SAFETY OF NEW GENERATION INSECTICIDES TO BEE POLLINATORS

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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, Thrissur

Department of Agricultural Entomology

COLLEGE OF AGRICULTURE

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KERALA, INDIA

2013

DECLARATION

I hereby declare that this thesis entitled **"Safety of new generation insecticides to bee pollinators"** is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award of any degree, diploma, associateship, fellowship or other similar title, of any other university or society.

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CERTIFICATE

Certified that this thesis entitled "**Safety of new generation insecticides to bee pollinators**" is a record of bonafide research work done independently by Mr. Ravi Boli (2011-11-159) under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, fellowship or associateship to him.

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Dedicated to my Beloved Parents and guide Dr. K. S. Premila

ACKNOWLEDGEMENT

First of all I thank God for giving me confidence, courage strength and lots of blessings to complete my work successfully.

I am very happy and grateful to express my thanks to my chairman Dr. K.S. Premila, Associate Professor (Agricultural Entomology), AICRP Honey bees and Pollinators, College of Agriculture, Vellayani for her valuable guidance, encouragement, patience, motherly affection, understanding nature and timely correction of the thesis.

I express my gratitude to the members of the advisory committee, Dr. Sheela M.S, Professor and Head, Department of Agricultural Entomology, Dr. Hebsy Bai, Professor, Department of Agricultural Entomology and Dr. V.A. Celine, Professor, Department of Olericulture for their valuable suggestions, timely correction of thesis, moral support and constant encouragement.

It will be unredeemable fault on my part if I fail to express my heartful thanks to Dr. Thomas Biju Mathew, Professor, Dr. Nandakumar, Professor and Dr. Amritha. V.S, Assistant Professor, Department of Agricultural Entomology, Vellayani for their critical comments and constructive suggestions throughout the study.

I gratefully acknowledge Sri. C.E. Ajithkumar, Programmer, Department of Agricultural Statistics for his co-operation during the statistical analysis of the data.

I gratefully remember all the teaching and non teaching staff especially AICRP Honey bee and Pollinators faculty (Ms. Shailaja, Sanju, Abila, Aswathi chechi, Vijayakumar and Santhoshkumar) Department of Agricultural Entomology for their co-operation and encouragement during my course of study and research work.

I wish to express my heartfelt thanks to my loving classmates Sudhakar. S, Ravi G.B, Pallavi Nair, Angela cyriac, and Aswini for their moral support, co operation and help; my junior friends for their love and encouragement, our senior friends and all my friends of other departments for their inspiration and love.

I express my affection and indebtedness to my friends at P.G Hostel, Hasansa, Vijay, Rajgopal, Akshay, Gajanan, Ashish, Madhukar, Dattatray, Praveen John, Anand and Rahul, thank them for their companionship during my P.G. study.

Finally I express my gratitude to my parents Sri D. N. Boli, Smt. Shantha, my sister Sujatha and brother-in-law Sanganna for their constant encouragement, moral support and for their valuable love.

Ravi Boli

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LIST OF ABBREVIATIONS

@	-	at the rate of
%	-	Per cent
Viz	-	Namely
Dia	-	Diameter
$/m^2$	-	Per square meter
Sec	-	Seconds
a.i.	-	Active ingredient
CD	-	Critical difference
cm	-	Centimetre
DAS	-	Days after spraying
HAT	-	Hours after treatment
et al.	-	And others
Fig.	-	Figure
Sp.	-	Species
ha^{-1}	-	Hectare
g	-	Gram
ml	-	Milligram
i.e.	-	That is
SC	-	Suspenson concentrates
EC	-	Emulsifiable concentrates
SP	-	Soluble powder
SL	-	Soluble liquid
WP	-	Wettable powder
SG	-	Soluble granules
WG	-	Wettable granules
WDG	-	Wettable disperasable granule
h	-	Hour
L	-	Litre
m	-	Metre
No.	-	Number
POP	-	Package of practice
RBD	-	Randomized block design
CRD	-	Complete randomised block design
Sl.	-	Serial
LD_{50}	-	Lethal dose
*n*g	-	Nanogram

INTRODUCTION

1. INTRODUCTION

Insect pollinators and pollination are crucial in the functioning of almost all terrestrial ecosystems including agriculture/horticulture. Productivity of many crops benefits from the presence of pollinating insects. Approximately 70 per cent of tropical crop species depend on insect pollinators. It is estimated that about 90 per cent of the pollination in various crops *viz.*, vegetables, fruits, oilseeds and some field crops depend on insects (Klein *et al.*, 2007). The value of insect pollination for worldwide agriculture production is estimated at 153 billion, which represents 9.5 per cent of the value of the world agricultural production (Gallai *et al.*, 2009). Honey bees popularly called as 'Angels of Agriculture' are essentially recognized as the most important insects in the world and are the primary insect pollinators of most of the cross pollinated crops (Deodikar and Suryanarayana, 1997).

Bee pollinators (*Apis* and non *Apis* spp) contribute to crop pollination and maintain plant biodiversity, but there is potential decline of bee colonies, when the bees are exposed to insecticides. The exposure of honey bees to pesticides may occur through contaminated pollen/ nectar or by their direct contact on the sprayed field crops (Jaycox, 1964). The presence of pesticide residues even at the low amount in the honey bee body systems may prove detrimental to their important metabolic functions (Shivrana and Jain, 1994). It is also known that the contaminated pollen fed to the brood may poison and kill larvae in the early stages of development.

In modern agriculture the use of agrochemicals have become imperative for the protection of plants to enhance and sustain the productivity and yield in order to meet the growing demands for food (Anonymous, 2006). At present, the world pesticide market is around 0.8 billion $, which is highest among other agricultural inputs. Though the per hectare pesticide consumption in India is very low, the scenario is quite unhealthy, because we are still using and manufacturing a number of hazardous pesticides which are banned elsewhere. Control of pests with the highly

toxic conventional insecticides is fast losing its attraction in pest control. Ineffectiveness of continuous use of a single group of insecticide against pests, on account of development of resistance necessitated the formulation of selective insecticides of new molecules with high efficacy, low dose requirement and low toxicity to non target organisms. Safer alternatives are being progressively explored for pest management, especially in vegetables.

Monitoring of crop health through judicious use of pesticides and timely prevention of pest problems in vegetables leads to better crop yields. But, there is an increasing public concern about pesticide usage and residue contamination. The targeted modification of insecticides produce many new products with varying insecticidal activity. These insecticides with novel structures and modes of action are gaining importance now a days for pest management in vegetable ecosystem. Several new generation insecticides show very strong toxicity to pollinating insects and in particular to the honey bees. Before registration, formulated pesticides undergo various tests to assess the risk posed by these molecules to honey bees (CIBRC, 2009). IPM practices to combat the pest problems with new molecule insecticides which are specific to organisms and leave residues within the tolerance limit is the current need of vegetable growers. In view of the above issues, the present study is under taken with the following objectives.

- To evaluate the safety/toxicity of newer molecules of insecticides to honey bees *viz., Apis cerana indica, Apis mellifera* and *Trigona iridipennis.*
- To find out the foraging activity of bee pollinators on flowers of culinary melon after spraying selected new generation insecticides.

"If the bee disappeared off the surface of the globe then man would only have no more four years of life left. No more bees, no more pollination, no more plants, no more animals, no more man" (Albert Einstein).

REVIEW OF LITERATURE

2. REVIEW OF LITERATURE

The widespread use of pesticides in modern agriculture throughout the world have become necessary for the protection of the plants against insect pests and diseases to obtain higher yields to meet out the food requirement of increasing population but the injudicious use of pesticides has resulted in contamination of agroecosystem and agriculture produce including nectar and pollen and caused heavy losses to the pollinators (*Apis cerana indica* Fab. and *Apis mellifera* L.). Such contaminated nectar and pollen when brought to hive may cause damage to brood besides the contamination of the stored honey. New generation insecticides *viz.,* chlorantraniliprole, flubendiamide, emamectin benzoate, spinosad, indoxacarb, fipronil and dimethoate are recommended in the state whereas cartap hydrochloride, imidacloprid, acetamiprid, thiodicarb and thiacloprid, clothianidin, acephate are being recommended in India and elsewhere due to their higher efficacy against the pests of different agriculture ecosystem without knowing their toxic effects to honey bees, residue problems and other side effects. Several workers made attempts to study the efficacy of these pesticides against pests of vegetables but so far very little information is available on the toxicity to honey bees, residues in nectar, pollen and honey under different agro ecological regions of Kerala. The literature pertaining to honey bee toxicity, foraging activity and time spent by bees on flowers of different vegetables is reviewed here under.

2.1 LABORATORY EVALUATION OF THE SAFETY/TOXICITY OF NEW GENERATION INSECTICIDES TO BEE POLLINATORS

Chlorantraniliprole -Anthranilicdiamide

Chlorantraniliprole had an excellent profile of safety to beneficial arthropods, pollinators and non-target organisms such as earth worms and soil micro-organisms. The product effects on honeybees have been studied extensively demonstrating low

intrinsic toxicity of chlorantraniliprole in Denmark. They also reported that chlorantraniliprole had low toxicity and low risk for honey bees (*A. mellifera*) and bumble bee (*Bombus terrestris*) at 0.005 µg/bee demonstrated in acute oral and contact tests (Dinter *et al.*, 2008, 2009).

Flubendiamide

National Registration Authority for Agricultural and Veterinary Chemicals (2009) of Australia reported that flubendiamide 480 SC formulations were not acutely sensitive to honey bees with LD_{50} values greater than the highest test concentration 200 µg/bee. Chronic exposure to the 480 SC formulations of flubendiamide had no effect on mortality and flight intensity of honey bees (*A. c. indica*).

Spinosad - Spinosyns

Mayer *et al.* (2001) worked out the contact toxicity (LD_{50}) of spinosad against adult *A. mellifera* @ 0.078 µg/bee. On the basis of LD_{50}, the honey bee was the most susceptible followed by the alkali bee (0.773 µg g/bee) and the leafcutter bee (1.908 µg g/bee) in USA.

Cleveland *et al.* (2002) showed that spinosad was acutely toxic to bees under laboratory conditions. Mathirajan (2002) assessed the contact toxicity of spinosad 45 SC to honey bee *A. florea* at 25, 50, 75 and 100 g a.i./ha. The highest dose of spinosad caused only 25 and 26.2 per cent mortality after 72 hours of treatment. Spinosad was found that highly acute toxic to worker honey bees under laboratory conditions in UK (Miles, 2003). Spinosad was low toxicity to most beneficial insects, acute laboratory tests indicated that spinosad was intrinsically toxic to pollinators (Mayes *et al.* 2003). Miles and Anne (2011) reported the highest mortality in bees (*A. mellifera*) exposed to spinosad acute toxic standards on one day after treatment in the laboratory conditions at Netherland.

Indoxacarb- Oxidiazine

When honey bees were exposed to indoxacarb, it was found that bees were not affected after three hours (Brugger, 1997) and indoxacarb is considered highly toxic by contact and practically non toxic by dietary intake (Environmental protection agency, 2005).

Thiodicarb - Carbamates

European food safety authority (2005) reported the high oral and contact toxicity on bees when exposed to thiodicarb (48 h, LD_{50}0.153 µg/bee) and (48 h, LD_{50}3.1 µg/bee) in laboratory conditions.

Fipronil - Pyroles

Gunashekara *et al.* (2007) exposed fipronil on honeybees in laboratory conditions and observed the hyper excitation and highest mortality. Pastagia and Patel (2007) studied the toxicity of fipronil at (0.005 per cent) on honey bee (*A. c.indica*) and recorded 56.99 per cent mortality in laboratory conditions in Navsari. Laboratory studies showed that honey bees exposed to lethal dose resulted in the mortality and impairment of memory in USA (Aliouane *et al.*, 2009). Clara *et al.* (2011) studied the toxicity of fipronil and found that highly toxic to stingless bees (*Melipona scutellaris* L.*)* under laboratory conditions in Brazil. Cynthia *et al.* (2011) studied acute toxicity (LD_{50} and LC_{50}) of fipronil and found that values of 0.54 *n*g a.i./bee and 0.24 *n*g a.i./bee were considered as highly toxic to stingless bees (*Scaptotrigona postia* L.) in the laboratory condition.

Cartap hydrochloride -Nereis toxin

Laboratory evaluation of cartap hydrochloride showed that mortality of bumble bees (*B. terrestris*) was higher than the untreated controls in UAS (Marletto *et al.*, 2003) and Thomizawa and Cassida (2005) studied the acute toxicity of cartap hydrochloride 500 SP in *A. mellifera* and reported 100 per cent mortality of bees after

360 minutes the laboratory conditions in UK. Cartap hydrochloride was highly toxic by ingestion and moderately toxic by indirect contact on foraging honey bees under laboratory conditions in USA (Arzone and Patetta, 2011).

Acetamiprid- Chloronicotynyl

Iwasa *et al.* (2004) observed that nitro substituted compound of acetamiprid was more toxic to the honey bees (*A. mellifera*) with LD_{50} values of 7.1 µg/bee under laboratory conditions. Pastagia and Patel (2007) reported highest (73.47%) mortality of honey bee (*A. c. indica*) when exposed to acetamiprid under laboratory conditions. Laboratory studies showed that honey bees exposed to acetamiprid lethal dose (LD_{50}) resulted in the mortality and impairment of behavioural function of *A. mellifera* (Aliouane *et al.*, 2009).

Thiacloprid - Thiazolidine

Thiacloprid has broad spectrum activity particularly against sucking pests and is safe to honey bees (Horvat, 2001). The contact toxicity of thiacloprid LD_{50} value to forager of *A. mellifera* varied within the range of 10.00 to 40.00 *µg/* bee after 48 hours exposure (Jeschke *et al.*, 2001), whereas Solovera (2002) reported low mortality of honey bees when exposed to thiacloprid under laboratory conditions. Rabia *et al.* (2005) reported highest mortality of Indian bees (*A. c. indica*) when exposed to thiacloprid under laboratory conditions of Maharashtra. The mortality caused by thiacloprid was less both via ingestion and indirect contact on *A. mellifera* under laboratory conditions in Italy (Laurino *et al.*, 2011).

Imidacloprid - Chloronicotynyl

Contact LD_{50} values of imidacloprid to *A. mellifera* ranged from 0.040 and 0.104 µg/bee (Schmuck, 2004). Iwasa *et al.* (2004) observed that nitro substituted compound of imidacloprid was more toxic to honey bees (*A. mellifera*) with LD_{50} values of 0.018 µg/bee under laboratory conditions. The chronic dietary effects of imidacloprid to the honey bee *A. mellifera* showed high chronic toxicity under

laboratory conditions of Germany (Schumuck, 2004). Laboratory studies Rabia *et al.* 2005 showed highest mortality of Indian bees (*A. c. indica*) when exposed to imidacloprid. Pastagia and Patel (2007) reported highest (80.60%) mortality of honey bee (*A. c. indica*) when exposed to imidacloprid at 0.005 µg/bee under laboratory conditions. Pettis *et al.* (2012) investigated the interactions between chronic and sub lethal exposure of imidacloprid to honey bee colonies and results revealed that imidacloprid was intrinsic hazard to honey bees.

Clothianidin- Thionicotinyl

Iwasa *et al.* (2004) observed that nitro substituted compound of clothianidin was more toxic to honey bees (*A. mellifera*) with LD_{50} values of 0.022 µg/ bee under laboratory conditions in USA. Highest mortality of honey bee was observed when exposed to clothianidin (0.014 *µg/* bee) under laboratory conditions in Kanchipuram District (Jeyalakshmi *et al.*, 2011). Clothianidin caused total mortality of *A. mellifera* within 24 h at the concentration half of the field dose (Laurino *et al.*, 2011)

Buprofezin- Chitin synthesis inhibitors

Laboratory assessment of toxicity of buprofezin caused mortality to bumble bees (*B. terrestris*) of higher than the untreated controls (Marletto *et al.*, 2003). National Registration Authority for Agricultural and Veterinary Chemicals, (2001) reported that single oral dose of buprofezin 100 *µg*/bee revealed that buprofezin was non-toxic to bees by either contact or ingestion method.

Acephate-Organophosphates

The insecticide acephate was moderately toxic to *A. c. indica* when fed orally at Bangalore (Gowda *et al.* 2002). Laboratory assessment of the toxicity of acephate caused mortality to bumble bees (*B. terrestris*) of higher than the untreated control In UAS (Marletto *et al.*, 2003).

Dimethoate - Organophosphates

Vaidya and Satishkumar (1995) showed the decreasing toxicity of dimethoate to the foraging honey bees at Bangalore. There was significant reduction in the number of bees in both oral feeding and contact method in dimethoate treatments (Abrol and Rajiv, 2000). Dimethoate was highly toxic to eggs and larvae of *A. mellifera* by topical application resulting in its complete mortality (Gowda *et al.*, 2002). Relative toxicity of dimethoate to *A. mellifera* revealed that it was highly toxic under laboratory conditions at Jammu Kashmir (Sharma and Abrol, 2003). Abrol and Andorta (2003) evaluated the toxicity of dimethoate (30 EC) and results revealed that dimethoate (0.0224 µg) was highly toxic to honey bees.

2.2 FIELD EVALUATION OF THE SAFETY/TOXICITY OF NEW GENERATION INSECTICIDES TO BEE POLLINATORS

Flubendiamide

National Registration Authority for Agricultural and Veterinary Chemicals (2009) assessed the side effect of flubendiamide 24 WG on bumble bees (*B. terrestris*) in Australia. When flubendiamide 24 WG was applied as foliar spray on tomato crops and results showed that it did not affect the activity of pollinating bumble bees and colony development in green house condition.

Spinosad

Miles (2003) reported that when spinosad was applied to flowering crops there was less bee activity, later it was safe to bees in the field conditions of Germany.

Indoxacarb

Indoxacarb sprayed at rate of 133 g/ha on alfalfa showed the highest mortality of bees after 24 hours in the field (Hetrick and Abel, 2005).

Thiodicarb

Mohapatra and Patnaik (2009) reported that 100 per cent mortality of Indian bee (*A. c. indica*) on mustard crop after spraying of thiodicarb at recommended dose in the field.

Cartap hydrochloride

Cartap hydrochloride sprayed on mustard crop at recommended dose caused 50 per cent mortality of Indian bee (*A. c. indica*) after one day of spraying in the field at Uttarakhand (Mohapatra and Patnaik, 2009).

Thiacloprid

Elbert *et al.* (2000) found that thiacloprid significantly reduced activity of honey bees whereas thiacloprid is an acute and stomach poison and found that thiacloprid was safe to honey bees at Germany (Horvat, 2001).

Imidacloprid

Imidacloprid was highly toxic to bees whereas imidacloprid used as a seed treatment in the field crops (0.7 mg/seed) was found safe to *A. mellifera* (Ambolet *et al.*, 1997). Lambin *et al.* (2001) reported the topical application of imidacloprid at the doses of 0.005, 0.010 and 0.020 µg/bee did not produce any lethal effect to bees and also the lowest dose 0.020 µg/bee had no effect on the gustatory function of *A. mellifera*. Maus *et al.* (2003) reported imidacloprid used as seed dressing, posed only negligible risk to honey bees in sunflower in France. Thorat *et al.* (2004) studied toxicity of imidacloprid to honey bees when sprayed on field crops at Pantanagar and results found that it was highly toxic to bees (*A. mellifera*)

Gulati *et al.* (2005) studied the field toxicity of imidacloprid against *A. mellifera* and results revealed that killed 76.6 per cent foragers during spray at Orissa. Bailey *et al.* (2005) studied the foraging bees when exposed to treatments with imidacloprid had no impact on honey bees. Rortais *et al.* (2005) reported that

imidacloprid treated crops caused heavy losses to bee colonies in Europe and also caused the emergence of Colony Collapse Disorder in USA (Chensberg, 2012).

Clothianidin

Bailey *et al.* (2005) studied the foraging bees when exposed to treatments with clothianidin had no impact on honey bees, there were no impact on mortality of bees. Frazier *et al.* (2008) reported that reduced flight activity and colony collapse disorder when exposed to the clothianidin at North America. Beyond pesticides (2012) reported that decreased bee flight and behavior of bees when exposed to the clothianidin at five different doses in the field.

Buprofezin

Buprofezin sprayed on different crops at up to 2 kg/ha, no bee mortality was recorded as compared to controls. Field studies revealed that using buprofezin at 25 g/100 L showed there were no adverse effects on worker bees and effects seen only in development of eggs, larvae and cocoons exposed to the buprofezin at Australia (National Registration Authority for Agricultural and Veterinary Chemicals, 2001).

Acephate

Fielder and Drescher (1984) found that nectar contaminated with acephate after pre blossom treatment of flowers caused toxic effect on *A. mellifera* and field experiments conducted in USA to assess the effects of acephate treated crops found toxic effects on flight and behaviour of honey bees.

Dimethoate

Rana and Goyal (1996) reported that when dimethoate was sprayed on *Brassica chinensis*, it causes toxic effects on the population of *A. c. indica* in the field whereas the crops sprayed with dimethoate, less number of bees visited when compared to control treatments and it was considered as a repelling insecticide to bee pollinators under field conditions in Himachal Pradesh (Mall and Rathore, 2003).

Mohapatra and Patnaik (2009) reported that dimethoate sprayed on mustard crop at recommended dose revealed 70 per cent Indian bee (*A. c. indica*) mortality was observed after one day spraying in the field of Uttarkhand.

2.3 FORAGING ACTIVITY OF BEE POLLINATORS

2.3.1 Insect fauna in culinary melon

Cervancia and Bergonia (1990) reported that common flower visitors of cucumber were *A. dorsata, Xylocopa chlorinae, X. philippiinensis, Megachileatrata* and were most abundant from 1000 h to 1100 h. Eswarappa (2001) reported that the activity of different species of honey bees either in open plots or caged plots of chow-chow was maximum time spent in collection of pollen was by *A. florea* (14.63 sec.) followed by *A. dorsata* (5.77 sec.) whereas Sharma *et al.* (2001) reported that *A. florea* spent more time spent (37.99 sec./flower and visited ten number of flowers of onion (2.20 per min). Chandel *et al.* (2004) reported that *A. dorsata* has maximum foraging period (06.30- 18.55 h) followed by *A. c. indica* (06.45-18.30 h) and *A. mellifera* had the least foraging period (0.65-18.20 h) on onion seed crop at Himachal Pradesh. Gulati *et al.* (2005) reported that foraging speed of *A. dorsata* (58 sec/flower) during at 0700 - 0800 h in the cotton at Orissa. Neupane *et al.* (2006) reported that foraging activity of giant honey bees (*A. dorsata*) on summer squash (*cucurbita pepo*). Maximum peak activity during 7.30 and 11.00 am (6.83/min/m^2) and 3.00 and 5.30 pm (0.25/min/m^2) during early, mid and late flowering was assessed at Nepal. Ganapathi and Virkthamath (2006) studied the foraging activity of honey bees on transgenic cotton hybrids at Dharwad, results found that bee activity of *A. dorsata, A. florea* and other pollinators was observed from 0800 to 1600 hr with peak visitation during 1000 and 1200 h. The activity of bee pollinators is lowest during 1400 and 1600 h on both the hybrids. Jangaiah (2007) Studied that insect community analysis in cucurbitaceous vegetables and the bees were the predominant insect pollinators like *A. c. indica, A. mellifera* and *Trigona* sp. and also revealed the highest foraging activity was in oriental melon compared to

bitter gourd and snake gourd in Kerala. Brar *et al.* (2009) studied the relative abundance of various insect visitors during blooming of Radish and there were no visitation observed at 0600, 0800 and 1800 h in Punjab. Mupade and Kulkarni (2010) reported that time spent by *A. florea* for pollen foraging varies from 20.00 to 37.00 seconds and nectar it was 8.50 to 43.00 seconds on onion flowers. Pawana *et al.* (2012) studied that relative abundance of *Halictus* sp. was highest, followed *Megachila* sp. and *A. dorsata*. The maximum bee population at 0800 - 1000 h of the day in Hisar. Managanvi *et al.* (2012) reported that peak foraging activities of outgoing and incoming bees were observed at 1100 h with 44.4 foragers/5 minutes and 43.8 foragers/5 minutes. Maximum number of pollen forager noticed in morning hours at 1000 h with 19.6 foragers/5 minutes in Pantnagar.

2.3.2 Relative abundance of bee pollinators

Bee activity is one of the most important factors which aids in pollination. In the process of evolution, flowers have adopted to secrete or produce and offer nectar or pollen in large amounts to attract bees in large numbers. Bee visits almost coincide with the presence of viable pollen and at the time when the stigma is most receptive.

Apis cerana indica

Girish (1981) observed that during February *A. c. indica* began foraging on summer squash at 0600 h during May at Bangalore. Fakuda (1987) reported that honey bee (*A. c. indica*) activity on watermelon flower was highest from 0800 h to 1000 h and the bees visited male flowers more frequently than female flowers in Ezypt. Mohan Rao and Suryanarayana (a) (1988) stated that *A. c. indica* was the principal pollinating insect and was found to be efficient pollinator than *A. florea.* The maximum activity at 0900 h as the pollen gatherers were maximum during this period and also recorded that during pollen collection in watermelon at Vijarai (A.P). Viraktamath (1990) studied the foraging profile of *A. cerana* in Raichur, Karnataka. He observed major pollen foraging (80 per cent) before noon and

foraging throughout the day with a major peak during 0600 -1100 hr and minor peak during 1600 -1800 hr. He further observed more number of pollen and nectar foragers during August – February and August- March respectively, with a dearth period during May- July.

Sattigi *et al.* (1996) reported that in general foraging activity of honey bees (*A. c. indica*) was noticed throughout the day, but it was at its peak between 0800 to 1100 h in winter, 0600 to 1100 h and 1600 to 1800 h in summer and 0800 to 1200 h in monsoon irrespective of the crops in transitional area of Dharwad. The foraging activity was low during other hours of the day in different seasons. Holi and Viraktamath (1997) reported that foraging behaviour was more or less similar in monsoon and winter with a peak activity of outgoing foragers, pollen and nectar foragers during 1100-1300 h in Dharwad. In summer, there were two distinct peaks as against only one during monsoon and winter season. A major outgoing and pollen foragers occurred between 0700-0800 h and a minor peak between 1700-1800 hr. The nectar foragers were maximum between 0700-1000 h and 1700-1800 h. Foraging activities had positive correlation with the temperature and negative correlation with the rainfall and RH in Dharwad conditions.

Eswarappa (2001) reported that the activity of different species of honey bees (*A. c. indica*) either in open plots or caged plots of chow-chow was found to be maximum at 1000 to 1100 h and lowest at 0600 h. Same author reported that the peak pollen foraging activity was found at 1000 h and the time spent by different honey bee species for collection of pollen was found to be maximum between 0800 and 0900 h in chow-chow crops at Bangalore. Prakash (2002) reported that the activity of *A. c. indica* either in open plots or caged plots of cucumber was found to be maximum at 1000 h and lowest at 1800 h. The peak pollen foraging activity of *A. c. indica* was found at 1000 hand also the time spent by different honey bee species in collection of pollen was found to be maximum between 0800 and 0900 h in cucumber at Bangalore.

Jyothi (2003) recorded foraging activity of *A. c. indica* at 1300 h (24.3 to 26.7 bees) and then decreased to 0.00 bees for *A. c. indica* at 1800 h, around Bangalore, whereas Kencharaddi *et al.* (2003) reported that insect pollinators and their abundance in Niger and pollinator activity showed two distinct peaks, one in the morning between 1000 - 1200 h and one in the evening between 16.00 - 18.00 h at Bangalore. Nidagundhi (2004) studied that foraging period of different bee species in which peak activity of *A. florea* was observed at 1200 h, *A. c. indica* and others were active at 1000 h in Dharwad. Sajjanar *et al.*(2004) reported that in cucumber flowers, *A. c. indica* initiated activity by 0600 h, the activity was at a peak (6 bees/m^2/5 min) by 1000 h, declined gradually till 1800 h, whereas, nectar foragers initiated activity by 0700 h, remained in low numbers initially but picked up activity by noon to attain a peak by 1300 h, with 6.89 bees/m^2/5 min, followed by a gradual decline in the activity. Chandel *et al.* (2004) reported that *A. c. indica* (06.45-18.30 h) has maximum foraging period followed by *A. mellifera* had the least foraging period (0.65-18.20 h) on onion in Himachal Pradesh.

Milki and Gowda (2005) studied that comparative foraging activity of hygienic and non hygienic colonies of Indian honey bee (*A. c. indica*) were recorded for 5 minutes between 0600 to 1800 h at hourly interval. Chand and Kumar (2005) reported that foraging activity of honey bee *A. c. indica* on flowering mustard. The activity of both species *A. c. indica* was maximum at 1100 h (10.25 bees/minute/m^2) followed by 1300 h (8.20 bees/minute/m^2) and 0900 h (8.10 bees/minute/m^2), 1500 h (6.60 bees/minute/m^2) at New delhi. Chowde *et al.* (2005) reported that in *A. cerana* number of pollen foragers was more during 9.00 to 11.00 hr; nectar foragers were maximum during 13.00 to 16.00 hr of the day. The number of nectar foragers was maximum during January to April and pollen foragers were maximum during November to December.

Kumar and Singh (2005) reported that abundance of *Apis* spp. at different hours of the day revealed that peak activity was at 1300 h (27.76, 28.51) and minimum at 1500 h

(14.91, 17.62) in the bloom of toria (*Brassica compestris* var. *toria*) at New delhi, whereas Singh *et al.* (2006) studied the relative abundance of *Apis* species were more in early flowering stage than mustard flowers. Jangaiah (2007) observed the relative abundance of different insect pollinators visiting cucurbitaceous vegetables and reported that *A. c. indica* was the dominant one in Kerala. Soni *et al.* (2010) reported that relative abundance of different insect visitors during different day- hours on Pepino bloom was observed and it was found that during morning and evening hours, an average number of 2.35 and 2.36 insects/m^2/10 min visited the bloom respectively at Solan. The maximum relative abundance of *A. c. indica* was recorded 4.22/m^2/10 min. Mohan Rao (b) (2013) reported the foraging of *A. c. indica* as highest during rainy (36.64/5 min. at 1000 h) than during winter (27.00/5 min.) and summer (25.00/5 min.) seasons at 3.00 pm in Vijayarai, Andhra Pradesh.

Apis mellifera

Jyothi (2003) recorded foraging activity of *A. mellifera* peaked between 1000 and 1300 h (35.7 to 37.7 bees) then decreased to 3.6 bees for *A. mellifera* at 1800 h, around Bangalore, whereas Marabi *et al.* (2003) studied on foraging behaviour of Italian bees (*A. mellifera*) on Niger, the foraging activity recorded during 0800 to 1700 h. During 50 per cent flowering peak period were estimated to be 36.14 at 1000 h and 34.71 at 1100 h respectively, whereas during full blooming period the peak period of outgoing and incoming bees from colony where 29.71 at 10.00 and 46.57 at 1100 h respectively. Chand and Kumar (2005) reported that foraging activity of honey bee (*A. mellifera)* on flowering mustard. The activity of *A. mellifera* was maximum at 1100 h (10.25 bees/minute/m^2) followed by 1300 h (8.20 bees/minute/m^2) and 0900 h (8.10 bees/minute/m^2), 1500 h (6.60 bees/minute/m^2). Singh *et al.* (2006) studied the relative abundance of *Apis* species on parental lines *Brassica napus,* Italian bee (*A. mellifera)* was the dominant visitor and maximum abundance of *Apis* species recorded at 1200 h and 1400 h on R and CMS lines respectively. *A. mellifera* L. least visited cucurbit flowers and peak period of activity of the pollinator was noted to be during 1000 h to 1100 h. Soni *et al.* (2010) reported that relative abundance of different insect visitors during different

day- hours on pepino bloom was observed and it was found that during morning and evening hours, an average number of 2.35 and 2.36 bees/m^2/10 min visited the bloom respectively. The maximum relative abundance of *A. mellifera was* 1.56/m^2/10 min. Mohan Rao (2013a) reported the foraging of *A. mellifera* as highest during rainy (36.64/5 min. at 1000 h) than during winter (27.00/5 min) and summer (25.00/5 min.) seasons at 1500 h in Vijayarai, Andhra Pradesh.

Trigona iridipennis

Rakhee and Devanesan (2000) reported that behaviour of the stingless bee (*T. iridipennis*) by maintaining the bee hives whereas Devanesan *et al.* (2002) reported that foraging activity of *T .iridipennis* started around at 0700 h and a gradual rise in activity was observed at 1300 h then increased and reached its second peak at 1500 h and there was almost no activity at 1800 h, around Kerala. Prasad and Chand (2003) reported that foraging activity of stingless bee (*T. iridipennis*) the number of incomings pollen foragers ranged from 0.7 to 2.92/minute while that non pollen foragers varied from 0.34 to 6.94/minute. Maximum foraging activity during February to July and these commenced from early morning and reached its peak at 1000 to 1100 h of the day whereas Bennet *et al.* (2003) Behaviour of stingless bee (*T. iridipennis*) differs from the *Apis* sp around Kerala. Mohan Rao (2013b) reported the foraging of *T. iridipennis* as highest during rainy (36.64/5 min. at 1000 h) than during winter (27.00/5 min) and summer (25.00/5 min.) seasons in Vijayarai, Andhra Pradesh.

2.3.3 Time spent by different bee pollinators

Apis cerana indica

Mohana Rao and Suryanarayana (1988) stated that *A. c. indica* was the principal pollinating insect and was found to be efficient pollinator than *A. florea* in watermelon and *A. c. indica* spent 1.40 to 6.90 seconds on each staminate flower.

They spent less time in the early hours and the time spent was steadily increased up to 1100 h during which time pollen availability was decreased.

Eswarappa (2001) reported that the activity of honey bee *A. c. indica* either in open plots or caged plots of chow-chow was maximum time spent in collection of pollen was by (7.59 sec.) at Bangalore. Prakash (2002) reported that the time spent by *A. c. indica* (38.12 sec on pistillate and 35.31 sec on staminate flower) in Bangalore. Choudhary *et al.* (2002) reported foraging speed by *A. c. indica* (5.37 sec./capitulum). The highest foraging speed recorded at 14.00 h and lowest at 10.00 h in Sunflower. Choudhari *et al.* (2006) studied that foraging speed (time spent in seconds/panicle) was observed to be 2.71, 5.06 and 1.70 seconds by *A. c. indica* but lesser speed was recorded in early morning and again in evening whereas Mupade and Kulkarni (2010) reported that time spent by *A. c. indica* for pollen foraging varies from 8.50 to 21.00 seconds and nectar it was 11.40 to 23.00 seconds on onion flowers at Parbhani.

Apis mellifera

Sharma *et al.* (2001) reported foraging behavior of *A. mellifera* spent least time (1.64 sec) per flower/minute on *Brassica* flowers. Prakash (2002) reported that the time spent by *A. mellifera* (37.47 sec on pistillate and 34.00 sec on staminate flower). Choudhari *et al.*(2006) studied that foraging speed of *A. mellifera* (time spent in seconds/panicle) was observed to be 3.40 seconds by *A. mellifera* at Hissar whereas, Mupade and Kulkarni (2010) reported that time spent by *A. mellifera* for pollen foraging varies from 7.30 to 11.00 seconds and nectar it was 10.50 to 16.00 seconds on onion flowers. Maximum foraging time was spent for pollen and nectar (11.00- 14.00 seconds) at 8-10 h of the day in Parabani.

Trigona iridipennis

Eswarappa (2001) reported that the activity of different species of honey bees either in open plots or caged plots of chow-chow the time spent in collection of pollen was *T. iridipennis*(12.89 sec) whereas, Prakash (2002) reported that the time

spent by *T. iridipennis* (928.61 sec. on pistillate and 271.99 sec. on staminate flower. Mupade and Kulkarni (2010) reported that time spent by *T. iridipennis* for pollen foraging varies from 39.00 to 55.00 seconds and nectar it was 39.00 to 59.00 seconds on onion flowers.

MATERIALS AND METHODS

3. MATERIALS AND METHODS

The laboratory and field experiments on the safety of new generation insecticides to bee pollinators were carried out at All India Co- ordinated Research Project (AICRP) on Honey bees and Pollinators, Department of Agricultural Entomology, College of Agriculture, Vellayani during the year 2012-13. The materials used and the methods followed for these investigations are presented in this chapter.

3.1 LABORATORY EVALUATION OF THE NEW GENERATION INSECTICIDES TO BEE POLLINATORS

The experiment was laid out in completely randomized design with sixteen treatments and three replications. The details of the new generation insecticides used in the laboratory for the evaluation of safety to bee pollinators are depicted in Table 1.

3.1.1 Collection and acclimatization of honey bees

The foraging worker bees were used in the toxicity studies. For the entire experimentation the bees from a particular colony were used, as the susceptibility of different colonies may vary from each other. Colonies of *Apis cerana indica* Fab. *Apis mellifera* L. and *Trigona iridipennis* Smith. were maintained near the experimental site. The foraging bees were collected from the entrance of the hive using thick gauged, wide mouthed plastic containers one side of which was closed with wire mesh using rubber band (Plate 1). The open end of the container mouth was placed near the hive entrance. Air was blown into the hive while gently holding the tube in slanting position to facilitate trapping of bees. On collecting the required number of bees, the open end of the tube was closed with another clean, muslin cloth secured using rubber band. The collected bees were then taken to the laboratory and kept there for one hour to acclimatized them.

Table 1. New generation insecticides used in the laboratory for the evaluation of safety to bee pollinators

Sl. No.	Insecticide groups	Insecticides	Dosag (g a.i. ha^{-1})	Source	Formulation (%)	Trade names
A.	Used against defoliators					
1	Anthranilic diamide	Chlorantraniliprole	30	EI Dupont	18.5 SC	Coragen
2		Flubendiamide	75	Bayer Crop Science	480 SC	Fame
3	Avermectins	Emamectin benzoate	10	Coromandel International Ltd.	5 SG	Benzate
4	Spinosyns	Spinosad	75	Dow Agro Science	45 SC	Tracer
5	Oxadiazine	Indoxacarb	75	EI Dupont	15.8 SC	Avaunt
6	Carbamate	Thiodicarb	750	Bayer Crop Science	75 WP	Larvin
7	Phenyl pyrazole	Fipronil	50	Coromandel International Ltd.	5 SC	Hexanil
8	Nereistoxin	Cartap hydrochloride	500	Excel Crop Care Limited	50 SP	Celtap
B	Used against sucking pests					
9	Chloronicotinyl	Acetamiprid	10	Dow Agro Science	20 SP	Pride
10	Thiazolidine	Thiacloprid	30	Bayer Crop Science	21.7 SC	Calypso
11	Chloronicotinyl	Imidacloprid	20	Bayer Crop Science	17.8 SL	Confidor
12	Thionicotinyl	Clothianidin	20	Nagarjuna Agro Ltd.	50 WDG	Dantop
13	Benzylureas	Buprofezin	250	Tata Rallis India Ltd.	25 SC	Applaud
14	Organophosphates	Acephate	292	Coromandel International Ltd.	75 SP	Ace
15		Dimethoate (Insecticidal Check)	0.05	Tata Rallis India Ltd.	30 EC	Rogor
16		Untreated (Check)				

3.1.2 Preparation of spray solutions of new generation insecticides under laboratory conditions

The following newer molecules of insecticides used against defoliators and sucking pests of vegetables were prepared at the recommended dose as detailed below.

Against defoliators

Chlorantraniliprole

The quantity of 0.32 ml Coragen 18.5 SC was measured in micropipette and it was then dissolved in 1000 ml of water.

Flubendiamide

The solution was prepared by weighing 0.5 g Fame 480 SC on an electronic balance and dissolved in 1000 ml of water.

Emamectin benzoate

The solution was prepared by weighing 0.4 g Benzate 5 SG on an electronic balance and dissolved in 1000 ml of water.

Spinosad

The quantity of 0.32 ml Tracer 45 SC was measured in micropipette and it was then dissolved in 1000 ml of water.

Indoxacarb

The quantity of 1.0 ml Avaunt 15.8 SC was measured in micropipette and it was then dissolved in 1000 ml of water.

Thiodicarb

The solution was prepared by weighing 2 g Larvin 75 WP on an electronic balance and dissolved in 1000 ml of water.

Fipronil

The quantity of 2 ml Hexanil 50 SC was measured in micropipette and it was then dissolved in 1000 ml of water.

Cartap hydrochloride

The solution was prepared by weighing 2 g Celtap 50 SP on an electronic balance and dissolved in 1000 ml of water.

Against sucking pests

Acetamiprid

The solution was prepared by weighing 0.1 g Pride 20 SP on an electronic balance and dissolved in 1000 ml of water.

Thiacloprid

The quantity of 0.27 ml Calypso 21.7 SC was measured in micropipette and it was then dissolved in 1000 ml of water.

Imidacloprid

The quantity of 0.2 ml Confidor 17.8 SL was measured in micropipette and it was then dissolved in 1000 ml of water.

Clothianidin

The solution was prepared by weighing 0.08 g of Dantop 50 WDG on an electronic balance and dissolved in 1000 ml of water.

Buprofezin

The quantity of 2 ml Applaud 25 SC was measured in micropipette and it was then dissolved in 1000 ml of water.

Acephate

The solutions was prepared by weighing 0.77 g of Ace 75 SP on an electronic balance and dissolved in 1000 ml of water.

Dimethoate (Insecticidal Check)

The quantity of 1.32 ml of Rogor 30 EC was measured in micropipette and it was then dissolved in 1000 ml of water.

3.1.3 Assessment of safety/toxicity of new generation insecticides to bee pollinators under laboratory condition

The test insecticides from different new generation groups were evaluated for their safety to three species of honey bees, *A. c. indica*, *A. mellifera* and *T. iridipennis* by dry film technique (Plate 2) using standard procedures (Beevi *et al.*, 2004).

The formulation of the test insecticides at the recommended dose were prepared as described in 3.1.2. Round aquarium glass jar of 12 inch dia. was washed thoroughly and dried. Whatman No.1 filter paper was cut into 7 cm dia. discs and kept at inner lower surface of the glass jar. One ml of the insecticide solution was transferred per jar, using one ml pipette. One glass jar served as one replication. The glass jar and Whatman filter paper with insecticide solution were rotated in both ways, so that the solution coated the inner surface uniformly. The glass jar was

rotated till the water was dried and a thin dry coat of the insecticide only remained. The collected bees were as described in 3.1.1 and kept inside a refrigerator for two minutes to reduce their activity, then they were taken out and immediately transferred to the insecticide treated glass jars, such that only ten worker bee of each species was allowed per glass jar. One ml of 40 per cent honey solution was pipetted out and spread on the filter paper inside the glass jars which served as food for the bees. The mouth of the glass jars were covered with muslin cloth and tied with rubber band which provided enough aeration to the honey bees. The glass jar treated with water alone, having ten bees served as control. Mortality counts of the treated bees were taken at hourly intervals.

3.2 FIELD EVALUATION OF THE SAFETY/TOXICITY OF NEW GENERATION INSECTICIDES TO BEE POLLINATORS

Newer molecules of insecticides, three each from group A and B found less toxic to bee pollinators (three species of bees- *A. c. indica*, *A. mellifera* and *T. iridipennis*) in the laboratory studies were chosen for field evaluation.

3.2.1 Experimental site

The field evaluation of new generation insecticides to test their effect on foraging activity of honey bees was carried out during 2012-13 near the apiary shed of AICRP on Honey bee and Pollinators at the College of Agriculture, Vellayani.

Seeds of culinary melon (*Cucumis melo* var. *acidulus*) vernacularly known as 'Vellari' were sown near apiary shed (Plate 3). The crop husbandry practices were done as envisaged in the package of practice recommendations of Kerala Agricultural University (KAU POP, 2011). The experiment was laid out as detailed below.

Design : RBD

Plot size: 15 m^2

Spacing: 2 X 1.5 m

Number of observational plants per plot: 4

Replications: 3

Treatments: 9

The treatments were:

A. Against defoliators

T1 - Chlorantraniliprole 30 g a.i. ha^{-1}

T2 - Emamectin benzoate 10 g a.i. ha^{-1}

T3 - Spinosad 75 g a.i. ha^{-1}

T4 - Cartap hydrochloride 500 g a.i. ha^{-1}

B. Against sucking pests

T5 - Acetamiprid 10 g a.i. ha^{-1}

T6 - Imidacloprid 20 g a.i. ha^{-1}

T7 - Buprofezin 250 g a.i. ha^{-1}

T8 - Dimethoate 200 g a.i. ha^{-1} (Insecticidal Check)

T9 - Untreated Check

The treatments within each replication were kept one meter apart from each other to avoid drifting while spraying of new generation insecticides.

Strong colonies of four *A. c. indica*, one *A. mellifera* and one *T. iridipennis* were placed at a distance of 5 m from the experimental field at the beginning of 10 per cent flowering. In each plot one square meter area was marked randomly before the application of insecticides. The activity of different species of honey bees recorded from the one m^2 area of culinary melon flowers for a period of five minutes at hourly interval from 6 AM to 6 PM and peak periods of activity of each species

were recorded. The new generation insecticides were sprayed using high volume sprayer during the peak flowering stage. Polythene sheets were placed between the treatment as a barrier to avoid the cross contamination of insecticide due to drifting (Plate 4).

3.2.2 Preparation of spray solutions of new generation insecticides for field application

The commercial formulation of different new generation insecticides recommended in vegetables like, chlorantraniliprole 30 g a.i. ha^{-1}, emamectin benzoate 10 g a.i. ha^{-1}, spinosad 75 g a.i. ha^{-1}, cartap hydrochloride 500 g a.i. ha^{-1}, acetamiprid 10 g a.i. ha^{-1}, imidacloprid 20 g a.i. ha^{-1}, buprofezin 250 g a.i. ha^{-1}, dimethoate 200 g a.i. ha^{-1} (Insecticidal Check) were prepared by mixing of above formulations in 5 litres water for field application.

3.3 FORAGING ACTIVITY OF BEE POLLINATORS

The foraging activity of bee pollinators and other insect visitors *viz.*, wasps, beetles, flies, butterflies and moths were recorded at 10 per cent bloom of culinary melon.

3.3.1 Relative abundance

The relative abundance of different species of honey bees and other insect visitors was recorded as the number of pollinators or flower visitors from the randomly marked one square meter area of each plot for a period of 5 minutes and represented as mean number/m^2/5 minutes at hourly interval from 6 AM to 6 PM. The peak period of activity of each species was noted. Observations were recorded on the relative abundance of bee pollinators before insecticide application and one, three, five, seven, nine, twelve and fifteen days after the insecticide application.

3.3.2 Time spent by bee pollinators on flowers of culinary melon

The foraging time of different species of honey bees were recorded as the number of pollinators or flower visitors. The time spent by a bee (sec.) on an individual flower of culinary melon was recorded from 6 AM to 6 PM by using stop watch. The times spent by different bee pollinators before insecticide application and one, three and seven days after the application of insecticides were recorded.

3.3.3 Pre treatment count of bee pollinators/flower visitors on culinary melon

Different species of insects visiting the culinary melon flowers were observed initially for one, two, three and four days before spraying to generate data about their foraging behaviour. Flying insects, which included bees, wasps, flies and moths were collected with the help of a sweep net having 20, 50 and 30 cm as diameter of the frame, length of the cloth and length of the handle respectively. The collected insects were then brought to the laboratory, killed using chloroform, sorted, pinned, labelled and preserved for identification.

3.3.4 Statistical Analysis

The data generated were subjected to analysis of variance and correlation studies (Panse and Sukhatme, 1985). Wherever the results were significant, the critical difference was worked out at five per cent probability. Per cent mortality in all the treatments was calculated and mortality observed in control treatments was adjusted using Abbots formula (Abbot, 1925). Corrected mortality percentage was transformed into $\sqrt{x+1}$ values and subjected to analysis of variance.

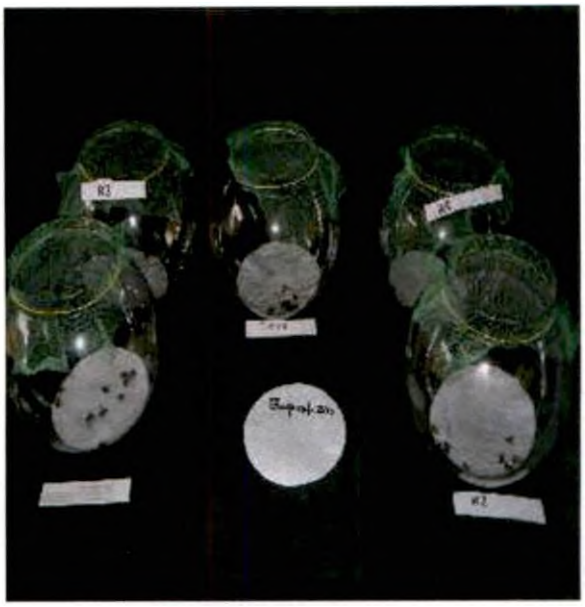
Apis cerana indica

Apis mellifera

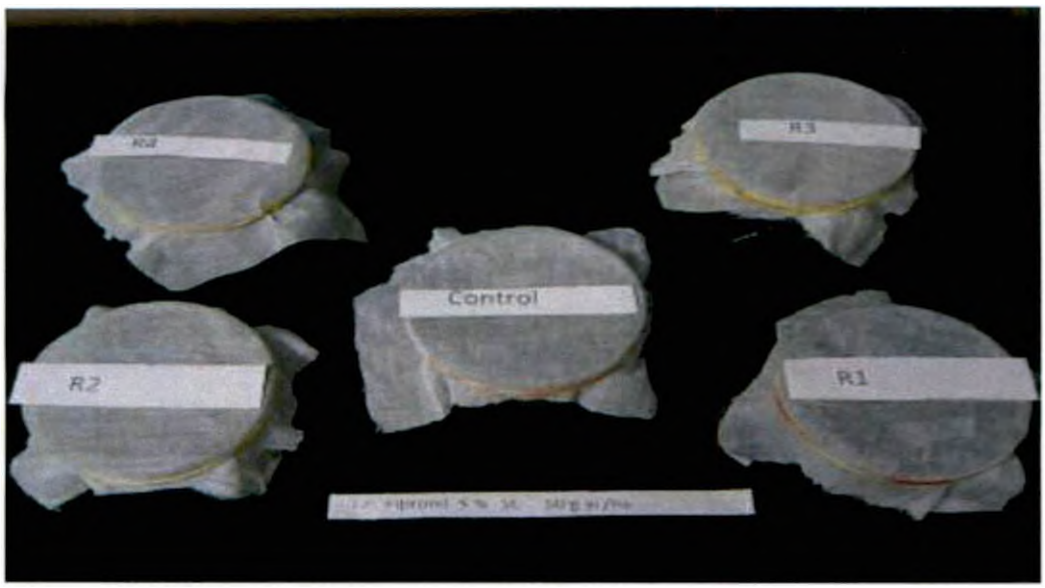
Trigona iridipennis

Plate 1. Various species of bees collected from bee hives

A. c. indica



A. mellifera



T. iridipennis

Plate 2. Testing safety/toxicity of new generation insecticides to three species of bees

Plate 3. General view of experimental site

Plate 4. Spraying of new generation insecticides at 10 per cent flowering of culinary melon

RESULTS

4. RESULTS

The results of the investigation on safety of new generation insecticides to bee pollinators in culinary melon (*Cucumis melo* var. *acidulus*) conducted at All India Co- ordinated Research Project (AICRP) on Honey bees and Pollinators, Department of Agricultural Entomology, College of Agriculture, Vellayani are presented in this chapter.

4.1 LABORATORY EVALUATION OF THE SAFETY/TOXICITY NEW GENERATION INSECTICIDES TO BEE POLLINATORS

The mortality of different species of bees after the application of new generation insecticides recommended against defoliators and sucking pests are vegetables are presented in Table 2 and 3.

4.1.1 Safety/Toxicity of new generation insecticides recommended against defoliators

Mortality of bees at two hours after treatment

Mortality of *A. c. indica* was not recorded in chlorantraniliprole 30 g a.i. ha^{-1}, emamectin benzoate 10 g a.i. ha-1 and thiodicarb 750 g a.i. ha^{-1}, so these were least toxic and safe at two hours after treatment (Table 2). Fipronil 50 g a.i. ha^{-1} recorded 0.64 per cent mortality which was followed by flubendiamide 75 g a.i. ha^{-1}, the mortality being 10.00 per cent. Spinosad 75 g a.i. ha^{-1} which caused 42.00 per cent mortality was on par with cartap hydrochloride 500 g a.i. ha^{-1}, mortality being 47.40 per cent. Indoxacarb 75 g a.i. ha^{-1} recorded the highest mortality and was more toxic at two hours after treatment.

In the case of *A. mellifera* mortality was not recorded in chlorantraniliprole 30 g a.i. ha^{-1}, flubendiamide 75 g a.i. ha-1 and indoxacarb 75 g a.i. $^{ha-1}$ and these were safe at two hours after treatment under laboratory condition. This was followed by thiodicarb 750 g a.i. ha^{-1} (0.64 per cent mortality). Emamectin benzoate 10 g a.i.

ha^{-1} recorded 19.40 per cent mortality which was on par with fipronil 50 g a.i. ha^{-1} which recorded 27.60 per cent mortality. Spinosad 75 g a.i. ha^{-1} and cartap hydrochloride 500 g a.i. ha^{-1} recorded highest mortality of *A. mellifera* at two hours after treatment with a mean value of 60.10 per cent and 65.40 per cent mortality respectively and were on par.

Mortality of *T. iridipennis* was not recorded in chlorantraniliprole 30 g a.i. ha^{-1}, emamectin benzoate 10 g a.i. ha^{-1} and thiodicarb 750 g a.i. ha^{-1}, which were least toxic and safe at two hours after treatment under laboratory condition. This was followed by fipronil 50 g a.i. ha^{-1} and flubendiamide 75 g a.i. ha^{-1}, the mortality being 3.80 per cent and 10.00 per cent respectively which were statistically on par. Indoxacarb 75 g a.i. ha^{-1} and cartap hydrochloride 500 g a.i. ha^{-1} caused 40.00 per cent and 52.50 per cent mortality respectively which were statistically not significant. Spinosad 75 g a.i. ha^{-1} recorded the highest mortality of *T. iridipennis* with a mean value of 73.60 per cent indicating its higher toxicity under laboratory condition.

Mortality of bees at four hours after treatment

Emamectin benzoate 10 g a.i. ha^{-1} recorded least mortality of *A. c. indica* with a mean value of 9.40 per cent followed by chlorantraniliprole 30 g a.i. ha^{-1} recorded 20.00 per cent mortality at four hours after treatment under laboratory condition. The per cent mortality of *A. c. indica* was 47.40, 52.50 and 55.10 for thiodicarb 750 g a.i. ha^{-1}, fipronil 50 g a.i. ha^{-1} and cartap hydrochloride 500 g a.i. ha^{-1} respectively and was on par. This was followed by indoxacarb 75 g a.i. ha^{-1}, mortality being 72.60 per cent which was statistically on par with flubendiamide 75 g a.i. ha^{-1} (78.30 per cent mortality). The highest mortality of *A. c. indica* was recorded in spinosad 75 g a.i. ha^{-1} at four hours after treatment with a mean value of 88.80 per cent and it was more toxic than the other chemicals tested.

The least mortality of (0.64 per cent) of *A. mellifera* was recorded in chlorantraniliprole 30 g a.i. ha^{-1} under laboratory condition at four hours after treatment. Thiodicarb 750 g a.i. ha-1 (13.50 per cent mortality) was statistically on par with indoxacarb 75 g a.i. ha^{-1} (26.50 per cent mortality). Emamectin benzoate 10 g a.i. ha^{-1} recorded 60.00 per cent mortality which was statistically different from other treatments. Flubendiamide 75 g a.i. ha^{-1}, cartap hydrochloride 500 g a.i. ha^{-1} and fipronil 50 g a.i. ha^{-1} were statistically on par, the per cent mortality being 85.80, 86.47 and 99.36 per cent respectively. The cent per cent mortality of *A. mellifera* was recorded in spinosad 75 g a.i. ha^{-1} at four hours after treatment.

Mortality of *T. iridipennis* was not recorded in chlorantraniliprole 30 g a.i. ha-1 at four hours after treatment and was safe under laboratory condition. This was followed by fipronil 50 g a.i. ha^{-1} (55.02 per cent mortality) and thiodicarb 750 g a.i. ha^{-1} (60.10 per cent mortality) which were on par. The next order of toxicity was flubendiamide 75 g a.i. ha^{-1} (67.50 per cent mortality), indoxacarb 75 g a.i. ha^{-1} (70.00 per cent mortality), emamectin benzoate 10 g a.i. ha^{-1} (80.50 per cent mortality) and cartap hydrochloride 500 g a.i. ha^{-1} (99.36 per cent mortality) of *T. iridipennis* under laboratory condition. Spinosad 75 g a.i. ha^{-1} showed highest toxicity and recorded cent per cent mortality of *T. iridipennis* at four hours after treatment.

Mortality of bees at six hours after treatment

Least mortality of *A. c. indica* was observed in chlorantraniliprole 30 g a.i. ha^{-1} (34.50 per cent) at six hours after treatment under laboratory condition. The next order of mortality was shown by emamectin benzoate 10 g a.i. ha^{-1} (67.50 per cent mortality), indoxacarb 75 g a.i. ha^{-1} (88.50 per cent mortality), cartap hydrochloride 500 g a.i. ha^{-1} (91.85 per cent mortality) and thiodicarb 750 g a.i. ha^{-1} (99.20 per cent mortality). Highest mortality (100 per cent) of *A. c. indica* was recorded in flubendiamide 75 g a.i. ha^{-1}, spinosad 75 g a.i. ha^{-1} and fipronil 50 g

Table 2. Mortality of different species of bees after the application of new generation insecticides recommended against defoliators under laboratory condition

Treatments	Dosage (g a.i. ha^{-1})	Mortality of honey bees at different intervals (%)								
		2 HAT			4 HAT			6 HAT		
		A. c. i	*A. m*	*T. i*	*A. c. i*	*A. m*	*T. i*	*A. c i*	*A. m*	*T. i*
Chlorantraniliprole	30	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	20.00 (26.55)	0.64 (4.60)	0.00 (0.00)	34.50 (35.98)	19.40 (26.18)	32.19 (34.54)
Flubendiamide	50	10.00 (18.42)	0.00 (0.00)	10.00 (18.42)	78.30 (62.22)	85.80 (67.80)	67.50 (55.20)	100 (90.00)	100 (90.00)	100 (90.00)
Emamectin benzoate	10	0.00 (0.00)	19.40 (26.18)	0.00 (0.00)	9.40 (17.88)	60.00 (50.87)	80.50 (63.70)	67.50 (55.26)	75.16 (60.00)	99.90 (90.00)
Spinosad	75	42.00 (40.50)	60.10 (50.80)	73.60 (59.11)	88.80 (70.42)	100 (90.00)	100 (90.00)	100 (90.00)	-	-
Indoxacarb	75	57.00 (49.30)	0.00 (0.00)	40.00 (39.21)	72.60 (58.42)	26.50 (31.09)	70.00 (56.70)	88.50 (70.50)	97.10 (80.20)	100 (90.00)
Thiodicarb	750	0.00 (0.00)	0.64 (4.60)	0.00 (0.00)	47.40 (43.54)	13.50 (21.62)	60.10 (50.81)	99.20 (85.12)	89.40 (71.00)	96.78 (79.60)
Fipronil	50	0.64 (4.60)	27.60 (31.7)	3.80 (11.24)	52.50 (46.42)	99.36 (85.30)	55.02 (47.8)	100 (90.00)	100 (90.00)	95.15 (77.30)
Cartap hydrochloride	500	47.40 (43.00)	65.40 (53.9)	52.50 (46.4)	55.10 (47.92)	86.47 (68.30)	99.36 (85.30)	91.85 (73.30)	100 (90.00)	100 (90.00)
C D (0.05)		(6.89)	(16.27)	(10.12)	(11.67)	(15.91)	(8.923)	(10.14)	(14.49)	(15.50)

A. c. i - *Apis cerana indica* A. m - *Apis mellifera* *T. i* - *Trigona iridipennis* HAT - Hours after treatment

Figures in parentheses are angular transformed values.

a.i. ha^{-1} which were statistically on par and highly toxic to bees at six hours after treatment under laboratory condition.

Lowest mortality of *A. mellifera* was recorded in chlorantraniliprole 30 g a.i. ha^{-1} (19.40 per cent) and was safe at six hours after treatment under laboratory condition. The next order of toxicity were emamectin benzoate 10 g a.i. ha^{-1} (75.16 per cent mortality), thiodicarb 750 g a.i. ha^{-1} (89.40 per cent mortality) and indoxacarb 75 g a.i. ha^{-1} (97.10 per cent mortality). There was cent per cent mortality of *A. mellifera* recorded in flubendiamide 75 g a.i. ha^{-1}, spinosad 75 g a.i. ha^{-1}, fipronil 50 g a.i. ha^{-1} and cartap hydrochloride 500 g a.i. ha^{-1} at six hours after treatment which were statistically on par and were more toxic than the treatments.

Least mortality (32.19 per cent) was observed in chlorantraniliprole 30 g a.i. ha^{-1} at six hours after treatment under laboratory condition. Fipronil 50 g a.i. ha^{-1} (95.15 per cent mortality) and thiodicarb 750 g a.i. ha^{-1} (96.78 per cent mortality) were statistically on par with emamectin benzoate 10 g a.i. ha^{-1} (99.90 per cent mortality). *T. iridipennis* recorded cent per cent mortality in flubendiamide 75 g a.i. ha^{-1}, spinosad 75 g a.i. ha^{-1}, indoxacarb 75 g a.i. ha^{-1} and cartap hydrochloride 500 g a.i. ha^{-1} at six hours after treatment under laboratory condition showing its higher toxicity.

4.1.2 Safety/Toxicity of new generation insecticides recommended against sucking pests

The per cent mortality of different species of bees after the application of new generation insecticides recommended against sucking pests in vegetables are presented in Table 3.

Mortality of bees at two hours after treatment

Mortality of *A. c. indica* was not recorded in imidacloprid 20 g a.i. ha^{-1}, buprofezin 250 g a.i. ha^{-1} and dimethoate 200 g a.i. ha^{-1} and were safe at

two hours after treatment (Table 3). Clothianidin 20 g a.i. ha $^{-1}$ and acetamiprid 10 g a.i. ha^{-1} were on par, the mortality being 1.30 per cent and 5.70 per cent respectively. Acephate 292 g a.i. ha^{-1} (34.91 per cent mortality) was statistically on par with thiacloprid 30 g a.i. ha^{-1} which recorded highest mortality of *A. c. indica*, with a mean value of 47.30 per cent was more toxic at two hours after treatment.

Mortality of *A. mellifera* was not recorded in buprofezin 250 g a.i. ha^{-1} and was safe at two hours after treatment under laboratory condition. Acetamiprid 10 g a.i. ha^{-1} (10.00 per cent mortality) and dimethoate 200 g a.i. ha^{-1} (12.91 per cent mortality) were on par. The next order of toxicity was clothianidin 20 g a.i. ha^{-1} (24.80 per cent mortality), imidacloprid 20 g a.i. ha^{-1} (34.90 per cent mortality) and acephate 292 g a.i. ha^{-1} (44.80 per cent) which were on par. Highest mortality of *A. mellifera* was recorded in thiacloprid 30 g a.i. ha^{-1} at two hours after treatment with a mean value of 79.20 per cent and was more toxic.

Mortality of *T. iridipennis* was not recorded in buprofezin 250 g a.i. ha^{-1} and was safe to bees at two hours after treatment under laboratory condition and it was on par with acetamiprid 10 g a.i. ha^{-1} (1.33 per cent mortality). This was followed by dimethoate 200 g a.i. ha^{-1} (18.60 per cent mortality). The next order of toxicity was recorded in thiacloprid 30 g a.i. ha^{-1} and clothianidin 20 g a.i. ha^{-1} which were statistically on par with the mortality of 79.20 per cent and 80.00 per cent respectively. Highest mortality of *T. iridipennis* was recorded in imidacloprid 20 g a.i. ha^{-1} and acephate 292 g a.i. ha^{-1} with a mean value of 99.90 per cent each which were more toxic to bees under laboratory condition.

Mortality of bees at four hours after treatment

Least mortality was recorded in acetamiprid 10 g a.i. ha^{-1} (17.23 per cent mortality) and was safe to *A. c. indica* at four hours after treatment. Buprofezin 250 g a.i. ha^{-1} (34.60 per cent mortality and dimethoate 200 g a.i. ha^{-1} (34.65 per

cent mortality) were on par. Imidacloprid 20 g a.i. ha^{-1}, clothianidin 20 g/ha and acephate 292 g a.i. ha^{-1} recorded 70.00 per cent, 73.40 per cent and 83.23 per cent mortality of *A. c. indica* respectively. Highest (100 per cent) mortality of *A. c. indica* was recorded in thiacloprid 30 g a.i. ha^{-1} and was more toxic at four hours after treatment under laboratory condition.

Mortality of *A. mellifera* was not recorded in buprofezin 250 g a.i. ha^{-1} and was least toxic and safe and was on par with acetamiprid 10 g a.i. ha^{-1} (1.33 per cent) and this was followed by dimethoate 200 g a.i. ha^{-1} (18.60 per cent) which was significantly different from clothianidin 20 g a.i. ha^{-1} (80.00 per cent mortality) and thiacloprid 30 g a.i. ha^{-1} (85.30 per cent mortality) which were on par. Highest mortality of *A. mellifera* was recorded in imidacloprid 20 g a.i. ha^{-1} and acephate 292 g a.i. ha^{-1} at four hours after treatment with a mean value of 99.90 per cent each under laboratory condition.

Least mortality was recorded in buprofezin 250 g a.i. ha^{-1} (10.00 per cent) and was safe to *T. iridipennis* at four hours after treatment. The per cent mortality of *T. iridipennis* was significantly different in acetamiprid 10 g a.i. ha^{-1} (39.89 per cent) and dimethoate 200 g a.i. ha^{-1} (72.01 per cent) at four hours after treatment. Highest (100 per cent) mortality of *T. iridipennis* was recorded in thiacloprid 30 g a.i. ha^{-1}, imidacloprid 20 g a.i. ha^{-1}, clothianidin 20 g a.i. ha^{-1} and acephate 292 g a.i. ha^{-1} was very toxic to bees at four hours after treatment.

Mortality of bees at six hours after treatment

Buprofezin 250 g a.i. ha^{-1} recorded 42.47 per cent mortality of *A. c. indica* at six hours after treatment under laboratory condition. The next order of mortality was in acetamiprid 10 g a.i. ha^{-1} (94.70 per cent mortality) and dimethoate 200 g a.i. ha^{-1} (99.28 per cent) and which were statistically on par. There was cent per

Table 3. Mortality of different species of bees after the application of new generation insecticides recommended against sucking pests under laboratory condition

Treatments	Dosage (g a.i. ha^{-1})	Mortality of honey bees at different hour intervals (%)								
		2 HAT			4 HAT			6 HAT		
		A. c. i	*A. m*	*T. i*	*A .c. i*	*A. m*	*T. i*	*A. c. i*	*A. m*	*T. i*
Acetamiprid	10	5.70 (13.80)	10.00 (18.42)	1.33 (6.63)	17.23 (24.52)	1.33 (6.63)	39.89 (39.10)	94.70 (76.70)	78.32 (62.22)	60.10 (50.81)
Thiacloprid	30	47.30 (43.40)	79.20 (62.80)	79.20 (62.80)	100 (90.00)	85.30 (67.40)	100 (90.00)	-	100 (90.00)	-
Imidacloprid	30	0.00 (0.00)	34.90 (36.20)	99.90 (90.00)	70.00 (57.07)	99.90 (90.00)	100 (90.00)	100 (90.00)	-	-
Clothianidin	20	1.30 (6.60)	24.80 (29.80)	80.00 (63.40)	73.40 (58.90)	80.00 (63.40)	100 (90.00)	100 (90.00)	100 (90.00)	-
Buprofezin	250	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	34.60 (36.00)	0.00 (0.00)	10.00 (18.40)	42.47 (40.60)	20.76 (27.00)	10.00 (18.42)
Acephate	292	34.91 (36.20)	44.80 (42.03)	99.90 (90.00)	83.23 (65.80)	99.90 (90.00)	100 (90.00)	100 (90.00)	-	-
Dimethoate (I.C)	200	0.00 (0.00)	12.91 (21.04)	18.60 (25.50)	34.65 (36.05)	18.60 (25.50)	72.01 (58.00)	99.28 (85.10)	100 (90.00)	99.19 (84.81)
CD (0.05)		(11.39)	(14.72)	(10.99)	(10.14)	(10.99)	(5.70)	(17.00)	(17.24)	(10.55)

A. c. i - Apis cerana indica *A. m - Apis mellifera* *T. i - Trigona iridipennis* HAT - Hours after treatment

(I.C) – Insecticidal Check Figures in parentheses are angular transformed values.

cent mortality of *A. c. indica* in thiacloprid 30 g a.i. ha^{-1}, imidacloprid 20 g a.i. ha^{-1}, clothianidin 20 g a.i. ha^{-1} and acephate 292 g a.i. ha^{-1} and were more toxic.

Buprofezin 250 g a.i. ha^{-1} recorded only 20.76 per cent mortality *A. mellifera,* which inturn was safe at six hours after treatment. Acetamiprid 10 g a.i. ha^{-1} recorded 78.32 per cent mortality. Highest mortality of *A. mellifera* (cent per cent) was recorded in thiacloprid 30 g a.i. ha^{-1}, imidacloprid 20 g a.i. ha^{-1}, clothianidin 20 g a.i. ha^{-1}, acephate 292 g a.i. ha^{-1} and dimethoate 200 g a.i. ha^{-1} at six hours after treatment under laboratory condition and were more toxic.

Buprofezin 250 g a.i. ha^{-1} was comparatively safe as it recorded only 10.00 per cent mortality of *T. iridipennis* at six hours after treatment. Acetamiprid 10 g a.i. ha^{-1} (60.10 per cent mortality) was not statistically significant with dimethoate 200 g a.i. ha^{-1} which recorded 99.19 per cent mortality. Cent per cent mortality was recorded in thiacloprid 30 g a.i. ha-1, imidacloprid 20 g a.i. ha^{-1}, clothianidin 20 g a.i. ha^{-1} and acephate 292 g a.i. ha^{-1} at six hours after treatment and were more toxic under laboratory condition.

4.2 FIELD EVALUATION OF THE SAFETY/TOXICITY NEW GENERATION INSECTICIDES TO BEE POLLINATORS

New generation insecticides *viz.*, chlorantraniliprole 30 g a.i. ha^{-1}, emamectin benzoate 10 g a.i. ha^{-1}, spinosad 75 g a.i. ha-1, cartap hydrochloride 500 g a.i. ha^{-1}, acetamiprid 10 g a.i. ha^{-1}, imidacloprid 20 g a.i. ha^{-1}, buprofezin 250 g a.i. ha^{-1}, dimethoate 200 g a.i. ha^{-1} (Insecticidal Check) were found least toxic to bee pollinators in the laboratory studies were evaluated under field conditions.

4.2.1 Insect fauna on culinary melon

The insect pollinators/flower visitors, pests and natural enemies observed on culinary melon during the study period is presented Table 4.

Insect pollinators/flower visitors

The total number of different species of insect pollinators/flower visitors recorded on the flowers of culinary melon was 15. Of these, hymenoptera, coleoptera, diptera and lepidoptera were represented by 8, 3, 2 and 2 respectively. The hymenopterans consisted of two species from the family apidae, one species each from meliponidae, megachilidae, halictidae, xylocopidae, anthophoridae, bombylidae. Among all these, the major pollinators were *A. c. indica*, *A. mellifera* and *T. iridipennis* belonging to the families apidae and meliponidae under hymenoptera (Plate 5). The coleopterans included three species from family chrysomelidae. The dipterans were represented by one species each from the families of tephritidae and tachnidae. The two lepidopterans were represented by one species each from the families of papilionidae and lycaenidae. *Papilio polytes stichus* Hubner and *Lampides boeticus* L (Plate 6) were the flower visitors belonging to the order lepidopteran. The major coleopterans included *Aulacophora foveicollis* L., *A. stevensi* Baly and *A. lewesi* Baly. *Bactrocera cucurbitae* Coq. was the dipteran in culinary melon.

Insect pests

The total number of insect pests recorded on the flowers of culinary melon was 11. Of these, five species belonged to the order coleoptera, two species each from diptera and lepidoptera and one species each from orthoptera and hemiptera. There were three species from the family chrysomelidae and one species each from coccinellidae and cetonidae in coleoptera. There was one species each from families of tephritidae and agromyzidae in the order diptera. The two lepidopterans

A. c. indica

A. mellifera

T. iridipennis

Andrena sp.

Unidentified

Xylocopa sp.

Plate 5. Hymenopterans visiting on the flowers of culinary melon

Aulacophora foveicollis

Aulacophora lewesi

Lampides sp.

Lampides boeticus

Plate 6. Coleopterans and lepidopterans visiting on the flowers of culinary melon

Table 4. Occurrence of different insect pollinators on culinary melon

Common names	Scientific names	Family	Order
1. Insect pollinators/flower visitors			
Indian bee	*Apis cerana indica* Fab.	Apidae	Hymenoptera
Italian bee	*Apis mellifera* L.	Apidae	
Stingless bee	*Trigona iridipennis* Smith.	Meliponidae	
Leaf cutter bee	*Megachila* sp.	Megachilidae	
	Helictus sp.	Halictidae	
Carpenter bees	*Xylocopa* sp.	Xylocopidae	
Solitary bees	*Andrena* sp.	Anthophoridae	
	Bombus sp.	Bombylidae	
Melon fly	*Bactrocera cucurbitae* Coq.	Tephritidae	Diptera
	Unidentified	Tachnidae	
Pumpkin beetles	*Aulacophora foveicollis* Lucas *Aulacophora lewesi* Baly *Aulacophora stevensi* Baly	Chrysomelidae	Coleoptera
Swallow butterfly	*Papilio polytes stichius* Hubner	Papilionidae	Lepidoptera
Blue butterfly	*Lampides boeticus* L.	Lycaenidae	
2. Insect pests			
Pumpkin beetles	*Aulacophora foveicollis* Lucas *Aulacophora lewesi* Baly *Aulacophora stevensi* Baly	Chrysomelidae	Coleoptera
Epilachna beetle	*Henosepilachna* sp.	Coccinellidae	Coleoptera
Rose chaffer beetles	*Oxycetonia* sp.	Cetonidae	
American serpentine leaf miner	*Liriomyza trifoli* Burgess	Agromyzidae	Diptera
Pumpkin caterpillar	*Diaphania indica* Saunders	Pyraustidae	Lepidoptera
Snake gourd caterpillar	*Anadevedia peponis* Fb.	Pyraustidae	
Green grass hopper	*Atractomorpha crenulata* Fabr.	Acrididae	Orthoptera
Leaf footed bug	*Leptoglossus australis* F.	Coreidae	Hemiptera
3. Natural enemies			
Coccinellid beetles	*Menochilus sexmaculatus* Fab.	Coccinellidae	Coleoptera
Parasitoids	*Cotesia* sp. *Chrysocharis johnsoni* Walker	Braconidae Eulophidae	Hymenoptera
Praying mantids	*Mantis religiosa*	Mantidae	Mantodea

were from the family pyraustidae. There was one species from orthoptera which belonged to the family acrididae and one species from hemiptera which belonged to the family coreidae. Among all these, the major pests were *Aulacophora foveicollis.*, *A. lewesi.* and *Henosepilachna* sp. belonging to coleopterans. *Liriomyza trifoli, B. cucurbitae, Diaphania indica* Saunders and *Anadevedia peponis* Fb. were the insect pests belonging to the order diptera and lepidoptera respectively (Plate 7).

Natural Enemies

There were two species of predators and two species of parasitoids found on culinary melon. The two species of predators belonged to the order coleoptera and mantodea, one each from the family coccinellidae and mantidae respectively. The two species (*Cotesia* sp. and *Chrysocharis johnsonii* Walker) of parasitoids were from the order hymenoptera which belonged to the family of braconidae and eulophidae respectively (Plate 8).

4.2.2 Relative abundance of insect pollinators/flower visitors under pesticide free condition

Relative abundance of insect pollinators/flower visitors *viz.*, *A. c. indica*, *A. mellifera* and *T. iridipennis* visiting flowers of culinary melon at various times of a day under pesticide free conditions are presented in Table 5. The population of insect pollinators visited on culinary melon flowers was recorded at different time intervals on the seventh week after sowing (peak flowering stage) and expressed as mean number of bees/m^2/5 minutes.

A. c. indica and *T. iridipennis* started the foraging activity at 6 AM and continued up to 6 PM whereas *A. mellifera* began their activity at 7 AM and continued up to 6 PM.

Aulacophora foveicolis

Bactrocera cucurbitae

Liriomyza trifoli

Diaphania indica

Atractomorpha crenulata

Henosepilachna sp.

Plate 7. Symptoms of major pests of culinary melon

Cotesia sp.

Menochilus sexmaculatus

Unidentified

Mantis religiosa

Plate 8. Natural enemies of pests of culinary melon

The peak foraging activity of *A. c. indica* was at 10 AM (5.26) followed by 11 AM (4.36) and 9 AM (4.16). The second peak activity was at 2 PM (4.00) and was on par with foraging activity at 12 noon (3.76) and 1 PM (3.60). The minimum foraging activity was recorded at 6 AM (0.10) and was on par with the population observed at 6 PM (0.66) and 5 PM (1.33).

The peak foraging activity of *A. mellifera* was recorded at 10 AM with 3.40 bees/m^2/5 minutes and was significantly higher than the rest of the day. The second peak activity was at 11 AM (3.16) which was on par with the foraging activity at 9 AM, 12 noon and 2 PM with the mean number 3.03, 2.80 and 2.76 respectively. The minimum foraging activity was recorded at 6 AM (0.00) and on par with 6 PM (0.43), 7 PM (1.43) and 5 PM (1.60).

In the case of *T. iridipennis* the maximum activity was recorded at 10 AM with the mean number 5.80 and it was significantly higher than the rest of the hours of the day. There was no significant difference in the relative abundance of *T. iridipennis* at 10 AM, 9 AM, 11 AM and 12 noon and the population ranged from 4.30 to 5.80. The minimum foraging activity was recorded at 6 AM and 6.00 PM with the mean number 1.13 and 1.10 respectively. These were on par with 5 PM (2.60).

The relative abundance of coleopterans recorded at 10 AM and 3 PM were maximum with the mean number (2.06 each) and was on par with the mean number recorded at 5 PM (1.80), 8 AM (1.76) and 9 AM (1.66). The relative abundance recorded at 6 AM with the mean number (0.50) was on par with the population observed at other times of the day and the mean number ranged from 0.50 to 1.60.

Dipterans recorded at 5 PM with the mean number (2.03) was on par with the relative abundance at 10 AM and 4 PM (1.43 each). The second peak activity was

Table 5. Relative abundance of insect pollinators on culinary melon at various times under pesticide free condition

Time (h)	Mean number/m^2/5 minutes						
	A. c. indica	*A. mellifera*	*T. iridipennis*	Coleoptera	Diptera	Lepidoptera	Other insect visitors
6.00 AM	0.10	0.00	1.13	0.50	0.16	0.26	0.33
7.00	2.43	1.43	3.40	1.56	0.80	1.06	1.40
8.00	3.16	2.40	3.90	1.76	1.10	1.23	1.46
9.00	4.16	3.03	4.36	1.66	0.90	0.76	0.83
10.00	5.26	3.40	5.80	2.06	2.03	1.80	1.86
11.00	4.36	3.16	5.10	1.50	1.20	0.70	1.10
12.00	3.76	2.80	4.30	1.66	0.80	1.40	0.60
1.00	3.60	2.70	3.50	1.66	1.00	1.10	1.00
2.00	4.00	2.76	3.40	1.43	1.03	1.43	1.50
3.00	3.23	2.56	3.60	2.06	0.80	0.90	1.50
4.00	2.66	2.43	4.06	1.60	1.43	1.20	1.00
5.00	1.33	1.60	2.60	1.80	1.43	1.53	1.10
6.00 PM	0.66	0.43	1.10	1.50	1.03	0.73	1.20
C D (0.05)	0.89	0.64	0.98	0.74	0.69	0.94	0.90

recorded at 11 AM (1.20) which was on par with the relative abundance at 8 AM, 1 PM and 6 PM with the mean number (1.10), (1.00) and (1.03) respectively. The relative abundance recorded at 6 AM (0.16) and was on par with the activity at 7 AM, 12 noon and 3 PM with the mean number (0.80 each).

In the case of lepidopterans, the relative abundance recorded at 4 PM with the mean number (1.80) was on par with the observations at 5 PM, 1 PM, 12 noon and 8 AM with the mean number (1.53), (1.13), (1.23) and (1.06) respectively. The minimum activity was recorded at 6 AM, 6 PM and 9 AM with the mean number (0.26), (0.73) and (0.76) respectively.

The relative abundance of other insect visitors observed at 10 AM with mean number (1.86) was on par with the mean number at 2 PM, 3 PM (1.50 each), 8 AM (1.46) and 7 AM (1.40). The activity of other insect visitors recorded at 6 AM (0.33) was on par with the relative abundance at 12 noon, 9 AM with a mean number 0.60 and 0.83 respectively.

The peak activity of coleopteran and dipteran insect visitors were recorded at 10 AM with mean number (2.06), (2.03) respectively. Similarly the peak activity of lepidopteran recorded (1.80) and that of other insect visitors were recorded at 10 AM (1.86).

4.2.3 Time spent by different bee pollinators on flowers of culinary melon under pesticide free condition

The mean time spent by different bee pollinators *viz.*, *A. c. indica*, *A. mellifera* and *T. iridipennis* on flowers of culinary melon recorded at seventh week after sowing (peak flowering stage) under pesticide free condition are given in Table 6.

The maximum time spent by *A. c. indica* was 5.06 seconds/flower at 10 AM and was statistically on par with the time spent at 9 AM and 11 AM, the

Table 6. Time spent by bee pollinators on culinary melon flowers at various times under pesticide free condition

Time (hrs.)	Number of seconds/flower		
	A. c. indica	*A. mellifera*	*T. iridipennis*
6.00 AM	1.83	0.16	0.16
7.00	2.80	1.43	1.43
8.00	3.16	2.40	2.40
9.00	4.40	2.90	2.90
10.00	5.06	4.30	4.36
11.00	4.30	3.40	3.40
12.00	3.60	2.80	2.80
1.00	3.40	2.70	2.70
2.00	3.90	2.70	2.76
3.00	3.36	2.56	2.56
4.00	2.86	2.43	2.43
5.00	1.93	1.63	1.60
6.00 PM.	1.36	0.43	0.43
C D (0.05)	0.59	0.61	0.61

mean value being 4.40 and 4.30 seconds/flower respectively. The next highest time spent by *A. c. indica* was 3.90 seconds at 2 PM, which was statistically on par with 3.60 seconds/flower at 12 noon. During rest of the period the time spent by *A. c. indica* ranged from 1.36 seconds to 3.40 seconds/flower. The minimum time spent was 1.36 seconds at 6 PM.

The maximum time spent by *A. mellifera* was 4.30 seconds/flower of culinary melon at 10 AM and was statistically on par with 3.40 seconds at 11 AM. The next highest time spent was 2.90 seconds recorded at 9 AM, which was statistically on par with 2.80, 2.70 and 2.70 seconds observed at 12 noon, 1 PM and 2 PM respectively. The minimum time spent by *A. mellifera* was 0.16 seconds followed by 0.43 seconds at 6 AM and 6 PM respectively. During rest of the day the time spent ranged from 0.16 seconds to 2.56 seconds/flower.

In the case of *T. iridipennis*, the maximum time spent was recorded as 4.36 seconds/flower at 10 AM and was statistically on par with 3.40 seconds at 11 AM. The next highest time spent was recorded as 2.90 seconds which was statistically on par with 2.80 seconds at 12 noon. The minimum time spent by *T. iridipennis* was 0.16 seconds followed by 0.43 seconds at 6 PM. The time spent by *T. iridipennis* ranged from 0.16 to 2.76 seconds/flower during the rest of the day.

4.2.4 Relative abundance of bee pollinators after application of new generation insecticides

The relative abundance of bee pollinators *viz., A. c. indica, A. mellifera* and *T. iridipennis* at different days after the application of new generation insecticides and expressed as number of bees/m^2/5 minutes is given in Table 7.

Apis cerana indica

Observations on the relative abundance of *A. c. indica* visiting flowers of culinary melon at different days after spraying new generation insecticides showed that there was significant reduction in the relative abundance of *A. c. indica* on the first day after spraying in all the treatments over untreated check (2.66) except chlorantraniliprole 30 g a.i. ha^{-1} which recorded a highest mean value of (3.00) and buprofezin 250 g a.i. ha^{-1}, the mean value being 2.66 bees/m^2/5 minutes and these were statistically on par and safe to *A. c. indica.* The lowest population of *A. c. indica* (1.00) was recorded in emamectin benzoate 10 g a.i. ha^{-1} which was significantly lower than the other treatments. The next order toxicity of different insecticides to *A. c. indica* was spinosad 75 g a.i. ha^{-1} (1.33), imidacloprid 20 g a.i. ha^{-1} (1.33), acetamiprid 10 g a.i. ha^{-1} (1.66), cartap hydrochloride 500 g a.i. ha^{-1} (2.00), dimethoate 200 g a.i. ha^{-1} (2.00) inturns of relative abundance.

The relative abundance of *A. c. indica* recorded in chlorantraniliprole 30 g a.i. ha^{-1} and untreated check were 3.00 bees/m^2/5 minutes each and it was statistically on par with cartap hydrochloride 500 g a.i. ha^{-1} and buprofezin 250 g a.i. ha-1, the mean value being 2.66 bees/m^2/5 minutes each which in turn was safer to *A. c. indica* on the third day after spraying. The order of toxicity of the evaluated new generation insecticides to *A. c. indica* was acetamiprid 10 g a.i. ha^{-1} (1.66), emamectin benzoate 10 g a.i. ha^{-1} (1.33), imidacloprid 20 g a.i. ha^{-1} (1.00), dimethoate 200 g a.i. ha^{-1} (1.00) and spinosad 75 g a.i. ha^{-1} (0.33).

The relative abundance of *A. c. indica* on the fifth day after spraying of new generation insecticides showed that chlorantraniliprole 30 g a.i. ha^{-1} (3.00), buprofezin 250 g a.i. ha^{-1} (2.66) were safer than other new generation insecticides tested. The order of toxicity was similar to one day after spraying.

The relative abundance on the seventh day after spraying of new generation insecticides revealed that the mean number of *A. c. indica* recorded from chlorantraniliprole 30 g a.i. ha^{-1} (3.00), untreated check (3.00), buprofezin 250 g a.i. ha^{-1} (2.66) and dimethoate 200 g a.i. ha^{-1} (2.66) were statistically on par and safer at 7 DAS. The order of toxicity of the other new generation insecticides tested ranged from 1.00 to 2.33 bees/m^2/5 minutes.

The highest relative abundance (4.33) was recorded in buprofezin 250 g a.i. ha^{-1} which indicates its safety to *A. c. indica* on 9 DAS. Significantly lower population of *A. c. indica* was recorded in emamectin benzoate 10 g a.i. ha^{-1}, imidacloprid 20 g a.i. ha^{-1} and spinosad 75 g a.i. ha^{-1} (1.66 each) when compared to all other treatments on the ninth day after spraying. The relative abundance of *A. c. indica* in chlorantraniliprole 30 g a.i. ha^{-1}, cartap hydrochloride 500 g a.i. ha^{-1}, acetamiprid 10 g a.i. ha^{-1} and dimethoate 200 g a.i. ha-1 ranged from 2.66 to 3.00 bees/m^2/5 minutes and were statistically on par with the untreated check (3.66).

The relative abundance of *A. c. indica* in all the treatments were not statistically significant except untreated check and chlorantraniliprole 30 g a.i. ha^{-1} which were on par and recorded the highest mean value of 3.33 bees/m^2/5 minutes each on 12 DAS. The relative abundance ranged from 1.33 to 2.33 bees/ m^2/5 minutes for the rest of the treatments

Maximum relative abundance of *A. c. indica* was recorded in untreated check (3.33) which was on par with the insecticidal check, dimethoate 200 g a.i. ha^{-1} (3.00), chlorantraniliprole 30 g a.i. ha^{-1}, imidacloprid 20 g a.i. ha^{-1} and buprofezin 250 g a.i. ha^{-1} (2.66 bees/m^2/5 minutes each). The relative abundance of *A. c. indica* recorded at 15 DAS ranged from 1.66 to 2.33 bees/m^2/5 minutes for the rest of the treatments.

Table 7. Relative abundance of *Apis cerana indica* on culinary melon flowers at different days after spraying of new generation insecticides

Chemicals	Dosage (g a.i. ha^{-1})	Mean number/m^2/5 minutes						
		1 DAS	3 DAS	5 DAS	7 DAS	9 DAS	12 DAS	15 DAS
Chlorantraniliprole	30	3.00	3.00	3.00	3.00	2.66	3.33	2.66
Emamectin benzoate	10	1.00	1.33	1.00	1.33	1.66	1.33	1.66
Spinosad	75	1.33	0.33	1.33	1.00	1.66	2.00	2.33
Cartap hydrochloride	500	2.00	2.66	2.00	2.33	3.00	1.66	2.33
Acetamiprid	10	1.66	1.66	1.66	2.00	3.00	2.33	2.33
Imidacloprid	20	1.33	1.00	1.33	2.00	1.66	2.00	2.66
Buprofezin	250	2.66	2.66	2.66	2.66	4.33	2.33	2.66
Dimethoate (Insecticidal check)	200	2.00	1.00	2.00	2.66	3.00	2.33	3.00
Untreated check		2.66	3.00	2.66	3.00	3.66	3.33	3.33
C D (0.05)		1.53						

DAS – Days after spraying

Apis mellifera

Observations on the relative abundance of *A. mellifera* visiting flowers of culinary melon at different days after spraying of new generation insecticides presented in Table 8. The lowest relative abundance of *A. mellifera* was recorded in imidacloprid 20 g a.i. ha^{-1} (1.33), spinosad 75 g a.i. ha^{-1} (1.66), emamectin benzoate 10 g a.i. ha^{-1} and cartap hydrochloride 500 g a.i. ha^{-1} (2.00 bees/m^2/5 minutes each) which were significantly lower than the other treatments on the first day after spraying. The relative abundance of *A. mellifera* was 3.00 bees/m^2/5 minutes in chlorantraniliprole 30 g a.i. ha^{-1}, dimethoate 200 g a.i. ha^{-1} and untreated check and it was on par with acetamiprid 10 g a.i. ha^{-1} and buprofezin 250 g a.i. ha^{-1} (2.66 bees/m^2/5 minutes each).

The relative maximum abundance of *A. mellifera* recorded in untreated check (3.33), chlorantraniliprole 30 g a.i. ha^{-1} and buprofezin 250 g a.i. ha^{-1} (2.66 bees/m^2/5 minutes each) were statistically on par with spinosad 75 g a.i. ha^{-1}, acetamiprid 10 g a.i. ha^{-1} and dimethoate 200 g a.i. ha^{-1} (2.00 bees/m^2/5 minutes each). The relative abundance of *A. mellifera* ranged from 1.33 to 1.66 bees/m^2/5 minutes in the rest of the new generation insecticides evaluated on the third day after spraying.

The relative abundance of *A. mellifera* on the fifth day after spraying of new generation insecticides showed that chlorantraniliprole 30 g a.i. ha^{-1} and dimethoate 200 g a.i. ha-^{1} recorded the same mean value (3.00) as that of the untreated check (3.00) which were statistically on par with acetamiprid 10 g a.i. ha^{-1} and buprofezin 250 g a.i. ha^{-1} (2.66 bees/m^2/5 minutes each). The mean number of *A. mellifera* recorded in the remaining treatments ranged from 1.33 to 2.00 bees/m^2/5 minutes.

The relative abundance of *A. mellifera* after spraying of new generation insecticides revealed that the mean number recorded in buprofezin 250 g a.i. ha^{-1}, emamectin benzoate 10 g a.i. ha^{-1} (3.00 each) followed by chlorantraniliprole 30 g a.i. ha^{-1} and acetamiprid 10 g a.i. ha^{-1} (2.66 each), which inturn was on par with untreated check, cartap hydrochloride 500 g a.i. ha^{-1} and dimethoate 200 g a.i. ha^{-1} (2.33 each). The lowest relative abundance was recorded in imidacloprid 20 g a.i. ha^{-1} and spinosad 75 g a.i. ha^{-1} (2.00 each) at 7 DAS.

Significantly lower relative abundance of *A. mellifera* was recorded in emamectin benzoate 10 g a.i. ha^{-1} and imidacloprid 20 g a.i. ha^{-1} (1.66 each) when compared to all other treatments. The highest relative abundance of 3.33 bees/m^2/5 minutes was recorded in chlorantraniliprole 30 g a.i. ha^{-1} which indicated its safety to *A. mellifera* at nine days after spraying. The relative abundance of *A. mellifera* ranged from 2.00 to 3.00 bees/m^2/5 minutes in rest of the treatments including untreated check.

The relative abundance of *A. mellifera* in all the treatments were not statistically significant on 12 DAS except emamectin benzoate 10 g a.i. ha^{-1} (3.33), chlorantraniliprole 30 g a.i. ha^{-1}, imidacloprid 20 g a.i. ha^{-1}, buprofezin 250 g a.i. ha^{-1} and untreated check (3.00 bees/m^2/5 minutes each) which were statistically on par with acetamiprid 10 g a.i. ha^{-1} and dimethoate 200 g a.i. ha^{-1} (2.66 each). The relative abundance of *A. mellifera* ranged from 2.00 to 2.33 bees/m^2/5 minutes for the rest of the treatments on 12 DAS.

Maximum relative abundance of *A. mellifera* was recorded in untreated check (3.66) which was on par with buprofezin 250 g a.i. ha^{-1}, acetamiprid 10 g a.i. ha^{-1}(3.33 bees/m^2/5 minutes each) followed by chlorantraniliprole 30 g a.i. ha^{-1}, emamectin benzoate 10 g a.i. ha^{-1} and imidacloprid 20 g a.i. ha^{-1} (3.00

Table 8. Relative abundance of *Apis mellifera* on culinary melon flowers at different days after spraying of new generation insecticides

Chemicals	Dosage (g a.i. ha^{-1})	Mean number/m^2/5 minutes						
		1 DAS	3 DAS	5 DAS	7 DAS	9 DAS	12 DAS	15 DAS
Chlorantraniliprole	30	3.00	2.66	3.00	2.66	3.33	3.00	3.00
Emamectin benzoate	10	2.00	1.33	2.00	3.00	1.66	3.33	3.00
Spinosad	75	1.66	2.00	1.66	2.00	2.00	2.00	2.00
Cartap hydrochloride	500	2.00	1.33	2.00	2.33	2.00	2.33	2.33
Acetamiprid	10	2.66	2.00	2.66	2.66	2.66	2.66	3.33
Imidacloprid	20	1.33	1.66	1.33	2.00	1.66	3.00	3.00
Buprofezin	250	2.66	2.66	2.66	3.00	3.00	3.00	3.33
Dimethoate (Insecticidal check)	200	3.00	2.00	3.00	2.33	2.00	2.66	2.66
Untreated check		3.00	3.33	3.00	2.33	3.00	3.00	3.66
C D (0.05)		1.53						

DAS – Days after spraying

bees/m^2/5 minutes each). The relative abundance of *A. mellifera* recorded at 15 DAS ranged from 2.00 to 2.66 bees /m^2/5 minutes for the rest of the treatments.

Trigona iridipennis

The relative abundance of *T. iridipennis* visiting flowers of culinary melon at different days after spraying of new generation insecticides presented in Table 9. There was significant reduction in the relative abundance of all the treatments over untreated check (3.00) except buprofezin 250 g a.i. ha^{-1} and chlorantraniliprole 30 g a.i. ha^{-1} recorded the mean value being 3.66 and 2.33 bees/m^2/5 minutes respectively on the first day after spraying. The lowest population of *T. iridipennis* was recorded in emamectin benzoate 10 g a.i. ha^{-1}, spinosad 75 g a.i. ha-1, acetamiprid 10 g a.i. ha-1 and dimethoate 200 g a.i. ha^{-1} (1.33 bees /m^2/5 minutes each) which in turn was on par with cartap hydrochloride 500 g a.i. ha^{-1} (1.66) and imidacloprid 20 g a.i. ha^{-1} (2.00) on 1 DAS.

The relative abundance of *T. iridipennis* recorded on the third day after spraying showed that chlorantraniliprole 30 g a.i. ha^{-1} (4.33 bees/m^2/5 minutes) and was statistically on par with untreated check (3.00 bees/m^2/5 minutes). The order of toxicity of the remaining new generation insecticides evaluated for safety to *T. iridipennis* ranged from 0.33 to 2.33 bees/m^2/5 minutes at 3 DAS.

The relative abundance of *T. iridipennis* on the fifth day after spraying of new generation insecticides showed that buprofezin 250 g a.i. ha^{-1} (3.66) and chlorantraniliprole 30 g a.i. ha^{-1} (2.33) were safer than other new generation insecticides tested and these were statistically on par with untreated check. The order of toxicity was similar to one day after spraying.

The relative abundance on the seventh day after spraying of new generation insecticides revealed that the mean number of *T. iridipennis* recorded from buprofezin 250 g a.i. ha^{-1}, chlorantraniliprole 30 g a.i. ha^{-1}, untreated check (3.00 each bees/m^2/5 minutes) and emamectin benzoate 10 g a.i. ha^{-1} (2.66) were statistically on par and safer at 7 DAS. The order of toxicity of the other new generation insecticides tested ranged from 1.66 to 2.33 bees/m^2/5 minutes.

The highest relative abundance was in chlorantraniliprole 30 g a.i. ha^{-1} (3.66) and untreated check (3.66) which were on par with buprofezin 250 g a.i. ha^{-1} (3.00) indicating its safety to *T. iridipennis* on 9 DAS. The relative abundance of *T. iridipennis* ranged from 2.66 to 3.33 bees/m^2/5 minutes in the rest of the treatments. Significantly lower population of *T. iridipennis* was recorded in spinosad 75 g a.i. ha^{-1} (1.33), imidacloprid 20 g a.i. ha^{-1} (1.66 bees/m^2/5 minutes acetamiprid 10 g a.i. ha-1 and cartap hydrochloride 500 g a.i. ha^{-1} (2.00 bees/m^2/5 minutes each) when compared to all other treatments.

Buprofezin 250 g a.i. ha^{-1} and untreated check recorded the highest relative abundance of *T. iridipennis* (3.33 bees/m^2/5 minutes each) which was on par with chlorantraniliprole 30 g a.i. ha^{-1} (3.00) and was safe on 12 DAS. The relative abundance of *T. iridipennis* in the remaining treatments ranged from 2.00 to 2.66 bees/ m^2/5 minutes.

Maximum relative abundance of *T. iridipennis* was recorded in buprofezin 250 g a.i. ha^{-1} (4.00) followed by untreated check (3.33), acetamiprid 10 g a.i. ha-1 (3.33), cartap hydrochloride 500 g a.i. ha^{-1} and dimethoate 200 g a.i. ha^{-1} (3.00 bees/m^2/5 minutes) which were on par. The relative abundance of *T. iridipennis* recorded at 15 DAS ranged from 1.66 to 2.66 bees/m^2/5 minutes for the rest of the treatments.

Table 9. Relative abundance of *Trigona iridipennis* on culinary melon flowers at different days after spraying of new generation insecticides

Chemicals	Dosage (g a.i. ha^{-1})	Mean number/m^2/5 minutes						
		1 DAS	3 DAS	5 DAS	7 DAS	9 DAS	12 DAS	15 DAS
Chlorantraniliprole	30	2.33	4.3	2.33	3.00	3.66	3.00	2.66
Emamectin benzoate	10	1.33	1.33	1.33	2.66	2.66	2.66	2.33
Spinosad	75	1.33	0.66	1.33	1.66	1.33	2.33	1.66
Cartap hydrochloride	500	1.66	0.33	1.66	1.66	2.00	2.33	3.00
Acetamiprid	10	1.33	0.33	1.33	1.66	2.00	2.33	3.33
Imidacloprid	20	2.00	0.33	2.00	2.33	1.66	2.00	1.66
Buprofezin	250	3.66	2.33	3.66	3.00	3.00	3.33	4.00
Dimethoate (Insecticidal check)	200	1.33	0.33	1.33	1.66	3.33	2.00	3.00
Untreated check		3.00	3.00	3.00	3.00	3.66	3.33	3.33
C D (0.05)		1.53						

DAS- Days after spraying

4.2.5 Time spent by bee pollinators after application of new generation insecticides

The time spent by *A. c. indica, A. mellifera* and *T. iridipennis* for collection of nectar and pollen from flowers of culinary melon at different intervals after spraying of new generation insecticides and expressed as number of seconds/flower is presented in Table 10, 11 and 12 respectively.

Apis cerana indica

There was significant reduction in the time spent by *A. c. indica* in all treatments over untreated check which was on par with buprofezin 250 g a.i. ha^{-1} (3.50 seconds/flower each) on the first day after spraying of new generation insecticides. The lowest time spent by *A. c. indica* was recorded in emamectin benzoate 10 g a.i. ha^{-1} (0.16 seconds). The time spent by *A. c. indica* ranged from 0.33 to 2.83 seconds/flower in the remaining treatments.

The lowest time spent by *A. c. indica* was recorded in imidacloprid 20 g a.i. ha-1 (2.16 seconds/ flower) and was on par with spinosad 75 g a.i. ha^{-1} (2.50 seconds), chlorantraniliprole 30 g a.i. ha^{-1}, cartap hydrochloride 500 g a.i. ha^{-1} (2.66 seconds/ flower each) and untreated check (2.80 seconds/ flower). Emamectin benzoate 10 g a.i. ha^{-1} recorded the highest time (4.66 seconds/flower) spent by *A. c. indica* which was on par with buprofezin 250 g a.i. ha^{-1} (3.66 seconds/flower). The rest of the treatments recorded 3.16 seconds/flower.

The highest time spent by *A. c. indica* was in emamectin benzoate 10 g a.i. ha^{-1} (4.33 seconds/flower) and was on par with acetamiprid 10 g a.i. ha^{-1}, buprofezin 250 g a.i. ha^{-1} (3.66 seconds/flower each) and untreated check (3.60 seconds/flower) which in turn was on par with cartap hydrochloride 500

Table 10. Time spent by *Apis cerana indica* on flowers of culinary melon at different days after spraying of new generation insecticides

Chemicals	Dosage (g a.i. ha^{-1})	Number of seconds/flower		
		1 DAS	3 DAS	7 DAS
Chlorantraniliprole	30	2.83	2.66	2.50
Emamectin benzoate	10	0.16	4.66	4.33
Spinosad	75	0.33	2.50	1.66
Cartap hydrochloride	500	2.80	2.66	3.33
Acetamiprid	10	2.50	3.16	3.66
Imidacloprid	20	1.16	2.16	2.83
Buprofezin	250	3.50	3.66	3.66
Dimethoate (Insecticidal check)	200	1.16	3.16	2.90
Untreated check		3.50	2.80	3.60
C D (0.05)		2.96		

DAS – Days after spraying

g a.i. ha^{-1} (3.33 seconds/flower). The lowest time spent by *A. c. indica* was recorded in spinosad 75 g a.i. ha^{-1} (1.66 seconds/flower), chlorantraniliprole 30 g a.i. ha^{-1} (2.50 seconds/flower) and imidacloprid 20 g a.i. ha^{-1} (2.83 seconds/flower) which were on par with dimethoate 200 g a.i. ha^{-1} (2.90 seconds/flower) on seventh day after spraying.

Apis mellifera

The highest time spent by *A. mellifera* was recorded in chlorantraniliprole 30 g a.i. ha^{-1} and buprofezin 250 g a.i. ha^{-1} the mean value being 3.16 and 3.33 seconds/flower respectively at one day after spraying (1 DAS). The lowest time spent by *A. mellifera* was recorded in dimethoate 200 g a.i. ha^{-1} (1.16 seconds) followed by spinosad 75 g a.i. ha^{-1} (1.33 seconds/flower), emamectin benzoate 10 g a.i. ha^{-1} (1.66 seconds/flower) and cartap hydrochloride 500 g a.i. ha^{-1} (1.83 seconds/flower) which were statistically on par with the imidacloprid 20 g a.i. ha^{-1} (2.80 seconds/flower) and acetamiprid 10 g a.i. ha^{-1} (3.10 seconds/flower).

Dimethoate 200 g a.i. ha^{-1} (1.33 seconds/flower) was on par with imidacloprid 20 g a.i. ha^{-1} (2.50 seconds/flower) on third day after spraying of new generation insecticides. There was no significant difference in cartap hydrochloride 500 g a.i. ha^{-1}, spinosad 75 g a.i. ha^{-1}, chlorantraniliprole 30 g a.i. ha^{-1} and acetamiprid 10 g a.i. ha^{-1} the mean value being 3.00, 3.16, 3.16 and 3.33 seconds/flower respectively. The highest time spent by *A. mellifera* was recorded in untreated check (6.16 seconds/flower) on 3 DAS.

The highest time spent was recorded in untreated check (5.33 seconds/flower) which was on par with chlorantraniliprole 30 g a.i. ha^{-1} (4.66 seconds/flower) and buprofezin 250 g a.i. ha^{-1} (4.33 seconds/flower). The time spent ranged from 3.33 to 3.66 seconds/flower in the remaining treatments

Table 11. Time spent by *Apis mellifera* on flowers of culinary melon at different days after spraying of new generation insecticides

Chemicals	Dosage (g a.i. ha^{-1})	Number of seconds/flower		
		1 DAS	3 DAS	7 DAS
Chlorantraniliprole	30	3.16	3.16	4.66
Emamectin benzoate	10	1.66	3.50	3.33
Spinosad	75	1.33	3.16	2.33
Cartap hydrochloride	500	1.83	3.00	3.33
Acetamiprid	10	3.10	3.33	3.66
Imidacloprid	20	2.80	2.50	3.66
Buprofezin	250	3.33	3.33	4.33
Dimethoate (Insecticidal check)	200	1.16	1.33	2.33
Untreated check		3.50	6.16	5.33
C D (0.05)		2.96		

DAS – Days after spraying

on 7 DAS. The lowest time spent by *A. mellifera* was recorded in dimethoate 200 g a.i. ha^{-1} (2.33 seconds/flower) and was statistically on par with spinosad 75 g a.i. ha^{-1} (2.33 seconds/flower) on seventh day after spraying.

Trigona iridipennis

The time spent by *T. iridipennis* was highest in untreated check (30.83 seconds/flower) and this was followed by chlorantraniliprole 30 g a.i. ha-1 (19.16 seconds/flower) and buprofezin 250 g a.i. ha^{-1} (13.33 seconds/flower) on the first day after spraying. The lowest time spent by *T. iridipennis* was recorded in dimethoate 200 g a.i. ha^{-1}, acetamiprid 10 g a.i. ha^{-1}, emamectin benzoate 10 g a.i. ha^{-1} spinosad 75 g a.i. ha^{-1} (0.00 seconds/flower each), which was followed by cartap hydrochloride 500 g a.i. ha^{-1} and imidacloprid 20 g a.i. ha^{-1} (1.66 seconds/flower each).

The highest time spent by *T. iridipennis* was recorded in buprofezin 250 g a.i. ha^{-1} (24.16 seconds/flower). The time spent by *T. iridipennis* ranged from 9.16 to 15.50 seconds/flower for the rest of the treatments at 3 DAS. The lowest time spent by *T. iridipennis* was recorded in cartap hydrochloride 500 g a.i. ha^{-1} (0.00 seconds/flower) followed by dimethoate 200 g a.i. ha^{-1}, acetamiprid 10 g a.i. ha-1 and imidacloprid 20 g a.i. ha^{-1} (1.66 seconds/flower each) on the third day after spraying.

The highest time spent by *T. iridipennis* was recorded in buprofezin 250 g a.i. ha^{-1} and untreated check (35.00 seconds /flower each) which was on par with chlorantraniliprole 30 g a.i. ha^{-1} (29.33 seconds/flower). The time spent by *T. iridipennis* ranged from 11.66 to 15.00 seconds/flower at 7 DAS. The lowest time spent by *T. iridipennis* was recorded in dimethoate 200 g a.i. ha^{-1} (6.00 seconds/flower) followed by imidacloprid 20 g a.i. ha^{-1} (8.00 seconds/flower) and acetamiprid 10 g a.i. ha^{-1} (8.33 seconds/flower) on seventh day after spraying.

Table 12. Time spent by *Trigona iridipennis* on flowers of culinary melon at different days after spraying of new generation insecticides

Chemicals	Dosage (g a.i. ha^{-1})	Number of seconds/flower		
		1 DAS	3 DAS	7 DAS
Chlorantraniliprole	30	19.16	9.16	29.33
Emamectin benzoate	10	0.00	15.00	15.00
Spinosad	75	0.00	11.60	11.66
Cartap hydrochloride	500	1.66	0.00	13.00
Acetamiprid	10	0.00	1.66	8.33
Imidacloprid	20	1.66	1.66	8.00
Buprofezin	250	13.33	24.16	35.00
Dimethoate (Insecticidal check)	200	0.00	1.66	6.00
Untreated check		30.83	15.50	35.00
C D (0.05)		2.96		

DAS – Days after spraying

DISCUSSION

5. DISCUSSION

The problem of pesticide toxicity to honey bees, the primary pollinator of crops, is an area of prime concern. as pesticide use in such crops resulted in high bee mortality. The continuous need for novel and selective insecticides to combat the pest problems in vegetable ecosystem necessitated the formulation of new molecules of insecticides targeted for pest management. Vegetable growers are using newly introduced chemicals without knowing their deleterious effects/ safety to non target organisms like bee pollinators and natural enemies. Though the safety of different conventional pesticides to honey bees was worked out, there is need to evaluate the safety of newer molecules of-insecticides with label claim for the management of pests of vegetables. Hence, the study was taken and the results obtained from the laboratory and field studies on the safety of the new generation insecticides recommended against defoliators *viz.*, chlorantraniliprole18.5 SC @ 30 g a.i. ha^{-1}, flubendiamide 480 @ 75 g a.i. ha^{-1}, emamectin benzoate 5 SG @ 10 g a.i. ha^{-1}, spinosad 45 SC @ 75 g a.i. ha^{-1}, indoxacarb 15.8 SC @ 75 g a.i. ha^{-1}, thiodicarb 75 WP @ 750 g a.i. ha^{-1}, fipronil 5 SC @ 50 g a.i. ha^{-1} and cartap hydrochloride 50 SP @ 500 g a.i. ha^{-1} and sucking pests *viz.*, acetamiprid 20 SP @ 10 g a.i. ha^{-1}, thiacloprid 21.7 SC @ 30 g a.i. ha^{-1}, imidacloprid 17.8 SL @ 20 g a.i. ha^{-1}, clothianidin 50 WDG @ 20 g a.i. ha^{-1}, buprofezin 25 SC @ 250 g a.i. ha^{-1}, acephate 75 SP @ 292 g a.i. ha^{-1} and the conventional insecticide dimethoate 30 EC @ 200 g a.i. ha^{-1} to three most common hive species of honey bee *viz., Apis cerana indica, Apis mellifera* and *Trigona iridipennis* are discussed under the following heads.

5.1 LABORATORY EVALUATION OF THE SAFETY/TOXICITY OF NEW GENERATION INSECTICIDES TO BEE POLLINATORS

Assessment of the safety of bee pollinators when exposed to new generation insecticides recommended against defoliators of vegetables

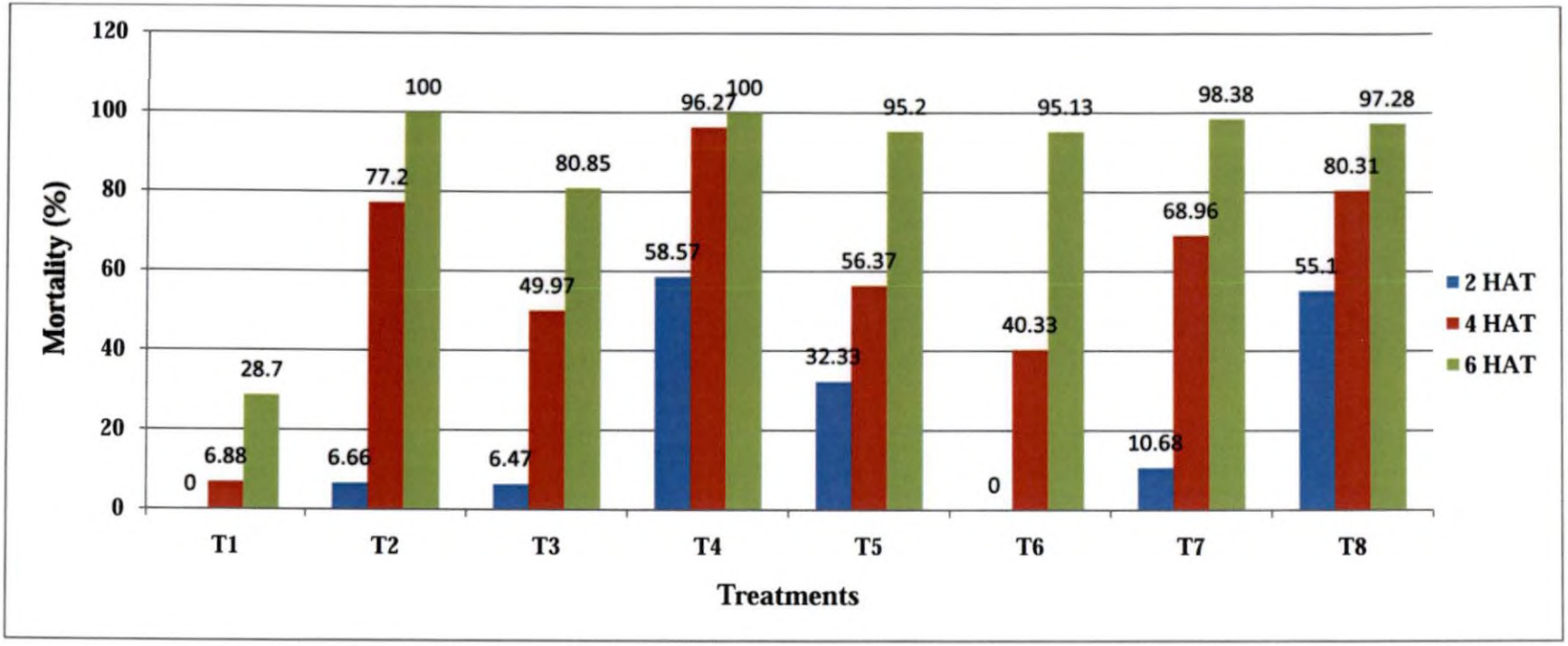
(Fig. 1) showed that chlorantraniliprole 30 g a.i. ha-1 and thiodicarb 750 g a.i. ha^{-1} had no toxicity to the bee pollinators when recorded two hours after treatment. Emamectin benzoate 10 g a.i. ha^{-1} (6.47 per cent), flubendiamide 75 g a.i. ha^{-1} (6.66 per cent) and fipronil 50 g a.i. ha^{-1} (10.68 per cent) too recorded low mortality of the bees followed by indoxacarb 75 g a.i. ha^{-1} (32.33 per cent). Cartap hydrochloride 500 g a.i. ha^{-1} (55.10 per cent) and spinosad 75 g a.i. ha^{-1} (58.57 per cent) showed higher toxicity to the bees.

Four hours after treatment, 6.88 per cent, 40.33 per cent and 49.97 per cent mortality of the bee pollinators was recorded in chlorantraniliprole 30 g a.i. ha^{-1}, thiodicarb 750 g a.i. ha^{-1} and emamectin benzoate 10 g a.i. ha^{-1}, respectively. Higher mortality of the bees was seen in indoxacarb 75 g a.i. ha^{-1} (56.37 per cent), fipronil 50 g a.i. ha^{-1} (68.96 per cent), flubendiamide 75 g a.i. ha^{-1} (77.20 per cent), cartap hydrochloride 500 g a.i. ha^{-1} (80.31 per cent) and spinosad 75 g a.i. ha^{-1} (96.27 per cent) treatments.

Again chlorantraniliprole 30 g a.i. ha^{-1} recorded least mortality (28.70 per cent) of bee pollinators and was found safe at six hours after treatment compared to all other insecticides evaluated. The mortality of bee pollinators recorded in the other treatments ranged from 80.85 to 100 per cent.

Considering the effect of the new generation insecticides on individual bee species, chlorantraniliprole 30 g a.i. ha^{-1} was found to be least toxic at the three time intervals observed, the mortality being 0.00 per cent to 34.50 per cent for *A. c. indica*, 0.00 per cent to 19.40 per cent for *A. mellifera* and 0.00 per cent to 32.19 per cent for *T. iridipennis*. Emamectin benzoate 10 g a.i. ha^{-1} recorded 0.00 per cent to 67.50 per cent mortality for *A. c. indica*, 19.40 to 75.16 per cent for *A. mellifera* and 0.00 to 99.90 per cent for *T. iridipennis* during the different hours tested. The order of safety of other insecticides to the different bees was thiodicarb, indoxacarb, cartap hydrochloride, fipronil and flubendiamide. Comparatively spinosad was more toxic to the bees, the mortality percentage recorded being 42.00

Fig. 1. Mortality of bee pollinators when exposed to new generation insecticides recommended against defoliators



T1: Chlorantraniliprole 30 g a.i. ha^{-1}

T2: Flubendiamide 75 g a.i. ha^{-1}

T3: Emamectin benzoate 10 g a.i. ha^{-1}

T4: Spinosad 75 g a.i. ha^{-1}

T5: Indoxacarb 75 g a.i. ha^{-1}

T6: Thiodicarb 750 g a.i. ha^{-1}

T7: Fipronil 50 g a.i. ha^{-1}

T8:Cartaphydrochloride 500 g a.i. ha^{-1}

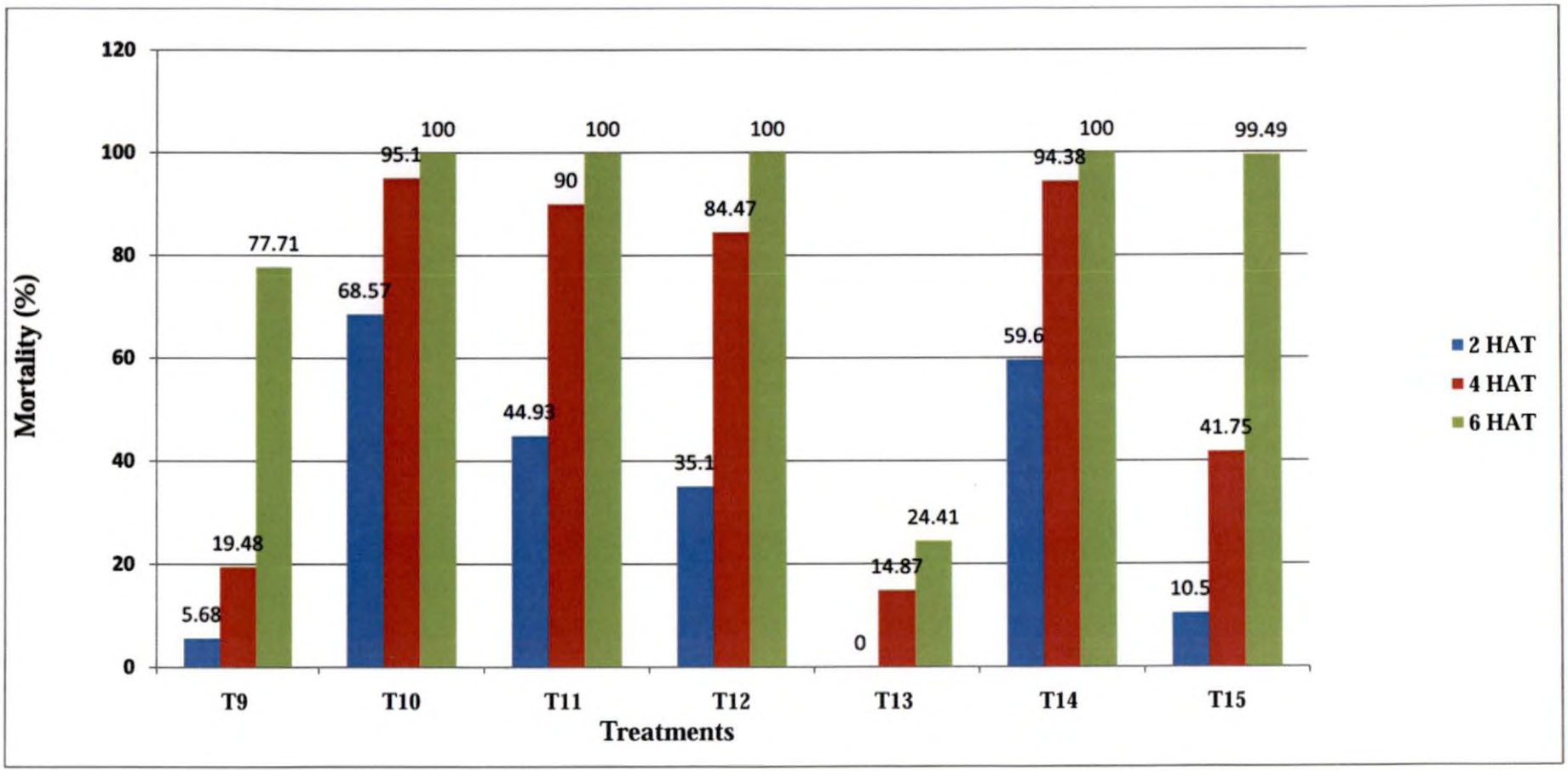
per cent to 100 per cent for *A. c. indica*, 60.10 per cent to 100 per cent for *A. mellifera* and 73.60 per cent to 100 per cent for *T. iridipennis*.

The results of the study are in agreement with the findings of several other research workers. The safety of chlorantraniliprole to honey bees observed in the present study conforms to the report of Dinter *et al.* (2009) who reported its safety to *A. mellifera* and the bumble bee, *B. terrestris* at 0.005 µg/bee through contact toxicity. The observations on the toxicity of cartap hydrochloride and spinosad to the bees observed in the present study corroborate the earlier reports of Cleveland *et al.* (2002) who showed that spinosad was acutely toxic to bees under laboratory conditions. Thomizawa and Cassida (2005) reported the acute toxicity of cartap hydrochloride 500 SP in *A. mellifera* and found 100 per cent mortality of bees after 360 minutes in the laboratory conditions at UK. Cartap hydrochloride was highly toxic by ingestion and moderately toxic by indirect contact on foraging honey bees under laboratory conditions in USA (Arzone and Patetta, 2011). In contrast to the findings of the present study, where flubendiamide recorded 77.20 to cent per cent mortality of bee pollinators, (NRAVC) National Registration Authority for Agricultural and Veterinary Chemicals (2009) reported the safety of flubendiamide to honey bees (*A. mellifera*) in Australia. The variation might be due to difference in the method of testing, exposure time, formulation strength and honey bee species.

Assessment of the safety of bee pollinators when exposed to new generation insecticides recommended against sucking pests of vegetables (Fig. 2) showed that mortality was not recorded in buprofezin 250 g a.i. ha^{-1} at two hours after treatment and this was followed by acetamiprid 10 g a.i. ha^{-1} (5.68 per cent) and dimethoate 200 g a.i. ha^{-1} (10.50 per cent). The next order of toxicity was imidacloprid 20 g a.i. ha^{-1} 44.93 per cent, acephate 292 g a.i. ha^{-1} (59.60 per cent) and thiacloprid 30 g a.i. ha^{-1} (68.57 per cent).

Buprofezin 250 g a.i. ha^{-1} recorded least mortality of bee pollinators at four hours after treatment (14.87 per cent) and at six hours after treatment (24.40 per

Fig. 2. Mortality of bee pollinators when exposed to new generation insecticides recommended against sucking pests



T9: Acetamiprid 10 g a.i. ha^{-1}

T10: Thiacloprid 30 g a.i. ha^{-1}

T11: Imidacloprid 20 g a.i. ha^{-1}

T12: Clothianidin 20 g a.i. ha^{-1}

T13: Buprofezin 250 g a.i. ha^{-1}

T14: Acephate 292 g a.i. ha^{-1}

T15: Dimethoate 200 g a.i. ha^{-1}

cent). The same trend was followed by acetamiprid 10 g a.i. ha^{-1} where the cumulative per cent mortality gradually increased from 19.48 per cent to 77.71 per cent, as the time of exposure advanced. The next order of toxicity was dimethoate 200 g a.i. ha^{-1}, clothianidin 20 g a.i. ha^{-1}, imidacloprid 20 g a.i. ha^{-1}, acephate 292 g a.i. ha^{-1} and thiacloprid 30 g a.i. ha^{-1}.

Considering the effect of new generation insecticides to individual bee species, buprofezin 250 g a.i. ha^{-1} was found to be least toxic at the three time intervals, the mortality being 0.00 per cent to 42.47 per cent for *A. c. indica*, 0.00 per cent to 20.76 per cent for *A. mellifera* and 0.00 per cent to 10.00 per cent for *T. iridipennis*.

Acetamiprid 10 g a.i. ha^{-1} recorded the mortality of individual bee species ranging from 5.70 per cent to 94.70 per cent for *A. c. indica*, 10.00 per cent to 78.32 per cent for *A. mellifera* and 1.33 per cent to 60.10 per cent for *T. iridipennis* during the different hours tested. The mortality percentage of imidacloprid *A. c. indica* ranged from 0.00 per cent to 100 per cent for *A. mellifera* 34.90 per cent to 100 per cent and 99.90 per cent to 100 per cent for *T. iridipennis*. Comparatively thiacloprid and acephate were highly toxic to the bees.

The observations made in the present study conform to that of NRAVC (2001) who reported that buprofezin 100 μg/bee was safe to bees by either contact or ingestion method. Rabia *et al.* (2005) and Pastagia and Patel (2007) reported highest mortality of Indian bees (*A. c. indica*) when exposed to imidacloprid which is in agreement with the results obtained for imidacloprid in the present study.

From the overall assessment of the laboratory studies, among the insecticides against defoliators of vegetables chlorantraniliprole18.5 SC @ 30 g a.i. ha^{-1}, emamectin benzoate 5 SG @ 10 g a.i. ha^{-1} which proved comparatively less toxic to the bees in the laboratory were selected for field evaluation. Literature scan showed that in field studies dry residues of spinosad was safe to foraging worker bees with no adverse effect on mortality (Miles, 2003). Since spinosad is commonly used by

the vegetable growers it was included for field evaluation. Similarly cartap hydrochloride, though found toxic to bee pollinators in the laboratory was chosen for field evaluation, since it is commonly used by vegetable growers against leaf miner incidence.

Among the treatments, buprofezin 25 SC @ 250 g a.i. ha^{-1}, acetamiprid 20 SP @ 10 g a.i. ha^{-1} and imidacloprid 17.8 SL @ 20 g a.i. ha^{-1} (yellow labeled) recommended against sucking pests of vegetables were included for field evaluation along with the conventional insecticide dimethoate 30 EC @ 200 g a.i. ha^{-1} as insecticidal check. Though the mortality of individual bee species was high, imidacloprid 20 g a.i. ha^{-1} is commonly used by the vegetable growers and hence it was included for field evaluation.

5.2 FIELD EVALUATION OF THE SAFETY/TOXICITY OF NEW GENERATION INSECTICIDES TO BEE POLLINATORS

Cucurbitaceae is considered as one of the largest botanical families of vegetables produced and consumed (Prem, 2007). Cucurbitaceae with its unisexuality stands unique as entomophilous family since insect pollination is chiefly of wide occurrence in bisexual plants. Though a wide variety of vegetables are cultivated in Kerala, cucurbitaceous vegetables are dominant, among them culinary melon (*Cucumis melo* var. *acidulus*) is most common. Moreover, insect community analysis of cucurbitaceous vegetables revealed the prevalence of 18 different insect pests in all stages of the crop (Jangaiah, 2007). Newly formulated chemicals are being widely used for the control of pests in the crop. Hence the crop was selected for assessing the safety of the newer molecules to the bee pollinators under field conditions. The following newer molecules of insecticides *viz.*, chlorantraniliprole 30 g a.i. ha^{-1}, emamectin benzoate 10 g a.i. ha^{-1}, spinosad 75 g a.i. ha^{-1}, cartap hydrochloride 500 g a.i. ha^{-1}, acetamiprid 10 g a.i. ha^{-1}, imidacloprid 20 g a.i. ha^{-1}, buprofezin 250 g a.i. ha^{-1} found less toxic to bee pollinators (three species of bees- *A. c. indica*,

A. mellifera and *T. iridipennis*) in the laboratory studies were chosen for field evaluation along with the insecticidal check dimethoate 200 g a.i. ha^{-1} in culinary melon. Prior to the evaluation of the insecticides in the field, the pollinator/flower visitors of the crop and their relative abundance under natural conditions were studied.

5.2.1 Insect fauna on culinary melon

Fifteen different pollinators/flower visitors could be recorded on culinary melon (Fig. 3). Of these, order hymenoptera (40 per cent) was dominant followed by coleoptera (20 per cent), lepidoptera (16 per cent), diptera (16 per cent) and hemiptera (8 per cent). Pest fauna included three species of coleoptera, two species of lepidoptera, two species of diptera and other minor pests. The natural enemies observed were two species of predators *viz., Menochilus sexmaculatus* and *Mantis religiosa* and two species of parasitoids *viz., Cotesia* sp. and *Chrysocharis johnsoni.* Similar observations were reported from Bangalore by Prakash (2002) who found that cucumber crop was visited by 27 insect species, of which 16 belonging to Hymenoptera and four each to Diptera, Lepidoptera and Coleoptera. The hymenopterans *viz., A. dorsata, A. cerana, A. florea* and *T. iridipennis* comprised more than 82 per cent of the total insect pollinators. From Kerala, Jangaiah (2007) observed the different groups of insect pollinators on cucurbitaceous vegetables, which included hymenoptera (38 per cent), lepidoptera (21 per cent), coleoptera (17 per cent), diptera (14 per cent), hemiptera (7 per cent) and thysanoptera (3 per cent).

5.2.2 Relative abundance of bee pollinators/flower visitors under pesticide free condition

Foraging activity of pollinators was observed in terms of relative abundance and time spent per flower. The activity was continous from 6 AM to 6 PM. The mean relative abundance of bee pollinators/flower visitors recorded under pesticide free conditions (Fig. 4) showed that the highest peak foraging activity of bee

Fig. 3. Insect visitors of culinary melon at peak flowering time

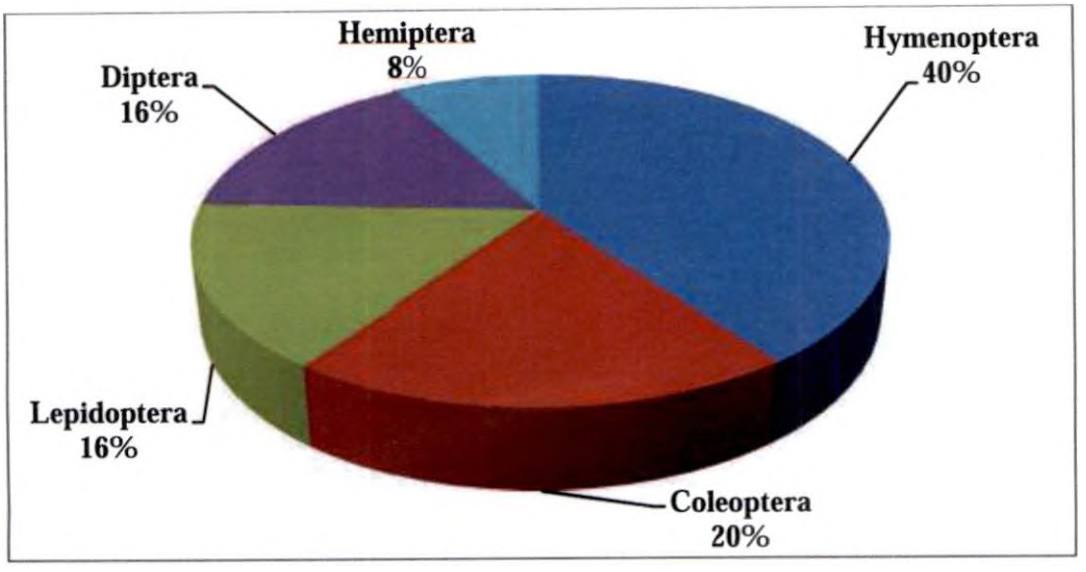
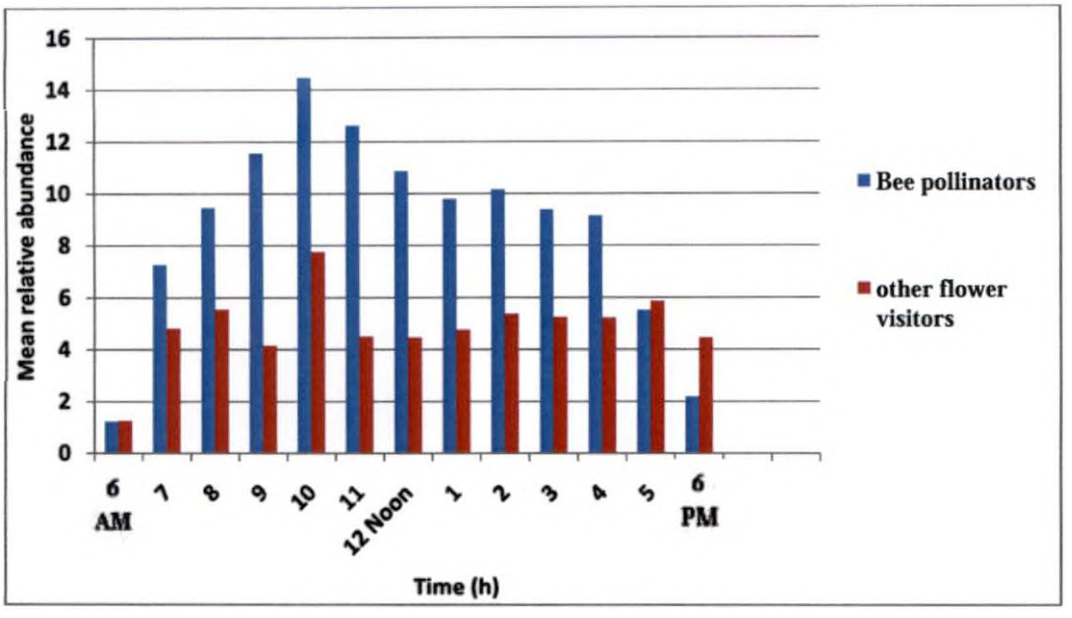


Fig. 4. Relative abundance of bee pollinators/flower visitors under pesticide free condition



pollinators were recorded at 10 AM and gradually declined afterwards. The lowest foraging activity was recorded at early morning, 6 AM and evening time at 6 PM.

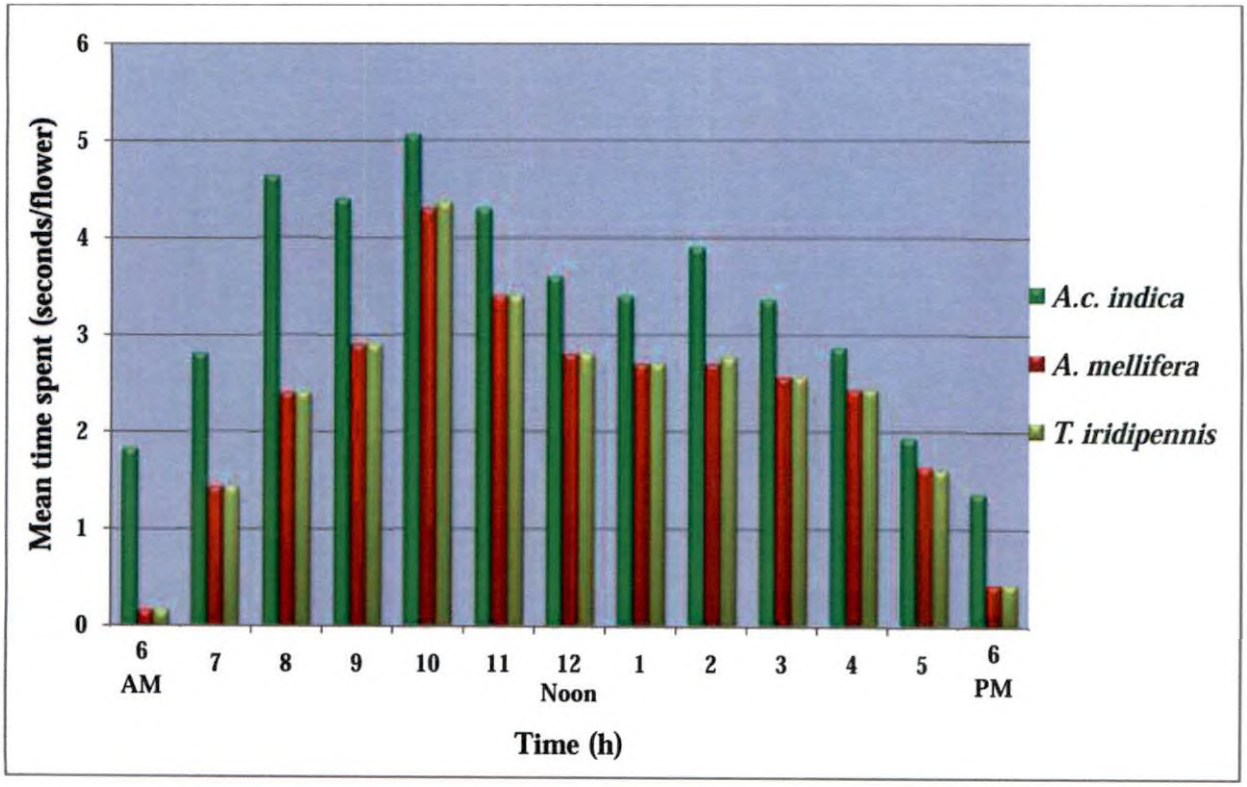
The mean relative abundance of other flower visitors (non *Apis* sp) recorded the peak at 10 AM and this was followed by at 8 AM and 5 PM. Lowest activity of flower visitors recorded in morning 6 AM and this was followed 6 PM. The higher activity may be due to the abundant availability of pollen and nectar in the mid morning hours.

T. iridipennis was the dominant bee pollinator compared to *A. cerana indica* and *A. mellifera* in culinary melon (*Cucumis melo* var. *acidulus*). The relative abundance of *T. iridipennis, A. c. indica and A. mellifera* were 5.80, 5.26 and 3.40 bees/m^2/5 minutes respectively during the peak foraging time.

The time spent by bee pollinators recorded during the peak foraging time 10 AM to 11 AM showed that *A. cerana indica*, *A. mellifera* and *T. iridipennis* apent 5.06, 4.30 and 4.36 seconds per flower respectively under pesticide free conditions (Fig. 5).

Bee pollinators showed significantly higher activity in the morning hours which may be due to the availability of fresh flowers and the influence of weather factors like temperature, humidity and light conditions as reported by Viraktamath (1990). These results of the present study are in close proximity with the findings of Eswarappa (2001) who reported that the activity of different species of honey bees either in open plots or caged plots of chow-chow was found to be maximum at 1000 to 1100 h and lowest at 0600 h and the time spent by different honey bee species were found to be maximum between 0800 and 0900 h in chow-chow crops. The present results are close with the findings of Chand and Kumar (2005) who reported the foraging activity of honey bees, *A. c. indica* and *A. mellifera* on flowering mustard. The activity of both the species was maximum at 1100 h (10.25 bees/minute/m^2) followed by 1300 h (8.20 bees/minute/m^2) and 0900 h (8.10 bees/minute/m^2), 1500 h (6.60 bees/minute/m^2) at Bangalore. Chowde *et al.* (2005)

Fig. 5. Comparative time spent by bee pollinators under pesticide free condition (seconds/flower)



and Jangaiah (2007) reported that in *A. cerana indica* foragers was more during 9.00 to 11.00 hr at Dharwad.

Mohan Rao and Suryanarayana (1988) reported that *A. c. indica* was the principal pollinating insect and was found to be efficient pollinator than *A. florea* in watermelon and *A. c. indica* spent 1.40 to 6.90 seconds on each flower. Choudhari *et al.* (2006) reported the foraging speed of *A. mellifera* (time spent in seconds/panicle) as 3.40 seconds in suringi (*Ochrocarpus longifolius*) at Maharashtra. Managanvi *et al.* (2012) reported that peak foraging activities of outgoing and incoming bees were observed at 11 AM in Pantanagar. Maximum number of stingless bees noticed in morning hours at 10 AM with 19.6 bees/5 minutes.

5.2.3 Relative abundance after spraying of new generation insecticides

The pesticides toxicity can be determined by suitable laboratory tests, but the hazards from the formulated pesticide are associated with specific circumstances in the field which must be considered while estimating the potential danger to the honey bees and other non target organisms. This hazard is a function of intrinsic toxicity of the pesticide, the field application rate (g a.i. ha^{-1}), the proportion of dose which is available for the transfer to the bees and the behaviour of the bee itself. Important factors include weather conditions, stage of flowering of the crop and its attractiveness to bees. It may further be related to the formulation type, mode of action and residual toxicity of the pesticide in particular repellency (Johansen, 1979).

Foliar spraying of new generation insecticides having least toxicity to honey bees, selected from the laboratory studies showed that chlorantraniliprole 30 g a.i. ha^{-1} recorded the maximum relative abundance of *A. c. indica* (2.95 bees/m^2/ 5 minutes) followed by buprofezin 250 g a.i. ha^{-1} (2.85 bees/m^2/5 minutes) proved to be safer than the other new generation insecticides evaluated in the field (Fig. 6). The same trend was observed in the relative abundance of *A. mellifera* and *T. iridipennis,* the mean values being 2.95 bees/m^2/5 minutes and 3.00 bees/m^2/5

minutes for chlorantraniliprole 30 g a.i. ha^{-1} and 2.80 bees/m^2/5 minutes and 3.28 bees/m^2/5 minutes for buprofezin 250 g a.i. ha^{-1} respectively and was safe.

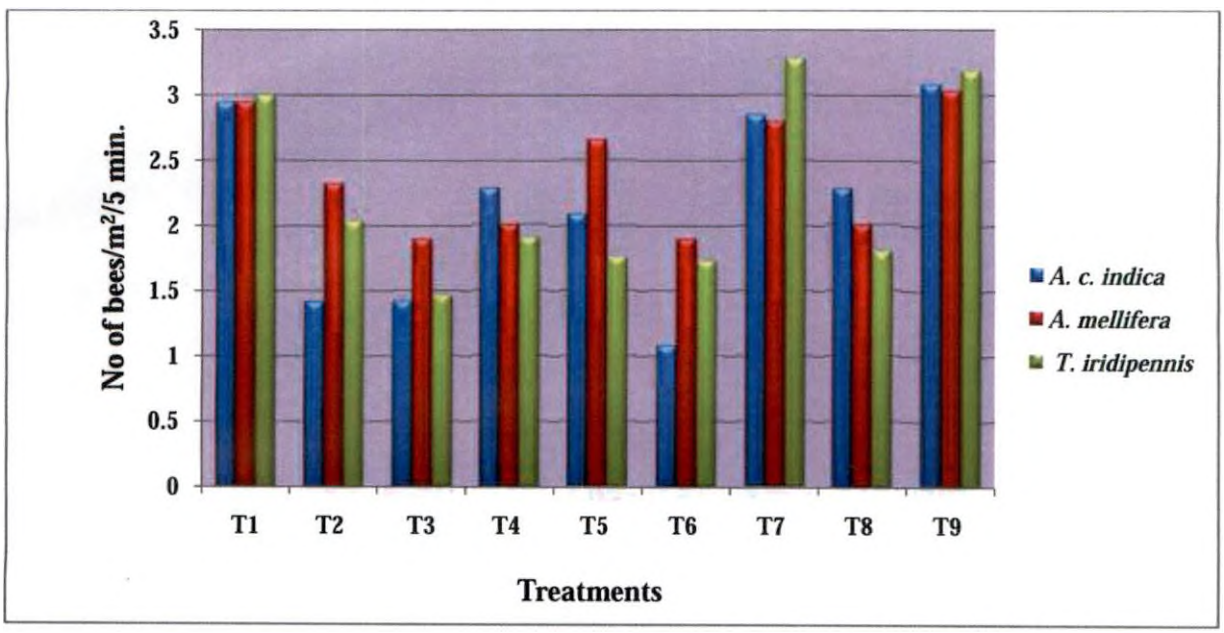
5.2.4 Time spent by bee pollinators after application of new generation insecticides

The mean time spent by *A. c. indica* was 3.16 seconds/flower in buprofezin 250 g a.i. ha^{-1}, whereas *A. mellifera* spent 3.66 seconds/flower each in chlorantraniliprole 30 g a.i. ha^{-1} and buprofezin 250 g a.i. ha^{-1}. *T. iridipennis* spent 24.16 seconds /flower in buprofezin 250 g a.i. ha^{-1} and 19.22 seconds/flower in chlorantraniliprole 30 g a.i. ha^{-1} after spraying of new generation insecticides at the peak foraging time, 10 AM (Fig. 7). The present results are close with findings of Choudhari *et al.* (2006) who reported the time spent was observed to be 2.71, 5.06 and 1.70 seconds by *A. c. indica, A. dorsata* and *A. florea* respectively as on average but lesser time was recorded in early morning and again in evening. Sharma *et al.* (2001) reported foraging behaviour of *A. mellifera* spent least time (1.64 seconds)/flower/minute on *Brassica* flowers. Mupade and Kulkarni (2010) reported that time spent by *T. iridipennis* for foraging varies from 39.00 to 55.00 seconds and nectar it was 39.00 to 59.00 seconds on onion flowers.

Chlorantraniliprole and buprofezin were safe to insect pollinators, earlier field studies revealed that buprofezin at 25 g/100 L showed no adverse effects on worker bees (NRAVC, 2001; Dinter *et al.*, 2009).

In brief, chlorantraniliprole 30 g a.i. ha^{-1} (Anthranilic diamide) and buprofezin 250 g a.i. ha^{-1} (Chitin synthesis inhibitor, benzylphenyl urea) were observed to have higher safety towards the honey bees. Simultaneously, these pesticides are also reported to have significant effect against various pests infesting cucurbitaceous vegetables. So to develop IPM modules for various pests on vegetables, where honey bees contribute to pollination, these newer molecules of insecticides could be incorporated which afford safety to the pollinators. In line with Good Agricultural Practice (GAP) and for the safety of pollinators spray applications should always be made when pollinators are not foraging or after daily bee flight, preferably in the evening hours.

Fig. 6. Comparative relative abundance of three species of honey bees on flowers of culinary melon after spraying of new generation insecticides



T1: Chlorantraniliprole 30 g a.i. ha^{-1}

T2: Emamectin benzoate 10 g a.i. ha^{-1}

T3: Spinosad 75 g a.i. ha^{-1}

T4: Cartap hydrochloride 500 g a.i. ha^{-1}

T5: Acetamiprid 20 g a.i. ha^{-1}

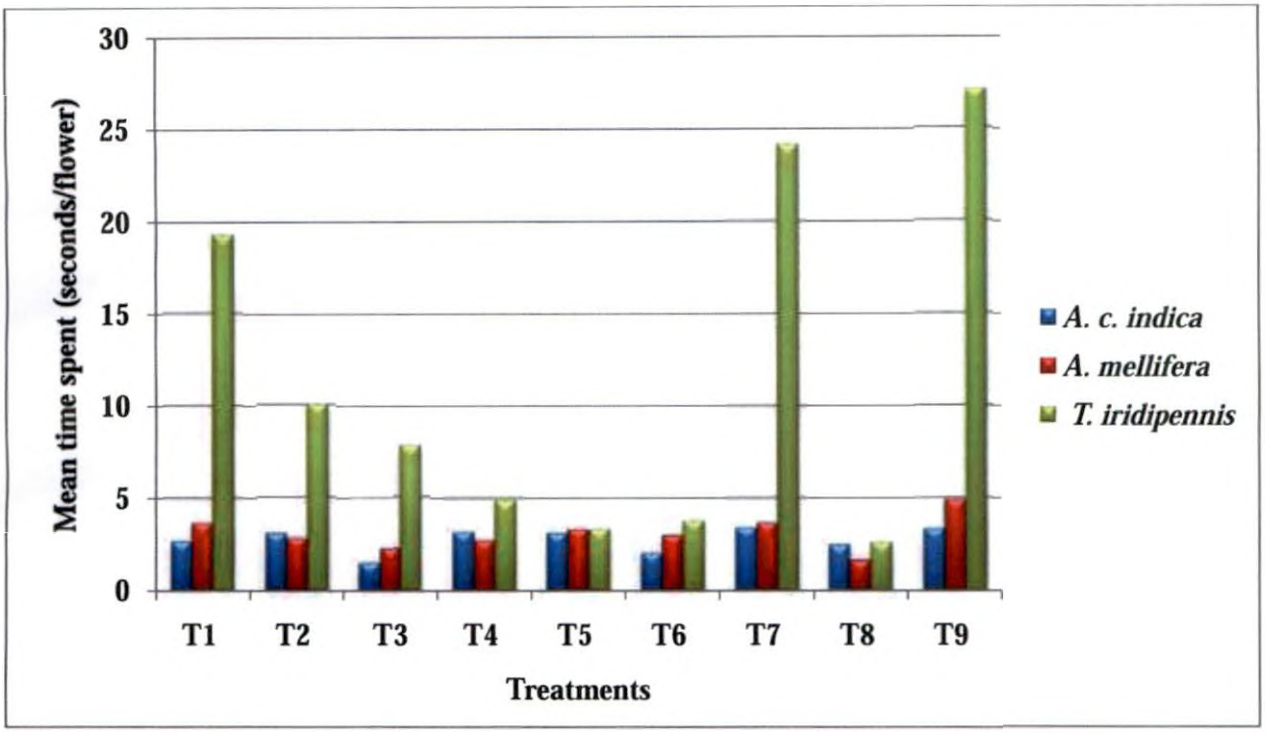
T6: Imidacloprid 20 g a.i. ha^{-1}

T7: Buprofezin 250 g a.i. ha^{-1}

T8: Dimethoate 200 g a.i. ha^{-1}

T9: Untreated Check

Fig. 7. Comparative time spent by three species of honey bees on flowers of culinary melon after spraying of new generation insecticides



T1: Chlorantraniliprole 30 g a.i. ha^{-1}

T2: Emamectin benzoate 10 g a.i. ha^{-1}

T3: Spinosad 75 g a.i. ha^{-1}

T4:Cartap hydrochloride 500 g a.i. ha^{-1}

T5: Acetamiprid 20 g a.i. ha^{-1}

T6: Imidacloprid 20 g a.i. ha^{-1}

T7: Buprofezin 250 g a.i. ha^{-1}

T8: Dimethoate 200 g a.i. ha^{-1}

T9: Untreated Check

SUMMARY

6. SUMMARY

Experiments carried out in the All India Co-ordinated Research Project on Honey bees and Pollinators, Department of Agricultural Entomology, College of Agriculture, Vellayani during 2012-13 to determine the safety/toxicity of some new generation insecticides to honey bees are summarised here under.

Safety of new generation insecticides recommended against defoliators of vegetable ecosystem was evaluated in the laboratory on the basis of contact toxicity to bee pollinators *viz., A. c. indica, A. mellifera* and *T. iridipennis.* Chlorantraniliprole 18.5 SC @ 30 g a.i. ha^{-1}, emamectin benzoate 5 SC @ 10 g a.i. ha^{-1} and thiodicarb 75 WP @ 750 g a.i. ha^{-1} were least toxic and safe at two hours after treatment since mortality of *A. c. indica* and *T. iridipennis* was not recorded. Mortality of *A. mellifera* was not recorded in chlorantraniliprole 18.5 SC @ 30 g g a.i. ha^{-1}, flubendiamide 480 SC @ 75 g a.i. ha^{-1} and indoxacarb 15.8 SC @ 75 g a.i. ha^{-1} and these were safe at two hours after treatment under laboratory condition.

Least mortality of *A. c. indica* was recorded in emamectin benzoate 5 SC @ 10 g a.i. ha-1 (9.40 per cent) followed by chlorantraniliprole 18.5 SC @ 30 g a.i. ha^{-1} (20.00 per cent) at four hours after treatment under laboratory condition whereas the later recorded the least mortality (0.64 per cent) of *A. mellifera* and no mortality of *T. iridipennis* was recorded and was safe to the bees tested.

Mortality of *A. c. indica, A. mellifera* and *T. iridipennis* observed in chlorantraniliprole 18.5 SC @ 30 g a.i. ha^{-1} was 34.50 per cent, 19.40 per cent and 32.19 per cent respectively at six hours after treatment under laboratory condition and was safe.

Safety of new generation insecticides recommended against sucking pests of vegetable ecosystem was evaluated in the laboratory on the basis of contact toxicity to bee pollinators showed that imidacloprid 17.8 SL @ 20 g a.i. ha^{-1}, buprofezin 25 SC @ 250 g a.i. ha^{-1} and dimethoate 30 EC @ 200 g a.i. ha^{-1} were safe to *A. c. indica* since mortality was not recorded at two hours after treatment. In the case of *A. mellifera* and *T. iridipennis* mortality was not recorded in

buprofezin 25 SC @ 250 g a.i. ha^{-1} at two hours after treatment under laboratory condition which indicated that these were safe to bee pollinators.

Acetamiprid 10 g a.i. ha-1 (17.23 per cent mortality) was safe to *A. c. indica* at four hours after treatment. Mortality of *A. mellifera* was not recorded in buprofezin 25 SC @ 250 g a.i. ha^{-1} but 10.00 per cent mortality of *T. iridipennis* was recorded in buprofezin 25 SC @ 250 g a.i. ha^{-1} at four hours after treatment and was least toxic and safe to bee pollinators.

Mortality of *A. c. indica A. mellifera* and *T. iridipennis* was 42.47 per cent, 20.76 per cent and 10.00 per cent respectively in buprofezin 25 SC @ 250 g a.i. ha^{-1} at six hours after treatment under laboratory condition and was comparatively safe.

Under pesticide free condition highest activity of insect visitors and maximum foraging activity of bee pollinators were recorded during 10 AM to 11 AM. *T. iridipennis* was the dominant bee pollinator compared to *A. c. indica* and *A. mellifera* in culinary melon (*Cucumis melo* var. *acidulus*). The foraging activity of bee pollinators were observed in terms of their relative abundance and foraging time. The relative abundance of *A. c. indica, A. mellifera* and *T. iridipennis* were 5.80, 5.26 and 3.40 bees/m^2/5 minutes respectively during the peak foraging time. The time spent by bee pollinators recorded during the peak foraging time (10 AM to 11 AM) showed that *A. c. indica, A. mellifera* and *T. iridipennis* spent 5.06, 4.30 and 4.36 seconds per flower respectively under pesticide free condition.

Fifteen different pollinators/flower visitors were recorded on culinary melon. Of these, order hymenoptera (40 per cent) was dominant followed by coleoptera (20 per cent), lepidoptera (16 per cent), diptera (16 per cent) and hemiptera (8 per cent). *A. c. indica* was the dominant bee pollinator. Pest fauna included three species of coleoptera, two species of lepidoptera and two species of diptera and other minor pests. The natural enemies observed were two species of predators and two species of parasitoids.

Foliar spraying of new generation insecticides having least toxicity and safe to honey bees, selected from the laboratory studies showed that chlorantraniliprole 18.5 SC @ 30 g a.i. ha^{-1} recorded the maximum relative abundance of *A. c. indica* (2.95 bees/m^2/ 5 minutes) followed by buprofezin 25 SC @ 250 g a.i. ha^{-1} (2.85 bees/m^2/5 minutes) proved to be safer than the other new generation insecticides evaluated in the field. The same trend was observed in the relative abundance of *A. mellifera* and *T. iridipennis*, the mean values being 2.95 bees/m^2/5 minutes and 3.00 bees/m^2/5 minutes for chlorantraniliprole 18.5 SC @ 30 g a.i. ha^{-1} and 2.80 bees/m^2/5 minutes and 3.28 bees/m^2/5 minutes for buprofezin 25 SC @ 250 g a.i. ha^{-1} respectively and was safe.

The mean time spent by *A. c. indica was* 3.16 seconds/flower in buprofezin 250 g a.i. ha^{-1}, whereas *A. mellifera* spent 3.66 seconds/flower each in chlorantraniliprole 18.5 SC @ 30 g a.i. ha^{-1} and buprofezin 250 g a.i. ha^{-1}. *T. iridipennis* spent 24.16 seconds /flowers in buprofezin 25 SC @ 250 g a.i. ha^{-1} and 19.22 seconds/flower in chlorantraniliprole 18.5 SC @ 30 g a.i. ha^{-1} after spraying of new generation insecticides at the peak foraging time, 10 AM.

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SAFETY OF NEW GENERATION INSECTICIDES TO BEE POLLINATORS

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(2011-11-159)

Abstract of the

Thesis submitted in partial fulfilment of the requirement

for the degree of

Master of Science in Agriculture

Faculty of Agriculture

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2013

ABSTRACT

The investigation on "Safety of new generation insecticides to bee pollinators" was conducted at the AICRP on Honey bee and Pollinators, Department of Agricultural Entomology, College of Agriculture, Vellayani during 2012- 2013. The objectives were to determine the safety of newer molecules of insecticides to bee pollinators mainly *Apis cerana indica* F., *Apis mellifera* L. and *Trigona iridipennis* Smith. under laboratory and field conditions.

New generation insecticides with label claim, suggested for pest management recommended against defoliators and sucking pests in vegetable ecosystems were chosen for the study. The insecticides selected were chlorantraniliprole 18.5 SC @ 30 g a.i. ha^{-1}, flubendiamide 480 SC @ 75 g a.i. ha^{-1}, emamectin benzoate 5 SG @ 10 g a.i. ha^{-1}, spinosad 45 SC @ 75 g a.i. ha^{-1}, indoxacarb 15.8 SC @ 75 g a.i. ha^{-1}, thiodicarb 75 WP @ 750 g a.i. ha^{-1}, fipronil 5 SC @ 50 g a.i. ha^{-1} and cartap hydrochloride 50 SP @ 500 g a.i. ha^{-1} (against defoliators). Acetamiprid 20 SP @ 10 g a.i. ha^{-1}, thiacloprid 21.7 SC @ 30 g a.i. ha^{-1}, imidacloprid 17.8 SL @ 20 g a.i. ha^{-1}, clothianidin 50 WDG @ 20 g a.i. ha^{-1}, buprofezin 25 SC @ 250 g a.i. ha^{-1}, acephate 25 SC @ 292 g a.i. ha^{-1} were chosen (against sucking pests) with dimethoate 30 EC @ 200 g a.i. ha^{-1} as insecticidal check and untreated check.

Laboratory evaluation of the two sets of new generation insecticides showed that chlorantraniliprole 18.5 SC @ 30 g a.i. ha^{-1}, emamectin benzoate 75 g a.i. ha^{-1} and spinosad 45 SC @ 75 g a.i. ha^{-1} recorded low mortality of bees ranging from 9.40 to 20.00 per cent and acetamiprid 20 SP @ 10 g a.i. ha^{-1}, imidacloprid 20 g a.i. ha^{-1} and buprofezin 250 g a.i. ha^{-1} recorded the per cent mortality ranging between 17.23 and 34.60 per cent. These new generation insecticides along with cartap hydrochloride 50 SP @ 500 g a.i. ha^{-1} and dimethoate 30 EC @ 200 g a.i. ha^{-1} were selected for field evaluation in culinary melon (*C. melo* var. *acidulus*).

Prior to the evaluation of new generation insecticides, the number of flower visitors/ pollinators recorded on culinary melon was found to be 15. Of these, the important groups were hymenoptera (40 per cent), coleoptera (20 per cent), lepidoptera (16 per cent), diptera (16 per cent) and hemiptera (8 per cent). Highest activity of insect pollinators were recorded under pesticide free condition. Maximum foraging activity of bee pollinators was recorded during 10 AM to 11 AM. *A. c. indica* was the dominant bee pollinator in culinary melon.

Foliar application of the selected new generation insecticides done at 10 per cent flowering showed that chlorantraniliprole 18.5 SC @ 30 g a.i. ha^{-1} and buprofezin 250 g a.i. ha^{-1} were safe to bee pollinators compared to other insecticides. The foraging activity of bee pollinators observed in terms of their relative abundance and foraging time revealed that there was no significant difference between treatments and untreated check.

To conclude, among the new generation insecticides evaluated for their safety to bee pollinators like *A. c. indica*, *A. mellifera* and *T. iridipennis*, chlorantraniliprole 18.5 SC @ 30 g a.i. ha^{-1} was safe when sprayed against defoliators and buprofezin 25 SC @ 250 g a.i. ha^{-1} was safe when sprayed against sucking pests of culinary melon (*C. melo* var. *acidulus*).