BIORATIONAL MANAGEMENT OF KEY PESTS OF JASMINE (*Jasminum sambac*)

By

G. HEMALATHA
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THESIS

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Faculty of Agriculture
Kerala Agricultural University, Thrissur

Department of Agricultural Entomology
COLLEGE OF HORTICULTURE
VELLANIKKARA, THRISSUR - 680 656
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DECLARATION

I, **G. Hemalatha** (2006-11-124) hereby declare that this thesis entitled "**Biorational management of key pests of Jasmine (*Jasminum sambac*)"** is a bonafide record of research work done by me during the course of research and this thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title of any other University or Society.

G. Hemalatha

Vellanikkara

CERTIFICATE

Certified that this thesis, entitled **"Biorational management of key pests of Jasmine (*Jasminum sambac*)"** is a record of research work done independently by **Ms. G. Hemalatha** 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 her.

Dr. Susannamma Kurien
(Chairperson, Advisory Committee)
Professor
Department of Agricultural Entomology
College of Horticulture
Kerala Agricultural University
Thrissur, Kerala

Vellanikkara

CERTIFICATE

We, the undersigned members of the advisory committee of **Ms. G. Hemalatha** a candidate for the degree of **Master of Science in Agriculture**, with major field in **Agricultural Entomology**, agree that the thesis entitled "**Biorational management of key pests of Jasmine (*Jasminum sambac*)**" may be submitted by **Ms. G. Hemalatha** in partial fulfilment of the requirement for the degree.

Dr. Susannamma Kurien
(Chairperson, Advisory Committee)
Professor
Department of Agricultural Entomology
College of Horticulture
Vellanikkara

Dr. Sosamma Jacob
(Member, Advisory committee)
Professor & Head
Department of Agrl. Entomology
College of Horticulture
Vellanikkara

Dr. A.M. Ranjith
(Member, Advisory committee)
Professor
Department of Agrl. Entomology
College of Horticulture
Vellanikkara

Dr. A. Sobhana
(Member, Advisory committee)
Associate Professor
Department of Pomology and Floriculture
College of Horticulture
Vellanikkara

EXTERNAL EXAMINER

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G. Hemalatha

Dedicated
to

My beloved
family members

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Introduction

1. INTRODUCTION

Jasmine (*Jasminum* spp.), native to tropical and warm temperate regions across the globe, are widely being cultivated for their strong and sweet scented flowers. Unlike other genera in the Oleaceae family, which have four petals, jasmines often have five or six petals. More than eighty jasmine species are found in India of which only three species are under commercial cultivation. They are *J. sambac* (malligai or mulla) *J. auriculatum* (mullai or soochimulla) and *J. grandiflorum* (jathimalli or pitchi or piccakamulla). The first two species are mainly cultivated for selling as fresh flowers whereas the last one is cultivated for concrete extraction.

The annual production of jasmine flowers in India is worth more than 120 million rupees (Chadha, 2007). Apart from internal trade, fresh flowers of jasmine are exported to Malaysia, Singapore and Sri Lanka. Tamil Nadu is the leading state in jasmine production in the country and in Kerala the Ernakulam Pushpa Karshaka Swashraya Sanghom is now a leading producer of jasmine with an area of 100 acres under jasmine cultivation.

As in the case of other ornamental plants, jasmine is also attacked by different insect pests. There are about fifty different insect species belonging to more than eight orders harbouring varied microhabitats of jasmine plants. The most devastating among them are budworm (*Hendecasis duplifascialis* Hampson), blossom midge (*Contarinia maculipennis* Felt), thrips (*Isothrips orientalis* Bagnall), whiteflies (*Dialeurodes kirkaldyi* Kotinsky), leaf webworm (*Nausinoe geometralis* Guenee) and red spider mite (*Tetranychus* spp.). Budworms cause damage to the tune of 40 to 50 per cent affecting the quality of flower and attributes for 30 to 70 per cent yield loss (Gunasekaran, 1989). Severe incidence of budworm, blossom midge and flower thrips, reduces the size of the flower buds and imparts dull colouration, which eventually brings down their market value. The whitefly and leaf webworm cause serious damage to the foliage thereby minimizing the vitality of the plant.

Farmers rely mostly on the chemical insecticides for managing these insect pests, because of the immediate and spectacular knockdown effect. However, the indiscriminate use of broad-spectrum insecticides has resulted in the reduction in biodiversity of natural enemies, development of resistance, resurgence and residues in harvested produce and adverse effect on other non-target organisms. Biopesticides were reported to be effective in managing the insect pests, when used as a component of the integrated pest management programme. They have been gaining increased attention and interest among those concerned with developing environment-friendly, safe and integrated crop management (ICM) which include compatible approaches and tactics for pest management (Copping and Menn, 2000).

The utilization of chemicals that affect insect behaviour, growth or reproduction, for suppression of insect populations is often referred to as birational control (Pathak and Dhaliwal, 1986). Most of these chemicals are more or less non-toxic to man and domestic animals. These compounds do not persist or accumulate in the environment and are degraded to simple molecules that are unlikely to cause problems of environmental contamination (Daliwal and Arora, 2006).

Hence, the present study is aimed at managing the key pests of jasmine with biopesticides and also with combination of biopesticides and standard insecticides. The objectives of the study include

1. To assess the field population dynamics of key pests of jasmine such as budworm, blossom midge, thrips and whiteflies.

2. To evaluate the efficacy of biopesticides *viz*., *Beauveria bassiana* (Balsamo) Vuillemin*, Metarrhizium anisopliae* (Metchinkoff) Sorokin*, Bacillus thuringiensis* Berliner, Neem Seed Kernal Extract (NSKE) and neem formulation containing azadirachtin 10,000ppm along with standard insecticides *viz*., imidacloprid, acephate, fipronil and carbosulfan against the key pests of jasmine.

Review of literature

2. REVIEW OF LITERATURE

Jasmine is one of the most important traditional fragrant flower crops of India. The flower is used for various purposes *viz*., making garlands, bouquet, decorating hair of women, religious offering etc. Like any other crop, many insect pests are found associated with this crop (Nair and Nair, 1974). A concise review of the previous research studies in relation to the present study has been done in this chapter.

2.1 PESTS OF JASMINE

2.1.1 Flower feeders

2.1.1.1 Jasmine budworm *Hendecasis duplifascialis* Hampson

Attack of budworm in jasmine was first reported by Hampson in 1896 from West Africa, India, Ceylon and in South India by David (1958). It caused damage from 40 to 50 per cent, affecting the quality of the flowers and attributed for 30 to 70 per cent yield loss (Gunasekaran, 1989). The adult moth is small, white with black wavy lines on hind wings and abdomen. The caterpillar is smooth and green with pale body hairs. It feeds inside the buds and pupates in soil. Caterpillar makes hole on the flower buds and feeds on the inner content. It attacks two to three buds which are webbed together by silken threads. Damaged buds drop from the plant (Muthukrishnan *et al*., 2005).

Suganthi *et al*. (2006) tested the biological efficacy of lamda-cyhalothrin at 10, 20, 30 g a.i. ha^{-1} against *H. duplifascialis* infesting jasmine cv. Ramnad. Lamda-cyhalothrin was sprayed three times at 15 days intervals. It was found that lamda-cyhalothrin at 20 g a.i. ha^{-1} effectively reduced the budworm infestation.

2.1.1.2 Blossom midge *Contarinia maculipennis* Felt

The first report of blossom midge was given by Rao *et al*. (1954) on *Jasminum sambac* (Linn.) Ait. in Andhra Pradesh. Later, it was recorded from *Jasminum auriculatum* Vahl. in Tamil Nadu (David, 1958).

Muthukrishnan *et al*. (2005) described the biology of blossom midge. The maggot was seen within the buds at the base of corolla and the attack caused swelling at the base of the bud. Buds became discoloured and dropped in large numbers. As many as 30 maggots could be found infesting a single bud. The maggots are white when newly hatched, becoming yellow with a pink tinge as they aged and pupate in soil. Adults have bright orange coloured abdomen.

2.1.1.3 Gallery worm *Elasmopalpus jasminophagus* Hampson

Gallery worm was first reported by David (1958). They make tunnels of silk and excreta outside the buds and feed on them. The moth is narrow, long and dark grey with pale hind wings. The larva has brown streaks on its body. It pupates within the tunnel.

2.1.1.4 Thrips *Thrips orientalis* Bagnall

Ananthakrishnan (1969) reported severe bud damage by flower thrips, *Thrips orientalis*. The flowers of *J. auriculatum* were found to be damaged by *Haplothrips ganglbaueri* and *Thrips hawaiiensis* apart from *T. orientalis* (Gurusubramanian and Ananthakrishnan, 1994).

T. orientalis is called the jasmine thrips due to its high preference for jasmine flowers. Feeding punctures are seen on them as elongate brownish streaks. The black thrips and its yellow nymphs feed and breed in the buds and the flowers and rarely on the tender leaves. It occurs throughout the year and is seen to cause severe leaf damage in Kerala (Nair, 1995).

2.1.2 Leaf feeders

2.1.2.1. a. Leaf webworm *Nausinoe geometralis* Guenee

Leaf webworm was first reported by Hampson (1896). The occurrence of *N. geometralis* had been further recorded in Sri Lanka, Myanmar, Java, China, West Africa, Australia and India (David and Venugopal, 1962). The larva skeletonizes the leaves by scraping away the parenchymatous tissues. The moth is brown with hyaline patches on both wings. Eggs are laid singly on leaves and the caterpillar is green. It pupates beneath the webbings spun over the leaves and the branches.

2.1.2.1. b. *Nausinoe neptis* Guenee

Sivagami and Janarthanan (1963) reported leaf web worm *N. neptis* on jasmine in South India. The caterpillar of *N. neptis* webs the leaves together and feed on them leaving only midribs. The moth has yellow forewings with a few shapeless black bordered spots. The caterpillar is dark green and hairy. It pupates inside the web.

2.1.2.2 Shoot web worm *Margaronia unionalis* Hubner

The occurrence of *M. unionalis* was reported in Tamil Nadu (Ayyar, 1940). This insect was widely distributed in South and West Africa, Madagascar, Mauritius, Greece, Aden, Australia, India, Indonesia and Sri Lanka (Kalshoven, 1950). The green caterpillar knits together the tender leaves with silk, scrapes their green matter in the early stages, and eats bulk leaf tissue in the later stages. It pupates in a silken cocoon within the leaf fold. The moth is white with semi hyaline forewings bearing a golden brown line along the anterior margin. It has a tuft of dark hairs at its caudal tip.

2.1.2.3 Other pests

The first report of moth bug, *Flata ocellata* Fb. and *Ricania fenestrata* Fb. was given by David (1958). *F. ocellata* adults and nymphs feed on terminal shoot of jasmine. The adult is pale green and moth like with minute red spots on forewings. The nymph is elongate and white with two green bordered yellow lines dorsally and bearing a pair of white caudal filaments (David, 1958).

R. fenestrata adults cause withering of the shoots. The adult is a brownish moth like bug with hyaline patches on wings. The nymphs are pale green with white wax on the body and long caudal filaments held like a fan over the body (David, 1958).

David (1960) reported the occurrence of leaf miner, *Phyllocnistis citrella* Stainton in jasmine. David and Kumaraswami (1975) recorded 'death's head moth', *Acherontia styx* Westw. on *Jasminum* spp.

The occurrence of the shoot fly, *Sycophila* sp. (Eurytomidae) was reported by Easwaramurthy *et al*. (1980) on *Jasminum grandiflorum* Linnaeus. The larva bores into the tender shoot, feeds the internal contents hollowing out the stem and finally pupates within the larval tunnel. The attacked shoots dry up. The wasp lays eggs inside the epidermis of tender shoot. The grub is parasitized by *Chrysonotomyia cinctiventris* Ashmead and *Megastigmus* sp.

2.1.3 Sap feeders

2.1.3.1 Whiteflies

Aleurotrachelus sp. occur in Tamil Nadu causing severe damage to *J. auriculatum* and was found to a lesser extent on *J. grandiflorum* and *J. multiflorum* Andrews (Nair, 1995). The nymphs of *Dialeurodes kirkaldyi* Kotinsky feed from the ventral surface of leaves of *J. sambac* whereas adults also feed on leaves (Nair, 1999). Ecological aspects of two whitefly species namely *Aleurotuberculatus jasmini* Takahashi and *D. kirkaldyi*, infesting Arabian jasmine were studied by Helmi (2005) by collecting the leaves at every 10 days intervals throughout the year. Seasonal fluctuations of alive total population, nymphs and adults (empty exuviae) of both species indicated that *D. kirkaldyi* was more dominant than *A. jasmini* throughout the year.

2.1.3.2 Lacewing bug *Corythauma ayyari* Drake

This is also a pest of *J. sambac* in Kerala. It infests the plant throughout the year (Nair and Nair, 1974). Adults and nymphs feed from the lower side of leaves causing yellow spots, the leaves then turn yellow and dry up. Due to continuous infestation, growth and flower production are retarded. Eggs are thrust into the mid rib or veins on the underside of leaves. The adult is a brownish lacewing.

2.1.3.3 Other pests

The other pests of jasmine are hard scale, *Aonidiella aurantii* Mask., pentatomid bug, *Antestiopsis cruciata* Fabricius and mealy bug, *Pseudococcus ornatus* Gr. and *Ferrisia virgatus* Cockll., which infest shoot (Nair, 1995).

2.1.4 Root feeders

2.1.4.1 White grub, *Holotrichia* sp.

This pest was reported to infest jasmine for the first time in Tamil Nadu during June to July period. Grubs damage the plants by feeding and cutting the root system (Perumal *et al*., 1971).

2.1.5 Non insect pests

2.1.5.1 Red spider mite *Tetranychus* sp.

David (1958) reported that *Tetranychus cucurbitae* Rah. was often found to attack the leaves of *J. sambac* and *J. auriculatum*. *J. sambac* was attacked by *T. cinnabarinus* Boisduval (Karuppuchamy *et al*., 1986). The removal of plant sap with chlorophyll and plant pigments resulted in characteristic blotching of leaves and devitalization of the plant by *Tetranychus* mite. The infestation was high on *J. sambac* and *J. auriculatum*.

Field experiments were conducted by Rajkumar *et al*. (2004) in farmer's field to investigate the effect of different insecticides and acaricides on the red spider mite (*T. urticae* Koch.) on uniform aged bushes of *J. sambac*. Among the test insecticides, abamectin recorded 5.60, 2.86 and 1.60 mites per leaf after 2, 7 and 12 days respectively. This was followed by dicofol, which recorded 6.96, 4.63 and 3.20 mites per leaf after 2, 7 and 12 days. The highest flower yield was recorded with abamectin (2876 kg/ha), which was significantly superior over other treatments.

2.1.5.2 Eriophyid mite *Aceria jasmini* Channabasavanna

This pest was recorded on *J. pubescens* Willd. by David (1958). *A. jasmini* produces white felt like hairy out growths on the leaf surface, tender stems and buds. Growth of the plant is stunted and the production of flowers is suppressed (Channabasavanna, 1966). The same mite was recorded on *J. auriculatum* (Sundararaj *et al*., 1967). The incidence of *A. jasmini* was reported to increase from March and reached peak during July (Jose *et al*., 1999).

Umapathy and Rajendran (1999) evaluated three granular insecticides (carbofuran, phorate and endosulfan at 1 and 2 kg a.i./ha) at two levels against *A. jasmini* on jasmine *J. auriculatum* in comparison with the soil application of neem cake (at 250 and 500 kg/ha) alone, soil application of neem cake 250 kg combined with foliar spray of neem seed kernel extract at 10 per cent and neem cake 250 kg plus neem oil 3 per cent foliar spray. The lowest leaf infestation (18.10%) was recorded in carbofuran treated plots, resulting in 76.10 per cent reduction over control. The results also indicated that soil application of neem cake at 250 kg ha^{-1} combined with foliar application of NSKE 10 per cent was as effective as granular insecticides applied at their higher dose (2.0 kg a.i./ha).

2.2 INSECT PEST MANAGEMENT BY ENTOMOPATHOGENIC FUNGI

Several asexual fungi are found associated with arthropods of which 700 to 750 species are pathogenic to insects (Purwar and Sachan, 2006). The white muscardine fungus, *Beauveria bassiana* (Balsamo) Vuillemin and the green muscardine fungus, *Metarrhizium anisopliae* (Metchinkoff) Sorokin had been reported to infect 500 and 200 insect species respectively, being species specific.

2.2.1 Bioefficacy of *Beauveria bassiana* (Balsamo) Vuillemin

Ota *et al*. (1999) reported that *B. bassiana* preparations were useful for the management of whiteflies attacking tomatoes. *B. bassiana* was found to be the most promising biocontrol agent for the control of cowpea aphid, *Aphis craccivora* Koch. (Ekesi *et al*., 2000). According to Benuzzi and Santopolo (2001), bioinsecticides were used in greenhouse crops to control whiteflies (*Trialeurodes vaporariorum* Westwood and *Bemisia tabaci* Gennadius), aphids, thrips and the spider mite *T. urticae*.

Studies were conducted by Viji and Bhagat (2001) in order to determine the efficacy of three neem products (Neemax, neem seed kernel powder (NSKP) and Achook), two entomopathogenic fungi (*M. anisopliae* and *B. bassiana*) and two insecticidal dusts (fenvalerate 2% D and chlorpyrifos 1.5% D) and three seed treatment chemicals (acephate 75 SP, chlorpyrifos 20 EC and imidacloprid 70 WS) against *Agrotis ipsilon* Hufnagel in maize. They found that seed treatment with chlorpyrifos 20 EC @ 5g a.i. kg^{-1} seed, imidacloprid 70 WP @ 3.5g a.i. kg^{-1} seed and insecticidal dust application of chlorpyrifos 1.5 per cent D @ 25 kg ha^{-1} resulted in higher yield and less plant mortality when compared to other treatments and control. Neemax, Achook, NSKP and fenvalerate 2 per cent D @ 20 kg ha^{-1} provided good protection to earlier stages of seedling growth whereas at later stages these were less effective but registered higher yields when compared to control. In *M. anisopliae* and *B. bassiana* @ 5 x 10^{12}spores, the damage was higher in the earlier stages of seedling growth whereas in later stages they gave good protection to the crop.

Ludwig and Oetting (2002) studied the effectiveness of *B. bassiana* in combination with attractants when used against western flower thrips on greenhouse grown chrysanthemum. Results showed that the treatments containing *B. bassiana* reduced thrips population. The treatments containing *B. bassiana* plus attractants did not reduce thrips population compared to the *B. bassiana* treatments without attractants.

Bioassays were carried out under controlled conditions to evaluate the effect of eight strains of the entomopathogenic fungus *B. bassiana* (Bb 4, Bb 7, Bb 9, Bb 16, Bb 18, Bb 24, Bb 25, Bb 26) upon larvae, pupae and adult females of the Mexican fruit fly, *Anastrepha ludens* Loew. Mortality of the immature fruit flies was low, 2 to 8 per cent in larvae and 0 per cent in pupae. Very high levels of mortality was obtained for adult flies with values of 100, 98 and 98 per cent for the strains Bb 16, Bb 24 and Bb 26 respectively (Rosa *et al*., 2002).

Afifi *et al*. (2004) studied the effect of entomopathogenic fungus *B. bassiana* (2 x 10^5, 2 x 10^6, 2 x 10^7 and 2 x 10^8) on the two spotted spider mite *T. urticae* under laboratory conditions. They found that the per cent of mite mortality increased with the increase in spore concentration. Experiments carried out by Sharma and Ahmed (2004) using microbial control agents against Marwar teak defoliator, *Patialus tecomella* gave 70 per cent mortality of the grown up weevils, when applied in a spore concentration of 3.5 x 10^7. Thus, the pathogen was proven to be highly effective against *P. tecomella*.

Kumar and Chowdhary (2004) indicated that isolate *B. bassiana* HBB-2 (90.0%), followed by DBB-1 (87.5%) and HBB-1 (75.0%) was pathogenic to *Helicoverpa armigera* (Hubner) larvae.

Badilla *et al*. (2004) reported that *B. bassiana* was effective against sugarcane leafhopper, *Perkinsiella saccharicida* Kirkaldy. Neves and Hirose (2005) found that CG425 strain of *B. bassiana* presented the highest total and confirmed mortality and highest sporulation against coffee berry borer, *Hypothenemus hampei* Ferrari. According to Wekesa *et al*. (2005), *B. bassiana* isolate, GPK was very effective against tobacco spider mite, *Tetranychus evansi* Baker.

Abe and Ikegami (2005) evaluated the susceptibilities of five thrips species*, Frankliniella intonsa* Trybom, *F. occidentalis, Thrips coloratus* Schmutz, *Thrips hawaiiensis* Morgan and *Thrips tabaci* Lindeman to three isolates of an entomopathogenic fungus, *B. bassiana* (isolates AZA 38, GOM 03 and KOG 02) under laboratory conditions. The results revealed that among the three fungal isolates inoculated with conidial suspensions at a concentration of 1 x 10^7 conidia ml^{-1}, isolate KOG 02 was more effective against the five thrips species.

2.2.2 Bioefficacy of *Metarrhizium anisopliae* (Metchinkoff) Sorokin

Paliwal and Jakhmola (1981) reported a green muscardine fungus, *M. anisopliae* which was effective against safflower caterpillar, *Cerigea capensis* Guenee. According to Ekesi *et al*. (2000), *M. anisopliae* was found to be a promising biocontrol agent for the control of cowpea aphid, *A. craccivora*.

Yadav *et al*. (2000) determined the mortality rates of first, second and third instar grubs of *Holotrichia consanguinea* Blanchard, which were introduced into plastic cups with *M. anisopliae* inoculated soil. It was found that the highest mortality rate (70%) for first instar grubs was recorded upon treatment with $1x10^{11}$spores for 16 days. Second instar grubs exhibited the highest mortality rate (60%) when treated with $1x10^{11}$ and $5x10^{10}$spores for 30 days. Third instar grubs showed the highest mortality rates (50%) after treatment with $1x10^{11}$ and $5x10^{10}$ for 25 to 30 days, and with $1x10^{10}$ for 30 days.

Tefera and Pringle (2004) evaluated four isolates of *M. anisopliae* (PPRC-4, PPRC-19, PPRC-61 and EE-01) and *B. bassiana* (BB-01) against *Chilo partellus* Swinhoe in maize. Leaf damage, stem tunnelling, dead heart, number of attacked nodes and holes were found to be reduced by the spraying of the isolates at $2x10^8$ conidia ml^{-1}, 24 h after infestation. Among the different isolates PPRC-4, PPRC-19, PPRC-61 seemed to be the best.

Kumar and Chowdhary (2004) conducted bioassays with several strains of *M. anisopliae* against tomato fruit borer, *H. armigera* to select the most virulent isolate for biological control efficacy. They found that all isolates of *M. anisopliae* were pathogenic to *H. armigera* larvae. The larval mortality ranged from 50 to 92.5 per cent. Maximum mortality was observed in isolate UTMA-1 (92.5%), followed by HMA-2 (90.00%) and UTMA-2 (80.00%). A study was conducted by Badilla *et al*. (2004) to evaluate the pathogenicity of five isolates of *M. anisopliae* and one isolate of *B. bassiana* on the adult and nymph stages of leaf hopper, *P. saccharicida* in green house and field conditions. They found that *M. anisopliae* was more effective against sugarcane leafhopper, *P. saccharicida*.

Studies on the relative susceptibility of different life stage (eggs, larvae, pupae) of the cashew stem and root borer, *Plocaederus ferrugineus* L. to *M. anisopliae* was evaluated by topical application of conidial suspension of 10^7 conidia ml^{-1}. Results indicated that *M. anisopliae* was found to be more effective with 36.0 and 33.3 per cent egg and larval mortality respectively and the pupal mortality was 8.00 per cent (Saminathan *et al*., 2004).

A study was conducted by Kulkarni *et al*. (2005) to evaluate different biopesticides against *H. armigera* on chickpea cv. ICCU-2. Results indicated that per cent reduction of *H. armigera* larvae increased with longer exposure to the biopesticides. Pod damage decreased while crop yield increased with increasing rates of biopesticides. Among the biopesticides, NPV recorded the highest grain yield (8.25 q/ha), followed by *Nomuraea rileyi* (7.44 q/ha) and *M. anisopliae* (7.42 q/ha), while *M. anisopliae* recorded the lowest pod damage (18.06%) followed by *N. rileyi* (18.64%) and NPV (20.07%). *M. anisopliae* isolate ICIPE 78 was found to be highly effective against tobacco spider mite, *T. evansi* (Wekesa *et al*., 2005).

Sreenivas *et al*. (2005) conducted laboratory studies to evaluate the efficacy of entomopathogenic fungi against red spider mite, *Tetranychus* *neocaledonicus* André. They found that among the three entomopathogenic fungi tested (*B. bassiana, M. anisopliae* and *Verticillium lecanii* (Zimmenn) Viegas), treatment with *M. anisopliae* at 1.2 x 10^8 CFU ml^{-1} registered higher per cent mycosis.

2.3 BIOEFFICACY OF *Bacillus thuringiensis* BERLINER

According to Jayanthi and Padmavathamma (1996), *B. thuringiensis* subsp. *kurstaki* was safe to coccinellid predators and was highly effective against the larvae of lepidopterous pests but not against homopteran insects.

Patel and Vyas (2000) evaluated formulations of *B. thuringiensis* subsp. *kurstaki* (Cutlass, Delfin, and Bactec) and neem (azadirachtin) for the management of cotton bollworms (*H. armigera, Earias vitella* Fabricius, and *Pectinophora gossypiella* Saunders). The results showed that Cutlass, Delfin and Bactec at one kg ha^{-1} were equally effective as the chemical insecticides. Neem was less effective than *B. thuringiensis* subsp. *kurstaki* but better than the untreated control. The highest yield of seed cotton was obtained using chemical insecticide treatment followed by *B. thuringiensis* subsp. *kurstaki* and neem. *B. thuringiensis* formulations were less toxic to predators in cotton fields compared to chemical and neem treatments.

B. thuringiensis products were found to be effective in controlling the larvae of leaf webbers *viz*., *Hymenia recurvalis* (Fabricius) and *Psara basalis* Walker. Dipel @ 0.7 ml^{-1} showed drastic reduction in the population of both leaf webbers (Leena, 2001). El-Gemeiy (2002) tested two formulations of *B. thuringiensis* subsp. *kurstaki* against *Earias insulana* Boisduval under laboratory conditions. The formulations were tested at 1.0, 0.5, 0.25, 0.125, 0.0625 and 0.0312 kg l^{-1}. The results indicated a positive relationship between the application rates and larval mortality rates.

A study was conducted by Hazzard *et al*. (2003) to evaluate vegetable and mineral oil, *B*. *bassiana* and *B*. *thuringiensis* subsp. *kurstaki* individually and in combination for the control of *Ostrinia nubilalis* Hubner, *Helicoverpa zea* Boddie and *Spodoptera frugiperda* Smith in sweet corn. It was found that combination of *B*. *thuringiensis* and mineral oil provided the largest and most consistent reduction in number of larvae and feeding damage to ears.

An experiment was conducted by Trujillo *et al*. (2003) in order to evaluate the effectiveness of different strains of *B*. *thuringiensis* under laboratory and field conditions for the control of *Thrips palmi* Karny in cucumber. Among these, *B*. *thuringiensis* strains LBT-13 and LBT-24 proved to be highly effective against *T. palmi*.

According to Singh and Singh (2004), *B*. *thuringiensis* subsp. *kurstaki* was the most effective in controlling the capitulum borer, *H*. *armigera*. The highest pooled mean seed yield of 21.73 q ha^{-1} was obtained in plots treated with *B*. *thuringiensis* subsp. *kurstaki* as against 16.74 q ha^{-1} in the untreated check.

Delfin at 500 g ha^{-1} was found to be effective against diamond back moth, *Plutella xylostella* Linnaeus in cauliflower (Jeyarani and Kennedy, 2004)). A field experiment was carried out by Vanitha and Dhandapani (2004a) in order to evaluate the effect of biocontrol agents and neem *viz*., Delfin @ 1.0 kg ha^{-1}, Halt @ 1.0 kg ha^{-1}, Biolep @ 1.0 kg ha^{-1}, *Chrysoperla carnea* @ 50,000 parasitoid grubs ha^{-1} per release, Bevphos @ 2.5 kg ha^{-1} and Econeem 0.3 per cent @ 1.0 l ha^{-1} on the pests of seven years old plants of *J. sambac*. The damage caused by jasmine pests *viz*., budworm *H. duplifascialis* and leaf web worm *N*. *geometralis* indicated that Delfin @ 1.0 kg ha^{-1} applied twice at 15 days interval were effective in reducing the damage. Highest flower yield (4554 kg/ha) and benefit: cost ratio (BCR) of 2.2:1 were recorded with Delfin treated plot followed by Halt treated plot (4497 kg/ha) with higher benefit: cost ratio (BCR) of 3.0:1.

Nandanwar *et al*. (2004) studied the effect of different biopesticides on the control of *H. armigera* on cotton. The average per cent boll damage of cotton due to *H. armigera* revealed that *B. thuringiensis* at 2 x 10^8spores ml^{-1} was more effective (13.98%) when compared to untreated control (27.85%). LC_{50} value for Delfin was obtained as 0.07 mg 100 ml^{-1} (366.3 mg/ha) when Vanitha and Dhandapani (2004b) conducted a bioassay with *B. thuringiensis* subsp. *kurstaki* on third instar larvae of *N. geometralis* in jasmine.

Mandal *et al*. (2006) evaluated the efficacy of the biopesticide *B. thuringiensis* applied in combination with endosulfan, acephate, neem cake and neem oil in controlling pests infesting okra cv. Pusa sawani. The results indicated that all the treatments provided better control of okra pests compared to control. *Amrasca biguttula biguttula* Ishida and *E. vitella* populations were lowest with the soil application of neem cake 200 kg ha^{-1} in combination with the spraying of neem oil 0.5 l ha^{-1} and endosulfan 250 g ha^{-1}. The highest crop yield of 127.48 q ha^{-1} was also obtained in the same treatment.

2.4 BIOEFFICACY OF NEEM

In an experiment conducted by Praveen and Dhandapani (2001) to evaluate the effectiveness of different biocontrol agents against the major pests of okra, it was found that release of *C. carnea* (25,000 larvae/ ha/release) + Econeem 0.3 per cent (0.5 l/ha) for three times at 15 days interval starting from 45 days after sowing was effective in reducing the population of sucking pests as well as the fruit borers. The per cent fruit damage by *H. armigera* (8.61%) and *E. vitella* (9.21%) was also reduced. Fruit damage in untreated check was recorded as 22.56 and 22.60 per cent respectively. The fruit yield of 10,326 kg ha^{-1} and benefit: cost ratio (BCR) of 2.60:1 were also higher, when *C. carnea* and Econeem 0.3 per cent were combined, compared to either *C. carnea* (9643 kg/fruit/ha and 2.39:1) or Econeem 0.3 per cent (9533 kg fruit/ha and 2.44:1) alone.

Vanitha and Dhandapani (2002) reported that among the plant products tested against *N. geometralis,* neem seed kernel extract (NSKE) at 5 per cent recorded minimum egg laying (0.34%) followed by TNAU neem oil 60 EC (10.68%) as against 26.62 per cent eggs in untreated check. Econeem 0.3 per cent and Neemazal 0.1 per cent were on par with each other in deterring the oviposition by *N. geometralis* in jasmine.

The laboratory efficacy of five new insecticides (profenofos at 0.05%, carbosulfan at 0.05%, Polytrin C (profenofos + cypermethrin) at 0.05%, imidacloprid at 0.007% and Koranda (fenvalerate+acephate) at 0.05%), four conventional insecticides (endosulfan at 0.07%, quinalphos at 0.05%, monocrotophos at 0.04% and dichlorvos at 0.075%) and four neem based formulations (Nimbecidine, Neemarin, Achook and neem oil, each at 0.50%) were evaluated by Singh *et al*. (2003) against the early third instar larvae of cabbage butterfly, *P. brassicae*. They found that all the treatments were significantly superior over the control in reducing larval population. All the insecticides caused 100 per cent larval mortality after 72 h of spraying and were significantly superior compared to the neem-based formulations. Among the neem-based formulations, Neemarin gave the maximum larval mortality (50.00%) and was significantly effective to other neem products after 72 h of spraying. Neem oil was the least effective, exhibiting 16.66% larval mortality after 72 h.

Basappa and Lingappa (2004) tested the efficacy of various neem preparations, i.e., neem seed kernel extract NSKE 5 per cent, neem leaf extract (NLE 5%), Margocide 20 EC (0.1%), Achook (0.3% water soluble neem powder) and Jawan (0.15% neem extract), along with *Bougainvillea glabra* cold alcohol extract (CAE, 30%) against castor semilooper. Results indicated that NSKE, Margocide and Jawan were superior in reducing the larval population of castor semilooper at three days after sowing. These botanicals also gave significantly higher seed yield than the untreated control. The highest benefit: cost ratio was recorded in NLE (2.80:1), followed by Margocide (2.20:1) and NSKE (1.94:1).

Sujatha *et al*. (2005) studied the efficacy of Econeem plus (azadirachtin at 10,000 ppm) against coconut eriophyid mite, *Aceria guerreronis* Keifer. It was observed that spraying of azadirachtin 10,000 ppm at 5 ml l^{-1} water or root feeding with the same chemical at 12.5 ml + 12.5 ml water could be recommended as one of the steps of integrated pest management for the ecofriendly management of coconut eriophyid mite.

Weathersbee and Mckenzie (2005) assessed the biological effects of a neem based biopesticide containing 4.5 per cent azadirachtin against the Asian citrus psyllid, *Diaphorina citri* Kuwayama. It was revealed that the densities of psyllid nymphs on treated plants exposed to green house populations were significantly reduced by concentrations as low as 10 ppm azadirachtin.

Rajabaskar (2006) assessed the efficacy of plant products against jasmine leaf webworm, *N. geometralis* in a farmer field. It was found that palmarosa oil 50 EC at 0.1 per cent and jatropha oil at 0.5 per cent recorded the lowest percentage of leaf damage (0.44 and 1.44% respectively), followed by NSKE and *Vitex negundo* leaf extract at 5.0 per cent each (3.00 and 7.10%) and Achook, neem oil and *Catharanthus roseus* leaf extract (8.70, 13.70 and 11.70%).

Jat and Jeyakumar (2006) conducted a study to evaluate the efficacy of NSKE (3, 5 or 7%) and neem oil (1, 2 or 3%) against jassids *A. biguttula biguttula* and whitefly *B. tabaci* on cotton. Results indicated that neem oil was more effective against jassids than NSKE. The jassid population increased by upto 8.7 per cent with 5 per cent NSKE, did not vary at 7 per cent NSKE, but decreased by 33.30 per cent with 3 per cent NSKE.

A field trial was conducted by Mwayawa (2006) to assess the efficacy of three insecticides: neem extract, Delfin (*Bacillus thuringiensis*) and Orthene for the control of diamond back moth (*P. xylostella*) and other common lepidopterous insects on head cabbages. Among these, neem extract was considered preferable to Delfin in relation to pesticide resistance development by insect pests and cost benefits.

To evaluate the efficacy of different botanicals against sucking pests of sunflower, a field experiment was conducted by Ravi *et al*. (2006). They could prove that seed treatment with Econeem plus at 25ml kg^{-1} of seed was the best treatment among the botanicals recording 38.28 per cent more seed yield over the untreated control with a benefit: cost ratio (BCR) of 2.04:1.

According to Gandhi *et al*. (2006), neem oil could be used as a potential seed dresser for managing sucking pests like leafhopper and aphids in okra. Naik *et al*. (2006) reported that neem oil was highly effective against cardamom capsule borer and thrips.

2.5 BIOEFFICACY OF FIPRONIL

Foliar application of fipronil 80 WG was evaluated by Christian *et al*. (1997) for early season thrips on cotton. The results showed that fipronil at 0.025 and 0.038 lbs a.i/a was effective for all species of thrips, across all trial locations. Field experiments were conducted by Valeeva *et al*. (2000) to protect potato against the colorado beetle, *Leptinotarsa decemlineata* Say. It was indicated that fipronil (Regent 0.025 kg/ha) was effective for 21 days after first application and controlled the beetle at larval and pupal stages.

In the study conducted by Saljogi *et al*. (2002), cartap hydrochloride (Padan 4 G) at 22.23 kg ha^{-1} was found to be most effective in reducing rice stem borer infestation, followed by fipronil (Regent 300 EC) at 197.6 ml ha^{-1}, Regent 300 EC mixed with fertilizer at 197.6 ml ha^{-1} and carbofuran (Furadan 3 G) at 19.76 kg ha^{-1} respectively. The highest yield was obtained from cartap hydrochloride treated plots followed by fipronil alone, fipronil mixed with fertilizer and carbofuran compared to untreated plots. Walunj and Pawar (2004) recommended the application of fipronil (Regent 5% EC) at 25 g a.i. ha^{-1}, for the significant control of aphids and white flies in chilli at 14 days after spraying.

Srinivas and Madhumathi (2004) tested the efficacy of twelve insecticides against gall midge infesting rice during kharif season. It was observed that carbofuran at 25 kg ha^{-1} was the most effective treatment among the twelve treatments and recorded an average of 12.54 galls per m^2 followed by fipronil (14.25/m^2) and chlorpyrifos (15.56/m^2).

A study was conducted by Panda *et al*. (2004) to study the effectiveness of fipronil (Regent 5 FS) along with chlorpyrifos 20 EC and imidacloprid 200 SL (each at 75 g a.i./ha) against rice yellow stem borer during kharif and summer season. Treatment with fipronil at 100 g a.i. ha^{-1} resulted in only 4.02 and 6.13 per cent dead heart at 14 and 21 days after transplanting in kharif, proving the efficacy over rest of the treatments. However, in summer, fipronil at all concentrations along with imidacloprid 200 SL recorded 5 per cent dead heart at 14 days after transplanting. Results indicated that fipronil at 100 g a.i. ha^{-1} and imidacloprid at 75 g a.i. ha^{-1} were effective in protecting the rice crop and also resulted in longer roots, more tillers and higher grain yield during both the years.

Field experiments were conducted by Chaudhary and Jaipal (2006) to test new insecticides for the control of whiteflies *Aleurolobus barodensis* Maskell and *Neomaskellia bergii* Signoret in sugarcane from 2002 to 2004. New insecticides, i.e. fipronil (Regent 5 SC) and imidacloprid (Confidor 200 SL) applied on foliage at 0.05 per cent each, were most effective and caused 85.10 and 83.10 per cent reduction in whitefly population. Nderitu *et al*. (2007) reported the effectiveness of fipronil (Regent 50 SC) against thrips in french beans. For the experiment, four varieties (Amy, Monel, Samantha and Impala) of french beans and four insecticides lamda-cyhalothrin (Karate 1.75 EC), petroleum spray oil, spinosad (Tracer 480 SC) and fipronil (Regent 50EC) were used. The results indicated that spinosad and fipronil sprayed plots had the lowest number of thrips across all varieties.

2.6 BIOEFFICACY OF CARBOSULFAN

According to Heungens and Buysse (1997), carbosulfan was moderately effective against green peach aphid on the ornamental umbrella tree *Schefflera venulosa*. Kontsedalov *et al*. (1998) tested the efficacy of seven insecticides in various concentrations in the laboratory against immature and adult western flower thrips. They observed that among the tested insecticides, carbosulfan had the highest efficacy against adults. According to Patel *et al*. (2003), carbosulfan at 0.1 per cent was the most effective insecticide in reducing whitefly nymph population in sugarcane.

Duraimurugan and Jagadish (2004) tested the efficacy of eight insecticides against thrips damaging rose flower. It was found that among the test insecticides lamda-cyhalothrin, carbosulfan and imidacloprid were the most effective against *Scirtothrips dorsalis* Hood on rose. Jeyarani and Kennedy (2004) observed the efficacy of carbosulfan (Marshal 25 EC) (1.0 l/ha) against *P*. *xylostella* on cauliflower. The insecticides were sprayed three times at weekly intervals starting from 45 days after sowing. Results indicated that carbsulfan was effective against the larval population on seventh day after first (4.0/ plant), second (2.7/plant) and third (2.7/plant) spraying. The highest mean head weight (500 g) and yield (18.0 t/ha) were obtained with carbosulfan.

Experiments were conducted by Pandya (2005) to test the mechanical and insecticidal control of sugarcane whitefly *A*. *barodensis* during 1998, 1999 and 2000 planting seasons. The treatments comprised spraying of monocrotophos 36 WSC at 0.036 per cent, endosulfan 35 EC at 0.075 per cent, triazophos 40 EC at 0.05 per cent, carbosulfan 25 SP at 0.1 per cent, acephate 75 SP at 0.1 per cent, Neemark (azadirachtin 100 EC) at 0.5 per cent, detrashing of leaves bearing puparia, and untreated control. Results indicated that among the test insecticides, monocrotophos, endosulfan, triazophos and carbosulfan recorded the highest per cent reduction of whitefly nymph and puparia during all years followed by Neemark and de-trashing of leaves bearing puparia.

Chaudhary and Jaipal (2006) reported that fipronil (Regent 5 SC) and imidacloprid (Confidor 200 SL) applied on the foliage of sugarcane at 0.05 per cent each were most effective and caused 85.10 and 83.10 per cent reduction in whitefly populations, followed by carbosulfan 25 EC (76.6%) and acephate 75 SP (73.7%) at 0.05%.

2.7 BIOEFFICACY OF ACEPHATE

According to Harding (1979), acephate was effective as foliage, systemic and contact insecticide for insects on flowers crops, vegetables and trees. Soil application of acephate 75 SP 0.5 kg a.i. ha^{-1} gave the best control of *B. tabaci* in cowpea (Patel and Srivastava, 1996). Application of acephate 0.1 per cent was the most effective insecticide against sap feeders *viz*., leafhopper and aphids in bitter gourd (Sunildutt, 2000). Cloyd and Sadof (2000) reported that spraying of acephate 600 mg l^{-1} was very effective against western flower thrips in floricultural crops. Konar and Chettri (2003) found that phorate was the most effective in controlling the potato aphids followed by acephate.

Tewari and Yadav (2005) tested the efficacy of new insecticides in controlling black bug and mealy bug infesting sugarcane. They found that all the tested insecticides provided efficient control of the pests compared to control, with acephate and acetamiprid treatment resulting in highest mortality of the black bug (93.33 and 98.33%) and mealy bug (95.00 and 96.66%) respectively.

A study conducted by Bhavani and Rao (2005) revealed that imidacloprid (Confidor 200 SL; 25 g a.i./ha) and acephate (Starthene 75 SP;

600 g a.i./ha) followed by cartap hydrochloride (Padan 50 WP; 300 g a.i./ha) gave the highest efficacy against the plant hoppers in rice. Acephate ranked first in terms of safety to mirid bugs followed by imidacloprid and cartap hydrochloride. Imidacloprid also ranked first in terms of safety to spiders, followed by acephate.

A field experiment was conducted by Jeyarani *et al*. (2006) to evaluate the efficacy of certain new insecticides against mango hoppers. It showed that among the newer insecticides the reduction in the population of hoppers was maximum (84.62%) in the trees treated with acephate 75 SP at 1.5 g followed by fenvalerate 20 EC at 1 ml. According to Bairwa *et al*. (2006), acephate 75 WP (0.037%) was moderately effective against whitefly *B*. *tabaci* on moth bean. Wu *et al*. (2006) proved the efficacy of acephate against gall midge, *Contarinia nasturtii* Kieffer in cruciferous plants.

Shukla (2007) reported pest management strategies for different floricultural crops like rose, chrysanthemum, marigold, gerbera, gladiolus, tuberose and orchids. In most of the crops, spraying of acephate (0.1%) was found to be very effective in controlling thrips. Dichlorvos 0.05 per cent reduced population of whiteflies (*B*. *tabaci*) in gerbera. Damage by bud borer, *H*. *armigera* in rose and chrysanthemum was controlled by NSKE 4 per cent or neem oil 1 per cent.

2.8 BIOEFFICACY OF IMIDACLOPRID

Attique and Ghaffar (1996) carried out field trials in cotton in which they found that seed treatment with seed protectant insecticides like furathiocarb (Promet) and imidacloprid (Confidor) gave effective control of early season attack of *Amrasca devastans* Distant, *B*. *tabaci* and *T*. *tabaci* for upto 4 weeks. The number of total bolls ha^{-1} and the yield of seed cotton was higher in the plots treated with confidor.

Cabello *et al*. (1997) reported that imidacloprid (Confidor) was effective against all ages of larvae of red palm weevil, *Rhynchophorus ferrugineus* Olivier in coconut. According to Kfoury *et al*. (1997), spraying of imidacloprid (1 ml/l as Confidor 200 SL) was found to be the most effective against *T. vaporariorum* and *B. tabaci* in cucumbers. Wahla *et al*. (1997) also observed that spraying of imidacloprid 200 SL at 40 ml a.i. acre^{-1} was the most efficient against cotton thrips.

Imidacloprid (Confidor) was found to be effective against rose aphid, *Dysaphis plantaginea* Passerini on apple (Bylemans, 1997). Four insecticides were tested against *A. biguttula biguttula* and *B. tabaci* on cotton. It was revealed that oxydemeton methyl (Metasystox 25 EC) at 750 ml/ha and imidacloprid (Confidor 200 SL) at 100 ml/ha significantly reduced the number of these pests (Brar *et al*., 1999).

Hernandez *et al*. (1999) reported that imidacloprid (Confidor 200 SC) applied via the irrigation system can be effective against aleyrodids and aphids in vegetable crops. Field trials were conducted by Mansanet *et al*. (1999) to assess the efficacy of imidacloprid (Confidor 200 SL) against citrus leaf miner on acid lime. Imidacloprid 200 SL was applied as foliar application at 0.025, 0.0375, 0.05, 0.0625 and 0.075 per cent product concentration. The results revealed that imidacloprid 200 SL at 0.0375 per cent to 0.075 per cent was effective against citrus leaf miner on acid lime.

Kumar and Santharam (1999) conducted a field study to evaluate the efficacy of imidacloprid against *A. gossypi* and *A. devastans*. Seed treatment resulted in 100 per cent mortality for upto 10 and 26 days after sowing against *A. gossypii* and *A. devastans* respectively. Foliar treatment of imidacloprid resulted in 100 per cent mortality against *A. gossypii* for 7 days after treatment and 10 days for *A. devastans*. It was concluded that a dose at 7 g kg^{-1} of imidacloprid as seed treatment or as foliar application at 100 ml ha^{-1} was effective for the control of both insects on cotton.

Manjunatha *et al*. (2000) proved the effect of 0.25 and 0.50 g l^{-1} of imidacloprid 75 WS combined with acephate 1 g l^{-1} applied as seed treatments, field or nursery sprays, seedling dip treatments against mite (*Polyphagotarsonemus latus* Banks) and thrips (*S. dorsalis*) infesting chilli.

Irulandi *et al*. (2000) evaluated the efficacy of imidacloprid 17.8 per cent SL against green scale (*Coccus viridis* Green) and brown scale (*Saissetia coffeae* Walker) infesting Arabica coffee seedlings. Results indicated that application rate of 0.0075, 0.01, 0.02, 0.05, 0.08 and 0.1 per cent a.i. on *C. viridis* and 0.01, 0.05 and 0.1 per cent a.i. on *S. coffeae* were found to be equally effective even at 30 days after application.

Field experiment was conducted by Misra (2005) to assess the efficacy of five newer insecticides along with five conventional pesticides against the whitefly, *B. tabaci* infesting okra. Out of total 10 pesticides, evaluated acetamiprid and imidacloprid @ 20 and 25 g a.i. ha^{-1} proved significantly the best in controlling the okra whitefly upto 3 weeks of insecticide application with a population reduction of 81.02 per cent and 82.71 per cent respectively over control.

Abanowski and Soika (2001) reported that imidacloprid (Confidor 200 SL) applied as spray treatment was very effective in controlling the cotton aphid *A. gossypi*, the glasshouse whitefly *T. vaporariorum*, the western flower thrips *F. occidentalis*, the flower thrips *F. intonsa*, the citrus mealy bug, *Planococcus citri* Risso and other insects on ornamental plants. Saleem and Khan (2001) also reported that imidacloprid (Confidor 200SL) was found to be the most effective against whitefly on cotton cv. CIM-443 followed by endosulfan (Thiodan 35EC) and bifenthrin (Talstar 10EC).

In the study conducted by Saleem *et al*. (2001), imidacloprid (Confidor 200 SL) was found to be the most effective in reducing cotton jassids and thrips up to 7 days after the spray. Singh *et al*. (2005) evaluated six newer insecticides against *B. tabaci* in chilli. Among the treatments imidacloprid 17.8 SL at 250 ml ha^{-1} was observed to provide the maximum reduction of whitefly at 1, 3, 7 and 14 days after sprays (i.e. 89.86, 95.58, 81.50 and 58.98 % respectively), followed by acephate 75 SP at 1250 g ha^{-1}. The highest yield was obtained from imidacloprid 17.8 SL treated plot (36.46 q/ha), which was at par with acephate 75 SP (33.96 q/ha).

An experiment was conducted by Ameta and Sharma (2005), to evaluate the bioefficacy of Confidor 350 SC (60 and 75 ml/ha) and Confidor 200 SL (100 and 125 ml/ha) against *A. gossypii, A. biguttula biguttula* and *T. tabaci* infesting cotton cv. GH-8. It was found that two sprays of Confidor 350 SC 75 ml ha^{-1} at 15 days interval gave the highest reduction in *A. gossypii, A. biguttula biguttula* and *T. tabaci* populations, which was at par with Confidor 200 SL at 125 ml ha^{-1}. Both Confidor 350 SC and 200 SL did not cause any adverse effect on the grubs and adults of predators like *C. carnea* and *Coccinella* sp. The highest cotton yield of 21.85 and 22.35 q ha^{-1} was recorded with 2 sprays of Confidor 350 SC at 75 ml ha^{-1} at 15 days interval.

A study conducted by Mishra *et al*. (2005) during kharif season, proved the effectiveness of imidacloprid 17.8 SL (0.022 kg a.i./ha) against chilli thrips. The insecticides were applied as foliar spray on the crop twice, i.e. 40 and 70 days after planting. Results indicated that imidacloprid was the most effective insecticide in suppressing the thrips population (1.46 thrips per 10 apical leaves) and increasing the pod yield of chilli (27.63 q/ha).

Aghdam and Ganbalani (2005) evaluated the efficacy of imidacloprid (imidacloprid) against the Colorado potato beetle, *L. decemlineata*. They could prove that imidacloprid was generally most effective against this beetle.

A laboratory study was conducted by Mittal *et al*. (2005) to evaluate the antifeedant effects of three new chemicals, i.e. thiamethoxam, (Actara 25 WG), indoxacarb (Avaunt 14.5 SC) and imidacloprid (Confidor 17.8 SL) against *Spodoptera litura* Fabricius. Results revealed that all the three insecticides possess antifeedant activity at sub lethal concentrations, with indoxacarb being the most effective followed by imidacloprid.

The efficacy of different chemical insecticides was studied by Syed *et al*. (2005) against *Myzus persicae* Sulzer infesting tobacco crop. The lowest mean population of aphid per leaf was recorded with imidacloprid (20 aphids/leaf) and thiamethoxam (18 aphids/leaf) treated plots. Tobacco yield was also highest (2253.0 kg/ha) with imidacloprid treated plots. According to Sazo *et al*. (2006), imidacloprid applied to the foliage, as Confidor forte 200 SL was efficient in controlling long tailed mealy bug, *Pseudococcus lingispinus* Targioni on avocado. Ahmadzadeh and Hatami (2006) observed that spraying of imidacloprid (Confidor 35% SC) caused highest mortality (88%) of nymphal stages of green house whitefly, *T. vaporariorum*.

A field experiment was conducted by Solangi and Lohar (2007) to determine the efficacy of different insecticides against different insect pests and their predators on okra cv. Sabzpari during the kharif season. It was observed that imidacloprid proved to be the most effective against all the insect pests under study compared to other insecticides. Imidacloprid also proved better than the other insecticides because the population of predators i.e. spiders, ants and beetles was less affected by imidacloprid compared to other insecticides.

Bhadane *et al*. (2007) conducted a field experiment to test the bioefficacy of imidacloprid (Confidor 200 SL) against sucking pests of groundnut during kharif 2000 and 2001. Imidacloprid was found to be significantly effective in reducing the nymphal population of thrips species and leafhopper at 3 days after spraying, recording 70 to 90 per cent reduction in pest population. Results indicated that imidacloprid gave significant protection and proved efficient against the sucking pests, thrips and leafhopper on groundnut.

2.9 COMPATIBILITY OF *Bacillus thuringiensis* WITH CHEMICAL INSECTICIDES

Abdalla (1969) reported use of chemical insecticides combined with insect pathogens, their effectiveness in insect control and the effect of chemical insecticides on the viability of the micro organism. Narayanan *et al*. (1975) reported that integrated control of aphid *M*. *persicae* and diamond back moth *P*. *xylostella* by applying a combination of dimethoate with *B*. *thuringiensis* was more effective than either of them alone.

Dibyantro and Siswajo (1988) obtained effective control of *H*. *armigera* when a mixture of *B*. *thuringiensis* subsp. *kurstaki* (0.05%) and acephate (0.05%) was applied in the tomato field. The highest yield of tomatoes was also obtained from this treatment. They also obtained effective control of *P*. *xylostella* on cabbage, when *B*. *thuringiensis* subsp. *kurstaki* (0.1%) and triazophos (0.05%) were applied together in the infested cabbage field.

Tomar (1998) tested the combinations of commercial formulation of *B*. *thuringiensis* (Dipel) with lower concentration of insecticides endosulfan, fenvalerate, multineem, carbaryl and acephate against okra shoot and fruit borer, *E*. *vitella*. He observed that the maximum yield of healthy fruits was obtained in Dipel (0.1%) with fenvalerate (0.0025%) followed by Dipel (0.1% with acephate 0.06%).

An experiment was carried out by Patel and Vyas (1999) to determine the compatibility of *B*. *thuringiensis* subsp. *kurstaki* with cypermethrin under laboratory conditions. Results showed that *B*. *thuringiensis* subsp. *kurstaki* was less effective against *S*. *litura* than *E*. *vitella*. However, *B*. *thuringiensis* subsp.

kurstaki was compatible with cypermethrin. Sunildutt (2000) reported that *B. thuringiensis* + acephate were more effective against gallfly in bitter gourd.

Compatibility and synergism of *B. thuringiensis* commercial formulation and lamda-cyhalothrin were evaluated by Khalique and Ahmed (2001) for the control of *H. armigera*. They found that combinations of low dosage of lamda-cyhalothrin and Costar (*B. thuringiensis* subsp. *kurstaki*) formulations were found highly compatible and synergistic and also effective against *H. armigera*. Levin (2004) observed that the treatment combinations Halt + spinosad (96.2%), Delfin+ spinosad (96.6%) and Dipel + spinosad (93.3%) recorded the maximum mortality of tomato fruit borer, *H. armigera* in tomato.

Field experiment was conducted by Bhanukiran and Panwar (2005) to assess the efficacy of neem and *B. thuringiensis* formulations alone and in combination with pesticides against *C. partellus* in maize. The results indicated that all neem and *B. thuringiensis* formulations along with insecticides were significantly effective in suppressing borer damage in relation to control. Significantly, less damage was observed in endosulfan treated plots followed by Neemazal-F 5 EC + diflubenzuron 25 WP. Leaf injury was significantly less in endosulfan followed by *B. thuringiensis* subsp. *kurstaki* + endosulfan, *B. thuringiensis* subsp. *kurstaki* and Neemazal-F + diflubenzuron. Neemazal-F + diflubenzuron were the potential treatment against stem tunneling. All the neem and *B. thuringiensis* formulations and insecticidal treatments resulted in significantly higher yields than control. Endosulfan recorded highest grain yield (19.73 q/ha) followed by *B. thuringiensis* subsp. *kurstaki* (17.07 q/ha), Neemazal-F + diflubenzuron (15.73 q/ha), Neemazal + *B. thuringiensis* subsp. *kurstaki* (15.93 q/ha) and Neemazal-F (15.73 q/ha).

2.10 COMPATIBILITY OF *Beauveria bassiana* WITH CHEMICAL INSECTICIDES

According to Lewis *et al*. (1995), application of *B. bassiana* in combination with carbofuran at whorl leaf stage and another at pollen shedding stage resulted in maximum mortality of second instar larvae of European corn borer, *O. nubilalis* on maize.

Two experiments were carried out by Batistafilho *et al*. (1996) in order to evaluate the efficacy of fipronil against banana root weevil, *Cosmopolites sordidus* Germar and its compatibility with the entomopathogenic fungi *B. bassiana*. Results proved that only fipronil was efficient against *C. sordidus* adults. Insecticides were mixed with the culture media proportionally to the recommended dosage against *C. sordidus*. Fipronil did not decrease spore production but slightly affected the average diameter of the colony.

Lagunes *et al*. (1997) evaluated the compatibility of *B. bassiana* with aqueous extracts of *Azadirachta indica* seeds (EASMAR) and could convince that doses of EASMAR of 0.5, 1.5, 2.5 and 5.0 per cent did not inhibit mycelial growth or spore viability of the entomopathogen.

Studies were conducted by Cavalcanti *et al*. (2002) to evaluate the effect of the insecticide *viz*., imidacloprid (Confidor), thiamethoxam (Actara), fenpropathrin (Meothrin) and iprodione (Rovral) on the germination, vegetative growth, sporulation and pathogenicity of the entomopathogenic fungus *B. bassiana*. They found that imidacloprid and thiamethoxam were compatible with *B. bassiana*.

Castiglioni *et al*. (2003) studied the compatibility of Nimkol-L, a commercial formulation of neem leaves with *B. bassiana* strain 634 against termite, *Heterotermes tenius* Hagen. It was found that Nimkol-L was compatible with *B. bassiana* strain 634 upto 1.84 per cent a.i. against *H. tenius*. Fadure and Amusa (2003) reported that application of Thuricide followed by monocrotophos was highly effective against bollworms and leaf roller in cotton. Oliverra *et al.* (2004) tested the compatibility of the entomopathogenic fungus *B. bassiana* with 12 acaricide formulations and found that among the acaricides tested *B. bassiana* was compatible with avermectin and the pyrethroids.

A study conducted by Andalo *et al.* (2004) in order to evaluate the effect of chemical pesticides used in coffee crop on the entomopathogenic fungus, *B. bassiana* for the control of the coffee root mealy bug, *Dysmicoccus texensis* Tinsley. Results showed that thiamethoxam, imidacloprid and carbofuran were compatible with *B. bassiana* and also effective against coffee root mealy bug. According to Bhattacharya *et al.* (2004), *B. bassiana* was compatible with monocrotophos, azadirachtin, imidacloprid and carbaryl. Purwar and Sachan (2006) studied the effect of *B. bassiana* on the toxicity of endosulfan, imidacloprid, diflubenzuron, dimethoate and oxydemeton methyl against 10 to 11 days old larvae of *Spilarctia obliqua* Walker. The combination treatments of some products showed higher dose mortality response than the sole treatment of fungal conidia or the insecticide. The combination of insecticides with *B. bassiana* showed 1.26 to 35.80 fold increase in toxicity of insecticides over sole treatment.

2.11 COMPATIBILITY OF *Metarrhizium anisopliae* WITH CHEMICAL INSECTICIDES

Castiglioni *et al.* (2003) studied the compatibility of Nimkol-L a commercial formulation of neem leaves with *M. anisopliae* strain 1037 against termite, *H. tenius* in laboratory. The results indicated that Nimkol-L was compatible with *M. anisopliae* strain 1037 upto 1 per cent a.i. against *H. tenius*.

Laboratory experiments were conducted by Albuquerque *et al.* (2004) to study the effect of imidacloprid (Confidor) on the germination, vegetative growth and sporulation of *M. anisopliae* var. *anisopliae*. Results showed that *M. anisopliae* was not only compatible with imidacloprid but also effective against termite, *Nasutitermes* sp.

Jaramillo *et al*. (2005) studied the effectiveness of combined applications of *M. anisopliae* and a lower dosage of imidacloprid. High mortality of subterranean burrower bug, *Cyrtomenus bergi* Froeschner nymphs was caused when the treatment was applied to a native Colombian soil under green house conditions. Fifteen days after application the interaction between *M. anisopliae* and imidacloprid was synergistic and 30 days after the application of the treatments nymphal mortalities of 88.30 and 85.00 per cent were recorded in sterile and non sterile soil respectively, compared to 70.80 and 41.70 per cent in the two soil types following a sole application of *M. anisopliae*.

Investigations were carried out by Purwar and Sachan (2006) to study the effect of *M. anisopliae* on the toxicity of endosulfan, imidacloprid, diflubenzuron, dimethoate and oxydemeton methyl against 10 to 11 days old larvae of *S. obliqua.* The combination treatments of some products showed higher dose mortality response than the sole treatment of fungal conidia or the insecticide. The combination of insecticides with *M. anisopliae* showed 1.05 to 72.00 fold increase in toxicity of insecticides over sole treatment. They found that imidacloprid 17.8 SL and oxydemeton methyl 25 EC could be used in combination with *M. anisopliae* for the management of *S. obliqua*.

Study conducted by Rachappa *et al*. (2007) revealed that except few (chlorpyriphos, endosulfan, dicofol, dichlorvos and malathion) all other insecticides can be safely used along with the myco pathogen. However, the laboratory results on artificial media could not be reproducible in field as there might be degradation of toxicants. Imidacloprid and spinosad could be mixed with the fungus to get enhanced effects.

Materials and Methods

3. MATERIALS AND METHODS

The present study on "Biorational management of key pests of Jasmine *Jasminum sambac"* was conducted in the Department of Agricultural Entomology, College of Horticulture, Vellanikkara during 2007 to 2008. The details of the materials used and the techniques adopted for the investigation are described below.

3.1 FIELD POPULATION DYNAMICS OF THE MAJOR INSECT PESTS OF JASMINE

3.1.1 Survey

A survey on the incidence of major insect pests of jasmine *viz*., budworm (*Hendecasis duplifascialis* Hampson), blossom midge (*Contarinia maculipennis* Felt), thrips (*Isothrips orientalis* Bagnall) and whiteflies (*Dialeurodes kirkaldyi* Kotinsky) was conducted in farmer's fields (area 0.02ha) located at Thanikudam, Madakkathara, Chirakkekodu and Pandiparambu of Thrissur district during the period from November 2007 to June 2008.

3.1.2. Seasonal incidence of insects pests on *J. sambac*

The occurrence of major pests on *J. sambac* was recorded at fortnightly intervals from November 2007 to June 2008 in four locations as cited above. Ten jasmine bushes were selected randomly from each plot and the pests noticed on them were recorded.

3.1.2.1 Estimation of damage caused by budworm, *Hendecasis duplifascialis* Hampson

Total number of buds on a selected bush was counted first. Then the number of buds showing bore holes due to infestation of budworm was recorded and the per cent damage was worked out (Plate 1).

3.1.2.2 Estimation of damage caused by blossom midge, *Contarinia maculipennis* Felt

The damage caused by blossom midge (Plate 2) was assessed by recording the total number of buds and number of buds showing discolouration due to attack of blossom midge. Then the per cent damage of *C. maculipennis* was worked out.

3.1.2.3 Estimation of thrips, *Isothrips orientalis* Bagnall population

Thrips were present in flowers as well as on leaves (Plate 3 and 4) and therefore, the counts were made from both leaves and flowers. In case of flower thrips, three flowers were selected randomly from each plant and the number of adult thrips present on the flowers was counted. In case of leaf thrips, three young leaves were selected from top of the plant and the nymphs present on them were counted using a microscope.

3.1.2.4 Estimation of whitefly, *Dialeurodes kirkaldyi* Kotinsky population

Counts of whiteflies (Plate 5) per plant were made on six leaves - two each from top, middle and bottom of the plant.

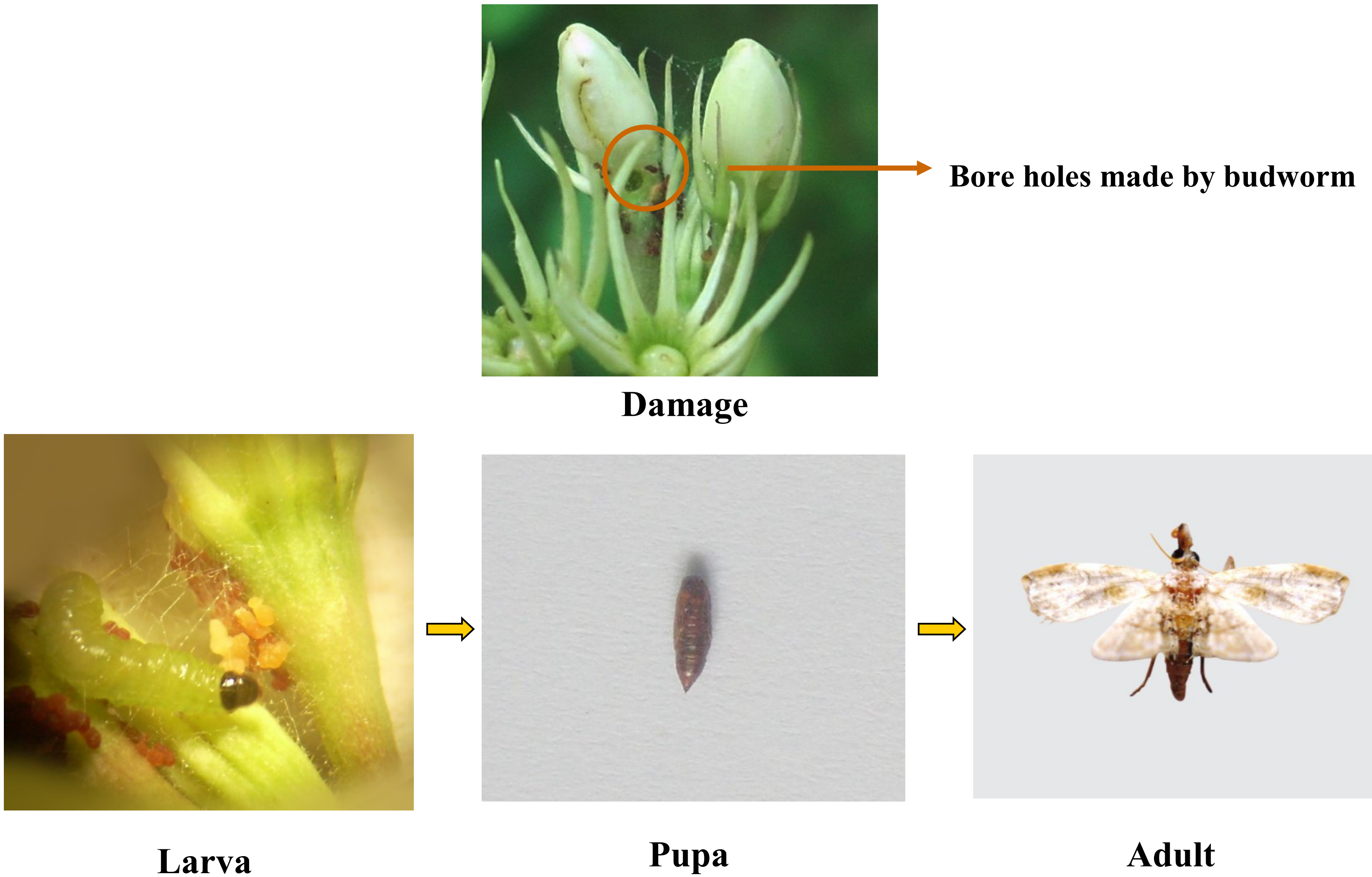


Plate 1. Budworm, *Hendecasis duplifascialis*

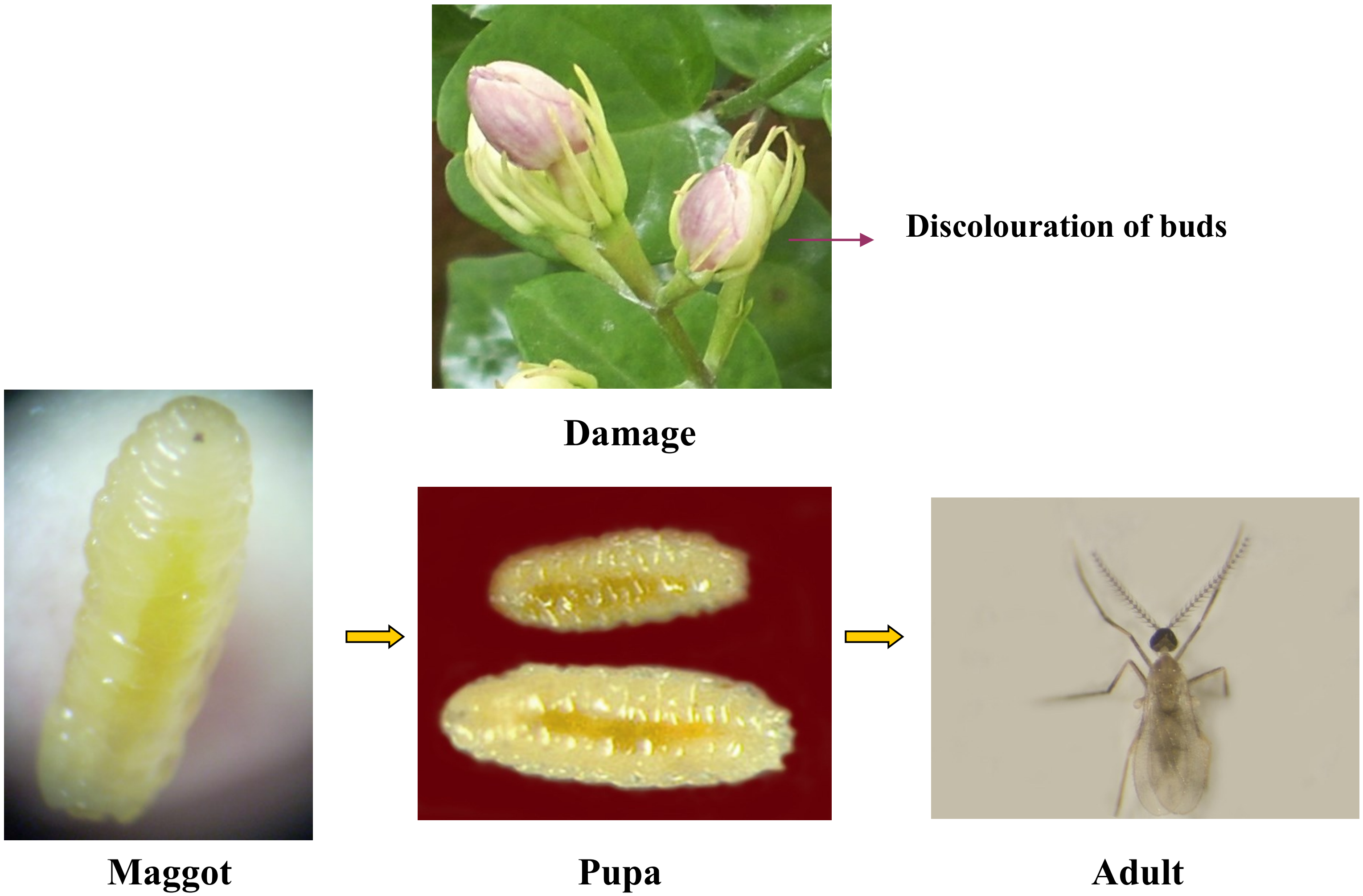
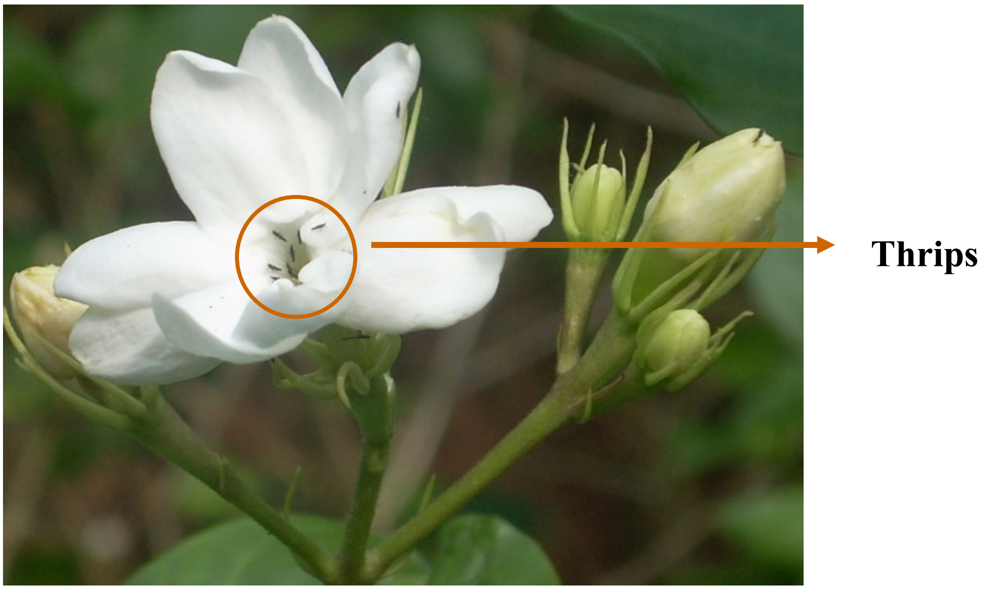


Plate 2. Blossom midge, *Contarinia maculipennis*



Thrips in the flower

Nymphs

Adult

Plate 3. Thrips, *Isothrips orientalis*

Crinkling and curling of leaves

Brownish streaks on flower petals

Plate 4. Symptoms of thrips infestation

Whiteflies on the under surface of leaf

Yellowing of leaf

Plate 5. Whitefly, *Dialeurodes kirkaldyi*

3.2 RECORDING OF METEOROLOGICAL PARAMETERS

The weather parameters such as maximum temperature, minimum temperature, rainfall and relative humidity were recorded from the Meteorological observatory of the College of Horticulture, Vellanikkara.

3.3 PREPARATION OF NEEM SEED KERNEL EXTRACT (NSKE) 5%

A quantity of 50g dried neem seed kernel was ground to a powder form and it was tied in a small muslin cloth bag and dipped in 100ml of water and kept overnight for 12 hours. Thereafter, the cloth bag was squeezed repeatedly so that the out flowing fluid from the cloth bag turned clear. Then, 900ml water was added to it and stirred well. The filtrate thus obtained was used for spraying.

3.4 FIELD EXPERIMENT TO EVALUATE THE BIOEFFICACY OF BIOPESTICIDES AND INSECTICIDES

A field experiment was carried out in the farmer's field at Thanikudam during the peak flowering period of jasmine from February to May 2008. The experiment was conducted on existing jasmine plants (eight year old) established in a farmer's field (size 0.02 ha). It was laid out in a randomized block design (RBD) with ten treatments including untreated check. Each treatment consisted of three plants and three replications were maintained for each treatment. Altogether there were ninety plants for the ten treatments.

The ten treatments of the experiment were categorized as given below:

(i) Biopesticides – T1, T2, T3, T4, T5
(ii) Biopesticides followed by chemical insecticides – T6, T7, T8
(iii) Chemical insecticides followed by azadirachtin – T9
(iv) Untreated check – T10

The details of the various treatments are furnished in Table 1.

Table 1. Details of treatments of the field experiment

Tr. No	Common name	Proprietory name (Source)	Formulation	Dosage
T1	*Beauveria bassiana*	Bio power (Stanes)	Liquid containing 1x 10^7spores / ml	1x 10^7spores / ml (0.2%)
T2	*Metarrhizium anisopliae*	Bio magic (Stanes)	Liquid containing 1x 10^7spores/ ml	1x 10^7spores / ml (0.2%)
T3	*Bacillus thuringiensis* subsp. *kurstaki*	Delfin (Margo)	5% WP	0.1%
T4	Neem Seed Kernel Extract (NSKE)	-	-	5%
T5	Azadirachtin	Econeem plus (Margo)	1%	0.002%
T6	*Metarrhizium anisopliae* followed by imidacloprid	Bio magic (Stanes) Confidor (Bayer)	Liquid containing 1x 10^7spores / ml 20SL	1x 10^7spores / ml (0.2%) 0.01%
T7	*Bacillus thuringiensis* subsp. *kurstaki* followed by carbosulfan	Delfin (Margo) Marshall (FMC Corporation)	5% WP 25EC	0.1% 0.05%
T8	*Beauveria bassiana* followed by fipronil	Bio power (Stanes) Regent (Bayer)	Liquid containing 1x 10^7spores / ml 5 SC	1x 10^7 spores/ ml (0.2%) 0.01%
T9	Acephate followed by imidacloprid and azadirachtin	Asataf (Rallis India Limited)) Confidor (Bayer) Econeem plus (Margo)	75% SP 20SL 1%	0.1% 0.01% 0.002%
T10	Control			

Tr. – Treatments

All the treatments were applied at fortnightly intervals from February 2008 to May 2008. Seven sprayings were given for each treatment. In the second category of treatments i.e. biopesticides followed by synthetic insecticides (T6, T7, T8), spraying of synthetic insecticides was given at five days after the biopesticide application in rotation. In the third category of treatments i.e. two synthetic insecticides followed by azadirachtain (T9), spraying of each insecticide was done at five days interval. In the last treatment of untreated check, only water was sprayed at the same intervals as above.

3.5 RECORDING OF OBSERVATION

Pre and post treatment observations on the incidence of budworm, blossom midge, thrips and whiteflies were recorded at fortnightly intervals following the same procedure carried out in the survey mentioned earlier (3.1.2). The per cent damage and population of the pests were calculated. The yield was also recorded from different treatments.

3.6 BENEFIT COST RATIO

Benefit: Cost ratio of different treatments was worked out using the following formula

$$\text{Benefit: Cost ratio} = \frac{\text{Total Benefit (Rs.)}}{\text{Total cost (Rs.)}}$$

3.7 STATISTICAL ANALYSIS

Data were subjected to ANOVA test and the means were separated by Duncan's Multiple Range Test. Correlation study of pest incidence and weather parameter was done using SPSS (Statistical Package for Social Sciences).

Results

4. RESULTS

The results of the study entitled “Bio rational management of key pests of Jasmine” conducted during the period from 2007 to 2008 at the Department of Agricultural Entomology, College of Horticulture, Vellanikkara are presented below.

4.1 POPULATION DYNAMICS OF KEY PESTS OF JASMINE

The survey was conducted at four locations of Thrissur district namely Thanikudam, Madakkathara, Chirakkekodu and Pandiparambu (Plate 6). The field incidence of budworm, blossom midge, flower thrips, leaf thrips and whiteflies were recorded at fortnightly intervals from November 2007 to June 2008 in the farmer’s field.

Locations:

4.1.1 Thanikudam

Table 2 illustrates the mean data of budworm, blossom midge, flower thrips, leaf thrips and whiteflies on jasmine at Thanikudam.

Budworm and blossom midge infestation at Thanikudam was reduced till January and then increased till April. Then gradual reduction was observed up to June. Maximum infestation was observed during second fortnight of March (30.50%, 24.30%). Lowest infestation was noticed during first and second fortnight of June (10.60%, 11.20% and 10.50%, 10.20%). At the early period of observation it was found that there was a fluctuation in the population of flower thrips and leaf thrips. The highest population was recorded during second fortnight of March (15.03, 5.80). Less population was noticed during second fortnight of June (3.93) and first fortnight of June (3.27) in case of flower thrips

Table 2. Field incidence of budworm, blossom midge, flower thrips, leaf thrips and whiteflies at Thanikudam during November 2007-June 2008

Period of observation	Mean infested buds (%)		Mean population		
	Budworm	Blossom midge	Flower thrips	Leaf thrips	Whiteflies
November 2nd fortnight	21.20	22.50	11.80	4.67	3.32
December 1st fortnight	20.50	21.20	9.50	5.57	4.48
December 2nd fortnight	20.10	20.30	5.30	4.17	3.22
January 1st fortnight	20.20	19.50	10.10	4.93	4.28
January 2nd fortnight	23.10	19.20	10.50	3.20	3.55
February 1st fortnight	26.10	21.10	12.33	4.00	4.30
February 2nd fortnight	28.12	22.50	12.53	4.23	4.60
March 1st fortnight	28.72	22.90	14.17	5.27	5.43
March 2nd fortnight	30.50	24.30	15.03	5.80	5.55
April 1st fortnight	29.20	20.20	11.00	4.57	6.33
April 2nd fortnight	20.57	15.50	13.07	4.80	6.80
May1st fortnight	12.34	12.20	8.37	4.87	5.05
May 2nd fortnight	12.33	12.10	5.03	4.20	4.47
June 1st fortnight	10.60	10.50	4.00	3.27	3.57
June 2nd fortnight	11.20	10.20	3.93	3.50	3.17

and leaf thrips respectively. The population of whiteflies was more during second fortnight of April (6.80) and after that the population showed a decline.

4.1.2 Madakkathara

At Madakkathara the infestation of budworm and blossom midge was found to be high during November, after which the infestation was decreased till first fortnight of January (Table 3). A high incidence of budworm and blossom midge was noticed during first fortnight of March (29.50%, 23.10%) and then the infestation showed a decreasing trend. Lowest infestation was observed during second fortnight of June (10.20%, 10.10%). The population of flower thrips and leaf thrips was maximum during first fortnight of March (13.40, 6.60). Lowest population was noticed during first fortnight of June (4.83 and 2.10). The population of whiteflies increased from second fortnight of November and reached maximum during first fortnight of April (6.17) and thereafter it showed a decreasing trend.

4.1.3 Chirakkekodu

From the data collected from Chirakkekodu (Table 4) it was found that the number of budworm and blossom midge infested buds was high during November and then started decreasing till first fortnight of January. Thereafter, a gradual increase of budworm and blossom midge incidence was noticed up to first fortnight of April and second fortnight of March respectively. A reduction in the infestation was observed thereafter maximum number of budworm and blossom midge infested buds was observed during first fortnight of April (30.40%) and second fortnight of February (22.50%) respectively. Population of flower thrips and leaf thrips was more during second and first fortnight of March respectively (14.50, 6.47) whereas less population was observed during first and second fortnight of June (4.03, 1.93). The whitefly population was highest during second fortnight of March (6.82) and lowest during second fortnight of June (2.23).

Table 3. Field infestation of budworm, blossom midge, flower thrips, leaf thrips and whiteflies at Madakkathara during November 2007-June 2008

Period of observation	Mean infested buds (%)		Mean population		
	Budworm	Blossom midge	Flower thrips	Leaf thrips	Whiteflies
November 2nd fortnight	21.50	21.40	8.40	4.53	3.12
December 1st fortnight	19.50	20.00	11.53	5.83	3.52
December 2nd fortnight	18.20	20.40	12.70	5.53	4.48
January 1st fortnight	18.50	20.20	8.90	5.13	4.28
January 2nd fortnight	21.89	21.80	7.80	4.20	4.55
February 1st fortnight	26.71	21.50	12.03	4.83	5.53
February 2nd fortnight	26.82	21.70	12.20	5.03	5.77
March 1st fortnight	29.50	23.10	13.40	6.60	6.13
March 2nd fortnight	28.90	20.50	9.57	4.47	4.50
April 1st fortnight	27.10	20.30	12.20	5.20	6.17
April 2nd fortnight	18.50	19.80	8.30	4.33	5.87
May1st fortnight	15.20	17.20	8.17	3.27	5.18
May 2nd fortnight	12.12	12.30	6.47	3.77	3.98
June 1st fortnight	11.20	10.50	4.83	2.10	3.30
June 2nd fortnight	10.20	10.10	4.90	3.53	2.15

Table 4. Field incidence of budworm, blossom midge, flower thrips, leaf thrips and whiteflies at Chirakkekodu during November 2007-June 2008

Period of observation	Mean infested buds (%)		Mean population		
	Budworm	Blossom midge	Flower thrips	Leaf thrips	Whiteflies
November 2nd fortnight	22.67	20.10	11.57	4.60	4.58
December 1st fortnight	21.83	17.50	10.80	4.73	5.20
December 2nd fortnight	18.33	17.20	10.37	3.20	5.30
January 1st fortnight	17.50	17.80	10.23	3.40	4.30
January 2nd fortnight	21.43	19.50	8.63	3.77	4.38
February 1st fortnight	20.20	21.20	9.87	4.67	6.33
February 2nd fortnight	27.25	22.50	11.50	5.47	6.03
March 1st fortnight	28.10	21.50	12.47	6.47	5.47
March 2nd fortnight	30.10	21.30	14.50	5.90	6.82
April 1st fortnight	30.40	18.50	13.03	5.57	5.50
April 2nd fortnight	27.50	15.50	10.00	5.60	6.47
May1st fortnight	13.90	14.60	8.40	4.27	6.57
May 2nd fortnight	10.60	13.20	5.30	2.90	5.52
June 1st fortnight	15.00	10.20	4.03	2.00	3.15
June 2nd fortnight	13.67	11.10	4.13	1.93	2.23

4.1.4 Pandiparambu

At Pandiparambu the budworm and blossom midge infested buds was more during second fortnight of November and then the infestation of the buds was reduced (Table 5). Maximum budworm infestation was noticed during second fortnight of April (31.60%) and the lowest damage was observed during first fortnight of June (10.60%). Blossom midge infested buds were more during first fortnight of March (21.80%). Till second fortnight of June, there occurred a decrease in the number of infested buds. Maximum population of flower thrips was observed during first fortnight of February (14.53). Lowest population was noticed during second fortnight of June (4.40). The leaf thrips population was more during first fortnight of March (6.97). Subsequently the population decreased from May to June. The whitefly population was highest during second fortnight of April (6.73) and lowest (2.15) during second fortnight of June.

4.1.5 Comparison of the pest incidence from four locations of Thrissur district

Results of the analysis of the incidence of the key pests of jasmine from four locations are presented in Table 6.

Budworm incidence was significantly higher during second fortnight of March (28.83%) and first fortnight of April (29.30%) while blossom midge infestation was significantly higher (22.33%) during March first fortnight. Flower thrips population was significantly higher (12.68, 12.38) during the first and second fortnight of March whereas significantly higher (6.33) population of leaf thrips was observed only during first fortnight of March. Second fortnight of April, recorded significantly higher population (6.47) of whiteflies. The field incidence of blossom midge, leaf thrips and whiteflies was significantly lower (10.33% and 10.48%, 2.64 and 3.02, 3.14 and 2.43 respectively) during first and

Table 5. Incidence of budworm, blossom midge, flower thrips, leaf thrips and whiteflies in jasmine at Pandiparambu during November 2007-June 2008

Period of observation	Mean infested buds (%)		Mean population		
	Budworm	Blossom midge	Flower thrips	Leaf thrips	Whiteflies
November 2nd fortnight	23.10	21.01	11.47	4.57	3.47
December 1st fortnight	20.20	17.14	12.47	4.60	4.52
December 2nd fortnight	19.50	18.18	10.57	4.00	3.52
January 1st fortnight	19.10	18.50	10.13	4.10	3.90
January 2nd fortnight	20.15	18.70	9.53	4.17	3.22
February 1st fortnight	21.50	20.10	14.53	5.23	4.67
February 2nd fortnight	24.50	20.50	12.83	5.13	5.03
March 1st fortnight	25.20	21.80	10.67	6.97	6.63
March 2nd fortnight	25.80	20.20	10.40	3.67	3.45
April 1st fortnight	30.50	18.18	12.17	5.57	6.23
April 2nd fortnight	31.60	17.14	10.00	5.60	6.73
May1st fortnight	14.30	15.50	9.20	4.17	5.58
May 2nd fortnight	12.50	12.20	6.50	4.13	5.07
June 1st fortnight	10.60	10.12	4.53	3.17	2.55
June 2nd fortnight	10.70	10.51	4.40	3.13	2.15

Table 6. Comparison of the pest incidence from four locations of Thrissur district during November 2007-June 2008

Period of observation	Mean infested buds (%)*		Mean population *		
	Budworm	Blossom midge	Flower thrips	Leaf thrips	Whiteflies
November 2nd fortnight	22.12^{b}	21.25^{f}	10.81^{e}	4.59^{c}	3.62^{b}
December 1st fortnight	20.01^{b}	18.84^{d}	11.08^{f}	5.18^{d}	4.43^{c}
December 2nd fortnight	19.03^{b}	18.47^{d}	9.74^{b}	4.22^{c}	4.13^{b}
January 1st fortnight	18.83^{b}	19.00^{e}	9.84^{b}	4.39^{c}	4.19^{b}
January 2nd fortnight	21.64^{c}	19.80^{e}	9.12^{b}	3.84^{b}	3.93^{b}
February 1st fortnight	23.63^{c}	20.98^{f}	12.19^{g}	4.68^{c}	5.21^{d}
February 2nd fortnight	26.67^{d}	21.80^{g}	12.27^{g}	4.97^{d}	5.36^{h}
March 1st fortnight	27.88^{e}	22.33^{h}	12.68^{h}	6.33^{e}	5.92^{j}
March 2nd fortnight	28.83^{f}	21.58^{g}	12.38^{h}	4.96^{d}	5.08^{d}
April 1st fortnight	29.30^{f}	19.30^{e}	12.10^{g}	5.23^{d}	6.06^{j}
April 2nd fortnight	24.54^{c}	16.99^{d}	10.34^{e}	5.08^{d}	6.47^{k}
May1st fortnight	13.76^{a}	14.88^{c}	8.54^{b}	4.15^{c}	5.59^{i}
May 2nd fortnight	11.89^{a}	12.45^{b}	5.83^{a}	3.75^{b}	4.76^{c}
June 1st fortnight	11.85^{a}	10.33^{a}	4.35^{a}	2.64^{a}	3.14^{a}
June 2nd fortnight	11.44^{a}	10.48^{a}	4.34^{a}	3.02^{a}	2.43^{a}

*Mean of four replications

In each column, figures followed by same letter do not differ significantly according to DMRT p=(0.05)

Thanikudam

Madakkathara

Plate 6. Survey plots

Chirakkekodu

Pandiparambu

second fortnight of June. Budworm and flower thrips incidence was significantly reduced from May to June. It is thus indicated that key pests population of jasmine was highest during March and April months.

Budworm and blossom midge was found to increase from November onwards and reached a peak during March second fortnight to April first fortnight and thereafter incidence showed a declining trend. The population of flower thrips recorded during December first fortnight was significantly higher than November second fortnight. From December second fortnight onwards thrips population showed a significant decline and again started increasing significantly from February first fortnight and reached at the peak during March. Thereafter a significant declining trend was observed.

4.2 CORRELATION OF WEATHER FACTOR WITH KEY PESTS OF JASMINE

The data on maximum temperature, minimum temperature, relative humidity and rainfall from November 2007 to June 2008 is given in Table 7.

Table 7. Weather data of College of Horticulture, Vellanikkara from November 2007 to June 2008

Month	Maximum temperature (ºC)	Minimum temperature (ºC)	Relative humidity (%)	Rainfall (mm)
November	31.7	21.6	67	24.8
December	31.6	22.7	59.5	8.7
January	32.3	21.7	59	0
February	33.6	22.9	60.5	29.7
March	33.2	23.4	63.5	205.3
April	35.3	21.4	74.5	65.6
May	35.8	23	72.5	11.5
June	33.1	21.3	85	636.7

Correlation of weather factors *viz*., maximum temperature, minimum temperature, relative humidity and rainfall with key pests of jasmine was analysed for Thrissur district in order to assess the degree of association between weather parameters and the incidence of pest population (Table 8).

Table 8. Correlation coefficient of jasmine pests with weather factors in Thrissur District

Pests	Temperature		Relative humidity	Rainfall
	Maximum	Minimum		
1. Budworm	0.037	0.163	-0.344	-0.401
2. Blossom midge	-0.254	0.368	-0.735*	-0.685
3. Flower thrips	-0.032	0.443	-0.643	-0.728*
4. Leaf thrips	-0.034	0.554	-0.631	-0.557
5. Whiteflies	0.676	0.566	-0.058	-0.437

* Significant at 1% level

Maximum temperature had a positive correlation with budworm infestation and whitefly population, whereas a negative correlation was observed with the population of flower thrips, leaf thrips and blossom midge infestation. Minimum temperature showed a positive correlation with all the pests. Both relative humidity and rainfall exhibited a negative correlation. Blossom midge incidence showed a significant negative correlation with relative humidity (-0.735). Flower thrips population indicated a significant negative correlation with rainfall (-0.728).

4.3 EFFICACY OF BIOPESTICIDES, CHEMICAL INSECTICIDES AND THEIR COMBINATIONS AGAINST THE KEY PESTS OF JASMINE

4.3.1 Field Experiment

The study was undertaken at Thanikudam (Plate 7) to find out the most effective insecticide against the pests *viz*., budworm, blossom midge, thrips and whiteflies of jasmine. The results on the efficacy of different insecticides against the pests are summarized below. One day prior to the application of treatments, observations on per cent infestation due to budworm, blossom midge and population of leaf thrips, flower thrips and whiteflies were recorded from the selected plants.

4.3.2 Effect of neem, microbial and chemical insecticides on budworm infestation

The results are presented in Table 9. All the insecticides were significantly effective as compared to control. Significantly lower infestation (15.95%) by budworm was observed after first spraying of *Bacillus thuringiensis* 0.1 per cent (T3) followed by *Beauveria bassiana* @ $1x10^7$spores ml^{-1} (T1-17.26%) and it was on par with (T7) rotational treatment of *B. thuringiensis* 0.1 per cent and carbosulfan 0.05 per cent (17.99%). Both the neem products (T4-NSKE 5%, T5-azadirachtin 1%) were significantly equally effective against budworm. The same trend was noticed during fourth spraying also.

In second spraying, the treatments T4-NSKE (5%), T5-azadirachtin (1%), T6-*Metarrhizium anisopliae* @ $1x10^7$spores ml^{-1} followed by imidacloprid (0.01%) and T8-*B. bassiana* @ $1x10^7$spores ml^{-1} followed by fipronil (0.01%) were found to be equally effective on budworm incidence. In fifth spraying the treatment T9 (acephate 0.1% followed by imidacloprid 0.01% and azadirachtin 1%) and T7 (*B. thuringiensis* 0.1% followed by carbosulfan 0.05%) were on par.

Plate 7. Experimental plot in Thanikudam

Table 9. Effect of neem, microbial and chemical insecticides on budworm infestation

Treatments	Mean per cent infestation* (15 days after treatment)							
	Precount	1st spray	2nd spray	3rd spray	4th spray	5th spray	6th spray	7th spray
T1 - *Beauveria bassiana* @ 1x10^{7}spores/ml	23.97^{b}	17.26^{e}	16.78^{d}	16.11^{d}	15.62^{d}	12.69^{fg}	10.84^{e}	9.03^{f}
T2 - *Metarrhizium anisopliae* @ 1x10^{7}spores/ml	29.54^{a}	21.02^{b}	20.32^{b}	20.07^{b}	19.81^{b}	18.21^{b}	15.02^{b}	12.69^{b}
T3- *Bacillus thuringiensis* subsp. *kurstaki* (0.1%)	26.43^{ab}	15.95^{f}	15.09^{e}	13.43^{e}	12.72^{e}	11.26^{g}	8.78^{f}	6.14^{g}
T4 - NSKE 5%	24.46^{ab}	19.93^{cd}	19.62^{bc}	19.36^{b}	18.73^{bc}	15.90^{d}	13.14^{c}	11.47^{cd}
T5 - Azadirachtin (1%)	26.52^{ab}	19.84^{cd}	19.29^{bc}	19.15^{b}	18.86^{bc}	14.78^{de}	12.94^{c}	10.94^{de}
T6 – *M. anisopliae* @ 1x10^{7}spores/ml and imidacloprid (0.01%)	24.30^{ab}	20.34^{bc}	20.11^{bc}	19.71^{b}	19.26^{b}	17.52^{bc}	14.86^{b}	12.67^{b}
T7 – *B. thuringiensis* subsp. *kurstaki* (0.1%) and carbosulfan (0.05%)	27.45^{ab}	17.99^{e}	17.42^{d}	16.31^{d}	15.93^{d}	13.26^{ef}	11.68^{de}	9.36^{f}
T8 - *B. bassiana* @ 1x10^{7}spores/ml and fipronil (0.01%)	25.74^{ab}	20.12^{bcd}	19.79^{bc}	19.64^{bc}	19.16^{bc}	16.18^{cd}	14.36^{bc}	12.01^{bc}
T9 - Acephate (0.1%), imidacloprid (0.01%) and azadirachtin (1%)	23.68^{b}	19.14^{d}	18.75^{c}	17.82^{c}	17.56^{c}	13.95^{ef}	12.83^{cd}	10.15^{ef}
T10 – Control	24.21^{ab}	23.21^{a}	22.79^{a}	22.62^{a}	22.56^{a}	21.43^{a}	19.58^{a}	19.47^{a}

*Mean of three replications

In each column, figures followed by same letter do not differ significantly according to DMRT p=(0.05)

Compared to other treatments, *M. anisopliae* @ $1x10^7$spores ml^{-1} (T2) and *M. anisopliae* @ $1x10^7$spores ml^{-1} followed by imidacloprid 0.01 per cent (T6) was found to be least effective against budworm in fourth, sixth and seventh sprayings. But the infestation was reduced upto 12.69 per cent and 12.67 per cent respectively.

After the application of seventh spraying, it was observed that *B. thuringiensis* 0.1 per cent (T3) was significantly effective in reducing the budworm infestation (6.14%) followed by *B. bassiana* @ $1x10^7$spores ml^{-1} (T1-9.03%) and it was on par with rotational treatment of *B. thuringiensis* 0.1% and carbosulfan 0.05 per cent (T7-9.36%). Among the neem derivatives azadirachtin 1 per cent (Econeem plus) (T5-10.94%) was more effective than NSKE (5%) (T4-11.47%). The treatment with acephate 0.1 per cent, imidacloprid 0.01 per cent and azadirachtin 1 per cent (T9) was more effective (10.15%) than azadirachtin 1 per cent alone (T5 -10.94%).

The descending order of effectiveness of different treatments in the field after the seventh spraying against budworm was T3 > T1, T7 > T9 > T5 > T4 > T8 > T2, T6.

4.3.3 Effect of neem, microbial and chemical insecticides on blossom midge infestation

The discolouration of buds due to blossom midge attack was effectively reduced by neem treatments *viz*., azadirachtin 1 per cent (T5-13.23%) NSKE 5 per cent (T4-13.53%) and rotational treatment of acephate 0.1 per cent, imidacloprid 0.01 per cent and azadirachtin 1 per cent (T9-13.72%) after first spraying and they were on par (Table 10).

The superiority of neem products in controlling blossom midge was observed in all the seven sprayings. In the second spraying, the treatments

Table 10. Effect of neem, microbial and chemical insecticides on blossom midge infestation

Treatments	Mean per cent infestation* (15 days after treatment)							
	Precount	1st spray	2nd spray	3rd spray	4th spray	5th spray	6th spray	7th spray
T1 - *Beauveria bassiana* @ 1x10^{7}spores/ml	19.45^{ab}	14.11^{de}	11.84^{cd}	13.79^{cd}	11.51^{cd}	10.89^{def}	10.80^{bc}	10.28^{c}
T2 - *Metarrhizium anisopliae* @ 1x10^{7}spores/ml	19.36^{ab}	15.73^{b}	15.01^{ab}	15.70^{ab}	13.77^{ab}	13.24^{ab}	12.58^{b}	12.30^{b}
T3- *Bacillus thuringiensis* subsp. *kurstaki* (0.1%)	19.21^{ab}	14.39^{cde}	12.19^{cd}	14.05^{bc}	12.02^{c}	11.58^{cde}	11.23^{bc}	10.75^{bc}
T4 - NSKE 5%	20.28^{a}	13.53^{e}	11.12^{d}	12.81^{d}	10.46^{d}	10.08^{fg}	8.62^{de}	6.71^{d}
T5 - Azadirachtin (1%)	19.39^{ab}	13.23^{e}	11.15^{d}	12.36^{d}	10.37^{d}	9.44^{g}	7.72^{e}	6.44^{d}
T6 – *M. anisopliae* @ 1x10^{7}spores/ml and imidacloprid (0.01%)	19.17^{ab}	15.35^{bc}	13.33^{bcd}	14.07^{bcd}	12.68^{bc}	12.41^{bc}	12.22^{b}	12.06^{bc}
T7 – *B. thuringiensis* subsp. *kurstaki* (0.1%) and carbosulfan (0.05%)	18.95^{ab}	14.20^{cde}	13.12^{bdc}	13.79^{cd}	12.67^{bc}	12.23^{bdc}	11.48^{bc}	11.50^{bc}
T8 - *B. bassiana* @ 1x10^{7}spores/ml and fipronil (0.01%)	18.01^{b}	14.96^{bcd}	13.54^{bc}	14.71^{bc}	12.61^{bc}	11.97^{bcd}	11.66^{bc}	11.13^{bc}
T9 - Acephate (0.1%), imidacloprid (0.01%) and azadirachtin (1%)	19.32^{ab}	13.72^{e}	11.57^{cd}	13.31^{cd}	11.21^{cd}	10.36^{efg}	9.88^{cd}	7.64^{d}
T10 – Control	20.24^{a}	17.99^{a}	16.06^{a}	17.30^{a}	15.12^{a}	14.35^{a}	16.32^{a}	14.63^{a}

*Mean of three replications

In each column, figures followed by same letter do not differ significantly according to DMRT p=(0.05)

T1-*B. bassiana* @ 1x10^7spores ml^{-1}, T3-*B. thuringiensis* 0.1 per cent, T9-acephate 0.1 per cent, imidacloprid 0.01 per cent and azadirachtin 1 per cent were found to be significantly equally effective in reducing blossom midge infestation. The treatments T1 (*B. bassiana* @ 1x10^7spores/ml), T9 (acephate 0.1 per cent, imidacloprid 0.01 per cent and azadirachtin 1 per cent) and T7 (*B. thuringiensis* 0.1% and carbosulfan 0.05%) were equally effective against blossom midge in third spraying.

The combination of biopesticides and insecticides (T6, T7 and T8) were found to be on par in the fourth spraying. In sixth spraying, biopesticide and their combinations were significantly equally effective (T1, T3, T7 and T8). The treatments T4 (azadirachtin 1%), T5 (NSKE 5%) and T9 (acephate 0.1%, imidacloprid 0.01% and azadirachtin 1%) showed equal significant effectiveness against blossom midge infestation after seventh spraying.

The blossom midge infestation was 6.71, 6.44 and 7.64 per cent in the most effective treatment of NSKE (T4), azadirachtin (T5) and acephate, imidacloprid and azadirachtin (T9) respectively. However, these treatments were on par. Compared to other treatments, *M. anisopliae* @ 1x10^7spores ml^{-1} (T2) was the least effective treatment in all the seven sprayings. But it reduced the blossom midge infestation upto 12.30 per cent after the seventh spray. *B. bassiana* @ 1x10^7spores ml^{-1} (T1) was the second best treatment (10.28%). The treatments T3 (*B. thuringiensis*), T6 (*M. anisopliae* @ 1x10^7spores/ml and imidacloprid 0.01%), T7 (*B. thuringiensis* 0.1% and carbosulfan 0.05%), and T8 (*B. bassiana* @ 1x10^7 spores/ml and fipronil 0.01%) were found to be on par.

Among the biopesticides, *B. bassiana* was the most effective one and the combination of biopesticide and chemical insecticide were on par. After the seventh spraying the efficacy of different treatments in the decreasing order was T5, T4, T9 > T1 > T3, T6, T7, T8 > T2.

4.3.4 Effect of neem, microbial and chemical insecticides on the population of flower thrips

Reduction in population of flower thrips was observed in plants treated with neem products, biopesticides and insecticides (Table 11). The flower thrips population was significantly reduced by (T9) rotational treatment of acephate 0.1 per cent, imidacloprid 0.01 per cent and azadirachtin 1 per cent (10.93) and it was on par with (T6) rotational treatment of *M. anisopliae* @ $1x10^7$spores ml^{-1} and imidacloprid 0.01 per cent (11.15) after first spraying. In second, third and fifth sprayings the treatments T5 (azadirachtin 1%) and T6 (*M. anisopliae* @ $1x10^7$spores/ml and imidacloprid 0.01%) were significantly effective in reducing flower thrips population. In fourth spraying, the treatment T9 (acephate 0.1% followed by imidacloprid 0.01% and azadirachtin 1%) was equally effective as T6 (*M. anisopliae* @ $1x10^7$spores/ml followed by imidacloprid 0.1%).

After the seventh spraying, the population of flower thrips (7.59) was significantly reduced by the rotational treatment of acephate 0.1 per cent, imidacloprid 0.01 per cent and azadirachtin 1 per cent (T9). It was followed by rotational treatment of *M. anisopliae* @ $1x10^7$spores ml^{-1} and imidacloprid 0.01% (T6-8.89) and azadirachtin 1 per cent (T5-9.18). The treatments T5 and T6 were on par.

M. anisopliae @ $1x10^7$spores ml^{-1} (T2) was least effective treatment against flower thrips in all seven sprayings. Though *M. anisopliae* (11.63) showed least effectiveness but it was found to be more effective when it was rotated with imidacloprid 0.01 per cent (8.89) after seventh spray. Among the neem products, azadirachtin 1 per cent (T5-9.18) was more effective than NSKE 5 per cent (T4-9.56). However, NSKE 5 per cent (T4) was on par with *B. thuringiensis* 0.1 per cent (T3). The descending order of effectiveness of different treatments against the population of flower thrips was T9 > T6, T5 > T3, T4 > T7 > T1, T8 > T2.

Table 11. Effect of neem, microbial and chemical insecticides on the population of flower thrips

Treatments	Mean population (no.)* (15 days after treatment)							
	Precount	1st spray	2nd spray	3rd spray	4th spray	5th spray	6th spray	7th spray
T1 - *Beauveria bassiana* @ 1x10^{7}spores/ml	14.93[a]	12.93[c]	11.96[cd]	11.67[d]	12.47[c]	11.33[d]	10.96[d]	10.82[c]
T2 - *Metarrhizium anisopliae* @ 1x10^{7}spores/ml	14.78[ab]	13.44[b]	12.41[b]	12.85[b]	13.00[b]	12.04[b]	11.85[b]	11.63[b]
T3- *Bacillus thuringiensis* subsp. *kurstaki* (0.1%)	14.52[b]	12.11[e]	10.74[e]	11.11[e]	11.56[d]	10.41[f]	10.00[f]	9.78[e]
T4 - NSKE 5%	14.15[c]	11.96[e]	10.26[f]	11.15[e]	11.07[e]	10.04[g]	9.82[f]	9.56[e]
T5 - Azadirachtin (1%)	14.04[c]	11.63[f]	9.89[g]	10.07[f]	10.59[f]	9.67[h]	9.44[g]	9.18[f]
T6 – *M. anisopliae* @ 1x10^{7}spores/ml and imidacloprid (0.01%)	14.15[c]	11.15[g]	9.74[g]	9.89[f]	10.11[g]	9.48[h]	9.04[h]	8.89[f]
T7 – *B. thuringiensis* subsp. *kurstaki* (0.1%) and carbosulfan (0.05%)	14.18[c]	12.59[d]	11.04[e]	11.48[de]	12.04[c]	10.89[e]	10.56[e]	10.33[d]
T8 - *B. bassiana* @ 1x10^{7}spores/ml and fipronil (0.01%)	14.74[ab]	13.18[bc]	12.00[c]	12.26[bc]	12.85[b]	11.78[c]	11.48[c]	11.15[c]
T9 - Acephate (0.1%), imidacloprid (0.01%) and azadirachtin (1%)	14.26[c]	10.93[g]	8.70[h]	8.89[g]	10.19[g]	8.52[i]	7.96[i]	7.59[g]
T10 – Control	14.82[a]	15.52[a]	14.93[a]	15.00[a]	15.15[a]	14.82[a]	14.41[a]	14.40[a]

*Mean of three replications

In each column, figures followed by same letter do not differ significantly according to DMRT p=(0.05)

4.3.5 Effect of neem, microbial and chemical insecticides on the population of leaf thrips

All the treatments were significantly effective in controlling leaf thrips population as compared to control in all the seven sprayings (Table 12). However, rotational treatment of acephate 0.1 per cent, imidacloprid 0.01 per cent and azadirachtin 1 per cent (T9) recorded the lowest thrips population (3.04) and it was on par with (T6) rotational treatment of *M. anisopliae* @ 1x10^7spores ml^{-1} and imidacloprid 0.01 per cent (3.07) after the first spraying. The same trend was noticed in second, third, fifth and seventh sprayings.

The treatments T4 (NSKE 5%) and T5 (azadirachtin 1%) were significantly effective against the population of leaf thrips in second, fifth and seventh sprayings. But in first, third, fourth and sixth sprayings, azadirachtin 1% (T5) was significantly more effective as compared to NSKE 5% (T4).

After the seventh spraying, leaf thrips population was significantly reduced by the rotational treatment of acephate 0.1 per cent, imidacloprid 0.01 per cent and azadirachtin 1 per cent (T9-0.93) and *M. anisoplae* @ 1x10^7spores ml^{-1} followed by imidacloprid 0.01 per cent (T6-1.30). Both were found to be on par.

Both the neem products (T4-azadirachtin 1%, T5-NSKE 5%) were equally effective in reducing the leaf thrips population. But all the biopesticides (T1, T2, and T3) and their combinations (T7, T8) were found to be least effective against leaf thrips. The decreasing order of efficacy of the treatments after the seventh spray was T9, T6 > T4, T5 > T1, T2, T3, T7, T8.

Table 12. Effect of neem, microbial and chemical insecticides on the population of leaf thrips

Treatments	Mean population (no.)* (15 days after treatment)							
	Precount	1st spray	2nd spray	3rd spray	4th spray	5th spray	6th spray	7th spray
T1 - *Beauveria bassiana* @ $1x10^7$spores/ml	5.11[a]	4.00[cd]	3.85[cd]	3.52[c]	3.74[bcd]	3.63[cd]	3.29[c]	3.18[b]
T2 - *Metarrhizium anisopliae* @$1x10^7$spores/ml	5.26[a]	4.33[b]	4.07[b]	3.74[b]	3.96[b]	3.85[b]	3.59[b]	3.48[b]
T3- *Bacillus thuringiensis* subsp. *kurstaki* (0.1%)	5.33[a]	3.82[d]	3.67[d]	3.33[d]	3.56[d]	3.44[d]	3.11[c]	3.00[b]
T4 - NSKE 5%	5.18[a]	3.56[e]	3.41[e]	3.07[e]	3.29[e]	3.18[e]	2.89[d]	2.41[c]
T5 - Azadirachtin (1%)	5.30[a]	3.33[f]	3.22[e]	2.89[f]	3.11[ef]	3.00[e]	2.67[e]	2.15[c]
T6 – *M. anisopliae* @ $1x10^7$spores/ml and imidacloprid (0.01%)	5.22 [a]	3.07[g]	3.00[f]	2.67[g]	2.89[fg]	2.78[f]	2.44[f]	1.30[d]
T7 – *B. thuringiensis* subsp. *kurstaki* (0.1%) and carbosulfan (0.05%)	5.56[a]	3.96[cd]	3.82[cd]	3.48[cd]	3.71[cd]	3.59[cd]	3.26[c]	3.15[b]
T8 - *B. bassiana* @ $1x10^7$spores/ml and fipronil (0.01%)	5.30 [a]	4.07[c]	3.96[bc]	3.48[cd]	3.85[bc]	3.74[bc]	3.56[b]	3.44[b]
T9 - Acephate (0.1%), imidacloprid (0.01%) and azadirachtin (1%)	5.30 [a]	3.04[g]	2.93[f]	2.56[g]	2.82[g]	2.71[f]	1.82[g]	0.93[d]
T10 – Control	5.22[a]	5.33[a]	5.11[a]	5.00[a]	5.04[a]	5.00[a]	4.89[a]	4.67[a]

*Mean of three replications

In each column, figures followed by same letter do not differ significantly according to DMRT p=(0.05)

4.3.6 Effect of neem, microbial and chemical insecticides on the population of whiteflies

In the first round of spray the lowest population of whiteflies was recorded (Table 13) in plants sprayed with rotational treatment (T9) of acephate 0.1 per cent, imidacloprid 0.01 per cent and azadirachtin 1 per cent (3.28), azadirachtin1 per cent alone (T5) and NSKE 5 per cent (T4) (3.32 and 3.46 respectively) after the first spraying. However, all these treatments were found to be on par. But in second, third, fourth, fifth, sixth and seventh sprayings T9 was found to be significantly effective as compared to neem products.

M. anisopliae @ $1x10^7$spores ml^{-1} (T2) was the least effective treatment in first, fifth, sixth and seventh sprayings. But in second and fourth sprayings, the treatments T3 (*B. thuringiensis* 0.1%) and T7 (*B. thuringiensisi* 0.1% and carbosulfan 0.05%) also found to be least effective as T2.

A significant reduction in whitefly population was observed after the seventh spraying of rotational treatment of acephate 0.1 per cent, imidacloprid 0.01 per cent and azadirachtin 1 per cent (T9-0.80) followed by azadirachtin 1 per cent (T5-1.74) indicating the superiority of T9. *M. anisopliae* @ $1x10^7$spores ml^{-1} (T2-3.08) was the least effective treatment followed by *B. thuringiensis* 0.1 per cent and carbosulfan 0.05 per cent (T7-2.96) after the seventh spraying. Out of the biopesticides used *B. bassiana* was the most effective one and *M. anisopliae* was the least effective one against whiteflies.

Azadirachtin 1 per cent (T5) was significantly effective against whiteflies when compared to NSKE 5 per cent (T4). But the treatment *M. anisopliae* @ $1x10^7$spores ml^{-1} and imidacloprid 0.01 per cent (T6) was also on par with NSKE 5 per cent (T4). Among the biopesticide and insecticide combinations, *M. anisopliae* @ $1x10^7$spores ml^{-1} and imidacloprid 0.01 per cent was more effective against whiteflies than the other combinations. The efficacy of different

Table 13. Effect of neem, microbial and chemical insecticides on the population of whiteflie

Treatments	Mean population (no.)* (15 days after treatment)							
	Precount	1^{st} spray	2^{nd} spray	3^{rd} spray	4^{th} spray	5^{th} spray	6^{th} spray	7^{th} spray
T1 - *Beauveria bassiana* @ $1x10^7$spores/ml	4.54^{ab}	3.85^{c}	3.67^{cd}	3.28^{c}	3.61^{cd}	3.15^{d}	2.61^{def}	2.33^{ef}
T2 - *Metarrhizium anisopliae* @ $1x10^7$spores/ml	4.58^{ab}	4.20^{b}	3.96^{b}	3.85^{b}	3.91^{b}	3.80^{b}	3.24^{b}	3.08^{b}
T3- *Bacillus thuringiensis* subsp. *kurstaki* (0.1%)	4.61^{ab}	3.96^{bc}	3.85^{b}	3.74^{b}	3.80^{b}	3.63^{bc}	2.89^{cd}	2.70^{cd}
T4 - NSKE 5%	4.37^{ab}	3.46^{d}	3.46^{ef}	2.95^{d}	3.35^{ef}	2.87^{e}	2.44^{fg}	2.07^{f}
T5 - Azadirachtin (1%)	4.52^{ab}	3.32^{d}	3.32^{f}	2.83^{d}	3.21^{f}	2.65^{f}	2.22^{g}	1.74^{g}
T6 – *M. anisopliae* @ $1x10^7$spores/ml and imidacloprid (0.01%)	4.30^{b}	3.81^{c}	3.56^{de}	3.26^{c}	3.46^{de}	3.07^{de}	2.54^{ef}	2.11^{f}
T7 – *B. thuringiensis* subsp. *kurstaki* (0.1%) and carbosulfan (0.05%)	4.60^{ab}	4.04^{bc}	3.91^{b}	3.78^{b}	3.85^{b}	3.67^{bc}	3.09^{bc}	2.96^{bc}
T8 - *B. bassiana* @ $1x10^7$spores/ml and fipronil (0.01%)	4.70^{a}	3.93^{c}	3.78^{bc}	3.67^{b}	3.72^{bc}	3.48^{c}	2.76^{de}	2.59^{de}
T9 - Acephate (0.1%), imidacloprid (0.01%) and azadirachtin (1%)	4.50^{ab}	3.28^{d}	3.13^{g}	2.24^{e}	2.87^{g}	2.11^{g}	1.85^{h}	0.80^{h}
T10 – Control	4.59^{ab}	4.68^{a}	4.52^{a}	4.37^{a}	4.44^{a}	4.33^{a}	4.28^{a}	4.22^{a}

*Mean of three replications

In each column, figures followed by same letter do not differ significantly according to DMRT p=(0.05)

treatments after the seventh spraying in the decreasing order was T9 > T5 > T4, T6 > T1 > T8 > T3 > T7 > T2.

4.4 EFFECT OF NEEM, MICROBIAL AND CHEMICAL INSECTICIDES ON YIELD OF JASMINE

Results on yield (Table 14) indicated that all the insecticide treatments caused a significantly higher yield in jasmine than the untreated check (T10). The treatment T9 (acephate, imidacloprid and azadirachtin) recorded the highest yield of 3405 kg ha^{-1} and it was significantly superior to other treatments. It was followed by T3 (*B. thuringiensis*) and T7 (*B. thuringiensis* and carbosulfan) and the lowest yield (2369 kg ha^{-1}) was obtained in T10 (untreated check).

Among the biopesticide treatements, T3 recorded a higher yield (3336 kg ha^{-1}) than the other treatments. The yield (2988 kg ha^{-1}) in azadirachtin (T5) treatment was significantly higher than the NSKE (T4-2919 kg ha^{-1}). No significance difference in yield was observed between treatments T1, T2, T8 and T6.

4.5 BENEFIT COST RATIO

Considering the total returns, the rotational treatment of acephate 0.1 per cent, imidacloprid 0.01 per cent and azadirachtin 1 per cent (T9) recorded the highest value (Rs.3,40,500 ha^{-1}) followed by (T3) *B. thuringiensis* 0.1 per cent alone (Rs. 3,33,600) (Table 15). The rotational treatment (T7) of *B. thuringiensis* 0.1 per cent and carbosulfan 0.05 per cent resulted in a return of Rs. 3,19,700 ha^{-1} followed by (T4) azadirachtin 1 per cent (Rs. 2,98,800 ha^{-1}) and NSKE 5 per cent (Rs.2,91,900 ha^{-1}). The lowest return was obtained in the treatment (T2) of *M. anisopliae* @ $1x10^7$spores ml^{-1} (Rs.2,57,100 ha^{-1}).

Table14. Effect of neem, microbial and chemical insecticides on yield of jasmine

Treatments	Yield of buds (kg/ha)
T1 - *Beauveria bassiana* @ 1x10^7spores/ml	2641[b]
T2 - *Metarrhizium anisopliae* @ 1x10^7spores/ml	2571[b]
T3- *Bacillus thuringiensis* subsp. *kurstaki* (0.1%)	3336[e]
T4 - NSKE 5%	2919[c]
T5 - Azadirachtin (1%)	2988[d]
T6 – *M. anisopliae* @ 1x10^7spores/ml and imidacloprid (0.01%)	2780[b]
T7 – *B. thuringiensis* subsp. *kurstaki* (0.1%) and carbosulfan (0.05%)	3197[e]
T8 - *B. bassiana* @ 1x10^7spores/ml and fipronil (0.01%)	2710[b]
T9 - Acephate (0.1%), imidacloprid (0.01%) and azadirachtin (1%)	3405[f]
T10 – Control	2369[a]

*Mean of three replications

In each column, figures followed by same letter do not differ significantly according to DMRT p=(0.05)

Table 15. Benefit: Cost ratio of different treatments against key pests of jasmine

Treatments	Yield of buds (kg/ha)	Total income (Rs 100/kg) (Rs ha^{-1})	Cost of treatment and other cost (Rs ha^{-1})	Benefit: Cost ratio
T1 - *Beauveria bassiana* @ $1x10^7$spores/ml	2641	264100	101396	2.60:1
T2 - *Metarrhizium anisopliae* @ $1x10^7$spores/ml	2571	257100	99996	2.57:1
T3- *Bacillus thuringiensis* subsp. *kurstaki* (0.1%)	3336	333600	138016	2.42:1
T4 - NSKE 5%	2919	291900	127436	2.29:1
T5 - Azadirachtin (1%)	2988	298800	116816	2.56:1
T6 – *M. anisopliae* @ $1x10^7$spores/ml and imidacloprid (0.01%)	2780	278000	122416	2.27:1
T7 – *B. thuringiensis* subsp. *kurstaki* (0.1%) and carbosulfan (0.05%)	3197	319700	150436	2.13:1
T8 - *B. bassiana* @ $1x10^7$spores/ml and fipronil (0.01%)	2710	271000	130776	2.07:1
T9 - Acephate (0.1%), imidacloprid (0.01%) and azadirachtin (1%)	3405	340500	152700	2.23:1
T10 – Control	2369	-	-	-

The result of benefit: cost ratio revealed that the application of *B. bassiana* @ $1x10^7$ spores ml^{-1} alone had the highest B: C ratio (2.60:1) and it was followed by *M. anisopliae* @ $1x10^7$spores ml^{-1} (2.57:1). Azadirachtin 1 per cent (Econeem plus) showed a benefit: cost ratio of 2.56:1 and the next highest value was recorded in the treatment of *B. thuringiensis* 0.1 per cent (2.42:1). The least B: C ratio was observed in the rotational treatment of *B. bassiana* @ $1x10^7$spores ml^{-1} and fipronil 0.01 per cent (2.07:1). All the biopesticides and botanicals were found to give a higher B: C ratio as compared to insecticide combinations.

Discussion

5. DISCUSSION

Among the flower crops, jasmine is being cultivated extensively in South India. Like any other crop, jasmine also is having the threat of many pests and diseases affecting its yield potential. Use of chemicals is in vogue among the jasmine growers to control these enemies. However, the common problems associated with the regular use of chemicals and the need to develop a low input sustainable cultural practice regime for jasmine cultivation has warranted the use of microbial agents with other routine control tactics to form an ideal Integrated Pest Management (IPM) programme. Besides, botanical pesticides can be integrated with the use of parasitoids and predators, microbial pesticides and even synthetic chemical pesticides to achieve greater efficiency. Hence, studies were conducted utilizing different ecofriently methods for the control of jasmine pests. The detailed discussion on the results is presented under the following headings.

a. Assessment of population dynamics of key pests of jasmine
b. Bioefficacy of biopesticides and chemical insecticides against the key pests of jasmine.
c. Effect of neem, microbial and chemical insecticides on yield of jasmine
d. Benefit: Cost ratio

5.1 ASSESSMENT OF POPULATION DYNAMICS OF BUDWORM, BLOSSOM MIDGE, THRIPS AND WHITEFLIES

5.1.1 Survey of key pests of jasmine

The survey on the population dynamics of key pests of jasmine was conducted at four locations and the observations were recorded at fortnightly intervals from November 2007 to June 2008 in the farmer’s field. The results of the present study are discussed here.

5.1.1.1 Seasonal variation of budworm and blossom midge infestation

The fortnightly mean data of budworm and blossom midge infestation of the four locations were analysed and illustrated in Fig. 1. A moderate to heavy infestation was seen throughout the period of study and the population was found to fluctuate from November to June. Maximum infestation was observed during November to April, which might be due to the more number of buds resulting in multiplication of pests. During heavy rains (June), the infestation was decreased and this decline was mainly due to the decrease in number of buds per plant. Budworm incidence was higher than that of blossom midge in the field. Both pests indicated same trend of infestation fluctuation.

Studies conducted by Hemchandra and Singh (2007) gave a similar trend to that of present study where the population of *Plutella xylostella* in cabbage was high during the month of March and April after which the larval population showed a steep decline. This abrupt decline was mainly due to the decrease in number of buds per plant. Another reason of the decline could be assigned to natural parasitism and predation. The present finding is in agreement with David *et al*. (1990) who reported that more than fifty per cent of flowers were damaged by blossom midge during summer months in *Jasminum sambac.*

5.1.1.2 Seasonal variation of sucking pests in jasmine

In the case of sucking pests *viz*., flower thrips, leaf thrips and whiteflies, the population was found to be fluctuating throughout the year (Fig. 2). Peak population of flower thrips, leaf thrips and whiteflies was observed during February to April, irrespective of the locations, indicating the influence of high temperature for the multiplication of thrips and whiteflies. This is in agreement with the study conducted by Duraimurugan and Jagadish (2002) in red rose during September 1999 to August 2000 on the incidence of rose thrips, *Scirtothrips dorsalis* Hood. The icidence prevailed throughout the flowering period and

Fig. 1 Budworm and blossom midge infestation from the selected four locations during November 2007 to June 2008

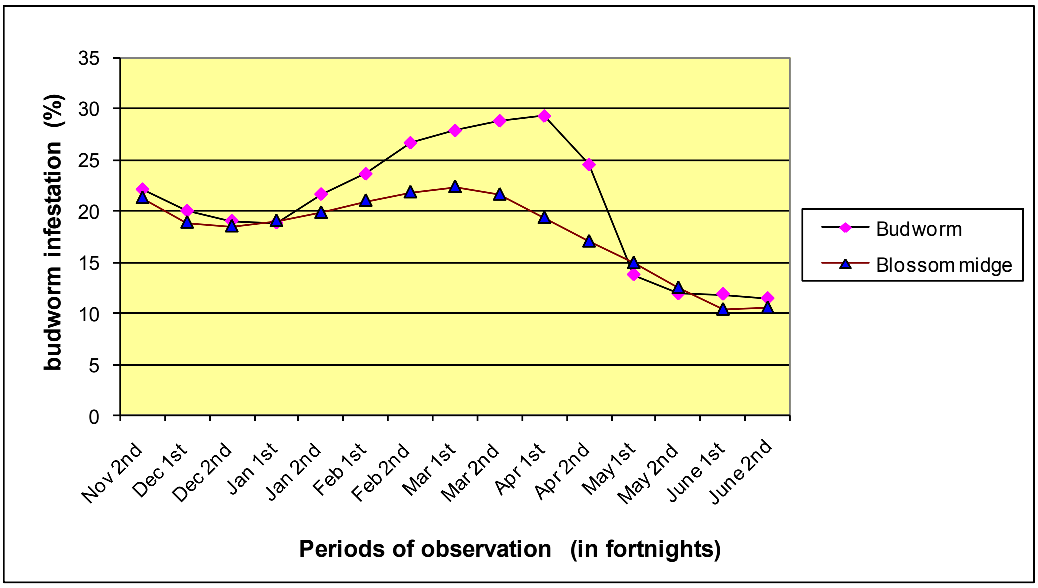
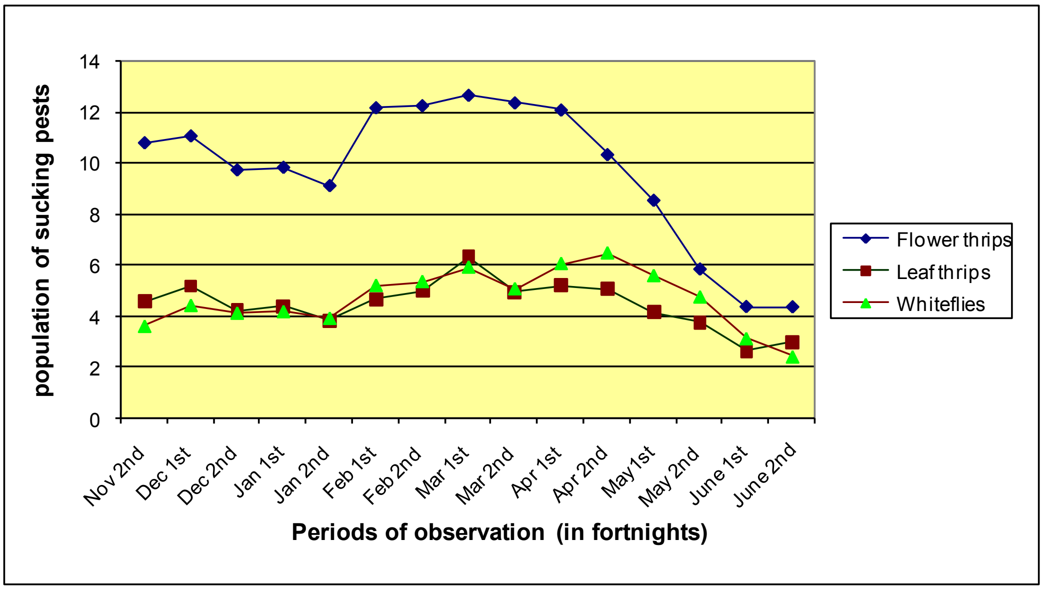


Fig. 2 Population of flower thrips, leaf thrips and whiteflies from four locations of Thrissur District during November 2007 to June 2008



reached peak during the first fortnight of April and severe infestation occurred between April and May. The population of safflower thrips was reported to be high during the first week of February (Mane *et al*., 2002). An increase in the population of potato whitefly *Bemisia tabaci* (Guennadius) from the first week of February, reaching its peak on the first week of March was observed by Kishore *et al*. (2005).

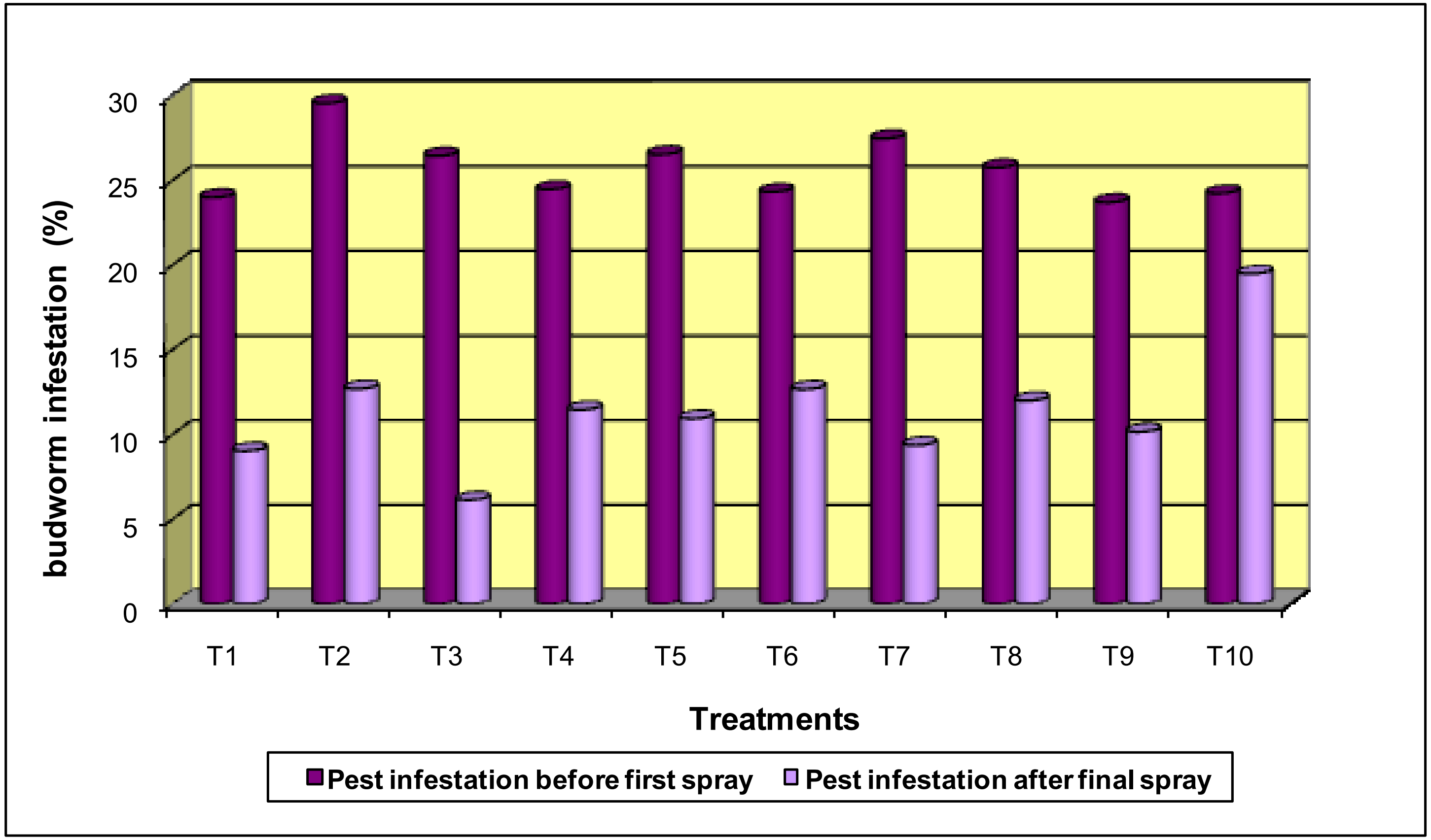
5.2 CORRELATION OF WEATHER PARAMETERS WITH PEST POPULATION

In the present study, blossom midge incidence showed a significant negative correlation with relative humidity. Flower thrips population indicated a significant negative correlation with rainfall. As there was an increase in the intensity of rainfall, the production of flowers was decreased, hence there was a decrease in flower thrips population. Also, the thrips were washed off due to rains. These findings are in line with that of Duraimurugan and Jagadish (2002), who revealed that, the incidence of *S. dorsalis* on rose was positively correlated with minimum temperature and negatively correlated with the total rainfall and wind velocity.

5.3 BIOEFFICACY OF BIOPESTICIDES, CHEMICAL INSECTICIDES AND THEIR COMBINATIONS AGAINST BUDWORM

The results revealed that the treatment, *Bacillus thuringiensis* subsp. *kurstaki* (Delfin) at 1.0 kg ha^{-1} gave consistently good results in bringing down the budworm infestation followed by *Beauveria bassiana* @ $1x10^7$spores ml^{-1} (Fig. 3). The present finding is in conformity with Vanitha and Dhandapani (2004) in jasmine. They found that treatment with Delfin @ 1.0 kg ha^{-1} at fifteen days interval was very effective against jasmine budworm. Kumar and Chowdhary (2004) indicated the pathogenicity of *B. bassiana* isolates, HBB-2 (90.0%), DBB-1 (87.5%) and HBB-1 (75.0%) against *Helicoverpa armigera* (Hubner). The

Fig. 3 Effect of neem, microbial and chemical insecticides on budworm infestation



efficacy of *B. thuringiensis* against different pests on different crops had been reported by several workers.

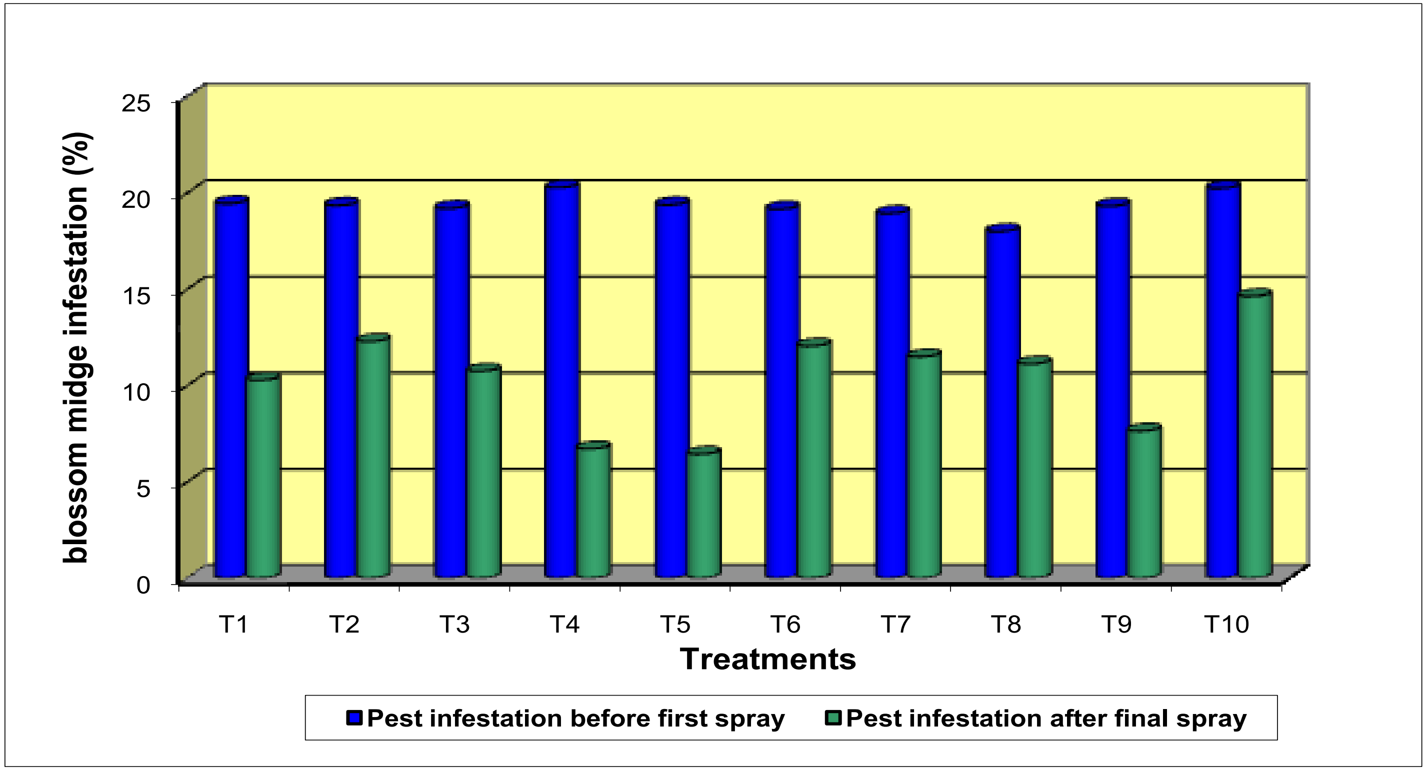
B. thuringiensis subsp. *kurstaki* was reported to be highly effective against the larvae of lepidopteran pests but not against homopteran pests (Jayanthi and Padmavathamma, 1996). *B. thuringiensis* is a bacterium that produces insecticidal crystal proteins during sporulation, highly toxic to various pests (Aranda *et al*., 1996). Thakur *et al*. (1996) proved that the treatment with *B. thuringiensis* subsp. *kurstaki* was more effective when compared to neem based pesticides in reduction of *H. armigera* larval population in cotton. Isabel (1996) found that *B. thuringiensis* subsp. *kurstaki* products 'Delfin' and 'Agree' gave good results against *Nausinoe geometralis* Guenee under laboratory conditions. Delfin 50 WG was more effective against DBM on cabbage (Kulkarni *et al*., 1995).

Similarly Burgio *et al*. (1994) also reported the effectiveness of Delfin against *Ostrinia nubilalis* Hubner. The mortality caused by *Bacillus* species and unidentified viral pathogen to *H. armigera* larvae on carnation was given by Kaushal *et al*. (1999). The effectiveness of Delfin and Halt @ 1.0 kg ha^{-1} against *H. armigera* was also given by Praveen *et al*. (2001).

5.4 EFFICACY OF TEST INSECTICIDES AGAINST BLOSSOM MIDGE INFESTATION

The present study pertaining to the efficacy of test insecticides against the blossom midge infestation showed that the treatment azadirachtin 1 per cent was the most effective one in reducing the blossom midge infestation followed by NSKE 5 per cent and rotational treatment of acephate 0.1 per cent, azadirachtin 1 per cent and imidacloprid 0.01 per cent as depicted in Fig. 4. The present findings agree with that of Mannion *et al*. (2006). They reported that azadirachtin was effective against blossom midge infestation in hibiscus. Foliar spray of acephate was effective against gall midge, *Contarinia nasturtii* Kieffer in cruciferous plants

Fig. 4 Effect of neem, microbial and chemical insecticides on blossom midge infestation



Wu *et al*., 2006). The adult stage of the blossom midge is vulnerable to contact insecticides, because the maggots are protected within the bud and the pupae are burrowed in the soil. Translaminar insecticides (those move from the sprayed leaf surface to the other surface) may be capable of penetrating the bud to affect the maggots (Osborne *et al*., 2001). Neem acts as a repellant, insecticidal, antibacterial, antifungal, antifeedant, oviposition and growth inhibiting, crop and grain protectant (Prakash and Rao, 1997).

5.5 EVALUATION OF TEST INSECTICIDES ON THE POPULATION OF FLOWER THRIPS AND LEAF THRIPS

The flower thrips and leaf thrips population was effectively reduced by the rotational treatment of acephate 0.1 per cent, azadirachtin 1 per cent and imidacloprid 0.01 per cent followed by the rotational treatment of *M. anisopliae* @ 1×10^7 spores ml^{-1} and imidacloprid 0.01 per cent (Fig. 5 and 6). Shukla (2007) reported that spraying of acephate 0.1 per cent was effective against rose thrips, *Rhipiphorothrips cruentatus* Hood, chrysanthemum thrips, *Microcephalothrips abdominalis* (Crawford), carnation thrips, *Frankliniella schultzei* (Trybom) and gladiolus thrips, *Taeniothrips simplex* (Morison). He also reported that orchid thrips was effectively reduced by spraying of imidacloprid (0.007%) at 10 days interval.

Rachappa *et al*. (2007) reported that synergistic interaction was found between imidacloprid and *M. anisopliae* and so the additive effect of *M. anisopliae* with imidacloprid was proved in the study. Similar result was obtained by Jaramillo *et al*. (2005). The nymphal mortality of subterranean burrower bug, *Cyrtomenus bergi* Froeschner was more during the combined application of *M. anisopliae* and imidacloprid compared to the fungus alone, and a synergistic interaction was found between the two agents. A study conducted by Mishra *et al*. (2005) during kharif season, proved the effectiveness of imidacloprid (17.8 SL) 0.022 kg a.i. ha^{-1} against chilli thrips. The results indicated that

Fig. 5 Effect of neem, microbial and chemical insecticides on the population of flower thrips

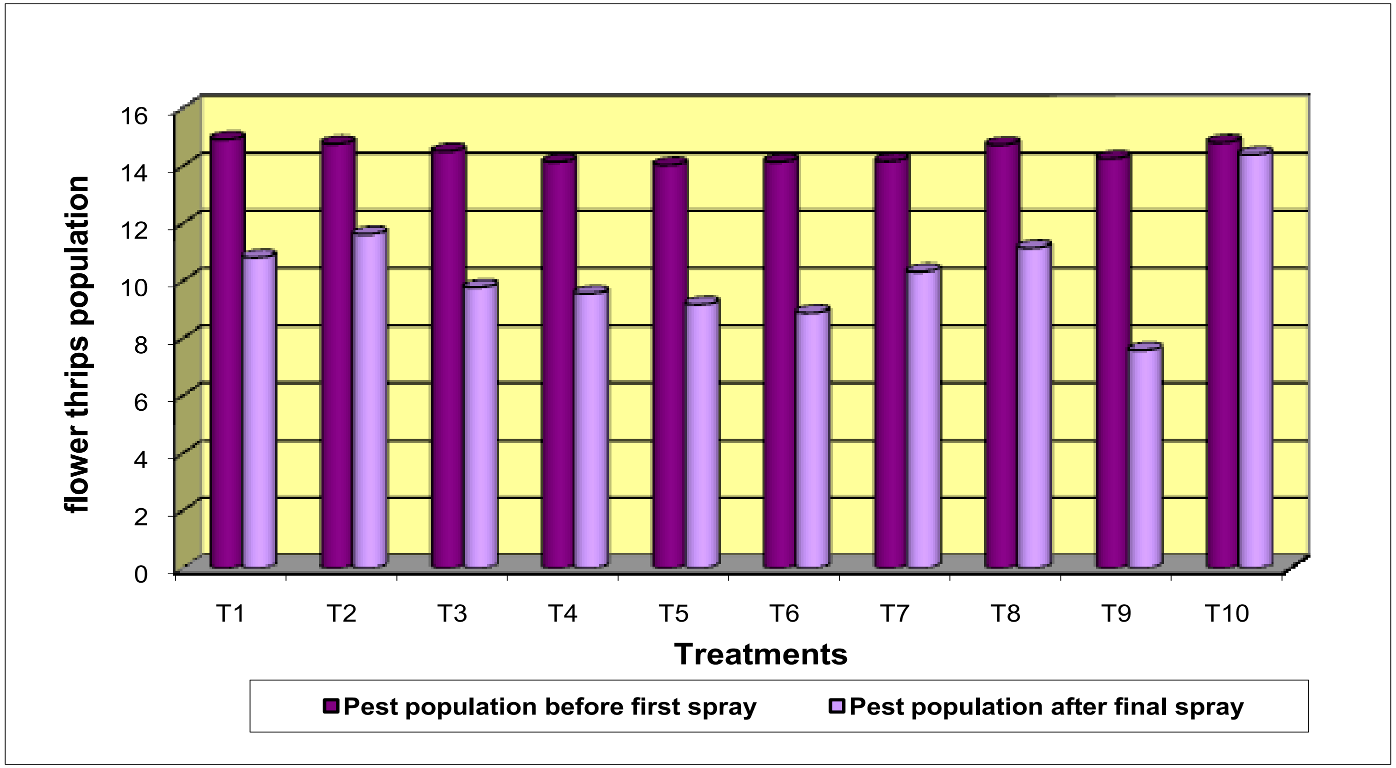
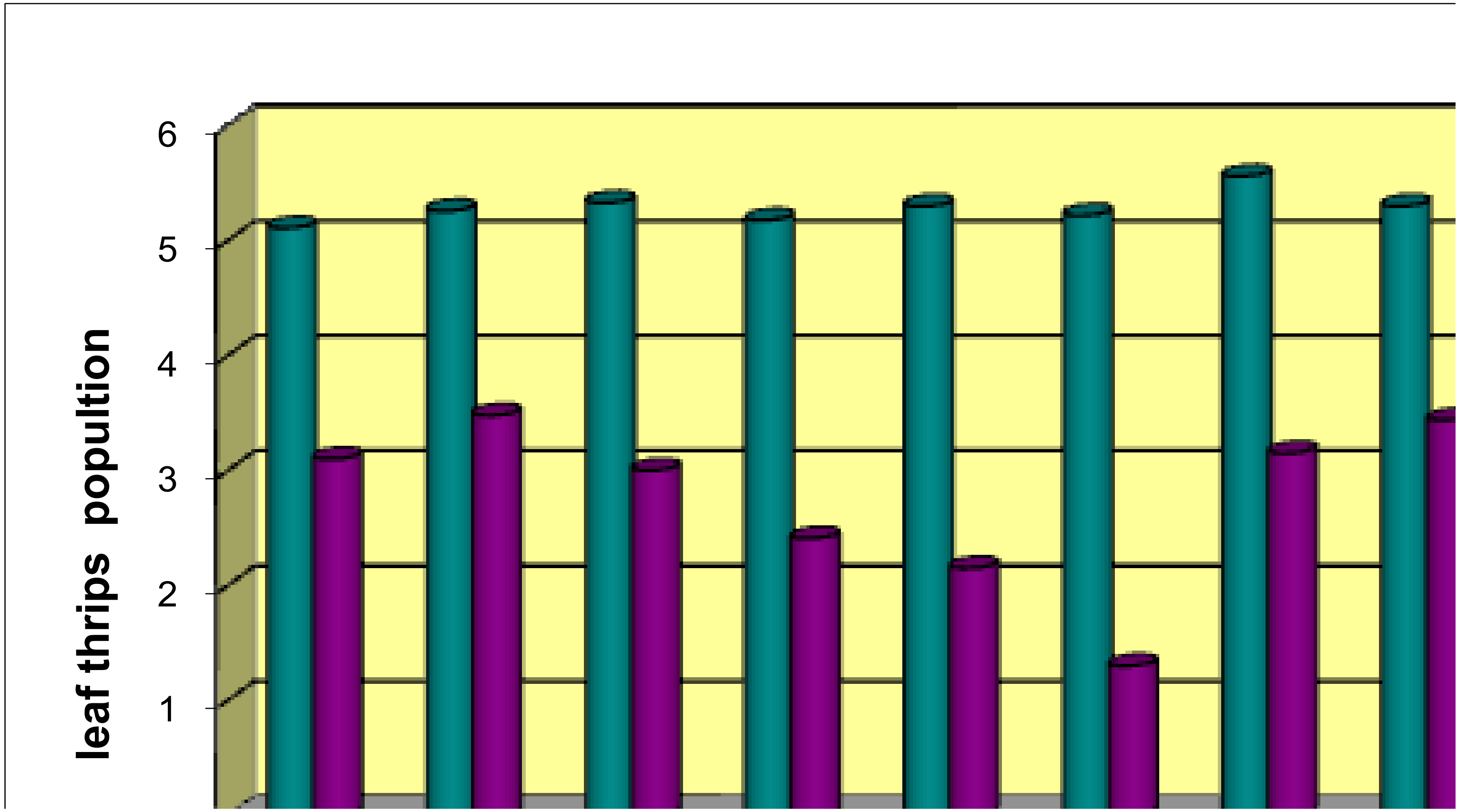


Fig. 6 Effect of neem, microbial and chemical insecticides on the population of leaf thrips



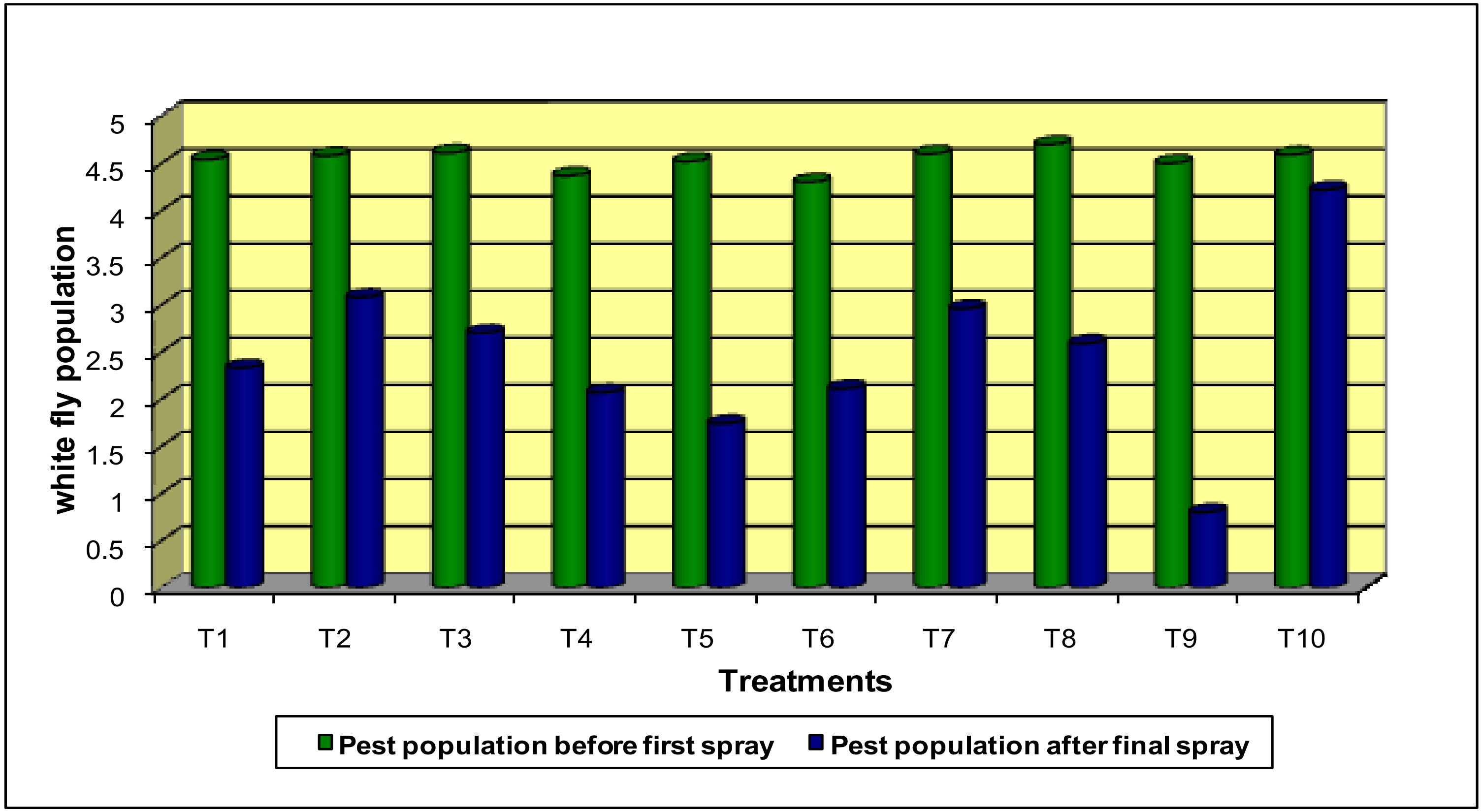
imidacloprid was the most effective in suppressing the thrips population. Similarly, Wahla *et al*. (1997) reported that spraying of Confidor 200 SL at 40 ml a.i. acre^{-1} was the most effective against cotton thrips. Confidor 200 SL gave significant control against thrips and leafhopper on groundnut (Bhadane *et al*., 2007). Gupta (2001) reported acephate, a systemic insecticide causing no phytotoxicity when used in recommended dosage and get disintegrated in soil and plants. Cloyd and Sadof (2000) also reported that spraying of acephate 600 g l^{-1} was effective against western flower thrips. Manjunatha *et al*. (2000) proved the effect of 0.25 and 0.50 g l^{-1} of imidacloprid 75 WS combined with acephate 1 g l^{-1} applied as seed treatments, field or nursery sprays, seedling dip treatments against mites (*Polyphagotarsonemus latus* Banks) and thrips (*S. dorsalis*) infesting chilli.

5.6 EVALUATION OF INSECTICIDES AGAINST WHITEFLIES

It was found that the whitefly population was effectively reduced by rotational treatment of acephate 0.1 per cent, azadirachtin 1 per cent and imidacloprid 0.01 per cent followed by azadirachtin 1 per cent. The results are presented in Fig. 7. This is in conformity with the results obtained in the study of Singh *et al*. (2005). They found that imidacloprid 17.8 SL at 250 ml ha^{-1} provided the maximum reduction of whitefly at 1,3,7 and 14 days after spraying (i.e. 89.86, 95.58, 81.50 and 58.98 % respectively) followed by acephate 75 SP at 1250 g ha^{-1}. Similarly, okra whiteflies *B. tabaci* was effectively reduced by imidacloprid @ 20 and 25 g a.i. ha^{-1} up to 3 weeks of insecticide application (Misra, 2005).

Raghuraman and Gupta (2005) also reported that acetamiprid 40 g a.i. ha^{-1} and imidacloprid 100 g a.i. ha^{-1} were most effective against cotton whitefly *B. tabaci*. Soil application of acephate 75 SP 0.5 kg a.i. ha^{-1} gave the best control of *B. tabaci* in cowpea as described by Patel and Srivastava (1996). Kfoury *et al.* (1997) recommended that spraying of imidacloprid (one ml l^{-1}as Confidor 200 SL) was found to be the most effective against *Trialeurodes vaporariorum* (Westwood) and *B. tabaci* in cucumber. Ahmadzadeh and Hatami (2006) proved

Fig. 7 Effect of neem, microbial and chemical insecticides on the population of whiteflies



that spraying of Confidor 35 per cent SC (Imidacloprid) caused highest mortality (88%) of nymphal stages of green house whitefly, *T. vaporariorum*.

5.7 EFFECT OF NEEM, MICROBIAL AND CHEMICAL INSECTICIDES ON YIELD OF JASMINE

A higher reduction in insect population was observed after the treatment of T9 (acephate 0.1%, imidacloprid 0.01% and azadirachtin 1%) leading to higher flower yield (Fig. 8). Among biopesticides, higher reduction in budworm infestation was observed in T3 (*B. thuringiensis* 0.1%). The pest population in untreated control was high which resulted in a lowest flower yield.

5.8 BENEFIT COST RATIO

The highest yield of 3408 kg ha^{-1} was obtained from the rotational treatment of acephate 0.1 per cent, azadirachtin 1 per cent and imidacloprid 0.01 per cent followed by *B. thuringiensis* 0.1 per cent alone (3336 kg ha^{-1}). Therefore, the yield was higher. However, benefit: cost ratio was less (2.23:1). *B. bassiana* @ $1x10^7$spores ml^{-1} recorded the highest benefit: cost ratio (2.60:1) followed by *M. anisopliae* @ $1x10^7$spores ml^{-1} (2.57:1) (Fig. 9). The present findings are in line with observations made by Praveen *et al*. (2001) in tomato fruit borer *H. armigera*, where Delfin @1.0 kg ha^{-1} was highly effective in reducing the larval population, per cent fruit damage and increased in fruit yield.

Higher benefit: cost ratio was obtained after the application of biopesticides. But a low B: C ratio with the highest flower yield was observed after the application of insecticides. This might be due to the higher cost of synthetic insecticides. Hence, the application of biopesticides can be recommended to manage the pests population of jasmine.

Fig. 8 Effect of neem, microbial and chemical insecticides on yield of jasmine

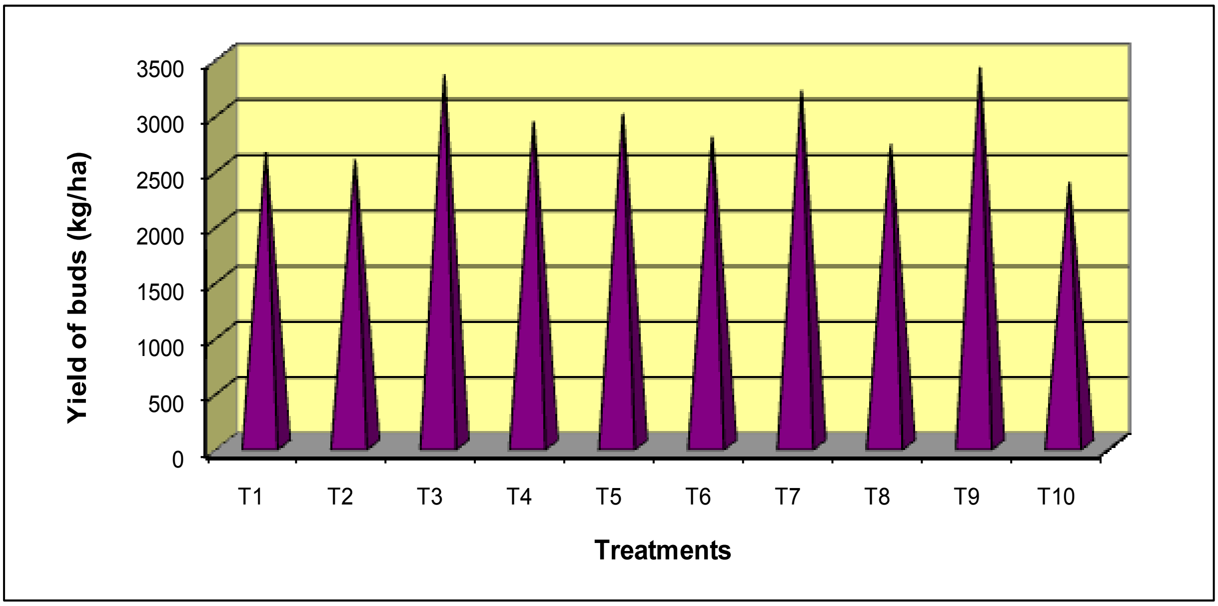
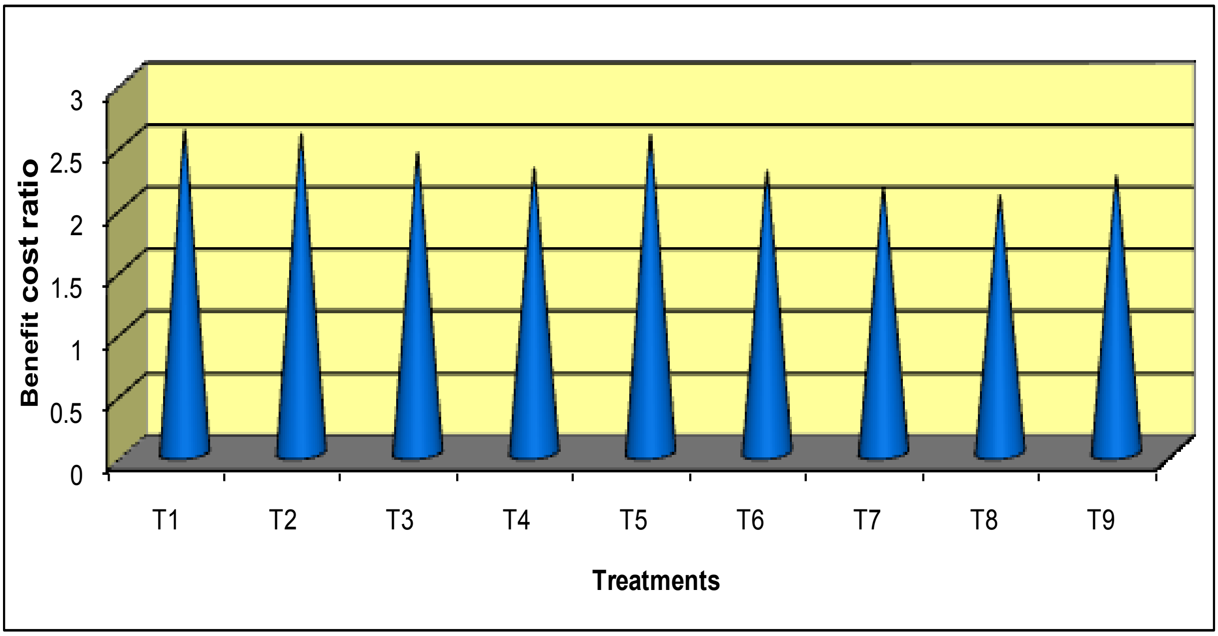


Fig. 9 Benefit: Cost ratio of different treatments against key pests of jasmine



Summary

6. SUMMARY

Jasmine, one of the most important fragrant flower crops is seriously damaged by numerous pests and diseases. To devise suitable IPM module, a field study involving chemical insecticides, neem products, biopesticides and their combinations was conducted in farmer's field at Thanikudam during 2007- 2008. The salient findings of the present investigations are summarized below.

A survey was conducted at four locations of Thrissur district during November 2007 to June 2008 to assess the population dynamics of key pests of jasmine such as budworm, blossom midge, thrips and whiteflies. Observations on the incidence of key pests were recorded at fortnightly intervals. The infestation of budworm was found to increase from November to April, and then it got reduced. Whereas lowest infestation was noticed during May and June.

As far as blossom midge infestation was concerned, the infestation was increased from November to March and lowest infestation was noticed during June. Regarding flower thrips, leaf thrips and whiteflies, the population was fluctuating throughout the study period. Highest population of flower thrips and leaf thrips was observed during March. While the lowest population was noticed during May to June period. The population of whiteflies reached maximum during the month of April and the lowest number was recorded during June.

Correlation analysis of jasmine pests with weather parameters viz., maximum temperature, minimum temperature, relative humidity and rainfall was done in four locations of Thrissur district in order to assess the degree of association between weather parameters and the pest population. A significant negative relationship was observed between relative humidity and blossom midge infestation, rainfall and flower thrips population. None of the other parameters had a significant influence on the population of the pests.

A field experiment was carried out in farmer's field at Thanikudam in order to evaluate the efficacy of biopesticides like *Beauveria bassiana* (Bio power) @ 1x10^7spores ml^{-1} *Metarrhizium anisopliae* (Bio magic) @ 1x10^7spores ml^{-1}, *Bacillus thuringiensis* (Delfin) @ 0.1%, NSKE (5%) and azadirachtin 1% (Econeem plus) @ 0.002 per cent along with standard insecticides such as imidacloprid (Confidor) @ 0.01 per cent acephate (Asataf) @ 0.1 per cent, fipronil (Regent) @ 0.01 per cent and carbosulfan (Marshall) @ 0.05 per cent against the key pests of jasmine such as budworm, blossom midge, flower thrips, leaf thrips and whiteflies.

From the field experiment, it was observed that application of *B. thuringiensis* at 0.1 per cent was most effective in reducing the budworm infestation followed by *B. bassiana* @ 1x 10^7spores ml^{-1} and rotational treatment of *B. thuringiensis* (0.1 %) and carbosulfan (0.05%) which were found to be on par. The neem products NSKE (5%) and azadirachtin 1% (Econeem plus) were proved to be very effective against blossom midge infestation. But azadirachtin (1%) gave consistently good results against blossom midge infestation followed by NSKE (5%).

The rotational treatment of acephate 0.1 per cent, imidacloprid 0.01 per cent and azadirachtin 1 per cent was found to be very effective in controlling flower thrips and leaf thrips population. The rotational treatment of *M. anisopliae* @ 1x 10^7spores ml^{-1} followed by imidacloprid (0.01%) was found to be the next best treatment. The whitefly population was effectively reduced by the rotational treatment of acephate (0.1%), imidacloprid (0.01%) and azadirachtin (1%) followed by azadirachtin (1%) alone.

Benefit: Cost ratio was calculated to work out the feasibility of using biopesticides against insecticides. The highest net profit of Rs. 3,40,500 was obtained from the treatment with rotational application of acephate 0.1 per cent, imidacloprid 0.01 per cent and azadirachtin 1 per cent with the highest marketable yield of 3405 kg ha^{-1}. This was followed by the treatment of *B. thuringiensis* 0.1 per cent which recorded a marketable yield of 3336 kg ha^{-1} with a net profit of Rs. 3,33,600 ha^{-1} . The highest benefit: cost ratio of 2.60:1 was obtained from the plants treated with *B. bassiana* @ 1x 10^7spores ml^{-1} followed by *M. anisopliae* @ 1x 10^7 spores ml^{-1} with a benefit: cost ratio of 2.57:1.

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* Originals not seen

Appendix

APPENDIX-1

Cost of cultivation of jasmine per hectare for four months

SI. No	Items	Cost (Rs)
1.	Fertilizer	15590
2.	Labour cost	1600
3.	Weeding	10,000
4.	Irrigation	12666
5.	Prunning	1200
6.	Harvesting	50922
7.	Plant protection chemicals	2652
8.	Application charges	1000
Total		Rs. 95630

BIORATIONAL MANAGEMENT OF KEY PESTS OF JASMINE (*Jasminum sambac*)

By

G. HEMALATHA
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ABSTRACT OF THE THESIS

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Faculty of Agriculture

Kerala Agricultural University, Thrissur

Department of Agricultural Entomology

COLLEGE OF HORTICULTURE

VELLANIKKARA, THRISSUR - 680 656

KERALA, INDIA

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ABSTRACT

Jasmine is cultivated extensively in South India. It is seriously damaged by numerous pests and diseases. The use of selective, biorational approaches in place of broad spectrum conventional insecticides offer several advantages in IPM programme. The present study on "Biorational management of key pests of Jasmine (*Jasminum sambac*)" was carried out in the Department of Agricultural Entomology, College of Horticulture, Vellanikkara. The main objectives of the study were to assess the population dynamics of key pests of jasmine and to evaluate the efficacy of biopesticides like *Beauveria bassiana*, *Metarrhizium anisopliae*, *Bacillus thuringiensis*, NSKE and Econeem plus along with standard insecticides such as imidacloprid, acephate, fipronil and carbosulfan.

To assess the population dynamics of key pests of jasmine a survey was conducted in the farmer's field in four locations of Thrissur district. It was found that budworm and blossom midge infestation were increased from November to March and the population of thrips and whiteflies were more during February to April, the peak flowering period. Correlation analysis of jasmine pests with weather parameters *viz*., maximum temperature, minimum temperature, relative humidity and rainfall revealed that a significant negative relationship exist between the relative humidity and blossom midge infestation. Flower thrips population was negatively correlated with rainfall.

From the field experiment it was observed that application of *B*. *thuringiensis* at 0.1 per cent was the most effective treatment against jasmine budworm, *Hendecasis duplifascialis* followed by *B*. *bassiana* @1x10^7spores ml^{-1} and the rotational treatment of *B*. *thuringiensis* (0.1%) and carbosulfan (0.05%). Blossom midge infestation was significantly reduced in azadirachtin (1%) treated plants followed by NSKE (5%) sprayed plants.

In the case of flower thrips and leaf thrips the rotational treatment of acephate (0.1%), imidacloprid (0.01%) and azadirachtin (1%) was found to be the

most effective. For controlling the whitefly population also, the same treatment gave consistently good results.

The highest yield (3405 kg ha^{-1}) with a net profit of Rs. 3,40,500 was obtained from the plants treated with rotational application of acephate, imidacloprid and azadirachtin. But the highest benefit: cost ratio of 2.60:1 was obtained from the plants treated with *B. bassiana* @$1x10^7$spores ml^{-1} followed by *M. anisopliae* @$1x10^7$spores ml^{-1} (2.57:1).

It is thus indicated that a highest benefit: cost ratio can be obtained by the application of biopesticides although higher flower yield was obtained by the application of insecticides. Hence, the application of biopesticides can be recommended to manage the pests population of jasmine.