Studies on the efficacy of label claimed insecticides for whitefly *Bemisia tabaci* (Gennadius) (Homoptera: Aleyrodidae) in cotton *Gossypium hirsutum* L., under field and laboratory conditions

BY

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CERTIFICATE – I

This is to certify that this thesis entitled **"Studies on the efficacy of label claimed insecticides for whitefly *Bemisia tabaci* (Gennadius) (Homoptera: Aleyrodidae) in cotton *Gossypium hirsutum* L., under field and laboratory conditions"** submitted for the degree of **Master of Science**, in the subject of **"Entomology"** to the CCS Haryana Agriculture University, is a bonafide research work carried out by **Naveen Rao** under my supervision and that no part of this dissertation has been submitted for any other degree.

The assistance and help received during the course of investigation have been fully acknowledged.

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CERTIFICATE – II

This is to certify that this thesis entitled, **"Studies on the efficacy of label claimed insecticides for whitefly *Bemisia tabaci* (Gennadius) (Homoptera: Aleyrodidae) in cotton *Gossypium hirsutum* L., under field and laboratory conditions"** submitted by **Naveen Rao** to the CCS Haryana Agricultural University in partial fulfillment of the requirements for the degree of **Master of Science**, in the subject of **"Entomology"** has been approved by the Student's Advisory Committee after an oral examination on the same.

MAJOR ADVISOR **EXTERNAL EXAMINER**

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Place: Hisar
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ABBREVIATIONS

Bt	*Bacillus thuringiensis*
C.D.	Critical Difference
cm	Centimeter
e.g.	For example
et al.	*et alii* (and others)
etc.	*et cectra* (and other things)
G	Gram
Ha	Hectare
i.e.	*id est.* (that is to say)
Ml	Millilitre
NS	Non-Significant
R.H.	Relative Humidity
viz.,	Namely
ºC	Degree Celsius
/	Per
%	Per cent
Mm	Millimeter
a.i./ha	active ingredient per hectare
Ppm	parts per million
ETL	Economic Threshold level
NSKE	Neem Seed Kernel Extract
EC	Emulsifiable Concentration
SP	Soluble Liquid
WG	Wettable Granules
@	at the rate
Q/ha	Quintal per hectare
WP	Wettable Powder
SC	Suspension Concentrate
OPs	Organophosphates
IGRs	Insect Growth Regulators
SL	Soluble Liquid

WSG	Water Soluble Granules
WDG	Water Dispersible Granules
WS	Water Dispersible Powder
SC	Suspension Concentrate
LC	Lethal Concentration
w/w	weight by weight
IRAC	Insecticide Resistance Action Committee
ht	Height
CRD	Completely Randomized Design
RBD	Randomized Block Design
D.O.S	Date of spray
RLRmax	Maximum registered label rate
DT	Development Period
µl/ml	Micro litre per millilitre

CHAPTER-I

INTRODUCTION

Cotton as a crop as well as commodity plays an important role in the agricultural and industrial activities of the nation and has a unique place in the economy of our country by earning foreign exchange to the tune of $ 10-12 billion from export of cotton yarn, thread, fabrics, apparel and made ups. In India, more than 60 million people are engaged in cultivation, processing, marketing and other cotton related activities (Singhal, 2003). Thus, it is an important commercial crop in India and therefore, is rightly called as "White Gold". India is the only country to grow all the four species of cultivated cotton: *Gossypium arboreum* and *G. herbaceum* (Asian cotton), *G. barbadense* (Egyptian cotton) and *G. hirsutum* (American upland cotton) along with intra and inter-specific hybrids. In India cotton is grown mainly in three zones: Northern zone, Central zone and Southern zone. During 2016-17, cotton was sown in an area of 105 lakh ha, having an production of 351 lakh bales with an productivity of 568 kg/ha, while in Haryana, cotton was cultivated on 4.98 lakhs hectares with production of 17 lakhs bales with an average yield of 683 kg/ha (Anonymous, 2017).

The productivity of cotton is affected by many factors, but the most serious among them is the intensity of insect-pests damage. About 184 insect pests had been recorded on cotton in India, out of them bollworms and sucking insect-pests caused 30–80% loss to yield (Dhawan, 2004). *Bt* cotton proved promising in the management of the bollworm population only (Fakrudin *et al*. 2003; Murugan *et al*. 2003), while the insect-pest complex has substantially changed since the introduction of *Bt* cotton hybrids. The sucking insects which were minor pests prior to 2002 have become major pests. The genetically modified bollworm resistance cotton succumbs to yield losses due to sucking pests from seedling emergence to harvest (Vennila *et al.* 2004). Sap feeders, *viz.*, leafhopper, *Amrasca biguttula biguttula* (Dist.); aphid, *Aphis gossypii* (Glover); thrips, *Thrips tabaci* Lindeman; and whitefly, *Bemisia tabaci* (Gennadius) damage the cotton crop with regular occurrence at different growth stages, reducing the growth and yield. Out of sucking pests the cotton whitefly *Bemisia tabaci* (Gennadius) (Homoptera: Aleyrodidae) had recently emerged as a major pest of cotton and other crops in the tropical and sub-tropical regions of Asia, Africa and America. *B. tabaci* is also known as the tobacco, cotton or sweet potato whitefly. Four common species of whitefly found throughout the world are mainly greenhouse whitefly, *Trialeurodes vaporariorum* (Westwood), silverleaf whitefly, *Bemisia argentifolii* (Bellow and Perring), sweet potato whitefly, *Bemisia tabaci* (Gennadius) and banded wing whitefly, *Trialeurodes abutilonea* (Haldeman). The actual biotype number of *B. tabaci* is unknown, but *B. tabaci* is a group of 36 cryptic species as reported by Naveen *et al*. (2017). Whitefly causes direct damage by piercing and sucking of sap from the foliage of plants.

Heavy infestation of adult and their progeny can cause the death of seedling, reduce the plant growth rate and yield due to sap removal. When adult and immature whiteflies feed, they excrete honeydew which serves as a substrate for growth of black sooty mould on leaves and bolls which reduces photosynthesis and lessens the value of the plant or yields rendering them unmarketable (Berlinger, 1986). Sukhija *et al.* (1986) reported 8-31 per cent loss in cotton yield due to whitefly infestation in Punjab whereas; 30-80 per cent losses in cotton were reported by Hameed *et al*. (1994) in Pakistan. According to Mansoor *et al.* 1999 an loss of about 7.4 million cotton bales valued at 4.98 billion US$ caused by whitefly from 1994 to 1999 in Pakistan. *B. tabaci* being a vector of several plant viruses groups including: geminiviruses, oviruses, carlaviruses, potyviruses, nepoviruses, loteoviruses and DNA-containing rod-shaped viruses (Duffus, 1996). Among geminivirus, Cotton leaf curl virus (CLCV) transmitted by *B. tabaci*, significantly reduces the yield.

In India *B. tabaci* was first recorded on cotton from Pusa (Bihar) during 1905 and was described as *Bemisia gossypiperda* M. and L. (Mishra and Lamba, 1929). Outbreaks of this pest were reported in southern parts of India during 1985-87 and in northern parts during 1987-95 on cotton, tobacco, eggplant, okra, tomato and several ornamental plants (Sharma and Batra, 1995; Palaniswami *et al.* 2001) and recently during 2015-16. Due to these whitefly outbreaks, there was widespread use of insecticides for its control (Agrihotri *et al*. 1999), which resulted in large-scale reduction of its natural enemies, resurgence of minor pests into major, environmental pollution and development of resistance to most of the synthetic insecticides (Mehrotra 1991). Monitoring of insecticide resistance revealed that this pest had developed a high level of resistance to organophosphates (OPs) like dimethoate, methamidophos and monocrotophos and to pyrethroids like cypermethrin and deltamethrin (Cahill *et al*. 1995; Ahmad *et al*. 2000, 2001, 2002) and to the newly introduced buprofezin and pyriproxyfen (Horowitz *et al*. 2002; Li *et al*. 2003; Ghanim and Kontsedalov, 2007).

The management of cotton whitefly has been a challenging task because of the presence of more than 910 host plant species (Rathore and Tiwari, 2014), biological characteristics including multivoltinism; broad host range; ability to migrate; high reproductive rate; tolerance for high temperature; and a capacity to develop resistance to wide classes of insecticides (Ellsworth and Jones, 2001; Naranjo, 2001). The use of insecticides in many cropping systems is the primary strategy used to control *Bemisia tabaci*, repeated spray applications have been necessary and often resulted in overuse of these chemicals which consequently, developed resistance to numerous conventional insecticides in *B. tabaci* throughout the world (Denholm *et al.* 1996, 1998). Several new classes of insecticide chemistry have been developed recently that effectively control *B. tabaci*, and perhaps more importantly, provide producers a diversity of chemicals to battle resistance (Horowitz and Ishaaya, 1996). In India the insecticides has been registered with label claim for whitefly on cotton. Many of these insecticides are obsolete, so the present study as warrants search for more effective chemicals to manage this pest and to evaluate relative toxicity of insecticides as an important aspect of pest management was planned with the following objective:

1. To study the efficacy of label claimed insecticides against whitefly under field conditions
2. To confirm the efficacy of label claimed insecticides against whitefly under laboratory conditions
3. To study the effect of insecticides on non- target organisms

CHAPTER-II

REVIEW OF LITERATURE

To carry out the present investigation in an effective manner, it is necessary to have a better understanding of various parameters of the test insect (*Bemisia tabaci*) such as efficacy of various classes of insecticides against whitefly, non target effect of insecticides and resistance development *etc*. A comprehensive review of available literature on the bioefficacy and management of whitefly will provide an enlightened path to precisely investigate the same, which is presented under the following sub-heads:

2.1 Origin as a pest and outbreaks

Bemisia tabaci was originally described as *Aleyrodes tabaci* (Gennadius) from whiteflies collected on tobacco in Greece (Gennadius, 1889) later another whitefly *Aleyrodes inconspicua* (Quintance) (Quintance, 1900) was collected from *Physalis alkekengi* L. in Southeastern USA. This species was moved into a new genus, *Bemisia*, in 1914, giving rise to *Bemisia inconspicua* (Quintance and Baker, 1914), later Takahshy (1936) placed the *tabaci* species in the genus *Bemisia*, resulting in *B. tabaci* (Gennadius). In India whitefly outbreaks occurred during late 1920s and early 1930s and subsequently in Sudan and Iran from the 1950s and 1961 in EL Salvador (Hirano *et al*. 1993).

2.2 Insecticides and their impact on natural enemies

Though integrated pest management of any pest relies on all available tactics like host plant resistance, cultural, mechanical, physical, biological and chemical control methods. Failure of host resistance or unavailability of suitable genotype, physical and biological control methods forced farmers to solely reliable on chemical control method. No doubt the insecticides are indispensable tools in pest management but there over and injudicious use is always detrimental to the crop and environment. A number of insecticide classes are available to control whitefly *viz.*, organophosphates (chloropyrifos, ethion and triazophos) which blocks activity of acetylcholine esterase, neonicotinoids (imidacloprid, acetamiprid, clothianidinand thiocloprid) which act as sodium channel blockers, pyrethroids (fenvalerate, lambda-cyhalothrin), IGRs (buprofezin, diflubenzuron and pyriproxifen) and botanicals *etc.*

Among the conventional insecticides, triazophos at 0.05 % effectively controlled *B. tabaci* on cotton (Sudhakar and Paul, 1991) however; at 0.1 % it exhibited persistent toxicity to parasitoids of *B. tabaci* (Helena, 1993). Kaur *et al.* (2015) reported maximum per cent reduction of whitefly population with trizophos 40 EC (63.22%) followed by the acetamiprid 20% SP (55.61%).

Among the neonicotinoids, imidacloprid as seed treatment has been an ideal strategy for integrated pest management in transgenic cotton against sucking pests (Kannan *et al*.

2004). Dey *et al*. (2005) found that, imidacloprid 70 WS as seed treatment @ 5-10 g/kg seed was most effective against early sucking pest complex (*Aphis gossypii*, *Thrips tabaci*, *Amrasca biguttula biguttula* and *Bemisia tabaci*) while imidacloprid 20 SL @100-125 ml/ha as spray during later infestation. Amjad *et al*. (2009) found that acetamiprid and imidacloprid were most effective against whitefly up to seven days after spray while thiamethoxam remained least effective and resulted less than 50% mortality throughout the experiment, while Aslam *et al.* (2004) reported that acetamiprid and thiomethoxam were most effective insecticides against whitefly; imidacloprid and acetamiprid against jassid; while acetamiprid, imidacloprid and methamedophos were highly effective against thrips. Similarly, Yasmin *et al*. (2009) reported that lowest population of jassid and whitefly population were recorded in imidacloprid followed by thiamethoxam 25WG with a per cent reduction of more than 50 per cent over control and also the number of okra yellow vein clearing mosaic virus infected plants and leaves were significantly lowest in imidacloprid treated plots at different stages. Kumar *et al.* (2017) found that thiamethoxam 25WG @ 100g/ha was found most effective insecticide in reducing the population of whitefly followed by imidacloprid 17.8 SL @ 100 ml/ha, while dimethoate 30 EC @ 500 ml/ha was reported least effective. Abbas *et al*. (2012) found imidacloprid, thiomethoxam and acetamiprid to be highly effective against jassid and whitefly, while against thrips the performance of thiomethoxam was less than the imidacloprid and acetamiprid.

Kadam *et al.* (2014) studied bioefficacy of neonicotenoids against sucking pest of cotton and reported that lowest population of sucking pests was in nitenpyram 10 per cent WSG, dinotefuran 20 per cent SG and clothianidin 50 per cent WDG as compared to acetamiprid 20 per cent SP, imidacloprid 17.8 SL, thiamethoxam 25 per cent WS and thiacloprid 21.7 per cent SC while Raghuraman and Gupta (2005); Afzal *et al.* (2002) reported, acetamiprid and imidacloprid as most effective treatments against whitefly on cotton. Boda and Ilyas (2017) studied efficacies of new insecticides against sucking insect pests and reported clothianidin 50% WDG as most superior in reducing aphids, jassids and mealy bug population, followed by acetamiprid 20% SP and thiamethoxam 25% WG whereas, the treatment fipronil 5 % SC was found most superior in reducing thrips population while spiromesifen 240 SC was found more superior in reducing whiteflies population. Naveen *et al.* (2011) conducted a leaf dip bioassay on whitefly *Bemisia tabaci* in cotton and leucaena and revealed that imidacloprid was least effective when compared to acetamiprid, acephate and cypermethrin. Asi *et al*. (2008) reported imidacloprid and diafenthiuron were highly effective while flufenoxuron was least effective against whitefly. Solangi and Lohar (2007) studied effect of different insecticides against sucking pests and their effects on predators and reported imidacloprid as most effective against all the sucking pests and also the population of predators, *i.e.* spiders, ants and beetles was significantly higher in imidacloprid treated plots than compared to sundaphos, diafenthiuron and acetamiprid. Bharpoda *et al.* (2014) reported imidacloprid 17.8 SL, thiamethoxam 25 WG and diafenthiuron 50 WP @ 0.05% as effective against sucking pests with highest Cost Benefit Ratio (1: 16.54) was found in imidacloprid and there insecticides were significantly safer to the natural enemies *viz.*, *Chrysoperla carnea* (adult), spiders and coccinellids (grubs and adult) while fipronil 5EC and carbosulfan 25 EC were found less effective group of chemicals.

Dhawan and Brar (1995) as well as Anuradha and Arjuna Rao (2005) reported that fenpropathrin 75 g a. i./ha was effective in controlling the sucking pests of cotton. Similar types of results were given by Singh and Kumar (2006) who reported acetamiprid 20 SP 20 g a.i./ha were effective in controlling sucking pests of cotton.

Patel *et al.* (2010) studied bio-efficacy of different classes of insecticide against whitefly, *Bemisia tabaci* and reported that among thio-ureas class, diafenthiuron 50 SC was most effective and relatively safer for potent predators, triazophos 40 EC and acetamiprid 20 SP were the next effective insecticides among organophosphate and neonicotinoids, respectively. Shivanna *et al*. (2011) evaluated efficacy of new insecticides against sucking insect pests of cotton and reported fenpropathrin as most superior at 24 hours after spray, followed by dimethoate, imidacloprid and acetamiprid while dimethoate alone was most effective against leafhopper, whitefly and thrips at three days after spray. Kalyan *et al*. (2012) reported highest avoidable losses (52.65%) were recorded in spinosad followed by imidacloprid (42.38%), acephate (31.47%), fipronil (28.23%) and dimethoate (28.12%). Ali *et al*. (2005) studied efficacy of IGR, neonicotinoid and other insecticides against whitefly *Bemisia tabaci* in cotton and reported, buprofezin as IGR was most effective against nymphs while acetamiprid, diafenthiuron and imidacloprid were most effective against the adults.

Yausi *et al.* (1987) studied effect of buprofezin on adults of greenhouse whitefly, *Trialeurodes vaporariorum* and revealed that, adults treated with buprofezin laid reduced number of eggs up to 24 hours after treatment; also the fecundity and hatchling survival of treated eggs were reduced. Mandal *et al.* (2015) reported, the most effective insecticides in case of whitefly was spiromesifen @ 150 g/ha followed by buprofezin @ 300 g/ha and least effective was buprofezin @ 150 g/ha. Sugiyama *et al.* (2011) studied toxicities of insecticides for *Eretmocerus mundus*, *Eretmocerus eremicus* and *Encarsia formosa* and reported mortalities for both pupae and adults of all three species insect by growth regulators (IGRs *i.e*. flufenoxuron and lufenuron), *Bacillus thuringiensis* (*Bt*), pymetrozine and sulfur were significantly lesser while neonicotinoids (acetamiprid, clothianidin, dinotefuran, imidacloprid and nitenpyram), synthetic pyrethroids (etofenprox and permethrin), organophosphates (acephate and fenitrothion), chlorphenapyr, emamectin benzoate, spinosad and tolfenpyrad were seriously harmful while acaricides (chinomethionat, milbemectin and pyridaben) were moderately harmful to adult parasitoids. Ishaaya *et al.* (1996) studied efficacy of novaluron (IGR), a novel benzoylphenyl urea and reported that it inhibits chitin synthesis in the advanced stages of whitefly development and also Ishaaya *et al.* (1997) found that novaluron apparently works by contact with *B. tabaci* eggs and nymphs and had no significant effects on various parasitoids. Kedar (2014) observed maximum suppression of nymphal population of *B. tabaci* in plants treated with novaluron (0.01%) followed by triazophos (0.08%) and azadirachtin on the cotton crop in Hisar.

Aggarwal and Brar (2006) reported nimbecidine did not cause any effect on the emergence of *Encarsia sophia* and contact toxicity to adults at lower doses whereas, chlorpyriphos, endosulfan and triazophos showed high toxicity both by contact and feeding method also the relative toxicity against egg and larval stages of *Chrysoperla carnea* (Stephens) was studied under laboratory conditions and found that nimbecidine did not induce any adverse effect on the hatchability of *C. carnea* eggs also the mortality of the first instars of *C. carnea* was not affected by azadirachtin enriched formulations; however, at higher dosage resulted in increased mortality of the first and second instar larvae of *C. carnea* whereas, triazophos induced very high mortality of all the three larval instars. Jayakumar *et al*. (2008) reported that Neem Seed Kernal Extract (NSKE) 5% is safer to natural enemies (spiders, coccinellids and chrysoperla sp.) in okra ecosystem. Meade and Bruce (1991) reported mortality of nymphs of all the three instars of whitefly were significantly higher than control was due to fungus *Veticillium lecanii*.

Ghelani *et al.* (2014) reported that the chemical pesticides caused higher mortality, while bio-pesticides caused moderate to lower mortality against sucking pests and observed that flonicamid 0.02 per cent was most effective against all major sucking pests, acetamiprid 0.004 per cent against aphid and whitefly, dinotefuran 0.008 per cent and imidacloprid 0.0089 per cent against jassid while thiamethoxam 0.01 per cent against thrips on *Bt* cotton while among the bio-pesticides, neem oil 1.0 per cent, *V. lecanii* @ 2.5 kg/ha and azadirachtin 0.0009 per cent were found to be moderate effective against major sucking pests of *Bt* cotton and safer to predators (coccinellids and chrysoperla) while chemical pesticides were found moderate to higher toxic to predators.

2.3 Resistance

Rao *et al*. (1999) studied the effect of recommended and sublethal doses of some insecticides on the biology and population of *Bemisia tabaci* and found that synthetic pyrethroids like deltamethrin, fenvalerate, permethrin and cypermethrin popularly used on cotton have contributed to resurgence of whitefly on cotton. The failure of these insecticides to control the whitefly also suggests the development of resistance to the chemicals.

Erdogana *et al.* (2008) studied polyacrylamide gel electrophoresis (PAGE) analysis of whitefly strains from Turkey and reported all strains showed significant resistance to pyrethroids and organophosphates while only one strain was reported to be resistant to buprofezin.

Wang *et al.* (2010) studied two different biotype of *B. tabaci* and reported moderate to high levels of resistance to two neonicotinoids (imidacloprid, thiamethoxam), medium to high levels of resistance to alpha-cypermethrin and low to medium levels of resistance to fipronil exhibited by both strains. Balakrishnan *et al.* (2002) reported that *B. tabaci* has developed 3.37, 10 3.12, 1.59 and 1.41 fold resistance to cypermethrin, monocrotophos, acephate and triazophos, respectively at LC_{50}. All the insecticides were less effective against cotton whitefly of Guntur strain since the LC_{50} values of these insecticides were higher than the corresponding recommended concentrations which imply the acquisition of resistance.

CHAPTER-III

MATERIALS AND METHODS

The studies on "Efficacy of label claimed insecticides for whitefly *Bemisia tabaci* (Gennadius) (Homoptera: Aleyrodidae) in cotton *Gossypium hirsutum* L." were carried out during *kharif* season of 2016 under field and laboratory conditions at Chaudhary Charan Singh Haryana Agricultural University, Hisar (Haryana) India. Different materials used and methodology adopted for various experiments are described below.

3.1 Efficacy of label claimed insecticides against whitefly adults under field conditions

3.1.1 Materials used during the studies

The following materials were utilized for setting up the experiment and for recording the observations: hand lens (10X), glass vials, marking tags, marking pencil, 12 megapixel digital camera, knapsack sprayers, label claimed insecticides *etc.*

3.1.2 Raising of the crop

For conducting different trials, cotton crop was raised during 2016 crop season, at Cotton Research Area, Department of Genetics and Plant Breeding following recommended package of practices, except spraying of insecticides (Anonymous, 2008).

3.1.3 Evaluation of efficacy of label claimed insecticides against whitefly under field conditions

Bt cotton hybrid NCS 855 BG II was sown under RBD (Randomized Block Design) with fifteen treatments including control and three replications of each treatment. Each replicated plot was 24 m^2 in size comprised sixteen rows with the spacing of 67.5 x 60 cm (row to row and plant to plant). A gap of 1.5 m was left between plots to avoid the influence of the treatments on the pest population in neighboring plots (Men *et al*. 2003).

The first spray was done in the month of August when the population of whitefly reached at Economic Threshold Level (ETL) *i.e.* 6-8 adults per leaf, total three sprays were applied at an interval of 15 days. The data on whitefly adults was recorded one day before spray and 3^{rd} and 7^{th} day after spray. Observations were recorded from 5 randomly selected tagged plants per plot, before 9:00 A.M. From each plant, one leaf was selected from each strata of the plant *i.e.* upper, middle and lower. Insecticides were sprayed with knapsack sprayer using hollow cone nozzle and the latter were held 0.3-0.5 m above the cotton plants while spraying (Wu *et al*. 2002). The crop was sprayed with an application rate of 500 liters water per hectare.

Different chemicals and their dosages used in the various treatments were as per the recommendation of Central Insecticides Board and Registration Committee **(**Anonymous, 2016). There were fifteen treatments including control and each treatment consisted of sprays of different insecticides (Table 1).

Table1. Label claimed insecticides used as treatments and their dosages

S. No.	Name of the treatments	Dosage/ha
T1	Acetamiprid 20% SP	100g
T2	Buprofezin 25% SC	1000ml
T3	Chlorpyrifos 20% EC	1250ml
T4	Dinotefuran 20% SG	125ml
T5	Ethion 50% EC	2000ml
T6	Fenpropathrin 30% EC	250ml
T7	Flonicamid 50% WG	150ml
T8	Monocrotophos 36% SL	1250ml
T9	Profenofos 50% EC	1250ml
T10	Thiacloprid 21.7% SC	600ml
T11	Thiamethoxam 25% WG	100g
T12	Fipronil 4% + Acetamiprid 4% W/W	1000ml
T13	Indoxacarb 14.5% + Acetamiprid 7.7% w/w SC	500ml
T14	Pyriproxyfen 5% EC + Fenpropathrin 15% EC	500ml
T15	Control	No spray

3.2 Evaluation of efficacy of insecticides against whitefly in laboratory conditions by leaf dip- bioassay method

3.2.1 Material used during studies

Insecticides solutions, whitefly adults, cotton leaf, insect breeding dish, Hand lens, sucrose solution , micro centrifuge tubes, rubber bands, muslin cloth and parafilm.

3.2.2 Methodology

Bioefficacy of various insecticides against adults of *B. tabaci* was evaluated in the laboratory as per methodology suggested by Insecticide Resistance Action Committee (IRAC) (Anonymous, 2009).Fresh leaves from cotton plants were excised along with a long petiole; leaves were washed with distilled water and air dried. The end of the petiole was given a slanting cut and wrapped with cotton. The cut ends were dipped in 1.5 ml micro centrifuge tube containing 10 per cent sucrose solution to maintain turgidity and tubes were sealed with parafilm. Test liquids of recommended concentration of insecticides mentioned in Table-1 were prepared. Leaves were then dipped in insecticide formulation with gentle agitation for five seconds. The treated leaves were air dried and then kept in wide mouthed plastic bioassay dishes (5cm diameter) with gauze -covered ventilation holes in lids.

The bioassay dishes were taken to infested cotton plant and with the lid on the upper surface of infested leaf and the petri dish was moved upwards onto the under leaf surface.

Plate 1. Cotton leaf with whitefly adults and immature stages

Plate 2. Cotton plant with sooty mould symptoms

Plate 3. Cotton leaf with whitefly in Insect Breeding Dish

Plate 4. Bioassay set up

Plate 5. Spider

Plate 6. Adult of *Coccinella septempunctata*

Plate 7. Adult of *Chrysoperla carnea*

The lid and dish were tapped together sideways off the leaf to trap the adult whiteflies. The procedure was repeated until approximately 50 adults per petri dish were collected. The number of adults per petri dish was recorded and kept at constant conditions, 28±2^{o}C. Each treatment was replicated thrice with at least 30 adults per replicate. Leaf dipped in distilled water served as control. Observations were taken at an interval of 24 hours and 72 hours after treatment. The numbers of dead insects were counted and the data was subjected to calculate the per cent mortality using the formula mentioned below.

$$\text{Mortality (\%)} = \frac{\text{Number of adults died}}{\text{Total number of adults released}} \times 100$$

3.3 Evaluation of effect of insecticides on non- target organisms.

Observations of natural enemies ((lady bird beetle, *Coccinella septempuncata;* green lacewing, *Chrysoperla carnea and* spider) were recorded from randomly selected 5 tagged plants from each plot, after seven days of spray. The standard method (beat basket method with diameter 30 cm, ht. 37.5 cm) was used for sampling however prior to this the selected plants were critically observed.

3.4 Statistical analysis

The data obtained during the evaluation of different chemicals against *B. tabaci*, laboratory studies and field studies were tabulated and subjected to the analysis of variance by using Completely Randomized Design (CRD) and Randomized Block Design (RBD), respectively. The differences were calculated at 5% level of significance. The data obtained on evaluation of different insecticide treatment against *B. tabaci* and effect of different insecticides on natural enemies on cotton were tabulated and subjected to the analysis of variance and standard error by using one factor Randomized Block Design. The differences were compared using critical difference (C.D.) at p=0.05 level of significance. The data were transformed using square root and angular transformation in OPSTAT.

CHAPTER-IV

EXPERIMENTAL RESULTS

Results of different experiments conducted on the efficacy of label claimed insecticides for whitefly, *Bemisia tabaci* in cotton are presented below and the data are interpreted and supplemented with different tables and figures.

4.1 Efficacy of label claimed insecticides against whitefly under field conditions

As per the protocol three sprays were applied at an interval of 15 days, started at 90 days after sowing. The data on whitefly adults were recorded one day before spray, and third and seventh day after application of insecticides.

4.1.1 Whitefly adult population during first spray

The first spray was applied on 90 days after sowing and observations recorded on the population of whitefly revealed that all the insecticides evaluated against whitefly adults recorded lower number of adult whiteflies as compared to control. As per the data recorded, after 3rd day of first spray, among the different insecticides tested, flonicamid 50WG was found most effective in reducing whitefly population (4.2 adults/leaf) against 15.4 adults/leaf in control and it was found statistically at par with dinotefuran 20% SG, pyriproxyfen 5% EC + fenpropathrin 15% EC and ethion 50% EC with 4.5, 4.5 and 4.7 adults/leaf, respectively. Thiacloprid 21.7% SC was the next effective treatment which recorded 6.3 adults/leaf and statistically at par with chlorpyrifos 20% EC. All other insecticides showed a moderate efficacy against adults wherein 8.0 to 10.2 adults per leaf were recorded whereas, fipronil 4% + acetamiprid 4% w/w and fenpropathrin 30% EC were least effective having a whitefly population of 12.5 and 12.2 adults/leaf, respectively (Table 2).

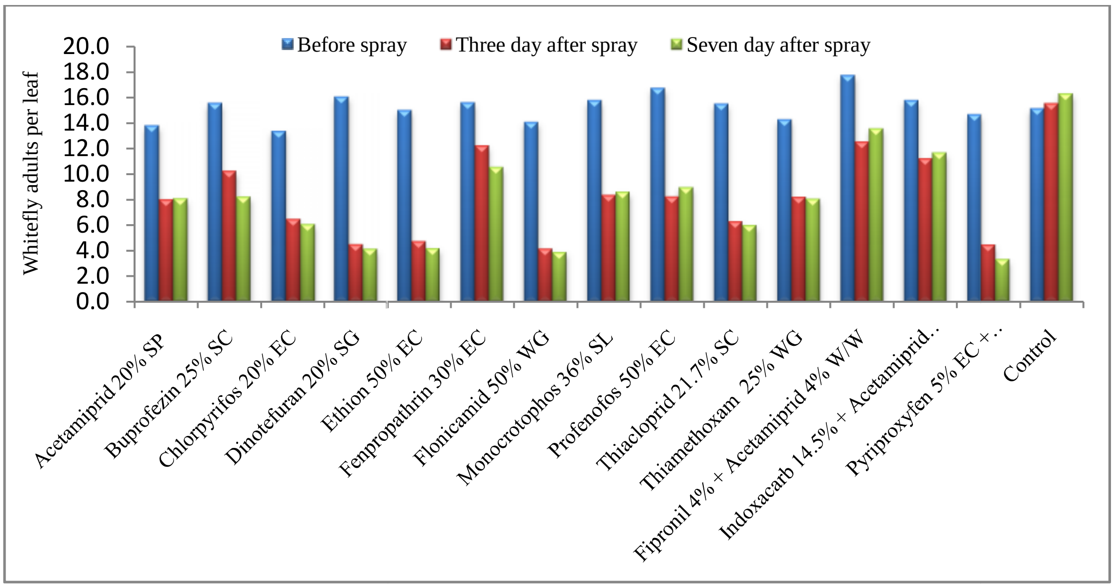

Figure 1: Whitefly adult population during first spray

Table 2: Efficacy of different insecticides against whitefly adults after first spray

S.No.	Treatments	Whitefly adults per leaf during first spray		
		Before spray	After spray	
			3rd day	7th day
T1	Acetamiprid 20% SP	13.7 (3.8)*	8.0 (3.0)	8.0 (3.0)
T2	Buprofezin 25% SC	15.4 (4.1)	10.2 (3.3)	8.2 (3.0)
T3	Chlorpyrifos 20% EC	13.3 (3.8)	6.4 (2.7)	6.1 (2.6)
T4	Dinotefuran 20% SG	16.0 (4.1)	4.5 (2.3)	4.1 (2.3)
T5	Ethion 50% EC	15.0 (4.0)	4.7 (2.4)	4.2 (2.3)
T6	Fenpropathrin 30% EC	15.6 (4.1)	12.2 (3.6)	11.8 (3.7)
T7	Flonicamid 50% WG	14.1 (3.9)	4.2 (2.3)	3.9 (2.2)
T8	Monocrotophos 36% SL	15.8 (4.1)	8.4 (3.1)	8.6 (3.1)
T9	Profenofos 50% EC	16.7 (4.2)	8.2 (3.0)	9.0 (3.2)
T10	Thiacloprid 21.7% SC	15.5 (4.1)	6.3 (2.7)	6.0 (2.6)
T11	Thiamethoxam 25% WG	14.3 (3.9)	8.2 (3.0)	8.1 (3.0)
T12	Fipronil 4% + Acetamiprid 4% W/W	17.7 (4.3)	12.5 (3.7)	13.6 (3.8)
T13	Indoxacarb 14.5% + Acetamiprid 7.7% w/w SC	15.8 (4.1)	10.5 (3.4)	9.6 (3.3)
T14	Pyriproxyfen 5% EC + Fenpropathrin 15% EC	14.7 (4.0)	4.5 (2.3)	3.3 (2.1)
T15	Control	15.0 (4.0)	15.4 (4.1)	16.2 (4.1)
	CD (p=0.05)	(NS)	(0.2)	(0.3)

*Figures in parentheses are the square root transformed values ($\sqrt{n+1}$).

At seven days after first spray pyriproxyfen 5% EC + fenpropathrin 15% EC was most effective by recording 3.3 adults/leaf and it was statistically at par with flonicamid 50 WG, dinotefuran 20% SG and ethion 50% EC with an population of 3.9, 4.1 and 4.2 adults/leaf, respectively against control *i.e.* 16.2 adults/leaf. Thiacloprid 21.7% SC was the next effective treatment recorded 6.0 adults/leaf and statistically at par with chlorpyrifos 20% EC whereas, fipronil 4% + acetamiprid 4% w/w and fenpropathrin 30% EC were least effective (13.6 and 11.8 adults/leaf), respectively.

4.1.2 Whitefly adult population during second spray

The second spray was applied on crop stage of 105 days after sowing. The data presented in the Table 3 revealed that the application of insecticides resulted in the reduction in whitefly adult population but the efficacy in comparison to first spray was less. The general population during one day before second spray varied between 7.4 (flonicamid) to 18.1 (control) adults/leaf. Data recorded after three days of second spray, showed that all the insecticidal treatments were significantly effective in reducing the population of whitefly similar to first spray application with flonicamid 50 WG recorded the lowest adult population of 3.1 adults/leaf and it was statistically at par with ethion 50% EC and pyriproxyfen 5% EC + fenpropathrin 15% EC with 3.6 and 4.0 whitefly adults/leaf, respectively followed by chlorpyrifos 20% EC (4.1 adults/leaf) whereas, fipronil 4% + acetamiprid 4% w/w and fenpropathrin 30% EC were poor in checking adult population and recorded the highest population of 8.0 and 7.2 adults/leaf, respectively.

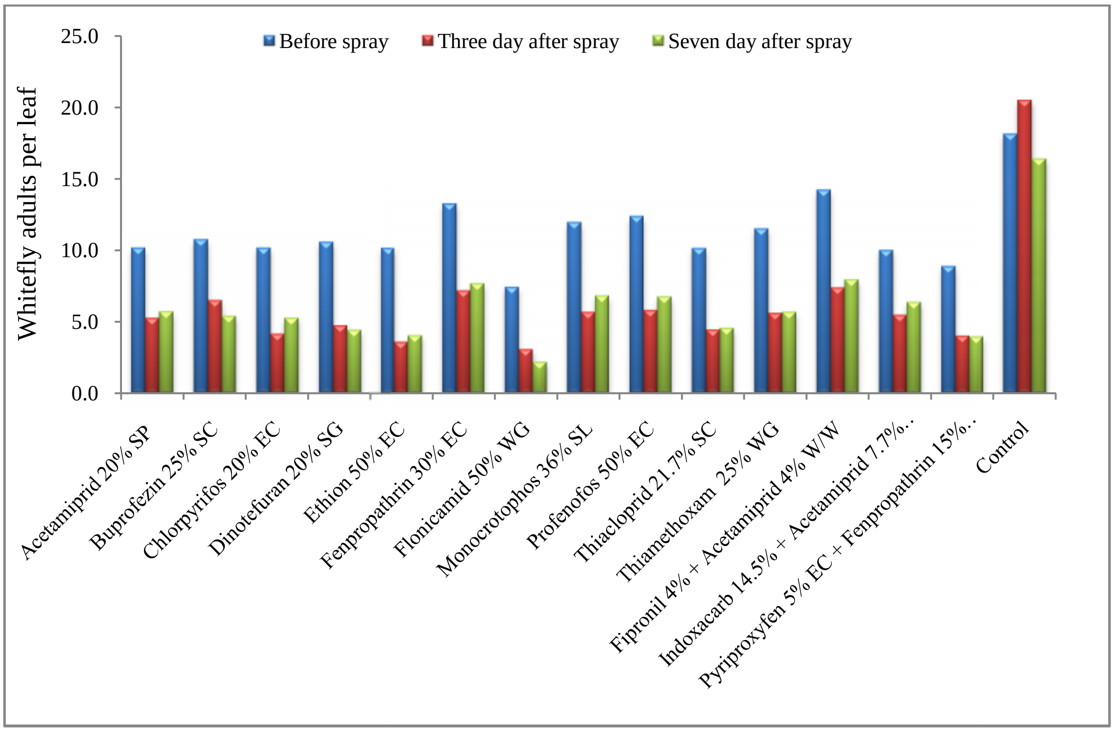

Figure 2: Whitefly adult population during second spray

At seven days after second spray significantly higher adult population was observed in case of control compared to plants sprayed with insecticides. Flonicamid 50 WG was significantly superior over other insecticides in reducing the whitefly adult population by recording 2.2 adults/leaf followed by pyriproxyfen 5% EC + fenpropathrin 15% EC (4.0 adults/leaf) and found statistically at par with ethion 50% EC, dinotefuran 20% SG and thiacloprid 21.7% SC. Fenpropathrin 30% EC and fipronil 4% + acetamiprid 4% w/w were least effective against adults, which recorded a population of 7.7 and 8.6 adults/leaf, respectively.

Table 3: Efficacy of different insecticides against whitefly adults after second spray

S.No.	Treatments	Whitefly adults per leaf during second spray		
		Before spray	After spray	
			3rd day	7th day
T1	**Acetamiprid 20% SP**	10.1 (3.3)*	5.2 (2.5)	5.7 (2.6)
T2	**Buprofezin 25% SC**	10.7 (3.4)	6.5 (2.6)	5.4 (2.5)
T3	**Chlorpyrifos 20% EC**	10.1 (3.3)	4.1 (2.4)	5.2 (2.5)
T4	**Dinotefuran 20% SG**	10.5 (3.4)	4.7 (2.5)	4.4 (2.3)
T5	**Ethion 50% EC**	10.2 (3.3)	3.6 (2.1)	4.3 (2.3)
T6	**Fenpropathrin 30% EC**	13.3 (3.8)	7.2 (2.9)	7.7 (2.9)
T7	**Flonicamid 50% WG**	7.4 (2.9)	3.1 (2.0)	2.2 (1.8)
T8	**Monocrotophos 36% SL**	12.0 (3.6)	5.7 (2.6)	6.8 (2.8)
T9	**Profenofos 50% EC**	12.4 (3.7)	5.8 (2.6)	6.8 (2.8)
T10	**Thiacloprid 21.7% SC**	10.2 (3.3)	4.5 (2.4)	4.6 (2.4)
T11	**Thiamethoxam 25% WG**	11.5 (3.5)	5.6 (2.6)	5.7 (2.6)
T12	**Fipronil 4% + Acetamiprid 4% W/W**	14.2 (3.9)	8.0 (3.2)	8.6 (3.1)
T13	**Indoxacarb 14.5% + Acetamiprid 7.7% w/w SC**	10.0 (3.3)	5.5 (2.5)	6.4 (2.7)
T14	**Pyriproxyfen 5% EC + Fenpropathrin 15% EC**	8.9 (3.3)	4.0 (2.2)	4.0 (2.2)
T15	**Control**	18.1 (4.4)	20.5 (4.6)	16.4 (4.2)
	CD (p=0.05)	(0.3)	(0.3)	(0.2)

*Figures in parentheses are the square root transformed values (√n+1).

4.1.3 Whitefly adult population during third spray

The data presented in the Table 4 indicated that whitefly adult population at one day before third spray was minimum in flonicamid 50 WG (5.4 adults/ leaf) against maximum in control (13.5 adults/leaf) after 15 days of second spray.

At three days after third spray similar pattern was observed with the lowest number of adults recorded in the plots treated with flonicamid 50 WG (2.7 adults/leaf) and it was found statistically at par with ethion 50% EC (2.8 adults/leaf) followed by dinotefuran SG 20% (3.4

adults/leaf). However, fenpropathrin 30% EC and fipronil 4% + acetamiprid 4% w/w recorded a significantly higher adult population of 7.0 and 7.3 adults/leaf, respectively.

At seven days after third spray flonicamid 50 WG was most effective in reducing the population of whitefly *i.e.* 2.4 adults/leaf and it was statistically at par with dinotefuran 20% SG (2.8 adults/leaf), followed by ethion 50% EC (3.1 adults/leaf) and statistically at par with thiacloprid 21.7% SC and thiamethoxam 25% WG whereas, fenpropathrin 30% EC and fipronil 4% + acetamiprid 4% w/w were least effective recorded an adult population of 7.2 and 8.0 adults/leaf, respectively.

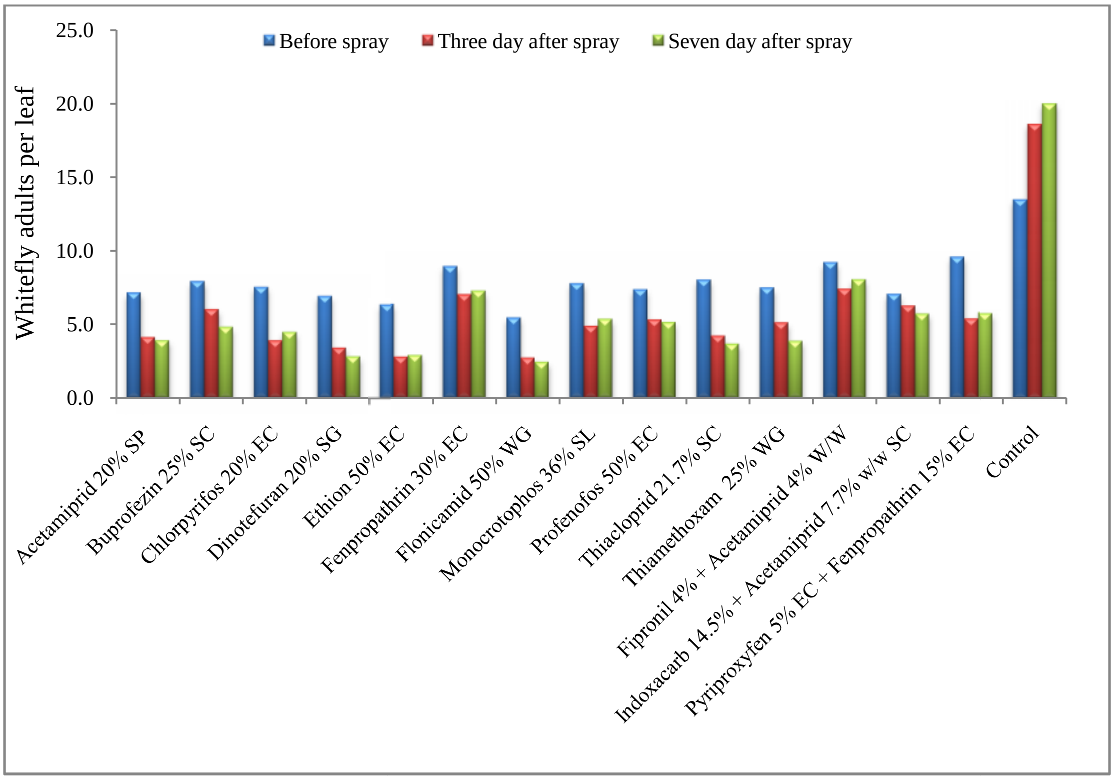

Figure 3: Whitefly adult population during third spray

4.1.4 Pooled data of first, second and third spray on efficacy of insecticides against *B. tabaci* adults under field conditions

The pooled data of three spray application on the efficacy of insecticides against adult whiteflies presented in the Table 5 revealed that flonicamid 50 WG was the most effective insecticide against adult whiteflies at three days after spray, which recorded a mean population of 3.3 adults per leaf and it was statically at par with ethion 50% EC (3.7 adults/leaf) and dinotefuran SG 20% (4.2 adults/leaf). Pyriproxyfen 5% EC + fenpropathrin 15% EC, chlorpyrifos 20% EC, and thiacloprid 21.7% SC were the next promising chemicals against adults. Higher mean adult population was recorded in fenpropathrin 30% EC and fipronil 4% + acetamiprid 4% w/w with 8.8 and 9.3 adults per leaf, respectively.

Table 4: Efficacy of different insecticides against whitefly adults after third spray

S.No.	Treatments	Whitefly adults per leaf during third spray		
		Before spray	After spray	
			3rd day	7th day
T1	**Acetamiprid 20% SP**	7.1 (2.9)	4.1 (2.3)	4.6 (2.4)
T2	**Buprofezin 25% SC**	7.9 (2.8)	6.0 (2.6)	4.8 (2.4)
T3	**Chlorpyrifos 20% EC**	7.5 (2.9)	3.9 (2.3)	4.5 (2.4)
T4	**Dinotefuran 20% SG**	6.9 (2.8)	3.4 (2.2)	2.8 (2.0)
T5	**Ethion 50% EC**	6.3 (2.7)	2.8 (2.0)	3.1 (2.1)
T6	**Fenpropathrin 30% EC**	8.9 (3.1)	7.0 (2.8)	7.2 (2.9)
T7	**Flonicamid 50% WG**	5.4 (2.4)	2.7 (1.9)	2.4 (1.8)
T8	**Monocrotophos 36% SL**	7.7 (2.9)	4.8 (2.4)	5.3 (2.5)
T9	**Profenofos 50% EC**	7.3 (2.9)	5.3 (2.5)	5.1 (2.5)
T10	**Thiacloprid 21.7% SC**	7.9 (2.9)	4.2 (2.3)	3.6 (2.2)
T11	**Thiamethoxam 25% WG**	7.4 (2.9)	5.1 (2.5)	3.8 (2.2)
T12	**Fipronil 4% + Acetamiprid 4% W/W**	9.1 (3.2)	7.3 (2.9)	8.0 (3.0)
T13	**Indoxacarb 14.5% + Acetamiprid 7.7% w/w SC**	7.0 (2.8)	6.2 (2.6)	5.7 (2.6)
T14	**Pyriproxyfen 5% EC + Fenpropathrin 15% EC**	9.5 (3.2)	5.3 (2.5)	5.7 (2.6)
T15	**Control**	13.5 (3.8)	18.6 (4.4)	20.0 (4.6)
	CD (p=0.05)	(0.2)	(0.2)	(0.2)

*Figures in parentheses are the square root transformed values (√n+1).

Table 5: Efficacy of different insecticides against whitefly adults (pooled data of first, second and third spray)

S.No.	Treatments	Whitefly adults per leaf		
		Before spray	After spray	
			3rd day	7th day
T1	**Acetamiprid 20% SP**	10.3 (3.3)*	5.8 (2.6)	6.1 (2.7)
T2	**Buprofezin 25% SC**	11.3 (3.5)	7.5 (2.9)	6.1 (2.7)
T3	**Chlorpyrifos 20% EC**	10.3 (3.3)	4.8 (2.4)	5.3 (2.5)
T4	**Dinotefuran 20% SG**	11.1 (3.4)	4.2 (2.3)	3.8 (2.2)
T5	**Ethion 50% EC**	10.5 (3.3)	3.7 (2.2)	3.9 (2.3)
T6	**Fenpropathrin 30% EC**	12.6 (3.8)	8.8 (3.1)	8.9 (3.1)
T7	**Flonicamid 50% WG**	9.0 (3.1)	3.3 (1.9)	2.8 (1.8)
T8	**Monocrotophos 36% SL**	11.8 (3.6)	6.3 (2.7)	6.9 (2.8)
T9	**Profenofos 50% EC**	12.1 (3.6)	6.4 (2.7)	6.9 (2.8)
T10	**Thiacloprid 21.7% SC**	11.2 (3.5)	5.0 (2.4)	4.7 (2.5)
T11	**Thiamethoxam 25% WG**	11.1 (3.4)	6.3 (2.7)	5.9 (2.6)
T12	**Fipronil 4% + Acetamiprid 4% W/W**	13.7 (3.9)	9.3 (3.2)	10.0 (3.3)
T13	**Indoxacarb 14.5% + Acetamiprid 7.7% w/w SC**	10.9 (3.4)	7.4 (2.9)	7.2 (2.9)
T14	**Pyriproxyfen 5% EC + Fenpropathrin 15% EC**	11.0 (3.5)	4.6 (2.4)	4.3 (2.3)
T15	**Control**	15.5 (4.1)	18.2 (4.4)	17.5 (4.3)
	CD (p=0.05)	(0.3)	(0.4)	(0.4)

*Figures in parentheses are the square root transformed values (√n+1).

At seven days spray, plants sprayed with insecticides significantly recorded lower number of adults as compared to control. Flonicamid 50 WG was the most effective treatment with minimum adult population (2.8 adults/leaf) and at par with dinotefuran 20% SG (3.8 adults/leaf). The next effective insecticides were ethion 50% EC, pyriproxyfen 5% EC + fenpropathrin 15% EC and thiacloprid 21.7% SC. The insecticides fenpropathrin 30% EC and fipronil 4% + acetamiprid 4% w/w recorded a significantly higher mean adult population of 8.9 adults/leaf and 10 adults/leaf, respectively. The remaining insecticides showed a moderate efficacy against adults with a population count varying from 5.3 to 7.2 adults per leaf. The highest population of 17.5 adults per leaf was observed in the case of control.

4.2 Efficacy of label claimed insecticides against whitefly adults under laboratory conditions through leaf dip- bioassay method

All insecticides proved significantly better over the control in checking adult population of *B. tabaci*. After 24 hours of treatment, flonicamid 50WG resulted into significantly higher adult mortality (61.1 per cent) than all other insecticides tested. The next promising insecticides against the adult was ethion 50% EC with 55.2 per cent mortality and it was at par with dinotefuran 20% SG and pyriproxyfen 5% EC + fenpropathrin 15% EC with 53.0 per cent and 49.2 per cent mortality, respectively. The remaining insecticides exhibited moderate effect on whitefly adult with mortality of 40.2 to 48.3 per cent whereas, lowest mortality 26.9 per cent was recorded in buprofezin 25% SC.

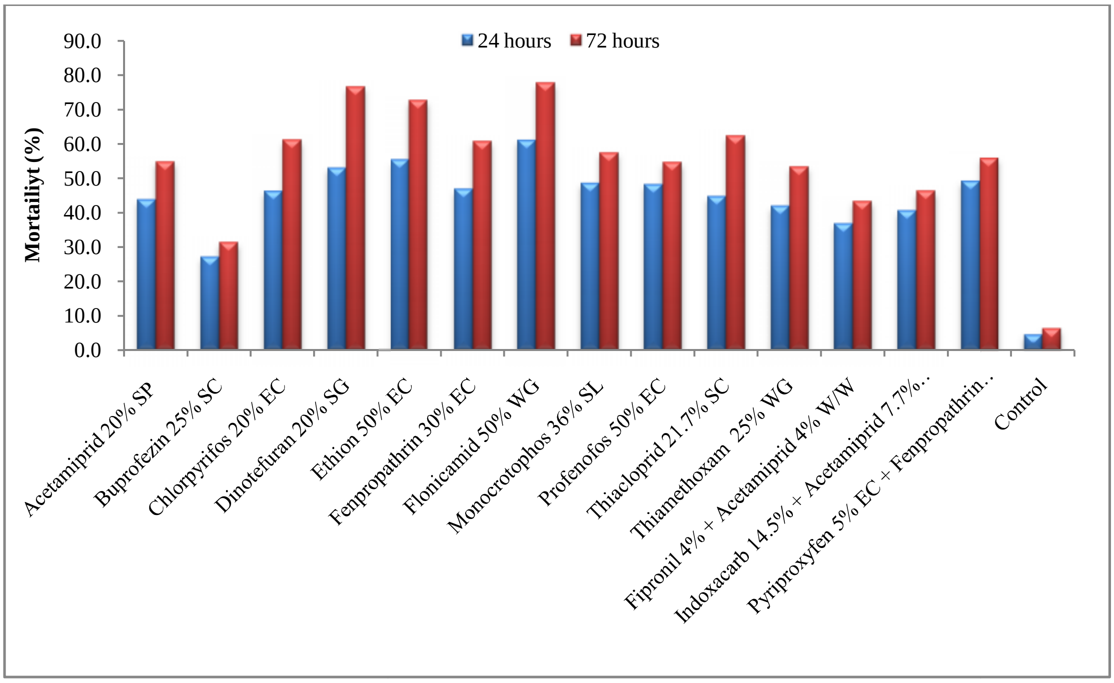

Figure 4: Whitefly adult mortality by label claimed insecticides under laboratory conditions

At 72 hours after treatment similar trend was observed with maximum whitefly adult mortality was recorded in flonicamid 50% WG (77.8 per cent) and dinotefuran 20% SG (76.6 per cent), these insecticides were significantly superior to all other treatments followed by ethion 50% EC (70.3 per cent) and thiacloprid 21.7% SC, whereas, mortality was recorded least in buprofezin 25% SC EC (31.0 per cent) Table 6.

Table 6: Efficacy of label claimed insecticides against whitefly adults under laboratory conditions

S.No.	Treatments	Mortality (%) of whitefly adults	
		After 24 hrs	After 72 hrs
T1	**Acetamiprid 20% SP**	43.5 (41.2)*	54.4 (45.8)
T2	**Buprofezin 25% SC**	26.9 (31.2)	31.0 (33.8)
T3	**Chlorpyrifos 20% EC**	46.0 (42.7)	60.8 (51.3)
T4	**Dinotefuran 20% SG**	53.0 (46.7)	76.6 (61.2)
T5	**Ethion 50% EC**	55.2 (47.9)	70.3 (56.4)
T6	**Fenpropathrin 30% EC**	46.6 (43.1)	60.5 (51.1)
T7	**Flonicamid 50% WG**	61.1 (51.5)	77.8 (61.9)
T8	**Monocrotophos 36% SL**	48.3 (44.0)	57.0 (49.1)
T9	**Profenofos 50% EC**	48.2 (43.9)	54.6 (47.6)
T10	**Thiacloprid 21.7% SC**	44.8 (42.0)	62.4 (52.2)
T11	**Thiamethoxam 25% WG**	41.6 (40.2)	52.9 (46.7)
T12	**Fipronil 4% + Acetamiprid 4% W/W**	36.5 (37.2)	43.0 (40.9)
T13	**Indoxacarb 14.5% + Acetamiprid 7.7% w/w SC**	40.2 (39.4)	45.9 (42.6)
T14	**Pyriproxyfen 5% EC + Fenpropathrin 15% EC**	49.2 (44.5)	55.8 (48.3)
T15	**Control**	4.5 (12.3)	6.3 (14.5)
	CD (p=0.05)	(3.4)	(4.9)

*Figures in parentheses are the angular transformed values.

4.3 Effect of label claimed insecticides on non target organisms

The insecticides because of their chemical nature are harmful to insects but under field conditions lot of non target insect species are also affected due to the activity spectrum of these insecticides. So, the data of generalized predators/plant in cotton was recorded on seventh day after application of insecticides.

4.3.1 Population of predators per plant during first spray

Observation recorded on natural enemies' population at seven days after spraying indicated significant differences among different treatments. Most of insecticides found highly toxic to the natural enemies *viz.*, chrysoperla and spider. Maximum population of chrysoperla was observed in control *i.e*. 2.0 per plant which was statistically at par with buprofezin 25% SC and flonicamid 50%WG with 1.6 per plant and 1.3 per plant, respectively. Similar impact of buprofezin 25% SC and flonicamid 50%WG have been observed on spider population having 2.1 and 1.8 spiders per plant, respectively *i.e*. statically at par with control (2.1 per plant).

Table 7: Population of predators per plant after first spray

S.No.	Treatments	Natural enemies per plant		
		Chrysoperla	Spider	Coccinellids
T1	Acetamiprid 20% SP	0.3 (1.1)*	0.3 (1.1)	0.0 (0.0)
T2	Buprofezin 25% SC	1.6 (1.6)	1.8 (1.7)	0.0 (0.0)
T3	Chlorpyrifos 20% EC	0.1 (1.0)	0.1 (1.0)	0.0 (0.0)
T4	Dinotefuran 20% SG	0.3 (1.1)	0.5 (1.2)	0.0 (0.0)
T5	Ethion 50% EC	0.5 (1.2)	0.7 (1.3)	0.0 (0.0)
T6	Fenpropathrin 30% EC	0.5 (1.2)	0.2 (1.1)	0.0 (0.0)
T7	Flonicamid 50% WG	1.3 (1.5)	2.1 (1.7)	0.0 (0.0)
T8	Monocrotophos 36% SL	0.1 (1.1)	0.2 (1.1)	0.0 (0.0)
T9	Profenofos 50% EC	0.4 (1.2)	0.3 (1.1)	0.0 (0.0)
T10	Thiacloprid 21.7% SC	0.1 (1.0)	0.1 (1.1)	0.0 (0.0)
T11	Thiamethoxam 25% WG	0.6 (1.3)	0.1 (1.1)	0.0 (0.0)
T12	Fipronil 4% + Acetamiprid 4% W/W	0.0 (1.0)	0.1 (1.0)	0.0 (0.0)
T13	Indoxacarb 14.5% + Acetamiprid 7.7% w/w SC	0.0 (1.0)	0.1 (1.1)	0.0 (0.0)
T14	Pyriproxyfen 5% EC + Fenpropathrin 15% EC	0.4 (1.2)	0.7 (1.3)	0.0 (0.0)
T15	Control	2.0 (1.7)	2.1 (1.8)	0.0 (0.0)
	CD (p=0.05)	(0.2)	(0.2)	(N.S)

*Figures in parentheses are the square root transformed values (√n+1).

However in none of the treatment coccinellid species was observed. Other than flonicamid 50WG and buprofezin 25% EC all other label claimed insecticide *i.e.* acetamiprid 20% SP, chlorpyrifos 20% EC, dinotefuran 20% SG, ethion 50% EC, fenpropathrin 30% EC, monocrotophos 36% SL, profenofos 50% EC, thiacloprid 21.7% SC, thiamethoxam 25% WG, fipronil 4% + acetamiprid 4% W/W, indoxacarb 14.5% + acetamiprid 7.7% w/w SC and pyriproxyfen 5% EC + fenpropathrin 15% EC were found toxic to both chrysoperla and spider (Table 7).

4.3.2: Population of predators per plant during second and third spray

A similar trend was observed of label claimed insecticides toxicity against natural enemies' population in second and third spray as observed during first spray. However at the time of third spray coccinellids population builds up to 1.8 per plant in control and both buprofezin 25% SC and flonicamid 50%WG were at par with control having a coccinellid population of 1.2 and 1.3 per plant, respectively (Table 8 and 9)

Table 8: Population of predators per plant after second spray

S.No.	Treatments	Natural enemies per plant		
		Chrysoperla	Spider	Coccinellids
T1	Acetamiprid 20% SP	0.3 (1.0)*	0.6 (1.3)	0.0 (0.0)
T2	Buprofezin 25% SC	1.7 (1.6)	0.8 (1.3)	0.0 (0.0)
T3	Chlorpyrifos 20% EC	0.0 (1.0)	0.2 (1.1)	0.0 (0.0)
T4	Dinotefuran 20% SG	0.8 (1.3)	0.4 (1.2)	0.0 (0.0)
T5	Ethion 50% EC	0.6 (1.3)	0.6 (1.3)	0.0 (0.0)
T6	Fenpropathrin 30% EC	0.8 (1.3)	0.2 (1.1)	0.0 (0.0)
T7	Flonicamid 50% WG	1.0 (1.4)	0.9 (1.4)	0.0 (0.0)
T8	Monocrotophos 36% SL	0.1 (1.1)	0.0 (1.0)	0.0 (0.0)
T9	Profenofos 50% EC	0.7 (1.3)	0.4 (1.2)	0.0 (0.0)
T10	Thiacloprid 21.7% SC	0.2 (1.1)	0.1 (1.1)	0.0 (0.0)
T11	Thiamethoxam 25% WG	0.4 (1.2)	0.8 (1.3)	0.0 (0.0)
T12	Fipronil 4% + Acetamiprid 4% W/W	0.0 (1.0)	0.0 (1.0)	0.0 (0.0)
T13	Indoxacarb 14.5% + Acetamiprid 7.7% w/w SC	0.2 (1.1)	0.3 (1.1)	0.0 (0.0)
T14	Pyriproxyfen 5% EC + Fenpropathrin 15% EC	0.4 (1.2)	0.5 (1.2)	0.0 (0.0)
T15	Control	1.1 (1.4)	1.1 (1.5)	0.0 (0.0)
	CD (p=0.05)	(0.2)	(0.2)	(N.S)

*Figures in parentheses are the square root transformed values ($\sqrt{n+1}$).

Table 9: Population of predators per plant after third spray

S.No.	Treatments	Natural enemies per plant		
		Chrysoperla	Spider	Coccinellids
T1	**Acetamiprid 20% SP**	0.6 (1.1)*	0.3 (1.1)	0.4 (1.2)
T2	**Buprofezin 25% SC**	0.9 (1.4)	1.5 (1.6)	1.2 (1.5)
T3	**Chlorpyrifos 20% EC**	0.1 (1.0)	0.1 (1.1)	0.0 (1.0)
T4	**Dinotefuran 20% SG**	0.6 (1.3)	0.7 (1.3)	0.3 (1.2)
T5	**Ethion 50% EC**	0.5 (1.2)	0.6 (1.3)	0.4 (1.2)
T6	**Fenpropathrin 30% EC**	0.5 (1.2)	0.2 (1.1)	0.6 (1.3)
T7	**Flonicamid 50% WG**	1.1 (1.4)	1.6 (1.6)	1.3 (1.5)
T8	**Monocrotophos 36% SL**	0.1 (1.1)	0.2 (1.10	0.0 (1.0)
T9	**Profenofos 50% EC**	0.4 (1.2)	0.4 (1.2)	0.5 (1.2)
T10	**Thiacloprid 21.7% SC**	0.0 (1.0)	0.0 (1.0)	0.2 (1.1)
T11	**Thiamethoxam 25% WG**	0.5 (1.2)	1.1 (1.4)	0.3 (1.2)
T12	**Fipronil 4% + Acetamiprid 4% W/W**	0.1 (1.0)	0.1 (1.1)	0.1 (1.0)
T13	**Indoxacarb 14.5% + Acetamiprid 7.7% w/w SC**	0.4 (1.2)	0.2 (1.1)	0.3 (1.1)
T14	**Pyriproxyfen 5% EC + Fenpropathrin 15% EC**	0.4 (1.2)	0.7 (1.3)	0.6 (1.3)
T15	**Control**	1.6 (1.6)	2.0 (1.7)	1.8 (1.7)
	CD (p=0.05)	(0.2)	(0.2)	(0.2)

*Figures in parentheses are the square root transformed values (√n+1).

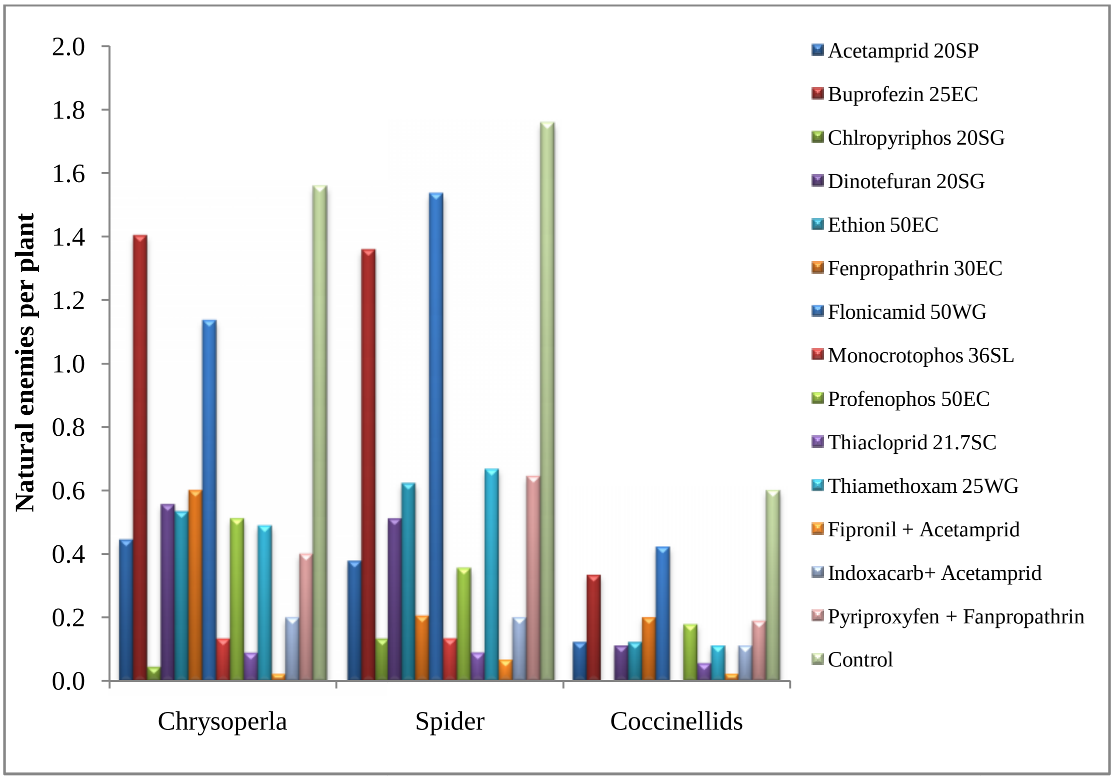

Figure 5: Average mean population of predators in different treatments

CHAPTER-V

DISCUSSION

Whitefly, *Bemesia tabaci*, is one of the most important cotton pest of worldwide occurrence causing considerable quantitative loss. It is causing severe economic damage in over 60 crop plants as a phloem sap sucking pest or as a vector of viral diseases. Commercially grown *Bt* cotton hybrids in North India are susceptible to this pest. *B. tabaci* has tremendous potential to develop resistance to insecticides. To date, *B. tabaci* has shown resistance to more than 40 active ingredients of insecticides (Whalon *et al*. 2013). Several field problems such as poor selection of chemicals and sub-standard application practices exacerbated the control failures of insecticides against *B. tabaci* in India. The repeated use of compounds of same active ingredients and application of excessive doses of insecticides within a given cropping season has led to the development of insecticide resistance against OPs and pyrethroids in *B. tabaci.*

A number of label claimed insecticides registered by Central Insecticide Registration Board are presently available in market, which needed to be continuously evaluated for their efficacy and to evaluate whether whitefly has developed resistance/resurgence mechanism against them. Also, the hazardous effect of these insecticides on natural enemies has to be studied. Keeping in view the economic importance of whitefly, the present study was conducted on bioefficacy of label claimed insecticides in field and laboratory conditions and their impact on natural enemies. The results obtained out of this investigation on these aspects are discussed as under.

5.1 Efficacy of label claimed insecticides against whitefly adults under field conditions

The insecticidal interventions were applied thrice during the cotton crop season against whitefly. The results of the individual spray applications were present individually and collectively for all three sprays. Based on the pooled analysis, among the different insecticides tested, flonicamid 50 WG was most effective in reducing whitefly adult population up to after seven days after spray and it was statistically at par with dinotefuran 20% SG, and ethion 50% EC. The present study lend credence from Roditakis *et al*. (2014) who reported flonicamid 500 g kg^{-1} WG at the RLRmax (125 mg L^{-1}) caused 95% mortality to whiteflies at 10 days after treatment and delayed population growth by one generation (32 days) and significantly delayed nymphal development by increasing the development time (DT50) of treated insects by 7.2 days. Similar results were reported by Ghelani *et al.* (2014) that flonicamid 0.02 per cent was found most effective against all major sucking pests of cotton. Dinotefuran 20 per cent SG @ 50 g a.i. /ha was found to be second most effective after nitenpyram 10 per cent WSG as reported by Kadam *et al*. (2014).

Sahito *et al.* (2015) reported pyriproxyfen 10.8 EC as more effective against whitefly with overall reduction (67.31±1.27%) in overall sprays as compared to acetamaprid 20 SP. Also, Walaa El-sayed (2013) conducted an study on field evaluation of plant extracts and certain insecticides against *Bemesia tabaci* (Gennadius) on tomato plants at Cairo, Egypt and reported reduction in the mean number of *B. tabaci* was higher in thiacloprid (1.33 nymph/leaf) than thiamethoxamv (1.82 nymph/ leaf). Similarly, in present study pyriproxyfen 5% EC + fenpropathrin 15% EC and thiacloprid 21.7% SC were the next effective treatment after flonicamid.

However, it was observed that fipronil 4% + acetamiprid 4% w/w and fenpropathrin 30% EC were least effective having a higher whitefly population at three and seven days after spray among all other insecticides tested due to the problem of resurgence and resistance as reported by Wang *et al*. (2010), who reported that four out of 12 populations had low to medium levels of resistance to fipronil (10–25-fold). Erdogan *et al*. (2008) reported different strains of whitefly in turkey had resistance factors for fanpropathrin ranged from 57 to 290. Similarly, low efficacy of fanpropathrin was supported by Amjad *et al*. (2009) who reported mortality of fenpropatrin 20 EC at one day and seven days after spray was recorded 33.90% and 27.19 %, respectively followed by thiamethoxam 25WG with 26.99% mortality on first and 20.79% on seventh day. The efficacy of combination product fipronil + acetamprid of the present study was more or less similar to as reported by Bharpoda *et al*. (2014), that fipronil 5 EC @ 0.1% and carbosulfan 25 EC @ 0.025% were found more or less equally effective and proved to be less effective group of chemicals among nine synthetic insecticides studied under. But our findings are contradictory to Shivanna *et al*. (2011) who reported that fenpropathrin 30 EC had a superior efficacy in bringing down all the sucking pest population at one day after spray followed by dimethoate, imidacloprid and standard check acetamiprid but the differences could be due to shorter observation period in the earlier studies.

5.2 Efficacy of label claimed insecticides against whitefly adults under laboratory conditions

Among the different insecticides evaluated against whitefly adults of, *B. tabaci* under laboratory conditions revealed that flonicamid 50% WG was the most promising chemical against the adults causing significantly higher adult mortality than all other insecticides tested. However the results were contradictory with Babcock *et al*.(2010) concluding flonicamid was relatively weak against whiteflies, producing less than 50% mortality at the highest rate tested (200 mg L^{-1}) while, acetamiprid, thiamethoxam and dinotefuran were significantly more potent. The contradiction may be due to the dosage and insecticides use pattern, as the use of neonicotinoids in India is already saturated where as flonicamid is very new molecule to cotton crop.

The next promising insecticide against the adult was ethion 50% EC and it was statistically at par with dinotefuran 20% SG and pyriproxyfen 5% EC + fenpropathrin 15% EC. No information is available on the efficacy of these insecticides against adult whiteflies under laboratory conditions. Though the insecticides has label claim against whitefly but could not find a place in recommendation and can be next best options if currently used insecticides acquire resistance.

Bioassay studies against pomegranate aphid, *Aphis punicae* conducted by Rouhani *et al*. (2013), the probit analysis data revealed that the sensitivity of the aphid to the pesticides was imidacloprid > thiacloprid > flonicamid > thiamethoxam. The results showed that imidacloprid and thiacloprid at 1 µl/ml, thiamethoxam at 0.35 mg/ml and flonicamid at 0.1 mg/ml had the highest mortality. Whereas, mortality was recorded least in buprofezin 25% SC EC most likely due to the effect of buprofezin is least against adults as reported by Ishaaya *et al*. (1988) where various concentrations of buprofezin ranging from 3.9 to 500 mg/liter had no direct effect on adults or oviposition also Yausi *et al*. (1987) reported that buprofezin has no direct effect on eggs, but it seems to suppress embryogenesis indirectly through adults. In the present bioassay setup very poor efficacy of buprofezin can be attributed to its above characteristics of this particular insecticide.

5.3 Effect of label claimed insecticides on non target organisms

Other than flonicamid 50 WG and buprofezin 25% EC all other label claimed insecticide *i.e*. acetamiprid 20% SP, chlorpyrifos 20% EC, dinotefuran 20% SG, ethion 50% EC, fenpropathrin 30% EC, monocrotophos 36% SL, profenofos 50% EC, thiacloprid 21.7% SC, thiamethoxam 25% WG, fipronil 4% + acetamiprid 4% W/W, indoxacarb 14.5% + acetamiprid 7.7% w/w SC and pyriproxyfen 5% EC + fenpropathrin 15% EC were found toxic to natural enemies *viz*., chrysoperla, spider and coccinellids.

The findings of non target effect observations of the present studies are in conformation with, Sabry and Sayed (2011) who tested chlorpyrifos and buprofezin against the second instar larvae and adults of the green lacewing, *Chrysoperla carnea* and reported chlorpyrifos as more toxic to second instar larvae than buprofezin with LC_{50}, 1.78 and 997.05 ppm respectively. Buprofezin was least toxic to second instar larvae and adults of *C. carnea*. Similarly results are in agreement with Varghese and Beevi (2004) who found that chlorpyrifos as the most toxic to the second instar larvae of the green lacewing, *C. carnea* followed by profenfos.

The IGRs are comparatively safer to natural enemies as reported in the study. Naranjo *et al.* (2003) reported that management strategies based on the initial use of the IGRs buprofezin and pyriproxyfen preserves natural enemies compared with sole reliance on conventional insecticide mixtures. Direct toxicological effects of both IGRs have been shown in laboratory bioassays of various natural enemy species. Buprofezin reduced survival and prolonged development in first instars of *C. rufilabris* (Burmeister) (Liu and Chen, 2000) and pyriproxyfen had similar effects on eggs and larvae (Chen and Liu, 2002). However, Balasubramani and Regupathy (1994) reported no effect of buprofezin on larval stages of *C. carnea*. A high level of mortality to the adults of the coccinellid, *Hippodamia convergens* was caused by pyriproxyfen (Anonymous, 1998) also Ishaaya and Horowitz (1998) reported pyriproxyfen was relatively harmless to natural enemies, except ladybeetle predators. Although coccinellids were rare at our study site, we observed no consistent negative effects of either buprofezin on these taxa.

Naranjo and Akey (2005) that nine of 17 taxa of arthropod predators were significantly depressed with the use of acetamiprid compared with an untreated control, including common species such as *Geocoris punctipes*, *Orius tristicolor*, *Chrysoperla carnea*, *Collops vittatus*, *Hippodamia convergens* and *Drapetis divergens* support the findings of our study.

Garzon *et al*. (2015) tested the toxicity and sublethal effects of flonicamid under laboratory and found that flonicamid was innocuous to last instars larvae and adults of *Chrysoperla carnea* and *Adalia bipunctata*. Flonicamid did not affect the survival of *Eretmocerus eremicus* adults as reported by Roditakis *et al*. (2014).

The usage of IGRs and comparatively safer insecticides can be encouraged in a successful IPM program of insect pests especially in cotton to sustain the ecosystem and holistic approach of pest management.

CHAPTER-VI

SUMMARY AND CONCLUSION

The present studies entitled "Studies on the efficacy of label claimed insecticides for whitefly *Bemisia tabaci* (Gennadius) (Homoptera: Aleyrodidae) in cotton *Gossypium hirsutum* L., under field and laboratory conditions" were carried out during 2016-17, both in the laboratory as well as at Cotton Research Area of Department of Genetics and Plant Breeding, CCS Haryana Agricultural University, Hisar to generate information on efficacy of label claimed insecticides against whitefly and to study especially the effect of these insecticides on non- target organisms under field conditions. *Bt* Cotton hybrid NCS 855 BG II was sown during mid of May with fifteen treatments *i.e*. acetamiprid 20% SP, buprofezin 25% SC, chlorpyrifos 20% EC, dinotefuran 20% SG, ethion 50% EC, fenpropathrin 30% EC, flonicamid 50% WG, monocrotophos 36% SL, profenofos 50% EC, thiacloprid 21.7% SC, thiamethoxam 25% WG, fipronil 4% + acetamiprid 4% W/W, indoxacarb 14.5% + acetamiprid 7.7% w/w SC and pyriproxyfen 5% EC + fenpropathrin 15% EC and a control. While *in vitro* efficacy of these insecticides was studied under laboratory conditions at temperature 28±2°C and relative humidity 65 per cent.

The different insecticides belonging to organophosphate, neonicotinoids, new molecules and combination products having label claim against whitefly were selected for study. Evaluation of different insecticides against *B. tabaci* adults in field conditions revealed that, flonicamid 50WG was the most effective insecticide in controlling the adult whitefly population in all three sprays, followed by ethion 50% EC, dinotefuran 20% SG and pyriproxyfen 5% EC + fenpropathrin 15% EC proved promising in first spray at three and seven days after spray. Similar trend was observed during second and third spray however, during third spray higher population was recorded in pyriproxyfen 5% EC + fenpropathrin 15% EC because of whitefly resurgence due to fenpropathrin (synthetic pyrethroids) in the formulation. The plots treated with fenpropathrin 30% EC and fipronil 4% + acetamiprid 4% w/w sustained heavy infestation of whitefly in all three sprays applied because of resistance and resurgence issues.

Leaf dip bioassay studies on whitefly adults under laboratory conditions revealed, flonicamid 50 WG lead to maximum per cent mortality at 24 and 72 hours after treatment, followed by ethion 50% EC and dinotefuran 20 % SG, rest of insecticides gave moderate mortality, except buprofezin 25% SC recorded minimum per cent mortality because, buprofezin belongs to Insect Growth Regulator (IGR) class and most effective against nymphal stage only.

The non target effects of these label claimed insecticides were also studied and on the basis of predator population recorded in different treatment during first, second and third spray, it was found that the population of predators' *viz.*, chrysoperla and spider was higher in plot treated with buprofezin 25% SC and flonicamid 50WG and does not vary significantly with control whereas, natural population of coccinellids was absent during first and second spray. Population of coccinellids builds up during third spray and similar results were observed for these species of generalist predators. All other insecticides were found toxic to the predators.

Studies carried out under field and laboratory conditions to study efficacy of insecticides against whitefly adults and their effect on non target organisms revealed, flonicamid 50 WG as the best insecticide in managing whitefly population and least toxic to the natural enemies. However other promising insecticides such as ethion 50% EC and dinotefuran 20 % SG controls whitefly effectively but were found toxic to natural enemies *viz*., chrysoperla, spider and coccinellids. Buprofezin 25% SC was found statistically at par with flonicamid in respect to toxicity against natural enemies but not as much effective against whitefly adults in both field and laboratory conditions.

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ABSTRACT

Title of dissertation	**:**	Studies on the efficacy of label claimed insecticides for whitefly *Bemisia tabaci* (Gennadius) (Homoptera: Aleyrodidae) in cotton *Gossypium hirsutum* L., under field and laboratory conditions
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Year of award of degree	**:**	2017
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Total no. of pages in the dissertation	**:**	**30+vii**
No. of words in the abstract	**:**	222

Key words: *Bemisia tabaci,* Cotton, Label claimed insecticides, Bioefficacy.

The present studies entitled "Studies on the efficacy of label claimed insecticides for whitefly *Bemisia tabaci* (Gennadius) (Homoptera: Aleyrodidae) in cotton *Gossypium hirsutum* L., under field and laboratory conditions" were carried out during *Kharif* 2016 at Cotton Research Area, CCS Haryana Agricultural University, Hisar. Under field conditions out of 14 label claimed insecticides evaluated, flonicamid 50 WG, dinotefuran 20% SG and ethion 50% EC were most effective in reducing whitefly adult population up to after seven days after spray, followed by pyriproxyfen 5% EC + fenpropathrin 15% EC and thiacloprid 21.7% SC. Fipronil 4% + acetamiprid 4% w/w and fenpropathrin 30% EC were least effective among all label claimed insecticides tested. Under *in vitro* conditions, flonicamid 50% WG was the most promising chemical against adults causing significantly higher adult mortality than all other insecticides tested. Ethion 50% EC, dinotefuran 20% SG and pyriproxyfen 5% EC + fenpropathrin 15% EC were found to be second best insecticides succeded by flonicamid. When bioefficacy of buprofezin 25 % EC was evaluated against whitefly adults, it was found to be least effective as it is chitin biosynthesis inhibitor in nymphal stage. Only, flonicamid 50 WG and buprofezin 25% EC were observed to be safer toxic to natural enemies *viz*., chrysoperla, spider and coccinellids while all other tested insecticides were found to be moderate to highly toxic.

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NAVEEN RAO