliage feeders was ascertained by selecting six plants at random from each replication of the treatment and pests were counted. Six leaves, two each from the top, middle and bottom were observed for the population on 1,3,5,7 days and every week after the spray. The population was expressed as mean pest population per leaf and was subjected to square root transformation for statistical analysis as per Gomez and Gomez (1984).

3.1.3. Fruitfly and fruit borers

The fruit infestation was estimated by recording the number and weight of infested and total fruits after each harvest. The percentage infestation was worked out based on number and weight and transformed to arc sine values for statistical analysis.

3.1.4. Harvest data

The fruit yield from different treatments was separately recorded during each harvest. The percentage of healthy fruits on number and weight basis were worked out and transformed to arc sine values for statistical analysis.

3.2. BIOASSAY TECHNIQUES

The leaf dip method recommended by FAO (1979) was used for assessing the susceptibility of different populations of epilachna beetles against three insecticides viz., acetamiprid, ethofenprox and imidacloprid. Leaves of uniform size were collected from bittergourd plants and kept in petridishes (10 cm diameter) with petiole ends wrapped up with moist cotton. They were then immersed in different concentrations of insecticides for 10 seconds with gentle agitation. The leaves were then dried under fan for 15 minutes. Three replications were maintained for each treatment. An untreated control was also maintained by spraying the leaf with water alone.

Ten uniformly sized and aged epilachna beetle grubs were then transferred on the insecticide dipped leaves in petridishes by using a camel hairbrush and covered. The petridishes were kept in the laboratory at a temperature of 30 ± 1^0C. Observation on grub mortality was recorded from 4^{th} hour to 48^{th} hour at 4 hours interval after the treatment and the LC_{50} was worked out by probit analysis (Finney, 1971).

3.3. QUANTITATIVE ESTIMATION OF MICRO FLORA

The quantitative assay of micro flora was carried out to know the effect of insecticide applied as seed treatment using serial dilution plate techniques (Johnson and Curl, 1972). Soil sample of (10.0 g) was added to 100 ml sterile distilled water in 250 ml conical flask and shaken for 30 minutes in a orbital shaker. Supernatant (10ml) was transferred to another flask containing 90 ml sterile distilled water to get 10^{-2} dilutions followed by 10^{-4} and 10^{-6} dilutions by serial dilution.

3.3.1. Estimation of fungal pathogen

Soil dilution (1 ml of 10^{-4}) was transferred into sterile petriplates containing Martin's rose bengal streptomycin agar media (20 ml) and were replicated thrice. The petridishes with the media were swirled thoroughly to get uniform distribution. After solidification, the dishes were incubated at room temperature for three days. The fungal colonies developed at the end of three days were counted using dark field colony counter and expressed as number of colonies per gram of dry soil.

3.3.2. Estimation of actinomycetes population

The estimation of actinomycete population was done with a soil solution (10^{-6} dilution) using Kenknights agar medium and the method followed was as in the estimation of fungal population. The dishes were incubated for a week at room temperature and the actinomycete colonies were counted, using dark field colony counter and expressed as number of colonies per gram of dry soil.

3.3.3. Estimation of bacterial population

Bacterial population was estimated using (10^{-6} dilution) in nutrient agar medium. The same method employed for the estimation of fungal population was followed here also. The petriplates were incubated for 48 h at room temperature. The bacterial colonies developed were counted with the help of dark field colony counter and expressed as number of colonies per gram of dry soil.

3.4. ESTIMATION OF IMIDACLOPRID RESIDUES IN THE FRUIT

Residues of imidacloprid in bittergourd fruits were estimated by high performance liquid chromatographic (HPLC) method.

3.4.1. Sampling

Upon harvesting, bittergourd fruits were collected from all replications and pooled treatment wise. A representative sample was analysed for imidacloprid residues.

3.4.2. Extraction

A sample of 20g was soaked over night in 100 ml acetonitrile (AR grade), homogenized in a blender and filtered through Whatman No.41 filter paper in a Buchner funnel. The extraction was repeated two times and the combined extract was evaporated to near dryness in a rotary vacuum evaporator. Then the residue was transferred to a 500ml capacity separating funnel and 150 ml hexane and 50 ml saturated sodium chloride were added. After shaking vigorously for 10 minutes, the aqueous phase (bottom layer) was transferred to another 500ml capacity separating funnel and shaken with 100 ml of hexane: ethyl acetate (98:2 v/v) mixture. Again the aqueous phase (bottom layer) was collected and partitioned three times with 50ml each of dichloromethane. The dichloromethane layers were pooled and dried by passing through anhydrous sodium sulphate and evaporated to near dryness in a rotary vacuum evaporator. The residues were then dissolved in ethyl acetate and transferred to column for cleanup.

3.4.3. Cleanup

Glass chromatographic columns of 50 cm length and 1.5 cm diameter were used for the column cleanup. Florisil deactivated with water (5 %) was used as the absorbant. The drip tip of the glass column was plugged with cotton wool. Florisil (4.5 g) was added into the column and packed airtight. Over this, a 2.5 cm layer of anhydrous sodium sulphate was added. The column was pre washed with 20 ml of ethyl acetate. The residue taken in 5 to 10 ml ethyl acetate was transferred to the top of the column and eluted with 50ml of acetonitrile. The eluate was collected and evaporated to near dryness in a rotary vacuum evaporator. The residue was dissolved in 1 ml of acetonitrile (HPLC grade) and analysed by HPLC.

3.4.4. Recovery studies

Bittergourd samples (20 g) were fortified separately with standard imidacloprid at 1 and 3 ppm levels. The samples were extracted with acetonitrile, extract cleaned up and residues analysed by HPLC method. From the quantity of imidacloprid recovered and the quantity of imidacloprid added, the recovery percentage was worked out.

3.4.5. Quantification

High Performance Liquid Chromatography (HPLC) Hitachi model L 6200, was used for the estimation of residues with the following parameters.

Column		ODS 2
Mobile phase	-	Acetonitrile : water (35:65v/v)
Flow rate	-	1ml/min
Detector	-	Spectrophotometric detector
Wavelength	-	270 nm
Injection volume	-	10 μl

The residue was quantified using the formula

Residue (ppm)= A_s/A_{std} * W_{std}/W_s * V_{ex}/V_s * F

Where,

A_s - Peak area of the sample

A_{std} - Peak area of the standard

W_{std} - Weight of the standard injected (μg)

W_s - Weight of the sample (g)

V_{ex} - Volume of the final extract (ml)

V_s - Quantity of the sample injected (μl)

F- Recovery factor=100/mean recovery per cent

Results

4. RESULTS

Experiment were carried out to evaluate the bio efficacy of newer molecules *viz.*, acetamiprid, ethofenprox and imidacloprid against the bitter gourd insect pests *viz.*, leaf hopper, aphids, epilachna beetle, fruit fly and fruit borer and also assessed their relative

- safety to predators and parasitoids.
- effects on soil micro flora.
- the residue at harvest time

The result of the field and laboratory experiments is presented in this chapter.

4.1. FIELD EVALUATION OF NEWER MOLECULES (RABI, 2001)

Field experiments were conducted to evaluate the effectiveness of newer molecules as seed treatment and sprays at early vegetative, pre flowering and fruiting stage.

4.1.1. Major Pests of Bitter gourd

The following major pests were recorded on the bitter gourd crop during the period under study.

Table 2. Major pests of bitter gourd

S.N.	Common Name	Scientific Name
1.	Leaf hopper	*Empoasca (Empoasca) motti* Pruthi Hemiptera: Cicadellidae
2.	Aphid	*Aphis gossypii* Glover Hemiptera: Aphididae
3.	Epilachna beetle	*Henosepilachna septima* Dieke Coleoptera: Coccinellidae
4.	Fruit fly	*Bactrocera cucurbitae* (Coq.) Diptera: Tephritidae
5.	Fruit borer	*Helicoverpa armigera* (Hubner) Lepidoptera: Noctuidae
6.	Fruit borer	*Diaphania indica* (Saunders) Lepidoptera: Pyraustidae

4.1.2. Efficacy of newer molecules as seed treatment

Newer molecules like acetamiprid and imidacloprid were used as seed dressers to manage the early stage bitter gourd pests. The efficacy of the treatments on leaf hoppers is presented below.

4.1.2.1. Leaf hopper

During early stages of plant growth acetamiprid (1.5 g a. i. kg^{-1}) and imidacloprid (2 g a. i. kg^{-1}) were applied along with the seed to find out the effectiveness against the insect pests. In the early stages low incidence of leaf hopper was observed. Slowly the leaf hoppers increased in number and ranged between 0.380 and 1.509 insects/leaf at 30DAT. Thereafter the population builds up was steady in all the treated plots and control till the harvest at 100 DAT. But the number of insects in acetamiprid seed treated plots was always lower compared to the imidacloprid treated and control plots. However at 86 DAT, all the treatments were at par (Table 3a).

4.1.2.2. Epilachna beetle (H. septima)

The population of the defoliator in the seed treatment plots showed a gradual increase. In acetamiprid treated plots, the population reached its maximum (0.602 insect/leaf) on 72 DAT, where as in imidacloprid (2.276 insects/leaf) and control plots (4.896 insects/leaf) it was on 65 DAT and 58 DAT respectively (Table 3b). At the later stages of the crop, there was no significant effect of the treatment when compared to the control in respect of epilachna beetle population. Compared to the imidacloprid, acetamiprid as a seed dresser protected the crop for a longer time.

Table 3a. Population of leaf hopper (*E.mott*) at different intervals after seed treatment

(mean number of leaf hopper/ leaf) **(Rabi, 2001)**

S.N	Seed treatment	30 DAT	37 DAT	44 DAT	51 DAT	58 DAT	65 DAT	72 DAT	86 DAT	100 DAT
1.	Acetamiprid	0.380 (0.937) b	0.528 (1.013) b	0.676 (1.083) b	0.861 (1.165) b	1.148 (1.281) b	1.454 (1.395) b	1.796 (1.512) b	2.500 (1.731) a	3.102 (1.898) b
2.	Imidacloprid	0.704 (1.096) ab	0.898 (1.182) ab	1.102 (1.265) b	1.500 (1.414) b	1.704 (1.484) a	2.102 (1.613) ab	2.500 (1.732) ab	3.204 (1.924) a	4.601 (2.255) ab
3.	Control	1.509 (1.321) a	2.204 (1.485) a	2.685 (1.611) a	3.565 (1.831) a	4.222 (1.941) a	5.796 (2.206) a	6.500 (2.363) a	7.278 (2.440) a	9.296 (2.889) a

DAT -Days After Treatment

In a column mean followed by a common letter are not significantly different by DMRT ($P = 0.05$)

Values in parenthesis are $\sqrt{X+0.5}$- transformed values

Table 3b. Population of epilachna beetle (*H. septima*) at different intervals after seed treatment

(mean number of epilachna beetle/leaf) **(Rabi, 2001)**

S.N	Seed treatment	30 DAT	37 DAT	44 DAT	51 DAT	58 DAT	65 DAT	72 DAT	86 DAT	100 DAT
1	Acetamiprid	0.000 (0.707) [c]	6.065 (0.751) [c]	0.167 (0.816) [c]	0.204 (0.838) [c]	0.315 (.902) [c]	0.593 (1.041) [c]	0.602 (1.049) [c]	0.333 (0.913) [c]	2.559 (1.748) [a]
2.	Imidacloprid	0.957 (1.207) [b]	1.218 (1.311) [b]	1.351 (1.361) [b]	1.452 (1.396) [b]	1.860 (1.535) [b]	2.276 (1.665) [b]	2.035 (1.591) [b]	1.608 (1.451) [b]	2.581 (1.744) [a]
3	Control	3.159 (1.913) [a]	3.880 (1.972) [a]	3.880 (2.093) [a]	4.483 (2.232) [a]	4.896 (2.323) [a]	4.533 (2.243) [a]	4.021 (2.126) [a]	3.424 (1.981)	3.022 (1.877) [a]

DAT -Days After Treatment

In a column mean followed by a common letter are not significantly different by DMRT ($P = 0.05$)
Values in parenthesis are $\sqrt{X+0.5}$-transformed values

Table 3c. Population of aphid (*A. gossypii*) at different intervals after seed treatment

(mean number of aphid/leaf) **(Rabi, 2001)**

S.N	Seed treatment	30 DAT	37 DAT	44 DAT	51 DAT	58 DAT	65 DAT	72 DAT	86 DAT	100 DAT
1.	Acetamiprid	1.052 (1.246) ^{c}	1.469 (1.402) ^{c}	2.216 (1.643) ^{c}	3.329 (1.954) ^{c}	3.976 (2.115) ^{c}	4.815 (2.305) ^{c}	3.796 (2.073) ^{c}	2.778 (1.809) ^{c}	1.806 (1.518) ^{c}
2.	Imidacloprid	3.588 (2.0210) ^{b}	4.708 (2.282) ^{b}	6.554 (2.656) ^{b}	7.595 (2.845) ^{b}	10.332 (3.291) ^{b}	14.316 (3.849) ^{b}	7.979 (2.9110 ^{b}	6.061 (2.561) ^{b}	3.645 (2.034) ^{b}
3.	Control	18.472 (4.355) ^{a}	20.417 (4.573) ^{a}	26.361 (5.183) ^{a}	32.444 (5.740) ^{a}	45.278 (6.766) ^{a}	30.444 (5.563) ^{a}	26.472 (5.193) ^{a}	15.417 (3.989) ^{a}	10.241 (3.277) ^{a}

DAT - Days After Treatment

In a column mean followed by a common letter are not significantly different by DMRT(P = 0.05)
Values in parenthesis are $\sqrt{X+0.5}$-transformed values

4.1.2.3. Aphid (A. gossypii)

Weekly observations were recorded for aphid population after 30 DAT. An insignificant population existed on the crop until 30 DAT. Acetamiprid treated plots had a less number of aphids at 30 DAT (1.052 insects/leaf) compared to imidacloprid (3.588 insects/leaf). However in the control plot, a maximum of 18.472 aphids were observed. The increasing trend was following in all the plots and reached the maximum at 65 DAT in acetamiprid (4.815 insects/leaf) and imidacloprid (14.316 insects/leaf). In the control plots the maximum population was recorded on 58 DAT (45.278 insects/leaf). Though the population increase was recorded in the treatments, it was significantly lower than control. Subsequently, the population started declining till the last harvest of the crop at 100 DAT (Table 3c).

4.1.3. Efficacy of newer molecules at early vegetative stage

In the early vegetative stage of the crop insect pests *viz.*, leaf hopper, epilachna beetle and aphid were recorded on bitter gourd. Test insecticides were applied as spray using a high volume sprayer to check the insect population effectively. The data on the effectiveness of the insecticides on the population of leaf hopper, epilachna beetle and aphid are presented below.

4.1.3.1. Leaf hopper (E. motti)

The pretreatment count (PTC) of leaf hopper in the early vegetative stage treated plots noticed more or less similar number of insect pests at 36 DAS. One DAT, there was a steep decline in the leaf hopper population, in all the insecticide treated plots (Table 4a). After that, a gradual build up of population was recorded in all the treatments plots including control. The leaf hopper population reached its maximum on 63 DAT in all the insecticide treatment plots i.e., acetamiprid

Table 4a. Early vegetative stage spray of newer insecticides against bittergourd leaf hopper *(E.motti)*

(mean number of leaf hopper/ leaf) **(Rabi, 2001)**

S.N.	Treatments	Pre treatment count	1 DAT	3 DAT	5 DAT	7 DAT	14 DAT	21 DAT	35 DAT	49 DAT	63 DAT
1.	Acetamiprid	1.704 (1.489)[a]	0.454 (0.976)[c]	0.472 (0.986)[c]	0.593 (1.045)[c]	0.892 (1.182)[c]	1.287 (1.336)[c]	2.176 (1.636)[c]	3.111 (1.900)[c]	4.722 (2.279)[c]	5.602 (2.470)[c]
2.	Ethofenprox	1.796 (1.515)[b]	0.176 (0.822)[b]	0.130 (0.793)[b]	0.278 (0.882)[b]	0.537 (1.016)[b]	0.759 (1.121)[b]	1.602 (1.449)[b]	2.352 (1.688)[b]	3.704 (2.050)[b]	4.796 (2.301)[b]
3.	Imidacloprid	1.602 (1.449)[a]	0.083 (0.764)[c]	0.102 (0.776)[c]	0.250 (0.866)[c]	0.426 (0.960)[c]	0.741 (1.112)[c]	1.204 (1.305)[d]	2.102 (1.613)[c]	3.398 (1.974)[c]	4.500 (2.236)[d]
4.	Control	1.796 (1.515)[a]	2.204 (1.612)[a]	2.324 (1.680)[a]	2.407 (1.701)[a]	2.676 (1.789)[a]	3.556 (2.013)[a]	4.222 (2.158)[a]	5.796 (2.509)[a]	7.796 (2.873)[a]	9.296 (3.130)[a]

DAT -Days After Treatment

In a column mean followed by a common letter are not significantly different by DMRT (P = 0.05)
Values in parenthesis are $\sqrt{X+0.5}$ -transformed values

Table 4b. Early vegetative stage spray of newer insecticides against bittergourd epilachna beetle (*H.septima)*

(mean number of epilachna beetle/ leaf) **(Rabi, 2001)**

S N.	Treatments	Pre treatment count	1 DAT	3 DAT	5 DAT	7 DAT	14 DAT	21 DAT	35 5 DAT	49 DAT	63 DAT
1.	Acetamiprid	3.178 (1.918) a	0.019 (0.720) c	0.028 (0.726) c	0.046 (0.739) c	0.120 (0.786) c	0.167 (0.816) c	0.583 (1.041) c	0.630 (1.063) c	0.472 (0.983) c	0.398 (0.945) c
2.	Ethofenprox	3.255 (1.938) a	0.973 (1.214) b	1.020 (1.233) b	1.051 (1.245) b	1.173 (1.293) b	1.277 (1.333) b	1.888 (1.545) b	1.964 (1.566) b	1.815 (1.518) b	1.621 (1.455) b
3.	Imidacloprid	3.546 (1.823) a	0.009 (0.714) c	0.028 (0.726) c	0.037 (0.733) c	0.111 (0.781) c	0.194 (0.833) c	0.556 (1.027) c	0.583 (1.041) c	0.417 (0.955) c	0.333 (0.913) c
4.	Control	3.160 (1.927) a	3.388 (1.972) a	3.628 (2.032) a	3.719 (2.045) a	3.878 (2.092) a	4.466 (2.224) a	4.894 (2.322) a	4.017 (2.124) a	3.383 (1.969) a	2.978 (1.864) a

DAT -Days After Treatment

In a column mean followed by a common letter are not significantly different by DMRT ($P = 0.05$)
Values in parenthesis are $\sqrt{X+0.5}$ -transformed values

Table 4c. Early vegetative stage spray of newer insecticides against bittergourd aphid (*A.gossypii)*

(mean number of aphid / leaf) **(Rabi, 2001)**

S N.	Treatments	Pre treatment count	1 DAT	3 DAT	5 DAT	7 DAT	14 DAT	21 DAT	35 DAT	49 DAT	63 DAT
1.	Acetamiprid	15.694 (4.024) a	1.148 (1.282) c	1.111 (1.269) c	1.222 (1.312) c	3.296 (1.947) c	5.926 (2.526) c	11.111 (3.397) c	10.333 (3.286)	8.222 (2.953) c	7.000 (2.737) a
2.	Ethofenprox	16.546 (4.128) a	3.898 (2.096) b	3.779 (2.068) b	4.198 (2.167) b	6.841 (2.708) b	10.032 (3.244) b	17.108 (4.194) b	13.937 (3.786) b	13.960 (3.801) b	9.690 (3.169) a
3.	Imidacloprid	16.454 (4.117) a	0.898 (1.176) c	1.000 (1.222) c	1.333 (1.354) c	3.333 (1.957) c	6.593 (2.657) c	10.370 (3.293) c	11.333 (3.433) b	7.333 (2.799) d	8.222 (2.942) a
4.	Control	16.750 (4.153) a	18.417 (4.349) a	20.417 (4.573) a	23.648 (4.914) a	26.352 (5.182) a	32.463 (5.741) a	45.306 (6.768) a	26.472 (5.193) a	15.426 (3.990) a	10.222 (3.274) a

DAT -Days After Treatment

In a column mean followed by a common letter are not significantly different by DMRT ($P = 0.05$)
Values in parenthesis are $\sqrt{X+0.5}$ -transformed values

(5.602 insects/leaf), imidacloprid (4.500 insects/leaf) and ethofenprox (4.796 insects/leaf), whereas, the number of leaf hoppers observed in the control plots (9.296 insects/leaf) was significantly more as compared to other treated plots throughout the crop period.

4.1.3.2. Epilachna beetle (H. septima)

The insect caused considerable damage during the early vegetative period of the crop. The pre treatment count of mean epilachna beetle and grubs ranged between 3.160 and 3.546 per leaf. Immediately after the spray at one DAT, a drastic reduction of the epilachna beetle population was recorded in all the treatments *viz.*, acetamiprid (0.019 insects/leaf), ethofenprox (0.973 insects/leaf) and imidacloprid (0.009 insects/leaf). Both acetamiprid and imidacloprid treatments were superior to ethofenprox and control treatment (Table 4b). Thereafter a gradual builds up of beetle population recorded up to 35 DAT, in acetamiprid (0.630 insects/leaf), ethofenprox (1.964 insects/leaf) and imidacloprid (0.583 insects/leaf). The population showed the declining trend after 35 DAT. All the insecticides *viz.*, acetamiprid, ethofenprox and imidacloprid treatment resulted in significantly lower number of beetle population compared to the control.

4.1.3.3. Aphid (A. gossypii)

In the early vegetative stage of the crop the population of aphid caused considerable damage to the crop. Mean aphid population ranged between 15.694 and16.750 per leaf in the pretreatment count. One DAT, lower number of aphids were recorded in imidacloprid (0.898 insects/leaf), acetamiprid (1.148 insects/leaf) and ethofenprox (3.898 insects/leaf) treatments respectively. Compared to the control plots, all the insecticide treated fields recorded significantly lower aphid population. Among the insecticides, imidacloprid treatment resulted in the lowest number of insects but the results are not statistically different from that of acetamiprid. However, both the treatments were better than ethofenprox. Maximum leaf hopper population was recorded at 21 DAT in all the treatments except in imidacloprid (11.333 insects/leaf). The population showed declining phase from 35 DAT onwards (Table 4c).

4.1.4. Efficacy of newer molecules at pre flowering stage

The pre flowering stage spray was applied at 50^{th} day after sowing. During this period, the incidence of leaf hopper, epilachna beetle and aphids were observed in large numbers.

4.1.4.1. Leaf hopper (E. motti)

In pre flowering stage, the leaf hopper population was moderately higher when compared to other stages of growth of crop. The mean leaf hopper population was between 3.500 and 3.352 insects per leaf before the insecticide treatment. On one DAT, the number of leaf hopper significantly more in plots with the standard insecticide, acephate (0.898 insects/leaf) compared to acetamiprid (0.398 insects/leaf), ethofenprox (0.630 insects/leaf) and imidacloprid (0.167 insects/leaf) but lesser than the control (3.556 insects/leaf). Over a period of time the steady build up of leaf hopper population was recorded (up to 49 DAT). Maximum population of the insects was recorded at 49 DAT in all the plots *viz.*, acetamiprid (5.296 insects/leaf), ethofenprox (5.500 insects/leaf) and imidacloprid (5.102 insects/leaf), acephate (6.102 insects/leaf) and control (9.296 insects/leaf). All the insecticide treatments had a non-significant effect up on the number of leaf hopper after 42 DAT. At the same time all the insecticide treatments brought down the leaf hopper population significantly as compared to the control (Table 5a).

4.1.4.2. Epilachna beetle (H. septima)

Skeletonisation of the leaf was severe by the grubs and adult beetles during pre flowering stage. The pre treatment count of mean epilachna beetle adult as

Table 5a. Pre flowering stage spray of newer insecticides against bittergourd leaf hopper (*E.motti*)

(mean number of leaf hopper/ leaf) **(Rabi, 2001)**

S.N.	Treatments	Pre treatmet count	1 DAT	3 DAT	5 DAT	7 DAT	14 DAT	21 DAT	28 DAT	35 DAT	42 DAT	49 DAT
1.	Acetamiprid	3.352 (1.963)^{a}	0.398 (0.946)^{d}	0.398 (0.945)^{d}	0.648 (1.071)^{c}	0.620 (1.058)^{c}	0.843 (1.159)^{d}	1.389 (1.371)^{c}	1.898 (1.548)^{d}	2.704 (1.790)^{c}	4.583 (2.237)^{b}	5.296 (2.401)^{b}
2.	Ethofenprox	3.546 (2.011)^{a}	0.630 (1.063)^{c}	0.648 (1.071)^{c}	0.787 (1.133)^{c}	0.824 (1.149)^{c}	1.389 (1.373)^{c}	1.704 (1.484)^{c}	2.102 (1.613)^{c}	2.898 (1.843)^{c}	4.704 (2.281)^{b}	5.500 (2.433)^{b}
3.	Imidacloprid	3.398 (1.974)^{a}	0.167 (0.816)^{e}	0.176 (0.822)^{c}	0.222 (0.850)^{d}	0.259 (0.871)^{c}	0.352 (0.923)^{e}	0.759 (1.120)^{d}	1.500 (1.414)^{e}	2.296 (1.672)^{d}	5.130 (2.356)^{b}	5.102 (2.367)^{b}
4.	Acephate	3.620 (2.030)^{a}	0.898 (1.182)^{b}	0.796 (1.137)^{b}	1.388 (1.371)^{b}	1.796 (1.515)^{b}	2.296 (1.672)^{b}	2.796 (1.814)^{b}	3.500 (2.000)^{b}	4.203 (2.153)^{b}	5.296 (2.389)^{b}	6.102 (2.569)^{b}
5.	Control	3.500 (2.000)^{a}	3.556 (2.014)^{a}	3.889 (2.069)^{a}	4.102 (2.144)^{a}	4.222 (2.151)^{a}	5.778 (2.505)^{a}	6.500 (2.645)^{a}	7.796 (2.880)^{a}	8.194 (2.948)^{a}	8.796 (3.049)^{a}	9.296 (3.130)^{a}

DAT -Days After Treatment

In a column mean followed by a common letter are not significantly different by DMRT (P = 0.05)
Values in parenthesis are $\sqrt{X+0.5}$- transformed values

Table 5b. Pre flowering stage spray of newer insecticides against bittergourd epilachna beetle (*H.septima*)

(mean number of epilachna beetle/leaf) **(Rabi, 2001)**

S.N	Treatments	Pre treatment count	1 DAT	3 DAT	5 DAT	7 DAT	14 DAT	21 DAT	28 DAT	35 DAT	42 DAT	49 DAT
1.	Acetamiprid	5.667 (2.481) ^{bc}	0.028 (0.726) ^{d}	0.046 (0.739) ^{d}	0.056 (0.745) ^{d}	0.102 (0.775) ^{d}	0.204 (0.838) ^{d}	0.352 (0.923) ^{d}	0.204 (0.839) ^{d}	0.148 (0.804) ^{d}	0.083 (0.764)	0.028 (0.726) ^{d}
2.	Ethofenprox	5.928 (2.534) ^{ab}	1.004 (1.226) ^{c}	1.020 (1.233) ^{c}	1.082 (1.258) ^{c}	1.157 (1.281) ^{c}	1.351 (1.361) ^{c}	1.567 (1.437) ^{c}	1.365 (1.365) ^{c}	1.298 (1.338) ^{c}	1.112 (1.269)	1.020 (1.233) ^{c}
3.	Imidacloprid	6.683 (2.679) ^{a}	0.009 (0.714) ^{d}	0.019 (0.720) ^{d}	0.037 (0.733) ^{d}	0.056 (0.745) ^{d}	0.130 (0.793) ^{d}	0.259 (0.867) ^{d}	0.157 (0.811) ^{d}	0.130 (0.793) ^{d}	0.083 (0.764)	0.083 (0.764) ^{d}
4.	Acephate	4.890 (2.320) ^{cd}	1.849 (1.533) ^{b}	1.888 (1.545) ^{b}	1.964 (1.569) ^{b}	2.076 (1.605) ^{b}	2.293 (1.671) ^{b}	2.634 (1.769) ^{b}	2.364 (1.692) ^{b}	2.275 (1.666) ^{b}	1.983 (1.576)	1.869 (1.539) ^{b}
5.	Control	4.492 (2.232) ^{d}	4.716 (2.284) ^{a}	5.056 (2.357) ^{a}	4.851 (2.310) ^{a}	4.894 (2.322) ^{a}	4.515 (2.234) ^{a}	4.017 (2.124) ^{a}	2.609 (2.027) ^{a}	3.386 (1.971) ^{a}	3.386 (1.971)	2.982 (1.866) ^{a}

DAT -Days After Treatment

In a column mean followed by a common letter are not significantly different by DMRT (P = 0.05)

Values in parenthesis are $\sqrt{X+0.5}$-transformed values

Table 5c. Pre flowering stage spray of newer insecticides against bittergourd aphid ***(A.gossypii)***

(mean number of aphid / leaf) **(Rabi, 2001)**

S.N	Treatments	Pre treatment count	1 DAT	3 DAT	5 DAT	7 DAT	14 DAT	21 DAT	28 DAT	35 DAT	42 DAT	49 DAT
1.	Acetamiprid	38.528 (6.247)^{d}	0.630 (1.063)^{d}	0.630 (1.062)^{d}	0.815 (1.146)^{d}	1.074 (1.243)^{d}	2.345 (1.663)^{d}	3.407 (1.977)^{d}	3.759 (2.047)^{b}	2.963 (1.852)^{c}	2.481 (1.702)^{c}	2.111 (1.603)^{c}
2.	Ethofenprox	36.417 (6.076)^{c}	4.170 (2.159)^{c}	3.287 (1.945)^{c}	3.690 (2.046)^{c}	4.476 (2.230)^{c}	6.308 (2.583)^{c}	7.647 (2.853)^{c}	6.658 (2.663)^{b}	6.785 (2.696)^{b}	6.063 (2.546)^{b}	5.482 (2.437)^{b}
3.	Imidacloprid	40.336 (6.396)^{c}	0.565 (1.029)^{d}	0.693 (1.092)^{d}	0.583 (1.038)^{c}	1.389 (1.366)^{d}	1.713 (1.475)^{d}	2.861 (1.824)^{d}	4.167 (2.143)^{b}	2.843 (1.824)^{c}	1.713 (1.475)^{c}	1.444 (1.362)^{c}
4.	Acephate	47.473 (6.926)^{a}	6.437 (2.630)^{b}	6.924 (2.725)^{b}	7.087 (2.754)^{b}	9.130 (3.102)^{b}	11.185 (3.417)^{b}	14.286 (3.845)^{b}	17.847 (4.230)^{a}	14.880 (3.908)^{a}	10.241 (3.272)^{a}	10.791 (3.335)^{a}
5.	Control	43.683 (6.647)^{b}	35.528 (6.002)^{a}	38.417 (6.238)^{a}	40.509 (6.404)^{a}	46.204 (6.834)^{a}	36.750 (6.103)^{a}	26.472 (5.193)^{a}	18.463 (4.354)^{a}	15.435 (3.992)^{a}	13.361 (3.723)^{a}	10.222 (3.273)^{a}

DAT -Days After Treatment

In a column mean followed by a common letter are not significantly different by DMRT (P = 0.05)
Values in parenthesis are $\sqrt{X+0.5}$-transformed values

well as grubs ranged from 4.492 to 6.683 per leaf. One DAT, both the acetamiprid (0.028 insects/leaf) and imidacloprid (0.009insects/leaf) resulted in the lowest population followed by ethofenprox (1.004 insects/leaf) and acephate (1.849 insects/leaf), whereas, in control the population was more or less stable throughout the period until 21 DAT, thereafter the population got declined (Table 5b). The effectiveness of acetamiprid and imidacloprid treatments on the epilachna beetles was on par with each other throughout the crop period followed by ethofenprox and acephate. However, all the insecticide treated plots showed significantly lower number of epilachna beetle population when compared to control. The order of effectiveness of insecticides are imidacloprid = acetamiprid > ethofenprox > acephate.

4.1.4.3. Aphid (A. gossypii)

Vegetative parts were severely damaged by the aphids during the pre flowering stage of the crop. The mean aphid population ranged from 36.417 to 47.473 per leaf. A sudden reduction in the population of aphids were recorded immediately after the spray (1 DAT) in all the insecticide sprayed plots *viz.*, imidacloprid (0.565 insects/leaf), acetamiprid (0.630 insects/leaf), ethofenprox (4.170 insects/leaf) and acephate (6.437 insects/leaf). But in the control plots slight decline of initial aphid population from 43.683 to 35.528 insects/leaf (Table 5c). There after a gradual increase in the number of aphids noticed and it continued up to 7 DAT. Except ethofenprox (21 DAT), the maximum aphid population attained in other treatments was on 28 DAT. The population of aphids got declined as the crop neared maturity. The effectiveness of both acetamiprid and imidacloprid were on par with each other throughout the crop period followed by ethofenprox and acephate. However acephate showed significantly lower number of aphid population as compared to control up to 21 DAT and later the population of the insects was at par with control. Newer insecticides were far superior to the conventional insecticide acephate in bringing down the aphid population.

4.1.5. Efficacy of newer molecules at fruiting stage

The fruiting stage spray was applied at 64 days after sowing. The incidence of leaf hopper, epilachna beetle, aphid, fruit fly and fruit borers were observed.

4.1.5.1. Leaf hopper (E. motti)

The mean number of leaf hopper ranged between 5.602 and 5.694 insects per leaf in the pretreatment count. There was a significant reduction in the leaf hopper population consequent to the spray at one DAT, in all the insecticides treated plots. The lowest number of insects was recorded in treatments *viz.*, imidacloprid (0.278 insects /leaf), acetamiprid (0.454 insects /leaf) followed by ethofenprox (1.009 insects /leaf) as compared to the control plots (6.093 insects / leaf). Subsequently gradual buildup of leaf hopper population was recorded up to 35 DAT in all the treatment plots and in control. Acetamiprid and imidacloprid treated plots resulted in on par effects throughout crop period (up to 35 DAT). However, all the insecticides treatments resulted in significantly lower number of leaf hopper population compared to the control (Table 6a).

4.1.5.2. Epilachna beetle (H. septima)

The pretreatment count of epilachna beetle also showed less number compared to the pre flowering stage. The mean number of insects ranged from 5.138 to 6.320 per leaf in the fruiting stage. There was a steady decline in the population in control (Table 6b), where as, low epilachna beetle population was observed in acetamiprid (0.056 insect/leaf), ethofenprox (1.097 insects /leaf) and imidacloprid (0.046 insect/leaf), the next day of spray. In treated plots, a gradual build up of epilachna beetle population was recorded up to 21 DAT for acetamiprid (0.509 insect/leaf) up to 14 DAT for ethofenprox (1.718 insects/leaf) and imidacloprid (0.417 insect/leaf) (Table 6b). The results of the acetamiprid and

Table 6a. Fruiting stage spray of newer insecticides against bittergourd leaf hopper *(E.motti)*

(mean number of leaf hopper/leaf) **(Rabi, 2001)**

S.N	Treatments	Pre treatment count	1 DAT	3 DAT	5 DAT	7 DAT	14 DAT	21 DAT	28 DAT	35 DAT
1.	Acetamiprid	5.694 (2.409)[a]	0.454 (0.974)[c]	0.426 (0.961)[c]	0.463 (0.981)[c]	0.481 (0.989)[c]	0.556 (1.027)[c]	0.824 (1.150)[c]	0.926 (1.194)[c]	1.602 (1.449)[c]
2.	Ethofenprox	5.796 (2.509)[a]	1.009 (1.228)[b]	1.139 (1.280)[b]	1.157 (1.287)[b]	1.176 (1.294)[b]	0.861 (1.167)[b]	1.257 (1.326)[b]	1.713 (1.485)[b]	2.343 (1.684)[b]
3.	Imidacloprid	5.602 (2.470)[a]	0.278 (0.882)[c]	0.278 (0.882)[c]	0.306 (0.898)[c]	0.500 (0.998)[c]	0.426 (0.961)[c]	0.519 (1.008)[c]	0.861 (1.167)[c]	1.389 (1.374)[c]
4.	Control	5.694 (2.489)[a]	6.093 (2.567)[a]	9.176 (3.111)[a]	6.398 (2.626)[a]	6.500 (2.644)[a]	7.796 (2.866)[a]	8.194 (2.943)[a]	8.889 (3.064)[a]	9.296 (3.128)[a]

DAT -Days After Treatment

In a column mean followed by a common letter are not significantly different by DMRT (P = 0.05)

Values in parenthesis are $\sqrt{X+0.5}$- transformed values

Table 6b. Fruiting stage spray of newer insecticides against bitter gourd epilachna beetle *(H.septima)*.

(mean number of epilachna beetle/ leaf) **(Rabi, 2001)**

S.N	Treatments	Pre treatment count	1 DAT	3 DAT	5 DAT	7 DAT	14 DAT	21 DAT	28 DAT	35 DAT
1.	Acetamiprid	5.491 (2.445) a	0.056 (0.745) c	0.083 (0.764) c	0.130 (0.793) c	0.139 (0.799) c	0.444 (0.970) c	0.509 (1.002) c	0.269 (0.875) c	0.148 (0.805) c
2.	Ethofenprox	5.694 (2.486) a	1.097 (1.264) b	1.112 (1.269) b	1.203 (1.305) b	1.248 (1.332) b	1.718 (1.481) b	1.703 (1.481) b	1.482 (1.408) b	1.278 (1.333) b
3.	Imidacloprid	5.138 (2.370) a	0.046 (0.739) c	0.046 (0.739) c	0.074 (0.758) c	0.120 (0.786) c	0.417 (0.954) c	0.361 (0.928) c	0.250 (0.864) c	0.139 (0.799) c
4.	Control	6.320 (2.600) a	5.399 (2.426) a	4.965 (2.334) a	4.798 (2.302) a	4.003 (2.117) a	3.771 (2.066) a	3.382 (1.969) a	3.139 (1.908) a	2.982 (1.866) a

DAT -Days After Treatment

In a column mean followed by a common letter are not significantly different by DMRT (P = 0.05)

Values in parenthesis are $\sqrt{X+0.5}$ -transformed values

Table 6c. Fruiting stage spray of newer insecticides against bitter gourd aphid *(A.gossypii)*

(mean number of aphid / leaf) **(Rabi, 2001)**

S.N	Treatments	Pre treatment count	1 DAT	3 DAT	5 DAT	7 DAT	14 DAT	21 DAT	28 DAT	35 DAT
1.	Acetamiprid	62.674 (7.948)[a]	2.333 (1.683)[c]	2.185 (1.634)[c]	2.704 (1.784)[c]	4.185 (2.080)[c]	4.815 (2.264)[c]	3.000 (1.871)[c]	2.222 (1.641)[c]	1.185 (1.297)[c]
2.	Ethofenprox	60.022 (7.779)[ab]	6.934 (2.726)[b]	6.934 (2.726)[b]	8.216 (2.941)[b]	10.406 (3.290)[b]	11.250 (3.421)[b]	7.959 (2.887)[b]	7.562 (2.837)[b]	5.458 (2.432)[b]
3.	Imidacloprid	49.972 (7.104)[c]	1.815 (1.512)[c]	1.704 (1.475)[c]	2.000 (1.570)[c]	3.185 (1.917)[c]	2.074 (1.592)[d]	1.593 (1.436)[d]	1.296 (1.339)[d]	0.778 (1.330)[c]
4.	Control	53.467 (7.333)[bc]	50.454 (7.138)[a]	40.241 (6.383)[a]	35.593 (6.007)[a]	26.741 (5.219)[a]	20.741 (4.609)[a]	15.602 (4.012)[a]	13.259 (3.709)[a]	10.222 (3.274)[a]

DAT -Days After Treatment

In a column mean followed by a common letter are not significantly different by DMRT ($P = 0.05$)

Values in parenthesis are $\sqrt{X+0.5}$- transformed values

imidacloprid were at par and significantly better than ethofenprox and control. Compared to the control all other treatments were statistically significant.

4.1.5.3. Aphid (A. gossypii)

In fruiting stage the number of aphids recorded were higher in pretreatment count, when compared to other stages of pretreatment count in all the experimental plots. The mean aphid population in pretreatment count ranged between 49.972 and 62.674 insects/leaf. At one DAT, a sudden decline of aphid population was recorded in all the treatment plots including control plots i.e., acetamiprid (2.333 insects/leaf), ethofenprox (6.934 insects/leaf), imidacloprid (1.815 insects/leaf) and control (50.454 insects/leaf). Then a gradual build up was noticed in all the treatments except control plots (Table 6c). The highest number of aphids was recorded at 14 DAT in acetamiprid (4.815 insects/leaf) and ethofenprox (11.250 insects/leaf) and at 7 DAT in imidacloprid treatments (3.185 insects/leaf). However, control plots also recorded a decrease number of aphids from 1 DAT (53.467 insects/leaf) to 35DAT (10.22 insects/leaf). The results of the acetamiprid and imidacloprid were at par and significantly better than the ethofenprox and control. Compared to control, all other treatments were statistically better in their efficacy against the insect.

4.1.6. Effect of newer insecticide treatment on bitter gourd yield

The efficacy of , acetamiprid, ethofenprox and imidacloprid were assessed with the standard insecticide acephate The infestation of fruit fly and fruit borer pests of bitter gourd were compared and marketable yields of bitter gourd crop were worked out (Table 7).

Table 7. Total and marketable yield of bitter gourd fruits (Rabi, 2001)

S.N	Treatment	Total yield		Marketable yield	
		Fruit number ($8m^2$)	Fruit weight ($kg/8m^2$)	Fruit number ($8m^2$)	Fruit weight ($kg/8m^2$)
	Imidacloprid				
1.	Seed treatment	76.00	5.39	60.66	4.50
2.	Early vegetative stage spray	85.00	6.00	73.00	5.20
3.	Pre flowering stage spray	102.66	7.37	83.33	6.53
4.	Fruiting stage spray	87.33	6.71	79.00	6.13
	Acetamiprid				
5.	Seed treatment	75.66	5.20	60.33	4.13
6.	Early vegetative stage spray	75.66	5.40	63.00	4.53
7.	Pre flowering stage spray	95.33	7.05	86.33	6.41
8.	Fruiting stage spray	89.33	6.38	80.66	5.73
	Ethofenprox				
9.	Early vegetative stage spray	74.66	5.92	61.66	4.36
10.	Pre flowering stage spray	79.33	5.88	71.00	5.33
11	Fruiting stage spray	72.33	5.55	64.66	5.01
	Acephate				
12.	Pre flowering stage spray	71.00	5.67	63.33	4.78
13.	Control	78.33	5.05	59.33	3.98
	CD (P=0.05)	4.13	0.30	3.28	0.45

4.1.6.1. Effect of seed treatment

The infestation by fruit fly and fruit borer due to acetamiprid and imidacloprid seed treatment was compared with the untreated control. The effect of newer insecticides is expressed in terms of marketable fruit yield of bitter gourd.

4.1.6.1a. Total yield

Imidacloprid seed treated plots resulted the yield of 76.00 fruits/8m^2 and 5.39 kg/8m^2 in terms of number and weight basis respectively. Whereas, acetamiprid gave the yield of 75.66 fruits/8m^2 and 5.20 kg/8m^2 on number and weight basis respectively. However both treatments were on par with control.

4.1.6.1b. Marketable yield

In the imidacloprid seed treated plots a higher mean yield both in number (60.66 fruits/8m^2) and weight basis (4.50kg/8m^2) was recorded as compared to acetamiprid treated plots on number (60.33 fruits/8m^2) and weight basis (4.13 kg/8m^2). However control plots recorded on par results with both the insecticide treated plots.

4.1.6.2. Effect of early vegetative stage treatment

The early vegetative stage spray of newer molecules *viz.*, acetamiprid, ethofenprox and imidacloprid was carried out at 36 DAT. The higher yield was recorded in imidacloprid treated plots in both number and weight basis followed by acetamiprid and ethofenprox treated plots (Table 7)

4.1.6.2a. Total yield

In the early vegetative stage, imidacloprid treated plots recorded higher mean total yield (85.00 fruits/8m^2). In acetamiprid (75.66 fruits/8m^2) and ethofenprox (74.66 fruits/8m^2) plots lower yields were recorded. Higher weight of bitter gourd fruit (6.00 kg/8m^2) was recorded in imidacloprid treatment plots when compared to acetamiprid (5.40 kg/8m^2). Ethofenprox (5.92 kg/8m^2) treatment was on par with the imidacloprid treated plots. However, control plots recorded the lowest total yield weight (5.05 kg/8m^2) of bitter gourd fruits. In comparison to control, all the treated plots yields were significantly higher in their total yield harvest (Table 7).

4.1.6.2b. Marketable yield

Though there was a difference in the total yield in all the treatments, the marketable yield of fruits in acetamiprid and ethofenprox (63.00 and 61.67 fruits/8m^2) were not significantly different. Only, the imidacloprid treatment had resulted in higher yield (73.0 fruits/8m^2). But on weight basis, all the insecticide treatments recorded more yields and were statistically better than the control. The highest yield was recorded in the imidacloprid treatment (5.20 kg/8m^2) followed by acetamiprid (4.53 kg/8m^2) and ethofenprox (4.36 kg/8m^2).

4.1.6.3. Effect at pre flowering stage treatment

In the pre flowering stage, along with the newer molecules *viz.*, acetamiprid, ethofenprox, imidacloprid, a recommended standard insecticide acephate was also sprayed at 50 days after sowing. The effect of the insecticide treatments on the fruit fly and fruit borer pests were compared and the total and marketable yield of the bitter gourd fruits were worked out.

4.1.6.3a. Total yield

The standard insecticide acephate treatment had the lowest yield (71.0 fruit/8m^2) along with the treatments including control. Imidacloprid (102.66 fruits/8m^2) and acetamiprid (95.33 fruits/8m^2) treatments had resulted in higher yields. However, ethofenprox (79.33 fruits/8m^2) was almost equal to that obtained from the control plots (78.33 fruits/8m^2). However, the yield on weight basis gave a different picture. Both the acephate (5.67 kg/8m^2) and ethofenprox (5.89 kg/8m^2) treatments were on par but significantly less effective compared to imidacloprid (7.37 kg/8m^2) and the acetamiprid (7.06 kg/8m^2) treatments. All the insecticide treated plots had more yield on weight basis than the control (5.05 kg/8m^2).

4.1.6.3b. Marketable yield

Acetamiprid (86.33 fruits/8m^2) and imidacloprid (83.33 fruits/8m^2) were on par but superior to ethofenprox (71.00 fruits/8m2) at pre flowering stage. Acephate (63.33 fruits/8m^2) resulted lower number of marketable fruits, where as it was significantly higher than control plots (59.33 fruits/8m^2). On weight basis, imidacloprid (6.53 kg/8m^2) and acetamiprid (6.41 kg/8m^2) showed no significance yield, followed by ethofenprox (5.33 kg/8m^2). Whereas acephate recorded lower marketable fruits (4.78 kg/8m^2) that was significantly higher than control plots (3.98 kg/8m^2).

4.1.6.4. Effect at fruiting stage treatment

The effects of acetamiprid, ethofenprox and imidacloprid on the fruit fly and fruit borer pests were compared and total and marketable yield of the bitter gourd fruits were worked out.

4.1.6.4a. Total yield

The lowest yield was recorded in the ethofenprox treated plots and was lower than the untreated control (72.33 and 78.33 fruits/8m^2 respectively). However, imidacloprid (87.33 fruits/8m^2) and acetamiprid (89.33 fruits/8m^2) application yielded non-significant fruit numbers among them. This is true in case of yield of fruits on weight basis also (Table 7). All the insecticide treatments were significantly superior to the control.

4.1.6.4b. Marketable yield

Similar to the total yield results, the marketable fruit number also was more in the acetamiprid treatment (80.67 fruits/8m^2) and it was on par with the imidacloprid (79.00 fruits/8m^2) treatment. All the insecticide treatments were significantly different from each other and that of the control (3.98 kg/8m^2).

4.1.7. Effect of newer insecticide treatments on fruit fly and fruit borer infestation in bitter gourd fruits

The efficacy of newer molecules was assessed through various treatments as above against fruit fly *(B. cucurbitae)* and fruit borers (*H. armigera* and *D. indica*) infestation. The mean per cent of infestation by fruit fly and fruit borer on number and weight basis was recorded. In all the treatment fruit fly infestation was more than the fruit borer infestation. The data on the mean per cent infestation of fruit fly and fruit borers are presented here under.

4.1.7.1. Effect of seed treatment on fruit fly and borer pests

The seed treatment effects of imidacloprid and acetamiprid were studied on the later stage fruit fly and fruit borer infestation. In general, seed treated plots recorded higher fruit fly and borer infestations both in terms of fruit number and

Table 8. Total fruit infestation at different treatments (Rabi. 2001)

S.N	Treatments	Mean percentage of infestation			
		Furit fly (*B. cucurbitae*)		Borers *H. armigera* and *D. indica*	
		Fruit number	Fruit weight	Fruit number	Fruit weight
	Imidacloprid				
1.	Seed treatment	12.50 (0.357)	12.03 (0.328)	8.18 ((0.286)	5.43 (0.222)
2.	Early vegetative stage spray	8.94 (0.29)	8.33 ((0.285)	4.98 (0.217)	5.02 (0.224)
3.	Pre flowering stage spray	6.29 (0.153)	5.18 (0.204)	2.55 (0.153)	4.80 (0.205)
4.	Fruiting stage spray	5.94 (0.229)	5.50 (0.219)	3.39 (0.182)	3.00 (0.166)
	Acetamiprid				
5.	Seed treatment	12.60 (0.361)	12.85 (0.361)	7.46 (0.275)	7.80 (0.279)
6.	Early vegetative spray	9.66 (0.292)	8.97 (0.269)	6.46 (0.250)	7.18 (0.257)
7.	Pre flowering stage spray	5.65 (0.194)	4.94 (0.184)	3.33 (0.172)	4.13 (0.197)
8.	Fruiting stage spray	5.46 (0.221)	5.17 (0.213)	4.05 (0.194)	4.81 (0.216)
	Ethofenprox				
9.	Early vegetative stage spray	10.16 (0.322)	1[illegible] 11 (0.[illegible]94)	6.97 (0.259)	11.14 (0.327)
10.	Pre flowering stage spray	6.18 (0.24[illegible]	5.03 (0.222)	4.11 (0.190)	4.17 (0.198)
11.	Fruiting stage spray	5.9[illegible] [illegible].24[illegible]	5.56 (0.234)	4.64 (0.209)	4.05 (0.202)
12.	**Acephate** Pre flowering stage spray	7.04 [illegible]	6.89 (0.262)	3.75 (0.194)	2.94 (0.170)
13.	Control	13.62 (0.367)	15.30 (0.375)	9.98 (0.312	5.65 (0.230)
	CD (P=0.05)	NS	NS	NS	NS

Values in parenthesis are arc sine transformed values. NS-Non significant weight basis compared to early vegetative, pre flowering and fruiting stage over a period of time.

4.1.7.1a. Fruit fly

As high as 13.62 per cent damage was recorded in the untreated control plots. In the insecticide treatment though the per cent damage was low (12.50 and 12.60% respectively for imidacloprid and acetamiprid). This was true for the fruit fly damage on fruit weight basis also. The treatments were not significantly different from each other (Table 8).

4.1.7.1b. Fruit borers

In acetamiprid seed treated plots lower infestation of borers (7.46%) was recorded compared to imidacloprid (8.18%). But the opposite was true on weight basis i.e., imidacloprid showed lower per cent (5.43%) infestation compared to acetamiprid (7.80%), control plots recorded higher per cent infestation on number basis (9.98%) and moderate per cent of infestation (5.65%) on weight basis. But all the treatments were on par.

4.1.7.2. Effect of early vegetative stage spray on fruit fly and borer pests

The early vegetative spray of newer molecules was carried out at 36 days after sowing. The highest mean per cent of infestation of fruit fly and borers were noticed in ethofenprox treated plots followed by acetamiprid and imidacloprid among the insecticide treatments on both fruit number and weight basis.

4.1.7.2a. Fruit fly

In the early vegetative stage, fruit fly damage was the lowest in the imidacloprid treatment (8.94%) followed by acetamiprid (9.66%) and ethofenprox

(10.16%). All the insecticide treatments considerably reduced the infestation but not statistically different when compared with the control (13.62%), Ethofenprox (15.11%) and the control (15.30%) had the higher infestation compared to the imidacloprid (8.33%) and acetamiprid (8.97%) on weight basis.

4.1.7.2b. Fruit borer

Against the fruit borer, imidacloprid treatment appeared to be promising (4.98% infestation only) followed by acetamiprid (6.46%) and ethofenprox (6.94%). A different picture was noticed on the mean per cent damage of the fruits on weight basis. Both the acetamiprid and ethofenprox treatment (7.18 and 11.14%) recorded more infestation by fruit borer but the variation on the per cent infestation is insignificant statistically (Table 8).

4.1.7.3. Effect of pre flowering stage spray on fruit fly and borer pests

The pre flowering stage spray of newer molecules and standard check acephate were carried out at 50 days after sowing. The effect of the insecticides on fruit fly and fruit borer was recorded based on mean per cent infestation in both fruit number and fruit weight basis.

4.1.7.3a. Fruit fly

Compared to control, all the insecticide treatments have shown lesser damage by the fruit fly (Table 8). Acetamiprid (5.65%) was the best among the treatment followed by imidacloprid (6.29%), ethofenprox (6.18%) and the recommended insecticide acephate (7.04%). Similar results were obtained when the mean per cent infestation on the fruits was worked out on weight basis also. Though variations exist among the treatment none of them were significantly different from each other.

4.1.7.3b. Fruit borer

Imidacloprid resulted in lowest mean per cent of infestation (2.55%) followed by acetamiprid (3.33%), acephate (3.75%) and ethofenprox (4.11%), whereas the highest mean per cent of infestation was recorded in control plots (9.98%) on number basis. On weight basis, acephate recorded lowest per cent of infestation (2.94%) followed by acetamiprid (4.13%), ethofenprox (4.17%) and imidacloprid (4.80%). Control plots recorded the highest mean per cent of infestation (5.65%).

4.1.7.4. Effect of fruiting stage spray on fruit fly and borer pests

After 64DAT, a spray with the candidate insecticides was given. The effect of the spray on the fruit fly and fruit borer is presented (Table 8).

4.1.7.4a. Fruit fly

In fruiting stage, the mean per cent infestation of fruit fly was less compared to other stages. Acetamiprid treated plots had less mean per cent infestation (5.46%) compared to other treatments. However the infestation was the maximum in control (13.62%) plots. On weight basis, all the insecticides had almost the same per cent infestation *viz.*, ethofenprox (5.56%) followed by acetamiprid (5.17%) and imidacloprid (5.50%). There was more infestation (15.3%) in control plots (Table 8).

4.1.7.4b. Fruit borer

The mean per cent infestation by fruit borer was lower in all treatment compared to fruit fly infestation. Imidacloprid protected the crop with lower mean per cent of infestation (3.39%) in fruiting stage followed by acetamiprid (4.05%) and ethofenprox (4.64%) on number basis. Control plots recorded high mean per cent (9.98%) of infestation. Similar trend was observed when the infestation was expressed in terms of the weight of the fruits. Imidacloprid treated plots had the lowest damage followed by ethofenprox (4.05%) and acetamiprid (4.81%). All the treatments were not significantly different from each other.

4.2. FIELD EVALUATION OF NEWER MOLECULES (SUMMER, 2002)

Field experiment was carried out in summer, 2002 also to evaluate the bioefficacy of newer molecules as seed treatment, early vegetative, pre flowering and fruiting sprays.

4.2.1. Efficacy of newer molecules as seed treatment

To manage the early stage bitter gourd pests newer molecules like acetamiprid and imidacloprid were used as seed dressers. The efficacies of the treatment on bitter gourd pests were presented below.

4.2.1.1. Leaf hopper (E. motti)

Acetamiprid (1.5 g a. i. kg^{-1}) and imidacloprid (2 g a. i. kg^{-1}) were applied with the seed to find out the effectiveness against the insect pests during the early stages of growth. Less number of leaf hoppers was recorded in the initial stages. However at 30 DAT, the mean leaf hopper population ranged from 0.019 (acetamiprid) to 8.500 (control) per leaf. Subsequently the populations build up observed up to 72 DAT in control (16.00 insects/leaf), up to 100 DAT in acetamiprid (8.036 insects/leaf) and up to 86 DAT in imidacloprid (12.703 insects/leaf). But acetamiprid seed treated plots always had lower number of leaf hopper compared to imidacloprid as well as control plots. There was significantly higher number of leaf hopper in control compared to both acetamiprid and imidacloprid. The persistence of acetamiprid was better than the imidacloprid as seed treatment for leaf hopper.

Table 9a. Population of leaf hopper (*E.motti*) at different intervals after seed treatment

(mean number of leaf hoppers/leaf) **(Summer, 2002)**

S.N	Seed treatment	30 DAT	37 DAT	44 DAT	51 DAT	58 DAT	65 DAT	72 DAT	86 DAT	100 DAT
1.	Acetamiprid	0.019 (0.720) ^{c}	0.046 (0.739) ^{c}	0.056 (0.745) ^{c}	0.222 (0.850) ^{c}	0.481 (0.988) ^{c}	0.722 (1.105) ^{c}	3.111 (1.845) ^{b}	7.443 (2.651) ^{a}	8.036 (2.773) ^{a}
2.	Imidacloprid	1.020 (1.233) ^{c}	1.035 (1.239) ^{b}	1.173 (1.293) ^{b}	1.437 (1.391) ^{b}	1.928 (1.558) ^{b}	2.225 (1.651) ^{b}	5.884 (2.489) ^{a}	12.703 (3.600) ^{a}	8.974 (3.078) ^{a}
3.	Control	8.500 (3.000) ^{a}	9.086 (3.096) ^{a}	10.406 (3.301) ^{a}	10.236 (3.277) ^{a}	11.858 (3.515) ^{a}	12.533 (3.610) ^{a}	16.007 (4.036) ^{a}	13.863 (3.790) ^{a}	14.693 (3.898) ^{a}

DAT- Days After Treatment

In a column mean followed by a common letter are not significantly different by DMRT (P = 0.05)

Values in parenthesis are $\sqrt{X+0.5}$-transformed values

Table 9b. Population of epilachna beetle (*H.septima*) at different intervals after seed treatment

(mean number of epilachna beetle/leaf) (Summer, 2002)

S.N.	Seed treatment	30 DAT	37 DAT	44 DAT	51 DAT	58 DAT	65 DAT	72 DAT	86 DAT	100 DAT
1.	Acetamiprid	0.120 (.788) c	0.157 (0.811) c	0.213 (0.844) b	0.333 (0.9130 b	0.565 (1.032) b	0.583 (1.041) b	0.556 (1.027) a	0.528 (1.014) a	0.463 (0.979) a
2.	Imidacloprid	0.157 (.811) b	0.231 (0.855) b	0.278 (0.822) b	0.417 (0.955) ab	0.620 (1.058) b	0.759 (1.120) ab	0.630 (1.063) a	0.611 (1.054) a	0.528 (1.014) a
3.	Control	0.259 (0.871) a	0.343 (0.918) a	0.537 (1.017) a	0.685 (1.087) a	1.083 (1.257) a	0.880 (1.175) a	0.741 (1.112) a	0.620 (1.058) a	0.528 (1.011) a

DAT -Days After Treatment

In a column mean followed by a common letter are not significantly different by DMRT (P = 0.05)
Values in parenthesis are $\sqrt{X+0.5}$ -transformed values

4.2.1.2. Epilachna beetle (H. septima)

Epilachna beetle was significantly lower (30 and 37 DAT) in acetamiprid (0.120 insects/leaf) seed treatment than the imidacloprid (0.157 insects/leaf) and control (0.259 insects/leaf) during the same period. The population increased slowly in all the plots with varying rates till 63 DAT. At later stages of the crop (from 70 DAT) there was no significant effect of the treatments. When compared to imidacloprid, acetamiprid as a seed dresser gave protection to bitter gourd epilachna beetle in the early stages of the crop (Table 9a).

4.2.2. Efficacy of newer molecules at early vegetative stage

In the early vegetative stage, insect pests *viz.*, leaf hopper and epilachna beetle were recorded on bitter gourd. Test insecticides were applied as spraying using high volume sprayer (36 days after sowing) to check the insect population effectively. The results are presented below.

4.2.2.1. Leaf hopper (E. motti)

The pretreatment count (PTC) of leaf hopper in the early vegetative stage spray ranged between 8.854 and 9.196 insects per leaf. There was a steep decline in the leaf hopper population consequent of the spray at one DAT, in all the insecticide treated plots (Table 10a). In acetamiprid sprayed plots, the leaf hoppers rebuilt slowly throughout the crop period (till 63 DAT) where as the population increase was rather quick in ethofenprox (3.992 insects/leaf at 7 DAT) and started declining till 21 DAT, thereafter the increase was recorded. Imidacloprid treatment had the lowest population among all the treatments, but it was at par with acetamiprid and the build up was gradual till the harvest of the crop. In all the treatments, the number of insects was significantly lower than the control.

Table 10a. Early vegetative stage spray of newer insecticides against leaf hopper (*E.motti*)

(mean number of leaf hopper/ leaf) **(Summer, 2002)**

S N.	Treatments	Pre treatment count	1 DAT	3 DAT	5 DAT	7 DAT	14 DAT	21 DAT	35 DAT	49 DAT	63 DAT
1.	Acetamiprid	9.196 (3.114)[a]	0.037 (0.733)[c]	0.037 (0.733)[c]	0.074 (0.758)[c]	0.167 (0.816)[c]	0.278 (0.883)[c]	0.639 (1.067)[c]	0.907 (1.186)[c]	1.602 (1.415)[c]	2.102 (1.613)[c]
2.	Ethofenprox	8.854 (3.058)[b]	2.398 (1.699)[b]	2.647 (1.774)[b]	2.658 (1.777)[b]	3.992 (2.119)[b]	3.755 (2.059)[b]	3.684 (2.043)[b]	3.932 (2.105)[b]	5.475 (2.444)[b]	6.073 (2.564)[b]
3.	Imidacloprid	8.747 (3.041)[b]	0.028 (0.729)[c]	0.064 (0.750)[c]	0.070 (0.755)[c]	0.120 (0.788)[c]	0.241 (0.861)[c]	0.583 (1.041)[c]	0.731 (1.110)[c]	1.296 (1.340)[c]	1.796 (1.515)[c]
4.	Control	9.092 (3.097)[a]	9.474 (3.158)[a]	9.980 (3.236)[a]	10.119 (3.257)[a]	10.302 (3.284)[a]	10.630 (3.332)[a]	11.384 (3.493)[a]	12.074 (3.532)[a]	12.811 (3.629)[a]	13.485 (3.714)[a]

DAT -Days After Treatment

In a column mean followed by a common letter are not significantly different by DMRT (P = 0.05)

Values in parenthesis are $\sqrt{X+0.5}$-transformed values

Table 10b. Early vegetative stage spray of newer insecticides against bitter gourd epilachna beetle *(H.septima)*

(mean number of epilachna beetle/leaf) **(Summer, 2002)**

S.N.	Treatments	Pre treatment count	1 DAT	3 DAT	5 DAT	7 DAT	14 DAT	21 DAT	35 DAT	49 DAT	63 DAT
1.	Acetamiprid	0.296 (0.796) a	0.056 (0.555) c	0.074 (0.574) b	0.074 (0.574) b	0.120 (0.620) b	0.287 (0.787) c	0.463 (0.963) b	0.685 (1.185) b	0.583 (1.083) a	0.259 (0.866) b
2.	Ethofenprox	0.204 (0.704) c	0.083 (0.583) b	0.093 (0.593) b	0.083 (0.583) b	0.157 (0.657) b	0.343 (0.843) b	0.519 (1.019) b	0.713 (1.213) b	0.620 (1.120) a	0.287 (0.897) a
3.	Imidacloprid	0.287 (0.787) a	0.028 (0.528) d	0.037 (0.537) c	0.037 (0.537) b	0.093 (0.593) b	0.222 (0.722) d	0.361 (0.861) d	0.837 (1.037) c	0.556 (1.056)	0.241 (0.861) b
4.	Control	0.259 (0.759) b	0.324 (0.824) a	0.361 (0.861) a	0.417 (0.917) a	0.537 (1.037) a	0.870 (1.370) a	1.083 (1.583) a	0.880 (1.382) a	0.722 (1.222)	0.296 (0.892) a

DAT -Days After Treatment

In a column mean followed by a common letter are not significantly different by DMRT (P = 0.05)

Values in parenthesis are $\sqrt{X+0.5}$- transformed values

4.2.2.2. Epilachna beetle (H. septima)

Prior to the insecticide treatments the mean number of epilachna beetles ranged between 0.204 and 0.296 insects per leaf. Immediately after the spray a drastic reduction of the epilachna beetle population was recorded at one DAT in all the treatment *viz.*, acetamiprid (0.056 insects/leaf), ethofenprox (0.083 insects/leaf) and imidacloprid (0.028 insects/leaf). Thereafter, a gradual buildup of beetle population was recorded up to 35DAT in all the insecticide treatment *viz.*, ethofenprox (0.713 insects/leaf) and imidacloprid (0.837 insects/leaf), where as in control the increasing trend of the population was only up to 21DAT and thereafter it started declining towards the end of the crop (Table 10a).

4.2.3. Efficacy of newer molecules at pre flowering stage

The pre flowering stage spray was applied at 50 days after sowing. Leaf hopper and epilachna beetle incidence was recorded during that time. The data on the population of leaf hopper and epilachna beetle were recorded.

4.2.3.1. Leaf hopper (E. motti)

In the pre flowering stage, the leaf hopper population was higher compared to other stages of growth of the crop. Mean leaf hopper population was between 10.032 and 10.370 per leaf before the treatment of the insecticides. One DAT, the number of leaf hopper reduced significantly. The population was significantly more (1.158 insects/leaf) in ethofenprox treatment compared to acetamiprid (0.083 insects/leaf), imidacloprid (0.065 insects/ leaf) and standard check acephate (2.076 insects/leaf). But control recorded increased number of leaf hopper between 10.119 and 10.333 insects/leaf. Imidacloprid and acetamiprid did not differ significantly up to 14 DAT. The highest number of leaf hopper recorded for imidacloprid (0.963 insects/leaf), acetamiprid (5.016 insects/leaf) and control

Table 11a. Pre flowering stage spray of newer insecticides against bittergourd leaf hopper (*E.motti*)

(mean number of leaf hopper/leaf) **(Summer, 2002)**

S.N.	Treatments	Pre treatment count	1 DAT	3 DAT	5 DAT	7 DAT	14 DAT	21 DAT	28 DAT	35 DAT	42 DAT	49 DAT
1.	Acetamiprid	10.222 (3.274) [a]	0.083 (0.764) [bc]	0.083 (0.764)[d]	0.120 (.788) [d]	0.148 (0.805)[d]	0.324 (0.908)[d]	0.463 (0.981)[e]	0.574 (1.036)[d]	0.630 (1.063)[d]	0.944 (1.202)[d]	1.500 (1.414)[d]
2.	Ethofenprox	10.241 (3.272) [a]	1.158 (1.288) [a]	1.188 (1.299)[c]	1.173 (1.293)[c]	1.337 (1.355)[c]	1.750 (1.500)[c]	1.929 (1.558)[b]	2.091 (1.610) [c]	2.211 (1.647)[c]	2.887 (1.840)[c]	3.438 (1.984)[c]
3.	Imidacloprid	10.370 (3.293) [a]	0.065 (0.751) [b]	0.074 (0.758)[d]	0.083 (0.764)[d]	0.120 (0.788)[d]	0.241 (0.861)[d]	0.370 (0.933)[e]	0.463 (0.981) [e]	0.583 (1.041)[d]	0.722 (1.106)[e]	0.963 (1.210)[e]
4.	Acephate	10.032 (3.244) [a]	2.076 (1.605) [c]	2.095 (1.611)[b]	2.131 (1.622)[b]	2.293 (1.671)[b]	2.770 (1.807)[b]	3.051 (1.844) [d]	3.211 (1.926)[b]	3.477 (1.994)[b]	4.561 (2.250)[b]	5.016 (2.349)[b]
5.	Control	10.119 (3.257 [a]	10.333 3.2860) [a]	10.302 (3.284)[a]	10.630 (3.332)[a]	11.834 (3.439)[a]	12.074 (3.532)[a]	12.533 (3.610)[a]	13.863 (3.790)[a]	14.693 (3.898)[a]	15.090 (3.949)[a]	16.007 (4.036)[a]

DAT - Days After Treatment

In a column mean followed by a common letter are not significantly different by DMRT ($P = 0.05$)
Values in parenthesis are $\sqrt{X+0.5}$-transformed values

Table 11b. Pre flowering stage spray of newer insecticides against bittergourd epilachna beetle (*H.septima*)

(mean number of epilachna beetle/ leaf) **(Summer, 2002)**

S.N.	Treatments	Pre treatment count	1 DAT	3 DAT	5 DAT	7 DAT	14 DAT	21 DAT	28 DAT	35 DAT	42 DAT	49 DAT
1.	Acetamiprid	0.583 (1.041) bc	0.213 (0.844) b	0.194 (0.833) b	0.231 (0.855) bc	0.259 (0.871) b	0.287 (0.887) c	0.358 (.923) b	0.509 (1.005) b	0.435 (0.967) c	0.398 (0.948) c	0.315 (0.903) a
2.	Ethofenprox	0.620 (1.058) ab	0.250 (0.866) b	0.231 (0.855) b	0.250 (0.866) bc	0.278 (0.882) b	0.306 (0.897)	0.376 (0.933) b	0.528 (1.014) b	0.472 (0.986) bc	0.426 (0.962) bc	0.352 (0.920) a
3.	Imidacloprid	0.556 (1.027) c	0.176 (0.822) b	0.176 (0.822) c	0.194 (0.833) c	0.222 (0.850) b	0.269 (0.877)	0.315 (0.963) b	0.491 (0.995) b	0.472 (0.986) bc	0.407 (0.952) bc	0.287 (0.887)
4.	Acephate	0.630 (1.063) a	0.269 (0.877) b	0.296 (0.892) b	0.306 (0.898) b	0.315 (0.903) b	0.352 (0.923)	0.398 (0.948) b	0.556 (1.025) a	0.491 (0.995) b	0.444 (0.972) b	0.380 (0.938) a
5.	Control	0.620 (1.058) ab	0.778 (1.129) a	0.963 (1.208) a	1.019 (1.231) a	1.083 (1.258) a	0.880 (1.175)	0.824 (1.149) a	0.722 (1.104) a	0.648 (1.071) a	0.593 (1.045) a	0.528 (1.013)

DAT -Days After Treatment

In a column mean followed by a common letter are not significantly different by DMRT (P = 0.05)
Values in parenthesis are $\sqrt{X+0.5}$- transformed values

(16.007 insects/leaf) at 49 DAT. Hence the effect of newer molecules on bitter gourd leaf hopper during pre flowering stage resulted in the order of imidacloprid = acetamiprid > ethofenprox > acephate.

4.2.3.2. Epilachna beetle (H. septima)

The skeletonisation of the leaf was severe by the grubs and adult beetles at pre flowering stage. The pretreatment count of epilachna beetle (adult as well as grubs) ranged between 0.556 and 0.630 insects/leaf. One DAT, imidacloprid recorded the lowest population (0.176 insects/leaf) followed by acetamiprid (0.213 insects/leaf), ethofenprox (0.250 insects/leaf) and acephate (0.269insects/leaf). There after the population of the insect grew gradually and reached the maximum at 21 DAT in acetamiprid (0.509 insects /leaf), ethofenprox (0.528 insects/leaf) and imidacloprid (0.491 insects/leaf), where as it was observed in control in just 7DAT(1.083 insects/leaf).

4.2.4. Efficacy of newer molecules at the fruiting stage

Insecticides (acetamiprid, ethofenprox and imidacloprid) spray was given at this stage to reduce the population of insect and also to know the efficacy of treatment.

4.2.4.1. Leaf hopper

The pretreatment count of mean leaf hopper population ranged from 11.707 to 12.985 insects/leaf. Lowest number of insects were recorded in treatments *viz.*, acetamiprid (0.120 insects/leaf), ethofenprox (2.716 insects/leaf) and imidacloprid (0.074 insects/leaf) compared to control (12.985 insects/leaf). A moderate increase of leaf hopper population was observed in the control plots till the crop end (35 DAT) Initial population of leaf hopper in acetamiprid (0.120 insects/leaf), ethofenprox (2.716 insects/leaf) and imidacloprid (0.074 insects/leaf) as increased

Table 12a. Fruiting stage spray of newer insecticides against bitter gourd leaf hopper (*E.motti*)

(mean number of leaf hopper/leaf **(Summer, 2002)**

S.N	Treatments	Pre treatment count	1 DAT	3 DAT	5 DAT	7 DAT	14 DAT	21 DAT	28 DAT	35 DAT
1.	Acetamiprid	11.707 (3.494) ^{d}	0.120 (0.788) ^{c}	0.120 (0.788) ^{c}	0.038 (0.726) ^{c}	0.176 (0.822) ^{c}	0.287 (0.877) ^{c}	0.556 (1.027) ^{c}	0.778 (1.126) ^{c}	1.500 (1.414) ^{c}
2.	Ethofenprox	11.858 (3.515) ^{c}	2.716 (1.793) ^{b}	2.696 (1.788) ^{b}	2.758 (1.805) ^{b}	2.861 (1.833) ^{b}	3.140 (1.908) ^{b}	3.755 (2.062) ^{b}	4.314 (2.194) ^{b}	5.201 (2.387) ^{b}
3.	Imidacloprid	12.554 (3.613) ^{b}	0.074 (0.758) ^{d}	0.056 (0.745) ^{d}	0.083 (0.764) ^{c}	0.120 (0.788) ^{c}	0.241 (0.861) ^{c}	0.481 (0.988) ^{c}	0.630 (1.063) ^{c}	1.389 (1.374) ^{c}
4.	Control	12.985 (3.672) ^{a}	12.985 (3.672) ^{a}	13.208 (3.703) ^{a}	13.468 (3.737) ^{a}	13.863 (3.790) ^{a}	14.272 (3.863) ^{a}	14.902 (3.929) ^{a}	15.090 (3.949) ^{a}	15.703 (4.026) ^{a}

DAT -Days After Treatment

In a column mean followed by a common letter are not significantly different by DMRT (P = 0.05)
Values in parenthesis are $\sqrt{X+0.5}$- transformed values

Table 12b. Fruiting stage spray of newer insecticides against bittergourd epilachna beetle (*H.septima*)

(mean number of epilachna beetle/ leaf) **(Summer, 2002)**

S.N	Treatments	Pre treatment count	1 DAT	3 DAT	5 DAT	7 DAT	14 DAT	21 DAT	28 DAT	35 DAT
1.	Acetamiprid	0.926 (1.194) ^{a}	0.380 (0.936) ^{b}	0.352 (0.923) ^{b}	0.398 (0.948) ^{b}	0.426 (0.962) ^{bc}	0.509 (1.005) ^{b}	0.574 (1.036) ^{b}	0.556 (1.027) ^{ab}	0.509 (1.005) ^{a}
2.	Ethofenprox	0.861 (1.670) ^{a}	0.463 (0.980) ^{b}	0.463 (0.980) ^{b}	0.481 (0.991) ^{b}	0.491 (0.995) ^{b}	0.546 (1.023) ^{ab}	0.611 (1.054) ^{ab}	0.565 (1.032) ^{ab}	0.528 (1.014) ^{a}
3.	Imidacloprid	0.824 (1.149) ^{a}	0.306 (0.897) ^{b}	0.315 (0.903) ^{b}	0.333 (0.913) ^{b}	0.352 (0.923) ^{c}	0.472 (0.986) ^{b}	0.509 (1.005) ^{b}	0.454 (0.977) ^{b}	0.435 (0.967) ^{a}
4.	Control	0.843 (1.159) ^{a}	0.898 (1.182) ^{a}	0.861 (1.167) ^{a}	0.843 (1.156) ^{a}	0.824 (1.149) ^{a}	0.722 (1.103) ^{a}	0.741 (1.114) ^{a}	0.593 (1.045) ^{a}	0.500 (0.997) ^{a}

DAT -Days After Treatment

In a column mean followed by a common letter are not significantly different by DMRT (P = 0.05)

Values in parenthesis are $\sqrt{X+0.5}$- transformed values

to acetamiprid (1.500 insects/leaf), ethofenprox (5.201 insects/leaf) and imidacloprid (1.389 insects/leaf) at the end of the crop at 35 DAT. Although imidacloprid was far superior than any other treatment until 3 DAT, it was on par with acetamiprid treated plots in rest of the period.

4.2.4.2. Epilachna beetle (H. septima)

The population of the insect was more in the fruiting stage than the pre flowering stage. The mean number of insects ranged between 0.824 and 0.926 insects/leaf in the fruiting stage prior to the insecticide treatments. Epilachna beetle population reduced in acetamiprid (0.380 insects/leaf), ethofenprox (0.463 insects/leaf) and imidacloprid (0.306 insects/leaf) treatment. Five days after the treatments, the populations of the insects were on par in all the insecticide sprayed plots. There after, acetamiprid and imidacloprid resulted on par effects up to 28 DAT (Table 12b). At 35 DAT, all the treatments (acetamiprid, ethofenprox and imidacloprid) were on par with the control.

4.2.5. Effect of newer insecticide treatments on the bitter gourd yield (Summer, 2002)

Acetamiprid, ethofenprox and imidacloprid were sprayed at various stages to assess the efficacy on bitter gourd fruit fly and fruit borer pests. The infestation of fruit fly and fruit borer pests of bitter gourd was compared and total as well as marketable yields were worked out (Table 13).

4.2.5.1. Effect of seed treatment

The seed treatment effect of newer insecticides on the infestation of fruit fly and fruit borer pests was compared and expressed in terms of total and marketable yield of bitter gourd fruits (Table 13).

4.2.5.1a. Total yield

The total yield of bitter gourd fruit recorded was higher in imidacloprid seed treated plots (85.33 fruits/8m^2), followed by acetamiprid (79.33 fruits/8m^2) treatment but the yield in imidacloprid plots (85.33 fruits/8m^2) found statistically non significant with control (83.33 fruits/8m^2). However on weight basis, imidacloprid (6.08 kg/8m^2) showed significantly higher yield than the control (5.5kg/8m^2). Both acetamiprid treated and control plot yields were statistically non significant.

4.2.5.1b. Marketable yield

Imidacloprid seed treated plots recorded significantly higher marketable yield both in number (73.33 fruits/8m^2) and weight (5.16 kg/8m^2) basis. Once again acetamiprid treated plots recorded lower yield and it was statistically non significant (54.33 fruits/8m^2), but found significant on weight (476 kg/8m^2) basis with the control plots.

4.2.5.2. Effects of early vegetative stage treatment

Acetamiprid, ethofenprox and imidacloprid were sprayed at early vegetative stage and the efficacy of the insecticides was compared with the infestation of fruit fly and fruit borer pests. The total and marketable yields of bitter gourd fruits were presented (Table 13).

4.2.5.2 a. Total yield

Imidacloprid treated plots recorded significantly higher yield (88.33 fruits and 6.45 kg/ 8m^2). Though there was no significant difference in the total yield of acetamiprid and ethofenprox (76.33 and 78.00 fruits/8m^2) treated plots, on number basis, it was observed a significant variation on weight basis.

Table 13. Total and marketable yield of bitter gourd fruits (Summer, 2002)

S. N.	Treatment	Total yield		Marketable yield	
		Fruit number ($8m^2$)	Fruit weight ($kg/8m^2$)	Fruit number ($8m^2$)	Fruit weight ($kg/8m^2$)
	Imidacloprid				
1.	Seed treatment	85.33	6.08	73.33	5.16
2.	Early vegetative stage spray	88.33	6.45	76.33	5.63
3.	Pre flowering stage spray	101.66	7.81	95.00	7.35
4.	Fruiting stage spray	96.66	7.16	89.66	6.70
	Acetamiprid				
5.	Seed treatment	79.33	5.66	64.33	4.76
6.	Early vegetative stage spray	76.33	5.78	67.66	4.96
7.	Pre flowering stage spray	97.66	7.50	91.33	7.03
8.	Fruiting stage spray	92.33	6.75	86.00	6.29
	Ethofenprox				
9.	Early vegetative stage spray	78.00	6.36	65.66	4.85
10.	Pre flowering stage spray	82.33	6.33	77.00	5.93
11.	Fruiting stage spray	81.00	6.00	74.66	5.58
	Acephate				
12.	Pre flowering stage spray	79.66	6.25	74.00	5.87
13.	Control	83.33	5.500	67.33	4.47
	CD (P=0.05)	3.92	0.45	3.74	0.38

Imidacloprid and ethofenprox treatments have resulted on par yields where as, statistically non significant with the control plots (5.50 $kg/8m^2$) on weight basis.

4.2.5.2b. Marketable yield

Acetamiprid and ethofenprox treatments at the early vegetative stage did not differ significantly in both number (65.66 and 67.33 $fruits/8m^2$) and weight (4.96 and 4.85 $kg/8m^2$) basis, where as imidacloprid as an early vegetative stage treatment differed significantly both on number (76.33 $fruits/8m^2$) and weight (5.63 $kg/8m^2$) basis compared to other treatments including control (67.33 $fruits/8m^2$) and (4.47 $kg/8m^2$)
respectively.

4.2.5.1. Effect of pre flowering stage spray

Along with the newer molecules *viz.*, acetamiprid, ethofenprox and imidacloprid the recommended standard insecticide acephate was also sprayed in the pre flowering stage treatment. The effect of these insecticides treatments on the fruit fly and fruit borer pests were compared and the total and marketable yield of the bitter gourd fruit were worked out (Table 13).

4.2.5.3a. Total yield

The standard insecticide acephate treatment had the lowest yield on both number (79.66 $fruits/8m^2$) and weight basis (6.25 $kg/8m^2$) and statistically different from the control plots. Imidacloprid treatment plots resulted in the highest total yield (101.66 $fruits/8m^2$) followed by acetamiprid treatment (97.66 $fruits/8m^2$), where as on weight basis both acetamiprid (7.50 kg $/8m^2$) and imidacloprid (7.81 $kg/8m^2$) did not differ significantly. However, the yields in control plots significantly differed with all other treatment plots (83.33 $fruits/8m^2$) and (5.50 $kg/8m^2$) with respect to pre flowering stage treatment plots.

4.2.5.3b. Marketable yield

Imidacloprid treatment plots had resulted significantly higher yield (95.00 fruits/$8m^2$) followed by acetamiprid and ethofenprox (91.33 and 77.00 fruits/$8m^2$) respectively. However both acephate (74.00 fruits/$8m^2$) and ethofenprox (77.00 fruits/$8m^2$) treatments were on par. On weight basis the treatments showed significantly higher yields compared to control plots. Here imidacloprid (7.35 kg/ $8m^2$), acetamiprid (7.03 kg/$8m^2$) and acephate (5.87 kg /$8m^2$) treatments were on par (Table 13).

4.2.5.2. Effect of fruiting stage treatment

The infestation of fruit fly and fruit borer pests of bitter gourd was worked out and the total and the marketable yield of bitter gourd fruits were compared.

4.2.5.4a. Total yield

Imidacloprid (96.99 fruits/$8m^2$) treated plots recorded the maximum yield followed by acetamiprid treatments (92.33 fruits/$8m^2$) but ethofenprox (81.00 fruits/$8m^2$) showed insignificant results with the control (83.33 fruits/$8m^2$) plots.

On weight basis all the insecticide treatments *viz.*, imidacloprid (7.16 kg /$8m^2$), acetamiprid (6.75 kg /$8m^2$) and ethofenprox (6.00 kg /$8m^2$) yielded significantly higher yields compared to the control of plots (67.33 kg/$8m^2$) in respect to the fruiting stage spray treatments.

4.2.5.4b. Marketable yield

Marketable yield of bitter gourd fruits were significantly higher in all the insecticide treatments *viz.*, imidacloprid (89.66 fruits/8m^2), acetamiprid (86.00 fruits/8m^2), and ethofenprox (74.66 fruits/8m^2) compared to the control plots (67.33 fruits/8m^2). Imidacloprid treated plots had resulted in the highest marketable yield on weight basis (6.70 kg/8m^2) also, whereas the ethofenprox treatment recorded significantly the lowest yield (5.58 kg/8m^2) among the insecticide treatment plots. However control plots differed significantly from all the treatments in both number (67.33 fruits/8m^2) and weight basis (4.47 kg/8m^2).

4.2.6. Effect of newer insecticide treatment on fruit fly and fruit borer infestation in bitter gourd fruit

The efficacy of newer insecticides was assessed through various treatments as above against fruit fly and fruit borer infestation. The per cent infestation of fruit fly and fruit borers are presented.

4.2.6.1. Effects of seed treatment on fruit fly and borer pests

Seed treatment effects of acetamiprid and ethofenprox were studied on fruit fly and fruit borer infestation.The per cent infestation of fruit fly and fruit borers was recorded on both number and weight basis. Similar to rabi season, summer also the higher per cent, infestation by fruit fly, was observed compared to fruit borer infestation over a period of time.

Table 14. Total fruit infestation at different treatments (Summer, 2001)

S.N.	Treatments	Mean percentage of infestation			
		Furit fly (*B. cucurbitae*)		Borers *H. armigera* and *D. indica*	
		Fruit number	Fruit weight	Fruit number	Fruit weight
	Imidacloprid				
1.	Seed treatment	9.73 (0.317)	10.43 (0.328)	4.16 (0.190)	4.74 (0.212)
2.	Early vegetative stage spray	13.67 (0.37)	10.67 (0.330)	2.67 (0.161)	1.85 (0.131)
3.	Pre flowering stage spray	4.92 (0.210)	4.48 (0.195)	1.63 (0.127)	1.34 (0.112)
4.	Fruiting stage spray	4.52 (0.192)	4.60 (0.194)	2.76 (0.150)	1.99 (0.135)
	Acetamiprid				
5.	Seed treatment	13.77 (0.359)	12.05 (0.341)	4.01 (0.165)	3.82 (0.161)
6.	Early vegetative spray	7.85 (0.278)	9.67 (0.297)	3.49 (0.186)	3.90 (0.183)
7.	Pre flowering Stage spray	5.40 (0.229)	4.96 (0.214)	1.00 (0.081)	1.08 (0.085)
8.	Fruiting stage spray	5.37 (0.190)	4.90 (0.178)	1.45 (0.095)	1.88 (0.112)
	Ethofenprox				
9.	Early vegetative stage spray	10.64 (0.322)	17.90 (0.427)	4.41 (0.173)	10.00 (0.225)
10.	Pre flowering stage spray	5.26 (0.226)	5.46 (0.234)	1.21 (0.890)	0.77 (0.071) (0.198)
11.	Fruiting stage spray	5.48 (0.210)	5.34 (0.219)	1.97 (0.011)	1.74 (0.108)
12	**Acephate** Pre flowering stage spray	5.82 (0.236)	3.55 (0.183)	1.25 (0.122)	0.70 (0.083)
13.	Control	12.79 (0.35)	10.66 (0.330)	6.36 (0.245)	7.92 (0.269)
	CD (P=0.05)	NS	NS	NS	NS

Values in the parenthesis are arc sine transformed values NS-Non significant

4.2.6.1a. Fruit fly

As high as 12.79 per cent damage was recorded in control plots, where as insecticide treatment plots *viz.*, imidacloprid and acetamiprid recorded lower per cent infestation (9.73 and 13.77% respectively) on number basis. Acetamiprid treated plots recorded the highest infestation of 12.05 per cent where as, control treatments recorded only 10.66 per cent compared to the imidacloprid treatment plots (10.43%) on weight basis. But all the treatments were not significantly differ from each other (Table 14).

4.2.6.1b. Fruit borers

In untreated control plots the maximum per cent infestation by the fruit borer on both number and weight basis of fruits (6.36 and 7.92%) respectively. In the insecticide treatment plots per cent damage of fruit borer infestation was low 4.74 and 3.82 per cent respectively for imidacloprid and acetamiprid.

This was true for fruit borer damage in number basis also. But the per cent infestation was insignificant statistically for all the treatments including control.

4.2.6.2.Effect of early vegetative stage spray on fruit fly and borer pests

The newer insecticides were sprayed at early vegetative stage, to find out the efficacy of insecticides on fruit fly and fruit borer pests. The per cent infestation of fruit fly and fruit borer are presented in (Table 14).

4.2.6.2a. Fruit fly

Compared to control (12.79%), all the insecticide treated plots recorded the lowest per cent infestation except in imidacloprid (13.67%) treated plots. Acetamiprid treated plots had resulted the lowest per cent of infestation of fruits both on number and weight basis (7.85 and 9.67% respectively) where as, higher per cent infestation was in ethofenprox treated plots both on number (10.64%) and weight basis (10.90%). However none of the treatments were significantly different from each other including the control plots.

4.2.6.2b. Fruit borer

In the early vegetative stage, fruit borer damage was the lowest in the imidacloprid treatments (2.67%) followed by acetamiprid (3.49%) and ethofenprox (4.41%). Considerable reduction in fruit borer infestation was observed in all the insecticide treatments but all of them were on par with the untreated control (6.36%).

The highest per cent infestation was recorded in control plots (7.92%) whereas, only 1.85 per cent infestation was recorded in the imidacloprid treated plots (1.85%) in respect to early vegetative stage treatment on weight basis. However all the treatments did not differ significantly among them including control plots.

4.2.6.3.Effect of pre flowering stage spray on fruit fly and borer pests

Acetamiprid, ethofenprox and imidacloprid were compared with standard acephate in the pre flowering stage treatments. The effects of these insecticides on fruit fly and fruit borer were recorded based on mean per cent of infestation both fruit number and weight basis (Table 14).

4.2.6.3a. Fruit fly

Control plots had the highest per cent of infestation (12.79%) compared to other insecticide treatments *viz.*, imidacloprid, (4.92%), acetamiprid (5.40 %) and acephate (5.82 %) and ethofenprox (5.26 %) on number basis.

The control plots recorded the highest 10.66 per cent of infestation on weight basis. However other treatments *viz.*, imidacloprid, acetamiprid, ethofenprox and acephate had lower per cent of infestation (4.48, 4.96, 5.46 and 3.55% respectively). But the variations on the per cent infestation were insignificant statistically.

4.2.6.3b. Fruit borer

Similar to fruit fly here also control plots recorded the highest per cent of infestation on both number and weight basis. Acetamiprid treated plots had the lowest per cent of infestation (1.00%) followed by acephate (1.25%), imidacloprid (1.63%) and ethofenprox (1.21%) on number basis. Where as acephate resulted the lowest infestation on weight basis (0.70%) compared to control (7.92%) and other insecticides treatments *viz.*, ethofenprox (0.77%), acetamiprid (1.08%) and imidacloprid (1.34%). Though variation exists among the treatments none of them were significantly differ from each other.

4.2.6.4.Effects of fruiting stage spray on fruit fly and borer pests

The fruiting stage spray was carried out with test insecticides to assess the infestation of fruit fly and fruit borer pests on later stages. The per cent infestation of fruit fly and fruit borer pests are presented in (Table 14).

4.2.6.4a. Fruit fly

In all the candidate insecticides treatments lower per cent of infestation was on both number and weight basis compared to the control treatments. Imidacloprid treatment recorded the lowest (4.52%) of infestation followed by acetamiprid (5.37%) and ethofenprox (5.48%). On weight basis, the lowest infestation was recorded in imidacloprid (4.60%) treated plots followed by acetamiprid (4.90%) and ethofenprox (5.34%) compared to control plots (10.66%). However all the treatment were not significantly different.

4.2.6.4b. Fruit borer

Similar to fruit fly, here also the newer insecticides brought down the fruit borer infestation compared to the control on fruit number and weight basis. The lowest, 1.45 per cent infestation was recorded in acetamiprid treated plots followed by ethofenprox and imidacloprid (1.97 and 2.76% respectively) on number basis. Whereas, the lowest per cent infestation was observed in ethofenprox treated plots (1.74%) followed by acetamiprid (1.88%) and imidacloprid (1.99%) treated plots on weight basis. But the variations on the percent infestation were insignificant statistically.

4.3. EFFECT OF NEWER MOLECULES ON NATURAL ENEMIES OF BITTER GOURD ECOSYSTEM (RABI, 2001)

The following natural enemies were recorded during period under study

i) Grubs and adults of predatory coccinellid beetle

ii) Brown lace wing

iii) Syrphid maggots and

iv) Spiders

The data on the average number of different groups of predators observed during pest surveillance are presented in Table 15.

4.3.1. Effects of newer molecules on Brown lace wing

The newer molecules like acetamiprid and imidacloprid were used as seed dressers to manage early stage bitter gourd sucking pests and there by protect the natural enemies from direct spray application. Imidacloprid seed treated plots

Table 15. Effect of newer insecticides on natural enemies (Rabi. 2001)

S.N.	Treatment	Brown lace wing	Coccinellid		Syrphid larvae	Spiders
			Grubs	Adult		
	Imidacloprid					
1.	Seed treatment	7.887	8.833	3.000	4.322	1.667
2.	Early vegetative stage spray	2.447	4.000	2.667	2.887	0.777
3.	Pre flowering stage spray	3.723	4.553	1.610	4.170	1.000
4.	Fruiting stage spray	5.943	5.387	2.500	4.223	1.387
	Acetamiprid					
5.	Seed treatment	5.830	8.113	2.223	3.167	1.387
6.	Early vegetative stage spray	1.723	2.833	1.220	1.167	0.667
7.	Pre flowering stage spray	3.333	3.613	1.500	1.387	0.887
8.	Fruiting stage spray	3.833	4.553	2.057	2.000	1.223
	Ethofenprox					
9.	Early vegetative stage spray	2.053	2.770	1.053	1.110	0.833
10.	Pre flowering stage spray	3.553	2.770	1.053	1.110	0.833
11.	Fruiting stage spray	4.053	7.667	2.610	1.890	1.167
	Acephate					
12.	Pre flowering Stage spray	2.720	5.333	1.723	1.667	1.000
13.	Control	11.387	15.947	10.390	9.280	4.277
	CD (P=0.05)	0.884	0.634	0.688	0.502	0.277

Values given in the table are mean of six observations from 45 leaves recorded significantly higher number of brown lace wing (7.887) as compared to acetamiprid (5.830) seed treatment plots. The control plots recorded the highest brown lace wing population (11.387) throughout the crop period. Compared to all the stages of treatments, lower number of natural enemies was recorded in the early vegetative stage sprayed plots. Acetamiprid recorded significantly the lowest mean population (1.723) of brown lace wing followed by imidacloprid (2.477) and ethofenprox (2.053) treated plots. In the fruiting stage treated plots, imidacloprid had maximum number of brown lace wing (5.943) followed by ethofenprox (4.053) and acetamiprid (3.833) and were statistically differed among them as well as control plots.

4.3.2. Effect of newer molecules on Coccinellids

Coccinellids (both grubs and adults) were observed in large number in the seed treated plots especially imidacloprid treated plots (8.833 and 3.000 grubs and adults respectively) followed by acetamiprid (8.113 and 2.223 grubs and adults respectively). Acetamiprid and ethofenprox treated plots were not significantly different from each other in respect of coccinellids, both grubs (2.833 and 2.770 respectively) and adults (1.220 and 1.053 respectively) in the early vegetative stage treatment plots, where as the population of the predatory coccinellids were significantly low in all the insecticide treated plots compared to the control (15.947) in the early vegetative spray treatment.

In pre flowering stage, the number of predatory coccinellids ranged between 3.557 and 3.613 for grubs. For adult population, variation was statistically insignificant for imidacloprid and acetamiprid. Whereas, acephate treatment recorded significantly higher grubs (7.667) and adults (2.610).

In fruiting stage spray, imidacloprid, acetamiprid and ethofenprox were not statistically different for adults, but grubs differ significantly for all the newer insecticides compared to control plots (15.947).

4.3.3. Effect of newer molecules on Syrphid

Large number of syrphid larvae was found in the seed treated plots of imidacloprid (4.332) followed by acetamiprid (3.167). In the early vegetative stage treated plots, the lowest number of natural enemies was recorded compared to other stage treatment plots. Both acetamiprid and ethofenprox treatment were not significantly differ on population of syrphid maggot whereas, imidacloprid recorded higher number of syrphid larvae (2.887) in the early vegetative stage treatments.

In the pre flowering stage, acetamiprid (1.387) ethofenprox (1.667) and acephate (1.890) recorded non-significant number of syrphid larvae. At the same time, in imidacloprid treatment significantly (4.171) higher insects were recorded compared to other insecticides treatments. This same trend was resulted in fruiting stage treatment plots also. However control plots recorded the highest number of syrphid larvae and differ significantly from all the insecticide treatment plots.

4.3.4. Effects of newer molecules on spiders

In the same way of other stages, here also higher number of spiders was recorded in seed treated plots for both imidacloprid (1.667) and acetamiprid (1.387).

In the early vegetative stage treatment recorded the lowest number of spider. However it was not significantly different among the insecticide *viz.*, imidacloprid (0.777), acetamiprid (0.667) and ethofenprox (0.833).

In the pre flowering stage treatments imidacloprid (1.000) and ethofenprox (1.00) had same number of spiders followed by acetamiprid (0.887), but acephate recorded higher number of spiders (1.167). None of the treatments differ significantly among themselves in the pre flowering stage. Same trend was observed in fruiting stage treatment plots also. However, control plots recorded the highest number of spiders (4.277) and differ significantly among all the insecticide treatment plots.

4.4. EFFECTS OF NEWER INSECTICIDES ON SOIL MICRO FLORA

Seed treatment of chemicals becomes inevitable due to high intensity of labour requirement and for initial stage control of crop pests. But their use alters the delicate balance of various types of soil microorganisms, which are required for efficient use of nitrogen, carbon and other minerals. The result revealed that the non-significant effect of newer insecticides against seed treatment. (Table 16)

In the pretreatment count bacterial population ranged between 11.667 and 12.333. After one week, the reduction of bacterial count noticed in all the treatments plots including control plots. Then 14 DAT, there was slight increase in the bacterial count in control where as imidacloprid treated plots found slight reduction of bacterial count (12.333 to 10.667). At 21 DAT, there were an increasing number of bacteria observed in all the treatment plots including control plots whereas, at 28 DAT, slight reduction of population found in control plots and other treatment plots except imidacloprid, which showed increasing number of bacterial population (11.667 to 12.000).

There were more or less similar number of fungal count was observed in the pre treatment plots. One week after treatment, there was slight altering in the fungal count, but those will not show any significant effect. At 14 DAT, there was increasing number of fungal count noticed in all the treatment plots including control plots. Then one week after, a slight reduction in the fungal count was observed in the ethofenprox (10.667 to 10.000) treated plots. All the treatments showed non-significant result for the fungal population count.

Plate 1: Bitter gourd leaf hopper, *Empoasca (E.) motti*, nymph

Plate 2: Hopper burn on bitter gourd leaf caused by leaf hopper *Empoasca (E.) motti*

Plate 3: Bitter gourd aphid, *Aphis gossypii*

Plate 4: Epilachna beetle, *Henosepilachna septima* damage (skeletonisation) of leaves

Plate 5: Adult melon fruitfly *Bactrocera cucurbitae* ovipositing on bitter gourd fruit

Plate 6: Bitter gourd fruit borer, *Helicoverpa armigera*

Plate 7a: Effect on soil actinomycetes

Plate 7b: Effect on soil bacteria

Plate 7c: Effect on soil fungi

Plate 7: Effect of seed treatment (with newer molecules) on soil microflora

1. Acetamiprid **2. Ethofenprox** **3. Imidacloprid** **4. Control**
A - Actinomycetes **B - Bacteria** **F - Fungi**

Table 16. Effect of seed treatment of newer molecules on soil micro flora
(Bacteria and actinomycetes in millions and fungi in thousands/g of soil)

S.N	Treatments	Pre treatment Count	7 DAT	14 DAT	21 DAT	28 DAT
.	**Bacteria**					
1.	Acetamiprid	12.000	11.333	12.667	13.000	11.667
2.	Ethofenprox	11.667	9.667	12.000	13.000	12.333
3.	Imidacloprid	12.667	13.333	10.667	11.667	12.000
4.	Control	12.333	10.667	12.333	13.667	12.667
		NS	NS	NS	NS	NS
	Fungi					
1.	Acetamiprid	10.667	9.000	11.000	11.667	11.333
2.	Ethofenprox	9.333	9.667	10.667	10.000	9.667
3.	Imidacloprid	8.000	8.333	9.333	11.333	12.333
4.	Control	8.667	8.667	11.333	12.000	10.333
		NS	NS	NS	NS	NS
	Actinomycetes					
1.	Acetamiprid	4.000	4.333	3.667	4.333	3.333
2.	Ethofenprox	3.667	2.667	3.000	3.667	3.667
3.	Imidacloprid	2.667	3.667	4.000	4.667	4.333
4.	Control	3.000	4.000	4.333	5.000	4.667
		NS	NS	NS	NS	NS

Actinomycetes showed more or less similar number of count in the pretreatment plots. One week after there was slight increase in the actinomycetes population in the control plots (4.000) and acetamiprid treated plots (4.333), where as imidacloprid (3.667) and ethofenprox treated plots (2.667) remained in it for the second and third week. The increasing trend was observed in both control and treated plots where as, at fourth week the slight reduction of actinomycetes population noticed in control as well as treated plots. All the insecticides treatment showed on par results from the first week on wards.

4.5. ACUTE TOXICITY OF NEWER MOLECULES ON EPILACHNA BEETLE

A bioassay study was conducted in the laboratory to know the relative toxicity value of newer molecules (acetamiprid, ethofenprox and imidacloprid) against epilachna beetle and represented as LC_{50} values. The data on acute toxicity of newer molecules are presented in (Table 17).

4.5.1. Acetamiprid

The acute toxicity of acetamiprid to the grub of epilachna beetle was assessed by standard leaf dip method. The LC_{50} value was 38.252 ppm with upper and lower fiducial limits 40.218 and 36.285 respectively (Table 17). The regression equation obtained was Y=6.3105 + 7.1465x. The result indicated that fifty per cent mortality of insects could be obtained at a concentration of 38.252 ppm.

4.5.2. Ethofenprox

The acute toxicity LC_{50} of ethofenprox on epilachna grubs was 41.519 ppm with upper and lower fiducial limits 43.487 and 39.551 respectively (Table 17). The regression equation obtained was Y=3.0873 + 4.9975 x.

4.5.3. Imidacloprid

Table 17. Acute toxicity of newer insecticides for the grubs of epilachna beetle

Pesticide	LC_{50} (ppm)	95 % fiducial limits		a	b	Y = a + bx	χ^2 at p=0.05
		Upper limit	Lower limit				
Imidacloprid	39.023	40.026	38.025	6.452	7.197	6.452+7.197x	1.984
Ethofenprox	41.519	43.487	39.551	3.087	4.997	3.087+ 4.99x	1.632
Acetamiprid	38.252	36.285	40.218	6.310	7.146	6.310 + 7.146x	1.643

The acute toxicity of imidacloprid was found to be in between ethofenprox and acetamiprid i.e. 39.023 ppm. It exhibits upper and lower fiducial limits 40.026 and 38.020 respectively. The regression equation obtained was Y=6.4528 + 71970x

4.6. RESIDUES OF IMIDACLOPRID IN BITTER GOURD FRUITS

The residues of imidacloprid in bitter gourd fruits were determined by high pressure liquid chromatographic method.

4.6.1. Resolution of imidacloprid

Fig 1. represents a typical HPLC (High pressure liquid chromatography) chromatogram of imidacloprid. Under the specified condition of analysis, the retention time of the compound was 4.2 minutes. The peak had symmetric shape. The compound was well resolved from other components

The high pressure liquid chromatogram for 1 ppm, 3 ppm and 5 ppm standard solution of imidacloprid are given in Fig 1. The standard curve of imidacloprid across the 0-5 ppm range is presented in Fig 2. The minimum detectable quantity was 0.5 µg of imidacloprid equivalent to 0.025 ppm in fruits. No peak was detected at the time of retention of imidacloprid, in any of the control fruit samples analysed. The data on the recovery of imidacloprid for bitter gourd fruits at 1 and 3 ppm levels of fortification are given in table 18.The mean recovery of imidacloprid from the bitter gourd fruits was 82.65 per cent.

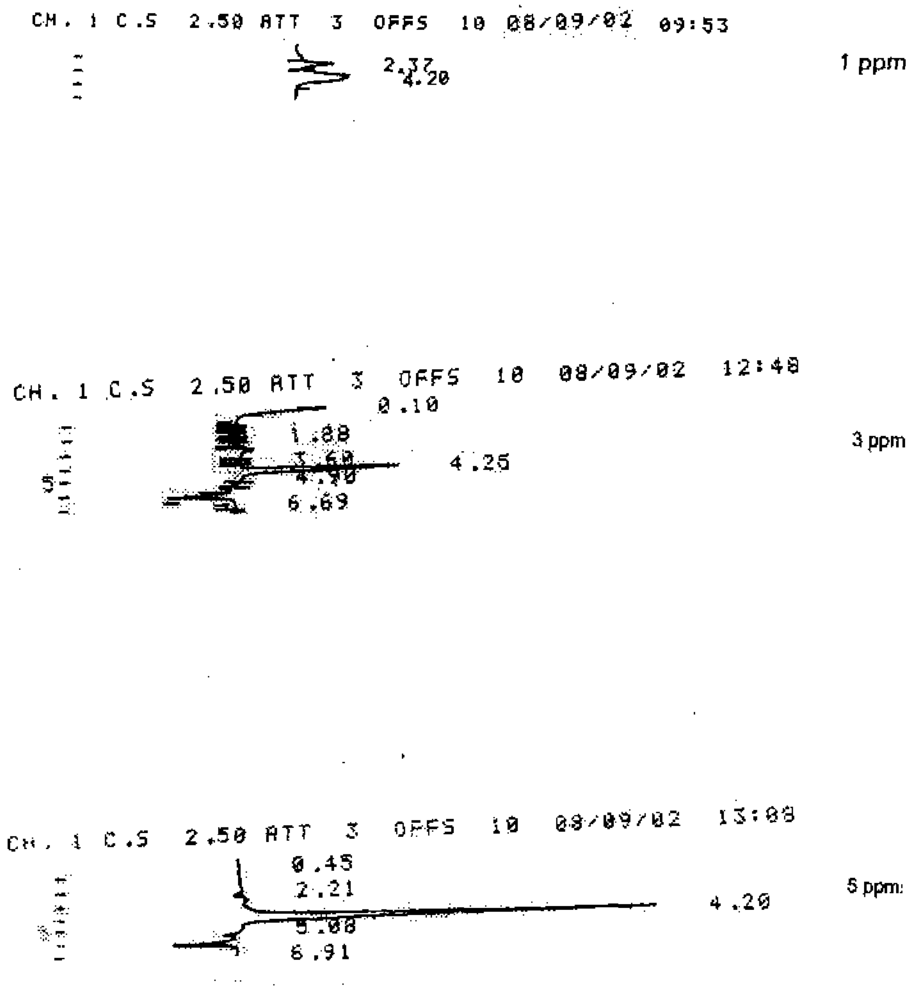

Fig. 1. High Performance Liquid Chromatograms of Standard Solution of imidacloprid

Table 18. Recovery of imidacloprid

S.N	Quantity added ppm	Quantity Recovered ppm	Recovery percent
1.	1.00	0.835	83.49
2.	1.00	0.825	82.47
3.	1.00	0.815	81.45
4.	3.00	2.745	91.52
5.	3.00	2.225	74.15
6.	3.00	2.486	82.83
Mean			82.65

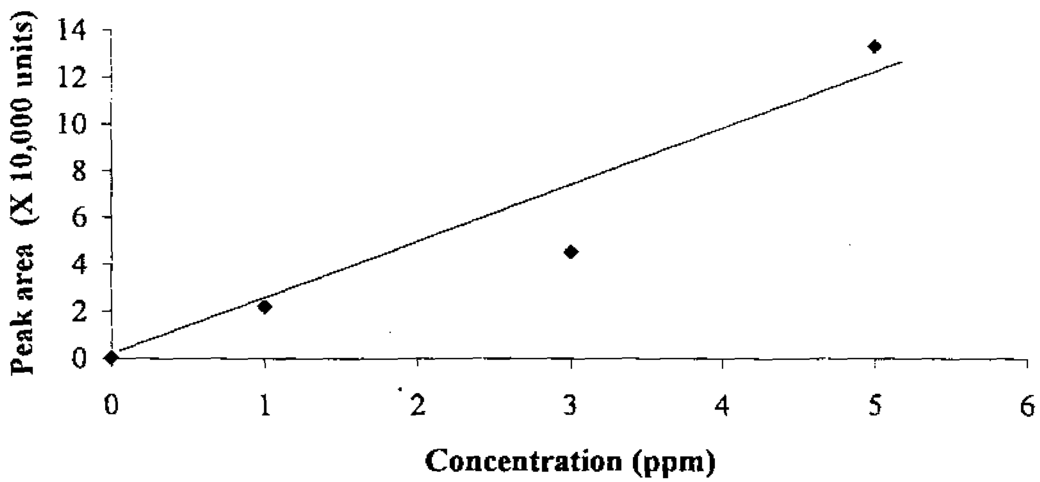

Fig. 2. Standard curve of imidacloprid

4.6.2. Residues of imidacloprid in bitter gourd fruit

Bitter gourd fruits collected from the imidacloprid treated plots in the field experiment conducted during summer, 2002 were pooled treatment wise and were subjected to residue analysis. The results showed that there was no detectable residue of imidacloprid in bitter gourd fruits collected for any treated plots. It is hence surmised that the samples contained residues only below the minimum detectable level of 0.025ppm.

Discussion

5. DISCUSSION

Bitter gourd (*M. charantia* L.) is being cultivated extensively throughout the year in Kerala and it is one of the most important cucurbitaceous vegetables. The major problem in the successful cultivation of bitter gourd is the incidence of insect pests. At present highly hazardous chemicals are being applied for the management of the same. These insecticides are not only killing a wide range of insects, but also cause considerable environmental toxicity. Hence an attempt has been made to use newer insecticides like acetamiprid, ethofenprox and imidacloprid to produce residue free product. A popular variety 'Preethi' released by Kerala Agricultural University was used for the study. The detailed discussion on the result is presented under the following headings.

a) Bio efficacy of newer insecticides against key pests of bitter gourd

b) Safety to natural enemies of bitter gourd insect pests

c) Effect on soil micro flora

d) Estimation of residues in the fruits

5.1. BIO EFFICACY OF NEWER INSECTICIDES AGAINST KEY PESTS OF BITTER GOURD

The efficacy of newer insecticides against key pests *viz.,* leaf hopper, aphid, epilachna beetle, fruit fly and fruit borers were studied for two consecutive seasons (Rabi, 2001 and Summer, 2002). The effects of these insecticides on different stage of the crop and their influence on yield parameters are discussed here.

5.1.1. Seed treatment

Acetamiprid and imidacloprid were applied along with the seed as seed dressing and sprayed during the pest incidence was recorded as per the schedule .

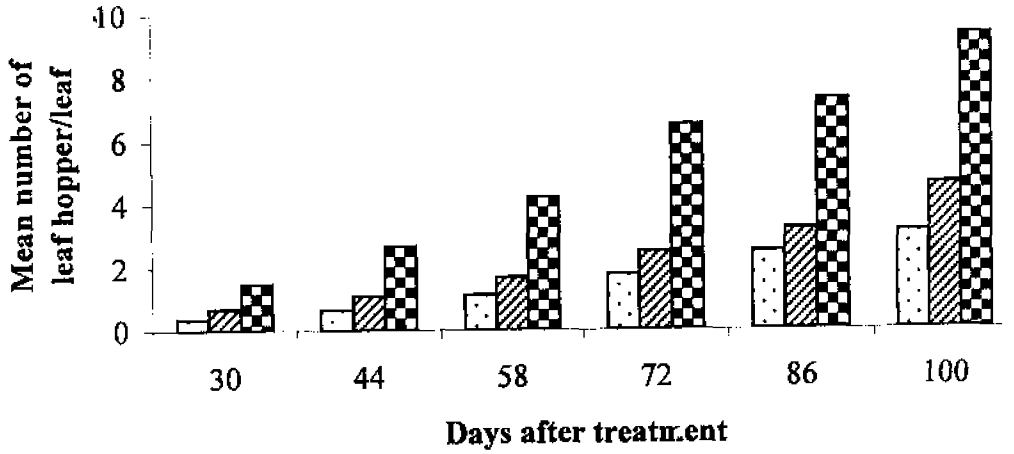

Fig. 3. Seed treatment effect of newer molecules on leaf hopper (Rabi, 2001)

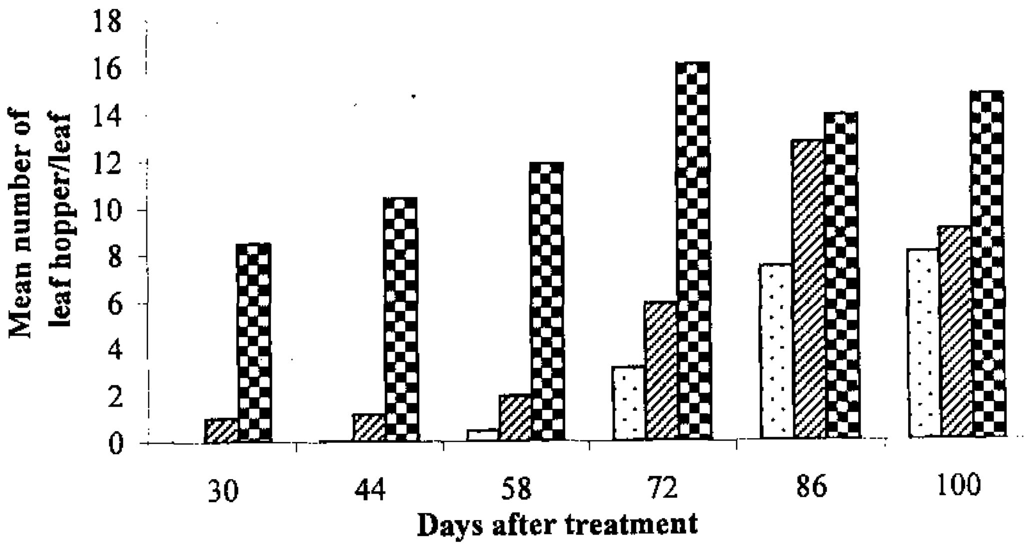

Fig. 4. Seed treatment effect of newer molecules on leaf hopper (Summer, 2002)

Upto 30 DAT the occurrence of the pests for both the seasons was insignificant. After that, only a marginal increase of insects pests was observed in all the treatments. Aphid incidence was not observed in the summer crop. In general pest incidence was higher in rabi season compared to the summer crop.

5.1.1.1. Leaf hopper

In the untreated control, leaf hopper (Plate 1) was more in both the seasons than the treatments. Summer crop had higher number of leaf hoppers in the initial stage itself but in the rabi crop comparatively lower number of leaf hopper was observed in the early stages (Fig. 4).

Acetamiprid treated plots showed significantly lower number of leaf hoppers compared to imidacloprid and control in summer season (Fig 3). The efficacy of acetamiprid against bitter gourd leaf hopper was in consonance with the finding of Kumar *et al.* (1999) in the cotton crop. They recommended acetamiprid (10g a. i. ha^{-1}) as good molecules to control the early stages pests. Similar result was reported by Kumar *et al.* (1999), that acetamiprid (10 g a.i ha^{-1}) provided consistently good control of cotton leaf hopper and aphids for an extended period of time. Whereas in rabi crop, acetamiprid gave on par results with imidacloprid throughout the crop period. Imidacloprid also gave significant effect as a seed dresser against on bhendi (Mote *et al.*, 1994) and cotton leaf hoppers (Gupta *et al.*, 1998).

These insecticides gave good control of leaf hopper in the early stages and constantly reduce the rebuild of leaf hopper population throughout the crop period, because of the mobility of the insecticides inside the plant system and translocation into the newly developed host tissues (Nauen, 1995; Devine *et al.*, 1996)

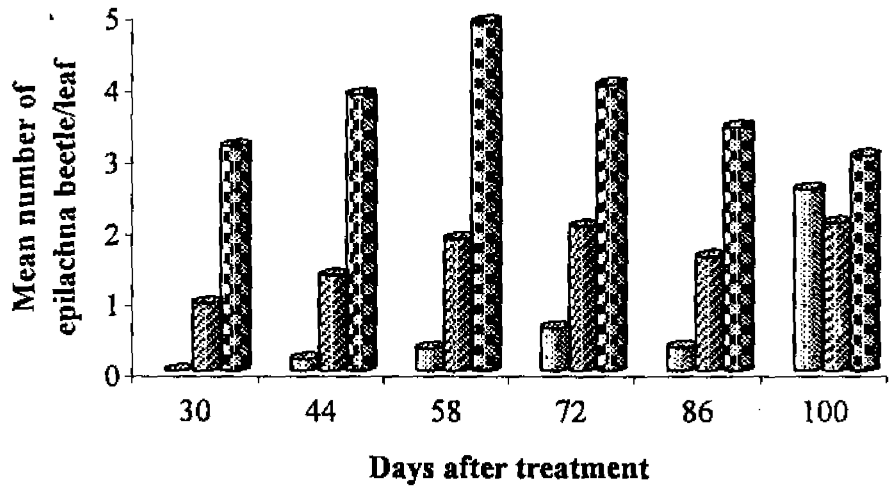

Fig. 5. Seed treatment effect of newer molecules on epilachna beetle (Rabi, 2001)

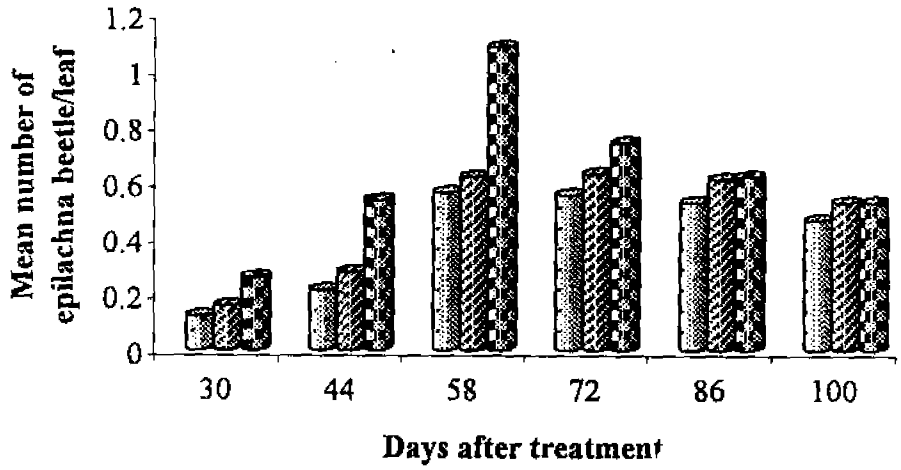

Fig. 6. Seed treatment effect of newer molecules on epilachna beetle (Summer, 2002)

5.1.1.2. Epilachna beetle

The infestation of the epilachna beetle was noticed four week after sowing. Compared to the summer season, rabi crop suffered more from the epilachna beetle (Fig 5). Acetamiprid treated plots showed less number of insects followed by imidacloprid throughout the crop period in rabi. Whereas in summer (Fig 6), significant difference was observed in between acetamiprid and imidacloprid treatments up to 37 DAT only. After 70 DAT, non-significant results were observed in all the treatments including control. It revealed that the effect of insecticide significantly reduce the population of the beetle up to 70 DAT, even though there was an increasing trend of the epilachna beetle population was observed in all the treatments. The effect of soil application of the newer insecticides was like that of the application of carbofuran granules (1.5kg a.i. ha^{-1}) at all the three stages of sowing, vining and flowering, which protected the bitter gourd crop up to 80 days of sowing (Thomas and Jacob, 1989).

5.1.1.3. Aphid

Compared to the control (18.472 insects/plant) treated plots showed lower number of aphid in the seed treated plots. At 30 DAT, acetamiprid showed 17.5 times lesser number of aphids compared to the control plots followed by imidacloprid (5.14 times) in the seed treated plots (Fig 7). Even though increasing number of aphids observed in all the treatment, subsequent reduction of aphid population (Plate 3) was noticed in between 55 and 65 days after sowing. It may be due to the persistence of newer molecules as that of the case reported by Nauen, (1995) that the aphid (*Myzus persicae*) migrate from the leaves treated with imidacloprid to untreated leaves or it may be due to the formation of secondary olefine metabolites (imidazoline derivative) of imidacloprid which cause more toxic than the present molecule (Nauen *et al.*, 1999).

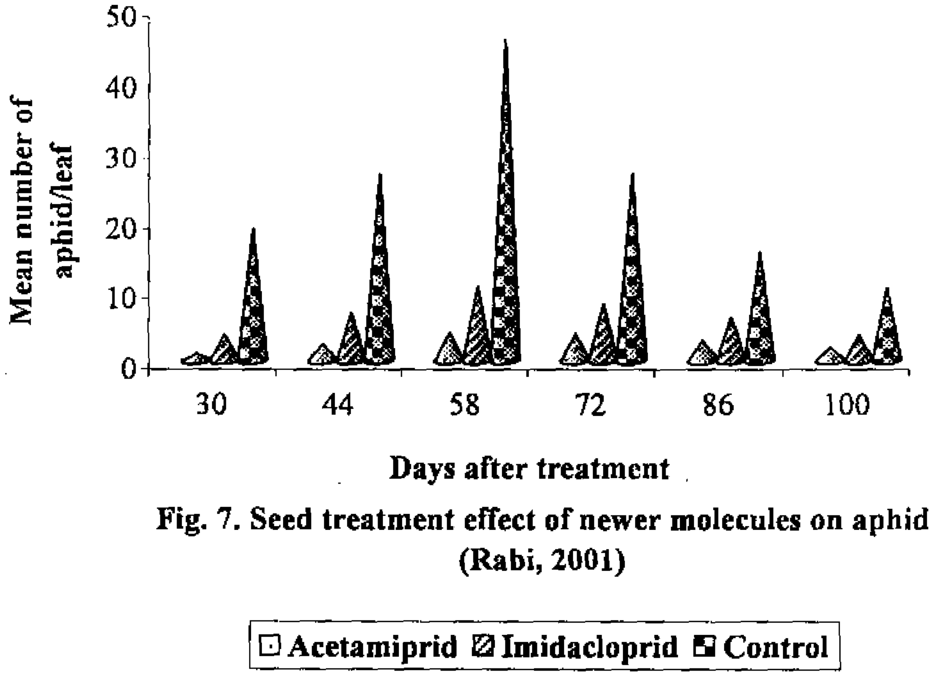

Fig. 7. Seed treatment effect of newer molecules on aphid (Rabi, 2001)

Acetamiprid treated plots have significantly lower number of aphids throughout the crop period compared to imidacloprid and control plots. Kumar *et al.*, (1999) reported that the acetamiprid (10 a.i. ha^{-1}) provided consistent control of sucking pests for an extended period of time. Turska and Wrobel. (2000) also reported about the use of acetamiprid (0.15 kg ha^{-1}) against potato aphid to limit the potato leaf roll leuto virus (PLRU).

5.1.2. Early vegetative stage treatment

In the early vegetative stage of the crop, higher number of insect pests was observed in rabi season than the summer. Leaf hopper population showed an increasing trend throughout the crop period, whereas the epilachna beetle and aphid population showed the reverse trend.

5.1.2.1. Leaf hopper

In rabi (Fig. 8), control plots had lesser number of leaf hopper (1.796 insects/leaf) compared to summer .One DAT, imidacloprid treated plots showed (96.7%) reduction of leaf hopper, followed by acetamiprid (92.2%) and ethofenprox (79.5%) compared to the control plot. Thereafter, an increasing trend of population of the leaf hopper was noticed in all the treatments. At 63 DAT, imidacloprid showed 2.06 times lower number of leaf hopper (4.500 insects/leaf) followed by acetamiprid (1.93 times lower) and ethofenprox (1.65 time lower) compared to control (9.296 insects/leaf). It can be inferred from both the season that imidacloprid and acetamiprid had more or less the same effect on leaf hopper population followed by ethofenprox. In the pre treatment count (PTC) all the treatment plots had more or less uniform number of leaf hopper, but one DAT acetamiprid and imidacloprid treated plots recorded nearly 100 per cent reduction of leaf hopper population followed by ethofenprox (73%). Then onwards a steady increase of leaf hopper population was

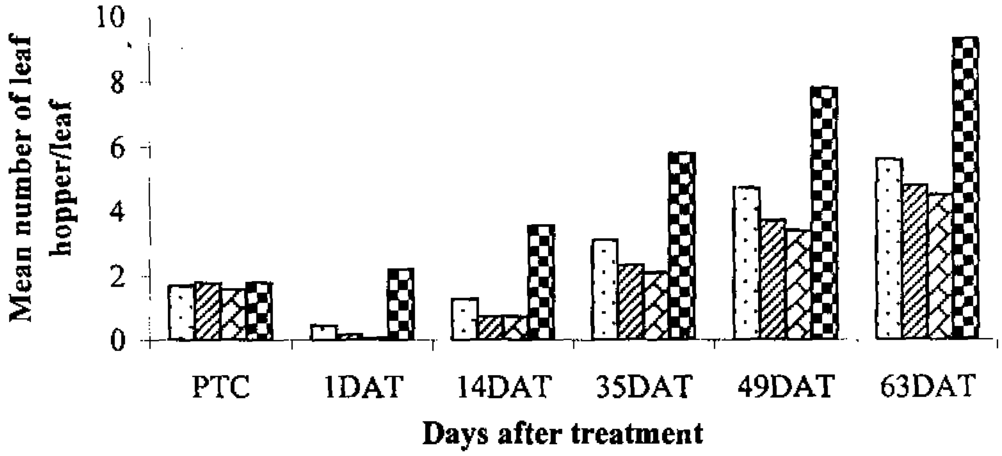

Fig. 8. Effect of newer molecules against leaf hopper at early vegetative stage (Rabi, 2001)

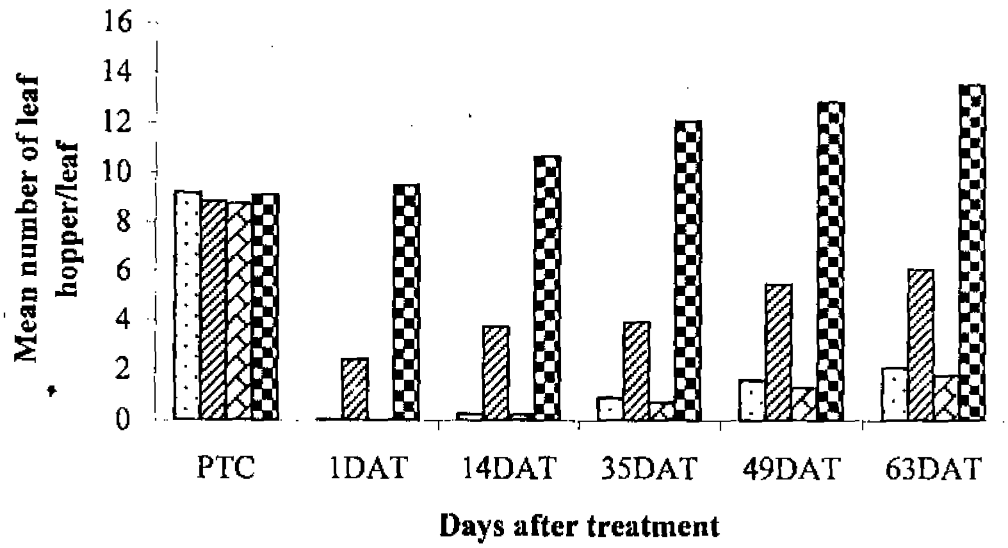

Fig. 9. Effect of newer molecules against leaf hopper at early vegetative stage (Summer, 2002)

noticed in all the treatment including control plots. The maximum number of leaf hopper was noticed 63 DAT in control (13.485 insects/leaf) but it was 7.5 times higher than imidacloprid (1.795 insects/leaf), 6.4 times higher than acetamiprid (2.102 insects/leaf) followed by 2.2 times higher than ethofenprox (6.073 insects/leaf) treated plots compared to control plots. Acetamiprid and imidacloprid treated plots gave consistently on par results throughout the crop period followed by ethofenprox in summer season. It might be due to the same insecticidal group (neonicotinoids), which acts on nicotinyl acetylcholine receptor (Ishaaya and Degheele., 1998). The reduced number of population in the treated plots, may be due to the newer group of insecticide to manage the resistant population, which might have developed by the continuous use of conventional insecticides like monocrotophos (Chalam *et al.*, 1999). Elbert *et al.*, (1996) reported that the resistant field strains of *Nephotettix cincticeps, Laodelphax striatellus, Sogetella furcifera* and *Nilaparvata lugens* were fully susceptible when imidacloprid was orally ingested.

5.1.2.2. Epilachna beetle

Epilachna beetle population (Plate 4) was lower in summer than in rabi. There was 12.5 times higher number of beetles in rabi (3.216 insects/leaf) compared to the summer (0.259 insects/leaf) in control plots. At one DAT, as high as 99 per cent reduction of beetle population observed in both imidacloprid and acetamiprid treatment, whereas, in ethofenprox, it was only 79 per cent reduction in beetle population. There after an increase number of beetles were observed in all the insecticide treatment plots and the highest number of beetles were recorded at 35 DAT (Fig 10). Subsequently there was a reduction of population till the crop matured. The reduction of insects might be due to the insufficient number of leaves for feeding and also the harvest time period of the crop. Whereas in summer, imidacloprid treated plots showed 92.3 per cent reduction of epilachna beetle at one DAT, followed by acetamiprid (81.1%) and ethofenprox (59.4%). But after five day

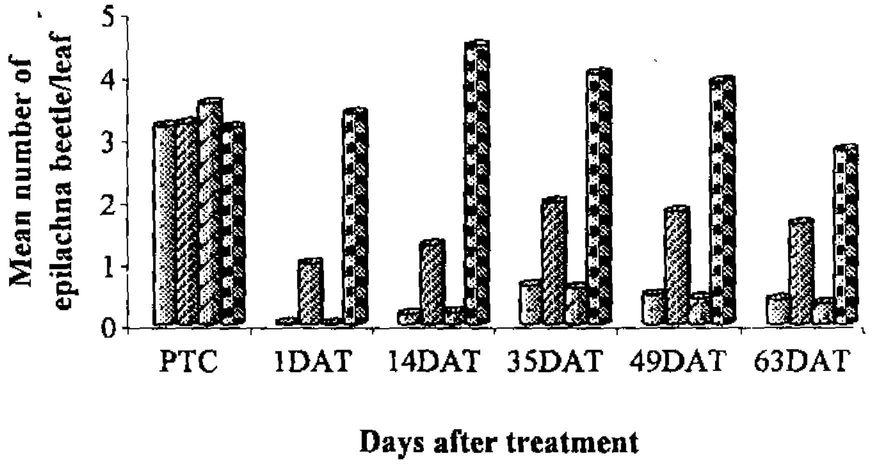

Fig. 10. Effect of newer molecules against epilachna beetle at early vegetative stage (Rabi, 2001)

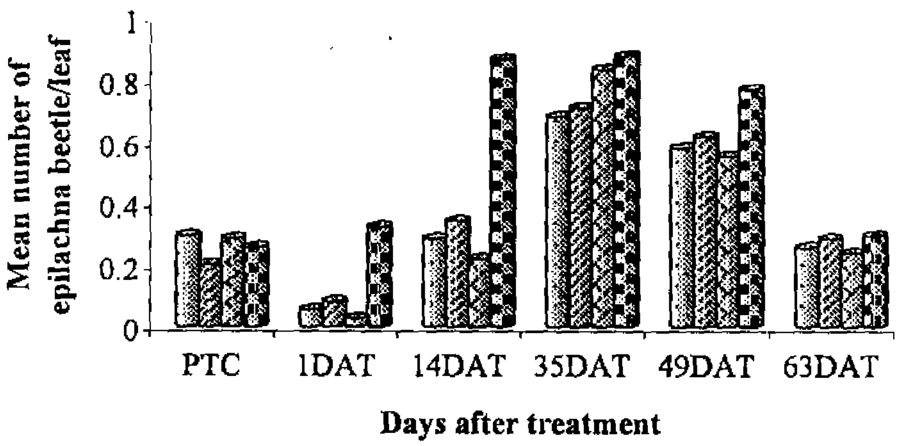

Fig. 11. Effect of newer molecules on epilachna beetle at early vegetative stage (Summer, 2002)

all the treatments showed on par results. The highest number of epilachna beetle reached between 21 to 49 DAT. After that it showed a decreasing trend, may be due to the dispersal of beetles to another place consequent to the scarcity of leaf for feeding. At the end of the crop (63 DAT), control plots showed 0.296 insects per leaf, which was 22.5 per cent higher than acetamiprid treated plots followed by imidacloprid (18.6%) (Fig.11). The newer insecticides *viz.*, acetamiprid and imidacloprid performed well in reducing the sucking pests, at the same time it showed favorable results against chewing insects also. It may be due to anti feeding effects of the insecticides, which was proved in black maize beetles *Heteronychus arator*, when feeding on stems of maize plants (Drinkwater and Greonwald, 1994). The colorodo potato beetle *Leptinotarsa decemlineata* is one of the chewing pests, which can be effectively controlled by imidacloprid (Elbert *et al.*, 1996).

5.1.2.3. Aphid

In rabi, more number of aphids was noticed in all the plots. One day after the imidacloprid treatment there was (94.55 %) reduction in aphid population followed by acetamiprid (92.69%) and ethofenprox (76.45%) treatments, whereas in control plots a continuous increase in the number of aphid was recorded (Fig. 12) Maximum number of aphids were noticed in between 21 and 35 DAT in all the plots including control. At 21 DAT control plots recorded the highest number of aphids (45.306 insects/leaf). It was 4.36 time higher than imidacloprid (10.370 insects/leaf) following 4.07 times of acetamiprid (11.111 insects/leaf) and 2.64 times of ethofenprox (17.108 insects/leaf). The reduction of population after 21 DAT, may be due to the substantial concentration of insecticides, which have strong effects on feeding behavior of aphids, resulting in suppression of honeydew excretion, wandering and subsequently death due to starvation (Nauen, 1995; Devine *et al.*, 1996). In imidacloprid treated plots, the maximum aphid population was observed at 35 DAT, long after other treatments. The persistency of the chemical on the crop

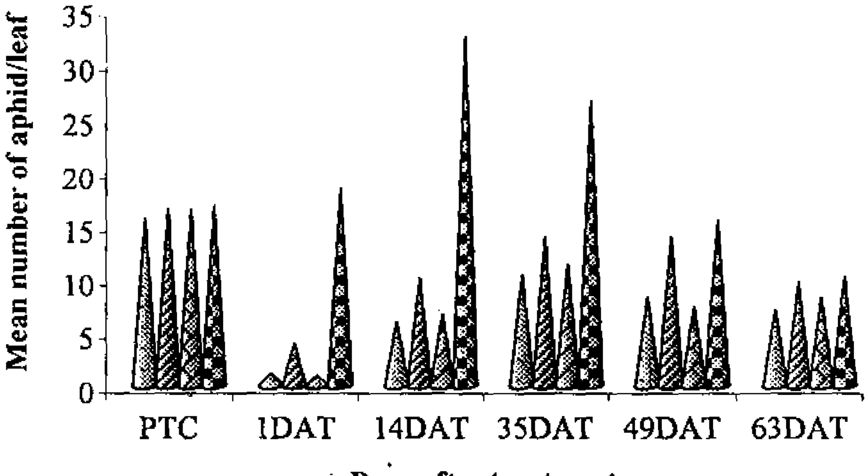

Fig. 12. Effect of newer molecules against aphid at early vegetative stage (Rabi, 2001)

could be the reason for the delay in the population rebuilt. There was insignificant population increase there after in all the plots, which may be due to the maturity of the crop.

In general, neonicotinoid compounds fairly reduced the aphids population due to its mode of action and the excellent translaminar transport of insecticide from the treated upper side of the leaf to the lower surface of leaf. It established by Elbert *et al.* (1991) in cabbage leaves.

5.1.3. Pre flowering stage treatment

In this stage more number of insect pest were observed in rabi season than in summer. There was no incidence of aphid pests in this stage also in summer crop.

5.1.3.1. Leaf hopper

All the treatments showed more or less equal number of leaf hopper before the treatment. One day after the treatment acetamiprid and imidacloprid treated plots recorded 99 per cent reduction in the leaf hopper population, followed by ethofenprox (88.7%) and acephate (79.31%). However the control plots recorded progressive increase in the leaf hopper population throughout the crop period (Fig. 13). May be due to the quick knock down effect of neonicotinoid compounds immediately after the treatment imidacloprid and acetamiprid showed 125 times lesser number of leaf hopper population compared to the untreated control plots. Acetamiprid and imidacloprid treated plots showed on par results up to 14 DAT.

Ethofenprox and the standard insecticides acephate (8.9 and 4.9 times lower respectively) showed lower population compared to the untreated control. After that at 49 DAT the maximum number of leaf hoppers was observed. The more number of

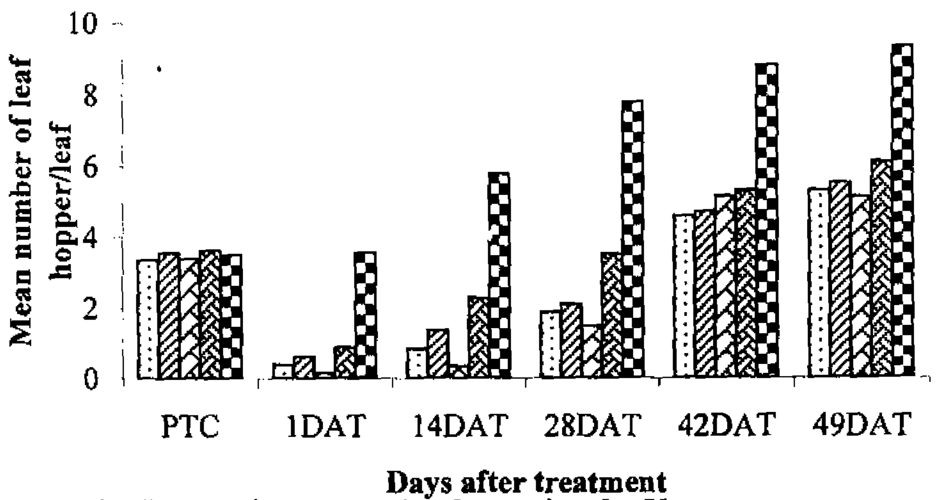

Fig. 13. Effect of newer molecules against leaf hopper at pre flowering stage (Rabi, 2001)

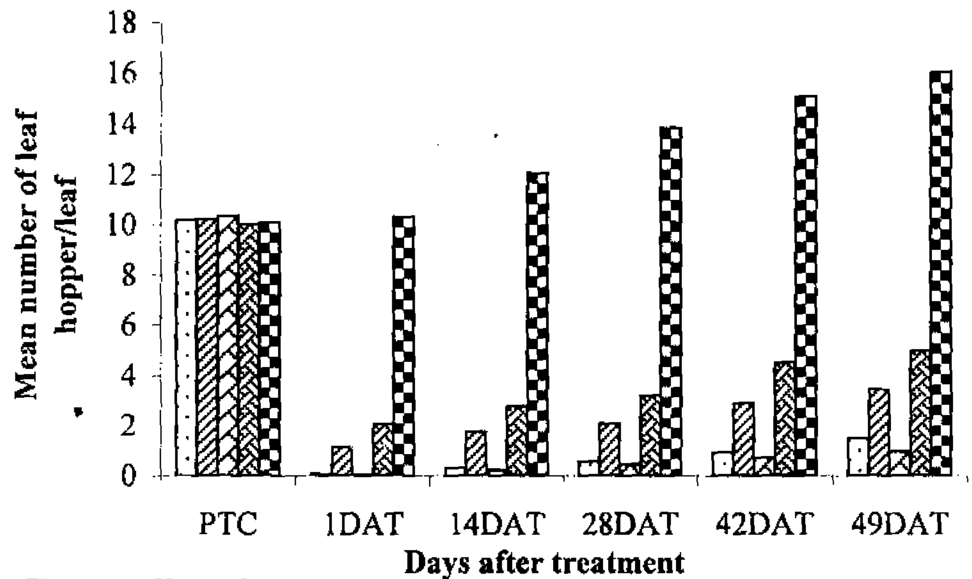

Fig. 14. Effect of newer molecules against leaf hopper at preflowering stage (Summer,2002)

leaf hoppers were observed in control plots (16.007 insects/leaf) where as in imidacloprid treated plots (6.01 %), acetamiprid (9.37%), ethofenprox (21.47%) and acephate (31.33%) population was observed (Fig. 14).

In rabi only lesser number of leaf hopper were observed in control plots (3.500 insects/leaf). At one day after the treatment imidacloprid recorded 95 per cent reduction in the population followed by acetamiprid (88.13 %), ethofenprox (82.24%) and acephate (75.2%).

Subsequent observation showed that an increase in number of leaf hoppers in all the plots including control. At 5 DAT statistically non significant number of leaf hoppers were observed in both acetamiprid and imidacloprid treated plots. All the treatments showed on par results at 42 DAT it revealed that the effect of the insecticides might be persistent up to 42 DAT. The maximum number of leaf hoppers were found at 49 DAT in control (9.296 insects/leaf). Generally imidacloprid and acetamiprid effectively reduce the population followed by ethofenprox and acephate owing to their long residual effects. The residual toxicity of imidacloprid was recorded up to 31days against groundnut leaf hopper (Babu, 1999). Kumar and Giraddi (2001) also found that the least population of leaf hopper (0.03) in mango up to 21 days after spray.

The constantly lower number of leaf hopper in the acetamiprid and imidacloprid treated plots, may be due to the susceptibility of tolerant strains of leaf hopper to the conventional organophosphate and carbamate insecticides. It was proved in the *Laodelphax striatellus* population, which showed high susceptibility to imidacloprid, but showed resistant to conventional insecticides (Sone *et al.*, 1995).

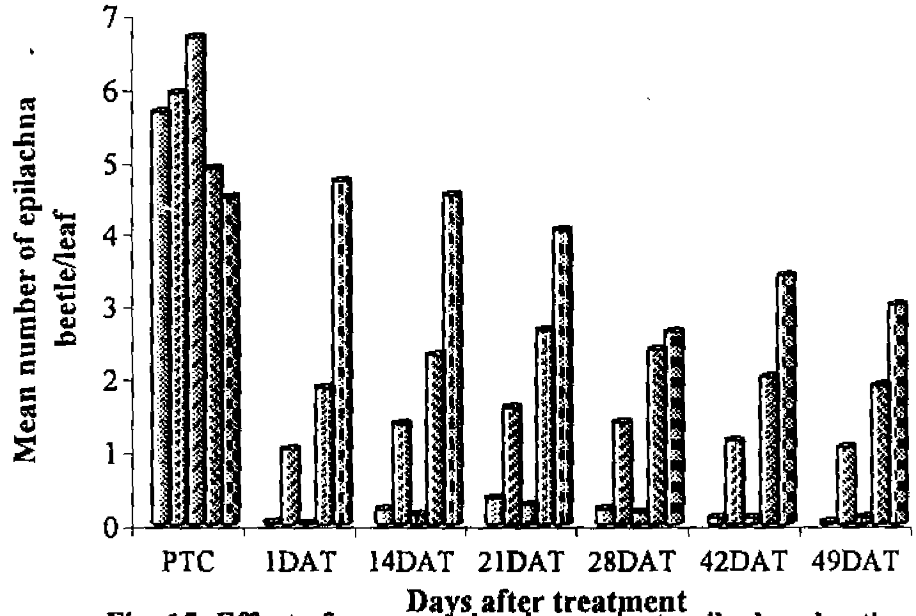

Fig. 15. Effect of newer molecules against epilachna beetle at preflowering stage (Rabi, 2001)

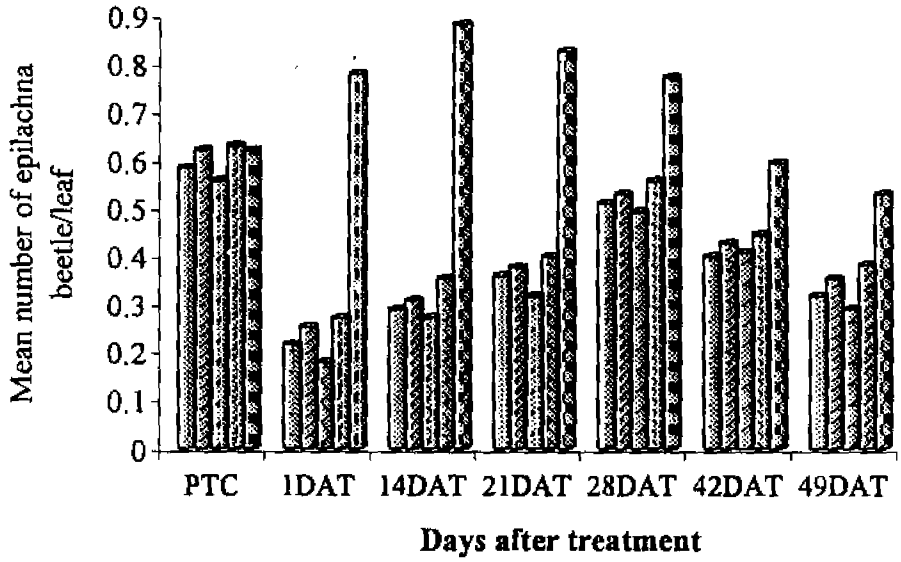

Fig. 16. Effect of newer molecules against epilachna beetle at preflowering stage (Summer, 2002).

5.1.3.2. Epilachna beetle

Compared to the PTC, one DAT acetamiprid and imidacloprid treated plots showed 99 per cent reduction of epilachna beetle followed by ethofenprox (83%) and acephate (62.19%). The effect of the acetamiprid and imidacloprid in the pre flowering stage was more or less same and statistically significant throughout the crop period (Fig. 15). The highest number of epilachna beetle reached at 21 DAT. Again it showed a decreasing trend at the end of the crop, might be due to the scarcity of leaf for feeding. But in summer, the infestation of epilachna beetle was less. It showed the highest population at 28 DAT in control (0.722 insects/leaf) followed by other insecticides treated plots *viz.,* acetamiprid (0.509 insects/leaf), ethofenprox (0.528 insects/leaf), imidacloprid (0.491 insects / leaf) and acephate (0.556 insects/ leaf) (Fig. 16). The newer insecticides *viz.,* acetamiprid and imidacloprid performed well in reducing the population of chewing insects, owing to their antifeeding effect of the chemicals. It showed the consonance with Elbert *et al.* (1996) that the coloroda pototo beetle, *Leptinotarsa decemlineata* is one of the chewing pests, which can be effectively managed by imidacloprid by its antifeeding effects.

5.1.3.3. Aphid

Insecticides *viz.,* acetamiprid and imidacloprid reduced as high as 99 per cent of aphid population followed by ethofenprox (88.55%) and acephate (86.45%) in the pre flowering stage sprayed plots. A drastic reduction of aphid population in the early stages may be due to the neonicotinoids compounds interference on the insect nervous system causing paralysis and death (Leicht, 1993). Increasing number of aphids was noticed subsequently on 3 DAT onwards reached the maximum in between 21 and 28 DAT. After 21DAT, a further reduction of aphid population was observed (Fig. 17). It may be due to the production of nonviable nature of young

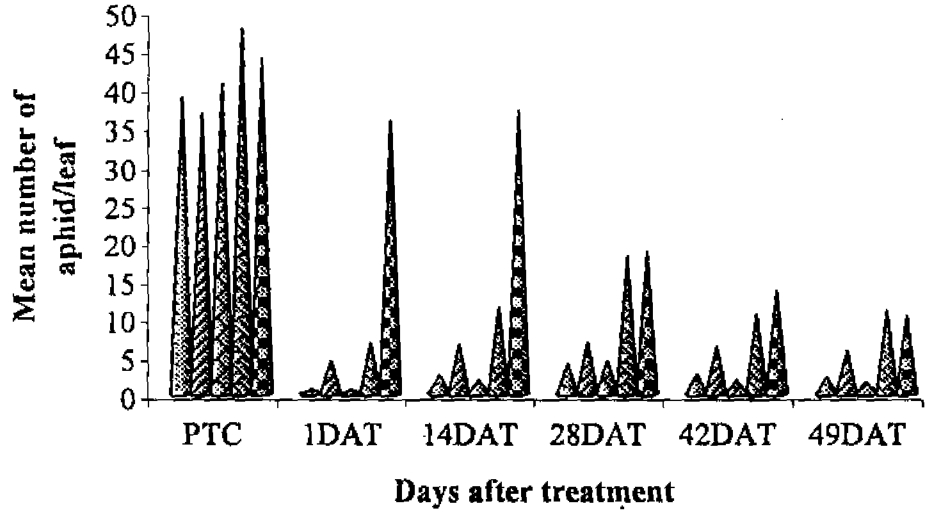

Fig. 17. Effect of newer molecules against aphid at pre flowering stage (Rabi, 2001)

ones, which might result from the adult, feeding on leaves systemically treated with imidacloprid. Similar results obtained by Devine *et al.* (1996).

Considerable reduction in the fertility due to starvation and the deposition of nonviable larvae were also reported for some grain aphids such as *Rhopalosiphum padi, Sitobion avanae and Metopolophium dirhodum* feeding on seed treated winter barley and oat plants (Knaust and Poehling, 1992) treated with imidacloprid.

5.1.4. Fruiting stage treatments

The decreasing trend of the insect pests was noticed after the fruiting stage in all the plots. Leaf hopper, epilachna beetle and aphids were recorded in rabi season crops where as in summer crop, only leaf hopper and epilachna beetles were observed.

5.1.4.1. Leaf hopper

Imidacloprid and acetamiprid showed nearly 99 per cent reduction of leaf hopper population followed by ethofenprox (87.10%) (Fig.19). Kumar (1998) reported that foliar application of imidacloprid (100 ml ha^{-1}) significantly reduced the leaf hopper population in cotton and the effect persisted for a week. Subramanian and Natarajan (1998) reported that acetamiprid (10 g a.i. ha^{-1}) gave superior control of leaf hopper in cotton. After the initial reduction in leaf hoppers the population picked up and the increase was noticed in all the treatments, up to 35 DAT. Acetamiprid and imidacloprid treated plots showed on par results through out the crop period followed by ethofenprox. The highest number of leaf hopper were observed at 35 DAT in all the treatment including control plots

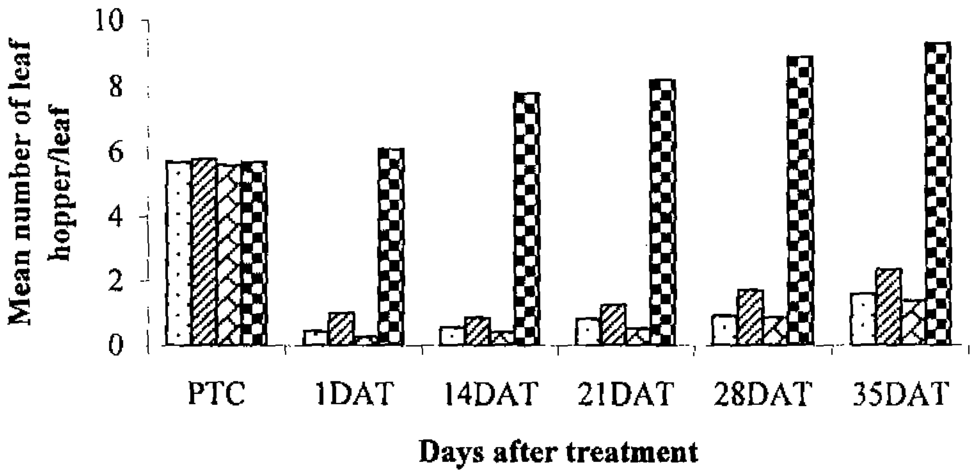

Fig. 18. Effect of newer molecules against leaf hopper at fruiting stage (Rabi, 2001)

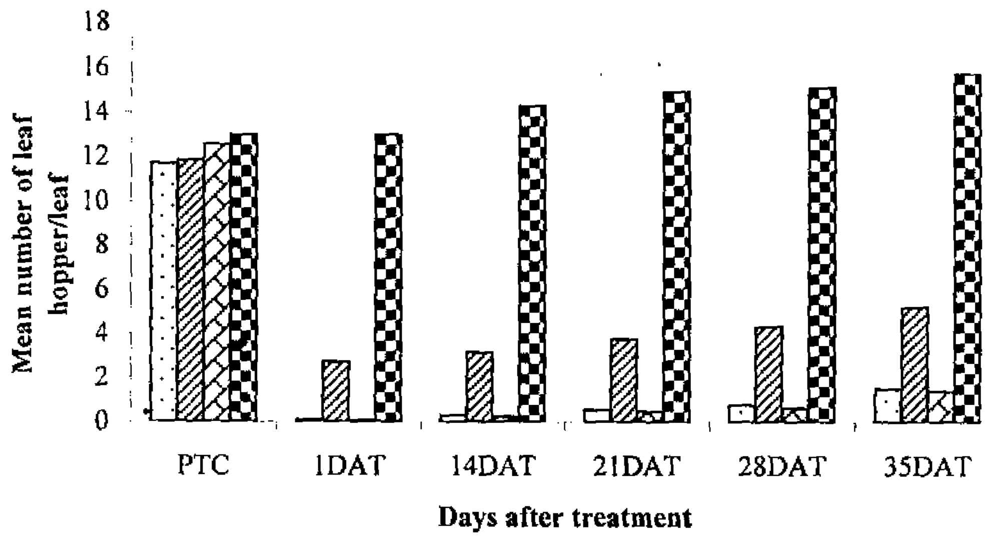

Fig. 19. Effect of newer molecules against leaf hopper at fruiting stage (Summer, 2002)

In rabi also, similar observations were recorded, imidacloprid the most efficient insecticide kept the insect population under check (95.04% reduction) followed by acetamiprid (92.03%) and ethofenprox (88.40%). At 35 DAT even though control plots had high number of leaf hoppers (9.296 insects/leaf), insecticides imidacloprid (1.389 insect/leaf) and acetamiprid (1.602 insects/leaf) treated plots had lesser number of leaf hoppers (Fig. 18). In mango persistency of imidacloprid was reported in the management of mango leaf hoppers up to 21 days after spray (Kumar and Giraddi, 2001). Iwaya and Tsuboi (1992) reported that foliar spray of imidacloprid (0.005 to 0.01 %) significantly reduced the population of leaf hopper and plant hopper including the virus vectors and insecticide resistant strains.

5.1.4.2. Epilachna beetle

Epilachna beetle infestation was more in rabi rather than in the summer season crop in the fruiting stage. Compared to the PTC, one DAT acetamiprid and imidacloprid treated plots showed 99 per cent reduction of epilachna beetle population followed by ethofenprox (71.74%). In effect of acetamiprid and imidacloprid in the fruiting stage was more or less same and statistically significant through out the crop (Fig. 20).

Even though neonicotinoids are much suitable for sucking insects, it can also protect the crop from chewing insects by antifeeding criteria of the chemicals. The same resultswas obtained by Ishaaya and Degheele (1998) in *Leptinotarsa decemlineata* in potato crop.

5.1.4.3. Aphid

The aphid population was in the declining trend in the all treatments including control in the fruiting stage. There was nearly 97 per cent reduction of population

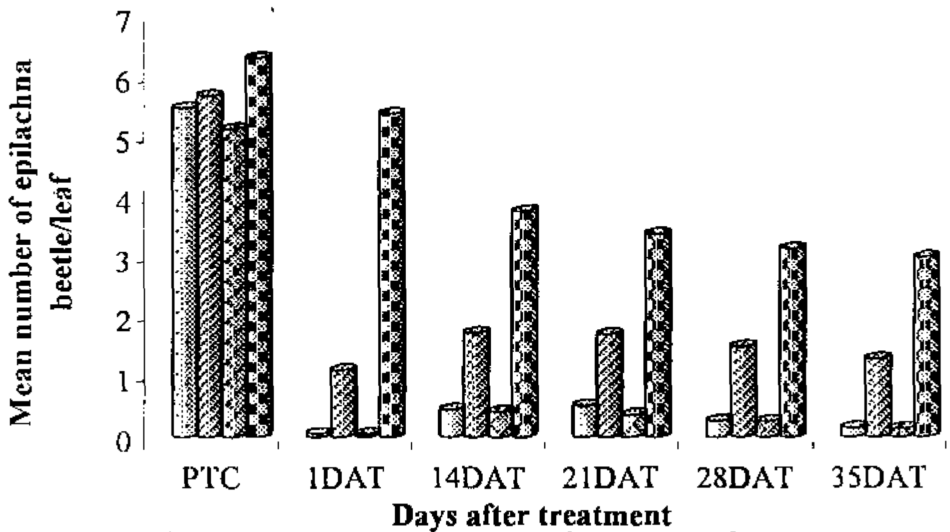

Fig. 20. Effect of newer molecules on epilachna beetle at fruiting stage (Rabi, 2001)

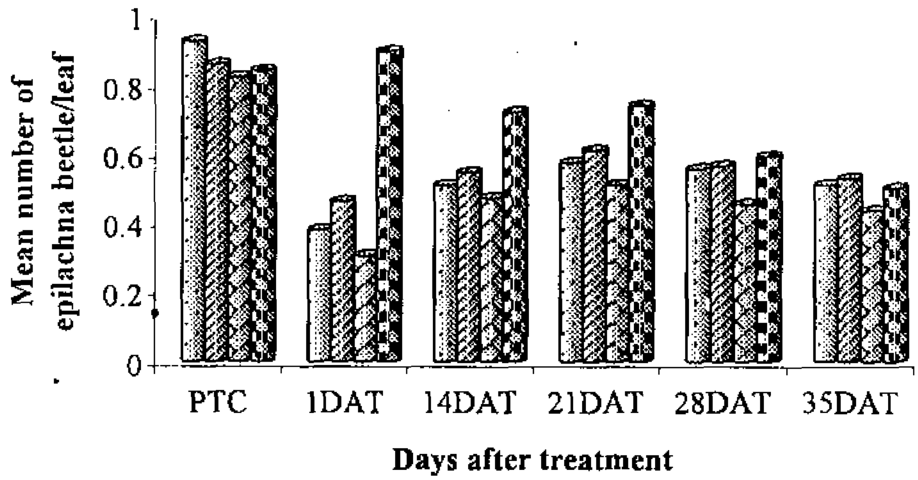

Fig. 21. Effect of newer molecules on epilachna beetle at fruiting stage (Summer, 2002)

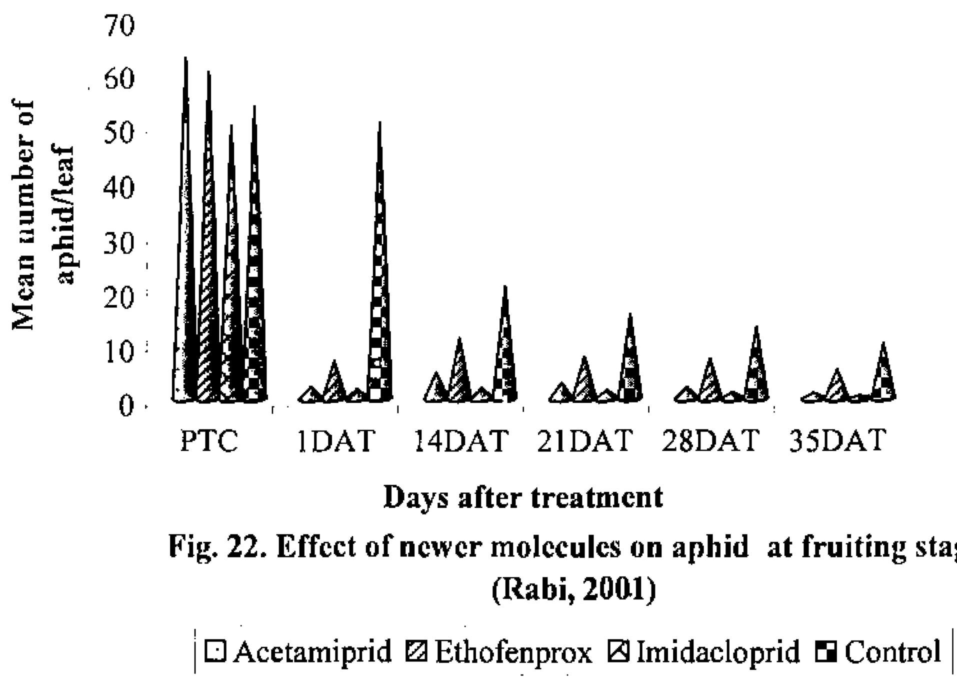

Fig. 22. Effect of newer molecules on aphid at fruiting stage (Rabi, 2001)

observed in both acetamiprid and imidacloprid treated plots following the insecticides spray at one DAT followed by ethofenprox (88.45%). A steady decline in the number of aphids was recorded in the control plots. So the spraying of insecticides at this stage (64 DAT) was not required (Fig. 22).

5.2. BIO EFFICACY OF TEST INSECTICIDES AGAINST FRUIT FLY

Analysis of the data on fruit fly infestation revealed that none of the insecticide treatments were significantly different both in terms of number and weight basis. Seed treated plots showed higher infestation than any other treated plots in both the season for all the insecticides. It might be due to infestation of fruit fly in later stages, up to which the efficacy of seed treated insecticides may not be extended. Mote *et al.* (1995) found the efficacy of imidacloprid as a seed dresser effectively checks the pest population only up to 6.days in cotton crop. In both the season, insecticides treatment at the fruiting stage showed the lowest fruit fly infestation (Plate 5) for both the number and weight basis. Imidacloprid showed the lowest infestation in both number (4.52%) and weight basis (4.60%) followed by acetamiprid in both number (5.37%) and weight basis (4.90%). It might be due to the effect of the insecticides, which prevented the fruit fly from ovipositing on the fruits, whereas in control plots recorded higher infestation of fruit fly in both number (13.62%) and weight basis (15.30%).

5.3. BIO EFFICACY OF INSECTICIDES AGAINST FRUIT BORERS

The fruit infestation by both *H. armigera* (Plate 6) and *D. indica* was noticed in all the treatments. Analysis of data on the per cent borer infestation indicated that none of the treatments were significantly differ both in terms of number and weight basis. In fact, more fruits were damaged in the seed treated plots compared to the subsequent treatment at different stages of the crop growth. It may be due to the persistence of seed treated chemicals not extending up to harvest (Ishii *et al.*, 1994). Iwaya *et al.* (1998) studied the persistence of imidacloprid in rice treated at 2-3 leaf stage protect the crop up to 60days from the infestation of brown plant hopper (BPH). The lowest fruit borer infestation was recorded in the fruiting stage treated plots on number and weight basis for both the season. In the present study 11.14 per cent fruit borer infestation was recorded in early vegetative stage treatment plots which is in agreement with the earlier report on the infestation of *H. armigera* on bitter gourd caused about 10 per cent loses of bitter gourd fruits (Mathew *et al.*, 1996).

5.4. EFFICACY OF INSECTICIDES ON YIELD OF BITTERGOURD

Due to the higher pest infestation from the initial stage to harvest stage of the crop in rabi, summer crop gave more total and marketable yield for all the treatments. The highest yield was recorded in the pre flowering stage treated plots in both the season. It may be due to the management of insect pest in this stage effectively which otherwise would have carried severe damage to crop leads to considerable yield reduction. In the pre flowering stage, imidacloprid treated plots gave the highest yield (101.66 fruits/8m^2) both in rabi and summer (102.667 fruits/8m^2). Babu (1999) found that the imidacloprid (100ml ha^{-1}) sprayed plots, gave increased (27.17%) pod yield over control in groundnut against the major pests. In all the treatment plots imidacloprid showed the highest marketable yield and it might be due to the phytotonic effect of the chemical. Dikshit et al. (2002) found the phytotonic effects of imidacloprid and the growth promoting factors in okra and the increased yield of 551 kg ha^{-1} was observed in rice due to seed hardening of imidacloprid (Saridha, 2002). Control plots recorded the lowest marketable yield (59.338 fruits/8m^2) in rabi and summer (67.33 fruits/8m^2).

5.5. EFFECT OF NEWER INSECTICIDES ON NATURAL ENEMIES

More number of natural enemies were found in the seed treated plots, where as, early vegetative stage treated plots showed lower number of natural enemies. Imidacloprid seed treated plots showed more number of brown lace wing (7.887) followed by acetamiprid (5.830). Imidacloprid (8g kg^{-1}) seed treatment could allow the *Chrysoperla* to lay more eggs in cotton crop (Katole and Patil 2000). Toda and Kashio (1997) reported that imidacloprid was less toxic to *chrysoperla* larvae among 34 insecticides tested.

Imidacloprid seed treated plots noticed higher number of coccinellids both grubs (8.833) and adult (3.00). Satpute (1999) observed more lady bird beetle adult population on imidacloprid (10 g a.i ha^{-1}) seed treated cotton plots where as in early vegetative stage treatment showed lesser number of coccinellid beetle. It might be due to the contact toxic effect of imidacloprid. Viggiani *et al.* (1998) observed contact action of imidacloprid causing toxic effect against coccinellids up to 20days. However fruiting stage treatment showed higher number of coccinellids than early vegetative stage treatment. Because in this stage more number of adult beetles were seen. Babu (2001) found the quantity of food consumed by the predator during its lifetime was relatively less when its prey diet comprised of only adults.

Syrphid larvae were also found more in imidacloprid seed treated plots (4.322) followed by acetamiprid treated plots (3.167). Control plots showed higher number of predator (9.280) compared to all other treated plots. Imidacloprid seed treated plots recorded more number of spiders (1.667) compared to other treatment plots. Iwaya and Tsuboi (1992) stated that the toxicity of imidacloprid to two species of spiders in rice fields was low. Control plots recorded the highest spider population (4.277)

5.6. EFFECT OF NEWER INSECTICIDES ON SOIL MICRO FLORA

The newer insecticides *viz.*, acetamiprid, ethofenprox and imidacloprid were used as a seed dresser and their effect on soil micro flora was evaluated. The results indicated the insecticides treatment effects were at par for the population of soil microflora *viz.*, bacteria, fungi and actinomycetes (Plate 7).

The activity of soil microorganisms was not impaired even at very high dose rates of 2000 g a.i. ha^{-1} of imidacloprid spray application (Pfluger and Schmuck, 1991). According to Anderson (1978) herbicides generally appear to have no adverse effect on the population of total bacteria in soil at the recommended doses. Even intensive pesticide use did not cause any cumulative effects on soil micro organism and crop (cereals and sugar beet) yields were not affected (Hurle, 1991).

5.7. ACUTE TOXICITY TEST OF NEWER INSECTICIDES AGAINST EPILACHNA BEETLE

The acute toxicity of newer insecticides *viz.*, acetamiprid, ethofenprox and imidacloprid were assessed by standard leaf dip method. The lowest LC_{50} (36.252 ppm) was for acetamiprid followed by imidacloprid (39.023 ppm) and ethofenprox (41.519 ppm). The present finding is in agreement with Elbert *et al.* (1991) where the LC_{50} values of imidacloprid on the chewing insect like Colorado potato beetle *Leptinotarsa decemlineata* (40 ppm) and *Agrotis segetum* (20ppm)

5.8. IMIDACLOPRID RESIDUES IN BITTER GOURD FRUITS

Imidacloprid was applied at the time of sowing as seed treatment, and further at early vegetative, preflowering and fruiting stages as spray. Since imidacloprid is a systemic insecticide and is translocated in the plant system through the sap, residues of the chemical can be expected to be present in fruits. The presence of imidacloprid in fruits at the time of harvest is of great significance as regards it safety from the standpoint of human health. Hence the level of residues of imidacloprid in the fruits harvested from plot, which received imidacloprid treatment, were undertaken to ascertain the safety of the produce for consumption.

In this study, the residues of imidacloprid in bitter gourd fruits collected from the plants treated with the chemical at the dosage of 20 g a.i.ha^{-1} and at different stages of growth (early vegetative, preflowering, fruiting stage) were below the detectable level of 0.025 ppm.

The level of residues of any pesticide in a plant material at any point of time depends upon the dosage of application and the rate of degradation of the chemical in the plant. Incase of imidacloprid because of its high bio efficacy, low dosage of (20g a.i.ha^{-1}) pesticides only are required. Since imidacloprid is relatively safe to mammals (LD_{50} oral rats 450 mg kg^{-1} body weight) the residue level on treated plots will go below critical safe levels with in a short period of time. Further, imidacloprid dissipates fast in crops. The half life of the compound was as low as 3 days in rice and cucumber (Ishii *et al.*, 1994; Iwaya *et al.*, 1998). It may be due to these reasons that the residues of imidacloprid in fruits of bitter gourd dissipates to very low levels by the time the fruits were ready for harvest.

Similar observations have been made by several workers in various crops. Sharma and Awasthi (1998) reported that no residues of imidacloprid were detected in mango fruits at harvest incase where the trees were sprayed at flowering. The safety of use of imidacloprid was demonstrated by Indumathi *et al.* 2001 in okra, Dikshit and Pachuri (2000) in tomato, Gajbhiye *et al.* 1997 in sugarcane and Mukerjee and Gopal (2001) in cotton. The result of the study indicates that the imidacloprid can be safely applied to bitter gourd even at the fruiting stage at the dose of 100ml/ha.

Summary

Summary

Bitter gourd (*Momordica charantia L.*) is being cultivated throughout the year in Kerala. At present highly hazardous chemical pesticides are applied by the farmers to manage the pest complex of bitter gourd. In order to reduce the increasing pesticide load in the environment and other harmful effects of the conventional insecticides, an attempt was made to evaluate the bio efficacy of some newer insecticides *viz.*, acetamiprid, ethofenprox and imidacloprid against the bitter gourd insect pest complex during 2001-2002.The salient findings of the investigation are summarised below

- Acetamiprid @ 1.5 g a. i. kg^{-1} seed treated plots showed significantly lower number of leaf hoppers both in rabi and summer seasons.

- Rabi season crop suffered more damage by the epilachna beetle compared to summer season. Acetamiprid (1.5 g a. i. kg^{-1} seed) treated plots showed less number of epilachna beetle followed by imidacloprid (2 g a. i. kg^{-1} seed) treated plots.

- Acetamiprid seed treated plots had significantly lower number of aphids throughout the crop period till harvest compared to imidacloprid treated plots.

- Imidacloprid (20 g a.i.ha^{-1}) and acetamiprid (10 g a.i.ha^{-1}) application as spray had more or less same effect in reducing the leafhopper population in the early vegetative stage of the crop.

- Imidacloprid treated plots showed 94.55 per cent reduction in aphid population followed by acetamiprid (92.69%) and ethofenprox (76.45%).

- In the pre flowering stage of the crop, acetamiprid and imidacloprid treated plots recorded 99 per cent reduction in the leaf hopper population due to the quick knock down effect of the chemicals, whereas ethofenprox and acephate showed 88.70 and 79.31 per cent reductions respectively.

- In the fruiting stage of the crop, in general insect population showed the decreasing trend. Imidacloprid was the most efficient insecticide kept the leafhopper population under check (95.04% reduction) followed by acetamiprid (92.03% reduction) and ethofenprox (88.40%) in this stage.

- Imidacloprid treated plots showed the lowest fruitfly infestation in both rabi (5.94% damage) and summer (4.52% damage) season crops in the fruiting stage. Similar results were observed in the case of fruit borer also in both rabi (3.39% damage) and summer season (3.00% damage).

- Highest yield was recorded from the plots received imidacloprid as pre flowering stage spray in rabi (101.66fruits/8m^2) and summer (102.66fruits/8m^2) season respectively

- Natural enemies were abundant in the seed treated plots, however foliar spray especially in the early vegetative stage showed fewer numbers of natural enemies.

- All the newer insecticides *viz.*, acetamiprid, ethofenprox and imidacloprid showed no significant detrimental effect on the population of soil micro flora *viz.*, fungi, bacteria and actinomycetes when applied along with the seed.

- Among the newer insecticides acetamiprid was the potent insecticide with lowest LC_{50} 36.252 ppm for the epilachna beetle followed by imidacloprid (39.023ppm) and ethofenprox (41.519 ppm).

- Studies on the residues of imidacloprid by high performance liquid chromatography indicated that imidacloprid applied at sowing, early vegetative, preflowering and fruiting stage to bitter gourd resulted no detectable residue in the harvested fruits.

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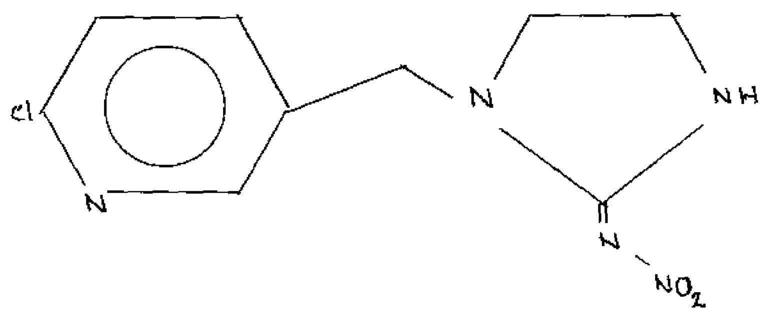
*Originals not seen

APPENDIX- I

Physical and chemical properties of imidacloprid

Empirical formula:	$C_9H_{16}Cl\ N_5\ O_2$
Chemical name:	1-(6-chloro-3-pyridylmethyl)-N-= nitroimidazolidin-2-ylideneamine
Code name:	105827-78-9

Structural formula



Molecular weight: 255.7 g/mole

Physical and Chemical Properties

Appearance:	Solid
Colour:	Colourless
Odour:	Characteristic inherent odour, slight
Melting point:	143.8^0 C
Vapour pressure:	2×10^{-9} h Pa at 20^0 C
Density:	1.54 g/cm^3 at 20^0 C
Partition coefficient:	log Pow: 0.57 at 20^0 C
Fat solubility: (g/100 g fat)	0.055 (determined in standard fat H B 307, NATEC, at 37^0 C)

Hydrolytic stability:	p^H 5 25^0 C $t^{1/2} > 1$ a
	p^H 5 25^0 C $t^{1/2} > 1$ a
	p^H 5 25^0 C $t^{1/2}$ about 1 a
Acute toxicity:	
Oral dose (LD_{50})	450 mg/kg in rats
	131 mg/kg in mice

(Source: Diehr etal.,1991)

APPENDIX- II

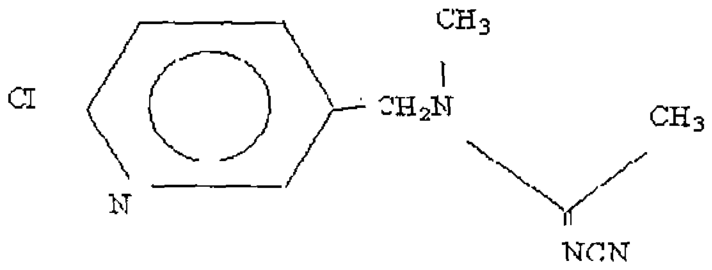
Physical and chemical properties of acetamiprid

Empirical formula: $C_{10} H_{11} Cl N_4$

Chemical name: (E)-N[1]-[(6-Chloro-3-Phridyl)methyl]-N[2]-cyano-N[1]- methlyaceamidine

Code Number: N 125

Structural formula:



Molecular Weight: 222.68

Physical appearance: Light grey to white crystalline solid

Specific gravity: 1.330

Melting point (^{0}C): 98.9

Vapour pressure: < 1 x 10^-6 pa (25^{0}C)

Solubility: 4.25 g/l

Solubility in organic

Solvents: Soluble in acetones, methanol, ethanol, chloroform, acetonitrate, tetra hydrofurane.

Partition coefficient: 0.08 (25^{0}C)

Toxicological properties

Acute oral (LD50 mg/kg)

Mouse:	184 for females
	198 for males
Rat:	146 for females
	217 for males

Acute dermal (LD50 mg/kg)

Male/female:	> 2000 (Rat)
Skin irritation:	none
Eye irritation:	none

(Source: Yamamoto, 1996)

APPENDIX- III

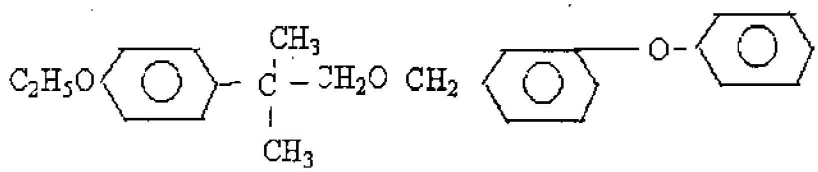
Physical and chemical properties of ethofenprox

Common name: Ethofenprox

Code name: MTI-500

Chemical name: 2-(4-ethoxyphenyl)-2-methylpropyl 3-phenoxy-benzylether

Structural formula:



Empirical formula: $C_{25} H_{28} O_3$

Molecular weight: 376.49 g/mole

Appearance: White crystalline solid

Melting point: 36.4-38.0 ^{0}.C

Vapour pressure: 2.4X10^{-4} mm Hg (100^{0}C)

Stability: Stable in acidic and alkaline solutions

Solubility: Solvent

Acetone 7,8000 (25^0 C)

Ethyl acetate 6000 (25^0 C)

Chloroform 9000 (25^0 C)

Acute toxicity:

Oral LD $_{50}$ (mg/kg)

Rats:	>42,880
Dermal:	>2,140
Subcutaneous:	>32,160
Intra peritoneal:	>42,880
Skin irritation:	None
Eye irritation:	None

(Source: Udagawa, 1986)

BIO EFFICACY OF NEWER INSECTICIDES AGAINST LEAF HOPPER, *Empoasca motti* Pruthi IN BITTER GOURD

By

R. KARTHIKEYAN

ABSTRACT OF THE THESIS

Submitted in partial fulfilment of the requirement for the degree of

Master of Science in Agriculture

Faculty of Agriculture
Kerala Agricultural University

DEPARTMENT OF AGRICULTURAL ENTOMOLOGY
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2003

ABSTRACT

Bio efficacy of newer insecticides was evaluated by two field experiments at the College of Horticulture, Vellanikkara during rabi, 2001 and summer, 2002.against major pests of bitter gourd. Imidacloprid (2 g a.i.kg^{-1}) and acetamiprid (1.5 g a.i.kg^{-1}) were used as a seed dressers .The newer molecules namely acetamiprid, ethofenprox and imidacloprid were sprayed at different crop stages *viz.*, early vegetative (30 DAS), pre flowering (50 DAS) and fruiting stage (64 DAS) as separate treatments. Acephate was used as a standard check. The present investigation revealed that acetamiprid (1.5 g a. i. kg^{-1}) was the most effective insecticide as seed dressers against sap feeders *viz.*, leaf hoppers and aphids. Foliar spray application revealed that both imidacloprid (20 g a.i.ha^{-1}) and acetamiprid (10 g a.i. ha^{-1}) consistently effective in reducing the sucking pests *viz.*, leaf hopper and aphids followed by ethofenprox (50 g a.i.ha^{-1}) in both the season.

Fruiting stage spray by acetamiprid and imidacloprid had registered the lowest fruitfly infestation .The fruit borer infestation was less in the plots, which received the preflowering and fruiting stage insecticide sprays. The highest yield of bitter gourd was recorded in the imidacloprid (pre flowering stage spray) treated plots in both rabi (101.66fruits/$8m^2$) and summer (102.66fruits/$8m^2$) seasons. Seed treatment of newer insecticides had no harmful effect on soil micro flora (fungi, bacteria and actinomycetes). Population of natural enemies was unaffected by the insecticide applied along with the seed compared to the foliar applications. Studies on the residues of imidacloprid by high performance liquid chromatography indicated that imidacloprid applied at different stage of the crop *viz.*, sowing, early vegetative, preflowering and fruiting stage to bitter gourd resulted no detectable residue in the harvested fruits.