POPULATION DYNAMICS AND MANAGEMENT OF SHOOT WEBBER AND HOPPERS INFESTING MANGO USING SAFER MOLECULES

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(2014-11-240)

DEPARTMENT OF AGRICULTURAL ENTOMOLOGY

COLLEGE OF AGRICULTURE

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by

SHIVAMURTHY

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2016

DECLARATION

I, hereby declare that this thesis entitled **"POPULATION DYNAMICS AND MANAGEMENT OF SHOOT WEBBER AND HOPPERS INFESTING MANGO USING SAFER MOLECULES"** is a bonafide record of research work done by me during the course of research and the thesis has not previously formed the basis for the award to me of any degree, diploma, associate ship, fellowship or other similar title, of any other University or Society.

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CERTIFICATE

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Shivamurthy

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LIST OF ABBREVIATIONS AND SYMBOLS USED

@	At the rate of
^{0}C	Degree Celsius
ANOVA	Analysis of variance
a.i.	Active ingredient
CD	Critical difference
cfu	Colony forming units
cm	centimeter
DDT	Dichlorodiphenyltrichloroethane
DAS	Days after spraying
EC	Emulsifiable concentrate
FN	Fortnight
et al.	and other co workers
G^{-1}	per gram
hrs	hours
IPM	Integrated pest management
ITCC	The Indian Type Culture Collection
i.e.	that is
Kg	Kilo gram
L^{-1}	Per litre
mg	milligram
mm	millimeter

NS	Non significant
NSKE	Neem seed kernel extract
No.	number
ppm	Parts per million
SC	Suspension concentrate
SL	Soluble liquid
Sl No.	Serial number
sp.	species
viz.,	namely
WP	Wettable powder

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1. INTRODUCTION

Mango (*Mangifera indica* L.) is the most important subtropical fruit crop of India. It is considered as the 'King of Fruits'. Mango is the native of Indo Burma (Myanmar) region (Decondele, 1904; Popenoe and Wilson, 1920; Vavilov, 1926). India accounts for 41 per cent of the world production of mango (Chakrabarti, 2014). It has great socio-economic, cultural and religious significance. It is rich in vitamin A (4800 IU), vitamin C, flavonoids, sterols, aromatic acids, phenolics, fatty acids and essential oil.

Many insect pests attack mango during its growth, flowering and fruiting stages. This is a major constraint in the mango production. There are 492 species of insects, 17 species of mites and 26 species of nematodes, attacking mango, of which 188 species have been reported from India (Tandon and Verghese, 1985; Srivastava, 1998). The pests include leaf hopper, mealy bug, inflorescence midge, fruit fly, scale insects, shoot borer, leaf webber and stone weevil, causing considerable crop damage (Hati *et al*., 2005). The major insect pests of mango in South India are mango hoppers, fruit fly and stem borer. Secondary pests generally occur at sub-economic levels. However, they can become serious pests due to changes in cultural practices or indiscriminate use of insecticides against a key pest. Mango shoot webber was found as a minor pest earlier but now, it infest all the varieties of mango in Kerala and has attained the status of a major pest (Rafeeque and Ranjini, 2011).

Mango shoot webber consists of two species *viz*., *Orthaga euadrusalis* Walker and *Orthaga exvinacea* Hampson and responsible for low productivity. It causes about 90 per cent of shoot damage, leading to improper fruit setting (Singh, 1988). The heavily infested trees present a burnt look and severe infestation results in complete failure of flowering (Verghese, 1998). It affects the flowers as well as the growth of new flush (Kavita *et al*., 2005). It is widely distributed in different agro-climatic zones of India and has gained the status of serious pest in Uttar Pradesh, Uttaranchal and Andhra Pradesh (Singh *et al*., 2006).

Mango hoppers are the most serious and wide spread pest in India. The most destructive species are *Idioscopus clypealis* Lethierry, *Idioscopus nitidulus* Walker and *Amritodus atkinsoni* Lethierry. These were first reported from Saharanpur in Uttar Pradesh (Lethierry, 1889). Das *et al*. (1969) recorded a new hopper *Amrasca splendens* Ghauri from Kerala. The nymphs and adult insects make punctures and suck the sap of tender leaves, inflorescence and fruits. It causes 20-100 per cent crop loss in India (Haseeb, 2006; Rahman and Kuldeep, 2007).

To tackle the problem of shoot webber and hoppers infesting mango, conventional and third generation insecticides are being used by the mango growers. Repeated application of pyrethroids results in resistance development in mango hoppers (Kumar *et al*., 2002). Malathion and dimethoate are currently recommended for controlling the defoliators and sucking pests of mango, respectively (KAU, 2011). Conventional insecticides and pyrethroids, due to their disadvantages, are being replaced by new molecules in the present day market. The broad spectrum activity of these new molecules at low dosages, coupled with low mammalian toxicity and safety to non target organisms made them an alternative to conventional insecticides (Kumar, 2006).

To develop an ecologically sound and economically viable management strategy, it is very important to assess the basic information on pest incidence, seasonal variation of pests and influence of weather parameters on pest activity. This will help in decision making for the appropriate time and selection of suitable methods of management. Hence, the present investigation entitled "Population dynamics and management of shoot webber and hoppers infesting mango using safer molecules" was carried out with the following objectives:

- To conduct a preliminary survey at different homesteads and also at the Instructional Farm, Vellayani to document the target pests
- To study the population dynamics of mango shoot webber and hoppers in relation to climatic factors and
- To standardize the use of newer and safer molecules for their management

2. REVIEW OF LITERATURE

Mango (*Mangifera indica* L) is popular and economically important crop and it is commercially cultivated nearly 87 countries (Tharanathan *et al*., 2006). It grows equally in tropics and sub-tropics. The fruits are utilized at all stages of development *i.e*., from immature stage to mature stage and during this period fruits are attacked by several insect-pests (Kumar *et al*., 2005). Many defoliators and sucking pests cause great loss to the mango production.

Mango shoot webber, *Orthaga euadrusalis* Walker and *Orthaga exvinacea* Hampson, (Lepidoptera: Pyralidae) are major pests responsible for low productivity. The extent of damage caused by this pest under favourable conditions was estimated as 35 per cent (Tandon and Srivastava, 1982). The heavily infested tree gives a burnt look and severe infestation results in complete failure of flowering (Verghese, 1998). *O. exvinacea*, was considered as one of the minor pests of mango but since last few years, it has attained the status of a major pest of mango in Kerala (Lakshmi *et al*., 2011; Rafeeque and Ranjini, 2011).

It is widely distributed in different agro-climatic zones of India and has gained the status of serious pest in Uttar Pradesh, Uttaranchal and Andhra Pradesh (Singh *et al*., 2006). The mango shoot webber is a major pest in intensively cropped areas of Andhra Pradesh and heavy infestation by this pest affects the flower as well as the growth of new flush (Kavita *et al*., 2005).

Mango hoppers are the dreadful, most serious and widespread monophagous pests of mango, throughout India. They cause heavy damage during flowering season resulting in 25-60 per cent yield loss (Patil *et al*., 1988). *Amritodus atkinsoni* (Leth.), *Amritodus brevistylus* (Viraktamath), *Idioscopus nitidulus* (Walker), *Idioscopus clypealis* (Leth.) and *Idioscopus nagpurensis* (Pruthi) are the major and economically important species. *Amrasca splendens* (Ghauri) is also associated with mango as a pest (Viraktamath, 1989), is also prevalent in different mango growing belts *viz*., Karnataka, Andhra Pradesh, Tamil Nadu, Maharashtra and Uttar Pradesh (Joshi and Kumar, 2012). Usually these hoppers were found colonized during both vegetative and reproductive phases of the mango crop. The hoppers were observed as the major problem during flowering, causing huge losses. Enormous nymphs and adult hoppers cluster on the panicle and suck sap during spring. The infested flowers shrivel, turn brown and ultimately fall off. The hoppers excreted honeydew that covered the panicle, leaves and fruits, that encouraged black sooty mold, *Meliola mangiferae* (Earle) which affected photosynthetic activity of leaves and market quality of fruits (Verghese and Jayanti, 1999).

The available literature on the population dynamics and management of mango shoot webber and hoppers are reviewed and presented under the following headings.

2.1 MANGO SHOOT WEBBER

2.1.1 Species Diversity and Distribution of Mango Shoot Webber

In India occurrence of mango shoot webber was documented from different parts of the country. This webber *O. exvinacea* was described by Ayyar in 1932. Singh (1979) documented the species *O. euadrusalis* occurrence at Pantnagar of Uttarakhand state. Srivastava and Verghese (1983) reported the occurrence of *O. euadrusalis* from Uttar Pradesh, whereas Shaw *et al*. (1996) reported the mango shoot webber *O. exvinacea* from Madhya Pradesh. *O. exvinacea* incidence was recorded at Bhubaneshwar in Orissa (Dash and Panda, 1997). Singh *et al*. (2006) reported that the pest is widely distributed in different agro-climatic zones of India and has gained the status of serious pest in Uttar Pradesh, Uttaranchal and Andhra Pradesh. Many other workers have reported the occurrence of the pest from different parts of India (Kavita *et al*., 2005; Kannan and Rao, 2006; Rafeeque and Ranjini, 2011; Singh and Verma, 2013).

2.1.2 Population Dynamics of mango Shoot Webber

Ayyar (1932) described the caterpillar of the mango shoot webber, *O. exvinacea* as a slender, pale green coloured, which occasionally becomes serious resulting in numerous conspicuous webbed and dry top shoots, preventing flower formation in many cases.

According to Cherian and Ananthanarayanan (1943) the incidence of mango shoot webber *O. exvinacea* was comparatively serious from February to October but was sparse during other periods. Sengupta and Behura (1957) reported that the shoot webber caused serious damage during August to March in Orissa.

Singh (1979) reported peak activity of *O. euadrusalis* in September to October. Hibernated larvae pupated in the silken cocoon in ground at the end of March and adults emergence was in April. First generation of the insect started in the last week of April and four to five generations were recorded at Pantnagar from May to November.

According to Srivastava and Verghese (1983), the webber *O. euadrusalis* infestation started from June and continued up to December with five generations in a year at Uttar Pradesh. David and Kumaraswami (1988) documented the shoot webber activity during February to October in Tamil Nadu. Dash and Panda (1997) observed peak incidence of mango shoot webber *O. exvinacea* from February to April at Bhubaneswar in Orissa though they observed that the pest was breeding throughout the year.

Babu *et al*. (2001) recorded shoot webber infestation both during vegetative and reproductive phases of the crop and he reported that the shoot webber first appeared during June and continued up to January, but the peak incidence was observed during September to November.

The flower webber became serious during flowering period in the fruit growing areas of Cuddapah and Chittoor districts of Andhra Pradesh. The flowers in the inflorescence were webbed together by the larvae and inside this silk lined gallery it remained and fed on flowers (Vijayabhaskar and Purushotham, 1999).

The caterpillars loosely webbed several leaves of a shoot together and within the web by defoliating. After feeding, it remained in dry bits of leaves and excreta. When the whole tree was attacked, it gave a completely burnt up appearance. The infestation range varied between 25 to 100 per cent on trees. The pest within a short period of time, gained a major problem status (Srivastava and Verghese, 1983; Srivastava, 1997). Mango shoot webber, *O. exvinacea* is an important pest of mango and influence the yield indirectly. Varying incidence of shoot webber was seen in the mango orchards of S.V. Agriculture College on different varieties (Kannan and Rao, 2006).

Kannan and Rao (2006) studied the seasonal incidence in Andhra Pradesh. They observed the occurrence of *O. exvinacea* throughout the year, except during the month of February to May *i. e.,* flowering to fruit maturity stages. They observed the peak incidence of webber during the first (I) fortnight (FN) of November about 19.4 webs tree^{-1}. A gradual increase in the webber population was observed from the I FN of July to I FN of November.

Singh and Verma (2013) studied the seasonal activity of shoot webber *O. exvinacea* at Fruit Research Station (FRS), Entkhedi. They observed the incidence of pest during the month of June and that the webber remained active up to the December, and after that population declined suddenly. Further, they reported that most active period was September to December with mean infestation of 20.00 to 25.00 webs tree^{-1}.

Incidence of shoot webber started in the month of June and that continued up to December. Peak incidence was recorded during the month of September at Koduru, Andhra Pradesh (Reddy, 2013).

Sinha and Sinha (1961) reported a new pyralid pest *Spectrotrota sordidalis* Hampson on mango in Bihar, feeding on shoots and young leaves. Numerous webbed up and dry shoots of mango were observed in the months of November and December. Verghese and Jayanthi (1999) recorded six different species feeding on mango inflorescence. Among these *Eucrostus* sp. (Geometridae), *Argyroploce aprobola* Meyrick (Eucosmidae) and *Euproctis fraterna* (Moore) (Lymantriidae) were found to be serious during December to March in Andhra Pradesh and Karnataka.

Babu *et al*. (2001) reported that blossom webber, *Eublemma versicolor* Walker, was active during the flowering season. The incidence started during second FN of December and gradually increased till the second FN of January. From the first FN of February onwards, the pest incidence started declining with the cessation of flowering period.

2.1.3 Effect of Weather Parameters on Incidence of Shoot Webber

Reddy (2013) reported that, maximum temperature had negative correlation with the webber activity, whereas rainfall and relative humidity showed the positive correlation.

Kannan and Rao (2006) studied the population dynamics of shoot webber in relation to abiotic factors at Tirupati, Andhra Pradesh. Their studies on correlation between webber incidence and weather parameters showed positive relationship with minimum temperature, relative humidity and rainfall and negative correlation with the maximum temperature.

Singh and Verma (2013) studied the correlation of shoot webber and weather parameters at Bhopal in Madhya Pradesh that there was no significant relation with weather parameters *viz*., maximum temperature, minimum temperature, relative humidity and rainfall had no direct influence on the activity of the pest.

2.1.4 Screening of Mango Cultivars Against Shoot Webber Attack

Srivastava and Verghese (1983) reported that old orchards with less space between the tree canopies (more shady conditions) harboured more insects than open orchards with average webs per tree were 194.20 and 40.75, respectively. A study on the direction of infestation revealed that southern side of the tree had maximum webber infestation.

Abbas and Sharma (1997) revealed that the maximum number of webs (24.25) was in the upper region, followed by middle region (7.75) and lower region (0.4) of the trees in the variety Dashehari. Maximum number of webs found located in South direction in cultivars Dashehari and Mallika, followed by West, East and North directions. In cultivar Chausa, maximum number of webs was found in South direction, followed by East, West and North. Higher shoot webber incidence was found in trees located in the centre of a block than those located at the periphery. The congested mango orchards had higher shoot webber incidence than those having wider spacing.

Srivastava and Verghese (1983) reported that the mango cultivar Dashehari had an infestation of 66.50 to 468.20 webs tree^{-1}, whereas Chausa had 5.97 to 114.50 webs tree^{-1}. The number of leaves webbed by a caterpillar ranged from 3 to 48, and usually one to nine caterpillars were found in each web.

Shaw *et al.* (1996) revealed that the shoot webber *O. exvinacea* incidence was more in Kishnabhog, Langra, Neelam and Dashehari with 685.50, 333.25, 236.37 and 149.25 webbed leaves tree^{-1}, respectively. No leaf was found infested with webber in the cultivar Bombay Green and hence it was considered to be the most resistant variety. Less incidence of shoot webber was observed in varieties like Aamin (4.06), Dilpasand (4.62) and Amrapalli (7.12).

Reddy (2000) reported that among thirteen mango cultivars selected for the screening and found that Neelum, Swarnajahangir, Bangalora and Panchadarakalasa × Willard were highly susceptible for the shoot webber attack.

Kannan and Rao (2006) screened eight varieties of mango in Andhra Pradesh. Their results revealed that variety Bangalora was severely affected by the shoot webber caterpillars with 29.47 webs tree^{-1}, 22.55 leaves web^{-1} and 8.35 larvae web^{-1}. Variety Neelum showed less infestation with 7.80 webs tree^{-1}, 5.82 leaves web^{-1} and 1.92 larvae web^{-1}. The remaining varieties Neeleshan, Cherakurasam, Mulgoa, Rumani, Baneshan and Swarnajahangir were moderately infested.

Singh *et al.* (2006) reported that the variety Dasheri was the most susceptible for webber attack. Further they observed that Mallika cultivar was less affected whereas Amrapalli was free from infestation.

Lakshmi *et al.* (2011) studied the varietal preference of mango shoot webber in Andhra Pradesh. Results revealed that AU Rumani was least preferred by the pest with 25 webs tree^{-1} followed by Peddarasam with 31.33 webs tree^{-1}. Suvarnarekha was highly preferred by the pest recording 93 webs tree^{-1}.

Singh and Verma (2013) screened the popular cultivars of mango of North India. Studies indicated that six varieties of mango *viz*., Chinnarasam, Bombay Green, Malda, Piddarasam, Sindhuri and Alphanso were the least susceptible with minimum infestation range 0.0 to 1.25 webs tree^{-1}. Varieties like Gulab Khas, Suvarna Rekha, Mulgoa, Dasheri, Hapus and Fajali were moderately infested. Most susceptible varieties were Langhra, Temuria, Dahiyar and Mango Glass.

2.1.5 Management of Mango Shoot Webber

Singh (1998) reported the efficacy of quinalphos 25 EC and multineem 0.4 per cent was found effective and superior to other treatments to manage the pest. *Bacillus thuringensis* (4 ml L^{-1}) also found effective in managing the shoot webber caterpillar.

Singh and Verma (2013) carried out the management studies on mango shoot webber at Entkhendi in Bhopal. All the selected treatments showed superior efficacy over the control trees. They found diflubenzuran 0.01 per cent followed by triazophos 0.06 per cent, chlorpyriphos 0.04 per cent, indoxacarb 0.01 per cent, imidacloprid 0.005 per cent were in order to show their efficacy against shoot webber. They also suggested the mechanical removal of webs after treatment gives better result.

Removal of webbed up leaves with larva and pupa, spraying of carbaryl 50 WP at the rate of 0.1 per cent and encouraging the activity of predator carabid beetle *Parena lacticincta*, reduviid *Oecama* sp. is recommended for managing the pest (TNAU, 2014).

ICAR (2014) suggested the management practice for controlling the mango shoot webber. Pruning of infested shoots and burning them, Spray of lambdacyhalothrin 5 EC (2 ml L^{-1} of water) and if pest persist still second spray can be given with lambdacyhalothrin 5 EC or quinalphos 25 EC (1.25 ml L^{-1} of water).

2.2 MANGO HOPPERS

2.2.1 Species Diversity of Mango Hoppers

In India, three species of mango hoppers, belonging to the genus *Idiocerus* (Cicadellidae: Hemiptera) were described by Lethierry (1889) as *Idiocerus atkinsoni* Leth., *Idiocerus nitidulus* Leth. and *Idiocerus clypealis* Leth. were first recorded from Saharanpur (Uttar Pradesh, India) and described by Lethierry (1889) as *Idiocerus atkinsoni*, *Idiocerus clypealis* and *Idiocerus niveosparsus*. Similarly, Distant (1908) also reported this hopper, while Baker (1915) erected a new genus *Idioscopus* and placed *clypealis* under this genus. Later, Maldonada-Copriles (1964) transferred *atkinsoni* and *niveosparsus* also under *Idioscopus. I. clypealis* was more injurious towards South than *I. nitidulus* which was dominant towards North. *A. atkinsoni* was abundant only during summer and monsoon seasons when other two species were practically absent (Wagle, 1934). The generic names of all the three species were subsequently changed to *Amritodus*

(*Idiocerus*) *atkinsoni* (Leth.), *Idioscopus* (*Idiocerus*) *nitidulus* (Leth.) and *Idioscopus* (*Idiocerus*) *clypealis* (Leth.) by Anufriev (1970). All the three species of mango hoppers were reported from Konkan area.

Ghauri (1967) described two more species of cicadellid hoppers, *A. splendens* from India and *Meganeura reticulata* Ghauri from Malaysia. Similarly, Viraktamath and Murphy (1980) found two more species, *I. nigroclypealis* and *Idioscopus clarosignatus* on mango in Singapore. Lastly, Viraktamath and Viraktamath (1985) reported two new species of mango hoppers namely *Busoniominus manjunathi* and *Idioscopus jayshriae* breeding on mango in Karnataka.

Studies in Philippines revealed that *I. nitidulus* and *I. clypealis* were present on mango trees throughout the year feeding on foliage. These were active only during the flowering period when they bred (Glass *et al.*, 1966). Das *et al.* (1969) reported the occurrence of a new species, *A. splendens* from Kerala.

I. clypealis was dominant in Konkan and Karnataka (Uppal and Wagle, 1944). Gangolly *et al.* (1957) reported the occurrence of *A. atkinsoni, I. nitidulus* and *I. clypealis* all over India, however *I. nitidulus* was absent in Punjab. Heavy attack of mango hoppers *A. atkinsoni* and *I. clypealis* was recorded in Punjab during 1970-71 (Bindra *et al.*, 1971).

2.2.2 Distribution of Mango Hoppers

Mango hoppers, *I. clypealis*, apart from India, have also been reported from Pakistan, Bangladesh, Taiwan, Burma (Myanmar), Sri Lanka and the Philippines (Baker, 1915; Kato, 1926; Jepson, 1935; Palo and Grecia, 1935; Alam-Zahurul, 1962; Ghauri, 1967). Vanhall (1924) recorded *I. niveosparsus* as a pest on mango in Indonesia. The two species, *I. clypealis* and *I. niveosparsus* were reported causing damage to mango orchards in Formosa (Kayashima, 1934).

Wide distribution of *A. atkinsoni* and *I. clypealis* was reported in Bihar (Sen and Prashad, 1954) and in North West India (Chopra, 1926; Rehman, 1939; Pruthi and Batra, 1960). *A. atkinsoni* and *I. clypealis* were more serious in Punjab (Atwal, 1963). Tandon and Lal (1979) found *I. clypealis* more severe in Andhra Pradesh, Bihar, Gujarat, Haryana, Himachal Pradesh, Karnataka, Maharashtra, Orissa, Punjab, Rajasthan, Tamil Nadu, Uttar Pradesh and West Bengal.

In Gujarat, besides the above reports, Patel *et al.* (1997) and Jhala *et al.* (1989) found abundance of *A. atkinsoni* in old mango orchards. Shah *et al.* (1989) indicated presence of *A. atkinsoni* and *I. clypealis* in serious form in South Gujarat. Patel *et al.* (1994) and Kumar and Bhatt (1999) reported abundance of *A. atkinsoni* in the South Gujarat.

2.2.3 Population Dynamics of Mango Hoppers

Investigation on seasonal incidence and the nature of damage of different species of mango hoppers (*A. atkinsoni, I. nitidulus* and *I. clypealis*) was conducted in Dharwad, Karnataka, during 1975-76. Adults of all these species were found on mango throughout the year. *A. atkinsoni, I. nitidulus* were found to breed both on tender leaves and flowers. *I. clypealis* was observed breeding only on flowers and thus caused maximum injury to flowers. Population of *A. atkinsoni*, *I. nitidulus* was greater in the non flowering season, compared to *I. clypealis*. During the flowering season the population of all the three species was found to increase considerably with *I. clypealis* becoming dominant (Hiremath, 1978).

Verghese and Rao (1987) observed the population of this pest at post bloom stage. Similarly, higher population build-up and rapid multiplication of mango hoppers, *A. atkinsoni* and *Idioscopus* sp. have been reported during flower initiation and full-bloom stage of the crop (Srivastava, 1998; Babu *et al.,* 2001 ;Kumar *et al.,* 2002).

Jhala *et al.* (1988) observed the abundance of the population of *A. atkinsoni* throughout the year with greater population in old orchards, compared to new and neglected orchards due to the different ecological conditions prevailing.

Kangane and Patil (1989) studied seasonal incidence of *A. splendens* on mango during 1985-86 at Dapoli, Maharashtra. Incidence was not observed up to II FN of September 1985 but later it increased gradually, reaching peak in January. Thereafter, there was a gradual decline of population from February to March 1986. Peak population of *I. nitidulus* and *A. atkinsoni* was recorded in January and thereafter slow decline was observed towards July in Tamil Nadu (Venkatesan, 1990). *I. clypealis* was mostly distributed on leaves and panicle and rarely on tree trunk (Abbas *et al.*, 1991).

Jilani *et al.* (1991) observed the abundance of *A. atkinsoni*, *I. nitidulus* and *I. clypealis* on mango in Bangladesh from June to late September. Among them *A. atkinsoni* was the most dominant, comprising 70 to 80 per cent while *I. clypealis* was the least abundant.

Dalvi *et al.* (1992) recorded 20 species of hoppers on mango in Konkan region of which *I. nitidulus* was the most predominant (40.71 per cent), followed by *A. atkinsoni* (30.38 per cent), *I. nagpurensis* (23.06 per cent), *A. splendens* (4.12 per cent) and *I. clypealis* (1.73 per cent). The population of each of the five species varied during different years or season and also locality. It was also observed that many species occurred on the same tree simultaneously but their intensity varied from locality to locality and season to season.

Dalvi and Dumbre (1994) studied seasonal incidence of mango hoppers at Dapoli, Maharashtra. The results showed that *A. atkinsoni* and *I. nitidulus* bred three times a year from June to July and October to November on the vegetative flush and from December to April on the panicle. *I. nagpurensis* bred only once a year during the flowering season from January to April. *A. splendens* bred exclusively on vegetative flush throughout the year.

Studies on the species composition and incidence of mango hoppers revealed the occurrence of *I. nagpurensis, I. nitidulus* and *A. atkinsoni* in Dharwad. Amongst these, *I. nitidulus* was the dominant species with as high as 225 and 104 hoppers per panicle during February–April in 1990 and 1991, respectively (Viraktamath *et al.*, 1994).

A fixed plot quantitative survey was made at the Central Institute of Horticulture for Northern Plains, Lucknow on the population of all three species of mango hoppers at fortnightly intervals. Results revealed that, during February and March, a moderate to high population of *I. clypealis* and a low (0.5 per cent) to moderate population of *I. nitidulus* was present on inflorescence and leaves. The population of *A. atkinsoni* was nil during these months (Abbas and Sharma, 1995).

Studies on the seasonal incidence of mango hoppers in Raichur, Karnataka from June 1988 to May 1990 indicated the occurrence of three species of *Idiocerinae* namely, *I. nagpurensis, I. nitidulus* and *A. atkinsoni* together, throughout the study period. Peak population of *I. nagpurensis* on Pairi occurred in July-August and then it declined gradually in September-October. There was a second peak in November but population considerably declined in December, reaching the lowest in February-March. In contrast, *I. nitidulus* was considerably low from June to December but there was a significant increase in population in January-March. Compared to these species, *A. atkinsoni* was very low with a minor peak in September-November and this species was found mainly on the trunk. From December to May, *I. nagpurensis* and *A. atkinsoni* constituted 24.7 and 2.8 per cent, respectively, while *I. nitidulus* constituted 72.5 per cent, in both protected and unprotected conditions. Though *I. nagpurensis* was dominant from June to December, this species was gradually replaced by *I. nitidulus* from

January attaining complete dominance over the other two species in February-March (Viraktamath *et al.,* 1996).

Kudagamage *et al.* (2001) studied population dynamics of three species of mango hoppers, *A. brevistylus, I. nitidulus* and *I. clypealis* at Kundasale and Gannoruwa in the mid country region of Sri Lanka over three years. The population of *I. nitidulus* and *A. brevistylus* began to increase in February with a peak in March-April in both the locations. The peak population of *I. clypealis* was observed in March and September at Gannoruwa, April and October in Kundasale. These populations peaks coincided with the occurrence of major or minor flowering seasons of mango. In case of *A. brevistylus* another peak was also observed in June. This species bred on vegetative shoots and the population increase coincided with the occurrence of vegetative flush.

Babu *et al.* (2002) studied the seasonal incidence of *A. atkinsoni* at Tirupati, Andhra Pradesh during 1989-99. Mango hoppers were found colonized during both vegetative and reproduction phases of the crop. Peak incidence was observed during full bloom stage of the crop, after which they migrated to cracks and crevices of the tree trunks.

2.2.4 Effect of Weather Parameters on Incidence of Mango Hoppers

Sood *et al.* (1971) reported from Gwalior, Madhya Pradesh that, the population of *I. clypealis* fluctuated in different months due to variation in environment. The mean catch was the highest in the month of August when the mean minimum and maximum temperatures ranged from 26 and 30 ^{0}C, respectively. The catch was the lowest during December and January when very low temperature prevailed. Further, correlation studies revealed that the highest population was found during the month of August when mean monthly maximum and minimum temperature were 26.2 ^{0}C and 30.1 ^{0}C, respectively with a relative humidity of 63 per cent.

Shekh *et al*. (1993) predicted outbreaks of mango hoppers when the minimum temperature and vapour pressure ranged between 20- 25 °C and 16-25 Hg. Respectively. Patel *et al*. (1994) indicated a positive correlation of minimum temperature and vapour pressure with mango hopper, *A. atkinsoni* population.

Patel *et al.* (1994) reported that *A. atkinsoni* was an important and regularly occurring insect pest of mango in Gujarat. It remained active throughout the year in the cracks and crevices of the mango trunk. However, maximum hoppers population was found in the II FN of September during 1988, I FN of May during 1989 and 1990 and II FN of March during 1991. The population on twigs was found only during the period when young leaves and panicles were available. The effect of various meteorological factors on population build up of *A. atkinsoni* revealed that only minimum temperature (r2=0.64) and vapour pressure (r1=0.73) showed a positive correlation.

Butani (1979) reported that mango hoppers start egg laying around end of January or early February and continues till March. He further revealed that in North India, there are two distinct generations of mango hopper in a year; spring generation in February to April and summer generation during June to August. Similarly, Dwivedi *et al.* (2003) found peak intensity (87.9/10 leaves) of mango hoppers in June. Tandon *et al.* (1983) found peak population of *I. clypealis* during March-April. The population was the smallest during December-January. They further stated that maximum and minimum temperatures and relative humidity contributed 89 percent of the population variation. Similarly, Kudagamage *et al.* (2001) observed peak population of *I. niveosparsus* and *A. brevistylus* in March-April in Sri Lanka.

Rajamanickam *et al.* (1997) studied seasonal abundance and influence of weather parameters on mango hoppers (*I. clypealis*) and found hoppers population to be high in the initial period of summer. A positive correlation of mango hoppers incidence with high relative humidity and maximum temperature and negative correlation with hot humid climate was also reported.

Gan and Qing (2000) observed that high temperature (18-28 °C) and humidity (more than 95 per cent) favoured multiplication of mango hopper (Cicadellidae). Pandey *et al.* (2003) observed the highest hopper population with higher temperature (more than 28 °C). They further stated that fortnightly rainfalls of more than 100 mm. had washing effect although the temperatures were optimum. The total contribution of abiotic factors ranged between 36 and 61 per cent.

Talpur *et al.* (2002) reported that population density of mango hopper had positive correlation with inflorescence phenology in all the mango cultivars; however population of hoppers had negative correlation with fruit development.

Pezhman (2005) observed maximum and minimum population densities in April-May and January- February in Siahoo and March-April and December-January in Minab, respectively. In both the regions, the temperature had positive while relative humidity had negative relation on the incidence of hoppers.

Varshneya and Rana (2008) recorded first appearance of hoppers (0.12 and 0.16) on the branches of mango trees in February, which was correlated with increase in maximum (23.89^{o}C and 24.29 ^{o}C) and minimum temperature (11.46 ^{o}C and 11.88 ^{o}C) and decrease in relative humidity (88.15 per cent and 86.85 per cent). Peak hoppers population (5.88 and 6.46) was recorded in May at the temperature range of 40.3 ^{o}C to 40.8 ^{o}C maximum and 27.2 ^{o}C to 27.6 ^{o}C as minimum temperature and relative humidity of 55.8 per cent to 55.0 per cent. Maximum and minimum temperatures positively affected the hoppers population, whereas, relative humidity had negative effect, but rainfall showed no significant effect, as it was fluctuating.

Lakshmi *et al.* (2010) studied seasonal incidence and influence of abiotic factors on the population of mango hoppers in panicles of seven varieties of mango during 2005-2010 and weather based pest forewarning models were developed using regression models. The seasonal incidence of mango hoppers, *Idioscopus* sp. was observed in the panicles during 49th standard week with the peak incidence during 8th and 9th standard weeks and the pest disappeared by 13th standard week. Correlation coefficient studies revealed the significant negative influence of relative humidity and positive influence of maximum temperature, evaporation and wind velocity speed on the population of mango hoppers.

Studies on population dynamics were conducted in five areas of Jammu region from April 2001 to March 2002. Hoppers population was at peak during April-May and the lowest during December-January. *I. clypealis* was found abundant and caused great damage to mango crop (Sharma and Sharma, 2011). Temperature had significant and positive correlation.

Debnath *et al.* (2013) studied population dynamics of *A. atkinsoni* on the basis of seasonal abundance, site of gathering on mango cultivar Langra during rabi season. Highest number of hoppers was recorded during May on primary branch followed by leaves and inflorescence. The mango hoppers had significant negative correlation with morning relative humidity (r=-0.445) and evening relative humidity (r=-0.118).

Saeed *et al.* (2013) conducted study to find out the seasonal incidence of mango hoppers. The peak population of mango hoppers was recorded at 31.96 ^{o}C from April to May. Correlation analysis revealed a strong positive correlation between temperature and the mean number of *I. clypealis* adults. Population peaks of *I. clypealis* were recorded at temperatures > 30 ^{o}C, while at lower temperatures relatively low numbers of adults were recorded.

Seasonal migratory behaviour of mango hoppers (*Idioscopus* sp.) from main tree trunk to flowering panicles in relation to host plant flowering phenology was studied. A significant positive correlation (r=0.65) between the hoppers present on the flower panicle with the availability of inflorescence on the tree and a significant negative correlation (r=-0.24) with the hoppers present on the main tree trunk strongly suggested the flowering phenomenon as a major factor triggering the niche shift in *Idioscopus* sp. The local migration of hoppers with the changing host plant phenology was explained by linear (y=0.078x-0.066; R_2=0.48) and exponential (y=0.0387e0.0033x; R_2=0.62) models (Gundappa *et al.*, 2014).

2.2.5 Screening of Mango Cultivars Against Mango Hoppers Attack

Nachiappan and Bhaskaran (1984) on the basis of natural population during flowering season on inflorescence categorized Baneshan, Chinarasam, Banglora and Khadar as resistant and Padiri, Neelam, Mulgoa, Peter and Sindura as highly susceptible varieties to hopper infestation. Similarly, Khaire *et al*. (1987) found that Rajmana and Vanraj were less susceptible to *I. clypealis*. Srivastava (1995) observed Amrapalli, Dashehari and Neelam as highly susceptible and Banglora as highly resistant to mango hoppers on the basis of natural incidence of the pest. They further stated that in case of outbreak of hopper, Alphonso suffered the most, leading to lot of economic loss. Similarly, Kumar *et al*. (2002) evaluated various mango hybrids on the basis of natural infestation of hopper in field conditions and categorized Arka Punit, Mehmud Bahar and Neleshan-Gujarat as less susceptible varieties where as Sonpari was found highly susceptible to mango hoppers. Talpur and Khuhro (2003) in Pakistan indicated higher incidence of mango hopper specie A. *atkinsoni*, *I. niveosparsus*, *I. clypealis* on Langra and Sarolee varieties. They further stated Neelam, Zafran and Dashehari harboured less numbers of mango hopper per shoot.

Viraktamath *et al.* (1996) studied the seasonal incidence of *I. nagpurensis*, *I. nitidulus*, *A. atkinsoni* and their succession in relation to varietal variability in eight cultivars (Alphonso, Piari, Mulgoa, Khader, Neelum, Baneshan, Allempur Baneshan, Panchadhara Kalasa). All the eight varieties and six hybrids differed significantly in their susceptibility to hoppers in various months. When these varieties and hybrids were ranked based on the lowest to highest incidence of hoppers, Baneshan was ranked one among vareities followed by Khadar, Panchadhara Kalasa, Pairi, Alempur Baneshan, Alphonso, Mulgoa and Neelum. Among hybrids, Neelgoa ranked one followed by, Rumani, Swarna Jahangir, Mallika, Neeluddin and Neeleshan. Khaire *et al.* (1997) studied the relative susceptibility of mango varieties to mango hoppers during the year 1993-94 and 1995-96. Out of 39 varieties screened none of them were completely free from the incidence of hoppers. The lowest population density of hoppers was recorded on variety Rajmanu (1.5 hoppers panicle^{-1}), while the highest number was recorded on the variety Swthen (60.50 hoppers panicle^{-1}).

Talpur *et al.* (2002) studied the relative population of mango hoppers species (*A. atkinsoni, I. nitidulus* and *I. clypealis*) on different cultivars of mango at Mir Ghulam Rasool Talpur Fruit Farm, Sindh, Pakistan during 2000. The cultivars screened for pest infestation were Sindhri, Langra, Sarolee, Dashehari, Swarnarika, Gulabkhas, Neelum, Zafran and Desi (indigenous). The Langra and Sarolee were relatively susceptible, showing mean population of 5.65 and 4.91 individuals per shoot. Neelum (1.40), Zafran (1.72) and Dashehari (2.10) harboured less numbers of mango hoppers shoot^{-1}. Reddy and Dinesh (2005) evaluated ten exotic mango varieties. Based on the pooled data of two years on the relative susceptibility for *I. nitidulus* five were found as susceptible, four moderately susceptible and one as the least susceptible. The susceptibility of five mango cultivars (Meghlanthan, Amrapali, Himasagar, Langra and Fazli) to mango hoppers in the new alluvial zone (Kalyani, Nadia) of West Bengal was evaluated from July 2003 to June 2004. Meghlanthan and Himsagar harboured the highest number of hoppers, while moderate population was recorded for Langra and Fazli (Hati *et al.*, 2006). Singh and Singh (2007) studied the varietal influence of 23 varieties on incidence of mango hoppers. based on the study Bangalora and Amebelaby were resistant, Gillas, Gulabkhas, Chandra Karan, Mallika and Gourjeet were rated as tolerant and Dashehari, Nisarpasand, Zardalu, Ratul and Neelum as highly susceptible. Thangam *et al.* (2013) evaluated 392 mango accessions among which 32 accessions were identified as less preferred which in spite of conducive breeding and feeding niches for hoppers showed zero hoppers population in both the years. For the moderate to highly susceptible accessions correlation analysis revealed positive significant correlation between the mean percentage shooting and mean hoppers population, confirming their susceptibility.

2.2.6 Management of Mango Hoppers

2.2.6.1 Conventional Insecticides

Diazinon (0.02 per cent), DDT (0.1 per cent) and endrin (0.02 per cent) have been found effective against various mango hoppers (Patel and Handi, 1953; Rao, 1953; Sen and Prashad, 1954; Gangolly *et al.*, 1967; Pruthi and Batra, 1960). Chari *et al.* (1969) reported that 0.02 per cent parathion, followed by 0.1 per cent endosulfan, and carbaryl to be more effective under North Indian climate. Similarly, Singh *et al.* (1974) reported 0.1 per cent carbaryl, 0.1 per cent fenitrothion and 0.03 per cent dimethoate to be better than nine other treatments in U.P. Jagtap *et al.* (1976) reported the use of 0.1 per cent carbaryl with sulphur, 0.02 per cent methyl demeton, 0.1 per cent orthene, 0.02 per cent dicrotophos and monocrotophos for the control of hoppers in Maharashtra.

Gandhali *et al.* (1975) found 0.03 per cent dimethoate, 0.03 per cent fenitrothion, 0.1 per cent mixture of carbaryl and sulphur (1:1) or 0.2 per cent of mixture of DDT and sulphur as effective chemicals when applied four times at the interval of 21 days starting from pre-flowering. Similarly, carbaryl 0.1 per cent has been found most effective against *A. atkinsoni* (Singh *et al.*, 1974; Sarma *et al.*, 1981; Shah and Valand, 1981; Patel *et al.*, 1987; Pingle and Patil, 1988).

Shah *et al.* (1979) in Gujarat recommended 0.03 per cent monocrotophos, 0.075 per cent endosulfan and 0.2 per cent carbaryl quite effective in controlling hopper population. Prashad and Bagle (1979) also recommended 0.2 per cent carbaryl, 0.05 per cent monocrotophos, 0.05 per cent phenthoate and 0.05 per cent phosalone to control mango hoppers. Tandon and Lal (1979) screened 19 insecticides against *I. cypealis* in Uttar Pradesh and found 0.15 per cent carbaryl, 0.04 per cent monocrotophos, 0.05 per cent phosphamidon and 0.05 per cent methyl parathion to be the most effective.

Yazdani and Mehto (1980) found dimethoate 0.5 kg ha^{-1} more efficacious than methyl parathion against *A. atkinsoni* this was later confirmed by Dakshinamurthy (1984) who found the lowest nymph population of *A. atkinsoni* with 0.03 per cent dimethoate. Nachiappan (1982) found 0.035 per cent endosulfan most effective followed by 0.08 per cent phosphamidon and 0.1 per cent carbaryl. They further observed that endosulfan resulted in maximum retention of fruits and hence, gave a better yield.

Kumar *et al.* (1985) found methyl-o-demeton causing rapid knock down of *A. atkinsoni* in laboratory as well as field trials. Abbas *et al.* (1987) found 0.2 per cent carbaryl, 0.063 per cent quinalphos, 0.054 per cent monocrotophos, 0.04 per cent chlorpyriphos, 0.075 per cent fenitrothion and 0.06 per cent dimethoate were effective insecticides against *I. nitidulus* and *I. clypealis*, whereas, Srivastava *et al*. (1987) reported the efficacy of 0.063 per cent quinalphos, 0.2 per cent carbaryl and 0.04 per cent chlorpyriphos against another mango hopper species *A. atkinsoni*.

Srivastava and Verghese (1989) recommended 0.04 per cent monocrotophos and 0.05 per cent Voltan for the control of *I. clypealis.* They further found phosaxin (Voltan) least toxic to the parasite, *Tetrastichus* spp. of the hoppers. Similar results were reported by Mishra and Choudhary (1996) against *I. clypealis*. Sarma *et al.* (1981) obtained cent per cent knock down of *Idioscopus* spp. on mango using BPMC {2-(1-methyl propyl) phenyl methyl carbamate} or isoprocarb (MIPC).

2.2.6.2 Synthetic Pyrethroids

Shukla and Prasad (1984) indicated effectiveness of permethrin, cypermethrin and fenvalerate at 0.02 per cent concentration each for the control of *I. clypealis* on mango. Datar (1985) found similar result of fenvalerate at lower dose (0.01 per cent) to control *A. atkinsoni*. Pingle and Patil (1988) found that 0.01 per cent permethrin reduced the population of both the species. Singh (1989) found 0.005 per cent fenvalerate and cypermethrin and 0.002 per cent decamethrin (deltamethrin) to be very effective against *A. atkinsoni*, while Shah *et al*. (1989) showed that permethrin and fenvalerate at 20 ppm and cypermethrin at 10 ppm were very effective against this pest species for over two months. Similar findings were reported by Srivastava and Verghese (1989) and Singh and Chopra (1997). Deltamethrin 0.01 per cent was the least toxic to the parasite, *Tetrastichus* sp. on hoppers (Srivastava and Verghese, 1989).

Ragini *et al.* (2001) indicated effectiveness of fluvalinate (Mavrik) at 0.016 and 0.02 per cent concentrations to bring down the population of mango hoppers below the economic threshold level. Verghese (2000) found effectiveness of lambdacyhalothrin at 0.5 ml L^{-1} as effective as monocrotophos (0.05 per cent) against *I. niveosparsus.* These results were later on confirmed by Pusphalatha *et al.* (2002) on *A. atkinsoni*. Synthetic pyrethroids are broad spectrum insecticides having quick knock down effect however there are reports that their repeated applications results in resurgence of sucking pests in particular. Repeated applications of same insecticides resulted in resurgence of mango hopper in south Gujarat (Kumar and Bhatt, 2002). They further found toxicity on *Menochilus sexmaculatus* and predatory spiders due to their repeated applications.

2.2.6.3 Biorational Insecticides

Large numbers of adult hoppers were found dead due to infection by the fungus, *V. lecanii* in mango orchard at Dharwad during October- December, 1991 (Virakthmath *et al*., 1994).

Kumar (2001) observed the natural incidence of *Verticillium lecanii* (*Lecanicillium muscarium*) which varied from zero to 5.79 per cent (II FN of October) at Dharwad.

Sahoo and Samanta (2006) evaluated different modules for the management of mango hoppers. A module consisting of nimbicidin (0.2 per cent) with three sprays recorded 5.44 hoppers per panicle, compared to untreated check (18.40 hoppers panicle^{-1}). The lowest mean population of hoppers (0.8 hoppers panicle^{-1}) was recorded with vertiguard (*V. lecanii*) + endosulfan (3.5g L^{-1} + 0.025 per cent) and the treatment vertiguard (3.5g L^{-1}) alone recorded mean population of 1.7 hoppers panicle^{-1}.

Daman (*Beauveria bassiana* Balsamo Vuillemin) (5g L^{-1}) recorded mean population of 5.2 hoppers panicle^{-1} as against 14.8 hoppers panicle^{1} in control (Singh, 2008). Visalakshy *et al.* (2010) observed an outbreak of entomopathogenic fungal infection of *Entomophthora* sp. causing about 87.88 per cent mortality of *I. nitidulus* adults during the off-season under field condition. Singh *et al.* (2010) found *V. lecanii* (1×10^{8} cfu g^{-1}) (2.37 hoppers panicle^{-1}) superior to Econeem (5.07 hoppers panicle^{-1}) but inferior to imidacloprid in reducing hoppers population.

An entomopathogenic fungus belonging to the genus *Hirsutella* sp. was found infecting the mango hoppers, *I. clypealis*, for the first time in India during September 2011. Choudhary *et al.* (2012) reported a natural control agent of mango hoppers during the off season had special significance because its outbreak depended upon its residual hibernating population.

2.2.6.4 IGR and Botanicals

The efficacy of buprofezin, an insect growth regulator was tested against *I. clypealis* in mango orchards, at five concentrations (*viz.,* 0.0125 per cent, 0.025 per cent, 0.0375 per cent, 0.05 per cent, 0.075 per cent). Buprofezin concentrations of 0.0375, 0.05 and 0.075 per cent proved satisfactory in reducing the pest populations after a week of treatment (Srivastava and Fasih, 1992). Srivastava and Haseeb (1992) evaluated four neem derivatives *viz.,* cake based (1 per cent), oil based (2 per cent), nemidin (0.25 per cent) and azadit (0.25 per cent) along with monocrotophos (0.054 per cent) against hoppers *I. nitidulus.* Neem was significantly superior to untreated control in bringing down the hoppers population.

Srivastava and Haseeb (1993) evaluated neem derivatives against mango hoppers. Of seven treatments, achook (0.5 per cent), neem guard (0.5 per cent), nemidin (0.25 per cent, 0.375 per cent), oil extract of neem (2 per cent, 3 per cent) and monocrotophos (0.054 per cent) consistently registered low population of hoppers and were significantly superior to other treatments. This was followed by neem guard (0.5 per cent) and oil based extract (3 per cent) of neem. Nemidin did not give satisfactory results. Achook (0.5 per cent) was inferior and at par with control.

Maximum numbers of dead hoppers (35.3 ± 9.94 hoppers 20 shoots^{-1}) due to fungal infection was found at the base of the shoots and minimum number (12.7 ± 5.99 20 leaves^{-1}) on the leaves. *I. nitidulus* constituted over 90 per cent of the total dead hoppers. No nymphal stages of the hoppers were found infected with the fungus (Viraktamath *et al.,* 1994). Two neem formulations (oil based concentrates) were developed and tested for efficacy against *A. atkinsoni* and *I. nitidulus.* The oil based concentrate (1 per cent) and the kernel based concentrate (0.2 per cent) caused 100 per cent and 66.6 per cent nymphal mortality of *I. nitidulus* in laboratory, respectively. The efficacy of the formulations was also determined in the field against *I. nitidulus.* While oil based concentrate killed nymphs in laboratory, the kernel based concentrate, did not show much promise (73.1 per cent). Both the formulations when tested for settling response in adults of *A. atkinsoni* at the same concentrations, only one fourth of adults settled on plants treated with formulations, compared to the control (Srivastava and Haseeb, 1993). The aqueous extract of neem kernel powder (2 per cent) was found quite effective in controlling the hoppers population in another study (Srivastava, 1995).

Azdirachtin (4.5 ppm) + monocrotophos (0.025 per cent) gave good control of hoppers for a FN. Same efforts were done to manage the mango hoppers at Central Horticulture Experiment Station, Ranchi. One spray of imidacloprid 0.025 per cent followed by NSKE 4 per cent recorded 0.8 and 1.0 hoppers per sweep, respectively (Verghese, 1997). Singh and Chopra (1998) evaluated two neem based insecticides *viz.,* margosa (amruth guard) and azadirachtin (0.3 per cent and 0.7 per cent) against mango hoppers *I. clypealis* during 1995 and 1996. During 1995, 15 days after spray, margosa @ 5 ml L^{-1} gave a mortality of 72 per cent which was on par with quinalphos and chlorpyriphos. During 1996, 15 days after spray, azadirachtin (0.7 per cent) gave 83 per cent mortality and was on par with conventional insecticides like monocrotophos and endosulfan (each at 0.05 per cent).

Kudagamage *et al.* (2001) recorded the lowest population in neem oil (3 per cent) treated trees and also found that sticky trap was more effective. Further, in another experiment, buprofezin (Applaud 10 per cent WP) was found effective against hoppers. Pasupathy (2001) reported that NSKE (5 per cent) and neem oil (3 per cent) reduced the hoppers population significantly. However, tulasi leaf extract was comparatively less effective. NSKE at 5 per cent recorded the lowest population of 0.4 hoppers $panicle^{-1}$.

Ray *et al.* (2011) used neem based pesticides. First and third spray were with NSKE (5 per cent) and second and fourth spray with azadirachtin (1500 ppm) and they recorded 10.35 hoppers $panicle^{-1}$ as against 61.60 $panicle^{-1}$ in untreated control.

Ghosh (2013) evaluated insect growth regulator (IGR) buprofezin 25 SC (buprostar), for control of mango hoppers (*A. atkinsoni* and *I. nitidulus*), in West Bengal. Imidacloprid 17.8 SL (0.0053 per cent) and profenophos 50 EC (0.075 per cent) were used as check. Imidacloprid (17.8 per cent SL) treatment resulted in the best suppression of hoppers population (91.89 per cent suppression) over untreated control, closely followed by profenophos 50 per cent EC (88.51 per cent suppression) and buprofezin 25 per cent SC (buprostar) (85.22 per cent suppression). Buprostar increased the natural enemies population from 3.85 to 7.83 and was similar to untreated control (4.26 to 7.06), indicating buprofezin 25 SC was safe to natural enemies. Imidacloprid 17.8 SL and profenophos 50 EC were moderate to highly toxic to natural enemies of mango. Buprostar (buprofezin) 25 SC @ 0.05 per cent gave more than 85 per cent control of mango hoppers and was safer to natural enemies of mango and had no adverse effect on mango leaves, flowers and fruits.

Saeed *et al.* (2013) conducted study to find out the attraction of mango hoppers, *I. clypealis* to sticky traps of different colors. Results indicated significant differences in the number of *I. clypealis* (adults) captured in different colored sticky traps. Yellow color was found most attractive with a capture of the highest number of adults (11.53 adults $trap^{-1}$). Pink and purple colors were less attractive.

3. MATERIALS AND METHODS

The present investigation on “Population dynamics and management of shoot webber and hoppers infesting mango using safer molecules” was carried out to study the population dynamics of mango shoot webber and hoppers in relation to climatic factors and to standardize the use of safer molecules for their management during 2014-16. Survey was conducted in the homesteads of Kalliyoor panchayath and the Instructional Farm, Vellayani. Evaluation of the efficacy of safer molecules was conducted in the Instructional Farm, Vellayani and College of Agriculture, Padanakkad, Kasargod.

The details of the experimental materials used, methods followed and the techniques adopted during the course of the investigation are described hereunder.

3.1 DOCUMENTATION OF MANGO SHOOT WEBBER AND HOPPERS

A preliminary survey was conducted to select the mango trees for fortnightly observations on target pests. Based on this 20 trees were selected from the homesteads of Kalliyoor panchayath (one tree homestead^{-1}) and 20 trees from the Instructional Farm, Vellayani during 2015-16. Incidence of shoot webber and leaf hoppers infesting mango was recorded. Pest specimens were preserved and later got identified by National Bureau for Agricultural Insect Resource, Bengaluru and the Centre for Insect Excellence, GKVK, Bengaluru.

3.2 POPULATION DYNAMICS OF MANGO SHOOT WEBBER AND HOPPERS

3.2.1 Scoring of Mango Shoot Webber Incidence

Mango shoot webber damage the foliage by making webs and feeding within. Hence, the number of webs in a tree and number of larvae in a web was taken for the study to indicate their incidence and infestation level. The sampling techniques are mentioned in detailed below.

3.2.1.1 Number of Webs Tree^{-1}

Mango shoot webber incidence was recorded for a period of one year from I FN of March 2015 to II FN of March 2016. Observations were recorded on the total webs in a individual tree by counting visually the number of webs formed in a tree. This was done by dividing the whole canopy of the tree into four quadrants according to four cardinal directions *i. e.,* East, West, North and South. The total number of webs per tree was arrived by adding the counts of the webs present in the four directions (Kannan and Rao, 2006; NICRA, 2012; Singh and Verma, 2013). This procedure was done for the 20 plants marked for observations in the Kalliyoor panchayath and in the Instructional Farm, Vellayani at regular fortnightly intervals.

3.2.1.1.1 Active Webs

Active webs are such webs where in, the webs consist of minimum one caterpillar actively feeding within. Webs without any caterpillar feeding within can be referred as inactive webs. These inactive webs are old, with dried, eaten up leaves with excreta of the caterpillars. Active webs could be confirmed by giving gentle shake to the webs harboring larvae.

3.2.1.1.2 Composite Webs

Normally the terminal leaves of the shoot are webbed up and fed by caterpillars of the shoot webber. In later stages as the caterpillar passes the third and fourth instar, it spreads to other shoots. It secretes silken thread and connects the leaves of three to four shoots nearby and makes it as composite web. It causes intensive damage to the mango tree by making composite webs.

3.2.1.2 Number of Larvae Webbing^{-1}

From each direction of the tree one web was selected for sampling, such that four webs were selected from each tree. Population of larvae in each web was counted. The mean of the larvae present in the four webs is represented as number of larvae web^{-1} (NICRA, 2012).

3.2.2 Reaction of Mango Varieties Against Shoot Webber Attack

Study was conducted in the instructional Farm to know the varietal influence on incidence and difference in the infestation level of shoot webber activity. Occurrence of shoot webber infestation in 10 mango varieties *viz*., Alphonso, Kalappadi, Himayudan, Mulgoa, Banganapally, Kundalatha, Vellari Varikka, Bangalora, Prior and Kottukonam was evaluated. The pest incidence was recorded as specified in 3.2.1.1 and 3.2.1.2. for a period of five months (October 2015 to February 2016). The damage levels in different mango varieties were categorized and ranked according to the grades given by Ketan (2012) as detailed in Table 1.

3.2.3 Scoring of Mango Hopper Incidence

Sampling for mango hoppers was done at the time of occurrence of these insects on tree. Since hoppers incidence is season bound they could be seen on inflorescence during the flowering season and on shoots during the vegetative growth. The sampling procedures for hoppers are mentioned below as number of hoppers panicle^{-1}, number of hoppers sweepnet^{-1} and number of hoppers shoot^{-1}.

3.2.3.1 Number of Hoppers Panicle^{-1}

The method followed to observe the population of hoppers on panicles was by bag trapping method (Verghese and Rao, 1987). Polythene bags of size 60 × 30 cm (Plate 1c) were used for the experiment. Cotton swab soaked in chloroform ($CHCl_3$) was kept in the covers as insect killing agent. Here also panicles were selected from each direction (East, West, North and South). The bags were emptied and the number of hoppers were counted from the each panicle. The mean of hoppers from the four panicles was referred as the sample of that particular tree and represented as number of leaf hoppers panicle^{-1}.

Table 1. Infestation Ratings of Mango Shoot Webber

Sl. No.	Category of susceptibility	Ratings	No. of webs / tree
1	Free (F) / Escape / Resistant (R)	0	—
2	Less susceptible (Low)	1	0-5
3	Moderately susceptible (Medium)	2	6-10
4	Highly susceptible (High)	3	>10

Table 2. Infestation Ranking of Mango Hoppers

Sl. No.	Category of susceptibility	Ranks	Number of leaf hoppers/ panicle or five sweep nets
1	Tolerant	I	0.00 to 5.00
2	Moderately tolerant	II	5.00 to 10
3	Susceptible	III	>10

3.2.3.2 Number of Hoppers Sweep Net^{-1}

Population of these hoppers was estimated by using standard insect collecting net. Four sweep nets were done across the zone of flight of hoppers after little disturbance (Plate 1d). One sweep net on the tree trunk was also done to estimate the hoppers present there. Mean of the hoppers in five sweep nets were represented as the number of hoppers sweep net^{-1} (Manjunatha, 2015).

3.2.3.3 Number of Hoppers Shoot^{-1}

Number of hoppers was recorded on visual observation. Four shoots were selected for a tree, one from each direction. Since the majority of them were nymphs, they can be counted visually (NICRA, 2012).

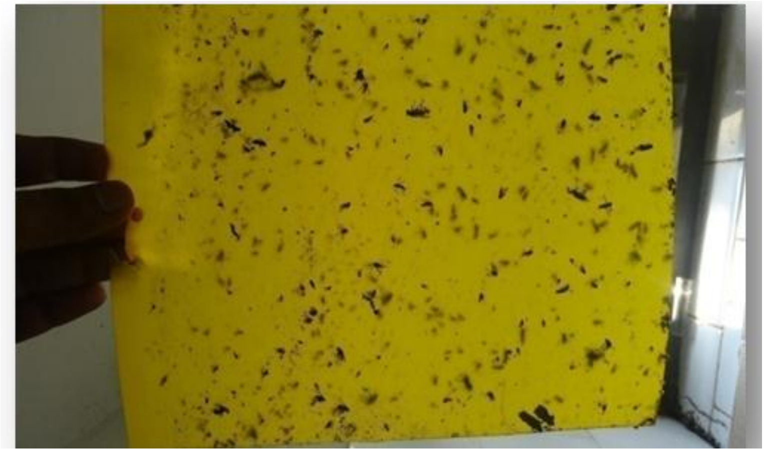
3.2.3.4 Monitoring Hoppers Population Through Yellow Sticky Trap

Hoppers were also monitored through setting up yellow sticky traps (Plate 1a) in Balarampuram homesteads for five months from December 2015 - April 2016. Ten mango trees were selected and two sticky traps per tree (25 × 20 cm) were installed for attracting the mango hoppers (Saeed *et al*., 2013). Traps were replaced after every month of installation (Plate 1b).

3.2.4 Reaction of Mango Varieties Against Hopper Attack

To evaluate the infestation level on different varieties, study was conducted in Kalliyoor Panchayath. Ten mango varieties *viz*., Mundappa, Alphonso, Kalappadi, Prior, Mulgoa, Banganapally, Vellari Varikka, Bangalora, kottukonam and Neelum were selected for study. The pest incidence was recorded as specified in 3.2.3.1, 3.1.3.2. and 3.2.3.3. for a period of four months (December, January, February and March). The damage levels in different mango varieties were categorized and ranked according to the standard grades given by Manjunatha, (2015) as detailed in Table 2.

1a. Yellow sticky trap during installation



1b. Yellow sticky trap month after installation

1c. Bag trapping method for hopper collection

1d. Hoppers collection through standard insect net

Plate 1. Sampling techniques for mango hoppers

3.2.5 Species Composition of Hoppers Occurring on Mango

Different species of mango leaf hoppers were observed during the study were identified. Study was conducted in the homesteads of Kalliyoor Panchayath and College of Agriculture, Padanakkad. During the peak incidence (December-April) sampling was carried out as mentioned above (3.1.2.1. to 3.1.2.3.). Population of different hopper species was recorded separately and percentage of each species was worked out. This was carried out for five months.

3.2.6 Correlation Studies with Weather Parameters

Weather parameters have direct or indirect effect on the insect activity. In order to assess the effect of different weather parameters *viz*., maximum temperature (^{0}C), minimum temperature (^{0}C), morning relative humidity (%), evening relative humidity (%), sunshine hours (bright hours) and rainfall (mm), weather data were collected and correlation studies were done (Appendix I).

3.3 NATURAL ENEMIES

In order to study the natural enemies occurring naturally in mango ecosystem, population of predators and parasites were recorded throughout the study period.

3.4 OTHER MANGO PESTS

During the study period observations were recorded on the other mango pests, following standard sampling methods (NICRA, 2012). The details are given in Appendix II.

3.5 MANAGEMENT OF MANGO SHOOT WEBBER AND MANGO HOPPERS

3.5.1 Evaluation of Efficacy of Safer Molecules for the Management of Mango Shoot Webber

Field experiments were conducted in the Instructional Farm, Vellayani to evaluate the efficacy of selected treatments, including new generation insecticides, conventional insecticides, one botanical and one biopesticide, for managing the mango shoot webber. The treatments were applied during December 2015 and February 2016. .

Design : CRD

Replication : 3 (one tree per replication)

Treatments : 11

The following were the treatments used for the study. Details of the insecticides used are given in Table 3.

T1 Emamectin benzoate 0.002%
T2 Spinosad 0.015%
T3 Lambdacyhalothrin 0.005%
T4 Flubendiamide 0.01%
T5 Chlorantraniliprole 0.03%
T6 Indoxacarb 0.02%
T7 Malathion 0.1%
T8 Azadirachtin 1%
T9 *B. bassiana* (ITCC 6063) WP 2%
T10 Water spray
T11 Untreated

Precount of webber population was recorded before imposing the treatments. Post treatment counts were recorded at 1, 3, 5, 7, 10 and 15 DAS. Two sprays were given and observations were recorded as per the sampling procedure followed for survey

3.5.2 Evaluation of Efficacy of Safer Molecules for the Management of Mango Hopper

Since the population levels of hopper was too low in the Instructional Farm, Vellayani, field experiments were carried out at the College of Agriculture, Padanakkad. Treatments included new generation insecticides, conventional insecticides, one botanical and one biopesticide for managing the mango leaf hoppers. Precount was recorded before imposing the treatments. First spray was done during the month of January 2016 and second spray was given during the month of March 2016.

Design : CRD

Replication : 3 (one tree per replication)

Treatments : 11

The following were the treatments selected for the study. Details of the insecticides used given in Table 4.

T1 Lambdacyhalothrin 0.005%
T2 Thiamethoxam 0.005%
T3 Deltamethrin 0.05%
T4 Imidacloprid 0.005%
T5 Dimethoate 0.05%
T6 Malathion 0.1%
T7 Azadirachtin 1%
T8 *B.bassiana* (ITCC 6063) WP 2%
T9 Water spray
T10 Untreated

Observation were recorded on precount just before the application of treatments , and after the application of treatmens at 1, 3, 5, 7, 10 and 15 DAS.

Table 3. Evaluation of Efficacy of Safer Molecules for the Management of Mango Shoot Webber

Treatment No.	Treatment	Formulation	Dosage
T1	Emamectin benzoate 0.002%	Proclaim 5% SG	0.40 g L^{-1}
T2	Spinosad 0.015%	Tracer 45% SC	0.33 ml L^{-1}
T3	Lambdacyhalothrin 0.005%	Karate 5% EC	1.00 ml L^{-1}
T4	Flubendiamide 0.01%	Fame 39.5% SC	0.25 ml L^{-1}
T5	Chlorantraniliprole 0.03%	Coragen 18.5% SC	1.62 ml L^{-1}
T6	Indoxacarb 0.02%	Ammate 15.8% EC	1.20 ml L^{-1}
T7	Malathion 0.1%	Malik 50% EC	2.00 ml L^{-1}
T8	Azadirachtin 1%	Neemazal 1% EC	4.00 ml L^{-1}
T9	*B. bassiana* (ITCC 6063) WP 2%		20.00 g L^{-1}
T10	Water spray		
T11	Untreated		

Table 4. Evaluation of Efficacy of Safer Molecules for the Management of Mango Hopper

Treatment No.	Treatments	Formulation	Dosage
T1	Lambdacyhalothrin 0.005%	Karate 5% EC	1.00 ml L^{-1}
T2	Thiamethoxam 0.005%	Extrasuper 25% WG	0.20 g L^{-1}
T3	Deltamethrin 0.05%	Taglise 2.8% EC	17.80 ml L^{-1}
T4	Imidacloprid 0.005%	Confidar 17.8% SC	0.28 ml L^{-1}
T5	Dimethoate 0.05%	Jagor 30%EC	1.60 ml L^{-1}
T6	Malathion 0.1%	Malik 50% EC	2.00 ml L^{-1}
T7	Azadirachtin 1%	Neemazal 1% EC	4.00 ml L^{-1}
T8	*B. bassiana* (ITCC 6063) WP 2%		20.00 g L^{-1}
T9	Water spray		
T10	Untreated		

3.5.3 Method of Insecticide Application

The treatments were randomized and data on population of target pests of mango were recorded before as well as after each insecticide application. In each treatment except untreated control, need based applications of insecticides were given (Table 5) based on Economic Threshold Level (ETL) of pests.

Table 5. ETL of Mango Hopper and Shoot Webber

Sl. No.	Pest	ETL
1	Mango leaf hoppers	(i) 5 nymph or adult or both / twigs at vegetative stage (ii) 5 nymph or adult or both / panicle at flowering stage.
2	Leaf webber	10 webs / tree

3.5.4 Percentage Reduction of Pest Population

After the application of the treatments , reduction of pest population over control was worked out using Handerson-Tilton's formula.

$$[1 - \frac{Ta}{Ca} \times \frac{Cb}{Tb}] \times \mathbf{100}$$

T_a – Infestation in treated trees after treatment
T_b – Infestation in treated trees before treatment
C_a – Infestation in control trees after treatment
C_b – Infestation in control trees before treatment

3.5.5. Statistical Analysis

The data obtained on the evaluation of efficacy of safer molecules was subjected to square root transformation and statistically analyzed.

4. RESULTS

The mango shoot webber and leaf hoppers are destructive pests posing threat to mango cultivation. A survey was conducted in the homesteads of Kalliyoor Panchayath and the Instructional Farm, Vellayani during 2015-16 in order to study the incidence and population dynamics of the two pests. Field experiments were conducted to standardize the use of newer and safer molecules of insecticides to manage the pests in the Instructional Farm, Vellayani and College of Agriculture, Padanakkad.

4.1 MANGO SHOOT WEBBER

4.1.1 Documentation of Mango Shoot Webber

Survey was conducted for 20 plants, selected for fortnightly observation, in the homesteads of Kalliyoor Panchayath and the Instructional Farm, Vellayani. The plants selected were of similar age. The plants were observed throughout the study period. Survey was conducted from first (I) fortnight (FN) of March 2015 to second (II) FN of March 2016. Other pests of mango were also documented.

4.1.2 Occurrence of Mango Shoot Webber

The shoot webber or leaf webber or tent caterpillar, *Orthaga exvinacea* Hampson was a grey moth with dark patches on wings (Plate 2a). The caterpillar was slender and pale green with dark bands. First instar larvae fed on leaf chlorophyll (Plate 2b), later instars fed within a web on the entire leaf, leaving behind only the midrib and veins. As the webbed up leaves gave a small tent-like appearance, it is popularly called as tent caterpillar. Several caterpillars were found in a single webbed up cluster.

4.1.3 Population Dynamics of Mango Shoot Webber in Homesteads of Kalliyoor Panchayath

Studies were conducted to know the population dynamics of mango shoot webber, in Kalliyoor Panchayath of Thiruvanathpuram district from I FN of March 2015 to II FN of March 2016 (Table 6).

Shoot webber damage was observed on the mango foliage throughout the year. Caterpillars fed gregariously, except during I FN of July 2015 to II FN of August 2015. The results indicated the significant variation with respect to the incidence of the pest and the damage or infestation level at different crop stages.

Early instars (1^{st} and 2^{nd}) of the webber caterpillar were tiny, pale green in color with dark prothorax and brown head (Plate 2b). Their incidence started during I FN of September 2015 (4.45 webs $tree^{-1}$, 3.65 larvae web^{-1} and 5 damaged leaves web^{-1}). They were feeding on individual leaf by scraping the chlorophyll content. Shoot webber incidence coincided with vegetative growth phase of mango.

Later instars (3^{rd} to 6^{th}) were observed from II FN of October 2015 onwards (9.45 webs $tree^{-1}$, 4 larvae web^{-1} and 30.35 damaged leaves web^{-1}). They were light greenish grey, with dark brown mottling on head capsule and a few brown markings or spots on prothorax (Plate 2c). There were seven instars of the caterpillar, later instars were causing more damage to the foliage by skeletonizing the leaves (Plate 5).

Shoot webber was found to be damaging more intensively to the mango foliage from I FN of December 2015 to I FN of February 2016 (20.50 webs $tree^{-1}$, 4.90 larvae web^{-1} and 85.65 damaged leaves web^{-1} to 21.65 webs $tree^{-1}$, 6.00 larvae web^{-1} and 132.4 damaged leaves web^{-1}). During this period there was rapid increase in the number of larvae per web, number of webs per tree and number of leaves damaged per web.

2a. Adult of mango shoot webber

2b. Early instar of mango shoot webber

2c. Late instar of mango shoot webber

2d. Composite web

Plate 2. Mango shoot webber *Orthaga exvinacea* Hampson

Table 6. Population Dynamics of Mango Shoot Webber at Homesteads of Kalliyoor Panchayath from March 2015 to March 2016

Fortnights	*No. of webs tree $^{-1}$	*No. of larvae web^{-1}	*No. of damaged leaves web^{-1}
I FN March-2015	15.85	4.35	65.10
II FN March-2015	16.15	4.00	70.10
I FN April -2015	15.70	4.35	74.45
II FN April -2015	13.30	4.65	68.35
I FN May -2015	12.45	4.90	64.65
II FN May -2015	11.20	4.90	59.30
I FN June-2015	9.30	4.35	51.55
II FN June -2015	4.90	3.00	42.55
I FN July -2015	2.80	2.30	25.60
II FN July -2015	0	0	0
I FN August-2015	0	0	0
II FN August -2015	0	0	0
I FN September-2015	4.45	3.65	5.00
II FN September -2015	4.85	4.15	10.35
I FN October-2015	6.70	3.90	25.25
II FN October -2015	9.45	4.00	30.35
I FN November-2015	12.50	4.15	49.90
II FN November -2015	14.05	4.65	65.35
I FN December-2015	20.50	4.90	85.65
II FN December -2015	24.40	5.25	96.35
I FN January-2016	25.60	6.33	103.6
II FN January-2016	23.15	6.15	122.6
I FN February-2016	21.65	6.00	132.4
II FN February -2016	18.40	6.10	130.7
I FN March- 2016	17.25	5.95	115.7
II FN March- 2016	15.15	5.15	103.5

*mean of 20 replications

During the II FN of July to II FN of August 2015 the mango trees were free from damage by the shoot webber caterpillars. Since all were 6^{th} and 7^{th} instar larvae they fed less and seen resting within web.

Peak Incidence and the intensive damage caused by mango shoot webber was observed during the I FN of January 2016 with 25.6 webs tree^{-1}, 6.33 larvae composite web^{-1} and 103.6 damaged leaves (Table 6). Majority of larvae were 4^{th} and 5^{th} instar and feeding on leaves of terminal shoot. They caused heavy damage by connecting two to three shoots together, making it composite web (Plate 2d) and fed within it.

4.1.4 Population Dynamics of Mango Shoot Webber in the Instructional Farm, Vellayani

Experiment was conducted in the Instructional Farm, Vellayani to study the population dynamics of mango shoot webber from I FN of March 2015 to II FN of March 2016 (Table 7).

Shoot webber damage to the mango foliage was observed throughout the year, except from II FN of July 2015 to II FN of August 2015. Pest was absent in majority of the trees during this period.

In farm orchard, shoot webber incidence started from I FN of September 2015 onwards with 2.1 webs tree^{-1}, 1.2 larvae web^{-1} and 6.25 damaged leaves web^{-1} and continued up to July I FN with 6.6 webs tree^{-1}, 2.1 larvae web^{-1} and 20.6 damaged leaves web^{-1}.

Pest was spreading rapidly and causing pronounced damage from I FN of December 2015 (14.8 webs tree^{-1}, 5.9 larvae web^{-1} and 40.75 damaged leaves web^{-1})

Table 7. Population Dynamics of Mango Shoot Webber at the Instructional Farm, Vellayani from March 2015 to March 2016

Fortnights	*No. of webs tree^{-1}	*No. of Larvae web^{-1}	*No. of damaged leaves web^{-1}
I FN March-2015	9.10	3.50	36.80
II FN March-2015	9.85	4.00	39.05
I FN April -2015	11.30	3.90	43.90
II FN April -2015	11.95	4.10	46.15
I FN May -2015	10.95	4.30	51.25
II FN May -2015	10.05	3.85	64.50
I FN June-2015	8.80	3.20	35.40
II FN June -2015	7.15	2.75	32.90
I FN July -2015	6.60	2.10	20.60
II FN July -2015	0	0	0
I FN August-2015	0	0	0
II FN August -2015	0	0	0
I FN September-2015	2.10	1.20	6.25
II FN September -2015	4.50	2.25	10.70
I FN October-2015	6.95	3.65	21.60
II FN October -2015	10.75	4.50	30.45
I FN November-2015	11.80	4.90	35.20
II FN November -2015	13.80	5.15	38.90
I FN December-2015	14.80	5.90	40.75
II FN December -2015	15.50	6.65	47.25
I FN January-2016	16.15	6.35	55.15
II FN January-2016	17.25	5.95	59.90
I FN February-2016	17.85	5.65	62.80
II FN February -2016	20.50	5.90	67.80
I FN March- 2016	21.25	4.50	61.75
II FN March- 2016	22.25	4.00	73.25

*mean of 20 replications

to II FN of March 2016 with 22.25 webs tree^{-1}, 4 larvae web^{-1} and 73.25 damaged leaves web^{-1}.

Peak Incidence and the intensive damage caused by mango shoot webber was observed during the II Fortnight of March 2016 with 22.25 webs tree^{-1}, 4 larvae per composite web and 73.25 damaged leaves web^{-1} (Table 7). Majority of larvae were 4th and 5th instar and feeding on leaves of terminal shoot. They caused heavy damage by feeding the webbed up leaves and plant showed a burnt up appearance.

4.1.5 Reaction of Mango Varieties Against Shoot Webber Attack

Study conducted on screening of mango cultivars at the Instructional Farm, (Table 8) revealed that the variety Kalappadi showed significantly higher incidence of shoot webber (17.33 webs tree^{-1}). This was followed by the varieties Kundalatha (15.79 webs tree^{-1}), Kottukonam (15.06 webs tree^{-1}) and Alphonso (14.78 webs tree^{-1}) which were statistically on par. However, the varieties Banganapally (5.10 webs tree^{-1}), Prior (8.07 webs tree^{-1}), Malgoa (10.13 webs tree^{-1}) and Himayudan (11.70 webs tree^{-1}) were found statistically different from each other. The variety Bangalora (10.92 webs tree^{-1}) was on par with Himayudan (11.70 webs tree^{-1}) and Malgoa (10.13 webs tree^{-1}). No webs were observed in case of Vellari Varikka which was free from shoot webber damage.

Based on the number of webs present in a tree, Alphonso, Kalappadi, Himayudan, Kundalatha, Bangalora and Kottukonam were categorized as highly susceptible varieties, whereas Mulgoa and Prior were moderately susceptible. Banganapally was less susceptible and the variety Vellari Varikka was free from the shoot webber attack.

Table 8. Reaction of Mango Varieties Against Shoot Webber Attack

Variety	*No. of webs $tree^{-1}$	Category
Alphonso	14.78 (3.90)[b]	HS
Kalappadi	17.33 (4.22)[a]	HS
Himayudan	11.70 (3.49)[c]	HS
Malgoa	10.13 (3.26)[d]	MS
Kundalatha	15.79 (4.03)[b]	HS
Banglora	10.92 (3.37)[cd]	HS
Prior	8.07 (2.92)[e]	MS
Kottukonam	15.06 (3.94)[b]	HS
Banganapally	5.10 (2.36)[f]	LS
Vellari Varikka	0 (0.70)[g]	T
CD value	**(0.160)**	

4.1.6 Correlation Studies of Shoot Webber Incidence with Weather Parameters

The average of the fortnightly data *viz*., rainfall, maximum temperature, minimum temperature, morning relative humidity, evening relative humidity and sunshine hours were collected. The fortnightly weather data were correlated with the population of shoot webber during 2015-16 and correlation coefficients were studied. Correlation studies were done for the observations taken in both the locations (Kalliyoor Panchayath and the Instructional Farm, Vellayani).

Correlation coefficients between the population of *O. exvinacea* in Kalliyoor Panchayath (Table 9) and weather parameters revealed that the population had a positive correlation and the relationship was significant with maximum temperature and morning relative humidity. Rainfall did not show any influence on occurrence of the shoot webber. However, minimum temperature, evening relative humidity and sunshine hours showed negatively significant correlation with the population of *O .exvinacea.*

Correlation coefficients (Table 10) between the population of *O. exvinacea* at the Instructional Farm, Vellayani and weather parameters revealed that the population had a positive correlation. Relation was significant with maximum temperature and morning relative humidity. However, minimum temperature, evening relative humidity and sunshine hours were negatively significant with the webber population. Here also rainfall did not show any influence on incidence of pest.

In both the locations, correlation studies revealed the same effect on the incidence of shoot webber.

4.2 MANGO HOPPERS

4.2.1 Documentation of Mango Hopper

Table 9. Correlation Studies for Shoot Webber Incidence with Weather Parameters of Kalliyoor Panchayath

Weather parameters	No. of webs tree^{-1}		No. of larvae web^{-1}	
	D.F.O.	D.F.P.O	D.F.O.	D.F.P.O
Max. temp. (^{0}C)	**0.401***	0.302	0.285	0.280
Min. temp. (^{0}C)	-0.614	-0.630	-0.526	**0.493***
Morning RH (%)	**0.581****	**0.613****	**0.623****	**0.601****
Evening RH (%)	-0.341	-0.251	-0.281	-0.250
Sunshine (hrs)	-0.609	0.675	-0.593	-0.597
Rainfall (mm)	0.030	0.049	0.116	0.073

D.F.O. – During the Fortnight Observation, D.F.P.O.-During the Fortnight Preceding Observation, ** Significant at 1 % level

Table 10. Correlation Studies for Shoot Webber Incidence with Weather Parameters of the Instructional Farm, Vellayani

Weather parameters	No. of webs tree^{-1}		No. of larvae web^{-1}	
	D.F.O.	D.F.P.O	D.F.O.	D.F.P.O
Max. temp. (^{0}C)	**0.619****	**0.543****	0.247	0.158
Min. temp. (^{0}C)	-0.418	-0.609	-0.584	-0.586
Morning RH (%)	**0.499****	**0.569****	**0.667****	**0.686****
Evening RH (%)	-0.254	-0.255	-0.211	-0.125
Sunshine (hrs)	-0.533	-0.540	-0.704	-0.676
Rainfall (mm)	-0.00	0.053	0.076	0.0620

D.F.O. – During the Fortnight Observation, D.F.P.O.-During the Fortnight Preceding Observation, ** Significant at 1 % level

Survey conducted for 20 plants selected for fortnightly observation in homesteads of Kalliyoor Panchayath and the Instructional Farm, Vellayani. The plants selected were of similar age. The plants were observed throughout the study period. Survey started from I FN of March 2015 to II FN of March 2016. Other pests of mango were also documented.

4.2.2 Occurrence of Mango Hoppers

During the survey different species of mango hoppers were observed and identified as *Amritodus* sp. (Plate 3a), *Idioscopus nitidulus* Walker (Plate 3c), *Idioscopus clypealis* Letheirry (Plate 3b) and *Idioscopus nagpurensis* Pruthi (Plate 3d).

All the three species of hoppers had wedge-shaped body with a broad head and narrow abdomen toward the back. The hind pair of legs was well adopted for quick hops. Four species of mango hoppers were morphologically distinct by color, size and spots on the scutellum (Table 11).

Table 11. Species of Mango hoppers Documented

Species	Colour and size	No. of spots on the scutellum	Other charecters
Idioscopus nitidulus	Slight brownish and smaller	3	Prominent white band across light brown wings
Idioscopus clypealis	Light brown and the smallest	2	Dark spots on vertex
Amritodus sp.	Light brown and the biggest	2	Lack in central longitudinal dark streak on scutellum
Idioscopus nagpurensis	Light brown and the smallest	2	Dark spots on vertex

3a. *Amritodus* sp.

3b. *Idioscopus clypealis* Letheirry

3c. *Idioscopus nitidulus* Walker

3d. *Idioscopus nagpurensis* Pruthi

Plate 3. Species of mango hoppers

4.2.3 Population Dynamics of Mango Hoppers in Homesteads of Kalliyoor Panchayath

Population dynamics of mango hoppers, in Kalliyoor Panchayath of Thiruvanathpuram district was observed from I FN of March 2015 to II FN of March 2016 (Table 12).

Incidence of mango hoppers from the I FN of December 2015 was observed to be 2.93 hoppers panicle^{-1}, 4.47 hoppers sweep net^{-1} and 1.97 hoppers shoot^{-1}. Incidence of hopper is coincided with initiation of flowering. They were of 2nd and 3rd nymphal instars crawling and feeding on succulent tissues of the plant, producing symptom on panicle and leaves and causing egg laying injury (Plate 4b and 4c).

Their activity was observed from I FN of December to I FN of July 2015. During this period hoppers passed three to four generations and caused reduction in fruit set. Their damage caused poor setting of flowers and dropping of immature fruits, thereby reducing the yield. Hoppers also caused honey dew secretion after severe damage which resulted in sooty mold development (Plate 4d).

Mango hoppers were absent from II FN of July 2015 to II FN of November 2015. The lowest incidence was recorded in I FN of July 2015 (1.07 hoppers panicle^{-1} and 2.30 hoppers sweep net^{-1}). The hopper *Amritodus* sp. was seen resting on tree trunk after flower set in mango trees (Plate 4a).

The hopper count consisted of different species, the species included *Amritodus* sp., *I. nitidulus*, *I. clypealis* and *I. nagpurensis.*

Peak incidence of hoppers was recorded during the I FN of April 2015 with 12.97 hoppers panicle^{-1}, 16.30 hoppers sweep net^{-1} and 4.53 hoppers shoot^{-1} (Table

4 a. Adult hoppers resting on tree trunk

4b. Nymphs of hopper feeding on young leaf

4c. Adults of hopper feeding on lower side of leaf

4d. Sooty mold on leaves, drying and withering of panicles

Plate 4. Hoppers damage and symptoms

Table 12. Population Dynamics of Mango Hopper at Homesteads of Kalliyur Panchayath from March 2015 to March 2016

Fortnights	*Mean no. of hoppers		
	Panicle^{-1}	sweep net^{-1}	Shoot^{-1}
I FN March-2015	10.60	13.97	4.17
II FN March-2015	11.83	15.17	4.40
I FN April -2015	12.97	16.30	4.53
II FN April -2015	11.20	17.07	4.73
I FN May -2015	7.07	15.43	0.00
II FN May -2015	6.30	7.27	0.00
I FN June-2015	4.07	5.20	0.00
II FN June -2015	1.83	2.60	0.00
I FN July -2015	1.07	2.30	0.00
II FN July -2015	0.00	0.00	0.00
I FN August-2015	0.00	0.00	0.00
II FN August -2015	0.00	0.00	0.00
I FN September-2015	0.00	0.00	0.00
II FN September -2015	0.00	0.00	0.00
I FN October-2015	0.00	0.00	0.00
II FN October -2015	0.00	0.00	0.00
I FN November-2015	0.00	0.00	0.00
II FN November -2015	0.00	0.00	0.00
I FN December-2015	2.93	4.47	1.97
II FN December -2015	3.17	5.63	2.63
I FN January-2016	3.73	6.30	3.27
II FN January-2016	4.03	7.13	3.60
I FN February-2016	10.40	8.53	3.80
II FN February -2016	10.47	9.83	3.87
I FN March- 2016	11.07	10.47	4.00
I FN March- 2016	10.40	10.47	4.50

mean of 20 replications , Mango hoppers (*Amritodus* sp.+ *I. clypealis,* + *I. nitidulus, +I. nagpurensis)*

12). Majority of the hoppers observed during this time were adult, having swift movement from one part to other part of the plant.

4.2.4 Population Dynamics of Mango Hoppers in the Instructional Farm, Vellayani

Population dynamics of mango hoppers, in the Instructional Farm Vellayani, Thiruvanathpuram was observed from I FN of March 2015 to II FN of March 2016 (Table 13).

Observations were recorded throughout the year on incidence and population fluctuation of hoppers. It was observed that the population of hopper was absent throughout the survey period, except in the months of January, February, March and April. During these months population was very less.

The highest number of hoppers recorded in this location was in the month of March 2016 (4 hoppers panicle^{-1}, 3.8 hoppers sweep net^{-1} and 2 hoppers shoot^{-1}). Species of hopper found was *Amritodus* sp. feeding on succulent tissues only. Other hopper species observed in other locations were absent in the Instructional Farm, Vellayani.

4.2.5 Population Dynamics of Mango Hoppers in the College of Agriculture, Padanakkad

The results of the experiment conducted in the College of Agriculture Padanakkad, Kasargod district are presented in Table 14. Observations on the hoppers were made from I FN of December 2015 to II FN of April 2016.

Incidence of mango leaf hoppers started during the II FN of November 2015 (4.33 hoppers panicle^{-1}, 4.00 hoppers sweep net^{-1} and 1.55 hoppers shoot^{-1}).

Table 13. Population Dynamics of Mango Hoppers at the Instructional Farm, Vellayani from March 2015 to March 2016

Months	*Mean No. of hoppers		
	Panicle^{-1}	sweep net^{-1}	Shoot^{-1}
March -2015	3 (2)	4 (2.23)	0 (1)
April -2015	2.5 (1.87)	3 (2)	0 (1)
May -2015	2 (1.7)	3 (2)	0 (1)
June -2015	0 (1)	0 (1)	0 (1)
July -2015	0 (1)	0 (1)	0 (1)
August -2015	0 (1)	0 (1)	0 (1)
September -2015	0 (1)	0 (1)	0 (1)
October -2016	0 (1)	0 (1)	0 (1)
November -2016	0 (1)	0 (1)	0 (1)
December -2016	0 (1)	0 (1)	0 (1)
January -2016	1.5 (1.58)	1.8 (1.67)	1 (1.41)
February - 2016	2 (1.73)	3 (2)	2 (1.73)
March- 2016	4 (2.23)	3.8 (2.19)	2 (1.73)

*mean of 20 replications, Mango hoppers (*Amritodus* sp.+ *I. clypealis*, + *I. nitidulus*, +*I. nagpurensis)*

Table 14. Population Dynamics of Mango Hopper at the College of Agriculture, Padanakkad from December 2015 to April 2016

Fortnights	*Mean No. of hoppers		
	Panicle^{-1}	sweep net^{-1}	Shoot^{-1}
II FN November-2015	4.33	4.00	1.55
I FN December-2015	7.47	5.00	1.87
II FN December -2015	8.57	6.30	2.17
I FN January-2016	10.57	8.47	2.33
II FN January-2016	12.10	9.67	2.50
I FN February-2016	16.97	15.07	4.17
II FN February -2016	18.67	17.07	4.33
I FN March- 2016	13.73	11.57	3.70
I FN March- 2016	12.53	9.63	2.90
I FN April -2016	6.50	7.07	2.50
II FN April -2016	2.90	4.03	2.07

*mean of 20 replications, Mango hoppers (*Amritodus* sp.+ *I. clypealis*, + *I. nitidulus*, +*I. nagpurensis*)

The highest number of hoppers was recorded in II FN of February 2016 (18.67 hoppers panicle^{-1}, 17.07 hoppers sweep net^{-1} and 4.33 hoppers shoot^{-1}). This was followed by I FN of February 2016 (16.97 hoppers panicle^{-1}, 15.07 hoppers sweep net^{-1} and 4.17 hoppers shoot^{-1}) and I FN of March 2016 (13.73 hoppers panicle^{-1}, 11.57 hoppers sweep net^{-1} and 3.70 hoppers shoot^{-1}).

The population of hoppers was found to be low during the II FN of April 2016 (2.90 hoppers panicle^{-1}, 4.03 hoppers sweep net^{-1} and 2.07 hoppers shoot^{-1}). This was followed by I FN of April 2016 (6.50 hoppers panicle^{-1}, 7.07 hoppers sweep net^{-1} and 2.50 hoppers shoot^{-1}).

4.2.6 Hoppers Population Monitored through Yellow Sticky Trap

Mango hoppers population was monitored through installing the yellow sticky trap (two trap tree^{-1}) at Balarampuram homesteads.

The incidence started in the month of November but population was negligible (10.55 hoppers yellow sticky trap^{-1}). During the I FN of December 2015 population of hopper incidence was recorded (72.33 yellow sticky trap^{-1}). Their incidence was in increasing trend from II FN of December 2015 onwards up to I FN of March 2016. From II FN of March 2016 onwards the population showed decreasing trend (Figure 1).

Peak incidence of hoppers was observed during the I FN of March 2016 (286.90 hoppers yellow sticky trap^{-1}), followed by the II FN of March 2016 (258 hoppers yellow sticky trap^{-1}). The population was low after the flowering season. II FN of May 2016 recorded the lowest number of hoppers (36.66 hoppers sticky trap^{-1}).

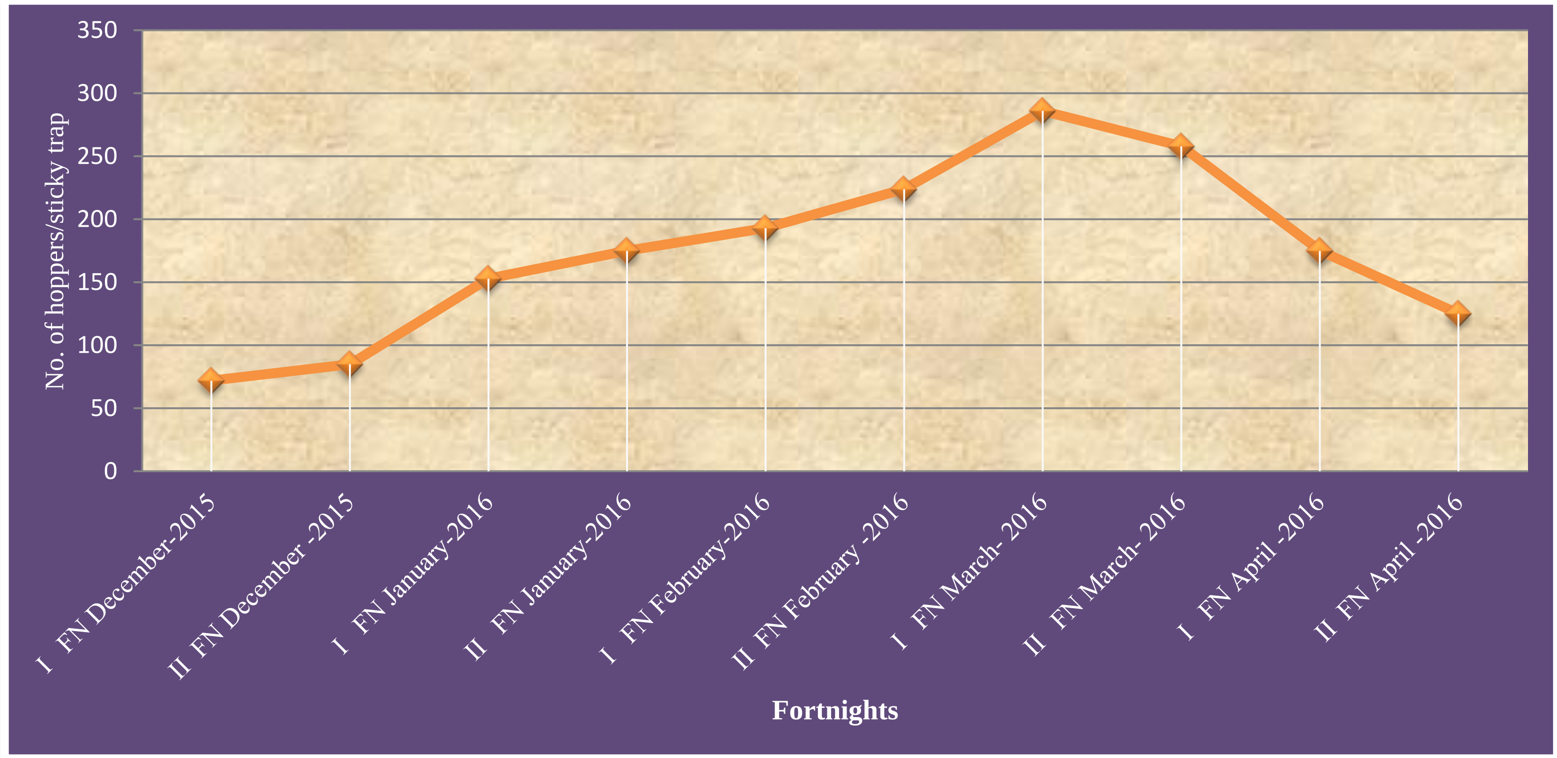


Figure 1. Hoppers Population Monitored Through Yellow Sticky Trap at Balarampuram

4.2.7 Reaction of Mango cultivars Against Hopper Attack

The observation on hopper incidence showed that the variety Alphonso (16.18 hoppers panicle^{-1}) recorded the highest incidence of mango hoppers, compared to all other varieties. This was followed by varieties Banganapalli (14.74 hoppers panicle^{-1}), Bangalora (14.55 hoppers panicle^{-1}) and Neelum (14.66 hoppers panicle^{-1}) which did not differ significantly. The lowest incidence of hoppers among the varieties was observed in Kottukonam (5.47 hoppers panicle^{-1}) and Prior (7.88 hoppers panicle^{-1}). Prior was on par with the variety Vellari Varikka (8.7 hoppers panicle^{-1}). Kalappadi (10.77 hoppers panicle^{-1}) and Mulgoa (10.10 hoppers panicle^{-1}) were on par (Table 15).

Based on the number of hoppers observed on the panicle the variety Mundappa, Alphonso, Kalappadi, Mulgoa, Banganapalli, Bangalora and Neelum were categorized as susceptible to hopper attack. Prior, Vellari Varikka and Kottukonam were found to be moderately tolerant to hopper damage.

4.2.8 Species Composition of Mango Hoppers

During the survey, different species of mango hoppers were documented (*Amritodus* sp., *I. nitidulus*, *I. clypealis* and *I. nagpurensis*). In order to know the proportion of species dominating in mango, species composition was worked out based on data obtained from the College of Agriculture, Padanakkad (Figure 2).

I. nitidulus was dominant among the four species which constituted 43 per cent of the total hopper population. This was followed by *I. clypealis* (20 %), *I. nagpurensis* (19 %) and *Amritodus* sp. (18 %) of the total population.

Species composition in homesteads of Kalliyoor Panchayath was also worked out (Figure 3). The homesteads plants were dominated by *Amritodus* sp. with 42 per

Table 15. Reaction of Mango Varieties Against Hoppers Attack

Variety	*Mean No. of hoppers		Category
	Panicle^{-1}	sweep net^{-1}	
Mundappa	12.85 (3.58)^{c}	13.96 (3.73)^{c}	S
Alphonso	16.18 (4.02)^{a}	15.83 (3.97)^{a}	S
Kalappadi	10.77 (3.28)^{d}	11.44 (3.38)^{e}	S
Malgoa	10.10 (3.10)^{de}	12.92 (3.59)^{d}	S
Prior	7.88 (2.80)^{f}	8.18 (2.87)^{g}	MT
Banganapalli	14.74 (3.83)^{b}	14.89 (3.85)^{f}	S
Vellari varikka	8.7 (2.94)^{ef}	9.14 (3.02)^{b}	MT
Banglora	14.55 (3.81)^{b}	14.96 (3.86)^{b}	S
Kottukonam	5.47 (2.33)^{g}	6.05 (2.45)^{h}	MT
Neelum	14.66 (3.82)^{b}	14.84 (3.85)^{b}	S
CD value	**(0.180)**	**(0.110)**	

Figures in parentheses are √x+1 transformed values

S- Susceptible MT- moderately tolerant

*mean of 3 replications

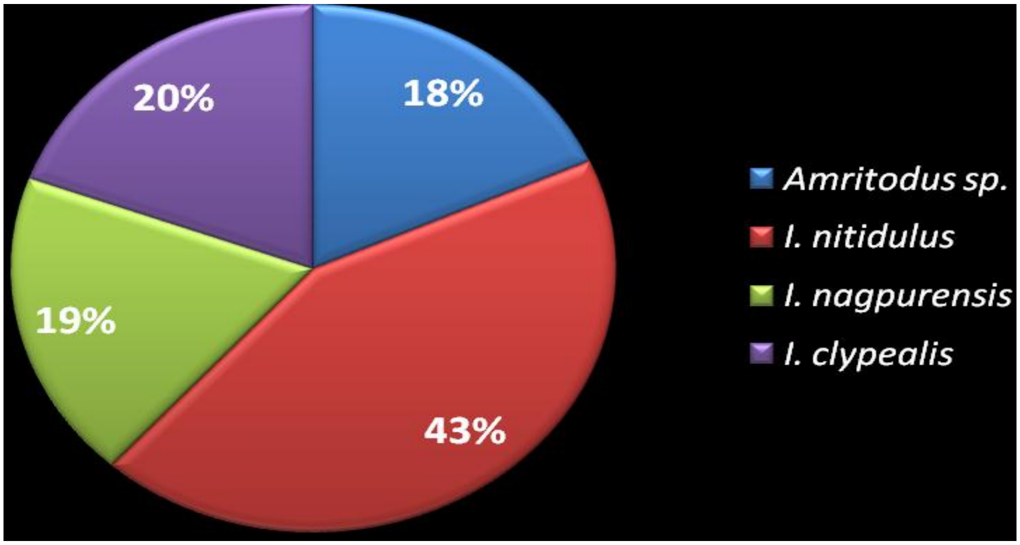


Figure 2. Species Composition of Mango Hoppers in the College of Agriculture, Padanakkad

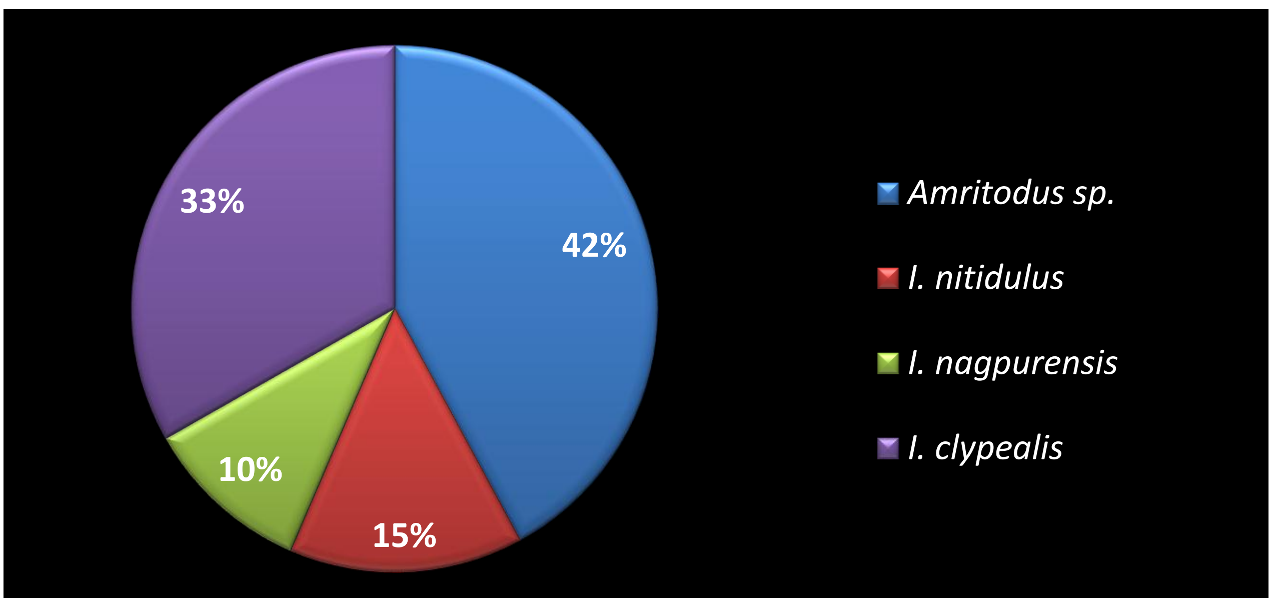


Figure 3. Species Composition of Mango Hoppers at the Homesteads of Kalliyoor Panchayath

cent of total hopper population, followed by *I. clypealis* (33 per cent), *I. nitidulus* (15 per cent) and *I. nagpurensis* (10 per cent).

4.2.9 Correlation Studies of Hopper Incidence with Weather Parameters

The average of the fortnightly data *viz*., rainfall, maximum temperature, minimum temperature, morning relative humidity, evening relative humidity and sunshine hours was collected. The fortnightly weather data were correlated with the population of hopper during 2015-16 and correlation coefficients were worked out.

Correlation coefficients between the population of mango hoppers in Kalliyoor Panchayath and weather parameters revealed that the population had a positive correlation and was significant with maximum temperature. However, minimum temperature, morning relative humidity, evening relative humidity and sunshine hours had a negative correlation. Rainfall did not showed any influence on hopper population (Table 16).

There was spare population of hoppers in the Instructional Farm, Vellayani during the season. It was absent in the rest of period. Hence the correlation studies with weather parameters were avoided.

4.3 NATURAL ENEMIES IN MANGO ECOSYSTEM

Activity of natural enemies *viz*., predators and parasitoids of the mango pests was observed. Presence of only predators was observed during the study period (Figure 4). Predatory spiders were identified as *Oxyopes javanus* Thorell (Plate 5a), *Argiope pulchella* Thorell (Plate 5b) and *Tetrognatha* sp. (Plate 5c).

Different predatory reduviid bugs were also observed on mango pests (Plate 5d). Their population count was also recorded during the survey

5a. *Oxyopes javanus* Thorell

5c. *Tetrognatha* sp.

5d. Predatory Reduviid bug

5b. *Argiope pulchella* Thorell

Plate 5. Natural enemies in mango ecosystem

Table 16. Correlation Studies for Hopper Incidence with Weather Parameters of Kalliyoor Panchayath

Weather parameters	No. of hoppers panicle^{-1}		No.of hoppers sweep net^{-1}		No. of hoppers/shoot	
	D.F.O.	D.F.P.O	D.F.O.	D.F.P.O	D.F.O.	D.F.P.O
Max. temp. (^{0}C)	**0.687****	**0.709****	**0.786****	**0.746****	**0.709****	**0.585****
Min. temp. (^{0}C)	-0.089	-0.333	-0.130	-0.436	-0.469	-0.628
Morning RH (%)	-0.108	0.062	0.103	0.083	0.158	0.336
Evening RH (%)	-0.600	-0.692	-0.639	-0.654	0.663	-0.665
Sunshine (hrs)	-0.007	-0.052	0.056	0.044	-0.060	-0.145
Rainfall (mm)	0.117	0.093	0.091	-0.005	-0.055	-0.241

D.F.O. – During the Fortnight Observation, D.F.P.O.-During the Fortnight Preceding Observation,
** Significant at 1 % level

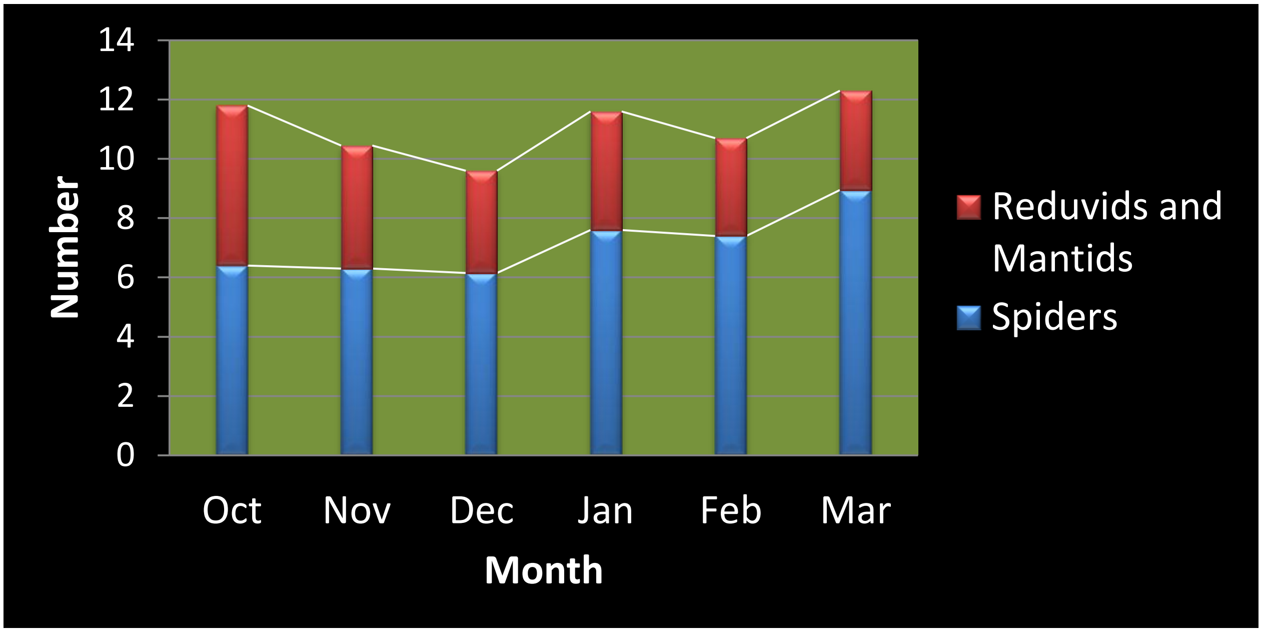


Figure 4. Population of Natural Enemies in Mango Ecosystem

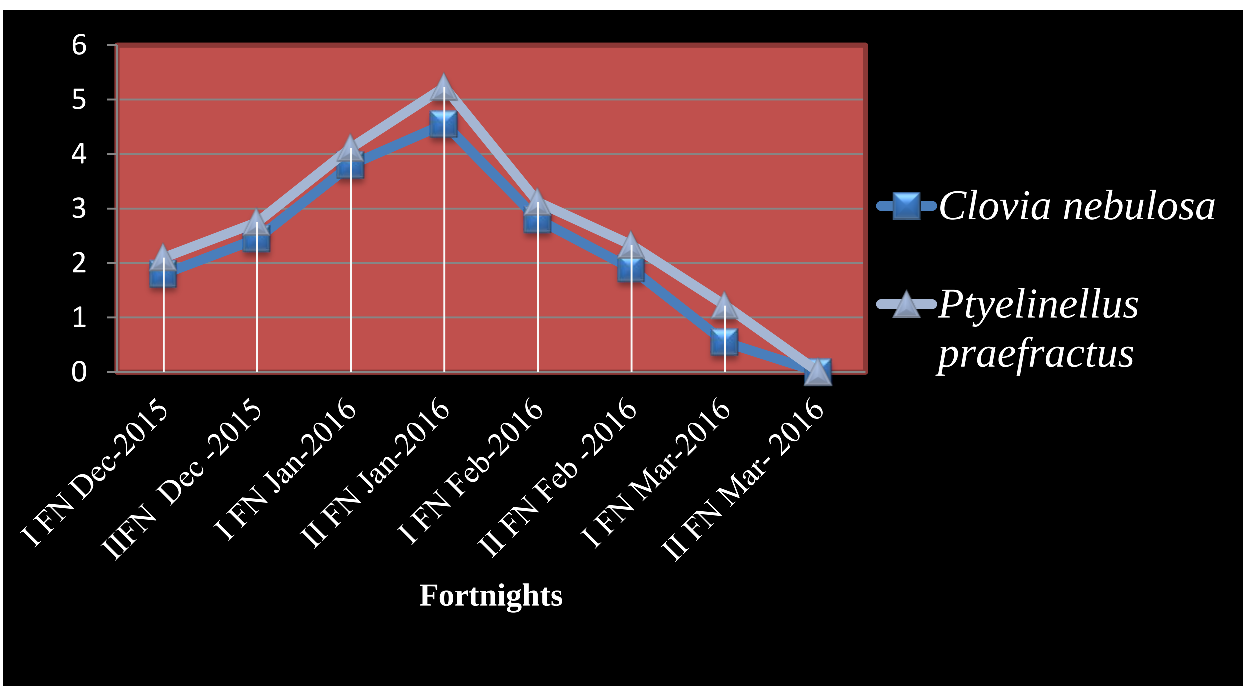


Figure 5. Population of Aphrophorid Bugs in Mango Orchard of the Instructional Farm, Vellayani

From October 2015 onwards fair number of spiders and reduviid bugs was recorded (6.4 spiders and 5.4 reduviids plant^{-1}). Significant population of natural enemies was observed up to April 2016. During the rest of the period the spider population was observed, but they were in less number.

The highest number of natural enemies and their activity were observed during March 2016 (8.95 spiders and 3.35 reduviids plant^{-1}).

Apart from reduviids, mantids, spiders, ants were also observed. The ants were identified as *Camponotus compressus* Fab. and *Oecophylla smaragdina* Smith. These ants were more in number than the other predators. Their population was observed throughout the survey period.

Throughout the study period no specific natural enemies were documented against the target pests.

4.4 OCCURRENCE OF OTHER MANGO PESTS

During the survey period other mango pests were also observed from October 2015 to April 2016 (Table 17). Their population was recorded and some of them were identified. The pest could be grouped into two categories *viz*., defoliators and sucking pests.

Among defoliators, leaf eating caterpillar (*Euthalia garuda* Moore), looper caterpillar (*Thalassodes quadraria* Gu.), flush caterpillar (*Bombotelia jocostrix* Gu.), hairy caterpillar (*Dasychira mendosa* Hbn.), inflorescence caterpillar (*Eublemma* sp.) shoot borer (*Chlumetia transversa*) and mango lycaenid (*Rothinda amor* Fab.) were observed during the vegetative growth phase and continued up to the flowering season (September to March).

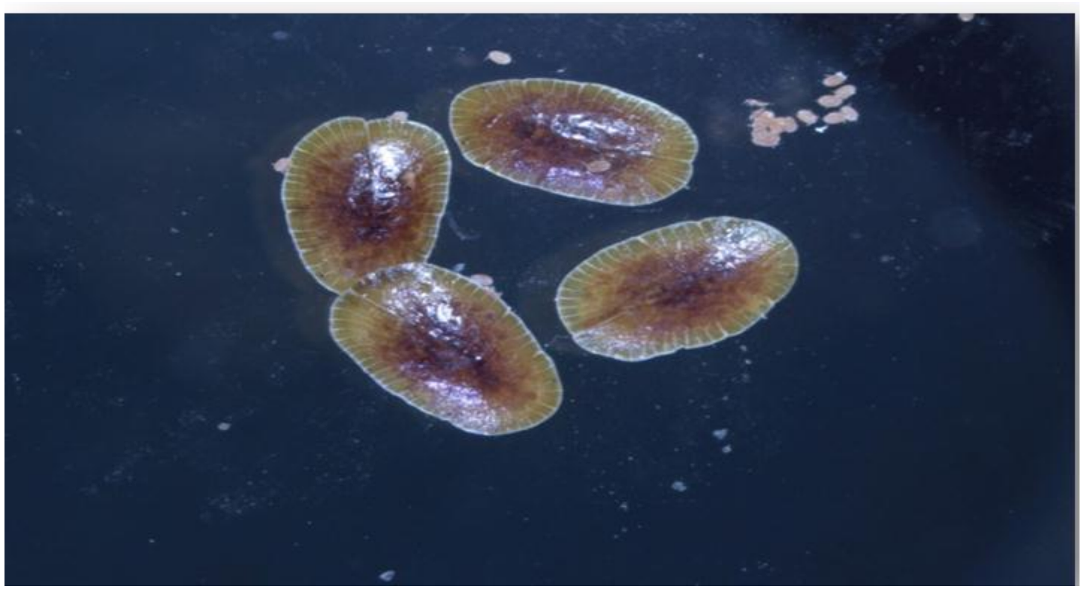
6a. *Rastrococcus iceryoides* Green

6b. *Icerya* sp.

6c. *Rastrococcus invadense* Williams

6d. *Formicococcus robustus* Ezzat & Mcconnell

Plate 8. Mealy bug complex in mango



7a. Mango scale *Eucalymnatus tessellates* Signoret

7 b. Mango pinkscale *Ceroplastes* sp.

Plate 7. Mango scales

Leaf eating beetles documented during the survey were leaf cutting weevil (*Deporaus marginatus* Pas.), leaf twisting weevil (*Apoderus trannquebaricus* Fab.), ash weevil (*Myllocerus sp.*) and leaf miner (*Rhynchaenus mangiferae* Ms.). These were found to be the common defoliators causing damage to mango foliage.

Among sucking pests, mealy bug complex was observed and identified as *Rastrococcus invadens* Williams (Plate 6c) , *Rastrococcus iceryoides* Green (Plate 6a), *Icerya* sp. (Plate 6b) and *Formicococcus robustus* Ezzat & Mcconnel (Plate 6d). Scales, *Eucalymnatus tessellates* Signoret (Plate 7a) and *Ceroplastes* sp. (Plate 7b) were also observed from September 2105 to April 2016.

In December 2015 two different bugs were identified. The species were *Clovia nebulosa* Fab. (Plate 8a) and *Ptyelinellus praefractus* Distant (Plate 8b), belonging to the family Aphrophoridae. These bugs were found to be resting and feeding on the young shoot of mango (Figure 5). During II FN of January 2016 their population was maximum and absent during March II FN.

In March 2016 a member of the membracidae family was found feeding on the tender shoots of mango and caused egg laying injury. All nymphal stages and adults were observed during the survey. It was identified as *Otinotus* sp.

4.5 MANAGEMENT OF MANGO SHOOT WEBBER AND HOPPERS

4.5.1 Efficacy of Safer Molecules for the Management of Mango Shoot Webber

Population of mango shoot webber was recorded before imposing the treatments.

4.5.1.1 First Spraying

8a. *Clovia nebulosa* Fabricius

8b. *Ptyelinellus praefracus* Distant

8c. Nymphs of *Otinotus* sp.

8d. Adults of *Otinotus* sp.

Plate 8. Other mango pests

Table 17. Occurrence of Other Mango Pests during March 2015 to March 2016

Name of pest	Affected part	Stage of damage	Period of Damage					
			Jan-Feb	Mar-April	May-June	July-August	Sept-Oct	Nov-Dec
Mealy bugs	All parts	Nymphs and adults	+	+	_	_	+	+
Scales	Leaf, fruit inflorescence	Nymphs and adults	+	+	_	_	+	+
Leaf minor	Leaf	Grub	+	+	+	_	_	+
Leaf gall midge	Leaf	Adult	+	+	+	_	+	+
Shoot borer	Terminal shoots	Caterpillar	+	+	_	_	+	+
Leaf twisting weevil	Leaf	Adult and grubs	+	+	_	_	_	+
Ash weevil	Leaf	Adults	+	+	-	-	+	+
Leaf cutting weevil	Young leaves and shoots	Adults	+	+	_	_	_	+
Leaf eating caterpillar	Young Leaves	Caterpillar	+	+	_	_	_	+
Mango hairy caterpillar	Leaf	Caterpillar	+	_	_	_	_	+
Cowbugs	Terminal shoot	Nymphs and adults	+	+	_	_	_	_
Inflorescence caterpillar	Inflorescence	Caterpillar	+	+	_	_	_	+
Fruit fly	Fruit	Adult and maggot	_	+	+	+	_	_
Black fly	Leaf	Nymphs and adults	+	+	_	_	+	+

4.5.1.1.1 Number of Active Webs Tree^{-1}

Results (Table 18) on population of *O. exvinacea,* recorded for different treatments under evaluation, showed significant impact of treatments over the control up to 15 days of spray.

It was found that there was no significant difference in number of active webs at 3 DAS.

After five days of treatment significant difference was observed among the treatments. Chlorantraniliprole 0.03 per cent and lambdacyhalothrin 0.005 per cent showed the highest efficacy by reducing the number of active webs per tree (13.67 and 14.34 active webs tree^{-1}, respectively). The treatments flubendiamide 0.01 per cent and emamectin benzoate 0.002 per cent did not differ in their efficacy and gave same results (14.67 active webs tree^{-1}). *B. bassiana* (ITCC 6063) WP 2 per cent, spinosad 0.015 per cent and malathion 0.1 per cent showed the same efficacy with 15.34 webs tree^{-1}. The lowest efficacy was observed in the case of indoxacarb 0.02 per cent and azadirachtin 1per cent, compared to the control.

Lambdacyhalothrin 0.005 per cent, flubendiamide 0.01 per cent and chlorantraniliprole 0.03 per cent were the superior treatments with 10.34, 10.67 and 11 active webs tree^{-1} after 7 DAS. Next best treatments were spinosad 0.015 per cent, azadirachtin 1 per cent and emamectin benzoate 0.002 per cent showed same efficacy, having statistically similar values. The lowest efficacy was shown by the treatments malathion 0.1 per cent and *B. bassiana* (ITCC 6063) WP 2 per cent (12.34 active webs tree^{-1}), which was on par with indoxacarb 0.02 per cent (13.00 active webs tree^{-1}).

At 10 DAS, chlorantraniliprole 0.03 per cent was superior to all other treatments with 7.34 active webs tree^{-1}, followed by flubendiamide 0.01 per cent

Table 18. Efficacy of Safer Molecules for the Management of Mango Shoot Webber - First Spraying

Treatments	*Mean No. of active webs tree^{-1}					
	Precount	3 DAS	5 DAS	7 DAS	10 DAS	15 DAS
T1- Emamectin benzoate 0.002%	16.67 (4.08)	15.67 (3.95)	14.67 $(3.82)^{cd}$	11.67 $(3.42)^{cd}$	9.67 $(3.10)^{d}$	6.67 $(2.58)^{de}$
T2- Spinosad 0.015%	17.67 (4.2)	16 (4)	15.34 $(3.91)^{bc}$	12 $(3.41)^{cd}$	10.34 $(3.21)^{cd}$	7.67 $(2.76)^{cd}$
T3- Lambdacyhalothrin 0.005%	16.67 (4.08)	15.67 (3.95)	14.34 $(3.78)^{de}$	10.34 $(3.26)^{d}$	9.34 $(3.05)^{de}$	6.34 $(2.52)^{e}$
T4- Flubendiamide 0.01%	17.34 (4.16)	16.67 (4.08)	14.67 $(3.82)^{cd}$	10.67 $(3.26)^{d}$	8.34 $(2.89)^{e}$	5.34 $(2.30)^{f}$
T5- Chlorantraniliprole 0.03%	17 (4.13)	16.67 (4.08)	13.67 $(3.70)^{e}$	11 $(3.31)^{d}$	7.34 $(2.70)^{f}$	4.34 $(2.07)^{g}$
T6- Indoxacarb 0.02%	17.34 (4.16)	16.67 (4.08)	15.67 $(3.95)^{b}$	13 $(3.60)^{b}$	10.34 $(3.21)^{cd}$	7.34 $(2.70)^{cde}$
T7-Malathion 0.1%	17.34 (4.17)	16.67 (4.08)	15.34 $(3.91)^{bc}$	12.34 $(3.51)^{bc}$	12.34 $(3.51)^{b}$	9.34 $(3.05)^{b}$
T8- Azadirachtin-1%	17 (4.13)	16.67 (4.08)	16 $(4.00)^{ab}$	11.67 $(3.41)^{cd}$	11.34 $(3.36)^{bc}$	8 $(2.82)^{c}$
T9- *B. bassiana* (ITCC 6063) WP 2%	17 (4.13)	16.67 (4.04)	15.34 $(3.91)^{bc}$	12.34 $(3.51)^{bc}$	9.67 $(3.10)^{d}$	8.34 $(2.89)^{bc}$
T10-Water spray	16.67 (4.08)	16 (4	16 $(4.0)^{ab}$	16.67 $(4.08)^{a}$	17.34 $(4.16)^{a}$	20.34 $(4.50)^{a}$
T11-Untreated	17.34 (4.16)	16.34 (4.04)	17 $(4.13)^{a}$	17.67 $(4.20)^{a}$	18.67 $(4.31)^{a}$	21 $(4.58)^{a}$
CD value	**NS**	**NS**	**(0.127)**	**(0.183)**	**(0.169)**	**(0.197)**

(8.34 active webs tree^{-1}) and lambdacyhalothrin 0.005 per cent (9.34 active webs tree^{-1}) which were on par. *B. bassiana* (ITCC 6063) WP 2 per cent and emamectin benzoate 0.002 per cent were similar in efficacy in controlling the pest. Less efficacy was observed in the case of indoxacarb 0.02 per cent, spinosad 0.015 per cent, azadirachtin 1per cent and malathion 0.1 per cent, in reducing the active webs in a tree.

Efficacy of treatments was more pronounced at 15 DAS. Among all the treatments chlorantraniliprole 0.03 per cent recorded the least number of active webs and was significantly different (4.34 active webs tree^{-1}) from all other treatments. Flubendiamide 0.01 per cent and lambdacyhalothrin 0.005 per cent (5.34 and 6.34 active webs tree^{-1} respectively) were the next best treatments. They were significantly different from all other treatments. The less efficacy was observed in treatments emamectin benzoate 0.002 per cent, indoxacarb 0.02 per cent, spinosad 0.015 per cent and azadirachtin 1per cent with 6.67, 7.34, 7.67 and 8 active webs tree^{-1}, respectively.

4.5.1.1.2 Number of Larvae Web^{-1}

Significant difference was observed in the mortality of shoot webber larvae in all the treatment at 3 DAS (Table 19). The lowest larval population was recorded in chlorantraniliprole 0.03 per cent, flubendiamide 0.01 per cent and azadirachtin 1per cent (4.00, 4.33 and 4.67 larvae web^{-1}, respectively) treated trees. Low efficacy was recorded in treatments emamectin benzoate 0.002 per cent, spinosad 0.015 per cent, indoxacarb 0.02 per cent, malathion 0.1 per cent and lambdacyhalothrin 0.005 per cent, which gave same results (5.33, 5.33, 5.67, 5.33 and 5.00 larvae web^{-1} respectively) webber larvae. In the case of *B. bassiana* (ITCC 6063) WP 2 per cent no mortality was observed.

At 5 DAS, chlorantraniliprole 0.03 per cent, flubendiamide 0.01 per cent and azadirachtin 1per cent (3.00, 3.33 and 3.67 larvae web$^{-1,}$ respectively) were found to be superior to other treatments. Lambdacyhalothrin 0.005 per cent and *B. bassiana* (ITCC 6063) WP 2 per cent (4.00 larvae web^{-1}) were the next best treatments. Emamectin benzoate 0.002 per cent, spinosad 0.015 per cent, malathion 0.1 per cent and indoxacarb 0.02 per cent (4.67, 4.33, 4.67 and 5.00 larvae web^{-1}, respectively) showed less efficacy to manage the pest.

Chlorantraniliprole 0.03 per cent and flubendiamide 0.01 per cent continued to prove their efficacy at 7 DAS, as the best treatments (2.00 and 1.92 larvae web^{-1}). *B. bassiana* (ITCC 6063) WP 2 per cent and lambdacyhalothrin 0.005 per cent were similar in managing the pest with 3.00 larvae web^{-1}. Azadirachtin 1per cent, malathion 0.1 per cent, indoxacarb 0.02 per cent, spinosad 0.015 per cent and emamectin benzoate 0.002 per cent were the next best treatments to manage the shoot webber larvae.

At 10 DAS, the treatments showed more efficacy in managing the pest. Increase in efficacy of all the treatments was observed. Unlike the previous observation, chlorantraniliprole 0.03 per cent and flubendiamide 0.01 per cent ranked first with 1.33 and 2.00 larvae web^{-1}, respectively. *B. bassiana* (ITCC 6063) WP 2 per cent and lambdacyhalothrin 0.005 per cent ranked as next best treatments, with no difference in their result (2.67 larvae web^{-1}). Less efficacy was recorded for malathion 0.1per cent, indoxacarb 0.02 per cent, spinosad 0.015 per cent and emamectin benzoate 0.002 per cent and azadirachtin 1per cent.

There was no much changes in the results at 15 DAS when compared to 10 DAS. Here also chlorantraniliprole 0.03 per cent and flubendiamide 0.01 per cent ranked first with 1.00 and 1.50 larvae web^{-1}, respectively. Better efficacy was recorded by lambdacyhalothrin 0.005 per cent and *B. bassiana* (ITCC 6063) WP 2

Table 19. Efficacy of Safer Molecules for the Management of Mango Shoot Webber - First spraying

Treatments	*Mean No. of larvae webbing^{-1}					
	Precount	3 DAS	5 DAS	7 DAS	10 DAS	15 DAS
T1- Emamectin benzoate 0.002%	6.33 (2.71)	5.33 (2.52)^{bc}	4.67 (2.38)^{c}	4.33 (2.31)^{de}	3.30 (2.07)^{cd}	3.33 (2.08)^{ef}
T2- Spinosad 0.015%	5.33 (2.52)	5.33 (2.52)^{bc}	4.33 (2.31)^{bc}	4.00 (2.24)^{bc}	3.67 (2.16)^{b}	3.67 (2.16)^{b}
T3- Lambdacyhalothrin 0.005%	5.67 (2.58)	5.00 (2.45)^{e}	4.00 (2.24)^{d}	3.00 (2.00)^{ef}	2.67 (1.92)^{d}	2.00 (1.73)^{de}
T4- Flubendiamide 0.01%	6.33 (2.71)	4.33 (2.31)^{de}	3.33 (2.08)^{e}	2.67 (1.92)^{g}	2.00 (1.73)^{e}	1.50 (1.58)^{f}
T5- Chlorantraniliprole 0.03%	6.00 (2.65)	4.00 (2.24)^{e}	3.00 (2.00)^{f}	2.00 (1.73)$_{h}$	1.33 (1.53)^{f}	1.00 (1.41)^{g}
T6- Indoxacarb 0.02%	6.33 (2.71)	5.67 (2.58)^{b}	5.00 (2.45)^{b}	4.00 (2.24)^{b}	3.33 (2.08)^{c}	2.50 (1.87)^{bc}
T7-Malathion 0.1%	5.77 (2.60)	5.33 (2.52)^{bc}	4.67 (2.38)^{cd}	3.67 (2.16)^{cd}	3.00 (2.00)^{c}	3.00 (2.00)^{bc}
T8- Azadirachtin-1%	6.33 (2.71)	4.67 (2.38)^{cde}	3.67 (2.16)^{ef}	3.33 (2.08)^{ef}	3.67 (2.16)^{b}	3.33 (2.08)^{cd}
T9- *B.bassiana* (ITCC 6063) WP 2%	6.00 (2.65)	6.00 (2.65)^{bcd}	4.00 (2.24)^{f}	3.00 (2.00)^{f}	2.67 (1.92)^{cd}	2.33 (1.82)^{cde}
T10-Water spray	6.33 (2.71)	6.33 (2.71)^{a}	6.33 (2.71)^{a}	6.33 (2.71)^{a}	6.00 (2.65)^{a}	6.00 (2.65)^{a}
T11-Untreated	6.00 (2.65)	6.00 (2.65)^{a}	6.00 (2.65)^{a}	6.33 (2.71)^{a}	6.33 (2.71)^{a}	6.33 (2.71)^{a}
CD value	**NS**	**(0.161)**	**(0.196)**	**(0.196)**	**(0.282)**	**(0.268)**

per cent they were ranked as next best treatments with 2.00 and 2.33 larvae web^{-1}, respectively. Low efficacy was recorded in case of malathion 0.1per cent, indoxacarb 0.02 per cent, spinosad 0.015 per cent, emamectin benzoate 0.002 per cent and azadirachtin 1per cent. However, the efficacy of all the treatments was better, compared to control trees (6.33 larvae web^{-1}).

4.5.1.2 Second Spraying

4.5.1.2.1 Number of Active Webs Tree^{-1}

Spraying was given in the month of February, when the treated trees showed the incidence of shoot webber again. Precount of webs in tree showed no significant variation.

The results (Table 20) for second spray showed that at 3 DAS there was no much changes in the number of active webs tree^{-1} in all the treatments.

At 5 DAS, all the treatments were effective and did not differ statistically in their efficacy to manage the pest. Chlorantraniliprole 0.03 per cent, flubendiamide 0.01 per cent, lambdacyhalothrin 0.005 per cent and indoxacarb 0.02 per cent were found statistically similar with 9, 9.33, 9 and 9.33 webs tree^{-1}, respectively. Malathion 0.1per cent, azadirachtin 1 per cent, *B. bassiana* (ITCC 6063) WP 2 per cent and emamectin benzoate 0.002 per cent were found on par with above four superior treatments.

Effect of treatments was significant at 7 DAS. Chlorantraniliprole 0.03 per cent and flubendiamide 0.01 per cent were the best treatments and they differed significantly (6.00 and 7.00 active webs tree^{-1}). Lambdacyhalothrin 0.005 per cent (7.66 active webs tree^{-1}) was statistically on par with flubendiamide 0.01 per cent. Azadirachtin 1per cent, spinosad 0.015 per cent, *B. bassiana* (ITCC 6063) WP 2 per

Table 20. Efficacy of Safer Molecules for the Management of Mango Shoot Webber - Second spraying

Treatments	*Mean No. of active webs tree^{-1}					
	Precount	3 DAS	5 DAS	7 DAS	10 DAS	15 DAS
T1- Emamectin benzoate 0.002%	11.33 (3.37)	11 (3.31)^{b}	9.66 (3.10)^{bc}	8.66 (2.95)^{bc}	5.66 (2.38)^{cde}	4.33 (2.20)^{cd}
T2- Spinosad 0.015%	10.67 (3.27)	10.33 (3.22)^{b}	10.66 (3.26)^{b}	8 (2.84)^{bcd}	6 (2.45)^{bcd}	4.67 (2.28)^{cd}
T3- Lambdacyhalothrin 0.005%	10.00 (3.16)	9.66 (3.10)^{a}	9 (2.90)^{c}	7.66 (2.76)^{cd}	5 (2.23)^{ef}	3.67 (2.03)^{d}
T4- Flubendiamide 0.01%	10.33 (3.22)	9.66 (3.10)^{a}	9.33 (3.05)^{c}	7 (2.65)^{d}	4.33 (2.07)^{f}	2.10 (1.18)^{e}
T5- Chlorantraniliprole 0.03%	10.00 (3.15)	10.67 (3.12)^{a}	9 (2.90)^{c}	6 (2.45)^{e}	2.33 (1.13)^{g}	1.00 (0.88)^{f}
T6- Indoxacarb 0.02%	10.33 (3.21)	10 (3.15)^{b}	9.33 (3.05)^{c}	8.66 (2.94)^{bc}	6.66 (2.58)^{b}	5.33 (2.41)^{bc}
T7-Malathion 0.1%	10 (3.15)	10 (3.15)^{b}	9.66 (3.10)^{bc}	9 (2.99)^{b}	6.66 (2.58)^{b}	5.67 (2.48)^{bc}
T8- Azadirachtin-1%	11 (3.32)	10 (3.15)^{b}	9.66 (3.10)^{bc}	8 (2.82)^{bcd}	6.33 (2.52)^{bc}	6.67 (2.67)^{de}
T9- *B. bassiana* (ITCC 6063) WP 2%	10.33 (3.21)	10.33 (3.20)^{b}	10 (3.16)^{bc}	8.33 (2.89)^{bc}	5.33 (2.30)^{de}	4.33 (2.20)^{cd}
T10-Water spray	20.33 (4.61)	20.33 (4.54)^{a}	21.66 (4.65)^{a}	21.66 (4.65)^{a}	21.66 (4.65)^{a}	23.00 (4.85)^{a}
T11-Untreated	21 (4.69)	21 (4.59)^{a}	21.33 (4.61)^{a}	21.33 (4.61)^{a}	21.33 (4.61)^{a}	23.00 (4.75)^{a}
CD value	**NS**	**(0.735)**	**(0.179)**	**(0.189)**	**(0.193)**	**(0.327)**

cent, indoxacarb 0.02 per cent, emamectin benzoate 0.002 per cent and malathion 0.1per cent were ranked as the next best treatments in managing the pest.

Efficacy of treatments were more pronounced over time. At 10 DAS chlorantraniliprole 0.03 per cent (2.33 active webs tree^{-1}) was significantly superior to the other treatments. This was followed by flubendiamide 0.01 per cent and lambdacyhalothrin 0.005 per cent (4.33 and 5.00 active webs web^{-1}, respectively), which were statistically on par. *B. bassiana* (ITCC 6063) WP 2 per cent, emamectin benzoate 0.002 per cent, spinosad 0.015 per cent and azadirachtin 1per cent did not differ statistically.

All the treatments showed better efficacy in managing the pest shoot webber at 15 DAS, when compared to control. Chlorantraniliprole 0.03 per cent (1.00 active webs tree^{-1}) was superior over the other treatments, followed by flubendiamide 0.01 per cent and lambdacyhalothrin 0.005 per cent (4.33 and 5.00 larvae web^{-1}, respectively) which were on par with each other. *B. bassiana* (ITCC 6063) WP 2 per cent, emamectin benzoate 0.002 per cent, spinosad 0.015 per cent, indoxacarb 0.02 per cent and malathion reduced the active webs considerably.

4.5.1.2.2 Number of Larvae Web^{-1}

Larval mortality recorded was analyzed. Precount was non significant indicating homogenous population in all the trees.

The treatments did not bring much changes at 3 DAS. Larval count was almost similar in all the treatments (Table 21).

At 5 DAS, slight mortality of shoot webber larvae was recorded. Chlorantraniliprole 0.03 per cent and flubendiamide 0.01 per cent recorded the same results (3.00 larvae web^{-1}). However, *B. bassiana* (ITCC 6063) WP 2 per cent, lambdacyhalothrin 0.005 per cent, indoxacarb 0.02 per cent and emamectin

Table 21. Efficacy of Safer Molecules for the Management of Mango Shoot Webber - Second spraying

Treatments	*Mean No. of larvae webbing^{-1}					
	Precount	3 DAS	5 DAS	7 DAS	10 DAS	15 DAS
T1- Emamectin benzoate 0.002%	4.67 (2.38)	4.33 (2.31)^{c}	3.67 (2.16)^{c}	3.33 (2.08)^{cd}	3.00 (2.00)^{bc}	2.67 (1.92)^{cde}
T2- Spinosad 0.015%	5.00 (2.45)	4.67 (2.38)^{c}	4.33 (2.31)^{bc}	3.67 (2.16)^{c}	3.67 (2.16)^{b}	3.33 (2.08)^{cd}
T3- Lambdacyhalothrin 0.005%	4.67 (2.38)	4.33 (2.31)^{c}	3.67 (2.16)^{c}	3.00 (2.00)^{de}	2.33 (1.82)^{bc}	2.00 (1.73)^{ef}
T4- Flubendiamide 0.01%	5.00 (2.45)	4.00 (2.24)^{bc}	3.00 (2.00)^{bc}	2.67 (1.92)^{f}	1.67 (1.63)^{d}	1.00 (1.41)^{f}
T5- Chlorantraniliprole 0.03%	5.00 (2.45)	4.60 (2.37)^{b}	3.00 (2.00)^{c}	2.00 (1.73)^{g}	0.67 (1.29)^{e}	0.33 (1.15)^{g}
T6- Indoxacarb 0.02%	4.67 (2.38)	4.33 (2.31)^{c}	3.67 (2.16)^{b}	3.00 (2.00)^{b}	2.67 (1.92)^{b}	2.33 (1.82)^{b}
T7-Malathion 0.1%	5.00 (2.45)	4.67 (2.38)^{c}	4.00 (2.24)^{bc}	3.00 (2.00)^{c}	2.33 (1.82)^{b}	1.67 (1.63)^{bc}
T8- Azadirachtin-1%	5.00 (2.45)	5.00 (2.45)^{c}	4.00 (2.24)^{bc}	3.33 (2.08)^{cd}	3.00 (2.00)^{bc}	2.00 (1.73)^{cde}
T9- *B. bassiana* (ITCC 6063) WP 2%	4.67 (2.38)	4.00 (2.24)^{c}	3.33 (2.08)^{c}	2.67 (1.92)^{ef}	2.00 (1.73)^{c}	2.00 (1.73)^{de}
T10-Water spray	6.00 (2.65)	6.00 (2.65)^{a}	6.33 (2.71)^{a}	6.33 (2.71)^{a}	6.00 (2.65)^{a}	6.33 (2.71)^{a}
T11-Untreated	6.00 (2.65)	6.33 (2.71)^{a}	6.33 (2.71)^{a}	6.33 (2.71)^{a}	6.33 (2.71)^{a}	6.00 (2.65)^{a}
CD value	**NS**	**(0.002)**	**(0.179)**	**(0.151)**	**(0.262)**	**(0.26)**

benzoate 0.002 per cent showed similar results and ranked as the next best treatments. Malathion 0.1 per cent, azadirachtin 1 per cent and spinosad 0.015 per cent were less effective in managing the pest.

Efficacy of treatments was good at 7 DAS. Chlorantraniliprole 0.03 per cent (2.00 larvae web^{-1}) was significantly superior to other treatments. Flubendiamide 0.01 per cent and *B. bassiana* (ITCC 6063) WP 2 per cent were the next best treatments (2.67 larvae web^{-1}) and both were on par. Lambdacyhalothrin 0.005 per cent, indoxacarb 0.02 per cent and malathion 0.1 per cent recorded same results and did not differ statistically. Azadirachtin 1 per cent, emamectin benzoate 0.002 per cent and spinosad 0.015 per cent were found to be less effective.

The treatments showed significant difference at 10 DAS. Chlorantraniliprole 0.03 per cent continued to prove its superior efficacy against shoot webber (0.67 larvae web^{-1}). Flubendiamide 0.01 per cent was the next best treatment with 1.67 larvae web^{-1} it was significantly different from the other treatments. 2.00, 2.33, 2.33 and 2.67 larvae web^{-1} was recorded by *B. bassiana* (ITCC 6063) WP 2 per cent, malathion 0.1 per cent, lambdacyhalothrin 0.005 per cent and indoxacarb 0.02 per cent, respectively. Azadirachtin 1 per cent, emamectin benzoate 0.002 per cent and spinosad 0.015 per cent recorded low efficacy against the target pest.

The highest reduction of larval population was observed at 15 DAS. Chlorantraniliprole 0.03 per cent recorded the lowest larval population (0.33 larvae web^{-1}), followed by flubendiamide 0.01 per cent with 1.00 larvae web^{-1}. 1.67 larvae web^{-1} was recorded in case of malathion 0.1per cent. Lambdacyhalothrin 0.005 per cent, *B. bassiana* (ITCC 6063) 2 per cent and azadirachtin 1 per cent showed similar results with 2.00 larvae web^{-1}. Emamectin benzoate 0.002 per cent and spinosad 0.015 per cent showed lesser efficacy against the target pest.

4.5.2 Efficacy of Safer Molecules for the Management of Mango Hoppers

Analysis on population of mango leaf hopper recorded before imposing the treatments indicated no significant results, suggesting that the leaf hopper population was homogeneous.

4.5.2.1 First Spraying

4.5.2.1.1 Number of Hoppers Sweep Net^{-1}

At 1 DAS, there was maximum reduction in hopper population in all the treatments, compared to control. There was no variation between treatments (Table 22).

Treatment effect at 3 DAS showed that, imidacloprid 0.005 per cent and dimethoate 0.05per cent (1.75 and 1.42 hoppers sweep net^{-1}, respectively) could control the activity of hoppers in mango trees. Deltamethrin 0.05 per cent, thiamethoxam 0.005 per cent and *B. bassiana* (ITCC 6063) WP 2 per cent recorded similar results and were on par. Malathion 0.1 per cent and azadirachtin 1 per cent were less effective in controlling the pest. 3.00 hoppers sweep net^{-1} was recorded in lambdacyhalothrin 0.005 per cent treated trees.

At 5 DAS, treatment efficacy was more or less similar. Imidacloprid 0.005 per cent (1.92 hoppers sweep net^{-1}) was superior to all other treatments, Lambdacyhalothrin 0.005 per cent and deltamethrin 0.05 per cent were the next best treatments. Dimethoate 0.05 per cent and thiamethoxam 0.005 per cent recorded same results and were on par. Malathion 0.1 per cent, azadirachtin 1 per cent and *B. bassiana* (ITCC 6063) WP 2 per cent were less effective in managing the pest.

There was increase in the population of hoppers in the treated trees at 7 DAS. The lowest population was recorded by imidacloprid 0.005 per cent and thiamethoxam 0.005 per cent, with 3.42 leaf hoppers sweep net^{-1}. *B. bassiana* (ITCC 6063) 2 per cent and lambdacyhalothrin 0.005 per cent treated trees were statistically

Table 22. Efficacy of Safer Molecules for the Management of Mango Hoppers - First spraying

Treatments	* Mean No. of hoppers sweep net^{-1}						
	Precount	1 DAS	3 DAS	5 DAS	7 DAS	10 DAS	15 DAS
T1- Lambda cyhalothrin 0.005%	12.92 (3.59)	0.25 (0.85)[d]	3.88 (1.95)[c]	3.00 (1.73)[c]	4.92 (2.15)[d]	6.00 (2.44)[cd]	3.08 (1.75)[e]
T2-Thiamethoxam 0.005%	12.67 (3.55)	0.33 (0.91)[c]	2.83 (1.68)[de]	3.50 (1.86)[c]	3.42 (1.84)[e]	3.00 (1.38)[e]	1.75 (1.32)[f]
T3-Deltamethrin 0.05%	12.92 (3.59)	0.33 (0.91)[c]	2.42 (1.55)[e]	3.17 (1.73)[c]	6.92 (2.62)[b]	7.17 (2.67)[bc]	4.17 (2.04)[d]
T4-Imidacloprid 0.005%	12.83 (3.58)	0.25 (0.85)[cd]	1.75 (1.31)[f]	1.92 (1.37)[d]	3.42 (1.84)[e]	2.83 (1.68)[e]	0.92 (0.95)[g]
T5-Dimethoate 0.05%	12.83 (3.58)	0.25 (0.86)[cd]	1.42 (1.18)[f]	3.50 (1.86)[c]	5.42 (2.32)[c]	5.83 (2.41)[cd]	3.25 (1.80)[e]
T6-Malathion 0.1%	12.58 (3.54)	0.17 (0.81)[cd]	3.08 (1.75)[d]	5.92 (2.42)[b]	7.67 (2.76)[b]	8.17 (2.85)[b]	6.17 (2.48)[b]
T7-Azadirachtin 1%	12.75 (3.56)	0.25 (0.85)[cd]	2.92 (1.70)[d]	6.92 (2.62)[b]	5.33 (2.30)[c]	5.33 (2.30)[d]	5.08 (2.25)[c]
T8-*B.bassiana* (ITCC 6063) WP 2%	12.67 (3.55)	0 (0.70)[d]	2.67 (1.63)[de]	6.83 (2.61)[b]	4.58 (2.13)[d]	4.50 (2.11)[d]	4.33 (2.08)[d]
T9-Water spray	12.67 (3.55)	3.50 (1.93)[b]	11.25 (3.35)[b]	12.58 (3.54)[a]	15.08 (3.88)[a]	15.17 (3.89)[a]	15.67 (3.95)[a]
T10-Untreated	12.58 (3.54)	11.25 (3.42)[a]	13.83 (3.71)[a]	13.42 (3.66)[a]	15.58 (3.94)[a]	16.08 (4.01)[a]	16.08 (4.01)[a]
CD value	NS	(0.172)	(0.152)	(0.319)	(0.141)	(0.355)	(0.123)

on par. Low efficacy was showed by azadirachtin 1 per cent, dimethoate 0.05 per cent, deltamethrin 0.05 per cent and malathion 0.1 per cent.

The mean number of hoppers sweep net^{-1} increased in all the treatments, except imidacloprid 0.005 per cent and thiamethoxam 0.005 per cent at 10 DAS. They were found to be superior over all other treatments.

Over the post treatment period of 15 days, imidacloprid 0.005 per cent and thiamethoxam 0.005 per cent were found to be the best treatments, recording the low hopper population (0.92 and 1.75 hoppers sweep net^{-1}, respectively) they were significantly different from other treatments. Lambdacyhalothrin 0.005 per cent and dimethoate 0.05 per cent were not statistically different and were the next best treatments. Low efficacy was recorded by the treatments deltamethrin 0.05 per cent, *B. bassiana* (ITCC 6063) WP 2 per cent, azadirachtin 1 per cent and malathion 0.1 per cent. Effect of water spray on hopper population was not significantly different from untreated control.

4.5.2.1.2 Number of Hoppers Panicle^{-1}

At 1 DAS, hopper population was reduced significantly in all the treatments, except in control and there was no much variation between treatments (Table 23).

At 3 DAS, imidacloprid 0.005 per cent and dimethoate 0.05per cent (1.17 and 1.58 mean hoppers panicle^{-1} respectively) significantly controlled the hoppers population in mango trees, superiorly than the other treatments. Malathion 0.1 per cent and azadirachtin 1 per cent showed relatively higher effect on reducing the population of hopper. Deltamethrin 0.05 per cent, thiamethoxam 0.005 per cent *B. bassiana* (ITCC 6063) WP 2 per cent, and lambdacyhalothrin 0.005 per cent were less effective.

Table 23. Efficacy of Safer Molecules for the Management of Mango Hoppers - First spraying

Treatments	*Mean No. of hoppers panicle^{-1}						
	Precount	1 DAS	3 DAS	5 DAS	7 DAS	10 DAS	15 DAS
T1- Lambda cyhalothrin 0.005%	13.92 (3.72)	0.67 (1.07)^{de}	4.33 (2.08)^{c}	7.42 (2.72)^{b}	4.50 (2.11)^{d}	4.25 (2.06)^{e}	3.33 (1.82)^{e}
T2-Thiamethoxam 0.005%	13.92 (3.73)	0.42 (0.95)^{ef}	3.33 (1.82)^{de}	4.25 (2.06)^{d}	3.50 (1.86)^{e}	3.08 (1.75)^{f}	2.08 (1.44)^{f}
T3-Deltamethrin 0.05%	13.75 (3.70)	0.25 (0.85)^{f}	3.92 (1.97)^{cd}	5.25 (2.28)^{c}	6.75 (2.59)^{b}	7.33 (2.70)^{b}	4.33 (2.08)^{d}
T4-Imidacloprid 0.005%	13.83 (3.71)	0.50 (1.00)^{def}	1.17 (1.07)^{g}	2.08 (1.44)^{f}	2.92 (1.70)^{f}	2.17 (1.46)^{g}	1.08 (1.03)^{g}
T5-Dimethoate 0.05%	13.83 (3.71)	1.17 (1.28)^{c}	1.58 (1.25)^{f}	3.08 (1.75)^{e}	5.42 (2.32)^{c}	6.00 (2.44)^{c}	3.33 (1.82)^{e}
T6-Malathion 0.1%	14.08 (3.75)	0.83 (1.14)^{cd}	1.67 (1.28)^{f}	5.17 (2.27)^{c}	6.92 (2.62)^{b}	7.50 (2.73)^{b}	6.58 (2.56)^{b}
T7-Azadirachtin 1%	13.92 (3.73)	0.67 (1.07)^{de}	2.83 (1.68)^{e}	2.83 (1.68)^{e}	4.58 (2.13)^{d}	5.92 (2.43)^{c}	4.58 (2.14)^{cd}
T8-*B.bassiana* (ITCC 6063) WP 2%	14.08 (3.75)	0.33 (0.90)^{ef}	4.08 (2.01)^{c}	4.67 (2.15)^{cd}	5.92 (2.43)^{c}	4.92 (2.21)^{d}	4.83 (2.19)^{c}
T9-Water spray	13.92 (3.73)	4.17 (2.15)^{b}	10.75 (3.27)^{b}	12.33 (3.51)^{a}	15.17 (3.89)^{a}	15.58 (3.94)^{a}	15.83 (3.97)^{a}
T10-Untreated	13.83 (3.71)	11.33 (3.43)^{a}	12.00 (3.46)^{a}	13.08 (3.61)^{a}	15.42 (7.85)^{a}	15.67 (3.95)^{a}	16.50 (4.06)^{a}
CD value	**NS**	**(0.191)**	**(0.154)**	**(0.159)**	**(0.151)**	**(0.148)**	**(0.114)**

At 5 DAS, imidacloprid 0.005 per cent and azadirachtin 1 per cent (2.08 and 2.83 mean hoppers panicle^{-1}, respectively) were superior over all other treatments. Dimethoate 0.05 per cent, thiamethoxam 0.005 per cent and *B. bassiana* (ITCC 6063) WP 2 per cent were the next best treatments. Malathion 0.1 per cent, deltamethrin 0.05 per cent and lambdacyhalothrin 0.005 per cent were less effective.

At 7 DAS, efficacy of treatments did not increase. The lowest population was recorded by imidacloprid 0.005 per cent and thiamethoxam 0.005 per cent with 2.92 and 3.50 mean leaf hoppers panicle^{-1}, respectively. Lambdacyhalothrin 0.005 per cent and azadirachtin 1 per cent gave similar results, followed by dimethoate 0.05 per cent, *B. bassiana* (ITCC 6063) WP 2 per cent, malathion 0.1 per cent and deltamethrin 0.05 per cent, in reducing the hopper population.

The mean number of hoppers panicle^{-1} increased in all the treatments, except imidacloprid 0.005 per cent and thiamethoxam 0.005 per cent at 10 DAS. They were found to be superior over all other treatments.

Analysis of the efficacy of treatments over a period of 15 days showed that, imidacloprid 0.005 per cent and thiamethoxam 0.005 per cent were found to be the best treatments, recording low hopper population (1.08 and 2.08 hoppers panicle^{-1}, respectively). They were significantly different from the other treatments. Lambdacyhalothrin 0.005 per cent and dimethoate 0.05 per cent were statistically not different and were the next best treatments. Low efficacy was recorded by the treatments deltamethrin 0.05 per cent, *B. bassiana* (ITCC 6063) 2 per cent, azadirachtin 1 per cent and malathion 0.1 per cent.

4.5.2.1.3 Number of Hoppers Shoot^{-1}

Precount of mean hopper population was non significant, indicating the population was homogeneous in selected trees.

Hopper population was non significant in all the treated trees except in water spray and untreated 1 DAS (Table 24).

Significant difference was recorded in hopper population at 3 DAS. Imidacloprid 0.005 per cent, deltamethrin 0.05 per cent and thiamethoxam 0.005 per cent recorded low population (2.67, 4.67 and 4.67 hoppers shoot^{-1}, respectively). This was followed by lambdacyhalothrin 0.005 per cent, Dimethoate 0.05 per cent and *B. bassiana* (ITCC 6063) WP 2 per cent. Hopper population was high in malathion 0.1 per cent and azadirachtin 1 per cent.

At 5 DAS, imidacloprid 0.005 per cent and thiamethoxam 0.005 per cent (2.00 and 3.00 hoppers shoot^{-1}, respectively) were superior over other treatments. Dimethoate 0.05 per cent and lambdacyhalothrin 0.005 per cent were statistically on par. *B. bassiana* (ITCC 6063) WP 2 per cent and deltamethrin 0.05 per cent were on par with 4.34 hoppers shoot^{-1}.

At 7 DAS, the lowest population was recorded by imidacloprid 0.005 per cent, thiamethoxam 0.005 per cent and lambdacyhalothrin 0.005 per cent with 0.67, 1.67 and 2.34 hoppers shoot^{-1}, respectively. Dimethoate 0.05 per cent, *B. bassiana* (ITCC 6063) WP 2 per cent and deltamethrin 0.05 per cent showed the same efficacy against hoppers.

The mean number of hoppers shoot^{-1} considerably decreased in all the treatments at 10 DAS. Imidacloprid 0.005 per cent, thiamethoxam 0.005 per cent and lambdacyhalothrin 0.005 per cent were the best treatments in controlling the hoppers with 0.34, 1 and 1.67 hoppers shoot^{-1}, respectively. Lambdacyhalothrin 0.005 per cent and *B. bassiana* (ITCC 6063) WP 2 per cent were also effective. Remaining treatments did not show much variation in their efficacy.

Table 24. Efficacy of Safer Molecules for the Management of Mango Hoppers - First spraying

Treatments	*Mean No. of hoppers shoot^{-1}						
	Precount	1 DAS	3 DAS	5 DAS	7 DAS	10 DAS	15 DAS
T1- Lambda cyhalothrin 0.005%	9 (2.99)	0 (1)	5.34 (2.3)^{de}	3.67 (1.91)^{cd}	2.34 (1.68)^{d}	1.67 (1.46)^{e}	1.34 (1.34)^{e}
T2-Thiamethoxam 0.005%	8.67 (2.95)	0 (1)	4.67 (2.15)^{e}	3 (1.71)^{d}	1.67 (1.46)^{d}	1 (1.22)^{e}	0.34 (0.87)^{f}
T3-Deltamethrin 0.05%	9 (2.99)	0 (1)	4.67 (2.15)^{e}	4.34 (2.07)^{c}	3.67 (2.03)^{c}	3.34 (1.95)^{cd}	2.34 (1.67)^{cd}
T4-Imidacloprid 0.005%	9.67 (3.1)	0 (1)	2.67 (1.62)^{f}	2 (1.41)^{e}	0.67 (1.05)^{e}	0.34 (0.87)^{f}	0.34 (0.87)^{f}
T5-Dimethoate 0.05%	10.34 (3.21)	0 (1)	5.34 (2.30)^{de}	3.67 (1.91)^{cd}	4 (2.11)^{c}	4 (2.11)^{bc}	3.34 (1.95)^{bc}
T6-Malathion 0.1%	9.34 (3.05)	0 (1)	6.67 (2.59)^{c}	5.67 (2.37)^{b}	5.34 (2.41)^{b}	4.67 (2.27)^{b}	4 (2.11)^{b}
T7-Azadirachtin 1%	9.67 (3.1)	0 (1)	6.67 (2.59)^{c}	6 (2.45)^{b}	4.67 (2.27)^{bc}	3.67 (2.04)^{bcd}	3 (1.87)^{bcd}
T8-*B.bassiana* (ITCC 6063) WP 2%	8.67 (2.94)	0 (1)	5.67 (2.37)^{cd}	4.34 (2.07)^{c}	3.67 (2.04)^{c}	2.67 (1.77)^{d}	2 (1.58)^{d}
T9-Water spray	9.67 (3.1)	0 (1)	8.67 (2.95)^{b}	9.34 (3.05)^{a}	9.67 (3.18)^{a}	10 (3.24)^{a}	10.34 (3.30)^{a}
T10-Untreated	9.67 (3.1)	9.45 (3.26)	10.34 (3.21)^{a}	10.67 (3.26)^{a}	11.34 (3.43)^{a}	11.34 (3.43)^{a}	12 (3.53)^{a}
CD value	**NS**	**(0.319)**	**(0.213)**	**(0.246)**	**(0.298)**	**(0.297)**	**(0.311)**

Over a period of 15 days, imidacloprid 0.005 per cent and thiamethoxam 0.005 per cent were the best treatments, recording low hopper population (0.34 hoppers shoot^{-1}). Lambdacyhalothrin 0.005 per cent, *B. bassiana* (ITCC 6063) WP 2 per cent and deltamethrin 0.05 per cent were the next best treatments with 1.34, 2.00 and 2.34 hoppers shoot^{-1}, respectively. Low efficacy was recorded in azadirachtin 1 per cent and dimethoate 0.05 per cent treated trees.

4.5.2.2 Second Spraying

4.5.2.2.1 Number of Hoppers Sweep Net^{-1}

Population of hopper was non significant among the treatments after 1 DAS, except in case of water spray and untreated trees (Table 25).

Significant difference in the population was observed at 3 DAS. Imidacloprid 0.005 per cent was the superior treatment with 2.58 hoppers sweep net^{-1}. This was followed by thiamethoxam 0.005 per cent, dimethoate 0.05 per cent and malathion 0.1 per cent with 4.00, 4.17 and 4.08 hoppers sweep net^{-1}, respectively. Deltamethrin 0.05 per cent, *B. bassiana* (ITCC 6063) WP 2 per cent and lambdacyhalothrin 0.005 per cent treated trees showed less efficacy on hopper population.

At 5 DAS, imidacloprid 0.005 per cent (1.75 mean hoppers sweep net^{-1}) was superior to the other treatments. Thiamethoxam 0.005 per cent and dimethoate 0.05 per cent recorded same results and did not differ statistically. Lmbdacyhalothrin 0.005 per cent, deltamethrin 0.05 per cent, *B. bassiana* (ITCC 6063) WP 2 per cent and malathion 0.1 per cent were the next best treatments.

Population of hoppers was found reduced in treated trees at 7 DAS. The lowest population was recorded by imidacloprid 0.005 per cent with 1.00 hoppers sweep net^{-1}. This was followed by thiamethoxam 0.005 per cent and azadirachtin 1 per cent with 2.75 and 2.67 mean leaf hoppers sweep net^{-1}, respectively and they were

Table 25. Efficacy of Safer Molecules for the Management of Mango Hoppers - second spraying

Treatments	*Mean No. of hoppers sweep net^{-1}						
	Precount	1 DAS	3 DAS	5 DAS	7 DAS	10 DAS	15 DAS
T1- Lambda cyhalothrin 0.005%	10.42 (3.22)	0 $(0.70)^{c}$	5.17 $(2.27)^{cd}$	5.08 $(2.25)^{d}$	3.50 $(1.86)^{bc}$	2.67 $(1.63)^{e}$	2.58 $(1.60)^{d}$
T2-Thiamethoxam 0.005%	9.75 (3.12)	0.08 $(0.76)^{c}$	4.00 $(1.99)^{f}$	3.33 $(1.82)^{e}$	2.75 $(1.65)^{de}$	1.67 $(1.28)^{f}$	1.42 $(1.18)^{e}$
T3-Deltamethrin 0.05%	10.75 (3.27)	0.17 $(0.81)^{c}$	4.67 $(2.15)^{de}$	4.50 $(2.12)^{d}$	3.25 $(1.80)^{bc}$	3.17 $(1.77)^{de}$	2.83 $(1.68)^{d}$
T4-Imidacloprid 0.005%	9.80 (3.14)	0.17 $(0.80)^{c}$	2.58 $(1.60)^{g}$	1.75 $(1.31)^{f}$	1.00 $(0.99)^{f}$	1.08 $(1.03)^{g}$	0.33 $(0.56)^{f}$
T5-Dimethoate 0.05%	10.33 (3.21)	0.08 $(0.80)^{c}$	4.17 $(2.04)^{ef}$	2.83 $(1.68)^{e}$	3.33 $(1.82)^{bc}$	3.42 $(1.84)^{d}$	2.42 $(1.55)^{d}$
T6-Malathion 0.1%	10.50 (3.24)	0.08 $(0.76)^{c}$	4.08 $(2.01)^{ef}$	5.17 $(2.27)^{d}$	3.75 $(1.93)^{b}$	4.33 $(2.08)^{c}$	5.00 $(2.23)^{b}$
T7-Azadirachtin 1%	9.33 (3.05)	0.17 $(0.76)^{c}$	5.67 $(2.37)^{c}$	6.33 $(2.51)^{c}$	2.67 $(1.63)^{e}$	3.42 $(1.84)^{d}$	2.67 $(1.63)^{d}$
T8-*B.bassiana* (ITCC 6063) WP 2%	9.67 (3.12)	0.17 $(0.81)^{c}$	5.08 $(2.25)^{cd}$	4.75 $(2.17)^{d}$	3.17 $(1.77)^{cd}$	2.67 $(1.63)^{e}$	3.50 $(1.86)^{c}$
T9-Water spray	10.17 (3.18)	1.83 $(1.52)^{b}$	12.17 $(3.48)^{b}$	12.92 $(3.59)^{b}$	12.17 $(3.48)^{a}$	12.08 $(3.47)^{b}$	12.17 $(3.48)^{a}$
T10-Untreated	10.75 (3.27)	14.58 $(3.88)^{a}$	13.67 $(3.69)^{a}$	15.58 $(3.94)^{a}$	12.67 $(3.55)^{a}$	13.42 $(3.66)^{a}$	12.67 $(3.55)^{a}$
CD value	**NS**	**(0.174)**	**(0.143)**	**(0.166)**	**(0.141)**	**(0.169)**	**(0.154)**

on par. *B. bassiana* (ITCC 6063) WP 2 per cent, lambdacyhalothrin 0.005 per cent, deltamethrin 0.05 per cent and dimethoate 0.05 per cent treated trees statistically gave similar results.

The mean number of hoppers sweep net^{-1} at 10 DAS, showed that imidacloprid 0.005 per cent and thiamethoxam 0.005 per cent were superior to all other treatments (1.08 and 1.67 mean hoppers sweep net^{-1}, respectively). Similar results were observed in lambdacyhalothrin 0.005 per cent and *B. bassiana* (ITCC 6063) WP 2 per cent treated trees. Low efficacy was recorded by azadirachtin 1 per cent and malathion 0.1 per cent.

Over the post treatment period of 15 days, imidacloprid 0.005 per cent and thiamethoxam 0.005 per cent were found to be best treatments in recording low hopper population (0.33 and 1.42 hoppers sweep net^{-1}, respectively). They were significantly different from other treatments. Lambdacyhalothrin 0.005 per cent, dimethoate 0.05 per cent, deltamethrin 0.05 per cent and azadirachtin 1 per cent were statistically not different in their efficacy against hoppers. Low efficacy was recorded by the treatments *B. bassiana* (ITCC 6063) 2 per cent and malathion 0.1 per cent.

4.5.2.2.2 Number of Hoppers Panicle^{-1}

Hopper population suddenly decreased at 1 DAS in all the treatments imposed on the selected trees, and the results were similar statistically (Table 26).

Efficacy of treatments was recorded at 3 DAS, imidacloprid 0.005 per cent, malathion 0.1 per cent and thiamethoxam 0.005 per cent (1.83, 3.17 and 3.17 hoppers panicle^{-1}, respectively) significantly controlled the hopper population in mango trees, than other treatments. Deltamethrin 0.05 per cent and azadirachtin 1 per cent recorded similar results and they did not differ statistically, with 3.67 and 3.75 mean hoppers panicle^{-1}. Dimethoate 0.05 per cent was on par with these two treatments.

However, lambdacyhalothrin 0.005 per cent and *B. bassiana* (ITCC 6063) WP 2 per cent also reduced the hopper population considerably (4.33 hoppers panicle^{-1}).

At 5 DAS, imidacloprid 0.005 per cent with 2.08 hoppers panicle^{-1} was superior to other treatments. Dimethoate 0.05 per cent and thiamethoxam 0.005 per cent did not differ statistically, with 2.50 and 2.67 hoppers panicle^{-1}. Azadirachtin 1 per cent, *B. bassiana* (ITCC 6063) WP 2 per cent and deltamethrin 0.05 per cent were on par with each other (3.83, 4.17 and 4.17 hoppers panicle^{-1}). Low efficacy was recorded by lambdacyhalothrin 0.005 per cent, with 5.17 hoppers panicle^{-1}.

At 7 DAS, the efficacy of treatments was pronounced, The lowest population was recorded by imidacloprid 0.005 per cent, deltamethrin 0.05 per cent, azadirachtin 1 per cent and thiamethoxam 0.005 per cent with 1.42, 2.67, 2.67 and 2.75 leaf hoppers panicle^{-1}, respectively. Lambdacyhalothrin 0.005 per cent, *B. bassiana* (ITCC 6063) WP 2 per cent and dimethoate 0.05 per cent did not differ statistically and were on par (3.08, 3.17 and 3.17 hoppers panicle^{-1}, respectively).

The number of hoppers panicle^{-1} lowered in the case of imidacloprid 0.005 per cent and thiamethoxam 0.005 per cent with 0.92 and 1.42 hoppers panicle^{-1}, they were found to be significantly superior to the other treatments at 10 DAS. Results of deltamethrin 0.05 per cent, azadirachtin 1 per cent and *B. bassiana* (ITCC 6063) WP 2 per cent with 2.92, 3.00 and 2.67 hoppers panicle^{-1}, respectively were on par with lambdacyhalothrin 0.005 per cent (2.58 hoppers panicle^{-1}). Treatments dimethoate 0.05 per cent and malathion 0.1 per cent also were effective against the hopper, with 3.67 and 3.25 hoppers panicle^{-1} respectiveely.

At the end of 15 DAS, imidacloprid 0.005 per cent and thiamethoxam 0.005 per cent were found to be best treatments in recording low hopper population (0.25 and 1.33 hoppers panicle^{-1}, respectively). They were significantly different from the other treatments. Deltamethrin 0.05 per cent, azadirachtin 1 per cent and dimethoate 0.05 per cent (2.67, 2.33 and 2.87 hoppers panicle^{-1}, respectively) were statistically

Table 26. Efficacy of Safer Molecules for the Management of Mango Hoppers - second spraying

Treatments	*Mean No. of hoppers panicle^{-1}						
	Precount	1 DAS	3 DAS	5 DAS	7 DAS	10 DAS	15 DAS
T1- Lambda cyhalothrin 0.005%	9.17 (3.02)	2.17 (1.46)^{e}	4.33 (2.08)^{b}	5.17 (2.27)^{c}	3.08 (1.75)^{bcd}	2.58 (1.60)^{d}	2.17 (1.63)^{d}
T2-Thiamethoxam 0.005%	8.90 (3.00)	1.50 (1.22)^{fg}	3.17 (1.77)^{d}	2.67 (1.63)^{f}	2.75 (1.65)^{cd}	1.42 (1.18)^{e}	1.33 (1.35)^{e}
T3-Deltamethrin 0.05%	9.10 (3.01)	1.83 (1.35)^{ef}	3.67 (1.91)^{c}	4.17 (2.04)^{de}	2.67 (1.63)^{d}	2.92 (1.70)^{cd}	2.67 (1.77)^{bcd}
T4-Imidacloprid 0.005%	9.15 (3.02)	1.42 (1.18)^{g}	1.83 (1.35)^{e}	2.08 (1.44)^{g}	1.42 (1.18)^{e}	0.92 (0.95)^{f}	0.25 (0.85)^{f}
T5-Dimethoate 0.05%	10.08 (3.10)	2.67 (1.63)^{d}	3.42 (1.84)^{cd}	2.50 (1.58)^{f}	3.17 (1.77)^{bc}	3.25 (1.79)^{bc}	2.67 (1.77)^{bcd}
T6-Malathion 0.1%	9.50 (3.08)	2.67 (1.63)^{d}	3.17 (1.77)^{d}	4.42 (2.10)^{d}	3.42 (1.84)^{b}	3.67 (1.91)^{b}	3.25 (1.93)^{b}
T7-Azadirachtin 1%	9.15 (3.01)	2.83 (1.68)^{d}	3.75 (1.93)^{c}	3.83 (1.95)^{e}	2.67 (1.63)^{d}	3.00 (1.73)^{cd}	2.33 (1.68)^{cd}
T8-*B.bassiana* (ITCC 6063) WP 2%	9.17 (3.02)	3.33 (1.82)^{c}	4.33 (2.08)^{b}	4.17 (2.04)^{de}	3.17 (1.77)^{bc}	2.67 (1.63)^{cd}	2.83 (1.82)^{bc}
T9-Water spray	11.42 (3.37)	6.00 (2.40)^{b}	12.42 (3.52)^{a}	13 (3.60)^{b}	12.25 (3.49)^{a}	12.17 (3.48)^{a}	11.75 (3.49)^{a}
T10-Untreated	11.58 (3.40)	12.00 (3.53)^{a}	13 (3.60)^{a}	14.75 (3.83)^{a}	12.67 (3.55)^{a}	12.25 (3.49)^{a}	12.50 (3.60)^{a}
CD value	**NS**	**(0.136)**	**(0.120)**	**(0.122)**	**(0.141)**	**(0.170)**	**(0.166)**

on par with lambdacyhalothrin 0.005 per cent and were the next best treatments. Deltamethrin 0.05 per cent, *B. bassiana* (ITCC 6063) WP 2 per cent and malathion 0.1 per cent were also effective.

4.5.2.2.3. Number of Hoppers Shoot^{-1}

Population of hoppers was non significant in precount observations on the shoots.

Hopper population was non significant in all the treated trees except in water spray and untreated control 1 DAS (Table 27).

Significant difference was recorded in hopper population at 3 DAS. Imidacloprid 0.005 per cent and thiamethoxam 0.005 per cent recorded low population (1.67 and 2.34 hoppers shoot^{-1}, respectively) which were on par. *B. bassiana* (ITCC 6063) WP 2 per cent and deltamethrin 0.05 per cent were on par with 2.67 and 3 hoppers shoot^{-}1, respectively. This was followed by lambdacyhalothrin 0.005 per cent, Dimethoate 0.05 per cent, malathion 0.1 per cent and azadirachtin 1 per cent in reducing the hopper population compared to control.

At 5 DAS, imidacloprid 0.005 per cent and thiamethoxam 0.005 per cent (0.67 and 1.67 hoppers shoot^{-1}, respectively) were superior over other treatments. lambdacyhalothrin 0.005 per cent, Dimethoate 0.05 per cent, *B. bassiana* (ITCC 6063) WP 2 per cent, deltamethrin 0.05 per cent, azadirachtin 1 per cent and malathion 0.1 per cent were statistically on par.

At 7 DAS, imidacloprid 0.005 per cent treated trees hopper population was nil and found superior to other treatments. Thiamethoxam 0.005 per cent and deltamethrin 0.05 per cent (0.67 and 1 hoppers shoot^{-1}, respectively) were on par and recorded as next best treatments. Followed by lambdacyhalothrin 0.005 per cent, azadirachtin 1 per cent, dimethoate 0.05 per cent and *B. bassiana* (ITCC 6063) WP 2 per cent in their efficacy compared to control.

The mean number of hoppers shoot^{-1} considerably decreased in all the treatments at 10 DAS. Imidacloprid 0.005 per cent and thiamethoxam 0.005 per cent were the best treatments, recording zero hopper population (0 hoppers shoot^{-1}). Deltamethrin 0.05 per cent, lambdacyhalothrin 0.005 per cent, *B. bassiana* (ITCC 6063) 2 per cent and azadirachtin 1 per cent were the next best treatments with 0.67, 1, 1.34 and 1.34 hoppers shoot^{-1}, respectively compared to control.

Over a period of 15 days of post treatment imidacloprid 0.005 per cent, thiamethoxam 0.005 per cent recorded zero hopper population and were superior to other treatments. Lambdacyhalothrin 0.005 per cent and deltamethrin 0.05 per cent were on par with 0.34 hoppers shoot^{-1}. Azadirachtin 1 per cent, *B. bassiana* (ITCC 6063) WP 2 per cent, dimethoate and malathion 0.1 per cent were in the above order to control the hoppers.

Table 27. Efficacy of Safer Molecules for the Management of Mango Hoppers - Second spraying

Treatments	*Mean No. of hoppers shoot^{-1}						
	Precount	1 DAS	3 DAS	5 DAS	7 DAS	10 DAS	15 DAS
T1- Lambda cyhalothrin 0.005%	5.67 (2.37)	0 (1.00)[c]	3.67 (1.92)[b]	2.34 (1.67)[bc]	1.34 (1.34)[cd]	1 (1.18)[c]	0.34 (0.87)[de]
T2-Thiamethoxam 0.005%	5 (2.22)	0 (1.00)[c]	2.34 (1.521)[de]	1.67 (1.46)[c]	0.67 (1.05)[de]	0 (0.70)[d]	0 (0.70)[e]
T3-Deltamethrin 0.05%	5.34 (2.3)	0 (1.00)[c]	3 (1.73)[bcd]	2.67 (1.78)[b]	1 (1.18)[d]	0.67 (0.99)[cd]	0.34 (0.87)[de]
T4-Imidacloprid 0.005%	5.34 (2.3)	0 (1.00)[c]	1.67 (1.27)[e]	0.67 (1.05)[d]	0 (0.701)[e]	0 (0.70)[d]	0 (0.70)[e]
T5-Dimethoate 0.05%	5 (2.22)	0 (1.00)[c]	3.67 (1.91)[b]	3 (1.87)[b]	2.34 (1.68)[bc]	2 (1.59)[b]	1.34 (1.34)[bc]
T6-Malathion 0.1%	5.34 (2.3)	0 (1.00)[c]	3.34 (1.82)[bc]	2.67 (1.77)[b]	2.67 (1.78)[b]	2.34 (1.68)[b]	1.67 (1.46)[b]
T7-Azadirachtin 1%	5.34 (2.3)	0 (1.00)[c]	3.34 (1.82)[bc]	3.34 (1.95)[b]	2 (1.58)[bc]	1.34 (1.35)[bc]	0.67 (1.05)[cde]
T8-*B.bassiana* (ITCC 6063) WP 2%	5.34 (2.29)	0 (1.00)[c]	2.67 (1.62)[cd]	2.67 (1.77)[b]	2.34 (1.67)[bc]	1.34 (1.34)[bc]	1 (1.80)[bcd]
T9-Water spray	5.67 (2.37)	2.7 (1.92)[b]	5.67 (2.37)[a]	5.34 (2.43)[a]	5.67 (2.48)[a]	6 (2.54)[a]	6.34 (2.64)[a]
T10-Untreated	5.34 (2.3)	5.34 (2.3)[a]	6 (2.44)[a]	6 (2.54)[a]	6 (2.54)[a]	6 (2.54)[a]	6 (2.54)[a]
CD value	**NS**	**(0.319)**	**(0.263)**	**(0.281)**	**(0.351)**	**(0.402)**	**(0.402)**

5. DISCUSSION

Mango is one of the most popular seasonal fruit crops of the tropics and subtropics. Its popularity is due to its excellent flavour, delicious taste, and high nutritive value, being rich in vitamins A and C (Salunkhe and Desai, 1994). There are many constraints in mango production. Among them insect pests are the major threat, causing great loss to mango growers. Mango hoppers are dreadful, causing serious damage. In severe cases, up to 20 to100 per cent loss of inflorescence occurred (Sohi and Sohi, 1990). Shoot webber, earlier, was a minor pest, but now a days it is spreading rapidly, causing damage up to 35 per cent (Lakshmi *et al*., 2011). Mango growers adopt chemical measures against shoot webber and hoppers, through insecticide cover sprays. Injudicious use of toxic chemicals causes health issues and pesticide residue problems. Current recommendation for mango shoot webber and hoppers includes the use of conventional organophosphate insecticide, malathion and dimethoate, respectively (KAU, 2011). Present investigation was carried out to standardize the use of new generation insecticides that are safe, target specific, less persistent and required in low dosages.

In order to develop suitable management strategy, it is essential to understand the changing pest status over the time. Knowledge on availability of host and climatic changes over the season is necessary to develop a suitable management strategy. Accordingly, a survey was conducted in the homesteads of Kalliyoor Panchayath and the Instructional Farm, Vellayani during 2014-16 to document the pest incidence, population dynamics and level of damage caused. Experiments were carried out to evaluate the efficacy and to standardize the use of new generation molecules in the Instructional Farm, College of Agriculture, Vellayani and the College of Agriculture, Padanakkad. The results of the study are discussed below.

5.1 MANGO SHOOT WEBBER

5.1.1 Documentation of Shoot Webber Incidence

Mango shoot webber incidence was documented from two selected locations of Thiruvanathapuram district during 2015-16.

Survey conducted revealed the incidence of *Orthaga exvinacea* Hampson in mango. Larvae were found to be pale greenish in colour with brown head. Pupa was dark brown and pupation occurred within the webbed foliage and in soil. The larvae webbed the adjacent leaves and were feeding on chlorophyll content initially. Later instars caused heavy damage by complete skeletonization of the leaves. The extensive damage could be seen in terms of terminal shoot webs with dried leaves, as reported by Kannan and Rao (2006).

5.1.2 Population dynamics of Mango Shoot webber

It is important to know the pest status during the different growth phases of the mango plant, since heavy damage results under neglected management. Due to heavy damage to foliage it reduces the photosynthesis and causes indirect damage to the plant. In the present study, the population of webber larvae was found to be fluctuating throughout the observation period (Table 6).

Shoot webber damage was observed throughout the year, except in July - August of 2015 in Kalliyoor Panchayath. The incidence of shoot webber caterpillar started in I FN of September 2015 with 4.45 webs tree^{-1}, 3.65 larvae web^{-1}and 5 damaged leaves web^{-1}. The damage was in its peak during the I FN of January 2016 with 25.6 webs tree^{-1}, 6.33 larvae composite web^{-1} and 103.6 damaged leaves web^{-1}. The damage of shoot webber was the minimum during the I FN of July 2015 with 2.80 webs tree^{-1}, 2.30 larvae composite web^{-1} and 25.60 damaged leaves web^{-1}.

Study was conducted on population dynamics of the pest at the Instructional Farm, Vellayani. The pest activity was recorded throughout the year, except in the months of July-August 2015 (Table 7). Incidence of caterpillars was recorded during the I FN of September 2015 onwards with 2.1 webs tree^{-1}, 1.2 larvae web^{-1}, 6.25 damaged leaves web^{-1}. Population reached the peak during the II Fortnight of March 2016 with 22.25 webs tree^{-1}, 4 larvae per composite web and 73.25 damaged leaves web^{-1}.

In the present study shoot webber activity was observed throughout the year, except in the month of July and August. However, Dash and panda (1997) observed pest activity throughout the year in Bhubaneshwar. The absence of shoot webber during July August in the present study might be due to heavy rains during July-August. Webber caterpillars were washed out completely in both the locations selected for the study. David and Kumaraswami (1988) documented the shoot webber activity during February - October in Tamil Nadu, which was slightly different from the present findings. Incidence of shoot webber in the present investigation is slightly different from the findings of Srivastava and Verghese (1983). They reported that the incidence of shoot webber started in the month of June in Uttar Pradesh. Dash and Panda (1997) observed the peak incidence of mango shoot webber during February - April at Bhubaneswar in Orissa, which is almost similar to the present findings. Bharatbabu (1999) recorded the incidence of shoot webber during both vegetative and reproductive phases of the crop, as in the present study.

The results on population dynamics were similar in both the locations, but there was difference in the infestation level. It could be due to difference in the age of the plants and varieties selected for the survey. In the Instructional Farm, the plants were relatively young (8-10 years old), compared to the plants in the homesteads of

Kalliyoor Panchayath (18-25 years old). This might be the reason for the low infestation level of webber in the Instructional Farm. In present study from July to August, because of heavy rains, the webber caterpillar and webs in the mango trees were seen washed out.

5.1.3 Reaction of Mango Varieties Against Shoot Webber Attack

The infestation of *O. exvinacea* starts from June and continues up to December and heavy infestation is observed in September (Reddy, 2013). In the present study ten mango varieties were observed for natural infestation of shoot webber. Observations were taken during both vegetative and reproductive phases. All the selected mango varieties were found to be susceptible to shoot webber attack, except the variety Vellari Varikka.

The shoot webber infestation in different varieties for a period of four months (from December to March 2015) ranged from 0 to 17.33 webs tree^{-1} (Table 8). The highest damage was recorded in the varieties Kalappadi (17.33 webs tree^{-1}), Kundalatha (15.79 webs tree^{-1}), Kottukonam (15.06 webs tree^{-1}) and Alphonso (14.78 webs tree^{-1}). Less foliage damage was observed in the varieties Banganapally (5.10 webs tree^{-1}) and Prior (8.07 webs tree^{-1}). Leaf morphology, texture and biochemical constituents can be the reason for non-preference of shoot webber for these varieties. Defense mechanisms involved diverse array of phytochemicals which acted as repellents, phagodeterrents, oviposition deterrents *etc.*, exhibiting resistance. Plants use many biochemical components to defend against hundreds of pests in their environment (Bell and Stipanovic *et al.*, 2000).

5.1.4 Correlation Studies of Shoot Webber Incidence with Weather Parameters

Weather is one of the important factors that influence the fluctuations in shoot webber population (ICAR, 2014). Attempts were carried out to study the population dynamics of the pest in relation to weather parameters (Table 9 and 10). During

2015-2016, strong positive correlation was observed between the population of *O. exvinacea* with maximum temperature and morning relative humidity. Minimum temperature, evening relative humidity, rain fall and sunshine hours did not show any influence on the webber population. The present findings showed similar results with respect to the influence of weather parameters on pest activity in both Kalliyoor Panchayath and the Instructional Farm, Vellayani. Same weather parameters prevailed in both the locations, since the places were adjacent.

The population of *O. exvinacea* showed a significant positive correlation with maximum temperature and morning Relative Humidity. The present findings are contradictory to the works of Verma and Singh (2010) who observed non significant relation of shoot webber with maximum temperature, minimum temperature, rainfall and relative humidity, Indicating that weather factors might not have direct influence on pest activity in mango orchard. Central Institute for Subtropical Horticulture (ICAR, 2014) reported that during rainy season, the pest status might increase because of prevailing favourable weather conditions. It might be due to variation in climatic conditions like intensity of rainfall prevailed in that area during the period of study..

5.2 MANGO HOPPERS

5.2.1 Documentation of Mango Hoppers

Mango hoppers were reported from both the locations selected for the study. During the survey, four species were recorded and identified as *Idioscopus nitidulus* Walker, *Idioscopus clypealis* Letheirry, *Idioscopus nagpurensis* Pruthi and *Amritodus* sp. All the four species were found damaging the mango tree during the flowering and fruit setting period. *Amritodus* sp. was light brown and the biggest compared to the other species of hoppers recorded, with two spots on the scutellum (Plate 3a). Adults were seen resting on the tree trunk and residing in cracks and crevices after fruit set. *I. nitidulus* was light brown and smaller, with three spots on the scutellum. The distinguishing character of *I. nitidulus* was the presence of prominent white band across the wings (Plate 3c). *I. clypealis* was light brown in color and was smaller in size. It had two spots on the scutellum and varying dark spots on the vertex (Plate 3b). *I. nagpurensis* was the smallest among the mango hoppers and light brown in color, with two spots on the scutellum (Plate 3d). *I. nitidulus*, *I. clypealis* and *I. nagpurensis* were found feeding and resting on leaves, inflorescence and young shoots. The adult laid eggs on ventral side of leaf, resulting in splitting of mid rib. Soon after hatching, the majority of nymphs crawled to the panicles and leaves. Less population was observed on the shoots. The nymphs and adults of all the hopper species were collectively sucking cell sap from the succulent tissues. Feeding habit of hoppers resulted in curling, deshaping, and drying of leaves. The inflorescence exhibited drying and withering of panicles. In severe cases, fruit setting was greatly affected. Immature fruit drop was observed after the hoppers fed on panicles. Similar findings on activity, symptoms and damage caused due to hopper incidence were made by Kumar (2006) and Manjunatha (2015). Due to the damage, honeydew excretion was common in heavily infested trees. As a result sooty mold developed on lower canopy leaves. Two to three generations of hoppers were observed during the flowering to fruit set in mango. This resulted in heavy loss to the production of mango. Late attack of these hoppers damaged the crop in full bloom and fruit set stages (pea and marble), causing large scale dropping of mango inflorescence and newly set fruits. Stone formation stage witnessed appearance of black spots or whole fruit blackening which deteriorated the quality of mango fruits.

5.2.2 Population Dynamics of Mango Hoppers

Mango hoppers incidence was the most abundant during the reproductive phase of the crop. Occurrence of hoppers in mango started when panicle emergence was seen, since they preferred inflorescence and tender leaves for breeding. Nymphal instars were seen only on newly emerged twigs and inflorescence. They were feeding by crawling from one part to other part. Their incidence in the offseason was very less and was absent in many trees selected for the study. Similar reports were made by Rahman and Singh (2004). They recorded the incidence of hoppers when panicle emergence started. Population of hoppers declined after fruit maturation, as observed in the present study.

Incidence of hoppers (2nd and 3rd instar) started in Kalliyoor Panchayath during I FN of December 2015, but the population was low. It coincided with panicle emergence. Similarly, Viraktamath *et al*. (1994), Dalvi and Dumbre (1994) and Talpur *et al.* (2002) observed the incidence of hoppers (nymphal instars) during the flowering season.

Presence of hoppers was observed from December to July. The hopper activity was confined to the reproductive phase of the tree. During this period they passed 2-3 generations. Dalvi and Dumbre (1994) also observed that the *I. nitidulus* and *Amritodus sp.* passed three generations and bred both during vegetative phase and reproductive phase.

During the off season, hoppers were practically absent. After fruit set, the hopper population declined suddenly, during II FN of May to II FN of June 2015. Their peak activity was observed in I FN of April 2015 at the time of fruit set (12.97 hoppers panicle^{-1}, 16.35 hoppers sweep net^{-1}). Kudugamage *et al*. (2001) also reported that the population of mango hoppers was in the peak during March-April.

Population of mango hoppers was practically absent in the Instructional Farm, Vellayani. Low population of *Amritodus* sp. was found during the flowering period but not on all the trees. Number of hoppers per panicle was negligible (3 hoppers panicle^{-1}, 4 hoppers sweep net^{-1} was observed as peak population). These hoppers did not cause any serious injury to the mango tree. After the flowering period, hoppers were completely absent in the orchard. It may be because the trees selected for the study were of 8 - 9 years only and the orchard was well maintained. In the old orchards of the Instructional Farm, Vellayani also hoppers were absent, as they were protected from pest and disease incidence by proper management measures. Jhala *et al*. (1988) also observed that the abundance of hoppers was more in old and neglected orchards, compared to new and protected orchards.

The hopper population at Padanakkad mango orchard showed the incidence during I FN of December 2015 with 7.47 hoppers panicle^{-1}. Peak incidence was recorded in II FN of February 2016 with 18.67 hoppers panicle^{-1}. After fruit set, the population had decreasing trend. Similar results were reported by Srivastava (1998), Babu *et al*. (2001) and Kumar *et al*. (2002). They observed higher population build up and rapid multiplication of the pest during the flower initiation and full bloom stages. The lowest population was recorded during the II FN of April 2016 (2.90 hoppers panicle^{-1}). The hopper population in Padanakkad was comparatively more than that of Kalliyoor Panchayath. The high density of planting in the orchards at Padanakkad compared to the homestead condition in Kalliyoor Panchayath might be the reason for the high level incidence of hoppers at Padanakkad. Moreover the orchard was not protected from the attack of pests and diseases.

5.2.3 Hopper Population Monitored Through Yellow Sticky Trap

Use of sticky traps for monitoring and managing the sucking pest is a common method in Agriculture. Atakan and Canhilall (2004) evaluated the use of sticky traps for monitoring and managing cotton pests setting at varying heights. Here efficacy of sticky traps were tested for attracting the mango hoppers at Balaramapuram in Thiruvananthapurm district (from November 2015 to March 2016). Since hoppers are tiny insects it is difficult to recognize them in the initial stage. By using yellow sticky traps incidence of hopper could be detected early. Hopper incidence was observed in month of November 2015. Initially, less hoppers were trapped. Later, from the month of December 2015 to March 2016 more number of hoppers were trapped (Figure 1). During the I FN of March 2016 the highest number of hoppers was trapped (286. 90 hoppers sticky trap^{-1}). After April 2016 the hopper population declined considerably. After May 2016, due to the non availability of flowers the population was not recorded in the sticky trap. Saeed *et al*. (2013) also reported that mango hoppers were highly attracted in yellow sticky traps, among the different colors used for trapping the hoppers. They recorded the peak population of hoppers during April-May. The variation might be due to the different climatic conditions in the location.

Apart from attracting hoppers on sticky traps it was also observed that different natural enemies and beneficial insects like pollinators also got attracted towards sticky traps though the count was very low. It was the major disadvantage in recommending the sticky traps for the management of hoppers in mango.

5.2.4 Reaction of Mango cultivars Against Hoppers Attack

Mango hoppers attack the crop mainly during the flowering season (Kumar *et al*., 2005). Ten mango varieties were studied for natural infestation of hoppers. Observations were taken during the flowering season. All the varieties were found susceptible. Variety Kottukonam and Vellari Varikka were found to be moderately tolerant for the hopper attack. Leaf tenderness, flowering habit and biochemical properties could be the reasons. Manjunatha (2015) reported that phenol content was inversely related to the hopper incidence. High reducing and non reducing sugars were observed in susceptible varieties. Variety Alphonso was highly susceptible for the hopper attack, followed by Banganapalli, Banglora and Neelum. Viraktamath *et al*. (1996) showed that Alphonso and Neelum ranked 1st in susceptibility to hoppers attack, which is in agreement with the present studies. Similar findings were reported by Singh and Singh (2007). They found that Neelum was highly susceptible among the 23 varieties selected for the screening mango cultivars. The present findings were in agreement with the studies of Manjunatha (2015), showing that Alphonso and Neelum were highly susceptible to the hopper attack.

5.2.5 Species Composition of Mango hoppers

Four different species were documented from Kalliyoor Panchayath and College of Agriculture, Padanakkad. In order to know the species composition of hoppers, observations were made during their peak activity. Results showed that species *Idioscopus nitidulus* was dominant throughout the observation, comprising 43 percent. It caused heavy damage during the flowering period. The other species of hoppers *I. clypealis* (20 per cent), *I. nagpurensis* (19 per cent) and *Amritodus* sp. (18 per cent) were comparatively in the same proportion at Padanakkad (Figure 3). In Kalliyoor Panchayath *Amritodus* sp. was predominant, constituting 42 per cent of the total population. *I. clypealis* comprised 33 per cent and the rest two species accounted for 15 and 10 per cent (*I. nitidulus* and *I. nagpurensis*) (Figure 4). This showed the variation in abundance of hopper species in different locality. Similar reports were made by Dalvi *et al*. (1992). *I. nitidulus* was the most predominant among the five hopper species. Population of each species varied during different seasons and locality. Viraktamath *et al*. (1994) also reported the same. *I. nitidulus* was the dominant among the three species recorded in Dharwad. It could be due to varietal influence, suitable climatic conditions favouring reproductive potential of the hopper species.

5.2.6 Population Dynamics of Mango Hoppers with Weather Parameters

Incidence of mango hoppers is highly influenced by weather parameters (Anithakumari *et al*., 2009). Study was conducted to understand the population dynamics of mango hoppers in relation to weather parameters. Results (Table 16) showed that there was a strong positive and significant correlation of mango hopper population with maximum temperature. However, the evening relative humidity showed strong negative correlation in Kalliyoor Panchayath.

Gan and Qing (2000) reported that maximum temperature (18-28 °C) favoured multiplication of mango hopper. Pandey *et al.* (2003) observed the highest hopper population with higher temperature (more than 28 °C). These reports are in agreement with the present findings. Further, Kudugamage *et al.* (2001), Dwivedi *et al*. (2003), Pezhman (2005) and Kumar *et al.* (2001) showed that high temperature favoured the rapid population build up of mango hoppers. These finding are in confirmation with the present investigation. Rainfall showed negative correlation with hopper population. This is in conformity with findings of Pandey *et al*. (2003), Gan and Qing (2000) and Varshneya and Rana (2008). They stated that fortnightly rainfall more than 100 mm had washing effect on the hopper population.

5.3 NATURAL ENEMIES IN MANGO ECOSYSTEM

Natural enemies are the primary agents of pest control in the agro ecosystem. Identification of potential natural enemies will be a novel tool in counteracting the pest activity. Attempts were made during the survey to identify the natural enemies of shoot webber and hoppers. Throughout the study period there was no specific natural enemies found against the target pest. Spiders *Oxyopes javanus* Thorell, *Argiope pulchella* Thorell and *Tetrognatha* sp. were observed in mango orchard and found feeding on caterpillars (Plate 9). Reduviid bugs were found to be preying on mango leaf twisting weevil (Plate 10). Srivastava *et al*. (1979), Cao (1986), Miah *et al*. (1986) and Kumar and Bhatt (1998) reported spider preying on mango hoppers and other pests of mango. Manjunatha (2015) reported *Endochus inornatus* (Stal), belonging to family reduviidae, as a predator of mango hopper. Singh (2005) reported *Brachyameria eascus* as a potential parasite of mango shoot webber.

5.4 OCCURRENCE OF OTHER MANGO PESTS

Mango is suffering from many insect pests. About 492 insect species have been reported worldwide, damaging the mango crop (Butani, 1974). Of these, over 188 species have been reported from India (Tandon and Verghese, 1985).

Different sucking pests and defoliators were seen damaging the mango in Kalliyoor Panchayath and Instructional Farm, Vellayani as mentioned in 4.5. of Results. Incidence of shoot feeders and sucking pests were documented from the Thiruvanathapuram district of Kerala by Preetha (2010) and this is in agreement with the present study.

There were two new aphrophorid bugs namely *Ptyelinellus praefractus* (Distant) and *Clovia nebulosa* (Fabricius) seen in the mango ecosystem. Only adults were seen resting and feeding on terminal shoots of mango. There is no fool proof evidence that mango is the host of these bugs, since they normally breed on Spahodea and Calotropis(Tandon, 1980).

Another member of membracid, *Otinotus* sp. was observed to cause damage to the young shoots of mango (Plate 8c and 8d). They caused similar damage similar to that of hopper, mango can be considered as host of the *Otinotus* sp. since all the life stages are recorded in mango. Tandon (1980) reported the incidence of *Otinotus* sp. in mango.

5.5 MANAGEMENT OF MANGO SHOOT WEBBER AND HOPPERS

5.5.1 Efficacy of Safer Molecules for the Management of Mango Shoot Webber

Field studies on management of shoot webber revealed that all the treatments *viz*., chlorantraniliprole 0.03 per cent, lambdacyhalothrin 0.005 per cent, flubendiamide 0.01 per cent, emamectin benzoate 0.002 per cent, indoxacarb 0.02 per cent, azadirachtin 1 per cent, spinosad 0.015 per cent, malathion 0.1 per cent and *B. bassiana* (ITCC 6063) WP 2 per cent were significantly superior to the untreated control.

5.5.1.1 First Spraying

All the treatments showed maximum reduction of shoot webber population at 15 DAS. Number of active webs tree^{-1} and larvae web^{-1} was reduced from 3 DAS to 15 DAS. Percentage reduction of webber population was worked out and discussed below.

At 15 DAS, chlorantraniliprole 0.03 percent gave the superior result in controlling the pest activity with 78.96 and 82.41 per cent reduction in the webs tree^{-1} and larvae web^{-1}, respectively. This was followed by flubendiamide 0.01 per cent which reduced 72.16 per cent and 74.60 per cent of webs tree^{-1} and larvae web^{-1}, respectively (Figure 5).

Remaining treatments showed their efficacy in the following order. Lambdacyhalothrin 0.005 per cent > indoxacarb 0.02 per cent > *B. bassiana* (ITCC 6063) WP 2 per cent > emamectin benzoate 0.002 per cent > azadirachtin 1 per cent > malathion 0.1 per cent > spinosad 0.015 per cent.

5.5.1.2 Second Spraying

At 15 DAS, chlorantraniliprole 0.03 per cent gave the superior result in controlling the pest activity with 93.40 and 96.96 per cent reduction in the webs tree^{-1} and larvae web^{-1}, respectively (Figure 6). This was followed by flubendiamide 0.01

per cent which reduced 80.00 and 91.16 per cent of webs $tree^{-1}$ and larvae web^{-1}, respectively.

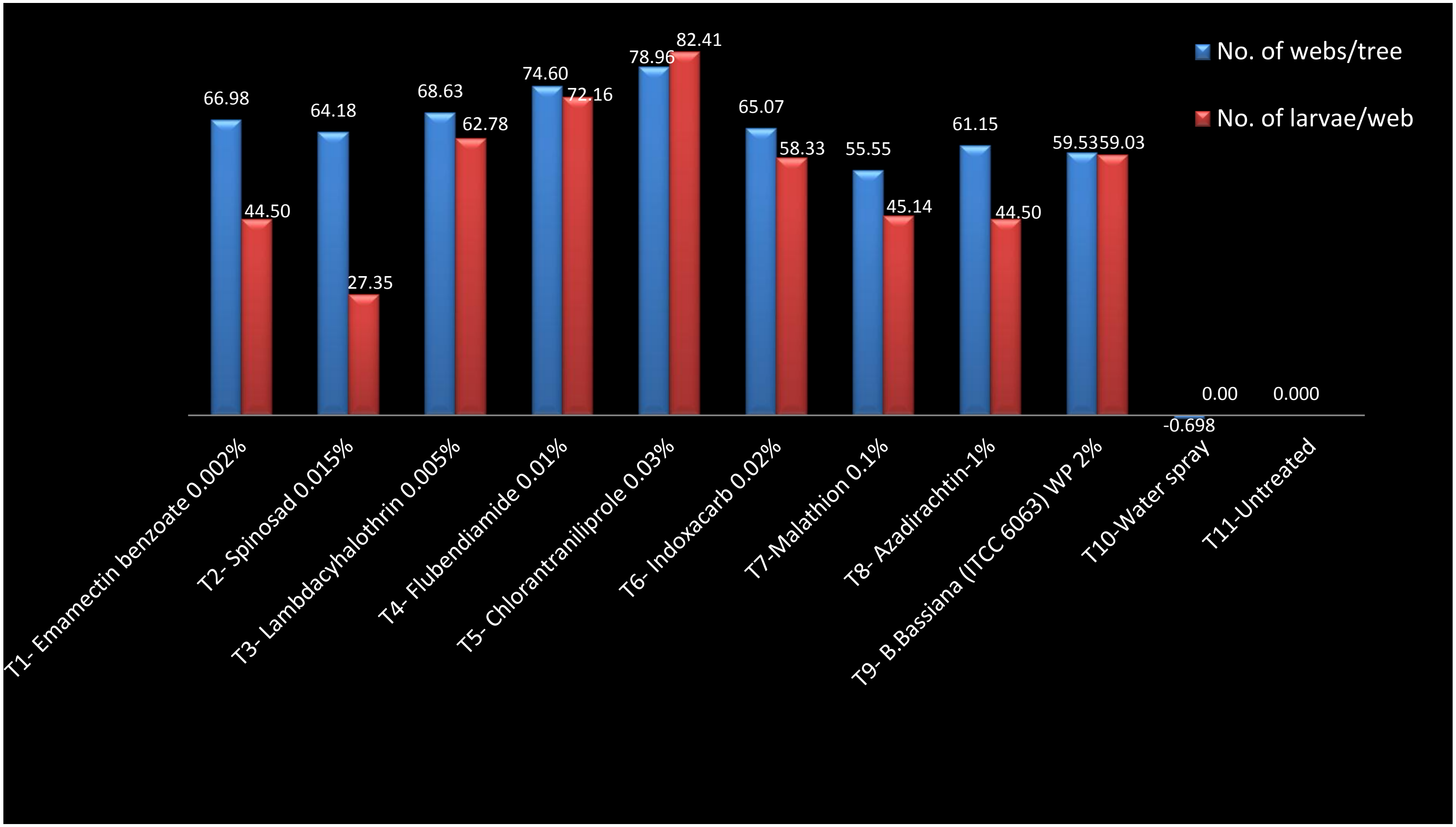


Figure 6. Percentage Reduction of Mango Shoot Webber *Orthaga exvinacea* Hamson– First Spraying

Remaining treatments showed their efficacy in the following order. Lambdacyhalothrin 0.005 per cent > *B. bassiana* (ITCC 6063) WP 2 per cent > malathion 0.1 per cent > emamectin benzoate 0.002 per cent > azadirachtin 1 per cent > indoxacarb 0.02 per cent > spinosad 0.015 per cent.

Good yield of cabbage heads was recorded in chlorantraniliprole 18.50 SC treated plots against *S. litura (*Prathiban *et al*., 2014). These reports confirm the present findings in which chlorantraniliprole showed its superior efficacy to manage the shoot webber than other treatments.

Many workers reported the efficacy of flubendiamide insecticide. Ameta and Bunker (2007) showed that flubendiamide 480 SC caused significantly higher reduction in diamond back moth. Tohnishi *et al*. (2005) reported that flubendiamide 480 SC was having extremely strong insecticidal activity against lepidopteran insect pests. It was very safe to non target organisms also. Flubendiamide is a novel insecticide and is very effective chemical against lepidopteran insects (Masanori *et al.*, 2005). Mallikarjunappa *et al.* (2008) reported that flubendiamide 20 WG @ 35 g a.i./ha was the most effective treatment in reducing the incidence of rice stem borer, *Scirphophaga incertulas* (Walker) and leaf folder *Cnaphalocrosis medinalis* (Guen.). Similar results was also obtained by Javaregowda and Naik (2005) reported that flubendiamide 20 WDG was very effective against paddy pests. These findings fall in line with the present findings and confirms the efficacy of flubendiamide against shoot webber. As per the findings of Tohnishi *et al*. (2005), flubendiamide is having green label and shows extremely strong insecticidal activity against lepidopteran insect pests and is very safe to non target organisms

Emamectin benzoate has already been reported to be effective against many lepidopteran pests (Murugaraj *et al.*, 2006 and Kumar and Devappa, 2006). Kumar *et al*. (2004) found that emamectin benzoate was effective against shoot tip

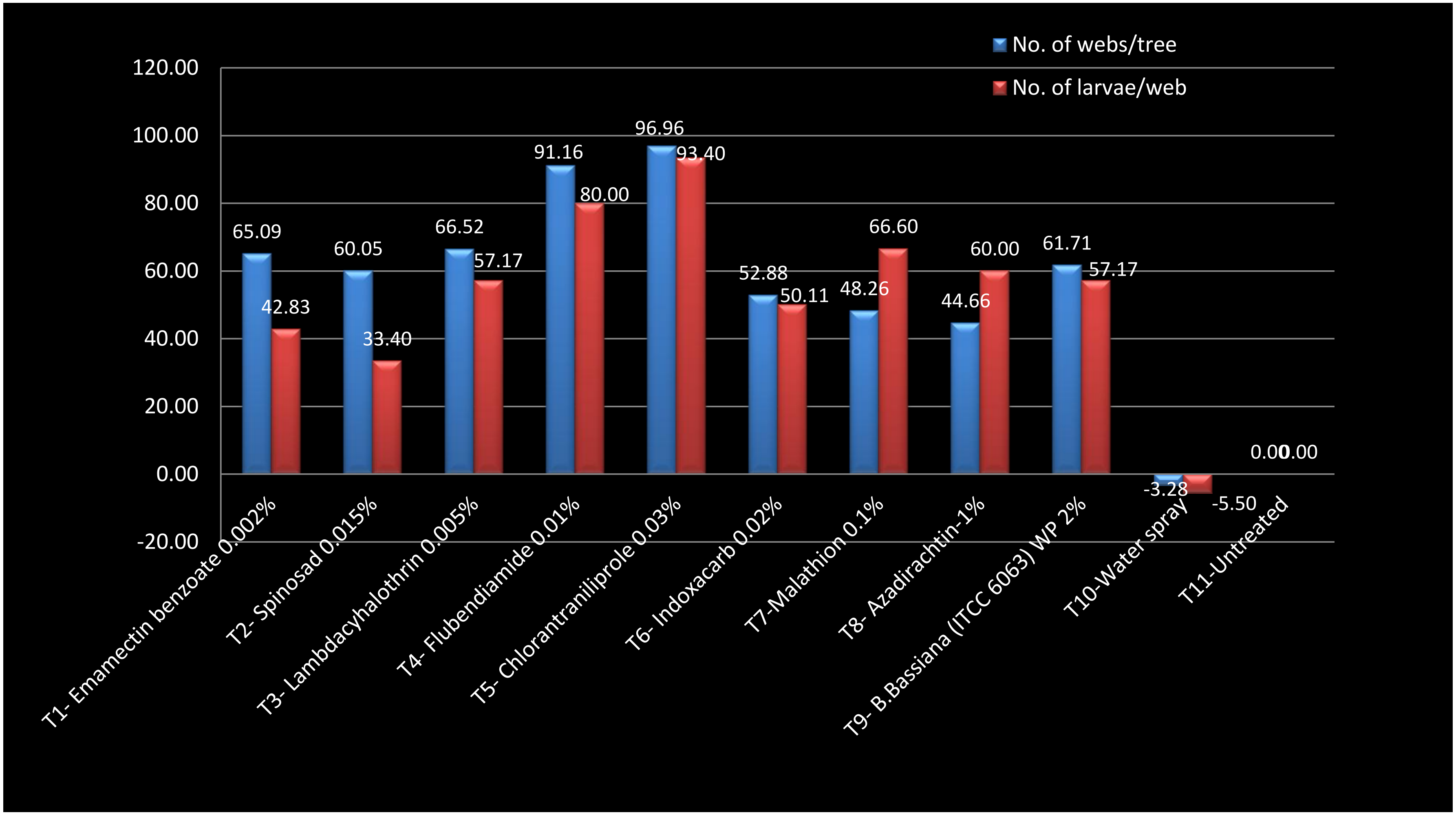


Figure 7. Percentage Reduction of Mango Shoot Webber *Orthaga exvinacea* Hampson– Second Spraying

caterpillar of cashew. After the first spray, higher population reduction was recorded in emamectin benzoate 0.002 per cent (0.00). Karuppaiah and Srivastava (2013) evaluated the efficacy of new generation insecticides against *S. litura* and found that emamectin benzoate was superior to chlorantraniliprole and indoxacarb insecticides. This reports are in contrast to the present findings. Diamide molecules proved to be superior over all the treatments in the present findings. Manjula and Kotikal (2015) reported that emamectin benzoate and indoxacarb were effective for the management of *Hymenia recurvalis* Fabricius, but indoxacarb was inferior to emamectin benzoate to bring faster mortality.

Stanley *et al.*, (2006) reported the acute toxicity of emamectin benzoate to *Helicoverpa armigera* Hubner under laboratory conditions. Similar trend was observed in the present study. After the second spraying emamectin benzoate was superior to indoxacarb. Similarly, Rao *et al.* (2006) observed that spinosad was effective againt shoot tip caterpillar. It has strong insecticidal activity against insects (Salgado, 1998), especially Lepidopteran *Helicoverpa armigera* (Wang *et a*l., 2009) and *Spodoptera frugiperda* (Méndez *et al*., 2002).

Cook *et al*. (2004) conducted field and laboratory trials on cotton and soybean for the control of the beet armyworm *Spodoptera exigua* (Hubner) and the fall armyworm *Spodoptera frugiperda*, using indoxacarb, spinosad, and emamectin benzoate. They demonstrated the efficacy of tested products, compared to the control. Plots treated with indoxacarb, spinosad and emamectin benzoate had significantly fewer beet armyworm larvae.

Wakil *et al*. (2009) in their study for the management of the pod borer, *Helicoverpa armigera* Hubner in Pakistan showed that indoxacarb spray was the most effective in reducing the larval population, pod infestation and maximum grain yield. Also in Cameroon, Brévault et *al.* (2008) reported indoxacarb as an efficient larval insecticide of *H. armigera.* Indoxacarb belongs to a novel class of insecticides, the oxadiazines. It is primarily used for the control of lepidopteran pests in foliage and fruity vegetables (Ishaaya *et al*., 2002). Bheemanna *et al.* (2005) and Sontakke *et al.* (2007), on okra found the highest mortality of lepidopteran pests. These findings, proved the efficacy of new generation molecules against lepidopteran insects. In the present findings also they showed superior efficacy over control.

B. bassiana, as a biocontrol agent, showed its potential to control the shoot webber damage. Jiji *et al*. (2008) reported the efficacy of the fungus *B. bassiana* (ITCC 6063) against the lepidopteran pests infesting vegetables. Efficacy of *B. bassiana* against mango shoot webber was reported by Patel *et al*. (2013). Moorthi *et al*. (2011) showed the efficacy of *B. bassiana* against *S. litura* under laboratory condition. Moorthi *et al*. (2015) showed the *B. bassiana* Bb 1 isolates had strong cuticle degrading enzyme, suggesting that it as one of the important components of the IPM.

Chlorantraniliprole 0.03 per cent and flubendiamide 0.01 per cent proved the highest efficacy among the treatments for the management of shoot webber. Hence they can be used for the management of shoot webber as alternative chemicals for the management of shoot webber.

5.5.2 Efficacy of Safer Molecules for the Management of Mango hoppers.

Field studies conducted on management of mango hoppers revealed that all the treatments *viz*., imidacloprid 0.005 per cent, thiamethoxam 0.005 per cent, lambdacyhalothrin 0.005 per cent, dimethoate 0.05 per cent, malathion 0.1 per cent, azadirachtin 1 per cent, deltamethrin 0.05 per cent and *B. bassiana* (ITCC 6063) 2 per cent were significantly superior to the untreated control.

5.5.2.1 First Spraying

All the treatments showed maximum reduction of hopper population after 24 hours of spray (Table 22, 23 and 24). Hopper population fluctuated from 3 DAS to 15 DAS. Majority of the nymphs were found to be dead. Less number of hoppers was recorded in imidacloprid 0.005 per cent and thiamethoxam 0.005 per cent treated trees up to 15 DAS. Percentage reduction of hopper population is worked out and discussed below.

Among the treatments imidacloprid 0.005 per cent showed the highest efficacy over the control. At 15 DAS this chemical recorded 81.27, 93.43 and 97.22 per cent reduction of hoppers sweep net^{-1}, hoppers panicle^{-1} and hoppers shoot^{-1}, respectively. It was followed by thiamethoxam 0.005 per cent. Here the reduction of hopper population over the control was 77.86, 87.45 and 96.90 per cent of hoppers sweep net^{-1}, hoppers panicle^{-1} and hoppers shoot^{-1}, respectively (Figure 8).

Lambdacyhalothrin 0.005 per cent (72.70, 79.92 and 88.07 per cent hoppers sweep net^{-1}, hoppers panicle^{-1} and hoppers shoot^{-1}, respectively), dimethoate 0.05 per cent (70.65, 74.01 and 79.80 per cent hoppers sweep net^{-1}, hoppers panicle^{-1} and hoppers shoot^{-1}, respectively), deltamethrin 0.05 per cent (68.98, 73.58 and 79.12 per cent hoppers sweep net^{-1}, hoppers panicle^{-1} and hoppers shoot^{-1}, respectively), *B. bassiana* (ITCC 6063) 2 per cent and azadirachtin 1 per cent were ranked as the next best treatments. Malathion 0.1 per cent recorded the least efficacy by reducing only 60.81, 65.48 and 68.16 per cent hoppers sweep net^{-1}, hoppers panicle^{-1} and hoppers shoot^{-1}, respectively.

5.5.2.2 Second Spraying

Among the treatments imidacloprid 0.005 per cent showed the highest efficacy over the control. At 15 DAS this chemical recorded 96.57, 97.19 and cent

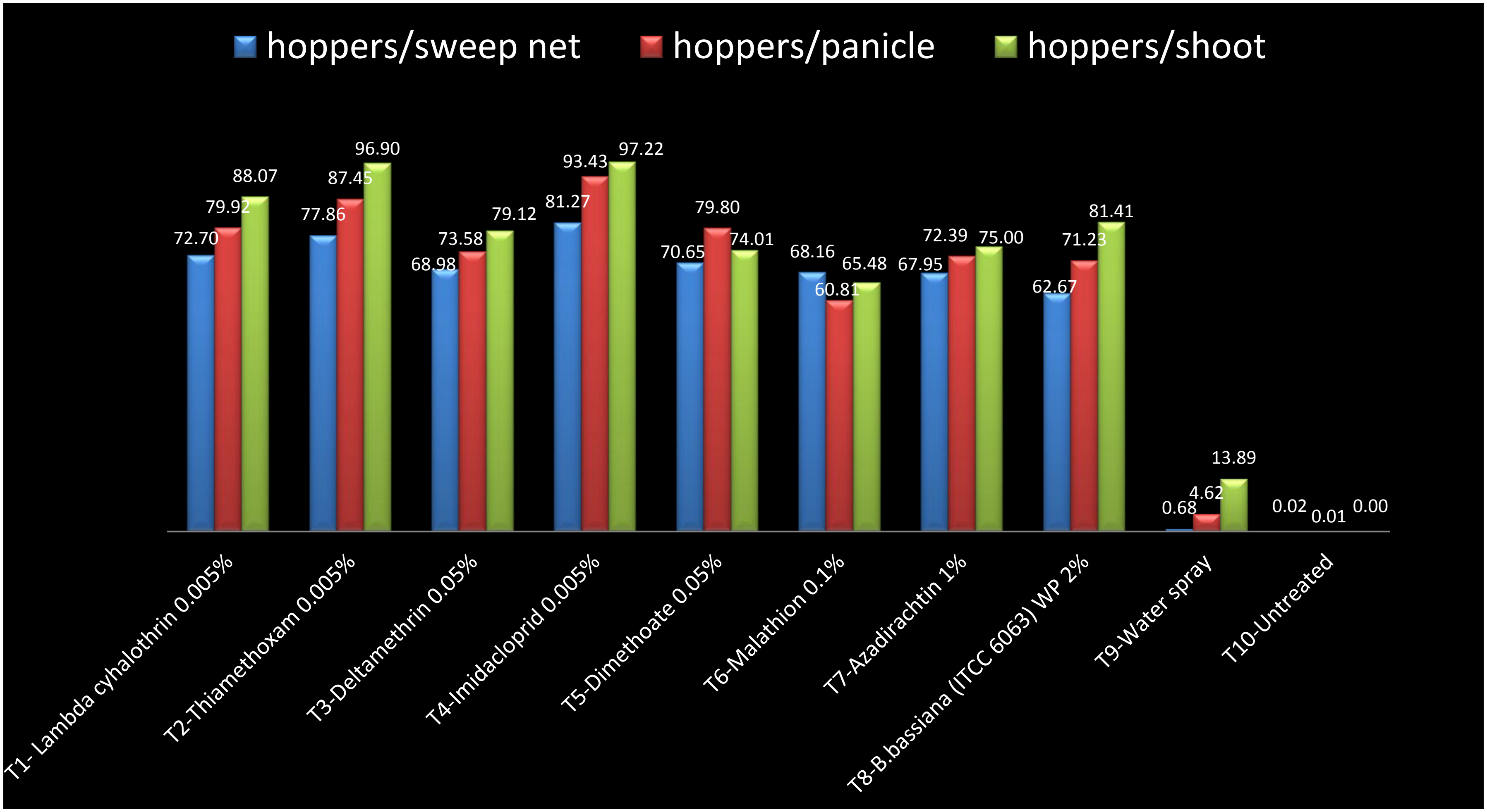


Figure 8. Percentage Reduction of Mango Hoppers (*Amritodus* sp., *Idioscopus clypealis, I. nitidulus, I. nagpurensis)* – First Spraying

percent reduction of hoppers sweep net^{-1}, hoppers panicle^{-1} and hoppers shoot^{-1}, respectively. It was followed by thiamethoxam 0.005 per cent. Here the reduction of hopper population over control was 86.26, 83.53 and cent per cent of hoppers sweep net^{-1}, hoppers panicle^{-1} and hoppers shoot^{-1}, respectively (Figure 9).

Remaining treatments, lambdacyhalothrin 0.005 per cent (78.95, 78.10 and 94.77 hoppers sweep net^{-1}, hoppers panicle^{-1} and hoppers shoot^{-1}, respectively), deltamethrin 0.05 per cent (77.63, 72.03 and 94.45 hoppers sweep net^{-1}, hoppers panicle^{-1} and hoppers shoot^{-1}, respectively), azadirachtin 1 per cent (75.75, 74.56 and 88.90 hoppers sweep net^{-1}, hoppers panicle^{-1} and hoppers shoot^{-1}, respectively), dimethoate 0.05 per cent (80.15, 75.49 and 76.31 hoppers sweep net^{-1}, hoppers panicle^{-1} and hoppers shoot^{-1}, respectively) and *B. bassiana* (ITCC 6063) 2 per cent (65.73, 71.36 and 83.34 hoppers sweep net^{-1}, hoppers panicle^{-1} and hoppers shoot^{-1}, respectively) were superior to control in reducing the population of hoppers.

Efficacy of new generation molecule imidacloprid 0.005 per cent was reported by many workers (Verghese, 2000; Indumati and Savithri 2003; Kumar *et al*. 2005; Bhaskar *et al*. 2007; Anithakumari *et al*. 2009; Samanta and Dhote 2009). It was superior to the other treatments in suppressing the pest. In the present findings also imidacloprid 0.005 per cent was superior to the other treatments. It was followed by thiamethoxam 0.005 per cent. Anithakumari *et al*. (2009) and Samanta *et al*. (2009) also showed that thiamethoxam was recorded as the second best treatment after imidacloprid. This is in agreement with the present findings. Lambdacyhalothrin was found to be effective against mango hoppers. Similar results were reported by Verghese (2000). Hopper population was significantly suppressed in lambdacyhalothrin treated trees.

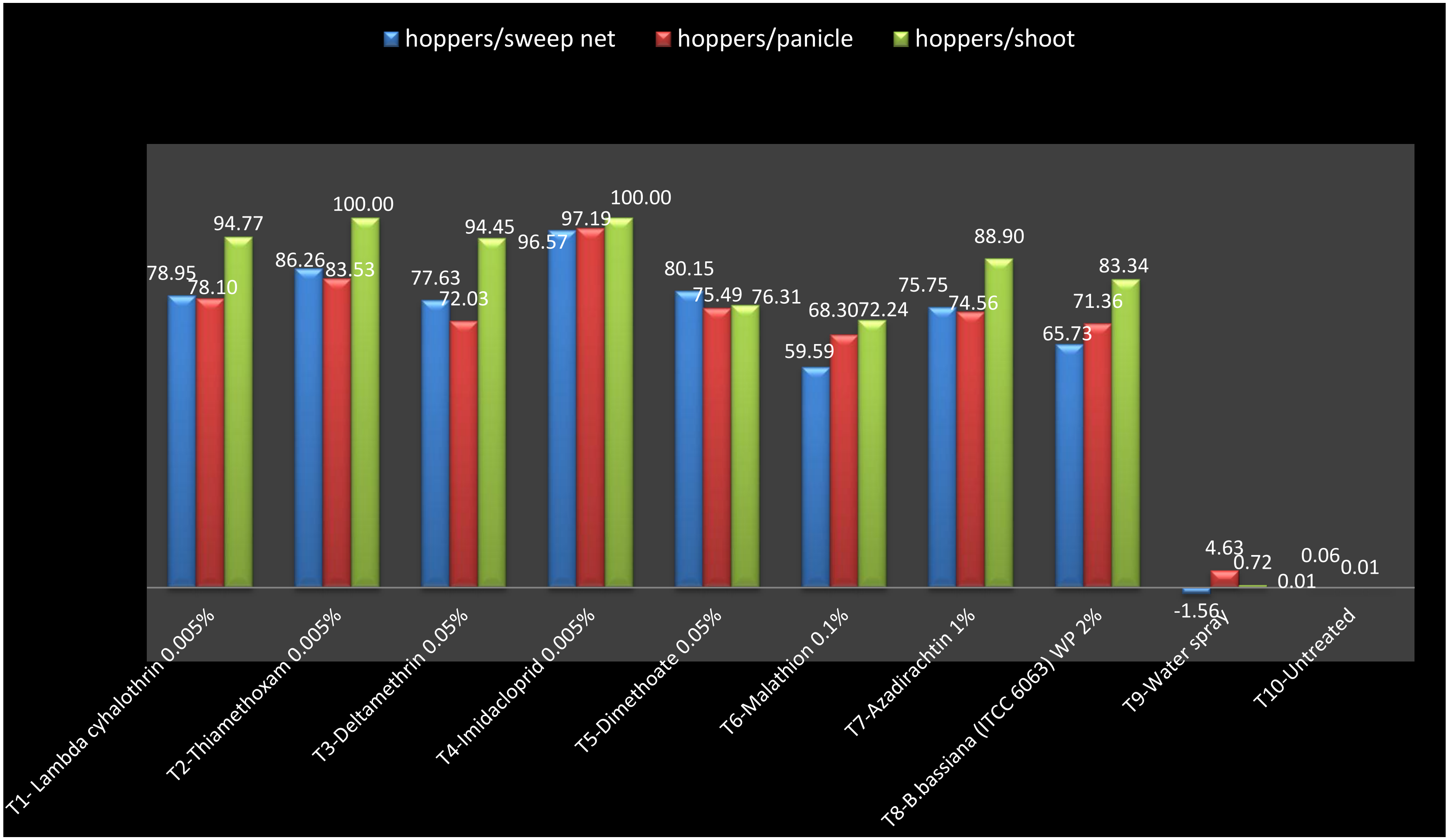


Figure 9. Percentage Reduction of Mango Hoppers (*Amritodus* sp., *Idioscopus clypealis, I. nitidulus, I. nagpurensis)* – Second Spraying

Many workers reported the efficacy of synthetic pyrethroids (Datar, 1985; Pingale and Patil, 1988; Singh, 1989; Srivastava and Verghese, 1989; Ragini *et al.*, 2001 and Pushpalatha *et al.*, 2002) against mango hoppers in different locations of India.

Dimethoate 0.05per cent was moderately effective in controlling the pest. Similar trend was also reported by Gandhali *et al*. (1975), Singh *et al*. (1974) and Patel *et al.* (1987). They found that repeated application of the chemical triggered the population of hoppers.

Imidacloprid 0.005 per cent and thiamethoxam 0.005 per cent were proved to be the best new molecules to manage the mango hoppers. These two molecules can be utilized for management of hoppers as alternate sprays for the management**.**

6. SUMMARY

Mango (*Mangifera indica* L.) is one of the most important fruit crops of the tropical and subtropical regions of the world. The shoot webber *Orthaga exvinacea* Hampson and hoppers (*Idioscopus nitidulus* Walker, *Idioscopus clypealis* Letheirry *Idioscopus nagpurensis* Pruthi. and *Amritodus* sp.) are destructive pests of mango causing massive loss. To manage these pests farmers use chemical control measures. Injudicious use of pesticides causes health hazards, by leaving behind more toxic residue load in the environment. As fruits are consumed raw and fresh, care should be taken selecting the pesticide. The current recommendation includes the conventional insecticide organophosphates molecules malathion and dimethoate, (KAU, 2011) which are outdated in the present day market. In order to manage shoot webber and hoppers alternative chemicals have to be standardized and popularized. The present investigation was undertaken to study the population dynamics and standardize the use of new generation molecules to manage the shoot webber and hoppers infesting mango. The major findings of the study are summarized below.

To assess the pest incidence and the extent of damage caused, survey was conducted in twenty homesteads of Kalliyoor Panchayath and the instructional Farm, Vellayani during 2015-2016. Study revealed the incidence of shoot webber, *O. exvinacea* and hoppers, *I. nitidulus*, *I. clypealis*, *I. nagpurensis* and *Amritodus* sp. in mango.

Seven instars were seen in their life cycle of *O. exvinacea*. Caterpillars were seen feeding on foliage gregariously, during the vegetative growth of the tree and gave a burnt up appearance. The caterpillar fed by webbing the leaves of terminal shoots.

Shoot webber occurrence was observed throughout the year. Their incidence started during I FN of September 2015 (4.45 webs tree^{-1}, 3.65 larvae web^{-1} and 5 damaged leaves web^{-1}). But peak incidence was in I FN of January 2016 with 25.6

webs tree^{-1}, 6.33 larvae composite web^{-1} and 103.6 damaged leaves web^{-1} in Kalliyoor Panchayath homesteads.

At the Instructional Farm, Vellayani incidence of shoot webber started during I FN of September 2015 onwards (2.1 webs tree^{-1}, 1.2 larvae web^{-1} and 6.25 damaged leaves web^{-1}) and continued up to July I FN (6.6 webs tree^{-1}, 2.1 larvae web^{-1} and 20.6 damaged leaves web^{-1}). The peak infestation was in the II Fortnight of March 2016 with 22.25 webs tree^{-1}, 4 larvae composite web^{-1} and 73.25 damaged leaves web^{-1}.

Ten varieties were selected for the screening of mango cultivars against shoot webber incidence at the Instructional Farm, Vellayani. Varieties, Kalappadi, Kundalatha, Kottukonam, Alphonso, Banganapally, Vellari Varikka, Prior, Malgoa, Himayudan and Banglora showed that all the varieties were susceptible except Vellari Varikka which was free from the pest attack. Kalappadi was highly susceptible to the shoot webber attack.

The fortnightly weather data were correlated with the population of shoot webber during 2015-16. Population had a positive correlation and the relationship was significant with maximum temperature and morning relative humidity. There was no effect of rainfall on shoot webber activity. However, minimum temperature, evening relative humidity and sunshine hours showed negative correlation with the population of *O. exvinacea.* Correlation studies in both the locations gave same coefficients for the selected weather parameters.

The occurrence of mango hoppers (*Amritodus* sp., *I. clypealis, I. nitidulus* and *I. nagpurensis*) was recorded from the I FN of December 2015 (2.93 hoppers panicle^{-1}, 4.47 hoppers sweep net^{-1} and 1.97 hoppers shoot^{-1}) and reached the peak in the I FN of April 2015 with 12.97 hoppers panicle^{-1}, 16.30 hoppers sweep net^{1} and 4.53 hoppers shoot^{-1} in the Kalliyoor Panchayath.

At the Instructional Farm, population of hoppers was negligible throughout the survey period. During the months of January, February, March and April 2016 incidence of hoppers recorded. The highest number of hoppers was recorded in the month of March 2016 (4 hoppers panicle^{-1}, 3.8 hoppers sweep net^{-1} and 2 hoppers shoot^{-1}).

In the College of Agriculture, Padanakkad hopper incidence was started from the II FN of December 2015 with 7.47, 5.00 and 1.87 hoppers panicle^{-1}, sweep net^{-1} and shoot^{-1}, respectively. During February 2016 peak incidence of hoppers was recorded (18.67, 17.07 and 4.33 hoppers panicle^{-1}, sweep net^{-1} and shoot^{-1}, respectively).

Hopper incidence was monitored through yellow sticky trap in Balarampuram homesteads. During the I FN of December 2015 population of hopper incidence was recorded (72.33 / yellow sticky trap). Their incidence was in increasing trend from II FN of December 2015 onwards up to I FN of March 2016. From II FN of March 2016 onwards the population showed decreasing trend.

Species composition of hoppers was studied at College of Agriculture, Padanakkad revealed that *I. nitidulus* was dominant among the four species which constituted 43 per cent of the total hopper population. This was followed by *I. clypealis* (20 per cent), *I. nagpurensis* (19 per cent) and *Amritodus* sp. (18 per cent). In Kalliyoor Panchayath *Amritodus* sp. dominated with 42 per cent of total hopper population, followed by *I. clypealis* (33 per cent), *I. nitidulus* (15 per cent) and *I. nagpurensis* (10per cent).

Study on mango hopper incidence in ten varieties conducted at Kalliyoor Panchayath. Results revealed that the varieties *viz.*, Alphonso, Banganapalli, Bangalora, Neelum, Kottukonam, Kalappadi, Mulgoa, Prior, Vellari Varikka and Mundappa showed that all the varieties were susceptible for hopper attack, except

Kottukonam and Vellari Varikka moderately tolerant. Highest damage was recorded in Alphonso variety.

Correlation coefficients between the population of mango hoppers in Kalliyoor Panchayath and weather parameters revealed that population had a positive correlation and was significant with maximum temperature. However, minimum temperature, morning relative humidity, evening relative humidity and sunshine hours had a negative correlation. Rainfall did not influence the activity of hoppers.

Among the natural enemies, predatory spiders were identified as *Oxyopes javanus* Thorell, *Argiope pulchella* Thorell and *Tetrognatha* sp. Unidentified reduviid bugs were also seen predating on mango pests. Population of natural enemies was high when the pest activity was more (October 2015 – March 2016). No specific predators were recorded on target pests.

Incidence of other mango pest was recorded and they are of two types sap feeders and defoliators. Their population was high during the vegetative phase and flowering period. The active period of many mango pests was seen from October 2015 to April 2016.

Aphrophorid bugs were found feeding on mango. They were identified as *Ptyelinellus praefractus* Distant and *Clovia nebulosa* Fabricius. Activity of nymphs and adults were observed from I FN of December to I FN of March. *Otinotus* sp. was found damaging the mango and considered as its host. Mealy bugs complex in mango was identified as, *Rastrococcus invadens*, *R. iceryoides*, *Icerya* sp. and *Formicococcus robustus*. Scales, *Ceroplastes* sp. and *Eucalymnatus tessellates* were identified from the Instructional farm.

Field experiment was carried out to evaluate the efficacy of safer molecules against mango shoot webber in the Instructional Farm, Vellayani and hoppers in the College of agriculture, Padanakkad.

The treatments evaluated for shoot webber were emamectin benzoate 0.002per cent, spinosad 0.015 per cent, lambdacyhalothrin 0.005 per cent, flubendiamide 0.01 per cent, chlorantraniliprole 0.03 per cent, indoxacarb 0.02 per cent, malathion 0.1 per cent, azadirachtin 1 per cent, *B. bassiana* (ITCC 6063) 2 per cent. All the treatments showed significant difference. Results revealed that the green labeled molecules, chlorantraniliprole 0.03 per cent showed the highest efficacy with 95.18 per cent hopper reduction over control, followed by flubendiamide 0.01 per cent (85.58 per cent). Azadirachtin 1 per cent and *B. bassiana* (ITCC 6063) 2 per cent were also significantly superior to the control.

For the management of hoppers the treatments selected were lambda cyhalothrin 0.005 per cent, thiamethoxam 0.005 per cent, deltamethrin 0.05 per cent, imidacloprid 0.005 per cent, dimethoate 0.05 per cent, malathion 0.1 per cent, azadirachtin 1per cent, *B.bassiana* (ITCC 6063) 2 per cent. Imidacloprid 0.005 per cent showed the highest efficacy with 97.92 per cent reduction followed by thiamethoxam 0.005 per cent (89.9 per cent), compared to control. Azadirachtin 1per cent was also found effective in managing the pest.

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*Originals not seen

Appendix I

Tree No.	No. of Hoppers/panicle/shoot/sweep net				No. of webbings/plant and no. of larvae/webbings			
	East	West	North	South	East	West	North	South
1								
2								
3								
4								
5								
6								
7								
8								
9								
10								

Appendix II

Fortnights (FN)	Temperature (^{0}C)		Relative Humidity (%)		Rainfall (mm)	Sunshine (hrs)
	maximum	minimum	morning	evening		
I FN March-2015						
II FN March-2015						
I FN April -2015						
II FN April -2015						
I FN May -2015						
II FN May -2015						
I FN June -2015						
II FN June -2015						
I FN July -2015						
II FN July -2015						
I FN August -2015						
II FN August -2015						
I FN Sep -2015						

POPULATION DYNAMICS AND MANAGEMENT OF SHOOT WEBBER AND HOPPERS INFESTING MANGO USING SAFER MOLECULES

by

SHIVAMURTHY

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Abstract of the thesis

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ABSTRACT

The work entitled “Population dynamics and management of shoot webber and hoppers infesting mango using safer molecules” was conducted at the College of Agriculture, Vellayani and College of Agriculture, Padanakkad during 2014-2016 with the objectives to study the population dynamics of mango shoot webber and hoppers in relation to climatic factors and standardize the use of newer and safer molecules for their management.

A survey was conducted in 20 homesteads in Kalliyoor panchayath (one plant homestead^{-1}) and in the Instructional Farm, Vellayani (20 plants) to study the population dynamics in relation to climatic factors. Mango shoot webber was identified as *Orthaga exvinacea* Hampson, and hoppers as *Amritodus* sp., *Idioscopus nagpurensis* Pruthi, *Idioscopus clypealis* Letheirry and *Idioscopus nitidulus* Walker.

Shoot webber occurrence was observed throughout the year, peak incidence was in January (25.6 webs tree^{-1}, 8.2 larvae web^{-1} and 103.6 damaged leaves composite web^{-1}) at homesteads of Kalliyoor, but in the Instructional Farm, Vellayani the peak infestation was in the month of March (22.25 webs tree^{-1}, 5.7 larvae web^{-1} and 62 damaged leaves composite web^{-1}). Studies on correlation with weather parameters revealed that maximum temperature and morning relative humidity had positive significant correlation with the population of mango shoot webber.

The occurrence of mango hoppers (*Amritodus* sp., *Idioscopus clypealis, I. nitidulus, I. nagapurensis*) was the highest in the month of April (12.97 hoppers panicle^{-1}, 17.07 sweep net^{-1}and 4.74 shoot^{-1}) in Kalliyoor panchayath, where as in the Instructional Farm, Vellayani the occurrence of the pests was low throughout the period of observation. Studies on correlation with weather parameters and population of mango hoppers showed that maximum temperature had positive significant correlation.

Occurrence of other mango pests were identified as *Clovia nebulosa* (Fab.), *Ptyelinellus praefractus* (Dist.) (Aphrophoridae) and *Otinotus* sp.,(Membracidae). Scales and mealybugs were identified as *Ceroplastes* sp., *Formicococcus robustus* (Ezzat & Mcconnell), *Eucalymnatus tessellates* (Signoret), *Rastrococcus iceryoides* (Green), *Rastrococcus invadens* (Williams) and *Icerya* sp. Ants viz. *Camponotus compressus* (Fabricius) and *Oecophylla smaragdina* (Smith) were the natural enemies.

Field experiments were carried out in completely randomised design to evaluate the efficacy of safer molecules against mango shoot webber and hoppers respectively. The treatments evaluated for shoot webber were emamectin benzoate 0.002%, spinosad 0.015%, lambdacyhalothrin 0.005%, flubendiamide 0.01%, chlorantraniliprole 0.03%, indoxacarb 0.02%, malathion 0.1%, azadirachtin-1%, *B. bassiana* (ITCC 6063) WP 2%, water spray and untreated. All the treatments showed significant difference compared to control. Chlorantraniliprole 0.03% showed the highest efficacy with 95.18 per cent reduction over control, followed by flubendiamide 0.01% (85.58 per cent). Azadirachtin 1% and *B. bassiana* (ITCC 6063) WP 2% were also significantly superior to the control.

For the management of hoppers the treatments were lambda cyhalothrin 0.005%, thiamethoxam 0.005%, deltamethrin 0.05%, imidacloprid 0.005%, dimethoate 0.05%, malathion 0.1%, azadirachtin 1%, *B.bassiana* (ITCC 6063) WP 2%, water spray and untreated. Imidacloprid 0.005% showed the highest efficacy with 97.92 per cent reduction followed by thiamethoxam 0.005% (89.9 per cent), compared to control. Azadirachtin 1% was also found effective in managing the pest.

It is concluded that the peak incidence of mango shoot webber and hoppers is in the month January and March, respectively. Correlation studies revealed that the webber population had significant positive correlation with maximum temperature and morning relative humidity whereas, hopper population showed significant positive correlation with maximum temperature only. Chlorantraniliprole 0.03%, flubendiamide 0.01% and biopesticide *B.bassiana* (ITCC 6063) WP 2% are found effective against mango shoot webber. Imidacloprid 0.005%, thiamethoxam 0.005% and botanical azadirachtin 1% are found effective against mango hoppers.