INCIDENCE AND MANAGEMENT OF INSECT PESTS INFESTING INFLORESCENCE OF MANGO

J. NAYANATHARA

(2018-11-069)

DEPARTMENT OF AGRICULTURAL ENTOMOLOGY

COLLEGE OF AGRICULTURE

VELLAYANI, THIRUVANANTHAPURAM-695 522

KERALA, INDIA

2020

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by

J. NAYANATHARA

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THESIS

Submitted in partial fulfilment of the requirement for the degree of

MASTER OF SCIENCE IN AGRICULTURE

Faculty of Agriculture

Kerala Agricultural University

DEPARTMENT OF AGRICULTURAL ENTOMOLOGY

COLLEGE OF AGRICULTURE

VELLAYANI, THIRUVANANTHAPURAM-695 522

KERALA, INDIA

2020

DECLARATION

I, hereby declare that this thesis entitled **"INCIDENCE AND MANAGEMENT OF INSECT PESTS INFESTING INFLORESCENCE OF MANGO"** 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, associateship, fellowship or other similar title, of any other University or Society.

Vellayani, **J. Nayanathara**

Date: 16-10-2020 (2018 -11-069)

CERTIFICATE

Certified that this thesis entitled **"INCIDENCE AND MANAGEMENT OF INSECT PESTS INFESTING INFLORESCENCE OF MANGO"** is a record of research work done independently by Ms. J. Nayanathara under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, fellowship or associateship to her.

Vellayani,
Date: 16 -10 -2020

Dr. R. Narayana
(Major Advisor, Advisory Committee)
Assistant Professor
Department of Agricultural Entomology
College of Agriculture, Vellayani

CERTIFICATE

We, the undersigned members of the advisory committee of Ms. J. Nayanathara a candidate for the degree of **Master of Science in Agriculture** with major in Agricultural Entomology, agree that the thesis entitled **"INCIDENCE AND MANAGEMENT OF INSECT PESTS INFESTING INFLORESCENCE OF MANGO"** may be submitted by Ms. J. Nayanathara, in partial fulfilment of the requirement for the degree.

Dr. R. Narayana
(Chairman, Advisory Committee)
Assistant Professor
Department of Agricultural Entomology
College of Agriculture, Vellayani
Thiruvananthapuram – 695 522

Dr. Anitha N
(Member, Advisory Committee)
Professor and Head
Department of Agricultural Entomology
College of Agriculture, Vellayani
Thiruvananthapuram – 695 522

Dr. S. Shanas
(Member, Advisory Committee)
Assistant Professor
Agricultural Research Station
Thiruvalla- 689 102

Dr. Santhosh Kumar, T
(Member, Advisory Committee)
Assistant Professor
Department of Agricultural Entomology
College of Agriculture, Vellayani
Thiruvananthapuram-695 522

Dr. A.V. Meera Manjusha
(Member, Advisory Committee)
Assistant Professor (Horticulture)
Regional Agricultural Research Station
Pilicode
Kasargod – 671 353

ACKNOWLEDGEMENT

The two years of journey was a blend of everything. And it's worth mentioning each and everyone who accompanied me, as I couldn't have reached my destination without them.

First of all, I thank my chairman Dr. R. Narayana for the valuable guidance, critical suggestions, support and his trust on me. The faith and hope someone shower on us truly is a responsibility that helped me to fulfil the journey. I will always be indebted to him for the research topic that he suggested. It was a real bliss.

I extend my heartfelt regards to our Head of the Department, Dr.N. Anitha, for the immense patience to listen the whole chaos I carry in my head. I will always treasure those affection and concern she made me feel whenever I was at my lowest. I will miss going in search of her, with a bundle of miseries and she having remedy for everything with a charming calmness of hers.

I am grateful to my advisory committee members Dr. Shanas.S., Dr. Santhosh Kumar. T and Dr. A.V. Meera Manjusha for all suggestions and support throughout the research work. I am obliged to Dr. Reji Rani for providing me with the necessary cultures from biocontrol department and lab facilities during the course of work.

Regarding the identification of specimens, I extend my immense gratitude to Dr. K.D. Prathapan (College of Agriculture, Vellayani), Dr. Sunil Joshi (Division of Insect Systematics, NBAIR), Dr. P.R. Shashank (Division of Entomology, IARI), Dr. M. Sampath Kumar (Division of Insect Systematics, NBAIR), Dr. Sunil Jose (Devamatha College, Kottayam), Dr. Hemant Ghate (Modern College of Arts Science and Commerce), Dr. Shanas.S (Agricultural Research Station, Thiruvalla) and Ms. Rachana R.R (Division of Insect Systematics, NBAIR). I express my thankfulness especially to Prathapan Sir and Shanas sir for being so supportive and encouraging always. Their genuine words of appreciation and encouragement were priceless.

I express my sincere thanks to my teachers Dr. Amritha .V.S., Dr. Ambily Paul, Dr. M. H. Faizal, Dr. R. Krishnakumar and rest of the teaching faculty for the classes and guidance during the course of study. I find words inadequate to thank Mr. Sangamesh Hiremath for all the support and guidance. From identification of specimens to taking photographs and all the valuable suggestions had helped me to a great extend. He was really an inspiration.

Then Mithra chechi.....I don't have enough words to express my gratitude to her for all the emotional support. She was and will always be the best companion someone could ever wish for. I will never let this rapport fade away. For being by my side always, I owe her a lot more than words could convey. And Kichu, I cannot thank him enough with a bundle of words for always being such a well-wisher of mine. Words will never fill up the gratitude, my heart wish to share; for all the love and care.

I cannot forget mentioning the names of Anusree chechi, Thejas chetan, Roshin, Sreekutty, Divya, Anusha, Karthik, Amal, Ravindran, Richu, Dr. K. Elanchezhyan and all my fellow batchmates (Ento- Nema friends);, for making things more easier and helping me at one point or the other whenever I was in need of someone.

I am so much indebted to Anusha and Lintu for all the happiness, love and support. Without these two, I would have struggled so much in this troublesome journey. They made my hostel life lively. Though we knew each other for a short period of time, I feel glad to thank Anju chechi, Aneetta chechi and Dundu for the support rendered and all the valuable suggestions throughout.

Regarding the field visits and experiment in Palakkad, I extend my heartfelt regards to Dr. C. Arumughan and Sukanya aunty for making me feel so home like, letting me stay with them and taking care of me so much. They were so welcoming always. And I will always be grateful to Shoukathikka, for helping me to visit the mango fields and so curiously enquiring the research updates. I feel extremely happy to thank Sreehari and Palpu for all the care and support.

I couldn't have made this possible without the love and support of my family. I will always treasure that confidence and pride. Achan, Amma and Kochu (Nandhana); I owe them a piece of my heart. I feel so fortunate enough for all the freedom and trust they had on me, for listening me and being with me always. It was their love and prayers that kept me going.

Last but not the least, I thank Almighty from the bottom of my heart for all the blessings showered on me, for making me withstand all the terrible situations and beyond everything, for making me believe in myself.....!!!

-Adapted from my heart

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LIST OF ABBREVIATIONS AND SYMBOLS USED

t	Tonnes
MT	Metric tonnes
mm	Millimetre
WP	Wettable powder
%	Per cent
g	Gram
a.i.	Active ingredient
ha^{-1}	Per hectare
g l^{-1}	Gram per litre
ml L^{-1}	Millilitre per litre
sp.	Species
spp.	Several species
EC	Emulsifiable concentrate
SL	Soluble liquid
SC	Suspension concentrate
µl	Microlitre
SP	Soluble powder
fl oz	Fluid ounce
ml^{-1}	Per millilitre
cfu	Colony forming units
@	At the rate of
DAS	Days after spraying
CD	Critical difference
viz.,	Namely
et al.,	And others
ITCC	The Indian Type Culture Collection

INTRODUCTION

1. INTRODUCTION

Mango; “The King of Fruits” is indeed a sheer delight to people all over the world (Mehta, 2017). This marvel fruit from the family Anacardiaceae have it’s origin in Indo- Myanmar region (Azam *et al.,* 2018).

Owing to more than 54 per cent of world’s mango production, India is one among the largest producer worldwide (Tharanathan *et al.,* 2006). Despite being a leading mango producer in the world, China overheads India in the aspect of productivity (Ahuja *et al.,* 2011). The total estimated area under mango cultivation in Kerala is 6.9 lakh hectares with an annual production of 382,380 t and a productivity of 5.5 mt ha^{-1} (NMD, 2017).

The yield of the fruit tree has been plagued by several primary, secondary occasional and key pests. Mango suffers a heavy toll of pest incidence from nearly 400 insect species and other non insect pests worldwide comprising of hemipteran, lepidopteran, coleopteran, dipteran and many other associated insects (Pena *et al*., 1998). In the Indian scenario, about 250 insect and other mite pests were recorded. Only about 30 insect species among these were found to cause a serious threat to the yield (Kapadia, 2003). The reproductive and vegetative stages of the plants are prone to severe pest and disease infestations.

Nearly 36 insect species among the 250 recorded from mango; was found to feed on mango panicle (Pena *et al.,* 1998).

The situation in Kerala is much different where the cultivation is not commercialised, rather restricted to different homesteads. Climatic conditions are more favourable in the district of Palakkad for mango production. Earliness is a significant feature regarding the mango production in Kerala. Indian markets receive the foremost mango fruits of the season from Kerala. This contributes to the significance of mango from the state towards the Indian markets (Radha and Nair, 1999).

Flowering is a decisive element concerning the mango production. Hoppers pose a serious threat to mango ecosystems with severe infestation during new flush

emergence and flowering, owing to a lion share of crop losses. The incidence is found to continue even after fruit setting with the population declining thereafter (Bana *et al.,* 2018).

In recent times, heavy toll of lepidopteran incidence in the panicle is a rising concern among the growers. The obscure nature of damage by a plethora of polyphagous caterpillar complex in panicle went unnoticed for a quite long period. The ravage in infestation level anticipated a surge in pest status of these caterpillars in near future to reach an outrageous extend (Jayanthi *et al.,* 2018).

The preliminary observations in different inflorescence samples collected, fall in line with these findings. Inorder to reach out a safety milestone with regard to the suppression of this tedious incidence has proved necessary. The documentation of the pest complex in inflorescence is of prime importance to formulate an effective means of management.

Hence the current study entitled "Incidence and management of insect pests infesting inflorescence of mango" was developed with the objectives of:

- Documentation of insect pests infesting mango inflorescence from the three different blocks of Thiruvananthapuram district.
- To evolve effective means of management for the insect pests associated with mango inflorescence.

REVIEW OF LITERATURE

2. REVIEW OF LITERATURE

Mango, an indigenous fruit belonging to the family of Anacardiaceae is known for its aroma and taste. It is vastly cultivated in India including Kerala. In Kerala, except a few orchards, they are grown in homesteads along with other tree crops. Mango is also a store house of various nutrients, including organic micronutrients (Shahidi *et al.*,1992) and polyphenols like mangiferin, quercetin, gallic acid, isoquercetin, gallotanin, etc (Berardini *et al.*, 2004, 2005).

Mango, considered as the National fruit of the country, besides its potential nutritional benefits, holds immense export potential. India tops the world's mango production with a major share of about 50% (Devi, 2014).

The major mango producing states in the country mainly include Uttar Pradesh, Andhra Pradesh and Bihar. According to the 2017-18 horticulture database, the major share of yield was from Uttar Pradesh (4.55 Lakh MT) followed by Andhra Pradesh (4.37 Lakh MT), although Andhra Pradesh (363000 ha) overheads Uttar Pradesh (265620 ha) in the area of mango cultivation (GOI, 2018).

Earliness is a significant feature regarding the mango production in Kerala. Indian markets receive the foremost mango fruits of the season from Kerala. This contributes to the significance of mango production of the state towards the Indian markets (Radha and Nair, 1999).

2.1. SEASON AND FLOWERING

Most of the early mangoes that reach the Indian market are from Kerala. Palakkad district has earned the credit of producing the earliest mangoes of the season in India. Climate is a significant factor that predisposes the trees to flower early. Various other factors which significantly influence early flowering include hormonal balance, age of the shoots as well as prevailing environmental conditions Because of these favourable climatic conditions, many commercial orchards have been established in and around Muthalamada area of Palakkad district (Radha and Nair, 1999).

The mango trees start flowering during the month of November – December. The fruits will be ready for harvesting by March to May depending upon the genetic characters of the mango varieties cultivated. Harvest begins in the month of February when mangoes have not arrived from other states. This has led to a greater demand of mangoes grown in Kerala from markets outside the state. The earliness of mango production has earned greater profits for the mango growers in Palakkad district (Radha and Nair, 1999).

The common commercial cultivars of mango grown in orchards located in Kerala are Alphonso, Bangalora, Banganapally, Bennet, Chandrakaran, Guddadat, Kalapady, Mundappa, Mulgoa, Muvandan, Nadasala, Neelum, Prior and Sindhuram (Radha and Nair, 1999).

2.2. MANGO INFLORESCENCE

Flowering is a decisive element affecting production and productivity of mango crop. Mango inflorescence was reported to be a complex and irregularly branched Panicle. The panicle has a main stock with numerous side branches and these numbers varies with variety. The number of individual blossoms in a panicle vary from about 100 to 1000 (Juliano, 1934; Cobin *et al.*, 1950). The number of panicles in a tree can vary from 200 to 3000 based on the age, bulkiness and formation of branches (McGregor, 1976).

Each flower in a mango panicle may either be a perfect flower or a staminate flower. The perfect flowers have an ovary in addition to stamens. However, there will be only one functional stamen in any flower and the other stamens are sterile staminoids. Flower drop is a major phenomenon reported as a drawback of mango inflorescence. All the individual flowers will not develop into a fruit. Most of these blossoms may drop off before fruit formation. Even those that form a fruit often fall off before reaching maturity (Sturrock, 1966).

Considerable changes in sex ratio were noticed within the same variety of mango irrespective of age of the tree or the locality of its cultivation (Coetzer *et al.*, 1995). The sex ratio of flowers may be influenced by external climatic conditions and internal physiological elements of the plant (Asif *et al*., 2002 and Davenport, 2009).

2.3. BARRIERS IN FRUIT PRODUCTION

India, despite being a major producer of mango in the world, trails behind China in its productivity. Various reasons can be attributed for low productivity of mango in the country (Ahuja *et al*., 2011). Climate is a decisive factor influencing flowering of mango and this has caused a havoc to mango growers (Misra *et al.*, 2012).

Climatic factors like rainfall, temperature or relative humidity and the combined effects of these factors were reported to influence mango cultivation (Pandey, 1988). Scarcity of water and incidence of pests or diseases, were the other parameters that were reported to contribute negatively to the yield of mango. (Soomro, 1988).

Obviously the number of fruits harvested is a reflection of perfect flowers the panicle owns. Some flowers that may externally appear perfect might also have ill developed structures hindering fruit formation. But the physical damages to which a flower gets exposed to is one among the various factors that determine the flower retention (Sturrock, 1966).

Verghese and Jayanthi (2001) reported the changes in pest scenario and pest status of mango from the past decades and attributed various parameters to such a change. Agronomic practices can be spotted as a reason for the situation. Adoption of practices like high density planting or ultrahigh density planting, drip irrigation and pruning were a few factors that can alter the change in the pest status.

In the case of high density planting or ultra high density planting, the troublesome situation was created due to diffused penetration of sunlight and overcrowding of branches which favoured the incidence of pests and diseases (Kumar, 2019).

Diseases reported to cause economic losses in mango include anthracnose, powdery mildew, sooty mould, malformation, die back and blossom blight, (Misra *et al.*, 2012). The complete control of diseases is not feasible in the real field situation and some extend of losses is inevitable.

According to a study conducted by Tandon and Verghese, (1985) around 400 insects belonging to orders Hemiptera, Lepidoptera, Coleoptera and Diptera have been recorded from mango. In the Indian scenario, about 250 insect and mite pests were recorded. Only about 30 insect species among these were reported to cause a serious threat to the yield of mango (Kapadia, 2003).

2.4. PEST INFESTATION IN MANGO

Insect and non insect pest attack on mango had been a potential havoc during the different stages of vegetative and flowering period (Pena, 1992). Pest attack in mango occurs throughout the different growth phases and almost on all the plant parts *viz.*, tender shoots, foliage, buds, shoots, stem and fruits.

Mango itself was recorded as a host for around 400 species of insects, another 26 species of nematodes and about 17 mite species. Among these insect species, about 250 and more were regarded as pests with nearly 180 species documented from India (Tandon and Verghese, 1985; Waite, 2002).

Leaf hoppers form a predominant share of yield loss in mangoes; at times reaching a vulnerable cent per cent yield reduction. There were reports of nearly 15 species of hoppers from the continent and about 20 mealybug species have been recorded from mango (Reddy *et al.,* 2018). Thrips were noticed to incur heavy damage to even flowers and fruits, apart from the leaves of mango.

Several pest species of lesser importance has also been raised to an economically significant level. Mango shoot webber, earlier considered as minor pest was reported to cause a havoc when it shifted its niche to the floral parts, qualifying its status as a major pest (Kavita *et al.,* 2005).

Beetle infestation in the newly emerging mango shoots incurred heavy losses. The notable species recorded in a study conducted in Thiruvananthapuram were mainly curculionids *viz.*, *Rhynchaenus mangiferae* Ms., *Myllocerus* spp., *Apoderus tranquebaricus* F. and *Deporaus marginatus* (Pas.) (Preetha, 2010).

The incidence of other pests include, mealy bugs (nearly 20 species have been documented from mango), scale insects, stem borers, nut weevil, fruit flies, and mites (Reddy *et al*., 2018).

2.5. ARTHROPOD COMPLEX IN INFLORESCENCE

Insect and non insect pests were reported to attack both during the vegetative and flowering phases of mango crop (Pena, 1992). Mango inflorescence was recorded as a host of wide variety of insect and non insect pests.

Around 400 species of insects, 26 species of nematodes and about 17 mite species were reported to be associated with mango. Among the insect species reported, about 250 were regarded as pests with nearly 180 species documented from India (Tandon and Verghese, 1985; Waite, 2002).

Jiron and Hedstrom (1985) reported the association of dipterans with mango inflorescence when they were in full bloom and filled with nectar. The majority of dipterans visitors were considered as vital pollinators. This included a share of about 51.6 per cent among the total floral visitors.

The houseflies *Musca domestica* were not much significant pollinators. Many other species including the stingless bees *Trigona* spp., were considered as important pollinators in India (Singh, 1960). Singh (1985) reported *Syrphus* sp. and *Melipona* sp. were efficient pollinators of mango flowers. Apart from these floral visitors, the mango panicle comprises of a varied insect complex diversity from different orders.

2.5.1. THYSANOPTERA

Thysanopterans hold a share of yield loss with dried up blooms. *Thrips imaginis* Bagnal, *Thrips hawaiiensis* (Morgan), *Frankliniella schultzei* (Trybom) and *Megalurothrips usitatus* (Bagnall) were some of the species reported infesting mango from different regions of the world (Waite, 2002; Aliakbarpour and Salmah, 2010).

Heliothrips haemorrhoidalis Bouché was recorded from Israel with economic significance (Wysoki *et al.*, 1992). Blossom damage was mainly caused by

Selenothrips rubrocinctus (Giard) and *Scirtothrips aurantii* Faure as per the survey conducted in Reunion Island (Amouroux and Normand, 2010).

Some of the partially predatory as well as phytophagous thrips were reported from the malformed inflorescence of mango grown in Israel. *Aelothrips collaris* Priesner, *A. gloriosus*, *Haplothrips andresi* Priesner, *H. clarisetis* Priesner, *H. ditinguendes* (Uzel), and *H. gowdeyi* (Franklin) were found associated with inflorescence of mango (Wysoki *et al.*, 1995).

Frankliniella kelliae (Sakimura), *F. occidentalis* (Pergande) and *F. bispinosa* (Morgan) were those found infesting mango flowers and damaging them by feeding the sap. They were also found to cause damage to the newly formed fruits exhibiting bronzing of the surface tissues (Lewis, 1973). They feed on the nectar and anther causing drying of flowers and eventually affecting fruit set and yield loss (Pena, 1992; Wysoki *et al.*, 1992).

Patel *et al*, (1997) reported the incidence of *Caliothrips impurus* Priesner, *S. rubrocinctus* and *Pantachaetothrips* sp., on mango rootstocks. Infestation of *Megalurothrips distalis* (Karny) was reported by Ramasubbarao and Thammiraju (1994) and *Haplothrips tenuipennis* Bagnall by Kannan and Rao (2006).

S. rubrocinctus and *S. mangiferae* Hood were reported from Kerala (Ananthakrishnan and Muraleedharan, 1974) and Haryana (Dahiya and Lakra, 2001) respectively.

There were also reports about the flower feeding thrips *viz., Scirtothrips dorsalis* (Hood), *Neoheegeria mangiferae* (Priesner), *Haplothrips ganglbaueri* (Schmutz), *Thrips palmi* Karny and *Ramaswamiahiella subnudula* (Karny) (Butani,1979; Tandon and Verghese 1987) from various parts of India.

First report of *Thrips subnudula* and *F. schultzei* infesting the inflorescence of mango were from India (Krishnamoorthy and Visalakshi, 2012). Incidence of *H. ganglbaueri* (Schmutz), *Exothrips hemavarna* Ramakrishna, *Rhipiphorothrip scruentatus* Hood, and *Scirtothrips dorsalis* Hood were recorded from mango ecosystems of Gujarat (Bana *et al.*, 2018).

2.5.2. HEMIPTERA

2.5.2.1. Hoppers

Hoppers were reported to be highly destructive to mango ecosystems with the peak periods during new flush emergence and flowering. The incidence was found to continue even after fruit setting with the population declining thereafter (Bana *et al.*, 2018).

The widespread dominant species of hoppers recorded from the tender parts and flowers of mango comprises of *I. nagpurensis* (Pruthi), *I. clypealis* (Lethierry), *I. nitidulus* (Walker), and *Amritodus atkinsoni* (Lethierry) (Veeresh 1985; Waite 2002). Hoppers as serious pests during the reproductive stage were found to cause threat, even during fruit set (Gundappa, 2014).

Hoppers were found to feed on the tender leaves and shoots, panicle and also the fruit rachis. Severe infestation of hopper was accompanied with honey dew and sooty mould formation leading to complete yield loss (Bana *et al.*, 2018).

The sooty mould *Meliola mangiferae* (Earle) was even found to hinder the photosynthetic activity of the plants (Verghese, and Jayanthi, 1999).

The two other hopper species identified were *Meganeura reticulate* Ghauri and *A. splendens* from Malaysia and India respectively by Ghauri (1967). *A. splendens* was first reported in Kerala by Das *et al.*, (1969). *I. clarosignatu* and *I. nigroclypealis* were other two species recorded from Singapore (Viraktamath and Murphy, 1980) whereas *I. ayshriae* and *Busoniominus manjunathi* were from Karnataka (Viraktamath and Viraktamath, 1985).

Idioscopus sp. along with *A. atkinsoni* were found to have peak population build up during the flower initiation period which continue till the full bloom stage (Srivastava, 1998; Babu *et al.*, 2001; Sushil *et al.*, 2002).

Nair (1989) reported three main hopper species from Kerala viz., *Amritodes atkinsoni* (Leth), *Idioscopus clypealis* (Leth) and *I. niveosparsus*. *Amrasca splendens* Ghouri was another leaf hopper reported from Kerala in mango.

2.5.2.2. Mealy bugs and scales

Mealy bugs are another serious sap sucking group incurring a yield loss of even 80 per cent. About 20 different species of mealybugs were recorded on mango grown in different parts of the world (Karar *et al*., 2012).

The major species included *Drosicha mangiferae* (Green), *Rastrococcus iceryoides* (Green) and *Drosicha stebbingi* (Green) (Tandon and Verghese, 1985). Severe infestation by mealy bugs results in covering of the entire panicle by them. They were also reported to cover the entire surface of the developing fruits. The infested fruits may shrink and drop off prematurely. The infested trees were found to be covered with sooty mould as a result of honey dew excreted by them (Singh, and Mukherjee, 1989).

There were reports from Florida regarding the presence of citrus mealybug, *Planococcus citri* and *Pseudococcus* spp. on mango. The excretion of honeydew by these mealybugs resulted in sooty mould formation on the shoots of mango (Pena, 1992).

Morganella longispina and *Racheospila gerularia* were the scale insects reported to cause damage to the mango flowers grown in Florida (Pena, 1992). *Ceroplastes floridensis* Comstock was an economically important scale insect reported to damage mango from Israel (Wysoki *et al.,* 1992).

Preetha (2010) conducted a study on the shoot feeder incidence on mango. The different species of scales and mealybugs recorded from mango shoots included *Phenacoccus* sp., *Ferrisia* spp., *Ceroplastes* spp., *Coccus* spp., *Aspidiotus* spp. and *Chionaspis* spp.

2.5.2.3. Psyllids

Apsylla cistellata Buckton, a monophagous mango pest, usually seen feeding on the midribs. But the gall formation was found to interfere with the floral development wherein the twigs end up drying finally (Singh *et al.,* 1975; Singh, 1978).

2.5.2.4. Mirids

Daghbertus olivaceous, Rhinacloa spp. and *Daghbertus fasciatus* were the mirids reported to damage the panicle with ovipositional punctures along with feeding injury (Pena, 1992).

2.5.3. LEPIDOPTERA

Abdullah and Shamsulaman (2008) reported lepidopterans as economically second important pests attacking inflorescence of mango. Perusal of information on the lepidopterans infesting inflorescence revealed the scantiness of literature.

Gymnoscelis imparatalis Walker, *Asurarupto fascia* Hampson, *Celamaanalis* Will, *Cosmostola laesaria* Walker, Westwood, *Celama fasciatus* Walker and *Eublemma* spp. were recorded as inflorescence feeders and were reported to cause webbings of flowers while feeding on them (Reddy *et al.*,2018).

The microlepidopteran infestation in mango panicle is quite common. Pena (1992) reported the incidence of *Platinota rostrana* (Walker), *Pococera atramentalis* (Lederer), *Pleuroprucha insulsaria* (Guenee), *Tallula sp*. and *Marmara* sp. in inflorescence of mango. The caterpillars were found feeding on the axis, petals and even floral ovaries. They seemed to form nests in inflorescence with fastened webbings of dried up flowers. The damage to fruit peduncle resulted in premature fruit drop.

In the collection of insect species from the malformed mango blossoms, the lepidopterans recorded were *Lobesia botrana* Den. et Schiff, *Cryptoblabes gnidiella* (Mill), *Gymnoscelis rufifasciata* (Haw.), *Stathmopoda* spp., together with many other microlepidopterans (Wysoki *et al*., 1995).

A set of inflorescence caterpillars, damaging the mango inflorescence were reported from Karnataka. These mainly included *Argyroploce aprobola* Meyrick, *Euproctis fraterna* (Moore) and *Eucrostus* sp. They were found to affect the flower retention and thereby the fruit set. The potential danger caused by the caterpillars in

inflorescence was underrated for a long period of time (Verghese and Jayanthi, 1999; Kannan *et al*., 2002).

Many caterpillars were found to form webbings with leaves and flower stalks of mango inflorescence and caused immense damage to a tune of 20 to 40 per cent yield loss (Verghese, and Jayanthi, 1999; Chowdhury, 2015).

Dudua aprobola was documented from the mango panicles with eggs laid in the flowering stalks during panicle initiation periods. *Chlumetia transversa*, *Porthesia scintillans*, *Thalassodes quadraria*, *Nanaguna* sp., *Anarsia* sp., *Orgyia australis*, *Hypotima* sp. and *Perixera illepidaria* were the other caterpillars collected from the panicle (Soumya *et al.,* 2017).

The shoot borer, *C. transversa* was found to bore into axis of panicles causing around 40 per cent damage. *Nanaguna* sp. and *Anarsia* sp. were commonly found to form webbings, thereby hindering the normal developmental process of the flowers. *O. australis* was found to cause nibbled appearance in the inflorescence whereas *Hypotima* sp. was reported to form webbing of the flowers and the larva was reported to feed within the nest (Soumya *et al.,* 2017).

Borers were noticed to lay eggs even in the panicle of mango. These pinkish caterpillars in turn tunnelled the stalks of the panicle after the hatch out from eggs. The major borers recorded from the inflorescence of mango were *C. transversa*, *Gatesclarkeana erotias* Meyrick, *Chelaria spathota* Meyrick, *C. alternans* Moore, *D. aprobola*, *Anarsia lineatella* Zeller and *A. melanoplecta* Meyrick (Butani, 1979; Srivastava, 1997).

The different shoot feeders of mango documented from a study in Thiruvananthapuram district included caterpillars, beetles and even midges. *Arhopala* sp., *Bombotelia jocosatrix* Guenee, *Lymantria* sp., *Euthalia garuda* (Moore), *Thalassodes quadraria* (Guenee), *Dasychira mendosa* (Hubner), *Orthaga exvinacea* (Hampson), *Rothinda amor* (Fabricius), and *Latoia lepida* (Cramer) were the caterpillars recorded (Preetha, 2010).

Nair (1989) reported the incidence of several caterpillars infesting mango in Kerala. The common noctuids reported were *Chlumetia transversa* Wlk., *Bombotelia jocosatrix* G., *Eublemma abrupta* Wlk, *E. brachygonia* Hmps., *E. angulifera* Moore and *Nanaguna breviuscula* Wlk. *Dasychira mendosa* Hb., *Euproctis xanthosticha* Hmps., *Perina nuda* Fab. and *Asura ruptofascia* Hmps. were the hairy caterpillars reported from mango ecosystems of Kerala. The incidence of geometrids included *Thalassodes quadraria* Guen., *Chloroclystlis* sp., *Comostola laesaria* Wlk., *Gymnoscelis transversa* Wlk. and *G. impartalis* Wlk. *Rapala manea*, a lycaenid was also found to damage floral causing yield reduction .

2.5.3.1. PEST SHIFT PARADIGM

In the recent scenario, mango plantations were reported to be severely attacked by the several species of polyphagous caterpillar pests. These incur tremendous loss to growers, even to a level comparable to those caused by hoppers and other conventional species present (Jayanthi *et al.*, 2018).

In a pest status review by Butani (1979), the pests attacking inflorescence of mango were classified as economically unimportant. The major share of loss was contributed by sap feeders. The pest scenario was found to change depending on the seasonal variations and geographical locations (Soumya *et al.*, 2017).

The detailed documentation studies later on carried out by Jayanthi *et al.* (2018) waved at the possibilities of niche shift in caterpillar species and even the chance of turning them to obtain a relevant pest status. In the surveillance study conducted at Indian Institute of Horticultural Research (IIHR), Bangalore, around 22 morphospecies of polyphagous pests from the different families of Crambidae, Eutellidae, Noctuidae, Nolidae, Hespiiridae, Pyralidae, Tortricidae and Lymantridae were noticed.

Abdullah and Shamsulaman (2008) reported the caterpillar shift in mango from the vegetative to reproductive parts. In the recent years, this shift in niche from leaves to flowers and the pest status of lepidopterans became quite evident. The

probable reasons could be varying. Pesticide usage patterns combined with the change in climatic situations proved to be a crucial factor (Jayanthi *et al.,* 2018).

2.5.4. DIPTERA

2.5.4.1. Gall midges

There were reports of around 16 species of gall midges infesting mango from the Asian subcontinent itself (Harris and Schreiner, 1992; Pena, 2002).

Mango panicle was found severely attacked by the devastation caused by the blister midge *Erosomya mangiferae* Felt incurring losses in fruit set to a tune of 70 per cent (Abbas *et al.,* 1985; Ahmed *et al.,* 2005).

Floral infestation by gall midges occur predominantly in the bud burst stage with eggs laid in between the folds of petals and sepals. Tunnelling occurs in the axis; hindering floral opening with a right angled bended appearance alongwith a pointed gall, ultimately affecting the yield. Severe infestation in the shoots end up with no inflorescence (Reddy *et al.,* 2018).

According to a survey conducted in Reunion Island, the green bug, *Orthops palus*, and *Procontarinia mangiferae* (Felt), were recorded as serious pests during flowering with a cumulative damage strategy (Amouroux and Normand; 2010). Oviposional site of *P. mangiferae*, may be the fleshy scale leaves of floral buds or the basal part of ovaries in mature ones. In case of severe attack the young floral buds were heavily affected and dried out.

Preetha (2010) reported the incidence of midge in mango shoots of Thiruvananthapuram district. The two main species recorded were *Proscontarinia* spp. Keiffer and *Erosomia indica* Grover.

Midges and other dipterans infesting mangoes were reported from Kerala, well before. These mainly included bud midge *Procystiphora mangiferae* (Felt) Hendel and shoot midge *Erosomyia indica* Grover (Nair 1989).

2.6. NATURAL ENEMIES

Despite the complex of insect pests, the mango panicle in turn hosts several natural enemies. In a survey conducted in Australia, various predatory and beneficial arthropods were documented. These were found to feed on thrips, aphids, mealybugs, immature scales, mango hoppers and even the lepidopteran eggs. The natural enemies including predators and parasitioids mainly comprises of lady bird beetles, lace wing bugs, hoverflies, spiders and ants (Peng and Christian, 2005).

2.6.1. ARANEAE

In a study conducted in the mango orchards of Lucknow, different spiders and coccinellids along with *Chrysoperla carnea* (Stephens) were noticed. *Lyssomanes sikkimiensis* (Tikader), *Plexippus payjtllli* (Audouin) and *Marpissa* spp. were the different spiders documented (Anonymous, 2004).

In a study conducted in the mango ecosystems of Gujarat, five different species of spiders *Argiope* sp., *Plexippus paykulli*, *Neoscona* sp., *Oxyopes* sp. and *Peucetia* sp. were found to prey mainly on hoppers. The peak activity was found positively correlated with the incidence of hoppers (Purohit and Kumar, 2008).

Srivastava *et al*., (1979) reported twelve different spider species along with predatory mantids, red ant, black ant and predatory bugs. The spiders documented were found to prey upon the mango hoppers. It includes *Uloborus* spp., *Theridion indica* (Tikader), *Araneus sinhagadensis* (Tikader), *Cyrtophora* spp., *Phiddipus* spp., *Marpisa* spp., *Rhene indicus, Oxyopes shweta* (Tikader), *C. cicatrasa, Hersilia sarigryi* (Audouin), *Stegodyphes sarsihorum* Karsch, *Linphia* spp. and *Cheiracanthium donicli* (Koch).

Shivamurthy (2016) recorded three different spider species from the mango orchard, comprising of *Argiope pulchella* Thorell, *Tetrognatha* sp. and *Oxyopes javanus* Thorell. Population of ants were high compared to other predators in his studies.

2.6.2. MANTODEA

Mantids were effective predators in the mango ecosystem where the peak incidence was usually noticed in the month of November where it continues till the end of reproductive phase. Devi *et al.,* (2011) reported that *Mantis religiosa* Linnaeus was an efficient predator of mango hoppers. They were also predatory on aphids, bugs, hoppers and larva of moths and butterflies.

2.6.3. HEMIPTERA

Manjunatha (2015) reported a reduvid bug, *Endochus inornatus* (Stal) as a predator of mango hopper, *Pselliopus barberi,* and *Eucanthecona furcelleta*, were recorded as natural enemies of mango hoppers (Anant, 2016).

2.6.4. COLEOPTERA

The predatory coleopterans recorded from the mango orchards include *Telsimia* sp., *Harmonia testudinria, Trichalus* sp., *Scymnodes* sp. and *Chilocorus* sp. (Krull, 2004). *Cryptolaemus* spp., *Menochilus sexmaculatus* (Fabricius), *Coccinella septumpunctata* (Linnaeus) and *C. transversalis* were the cocinellids reported from a study conducted in Lucknow. These coccinellids were found to prey upon *I. niveosparsus, I. clypealis* and *A. atkinsoni* (Anonymous, 2004).

2.6.5. HYMENOPTERA

The majority of hymenopteran predators were included under the family Formicidae comprising of *O. smaragdina*, *Camponotus* sp., *Paratrechina* sp., *Prolasius* sp., and *Prenolepis* sp. (Krull, 2004).

Shivamurthy (2016) in his studies identified and recorded, two species of ants *viz.*, *Oecophylla smaragdina* Smith and *Camponotus compressus* Fab. *Componotus* spp., the black ants were predatory on soft bodied insects. *Platigaster* sp. was another hymenopteran recorded as a natural enemy of mango hopper (Anant, 2016).

2.6.6. NEUROPTERA

The grubs and adults of *C. septumpunctata* and *Chrysoperla zastrowii* (Esben-Peterson), were important predators of various soft bodied insects including jassids, mealybugs, aphids and whiteflies (Khan *et al.,* 1999; Anant, 2016).

Chrysopids were recorded as a well defined predator for various soft bodied insects associated with mango. The predominant species include *Mallada boninensis* (Okamoto), *Apterochrysa crassinervis* (Esben-Peterson), and *C. carnea* (Stephens) (Anant, 2016).

The frequently noticed spiders from the inflorescence of mango were *Alpaida dominica* Levi, *Mesumenops* sp., and *Mesumina* sp. Some other predators recorded were *Orius* sp, Anthocorids, *Lestodiplosis* sp., (Whitwell, 1992).

2.7. MANAGEMENT

2.7.1. Chemical means

In a study conducted on the efficacy of buprofezin against *I. clypealis* in varying concentrations *viz.* 0.0125 %, 0.025 %, 0.0375 %, 0.05 %, and 0.075 %, pretty good reduction in population was recorded by 0.0375%, 0.05% and 0.075 % concentrations (Srivastava and Verghese, 1989).

Kudagamage *et al*. (2001) tested the effectiveness of neem oil with other insecticides including buprofezin (Applaud 10% WP), imidachloprid (Admire SL 200) (1 ml L^{-1}) and fention (Fenthion 50% EC). The treatments were applied twice, one immediately after flowering and the other 10 days later. Maximum efficiency was shown by imidachloprid (1 ml L^{-1}).

Buprofezin 25 SC was evaluated for the control of hoppers (*I. nitidulus* and *A. atkinsoni*) in a study conducted in West Bengal. Imidachloprid 17.8 SL (0.0053 %) gave best results in controlling the hoppers followed by profenophos 50 EC (0.075%). Buprofezin 25 SC suppressed the pest to a tune of 85.22 per cent. It was safer to use, exhibiting high population of natural enemies from 3.85 to 7.83 per cent compared to the untreated control (Ghosh 2013).

In a lab experiment conducted to evaluate the toxicity of sixteen different insecticides against the second instar of mango mealy bug *D. mangiferae*, maximum mortality was observed with Profenofos 50 EC (86.67 per cent) followed by Chlorpyrifos 40 EC (80 per cent) and Buprofezin (73.3 per cent). Whereas 100 per cent mortality was shown by Buprofezin (0.25 g per 30 ml) and Profenofos 50 EC (240 µl per 30 ml) after three days of spraying while it took around four days for Chlorpyrifos 40 EC (225 µl per 30 ml) to reach out, that level of mortality (Hussain *et al.*, 2012).

In a field experiment conducted during the 2015-16 to study the bioefficacy of different insecticides against slug caterpillar *Parasa lepida*, flubendiamide 480 SC @ 0.14 % showed least larval population followed by spinosad 45 SC @ 0.014 % and chlorantraniliprole 18.5 SC @ 0.006 % (Chaudhary *et al.*, 2018).

Karar *et al*. (2010) used eleven insecticidal formulations to study the best treatment for the management of mango mealy bug. Methidathion 40 EC (Supracide 40 EC, 150 mL) was the best treatment followed by acetamiprid 20 SP (Mospilan 20 SP, 100 g). Lowest mortality of 16 per cent was shown by buprofezin 20 SP (Starter 20 SP, 500 g).

In an experiment conducted to test the efficacy of different insecticides against the mango hopper *A. atkinsoni,* maximum suppression of mango hopper was exhibited by thiamethoxam 25 WG @ 25 g a.i. ha^{-}1. However, the pooled data showed that the predatory coccinellid population was highest with buprofezin 25 SC @ 250 g a.i. ha^{-1} followed by flonicamid 50 WG @ 75 g a.i. ha^{-1} (Kangale *et al.*, 2019).

Dwivedi *et al*. (2018) conducted an experiment to analyse the contact toxicity of fipronil (Regent 5 SC), imidachloprid (Maharaja 17.8 SL), chlorantraniliprole (Coragen 18.5 SC), indoxacarb (Avaunt 15.8 EC) and monocrotophos (Monodhan 36 SL) against the second instars of *Drosicha mangiferae* (Green) by the residue contact bioassay method. This was carried out on a glass surface and as nymphal dip method for second instar. 0.01% a. i fipronil (Regent 5 SC) and 0.01% a. i indoxacarb (Avaunt 15.8 EC) were found non toxic on glass surface method in the toxicity test.

In an evaluation study conducted against the white mango scale, *Aulacaspis mangifera*, three different treatments *viz*., buprofezin (Applaud 25% SC) 1.5 ml L^{-1}, lambda- cyhalothrin (Karate 2.5 % EC) 0.5 ml L^{-1} and malathion (Agrothion 57% EC) 2 ml L^{-1}) were utilised. The application of these chemicals against the nymphal stages proved malathion and lambda- cyhalothrin as better treatments whereas buprofezin remained second to best in all sprays during the season. Considering the adult females, maximum effectiveness was noticed in the case of buprofezin with cent percent mortality in certain situations during the study period (Salem *et al.,* 2011).

Shivamurthy (2016), reported that chlorantraniliprole 0.03% (Coragen 18.5% SC) 1.62 ml L^{-1} was the best treatment for the management of mango shoot webber, *Orthaga exvinacea* compared to eleven different treatments used. The maximum efficacy was shown by chlorantraniliprole at 0.03 % with a mortality of 95.18 per cent.

In a study conducted in 2006 against the avocado thrips *Frankliniella kelliae* and *F. bispinosa,* maximum reduction of population was observed in the treatment Novaluron 0.83 EC + oil and Z- cypermethrin (4 fl oz per 100 gallon) on par with danitol 2.4 EC (16 fl oz per 100 gallon) (Pena *et al*., 2006).

2.7.2. Non chemical means

Chemical method of pest control was found to show maximum effectiveness, despite the environmental issues created. The non chemical means of pest management was found safer with least disturbance to the ecological systems (Tewari and Krishnamoorthy, 1985).

In a comparative study, the effect of *Metarhizium anisopliae* ICIPE 69 (three doses; 10^8 conidia ml^{-1}, 10^9 conidia $ml^{-1,}$ and 2.10^9 conidia ml^{-1}) was evaluated along with another pesticide Chlorpyriphos-ethyl (480 g l^{-1}). *Rastrococcus invadens* and parasitoids; *Gyranusoidea tebygi* and *Anagyrus mangicola* were used in the study. .The bio pesticide was found compatible with parasitoids whereas the chemical treatment caused reduction in parasitoid number (Nebie *et al.,* 2018).

Sarode *et al*. (2016) used different treatments including biorationals for the management of hoppers in mango. Among the ten different treatments, all the four biorationals *viz.*, NSKE 5% @ 1500 ml ha^{-1}, *M. anisoplae* $1x10^8$ cfu ml^{-1} @ 0.004 %, *B. bassiana* $1x10^8$ cfu ml^{-1} @ 0.004 % and *V. lecanii* $1x10^8$ cfu ml^{-1} @ 0.004 %) were found equally effective.

In a study conducted against mango hoppers, the efficacy of different entomopathogenic fungi, *Leccaniicillium leccanii, Beauveria bassiana* and *Metarhizium anisopliae* in different concentrations and combinations were evaluated. It was revealed that the combination of *M. anisopliae* 10^8 cfu along with *L. leccanii* 10^8 cfu @ 10g was the best treatment in reduction of pest population (Valvi *et al.,* 2018).

Prabhakara *et al*., (2011) evaluated various doses (*viz.,* 2, 4 and 6 ml L^{-1}) of an oil based formulation of *B. bassiana* (Myco-jaal) against the mango hopper *I. nitidulus.* The highest dose was found to be most effective in pest control. Imidacloprid was used as a check in this experiment.

In a study conducted to evaluate the efficacy of botanicals against *D. marginatus* different formulations of neem and annona seeds were used. The treatments included Econeem plus 1 %, neem oil 2 %, neem seed kernel extract 5 %, neem oil garlic emulsion 2 % and annona seed extract 5 %. The effect on scraping and cutting of shoot by the pests were noticed. Econeem plus 1 % resulted in maximum control of leaf cutting whereas scraping was reduced to the best with annona seed extract 5 % (Preetha, 2010).

Shivamurthy (2016), evaluated the efficiency of different chemical and non chemical applications for the shoot webber and hopper management in mango. The maximum reduction in pest population was noticed in the chemicals applied. In his studies, *B. bassiana* (ITCC 6063) WP 2% and Azadirachtin 1% resulted in effective pest suppression among the biorationals against shoot webber attack.

MATERIALS AND METHODS

3. MATERIALS AND METHODS

Samples of mango inflorescence were collected from the three different blocks of Thiruvananthapuram district and it's pests were documented. The experiment regarding management of the insect species infesting mango inflorescence was conducted in a mango orchard located at Kollengode area of Palakkad district.

The materials gathered and methodologies followed in the investigation were explained in detail here under.

3.1. DOCUMENTATION OF INSECT PESTS AND THE NATURAL ENEMIES

In order to document the insect pests attacking mango inflorescence, three different blocks (*viz*., Nemom, Athiyannur and Parassala) of Thiruvananthapuram district were selected. The inflorescence samples were collected randomly from the mango trees grown in homesteads of these selected blocks. A minimum of ten different spots were randomly selected from each of these blocks for the purpose of documentation. Apart from this, documentation of insect pests was also done from the mango orchards located at Kollengode area of Palakkad district where the experiment involving pest management was undertaken.

3.1.1. COLLECTION AND PRESERVATON OF SPECIMENS

The inflorescence samples were collected in separate polythene covers with tags indicating the location, date of collection and sample number. The larvae of the lepidopteran pests were kept in large sized polythene zip lock covers whereas mango hoppers, mealybugs, natural enemies like spiders, ants, praying mantis and floral visitors were separately collected in vials of convenient sizes.

Mealybugs were collected along with the twigs in which they infested. They were also collected by removing them from the twigs delicately without spoiling the specimens. They were then placed in vials filled with absolute alcohol to the three fourth levels.

Thrips infesting inflorescence were collected by tapping the panicle on a white paper, and the collected specimens were preserved in 70% alcohol filled vials. These samples were brought to laboratory and examined under a microscope.

Caterpillars attacking inflorescence were collected from diverse locations and got labelled after individually separating them. Then they were provided with fresh inflorescence samples, after confirming that they were free of any other eggs or larvae. Then the morphological characters of larvae and time taken for pupation were recorded.

Apart from this, natural enemies and floral visitors were preserved for further identification.

3.1.2. PINNING AND SETTING OF THE MOTHS AND BUTTERFLIES.

The adults emerged from pupae were killed by using chloroform and pinned in the thoracic region with the aid of minuten pins. Then the wings of moths were stretched with the support of forceps and pins of convenient size. The setting of wings was done immediately to avoid damage of specimens, loss of scales and inability to stretch the wings. Since many of them were smaller in size, they were double mounted to eliminate further damage of the specimens. The pins were inserted in the suture found between mesoscutum and mesoscutellum or in the centre of mesothorax to prevent the wing muscles from getting transfixed.

Plastazote foams (2x4x15 mm) were used to pin the specimens after proper setting. These platazote foams loaded with minute pins were thereafter replaced with the normal entomological pins for easy handling and avoiding direct contact with the specimen. For the smaller specimens minuten pins (12 mm length x 0.15 mm diameter) were utilised.

The well-arranged specimens were preserved with naphthalene balls for later identification by the taxonomists.

3.1.3. LABELLING

The dried and preserved specimens were labelled. The specimens labelled basically had a primary label with details including the place of collection, date of collection, the name of collector and the host plant. This was placed in all the specimens to know about the primary details. However, determination label was kept next to the basic label after proper identification of the specimen.

Each of the specimens including pests, natural enemies and floral visitors were identified with the help of taxonomists.

3.2. MANAGEMENT OF INSECT PESTS IN INFLORESCENCE.

A field experiment was conducted in a mango orchard located at Kollengode area of Palakkad district to evaluate the treatments for management of insect pests infesting the mango panicles. Since the infestation of hoppers and other sucking pests were negligible, the present study was focused on the management of lepidopteran pests.

The study was conducted during the month of January 2020 in a high density mango orchard (Alphonso variety). Following were the details of treatments used for the experiment.

Design : CRD

Replication : 3

Treatments : 9

T1 : *Beauveria bassiana* (ITCC6063) WP 2%

T2 : Fish –jaggery mixture 0.5%

T3 : Azadirachtin 1%

T4 : Buprofezin 25% EC 62.5 g a.i. ha^{-1}

T5 : Novaluron 10% EC 100 g a.i. ha^{-1}

T6 : Chlorantraniliprole 18.5%SC 30 g a.i. ha^{-1}

T7 : *Metarhizium anisopliae* (Ma4) 20 g l^{-1}

T8 : Control (water spray).

T9 : Untreated Control

3.2.1. METHOD OF APPLICATION

Single spray of each treatment was undertaken on the mango trees during the flowering season. The spraying was done at 5 per cent incidence of the lepidopteran pests. The trees were randomly selected and tagged for the spraying schedule.

From each of the selected trees, four different branches facing towards the north, south, east and west directions were selected. From these selected branches three panicles of equal dimensions were selected and tagged separately for taking the observations.

Each of the nine treatments were replicated three times in a completely randomised block technique. Three out of the nine treatments were chemicals and water spray served as a check.

The talc formulation of ITCC6063 strain of *Beauveria bassiana* was prepared in the laboratory from the mother culture of the fungus and was grown in potato dextrose medium. This was incubated for about fourteen days to attain a maximum sporulation and the final product was mixed with talc in the ratio of 1:3.

The talc based formulation of *Metarhizium anisopliae* strain Ma4 was obtained from Biocontrol laboratory, Department of Agricultural Entomology, College of Agriculture, Vellayani. Fish–jaggery mixture was prepared in the laboratory. One kilogram of jaggery alongwith another one kilogram of the fish sardine was mixed and placed in a dry place for nearly 30 days. The product obtained was diluted to required concentration for further application.

Details regarding the application of treatments and dosage are as follows: Tabel 1: List of treatments selected for the field experiment

No.	Treatments	Dosage
1	*Beauveria bassiana* (ITCC6063) WP 2%	20 g L^{-1}
2	Fish –jaggery mixture 0.5%	5 ml L^{-1}
3	Azadirachtin 1%	10 ml L^{-1}
4	Buprofezin 25% EC 62.5 g a.i. ha^{-1}	1.6 ml L^{-1}
5	Novaluron 10% EC 100 g a.i. ha^{-1}	1 ml L^{-1}
6	Chlorantraniliprole 18.5%SC 30 g a.i.ha^{-1}	0.3 ml L^{-1}
7	*Metarhizium anisopliae* (Ma4) 2%	20 g l^{-1}
8	Control (water spray)	-
9	Untreated Control	-

3.2.2. OBSERVATIONS

Pre count of pest was recorded one day prior to the spraying schedule. Observations on the number of caterpillars were recorded on the fifth, tenth and fifteenth days after spraying. The number of fruits per panicle was then recorded from already tagged inflorescence at the peanut stage. The data collected were tabulated.

3.2.3. STATISTICAL ANALYSIS

All the tabulated data were subjected to statistical analysis. The date on pest number including pre count was subjected to square root transformation (Panse and Sukhatme 1967.

RESULTS

4. RESULTS

Incidence of various insect pests infesting the mango inflorescence resulted in varying degree of losses to the mango growers

4.1. DOCUMENTATION OF THE INSECT PESTS

Mango panicle was infested with a complex of insect pests representing various orders of insects. The different samples collected during the study included mango hoppers, mealybugs, thrips, cowbug and caterpillars. The samples were collected from different parts of Thiruvananthapuram and Kollengode area of Palakkad district during the flowering season of mango.

The pest species infesting mango inflorescence differed with seasons, which has reflected in the diversity of pests from the collected samples during different periods and locations thereof. The specimens thus collected were sent for identification to taxonomists of repute and the results were tabulated (Table 2 & 3).

4.1.1. Thysanoptera

During the month of July, 2019; a few samples collected from the areas adjacent to Athiyannur block exhibited severe drying up of inflorescence, examination of which showed the presence of thrips infestation.

The thrips *Gynaikothrips* sp. and *Haplothrips* sp., infested inflorescence exhibited bronzing symptoms and showed severe flower drop and failure of fruit set.

Table 2: Insect specimens documented from mango inflorescence.

No.	Specimen	Family	Order	Location	Co ordinates
1.	*Gynaikothrips* sp.	Phlaeothripidae	Thysanoptera	Athiyannur; Thiruvananthapuram	8º 25’ 56. 58755’’ N, 76º 59’14. 68982” E
2.	*Haplothrips* sp.	Phlaeothripidae	Thysanoptera	Athiyannur; Thiruvananthapuram	8º 25’ 56. 58755’’ N, 76º 59’14. 68982” E
3	*Idioscopus clypealis*	Cicadellidae	Hemiptera	Kollengode; Palakkad	10º 35’ 12. 45372’’ N, 76º 40’36. 6042” E
4.	*Amritodes* sp.	Cicadellidae	Hemiptera	Kollengode; Palakkad	10º 35’ 12. 45372’’ N, 76º 40’36. 6042” E
5	Unidentified (hoppers)	Cicadellidae	Hemiptera	Kollengode; Palakkad	10º 35’ 12. 45372’’ N, 76º 40’36. 6042” E
6.	*Icerya* sp.	Monophlebidae.	Hemiptera	Kollengode; Palakkad	10º 35’ 8. 47716’’ N, 76º 43’43. 61556” E
7	*Formicococcus mangiferacola*	Pseudococcidae	Hemiptera	Kollengode; Palakkad	10º 35’ 8. 47716’’ N, 76º 43’43. 61556” E

Table 2: Insect specimens documented from mango inflorescence (continued).

8	*Rastrococcus* sp.	Pseudococcidae	Hemiptera	Kollengode; Palakkad	10º 35’ 12. 45372’’ N, 76º 40’36. 6042” E
9.	*Crisicoccus hirsutus*	Pseudococcidae	Hemiptera	Athiyannur; Thiruvananthapuram	8º 24’ 16. 37604’’ N, 76º 59’51. 3852” E
10.	*Rastrococcus iceryoides*	Pseudococcidae	Hemiptera	Nemom; Thiruvananthapuram	8º 25’ 29. 90388’’ N, 77º 1’53. 64588” E
11.	*Ferrisia virgata*	Pseudococcidae	Hemiptera	Nemom; Thiruvananthapuram	8º 25’ 29. 75376’’ N, 77º 1’53. 2002” E
12.	Cowbug	Membracidae	Hemiptera	Athiyannur; Thiruvananthapuram	8º 25’ 56. 58755’’ N, 76º 59’14. 68982” E
13	*Nonartha* sp.	Chrysomelidae (Galerucinae)	Coleoptera	Athiyannur; Thiruvananthapuram	8º 25’ 21. 71’’ N, 76º 58’37. 23” E
14.	*Monolepta* sp.	Chrysomelidae (Galerucinae)	Coleoptera	Athiyannur; Thiruvananthapuram	8º 25’ 21. 71’’ N, 76º 58’37. 23” E
15	*Oecophylla smaragdina*	Formicidae	Hymemoptera	Athiyannur; Thiruvananthapuram	8º 24’ 16. 37604’’ N, 76º 59’51. 3852” E

4.1.2. Hemiptera

Mango hoppers, cowbugs, mealybugs and scale insects were the major hemipterans found attacking mango inflorescence. Mango hoppers were recorded from both shoots and inflorescence. *Idioscopus clypealis* and *Amritodes* sp. were the species of mango hoppers noticed, attacking mango grown in orchards located at Kollengode area of Palakkad district (Plate 1) whereas hoppers collected from mango orchard located at College of Agriculture, Vellayani of Thiruvananthapuram district are yet to be identified.

Cowbugs collected from Athiyannur area of Thiruvananthapuram district are yet to be identified (Plate 2). They were noticed to show association with hymenopterans like *Camponotus compressus.* Similar hemipteran- hymenopteran association were noticed with *Oecophylla smaragdina* and mealybug, *Rastrococcus iceryoides,* where the former feed on the secretions of mealybug and in return provide protection. Mealy bug infestation was noticed on both vegetative and flowering phase of mango, including fruits. Samples of mealy bugs and scales collected from mango trees during the month of November-December, 2019 was identified by Dr. Sunil Joshi, Principal Scientist from the Division of Insect Systematics, ICAR- National Bureau of Agricultural Insect Resources [NBAIR]. *Crisiococcus hirsutus* was recorded from Athiyannur area whereas *Rastrococcus iceryoides* and *Ferrisia virgata* were recorded from Nemom area of Thiruvananthapuram district. *Formicoccus mangiferacola, Rastrococcus* sp.and *Icerya* sp. were collected from Kollengode area of Palakkad district (Plate 3).

4.1.3. Coleoptera

Many tiny coleopterans were found in association with the mango inflorescence. High population of *Nonartha* sp. was recorded from Athiyannur area of Thiruvananthapuram district. *Monolepta sp.* was also recorded from the same location (Plate 4).

Plate 1: Hopper infestation in mango inflorescence

Cowbug (unidentified) - *Camponotus compressus*

Oecophylla smaragdina- Rastrococcus iceryoides *O. smaragdina* (Webbings)

Plate 2: Hemiptera - Hymenoptera: Association and Infestation in mango

Rastrococcus iceryoides

Crisicoccus hirsutus

Icerya sp.

Rastrococcus iceryoides

Ferrisia virgata

Formicococcus mangiferacola

Plate 3: Hemipteran (Mealybugs and Scales) infestation on mango

Nonartha sp. (8x)

Monolepta sp.

Plate 4: Coleopteran pests infesting mango inflorescence

4.1.4. Lepidoptera

Abundant number of lepidopteran infestation was recorded from the inflorescence of mango collected from Thiruvanantahpuram and Palakkad districts. The samples collected included individuals belonging to various families of order Lepidoptera including Geometridae, Lycaenidae, Torticidae, Nolidae, Noctuidae, Erebidae and Crambidae. Many individual larvae formed webbings whereas others were found inside boreholes made on peduncle and pedicel of flowers. Another common trend observed was the shift in shoot feeders to inflorescence.

The samples of caterpillars were collected during the month of November – December, 2018, March – April, 2019, November – December, 2019, January, 2020, and reared.. The identified specimens are tabulated (Table 3) and the details regarding the specimens are depicted below:

The larvae of *Perixera illepidaria* Guenee, Geometridae, were recorded from inflorescence of mango grown in Kollengode area of Palakkad district. The larvae were loopers moving from one panicle to other by hanging on a silken thread formed by them. The larvae were yellowish to dark brown in colour with banded appearance. There were a lot of variation in the colour of larvae of different instars. They were found feeding voraciously on flowers of the panicle. The newly formed pupae were green in colour, which subsequently turned brown before emergence of adults. The adults were fawn coloured with small dots on the margins of both the wings (Plate 5).

Table 3: Lepidopterans documented from mango inflorescence.

No.	Specimen	Family	Order	Location	Co ordinates
1.	*Perixera illepidaria*	Geometridae (Sterrhinae)	Lepidoptera	Kollengode; Palakkad	10º 35’ 8. 47716’’ N, 76º 43’43. 61556” E
2.	*Comostola laesaria*	Geometridae (Geometrinae)	Lepidoptera	Athiyannur; Thiruvananthapuram	8º 25’ 21. 71’’ N, 76º 58’37. 23” E
3	*Anthene lycaenina lycaenina*	Lycaenidae (Lycaeninae)	Lepidoptera	Nemom; Thiruvananthapuram	8º 25’ 27. 56712’’ N, 77º 1’52. 55256” E
4.	*Rapala manea*	Lycaenidae (Lycaeninae)	Lepidoptera	Parassala ; Thiruvananthapuram	8º 22’ 36. 12’’ N, 77º 6’45. 36” E
5	*Archips micaceana*	Torticidae (Tortricinae)	Lepidoptera	Athiyannur ; Thiruvananthapuram	8º 27’ 6. 36102’’ N, 76º 57’7. 506” E
6.	*Gatesclarkeana erotias*	Torticidae (Olethreutinae)	Lepidoptera	Athiyannur ; Thiruvananthapuram	8º 25’ 56. 58755’’ N, 76º 59’14. 68982” E
7.	*Nanaguna breviuscula*	Nolidae	Lepidoptera	Athiyannur ; Thiruvananthapuram	8º 25’ 56. 58755’’ N, 76º 59’14. 68982” E

Table 3: Lepidopterans documented from mango inflorescence (continued).

8.	*Eublemma* sp.	Erebidae (Boletobiinae)	Lepidoptera	Nemom; Thiruvananthapuram	8º 25’ 29. 90388’’ N, 77º 1’53. 64588” E
9.	*Eublemma abrupta*	Erebidae (Boletobiinae)	Lepidoptera	Nemom ; Thiruvananthapuram	8º 25’ 29. 75376’’ N, 77º 1’53. 2002” E
10.	*Eublemma* nr.*quadripunctata*	Erebidae (Boletobiinae)	Lepidoptera	Parassala ; Thiruvananthapuram	8º 21’ 8. 64’’ N, 77º 4’40. 44” E
11.	*Eublemma versicolor*	Erebidae, (Boletobiinae)	Lepidoptera	Parassala; Thiruvananthapuram	8º 20’ 26. 16’’ N, 77º 5’1. 32” E
12.	*Lymantria* nr.*ampla*	Erebidae (Lymantriinae)	Lepidoptera	Nemom; Thiruvananthapuram	8º 25’ 27. 56712’’ N, 77º 1’52. 55256” E
13	*Lymantria* sp.	Erebidae (Lymantriinae)	Lepidoptera	Nemom ; Thiruvananthapuram	8º 25’ 27. 56712’’ N, 77º 1’52. 55256” E
14	*Bombotelia jocosatrix*	Noctuidae (Euteliinae)	Lepidoptera	Athiyannur ; Thiruvananthapuram	8º 25’ 21. 71’’ N, 76º 58’37. 23” E

Table 3: Lepidopterans documented from mango inflorescence (continued).

15	*Chlumetia transversa*	Noctuidae (Euteliinae)	Lepidoptera	Athiyannur ; Thiruvananthapuram	8º 27’ 30. 94128’’ N, 76º 57’2. 16468” E
16	*Aetholix flavibasalis*	Crambidae (Spilomelinae)	Lepidoptera	Athiyannur ; Thiruvananthapuram	8º 25’ 56. 58755’’ N, 76º 59’14. 68982” E
17	Unidentified specimen 1		Lepidoptera	Parassala; Thiruvananthapuram	8º 20’ 26. 16’’ N, 77º 5’1. 32” E
18	Unidentified specimen 2	Torticidae (Torticinae)	Lepidoptera	Nemom; Thiruvananthapuram	8º 25’ 27. 56712’’ N, 77º 1’52. 55256” E
18	Unidentified specimen 3		Lepidoptera	Athiyannur; Thiruvananthapuram	8º 27’ 30. 94128’’ N, 76º 57’2. 16468” E
19	Unidentified specimen 4		Lepidoptera	Nemom; Thiruvananthapuram	8º 25’ 29. 75376’’ N, 77º 1’53. 2002” E
20	Unidentified specimen 5		Lepidoptera	Parassala; Thiruvananthapuram	8º 21’ 8. 64’’ N, 77º 4’40. 44” E
21	Unidentified specimen 6	Torticidae	Lepidoptera	Nemom; Thiruvananthapuram	8º 25’ 29. 90388’’ N, 77º 1’53. 64588” E

Table 3: Lepidopterans documented from mango inflorescence (continued).

22	Unidentified specimen 7		Lepidoptera	Parassala; Thiruvananthapuram	8º 20’ 31. 92’’ N, 77º 5’31. 2” E
23	Unidentified specimen 8		Lepidoptera	Athiyannur; Thiruvananthapuram	8º 28’ 11. 08164’’ N, 76º 56’53. 58948” E
24.	Unidentified specimen 9		Lepidoptera	Nemom; Thiruvananthapuram	8º 25’ 29. 90388’’ N, 77º 1’53. 64588” E
25	Unidentified specimen 10		Lepidoptera	Athiyannur; Thiruvananthapuram	8º 27’ 30. 94128’’ N, 76º 57’2. 16468” E
26	Unidentified specimen 11		Lepidoptera	Nemom ; Thiruvananthapuram	8º 25’ 27. 56712’’ N, 77º 1’52. 55256” E
27.	Unidentified specimen 12		Lepidoptera	Parassala ; Thiruvananthapuram	8º 20’ 31. 92’’ N, 77º 5’31. 2” E
28.	Unidentified specimen 13		Lepidoptera	Parassala ; Thiruvananthapuram	8º 22’ 36. 12’’ N, 77º 6’45. 36” E

Table 3: Lepidopterans documented from mango inflorescence (continued).

29.	Unidentified specimen 14		Lepidoptera	Nemom; Thiruvananthapuram	8º 25’ 29. 90388’’ N, 77º 1’53. 64588” E
30.	Unidentified specimen 15	Torticidae	Lepidoptera	Athiyannur; Thiruvananthapuram	8º 24’ 16. 37604’’ N, 76º 59’51. 3852” E
31.	Unidentified specimen 16	Torticidae	Lepidoptera	Nemom; Thiruvananthapuram	8º 25’ 29. 90388’’ N, 77º 1’53. 64588” E
32.	Unidentified specimen 17	Torticidae	Lepidoptera	Athiyannur; Thiruvananthapuram	8º 24’ 16. 37604’’ N, 76º 59’51. 3852” E

The caterpillar of *Comostola laesaria* (Walker), Geometridae, the red dotted emerald moth, is a looper of pale green or brown colour. The adult is light greenish coloured medium sized with reddish dots on the wings with slight orange coloured border. The pest incidence was severe in few panicles while others showed a medium level of infestation. The adults took eight days for emergence from pupal stage. The pest was recorded on panicles of mango trees collected from Athiyannur region of Thiruvananthapuram district (Plate 5).

The larvae of *Thalassodes* nr.*dissita,* Geometridae*;* were light greenish in colour resembling the stalks of panicle with patch like dark reddish spots on the dorsal surface of the caterpillars. The adult moths had dark green coloured wings (Plate 5).

This is the first report of *Anthene lycaenina lycaenina,* Dakhan pointed ciliate blue Lycanidae; infesting mango (Plate 6) .The pest was found infesting mango inflorescence from Athiyannur area of Thiruvananthapuram district. The samples were collected during the month of November 2019. There were about 1- 5 larvae per panicle. The larvae were stout reddish brown coloured with paired rows of yellowish pattern on the dorsal surface. The larva was found to feed on the inflorescence. The later instars were voracious feeders with only the stalks left behind. The upper side of the male butterfly was dark metallic navy blue with thin black line along outer margins. The females were blackish brown in colour. It has a black spot capped in white near the costal margin of hindwing and another black spot with an orange coloured topping over them towards the anal angle. The underside is similar in both sexes. .

Rapala manea (Hewitson), Lycanidae, was found infesting on the inflorescence of homestead grown mango trees located at Parassala area of Thiruvananthapuram district. The stout dull yellowish larva showed spine like projections along the sides of the body and a dark reddish brown line over the dorsal surface in the two ends. The early instar larva was found feeding on the floral parts while the later

instars were more voracious feeders, only the stalks of the inflorescence remained. The adult males were dark wings with a tinge of purple colour. Female moths were lighter in colour. The ventral side showed black coloured markings towards the anal angle with an orange colour topping (Plate 6).

Nanaguna breviuscula Walker, Nolidae; was collected from Athiyannur area of Thiruvananthapuram district. The larva was translucent pale green yellowish in colour with light red coloured lines running along whole length of the body. The larva had a brown coloured head. The adult moth was brownish in colour having a diffused blackish band on the forewings. The hindwings were dull white coloured (Plate 7).

A wide range of moths belonging to Torticidae was collected and reared from the inflorescence collected but not all samples were identified. The moths of *Archips micaceana* (Walker) had a bell shaped structure like most of the torticid moths. The larvae were found feeding on the inflorescence. The moths were having reddish orange forewings with red coloured wavy lines in between. There were greyish markings on the inner side of light yellowish coloured hindwings (Plate 7).

Gatesclarkeana erotias Meyrick, Torticidae; is a bell shaped moth reared from mango inflorescence. The larva is dark green coloured caterpillar with a brownish head. The forewings are dark dull coloured with metallic reddish brown streaks and the hindwings are with dark yellowish coloured shade all over (Plate 7). .

Two moth species from the family Erebidae, subfamily Boletobiinae, were reared and the larvae had capitate setae spread all over the dorsal surface of the body with sparsely dispersed non capitate setae (Plate 8). .

The larva of *Eublemma* sp.is bright yellow in colour with brownish patches spreading all over it's body. Adult is dull coloured having a dual transverse line running along the wings and bordering the outer margin. The larvae of *Eublemma abrupta* was blackish in colour with a yellow coloured 'v'

A. Larva - *Perixera illepidaria*

B. Adult - *Perixera illepidaria*

A. Larva - *Thalassodes* nr. *dissita*

B. Adult - *Thalassodes* nr. *dissita*

Comostola laesaria

Plate 5: Lepidopterans infesting mango inflorescence (Geometridae)

A. Larva - *Anthene lycaenina lycaenina*

B. Dorsal side -*Anthene lycaenina lycaenina*

C. Ventral side

A. Larva - *Rapala manea*

B. Dorsal side - *Rapala manea*

C. Ventral side - *Rapala manea*

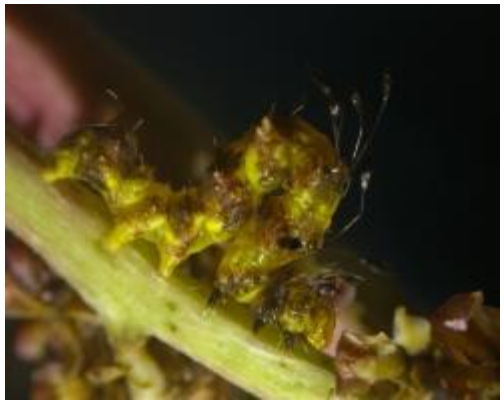
Plate 6: Lepidopterans infesting mango inflorescence (Lycaenidae)

A. Larva- *Nanaguna breviuscula* B. Adult - *Nanaguna breviuscula*

A. Larva - *Gatesclarkeana erotias* B. Adult- *Gatesclarkeana erotias*

Archips micaceana

Plate 7: Lepidopterans infesting mango inflorescence (Nolidae and Torticidae)



A. Larva - *Eublemma* sp.

B. Pupa- *Eublemma* sp.

C. Adult- *Eublemma* sp.

A.Larva - *Eublemma abrupta*

B. Larva - *Eublemma abrupta*

C. Adult- *Eublemma abrupta*

Plate 8: Lepidopterans infesting mango inflorescence (Boletobiinae; Erebidae)

shaped band near the head region and four eye like spots on the middle of dorsal surface. The moths were dull brown coloured with dual transverse lines of bland white shade running towards the inner side of forewings and the hindwings had black dots towards the lower end (Plate 8).

Eublemma versicolor Walker, Erebidae; was collected from Parassala area, Thiruvananthapuram district. The moths had a stout buff coloured body with a transverse brown coloured line running along the forewing and hindwing. The pupal case was hard and found having an outer cover of dried floral parts (Plate 9).

Larvae of *Lymantria* nr. *ampla* Walker, Erebidae; a hairy caterpillar was collected from full bloom panicles of mango grown in the Nemom area of Thiruvananthapuram. The adult moth is slightly more than medium in size having a golden brown coloured forewings with brown and black patches on it. The hindwings are light brown in colour (Plate 10).

Lymantria sp., the second species was also collected from Nemom area of Thiruvananthapuram district. The larvae were hairy caterpillars. The adult moth was whitish in colour with blackish brown patches smeared all over the surface of forewings and hindwings. The antennae of the moth were unipectinate type (Plate 10).

The larvae of *Bombotelia jocosatrix* Guenee, Noctuidae; was found feeding on flowers of mango grown in a homestead located at Athiyannur block. The larvae of these moths are stout, light greenish in colour with dark reddish pink tinges towards the anal region. The adult has blackish brown forewings; the margin of each of the forewing has an arc cut out of the tornus. The hindwings are white with a central black spot and a broad dark border (Plate 11). The moth has an unusual resting posture. Crest of scales are found raised over the head, the abdomen curled up over the body. The fifth instar larva was collected which pupated within two days. The pupal period was for 11 days.

The larva of *Chlumetia transversa* Walker, Noctuidae was collected from Athiyannur area of Thiruvananthapuram district. The larva was found infesting mango inflorescence. They were found among boreholes of peduncle and pedicles of flowers.

The larva is yellowish with peculiar red coloured pattern on the dorsal surface. The adults emerged within six days of pupal period. The adult moth has shining greyish brown coloured forewings and hind wings. The submarginal bands on the fore wings were found broken (Plate 11).

Aetholix flavibasalis Guenee, family Crambidae was collected from mango inflorescence of the trees grown in homestead of Athiyannur area of Thiruvananthapuram district. The moths had a medium body. The forewings were purplish in colour with pale spots. There was a white band across the hind wings (Plate 11). .

Unidentified specimen 1 was a medium sized white coloured moth with black coloured patch covering the coastal region in forewing having a buff coloured texture. The larva was yellowish in colour having three dark eye like spots on the middle of the body. The lateral side of the larva had a reddish coloured pattern intermingled with intermittent shades of yellow. Adult moths emerged after five days of pupal period (Plate 12).

Unidentified specimen 2, was a moth belonging to family Torticidae, collected from the Nemom area of Thiruvananthapuram district. The larva is a pale greenish coloured borer. The adult moth is bell shaped with brightly orange coloured forewings alongwith noticeable red coloured markings. The hindwings have a golden shade spreading all over the surface (Plate 12).

Unidentified specimen 3, was a light green coloured larva from the Athiyannur region of Thiruvananthapuram district. The larvae had reddish coloured markings on the dorsal surface. The adult was a medium sized yellowish golden coloured moth with dark brownish black wavy markings covering the entire wing surface (Plate 12).

A. Pupa - *Eublemma versicolor*

B. Adult- *Eublemma versicolor*

Eublemma nr. *quadripunctata*

Plate 9: Lepidopterans infesting mango inflorescence (Erebidae)

A. Larva -*Lymantria* nr.*ampla*.

B. Ventral side - *Lymantria* nr.*ampla*.

C. Dorsal side- *Lymantria* nr.*ampla*

A. Larva- *Lymantria* sp.

B. Pupa -*Lymantria* sp.

C. Dorsal side- *Lymantria* sp.

Plate 10: Tussock moths (Erebidae) associated with mango inflorescence.

A. Larva - *Bombotelia jocosatrix*

B. Adult - *Bombotelia jocosatrix*

A. Larva - *Chlumetia transversa*

B. Adult - *Chlumetia transversa*

Aetholix flavibasalis

Plate 11: Lepidopterans infesting mango inflorescence (Noctuidae and Crambidae)

A. Larva- Unidentified specimen 1

B. Adult - Unidentified specimen 1

A. Larva- Unidentified specimen 2

B. Adult - Unidentified specimen 2

A. Larva - Unidentified specimen 3

B. Adult - Unidentified specimen 3

Plate 12: Unidentified lepidopterans infesting mango inflorescence- 1

A. Larva - Unidentified specimen 4

B. Adult - Unidentified specimen 4

Unidentified specimen 5

Unidentified specimen 6

Unidentified specimen 7

Unidentified specimen 8

Plate 13: Unidentified lepidopterans infesting mango inflorescence- 2

Unidentified specimen 9

Unidentified specimen 10

Unidentified specimen 11

Unidentified specimen12

Unidentified specimen 13

Unidentified specimen 14

Plate 14: Unidentified lepidopterans infesting mango inflorescence- 3

Unidentified specimen 15

A. Larva - Unidentified specimen 16 B. Adult - Unidentified specimen 16

Unidentified specimen 17

Plate 15: Unidentified lepidopterans infesting mango inflorescence- 4

Unidentified specimen 4 (Plate 13), the larva was small in size and black in colour with tiny spots along the lateral sides of the body. Adult moth was a microlepidopteran with dark brown patches on a faded brown background. The hindwings had dull white coloured fringes. Unidentified specimen 5, was a microlepidopteran having an uniformly ash coloured forewings and hindwings. The hind wings had dull white coloured fringes (Plate 13).

Unidentified specimen 6, family Torticidae; the larvae had a pale greenish coloured body having a black ring near the thorax. The pupal stage took four days to emerge as adult moths. The adult was a buff coloured moth with and brown coloured wavy lines on the forwings (Plate 13).

Unidentified specimen 7.The adult was a dull coloured moth having large eye like spots on the forewings. The hindwings were dull white in colour (Plate 13). Unidentified specimen 8, the adult moth was a micolepidopteran having densely dark coloured forewings (Plate 13). There were several more lepidopteran specimens yet to be identified (Plate 14, Plate 15).

4.1.5. Natural enemies and floral visitors

Thomisus sp. and *Tetragnatha viridorufa* Gravely were the two main spider specimens collected from the Athiyannur area whereas *Cyrtophora cicatrosa* (Stoliczka) and *Tetragnatha* sp. were the two other specimens collected from the Nemom region of Thiruvananthapuram district (Table 4) (Plate 16). *Odontimantis pulchra* Olivier and *Odontimantis* sp. were the two specimens collected from the mango inflorescence collected from Athiyannur block. These green coloured mantids belong to the family Hymenopodidae (Table 5) (Plate 17).

Dipterans from the families of Syrphidae, Calliphoridae, Sarcophagidae and Drosophilidae were identified. The common floral visitors of mango inflorescence collected from the Athiyannur block were; *Eristalinus arvorum* (Fabricius), *Lucilia sericata* (Meigen), *Parasarcophaga dux* (Thomson) and *Drosophila* sp. (Table 5) (Plate 17).

Table 4: Spiders documented from mango inflorescence

No.	Specimen	Family	Order	Location	Co ordinates
1.	*Thomisus* sp.	Thomisidae	Araneae	Athiyannur; Thiruvananthapuram	8º 25’ 56. 58755’’ N, 76º 59’14. 68982” E
2.	*Tetragnatha viridorufa*	Tetragnathidae	Araneae	Athiyannur; Thiruvananthapuram	8º 24’ 16. 37604’’ N, 76º 59’51. 3852” E
3.	*Cyrtophora cicatrosa*	Araneidae	Araneae	Nemom; Thiruvananthapuram	8º 24’ 16. 37604’’ N, 76º 59’51. 3852” E
4.	*Tetragnatha* sp.	Tetragnathidae	Araneae	Nemom; Thiruvananthapuram	8º 25’ 27. 56712’’ N, 77º 1’52. 55256” E

Thomisus sp.

Cyrtophora cicatrosa

Tetragnatha viridorufa

Tetragnatha sp.

Plate 16: Spiders documented from the inflorescence samples

Table 5: Natural Enemies and floral visitors documented from mango inflorescence

No.	Specimen	Family	Order	Location	Co ordinates
1.	*Odontimantis pulchra*	Hymenopodide	Mantodea	Athiyannur; Thiruvananthapuram	8º 25' 56. 58755'' N, 76º 59'14. 68982" E
2.	*Odontimantis* sp.	Hymenopodide	Mantodea	Athiyannur; Thiruvananthapuram	8º 25' 56. 58755'' N, 76º 59'14. 68982" E
3.	*Eristalinus arvorum*	Syrphidae	Diptera	Athiyannur; Thiruvananthapuram	8º 25' 21. 71'' N, 76º 58'37. 23" E
4.	*Lucilia sericata*	Calliphoridae	Diptera	Athiyannur; Thiruvananthapuram	8º 25' 56. 58755'' N, 76º 59'14. 68982" E
5.	*Parasarcophaga dux*	Sarcophagidae	Diptera	Athiyannur; Thiruvananthapuram	8º 25' 56. 58755'' N, 76º 59'14. 68982" E
6.	*Drosophila* sp.	Drosophilidae	Diptera	Athiyannur; Thiruvananthapuram	8º 25' 56. 58755'' N, 76º 59'14. 68982" E

Table 5: Natural Enemies and floral visitors documented from mango inflorescence (continued)

7.	*Camponotus compressus*	Formicidae	Hymenoptera	Athiyannur; Thiruvananthapuram	8º 25’ 56. 58755’’ N, 76º 59’14. 68982” E
8.	*Hyalomorpha* sp.	Pentatomidae	Hemiptera	Nemom; Thiruvananthapuram	8º 25’ 27. 56712’’ N, 77º 1’52. 55256” E
9.	*Unidentified*	-	Neuroptera	Athiyannur ; Thiruvananthapuram	8º 27’ 6. 36102’’ N, 76º 57’7. 506” E

Odontimantis pulchra

Odontimantis sp.

Parasarcophaga dux

Bug -unidentified

Lucilia sericata

Eristalinus arvorum

Plate 17: Natural enemies and floral visitors from mango inflorescence

A total of 61 speciess were recorded from mango inflorescence. Among the 61 species, 31 species were recorded as pests of mango inflorescence whereas 12 as floral and natural enemies. 18 more species are yet to be identified. The dominance of pest was found to vary with season and location. The documentation of species from inflorescence revealed that the incidence of pests varied even in the same place with season to season.

4.2. MANAGEMENT OF INSECT PESTS OF INFLORESCENCE

A field experiment was conducted in Kollengode area of Palakkad district to evaluate the efficacy of nine different treatments *viz.*,

T1-*Beauveria bassiana* (ITCC6063) WP 2%,

T2-Fish – jaggery mixture 0.5%,

T3-Azadirachtin 1%,

T4-Buprofezin 25% EC 62.5 g a.i. ha^{-1},

T5-Novaluron 10% EC 100 g a.i. ha^{-1},

T6-Chlorantraniliprole 18.5%SC 30 g a.i. ha^{-1},

T7-*Metarhizium anisopliae* (Ma4) 20 g l^{-1},

T8-Control (water spray)

T9-Untreated control.

Since the incidence of lepidopteran pests was higher compared to other pests, the study was conducted to manage the caterpillar complex infesting mango inflorescence. Single spray of treatments were given on the inflorescence of mango and the reduction in population of the larvae was noticed on the fifth, tenth and fifteenth day after spraying (Table 6).

Pre count was recorded a day prior to the application of various treatments. The pre count of larvae was found non significant. Observations on the number of larvae (alive) were recorded on the fifth day after spray application. In general all the treatments were statistically significant at 5% level in reducing the larvae expect spraying of water on the inflorescence.

Table 6: Effect of different treatments on the caterpillars infesting mango inflorescence

Treatments	Mean number of larvae (alive)			
	Pre count	5 DAS*	10 DAS*	15 DAS*
Beauveria bassiana (ITCC6063) WP 2%	10.50 (3.32)	9.00 (3.08)^{c}	8.17 (2.94)^{c}	7.89 (2.90)^{b}
Fish –jaggery mixture 0.5%	10.90 (3.38)	10.06 (3.25)^{b}	8.83 (3.06)^{b}	8.33 (2.97)^{b}
Azadirachtin 1%	10.94 (3.38)	9.61 (3.18)^{bc}	8.22 (2.95)^{bc}	7.72 (2.87)^{b}
Buprofezin 25% EC 62.5 g a.i. ha^{-1}	11.00 (3.39)	8.11 (2.93)^{d}	6.56 (2.66)^{d}	5.33 (2.41)^{c}
Novaluron 10% EC 100 g a.i. ha^{-1}	11.06 (3.40)	8.06 (2.92)^{d}	6.28 (2.60)^{d}	5.22 (2.39)^{c}
Chlorantraniliprole 18.5% SC 30 g a.i. ha^{-1}	11.11 (3.41)	7.00 (2.74)^{e}	5.28 (2.40)^{e}	4.11 (2.15)^{d}
Metarhizium anisopliae (Ma4) 20 g l^{-1}	10.56 (3.32)	9.06 (3.09)^{c}	8.22 (2.95)^{bc}	7.94 (2.90)^{b}
Control (water spray)	11.33 (3.44)	11.06 (3.40)^{a}	10.78 (3.36)^{a}	10.56 (3.32)^{a}
Untreated Control	11.33 (3.44)	11.11 (3.41)^{a}	11.17 (3.42)^{a}	11.00 (3.40)^{a}
CD value (0.05)	NS	(0.129)	(0.110)	(0.123)

* DAS – Days after spraying

Values in parenthesis – Square root transformed values.

Table 7: Effect of treatments on number of fruits per panicle of mango

Treatments	No. of fruits
Beauveria bassiana (ITCC6063) WP 2%	16.33 (4.04)[c]
Fish –jaggery mixture 0.5%	10.67 (3.26)[d]
Azadirachtin 1%	15.00 (3.87)[c]
Buprofezin 25% EC 62.5 g a.i. ha^{-1}	20.33 (4.51)[b]
Novaluron 10% EC 100 g a.i. ha^{-1}	23.33 (4.83)[a]
Chlorantraniliprole 18.5%SC 30 g a.i. ha^{-1}	24.33 (4.94)[a]
Metarhizium anisopliae (Ma4) 20 g l^{-1}	15.67 (3.96)[c]
Control (water spray)	10.33 (3.21)[d]
Untreated Control	9.33 (3.05)[d]
CD (5%)	2.190 (0.287)

However, Chlorantraniliprole 18.5% SC 30 g a.i. $ha^{-1}$was the superior treatment in reducing the number of caterpillars (7.00) followed by Novaluron 10% EC 100 g a.i. ha^{-1} (8.06) and Buprofezin 25% EC 62.5 g a.i. ha^{-1} (8.11) and these treatments were statistically on par with each other.

Among the bio control agents maximum pest suppression was shown by *B. bassiana* (ITCC6063) (9.00) followed by *M. anisopliae* (Ma4) (9.06) and these treatments were on par with each other. Among the biorationals, application of azadirachtin 1% (9.61) was effective compared to fish –jaggery mixture @ 0.5% (10.06). Similar trend in observations were recorded on the 10^{th} day after spray application.

On the 15^{th} day of spraying chlorantraniliprole 18.5%SC 30 g a.i. ha^{-1} was the superior treatment (4.11) followed by novaluron 10% EC 100 g a.i. ha^{-1} (5.22) and buprofezin 25% EC 62.5 g a.i. ha^{-1}.(5.33). Among the non chemicals used, azadirachtin 1% (7.72) was the most effective treatment followed by *Beauveria bassiana* (ITCC6063) WP 2% (7.89), *Metarhizium anisopliae* (Ma4) 20 g l^{-1} (7.94) and fish – jaggery mixture 0.5% (8.33). All the non chemical treatments were on par with each other. Water spray treatment was not found effective compared to untreated control.

Observation on the fruit set per panicle of mango was recorded in the peanut stage of mango fruits and the data was analysed and results were tabulated (Table 7). Chlorantraniliprole 18.5% SC 30 g a.i. ha^{-1} (24.33) exhibited highest number of fruits per panicle compared to all other treatments followed by Novaluron 10% EC 100 g a.i. ha^{-1} (23.33) and these treatments were on par with each other. Buprofezin 25% EC 62.5 g a.i. ha^{-1} (20.33) was the next best treatment among the insecticidal sprays.

Among the biocontrol agents *B. bassiana* (ITCC6063) WP 2% (16.33) was the best treatment followed by *M. anisopliae* (Ma4) 20 g l^{-1} (15.67). Azadirachtin 1% (15.00) was the next best treatment and was on par with the biocontrol agents used. However, treatment with fish –jaggery mixture 0.5% (10.67) was inferior to all other treatments compared to the controls used. Water spray was also non significant in their effect on the number of fruits per panicle.

5. DISCUSSION

Pest and diseases are the important bottle necks for successful cultivation of mango. Among the insect pests recorded, sucking pests and fruit flies were of much importance as per the literature reviewed. However, inflorescence being the centre of all type of pest infestations in mango, the present study was focused on insect pests attacking inflorescence. Perusal of data revealed that the lepidopteran pests were higher in number in the areas selected for the study and they have the potential for causing much damage to flower and fruit set of mango. In this context, management of the caterpillar complex attacking panicles of mango has also been undertaken.

5.1. DOCUMENTATION OF INSECT PESTS

The study conducted to document the pest complex of inflorescence on mango trees grown in three different blocks of Thiruvananthpuram district revealed the incidence of pests belonging to orders; Thysonoptera, Hemiptera, Coleoptera, and Lepidoptera. Attempts were also made to document floral visitors and natural enemies associated with mango inflorescence.

Gynaikothrips sp. and *Haplothrips* sp., were the major thrips species identified from the samples of inflorescence collected from mango grown in the homesteads of Athiyannur area of Thiruvananthapuram district. The infested flowers exhibited pale appearance and they shrivelled and finally got dried up. There was excessive dropping of flowers and reduction in fruit set. In a study conducted in Israel, *Aelothrips collaris, A. gloriosus, Haplothrips andresi, H. clarisetis, H. ditinguendes* and *H. gowdeyi* were found associated with inflorescence of mango (Wysoki *et al.*, 1995). The findings were in tune with the study of Krishnamoorthy and Visalakshi, (2012) who reported the infestation of *Haplothrips* sp. on mango. Rocha *et al*., (2012) reported 15 species of thrips including *Haplothrips gowdeyi* from Mexico. Matos *et al*. (2019) reported *H. gowdeyi* infesting inflorescence of mango grown in orchards of Brazil.

Mango hoppers were reported from Kollengode area of Palakkad district. Whereas cowbugs, mealy bugs and scale insects were reported to infest mango

inflorescence from different locations of Thiruvananthapuram and Palakkad districts. *Idioscopus clypealis* and *Amritodes* sp. were the major hoppers encountered. The trees infested with mango hoppers were covered with sooty mould, grown in association with honey dew of the hoppers. Similar observations as a result of hopper infestation were reported by (Bana *et al.,* 2018).

Idioscopus sp. along with *A. atkinsoni* were found to have peak population build up during the flower initiation period which continued till the full bloom stage (Srivastava, 1998; Babu *et al*., 2001; Sushil *et al.,* 2002). Among the insect pests reported, the mango hoppers *A. atkinsoni* and *I. clypealis*, caused a loss of 20 - 100% of inflorescence in mango orchards located at central eastern part of Chhattisgarh. (Kaushik *et al*., 2014). *Amritodus* sp. and *I. nagpurensis* were the mango hoppers reported on inflorescence of mango grown in and around Bilaspur of Chhattisgarh state. (Anant, 2016). Mia *et al.* (2019) reported the occurrence of *I. clypealis*, *I. niveosparus* and *A. atkinsoni* on mango from Bangladesh.

Mealybugs were found infesting shoots, inflorescence and fruits of mango. The field visits undertaken in orchards located at Kollengode area of Palakkad recorded heavy infestation on developing fruits to fully developed ones covering the entire surface of the fruit including stalks in different varieties of mango *viz.* Banganapally, Alphonso and Sindhura. These findings were in accordance with the observations of Mani and Shivaraju (2016), reported that the pest completely cover the fruit surface in certain heavily infested stages reducing market value.

In the present study *Crisiococcus hirsutus* was recorded from Athiyannur area whereas *Rastrococcus iceryoides* and *Ferrisia virgata* were recorded from Nemom area of Thiruvananthapuram district. *Formicoccus mangiferacola, Rastrococcus* sp. and *Icerya* sp. were collected from Kollengode area of Palakkad district. About 20 different species of mealy bugs were recorded on mango grown in different parts of the world (Karar *et al*., 2012). They also reported that severe infestation caused by *R. iceryoides* on the inflorescence and fruits turned out to a menace mitigating the production and productivity of mango orchards. Godse (2003) documented the presence of *Ferrisia virgata* from mango in a study conducted in orchards of

Maharashtra. Williams (2004) reported *Crisicoccus hirsutus* and *F. mangiferacola* infesting mango. *Icerya seychellarum* (Westwood) was one among the different scale insects reported as a pest of mango (Grové and De Beer, 2015).

Nonartha sp. and *Monolepta* sp., were beetles associated with mango inflorescence collected from Athiyannur area of Thiruvananthapuram district. *Nonartha* sp. was dark bluish black in colour. Wysoki, (1996) found *Monolepta* sp. infesting mango along with several other beetles belonging to families Cerambycidae (*Macrotoma scutellaris*), Bostrychidae and Nitidulidae. Kirti and Sidhu (2015) reported the association of *Nonartha* sp with mango. In a study conducted to ascertain the insect pests of mango ecosystem in Israel,

Mango inflorescence sheltered numerous caterpillars with a varied diversity including semiloopers, loopers, flower webbers and peduncle borers. These lepidopterans were recorded from the inflorescence of mango collected from Thiruvanantahpuram and Palakkad districts. The samples collected included individuals belonging to various families including Geometridae, Lycaenidae, Torticidae, Nolidae, Noctuidae, Erebidae and Crambidae. The phenomenon exhibited by lepidopterans infesting mango was the shift of feeding site from vegetative to reproductive parts.

The larvae of *Perixera illepidaria*, Geometridae, were recorded from mango grown in Kollengode area of Palakkad district. The reproductive phase of mango was severely attacked by caterpillars of *P. illepidaria.* The larvae were found voraciously feeding on the floral parts leaving the stalks behind. Kumar *et al.*, (2014) reported the severe outbreak of *P. illepidaria* on litchi grown in many parts of India. Soumya *et al*., (2017) in a study conducted in the orchards located at Karnataka to ascertain the activity on two major varieties of mango *viz*., Alphonso and Totapuri, the attack of this looper pest was found more evident during the peak flowering period of mango.

Comostola laesaria was another looper pest found feeding on the panicles of mango grown in homesteads of Athiyannur region of Thiruvananthapuram district. Reddy *et al*., (2018) reported that *C. laesaria* caused webbings while feeding on the flowers of mango inflorescence.

The larvae of *Thalassodes* nr. *dissita,* was another floral feeder reported from Athiyannur region of Thiruvananthapuram district. Preetha (2010) reported *Thalassodes* sp infesting mango from Kerala. In the present study Dakhan pointed ciliate blue, *Anthene lycaenina lycaenina,* was recorded as a new pest of mango. However, Nitin *et al.,* (2018) reported several other host plants of *A. lycaenina lycaenina* including *Buchanania axillaris, Buchanania cochinchinensis, Bridelia retusa, Putranjiva roxburghii, Leucaena leucocephala, Acacia nilotca, Acacia pennata, Dalbergia latifolia, Moullava spicata, Pithecellobium dulce, Ventlago dentculata* and *Allophylus* sp.

Rapala manea was found infesting inflorescence of homestead grown mango located at Parassala area of Thiruvananthapuram district. Johnson (1980) reported *R. manea* as a new pest infesting mango from Kerala. Robinson *et al.* (2010) also reported mango as a host of *R. manea*.

*Archips micaceana*a moth belonging to family Torticidae and *Nanaguna breviuscula,* family Nolidae were recorded from samples collected from mango grown in Athiyannur region of Thiruvananthapuram district. The larvae of *A. micaceana* formed webbings of the floral parts and then bored the stalks of flowers and this has resulted in drying of flowers of the inflorescence. Dean (1978) reported the attack of *A. micaceana* and *Nanaguna breviuscula* on the inflorescence of mango. Similar observations were recorded by Prakash *et al.* (2002) in flowers of vanilla grown in Karnataka. The larvae webbed the flowers and bored the flower stalks which resulted in withering of vanilla flowers.

Gatesclarkeana erotias was reported from Athiyannur region of Thiruvananthapuram district. *C. transversa* were found among boreholes of peduncle and pedicles of flowers. This pest was collected from mango trees of Athiyannur region of Thiruvananthapuram district. This pest was found to infest all the varieties of mango, with considerable damage caused by boring of shoots (Singh and Kaur, 2014). The symptoms of damage exhibited by this pest was similar to one recorded by Soumya *et al.* (2017). Reddy *et al.,* (2018) reported the incidence of shoot borers in mango including *C. transversa* and *Gatesclarkeana erotias.*

Among the different *Eublemma* spp. reported in the study, *E. abrupta* was recorded from Nemom and *E. versicolor* was from Parassala. Two genera of *Eublemma* was reported from Nemom and Parassala of Thiruvananthapuram district. There were already reports regarding infestation of these pests from Kerala (Nair, 1989). Babu *et al.* (2001) and Kaushik (2009), reported the infestation of *Eublemma versicolor* on mango inflorescence at its full bloom state. Yadav *et al.* (2014) reported the incidence of *E. angulifera* M. from mango flowers in Kerala.

Infestation of floral parts of mango by several other caterpillars *viz. Bombotelia jocosatrix, Aetholix flavibasalis, Lymantria* sp., *Thalassodes* sp., and *Perixera illepidaria* including 15 unidentified specimens were documented in the present study. Sundararaju (2009) reported the incidence of *A. flavibasalis* from cashew. Preetha (2010) reported various caterpillar pests including *B. jocosatrix, Thalassodes* sp., and *Lymantria* sp., from mango.

5.2. NATURAL ENEMIES AND FLORAL VISITORS

*Thomisus s*p. and *Tetragnatha viridorufa* were the two main spider specimens collected from the Athiyannur area whereas *Cyrtophora cicatrosa* and *Tetragnatha* sp. were the two other specimens collected from the Nemom region of Thiruvananthapuram district. In a study conducted in China, 63 spiders belonging to 11 families were recorded from mango (Zhao *et al.,* 2013). *Argiope catenulate, Neoscona nautical, Cyrtophora citricola, Pardosa pseudoannulaa, Plexippus paykulli, Plexippus petersi, Thiania* sp., *Peucetia viridians, Oxyopes kohaensis, Oxyopes shweta, Stegodyphus sarasinorum,* and *Heteropoda nilgirina,* were the different species of spiders documented from the mango fields of Maharashtra (Phartale *et al.,* 2014). Shivamurthy (2016) documented spider species *viz., Tetrognatha* sp., *Oxyopes javanus* Thorell and *Argiope pulchella* Thorell associated with mango trees.

Odontimantis pulchra and *Odontimantis* sp. were the two species of praying mantis found associated with mango inflorescence. *Eristalinus arvorum, Lucilia sericata, Parasarcophaga dux* and *Drosophila* sp. were the floral visitors of mango trees recorded.

Yapo *et al*. (2019) reported several hymenopterans, hemipterans and dipterans from mango inflorescence. *Mantis religiosa, Coenagrion* sp, *Chrysoperla carnea, Formica rubra, Aeshna verticalis* and *Sineadia dema* were the predators reported to be associated with mango flowers (Amin *et al.,* 2015).

5.3. MANAGEMENT OF INSECT PESTS OF INFLORESCENCE

In the experiment conducted on Alphonso variety of mango grown in an orchard located at Kollengode area of Palakkad district to evaluate the efficacy of insecticides and biorationals for the management of caterpillars attacking mango inflorescence, chlorantraniliprole 18.5% SC @ 30 g a.i. ha^{-1} was found to be the superior treatment in reducing the population of larvae followed by novaluron 10% EC100 g a.i. ha^{-1} and buprofezin 25% EC 62.5 g a.i. ha^{-1} based on the observations recorded on 5^{th}, $10^{th}$and 15^{th} days after spraying (Figure 1, 2 and 3). In general all the treatments were statistically significant in reducing the larvae, except spraying of water on the inflorescence. The findings were in accordance with the findings of Chaudhary *et al.*,(2018) who reported that chlorantraniliprole 18.5 SC @ 0.006 % was equally effective as flubendiamide 480 SC @ 0.14 % in reducing the population of mango slug caterpillar *Parasa lepida* infesting mango whereas novaluron 10% EC 0.015 % was the next best treatment.

Similar findings supporting the superiority of chlorantraniliprole 18.5 SC was recorded against various lepidopteran pests by different workers on different crops *viz.,* borers in tomato (Pawar *et al.,* 2016), the bark eating caterpillar attacking guava *Indarbela tetraonis* Moore (Satyanarayana and Arunakumara, 2016), *Deodorex isocrates* in pomegranate (Nadaf, 2017), pod borers (*Maruca vitrata* larva) in pigeon pea (Nebapure, and Sagar, 2019), pink bollworm, *Pectinophora gossypiella* infesting cotton (Divya *et al.,* 2019), *Agrotis ipsilon* in cabbage (Verma, 2020), *Spodoptera litura* on soyabean (Dabhi *et al*., 2020) and diamond back moth on cauliflower (Patel and Patel, 2020).

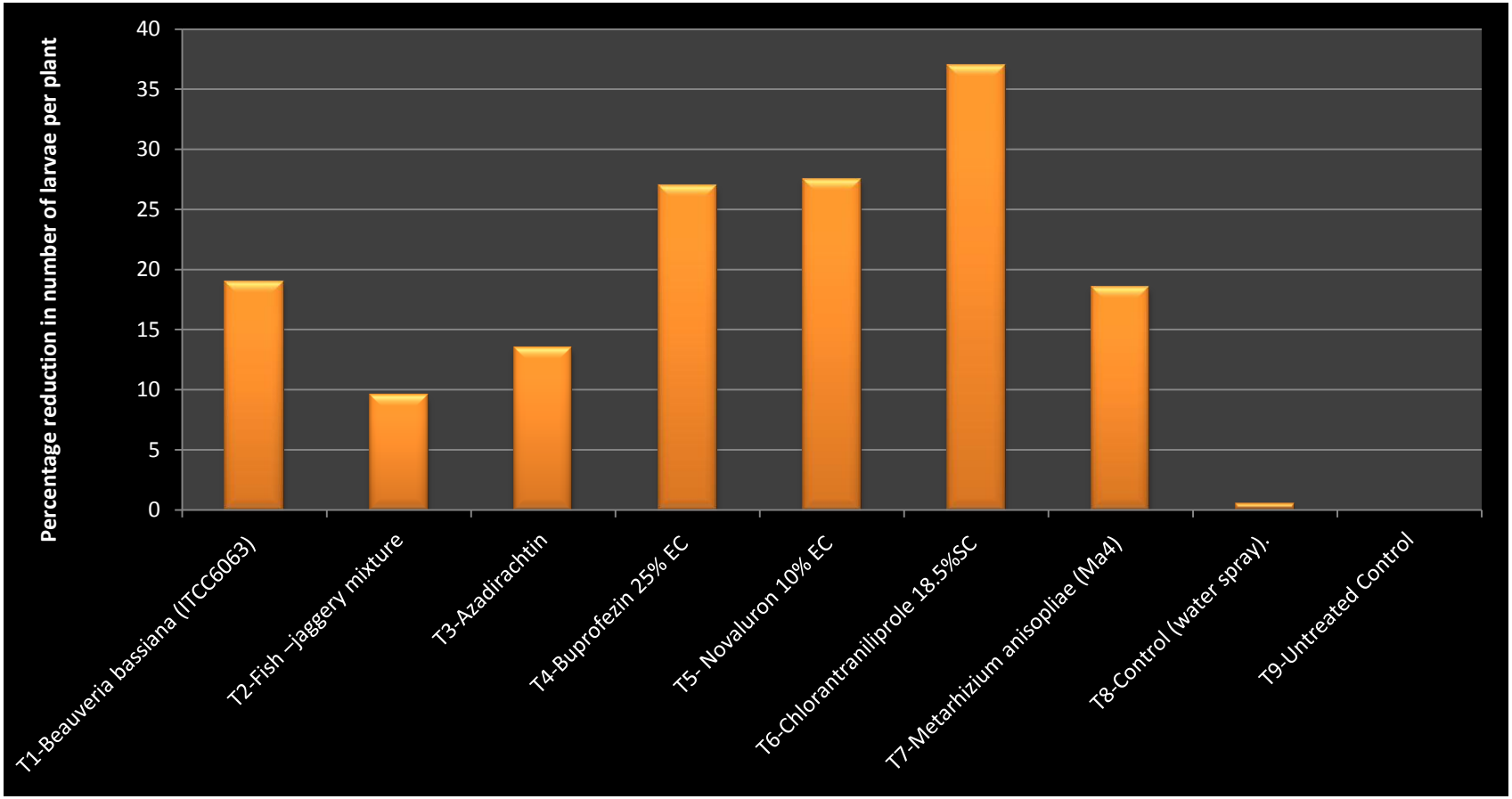


Fig 1: Percentage reduction of pests on 5 days after spraying over control

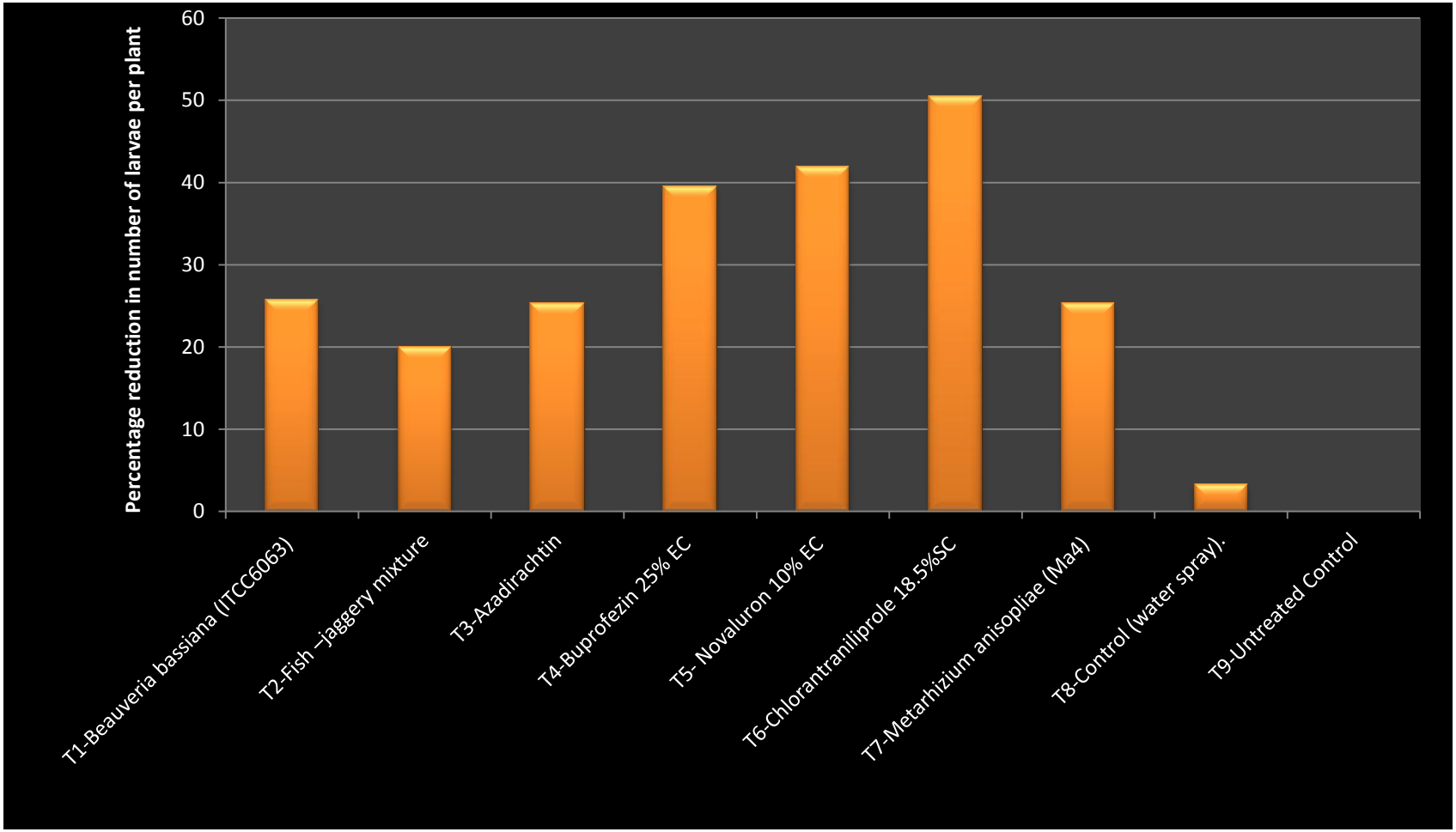


Fig 2: Percentage reduction of pests on 10 days after spraying over control

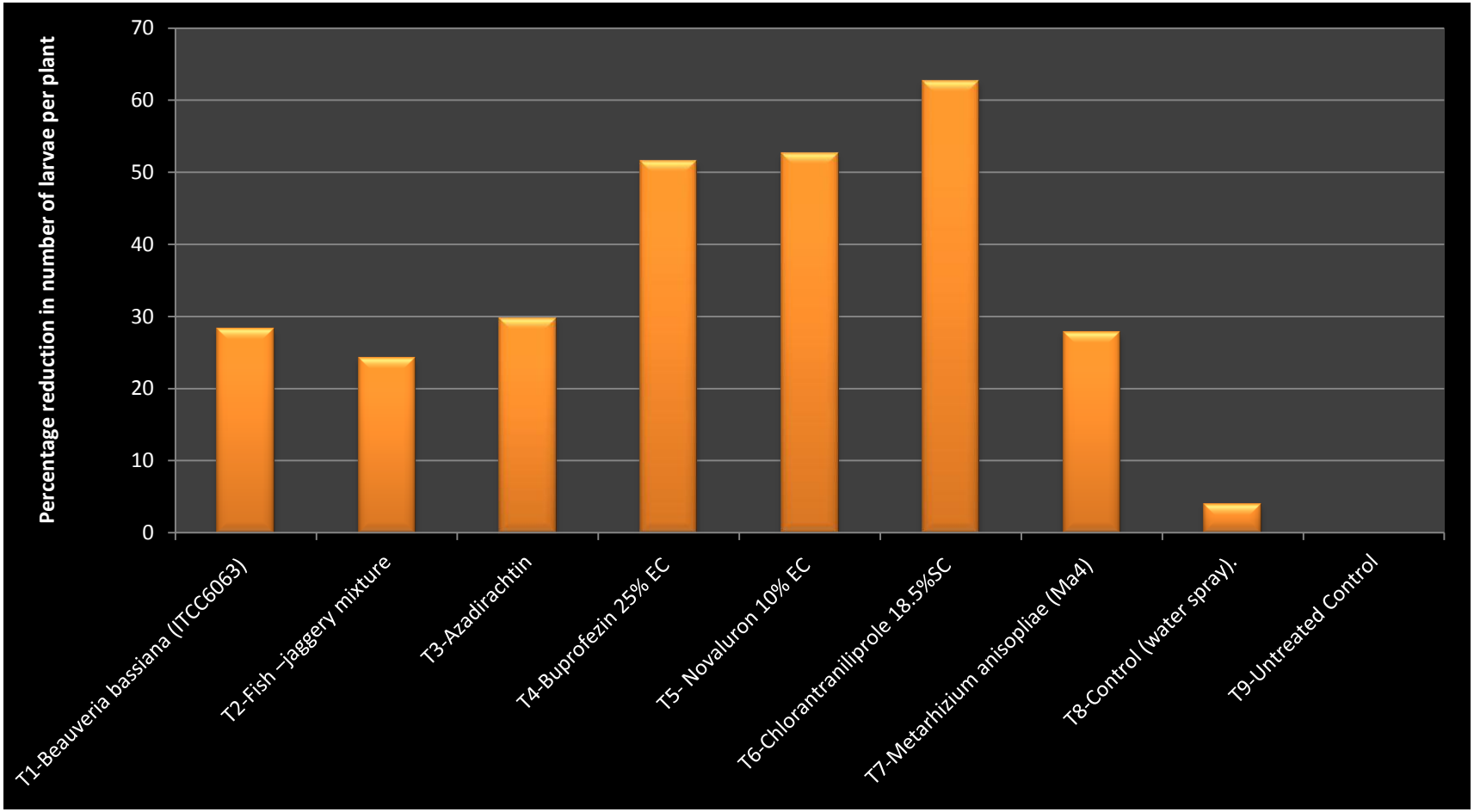


Fig 3: Percentage reduction of pests on 15 days after spraying over control

In an *in vivo* study to assess the oviposition deterrent activity of *Spodoptera litura* (Fabricius) using nine different treatments, thiodicarb 75 WP and chlorantraniliprole 18.5 SC showed its superiority to other treatments. (Natikar, and Balikai, 2015). In another study, chlorantraniliprole 18.5 SC was found to have compatibility with entomopathogenic fungi like *B. bassiana* (Joshi *et al*., 2018).

Among the various treatments applied against the control of seed borer in sapota, *Trymalitis margarias* Meyrick, novaluron 10 EC 0.005 % was found to provide effective control of pest along with good yield (Bisane *et al.,* 2019). In a bio efficacy study to control the infestation of *Maruca vitrata* on clusterbean, novaluron 10% 1.0 ml L^{-1} came up as the third best after Emmamectin Benzoate 0.5 g L^{-1} and Quinalphos 2.0 ml L^{-1} (Kishor 2020). In another experiment for the evaluation of different insecticides against the management of *Spilosoma oblique* on clusterbean, novaluron1.0 ml L^{-1} gave comparable effectiveness with other insecticides (Meena *et al.,* 2020).

In a study conducted to suppress the leaf hoppers infesting mango, buprofezin 25 SC 2000 g ha^{-1} exhibited a satisfying result with respect of pest reduction (Sharanabasappa and Adiveppar, 2018).Whereas in another study, treatment with buprofezin 250 g a.i. ha^{-1} was found safe for predatory coccinellids, and other natural enemies (Kangale *et al.,* 2019). Anant *et al.* (2019) reported that buprofezin 30 ml $tree^{-1}$ gave satisfying control of mango hoppers *viz*., *A. atkinsoni* and *I. clypealis* standing third in the order of effectiveness compared to other insecticides used.

Beauveria bassiana (ITCC6063) was the best non chemical treatment, followed by *Metarhizium anisopliae* (Ma4) based on the observations recorded on fifth and tenth days of spraying. The remaining treatments showed its effectiveness in the following order: azadirachtin 1% > fish –jaggery mixture 0.5% >water spray > untreated Control. Shivamurthy (2016) reported the effectiveness of *B. bassiana* (ITCC 6063) WP 2 % against the management of shoot webber infesting mango compared to other biorationals used.

Prasad and Syed (2010) reported the development of certain morphological abnormalities by the application of *Beauveria bassiana* against *Helicoverpa armigera*.

Being a chitin inhibitor, the fungus attacked the insect cuticle by the germination of conidia in the initial phase. Then the fungal hyphae penetrated and proliferated inside the body of the insect leading to its death. Moorthi *et al.,* (2015) confirmed the cuticle degrading property of *B. bassiana* Bb 1 isolates ensuring its effectiveness in IPM. The efficacy of *B. bassiana* (ITCC 6063) in the control of lepidopteran pests of vegetables was reported by Jiji *et al.,* (2008).

Fifteen days after spraying azadirachtin 1% showed superiority over the entomopathogenic fungi *B. bassiana* (ITCC6063) WP 2% and *Metarhizium anisopliae* (Ma4) 20 g l^{-1}.

The antifeedant activity of azadirachtin against lepidopterans *viz*., *Spodoptera frugiperda S. littoralis, Heliothis armigera* and *H. virescens* were reported in a bioassay (Blaney *et al*., 1990). The efficacy of azadirachtin might be due to its toxicity to the pests or antifeedant activity or combinations of various activities including repulsion. Azadirachtin holds a traditional value in pest control particularly as an antifeedant. It was found to show its effectiveness to delay insect moulting and at times permanently (Adel and Sehnal, 1999).

In the present study, chlorantraniliprole 18.5% SC @ 30 g a.i. ha^{-1}, was found as the superior treatment in effective control of caterpillars infesting the panicle. This was followed by novaluron 10% EC100 g a.i. ha^{-1} and thereafter buprofezin 25% EC 62.5 g a.i. ha^{-1} as the effective treatment in reducing the population of larvae on the 5^{th}, $10^{th}$and 15^{th}day of spraying various insecticides. Among the non chemicals, *Beauveria bassiana* (ITCC6063) WP 2% showed the best results in pest suppression followed by *Metarhizium anisopliae* (Ma4) 20 g l^{-1} on 5 and 10 days after spraying. After 15 days of spraying, Azadirachtin 1% was found to be the best among all the non chemicals used.

SUMMARY

6. SUMMARY

Mango growers encounter various difficulties during the production and post production phase of its cultivation. The struggle due to the infestation of pest and diseases is of prime importance to be tackled during the different growth phases of mango cultivation. It has been reported that there is an indiscriminate use of pesticides on this crop without any focus on recommendations based on research. This strategy among farmers might end up in situations like pest resurgence, problems created due pesticide residues, pesticide resistance shown by the pests and even ecological imbalances disturbing the natural enemy population. In order to mitigate this, proper documentation of the various pests infesting mango was quite imperative with more focus on the pests infesting and its management.

The documentation of pests infesting the mango inflorescence was carried out from the three different blocks of Thiruvananthapuram district *viz;* Nemom, Athiyannur and Parassala. The collected specimens were identified with the help of expert taxonomists from different fields. The identified specimens comprised of insect pests, floral visitors, and natural enemies belonging to nine different insect orders including Araneae.

Pests belonging to 15 different families of five different insect orders were identified. Many specimens are yet to be identified. The different samples collected during the study included mango hoppers, mealy bugs, thrips, cowbug and caterpillars.

Two species of thrips were identified; *Gynaikothrips* sp. and *Haplothrips* sp., both belonging to Phlaeothripidae; Tubulifera. The thrips infested inflorescence exhibited bronzing symptoms and showed severe flower drop and failure of fruit set. *Idioscopus clypealis* and *Amritodes* sp. were the species of mango hoppers noticed to attack mango grown in the orchards located at Kollengode area of Palakkad district whereas hoppers collected from mango orchard located at College of Agriculture, Vellayani of Thiruvananthapuram district are yet to be identified. Mealy bugs and scales form the other hemipterans recorded during the documentation studies. They were mainly from the families of Pseudococcidae and Monophlebidae consisting of

Crisicoccus hirsutus, Rastrococcus iceryoides, Ferrisia virgata, Formicococcus mangiferacola, Rastrococcus sp. and *Icerya* sp.

High population of *Nonartha* sp. was recorded from Athiyannur area of Thiruvananthapuram district. *Monolepta* sp. was also recorded from the same location.

Abundant number of lepidopteran infestation was recorded from the inflorescence of mango collected from Thiruvananthapuram and Palakkad districts. The samples collected included individuals belonging to various families of order Lepidoptera including Geometridae, Lycaenidae, Torticidae, Nolidae, Noctuidae, Erebidae and Crambidae. Around 17 lepidopteran specimens were identified; *Perixera illepidaria, Comostola laesaria, Anthene lycaenina lycaenina, Rapala manea, Archips micaceana, Thalassodes* nr. *dissita, Gatesclarkeana erotias, Nanaguna breviuscula, Eublemma* sp, *Eublemma abrupta, Eublemma* nr. *quadripunctata, Eublemma versicolor, Chlumetia transversa, Bombotelia jocosatrix, Aetholix flavibasalis* and two species of *Lymantria.* Another 14 species of lepidopterans collected for this, reared and preserved are yet to be identified.

Anthene lycaenina lycaenina, pointed ciliate blue, Lycanidae was found infesting mango inflorescence. The pest was recorded from Athiyannur area of Thiruvananthapuram district. This is the first report of the pest infesting mango.

Lepidopteran infestations on inflorescence and the considerable losses incurred were quite underrated for a long period of time with no detailed studies on this aspect. A predominant surge in the infestation level of these caterpillars, demand a proper attention to restrict the rise in severity to attain a pest status. The niche shift of caterpillar pest was another noticed trend. They probably in the near future, might turn out to form an outrageous pest status similar to hoppers in mango.

*Thomisus s*p. and *Tetragnatha viridorufa* were the two main spider specimens collected from the Athiyannur area whereas *Cyrtophora cicatrosa* and *Tetragnatha* sp. were the two other specimens collected from the Nemom region of Thiruvananthapuram district.

Odontimantis pulchra and *Odontimantis* sp. were the two species of preying mantids collected from the mango inflorescence from Athiyannur block. Dipterans from the families of Syrphidae, Calliphoridae, Sarcophagidae and Drosophilidae were identified. The common floral visitors of mango inflorescence collected from the Athiyannur block were; *Eristalinus arvorum*, *Lucilia sericata, Parasarcophaga dux* and *Drosophila* sp.

A field experiment was conducted in Kollengode area of Palakkad district to evaluate the efficacy of nine different treatments *viz.*, *Beauveria bassiana* (ITCC6063) WP 2%, fish –jaggery mixture 0.5%, azadirachtin 1%, buprofezin 25% EC 62.5 g a.i. ha^{-1}, novaluron 10% EC 100 g a.i. ha^{-1}, chlorantraniliprole 18.5%SC 30 g a.i. ha^{-1}, *Metarhizium anisopliae* (Ma4) 20 g l^{-1}, control (water spray) and untreated control.

In general all the treatments were statistically significant in reducing the larvae except spraying of water on the inflorescence. However, Chlorantraniliprole 18.5% SC 30 g a.i. ha^{-1} was the superior treatment in reducing the number of caterpillars (4.11) followed by Novaluron 10% EC 100 g a.i. ha^{-1} (5.22) and Buprofezin 25% EC 62.5 g a.i. ha^{-1} (5.33) and these treatments were statistically on par with each other.

Among the bio control agents maximum pest suppression was shown by *Beauveria bassiana* (ITCC6063) WP 2% (7.89) followed by *Metarhizium anisopliae* (Ma4) 20 g l^{-1} (7.94) and these treatments were on par with each other. Among the biorationals, application of azadirachtin 1% (7.72) was found most effective.

Chlorantraniliprole 18.5% SC 30 g a.i. ha^{-1} (24.33) exhibited highest number of fruits per panicle compared to all other treatments. Azadirachtin 1% (15.00) was the next best treatment and was on par with the biocontrol agents used.

REFERENCES

REFERENCES

Abbas, S. R., Verghese, A. and Fasih, M. 1985. Studies on the mango inflorescence midge, *Erosomyia indica* Grover. *Int. Symp. Mango*. 231: 593-596.

Abdullah, F. and Shamsulaman, K. 2008. Insect pests of *Mangifera indica* plantation in Chuping, Perlis, Malaysia. *J. Entomol.* 5(4): 239-251.

Adel, M. M. and Sehnal, F. 1999. Azadirachtin potentiates the action of ecdysteroid agonist RH-2485 in *Spodoptera littoralis*. *J. insect Physiol.* 46(3) :267-274.

Ahmed, W., Nawaz, M. A., Saleem, B. A. and Asim, M. 2005. Incidence of mango midge and its control in different mango growing countries of the world. *Int. Conf. Mango Date palm: Culture and Export* : 98-102

Ahuja, D. B., Vannila, S., Kalra, B. and Bambawale, O. M. 2011. Pest inflicting damage to mango and their management. In : *abstract book on Global conference on augmenting production and utilization of mango: biotic and abiotic stresses*-21-24 June, Lucknow.

Aliakbarpour, H., Salmah, M. D. and Rawi, C. 2010. Diurnal activity of four species of thrips (Thysanoptera: Thripidae) and efficiencies of three non-destructive sampling techniques for thrips in mango inflorescences. *J. Econ. Entomol.* 103(3): 31-640.

Amin, M. R., Namni, S., Miah, M. R. U., Miah, M. G., Zakaria, M., Suh, S. J. and Kwon, Y. J. 2015. Insect inventories in a mango-based agroforestry area in Bangladesh: foraging behavior and performance of pollinators on fruit set. *Entomol. Res.* 45(4): 217-224.

Amouroux, P. and Normand, F. 2010. Survey of mango pests in Reunion Island, with a focus on pests affecting flowering. *Int. Mango Symp.* 992: 459-466

Anant, A. K. 2016. Studies on insect-pests of mango with special reference to seasonal incidence and management of mango leaf hoppers. M. Sc. (Ag) thesis, Indira Gandhi Krishi Vishwavidyalaya, Raipur, Chatisgarh, 110p.

Anant, A. K., Awasthi, A. and Pandi, G. 2019. Evaluation of insecticides against mango hoppers *Amritodus atkinsoni* and *Idioscopus clypealis*. *Indian J. Entomol*. 81(2): 340-342.

Ananthakrishnan, T. N. and Muraleedharan, N. 1974. On the incidence and effects of infestation of *Selenothrips rubrocinctus* (giard) (Thysanoptera: Heliothripinae) on the free aminoacids of some susceptible host plants. *Curr. Sci.* 43(7): 216-218.

Anonymous. 2004. All India Coordinated Research Project on Sub-tropical Fruits, Annual Report, CSIR, Lucknow, 107-108.

Asif, M., Usman, M., Jaskani, M. J. and Khan, M. M. 2002. Comparative study of flower sex ratio in different cultivars of mango (*Mangifera indica* L.). *Int. J. Agric. Biol*. 4: 220–222

Azam, K., Mir, H., Kumar, R. and Ahmad, F. 2018. Study on flowering behaviour of elite mango cultivars in subtropical conditions of Bihar. *Int. J. Chem. Stud*. 6(2) : 2913-2917.

Babu, B. L., Maheshwari, T. U., and Venugopal R. T. 2001. Pest complex and their succession on mango, *Mangifera indica* in Peninsular India. *Indian J. Entomol*. 63(2): 158-162.

Bana, J. K., Kumar, S. and Sharma, H. 2018. Diversity and nature of damage of mango insect-pests in south Gujarat ecosystem. *J. Entomol. Zool. Stud*. 6: 274-278.

Berardini, N., Carle, R. and Schieber, A. 2004. Characterization of gallotannins and benzophenone derivatives from mango (*Mangifera indica* L. cv. 'Tommy Atkins') peels, pulp and kernels by high-performance liquid

chromatography/electrospray ionization mass spectrometry. *Rapid Commun. Mass Spectrom*. 18: 2208–2216.

Berardini, N., Fezer, R., Conrad, J., Beifuss, U., Carle, R. and Schieber, A. 2005. Screening of mango (*Mangifera indica L*.) cultivars for their contents of flavonol O- and xanthone C-glycosides, anthocyanins, and pectin. *J. Agric. Food Chem*. 53: 1563–1570.

Bisane, K. D., Shinde, B. D., Saxena, S. P. and Patil, P. 2019. Management of Sapota Seed Borer (*Trymalitis margarias* Meyrick) with some newer pesticides. *Pesticide Res. J.* 31(1): 48-53.

Blaney, W. M., Simmonds, M. S. J., Ley, S. V., Anderson, J. C. and Toogood, P. L. 1990. Antifeedant effects of azadirachtin and structurally related compounds on lepidopterous larvae. *Entomologia experimentalis et applicata*. 55(2) : 149-160.

Butani, D. K. 1979a. *Insects of fruit crops*. Periodical Expert Book Agency, Vivek Vihar, Delhi, 415p.

Butani, D. K. 1979b. *Pests of sub-tropical fruits (Ber)- Indian Insects and Fruits.* Periodical Expert Book Agency, New Delhi, 173p.

Chaudhary, N., J., Rabari, P. H., Rajput, V. S. and Patel, R. K. 2018. Bio-efficacy of newer molecules against slug caterpillar (*Parasa lepida* L) on mango. *J. Entomol. Zool. Stud.* 6(4): 1778-1781.

Chowdhury, S. K. 2015. Diversity and nature of damage of mango insect pests at Kaliachak-II Block of Malda, West Bengal, India. *J. Entomol. Zool. Stud.* 3(4): 307-311.

Cobin., Milton. and Harkness, W. R. 1950. Mango selection, propagation, and culture. *Fla. Agr. Exp. Sta. Ann. Rept.*: 243-247.

Coetzer, L. S., Oosthuyse, D. and Robbertse, W. P. 1995. *Influence of pruning on the flower sex ratio in some mango cultivars.* SA. Growers Assoc. Yearbook, 26–30.

Dabhi, M. R., Patel, S. R., Parmar, H. C. and Kalola, D. A. 2020 Relative toxicity of noval insecticides against leaf eating caterpillar, *Spodoptera litura* Fabricius infesting soybean. 8(3): 748-752.

Dahiya, K. K. and Lakra, R. K. 2001. Seasonal occurrence and succession of thrips, *Rhipiphorothrips cruentatus* Hood in important horticultural crops of Haryana. *Crop Res. Hisar.* 21(1):112-114.

Das, N. M., Ramamany, K. S. and Nair, M. R. G. K. 1969. Biology of a New Jassid of Mango *Amrasca splendens* Gauri. *Indian J. Entomol.* 31(3): 288-290.

Davenport, T. L. 2009. Reproductive physiology. In: Litz, R. E. (Ed.), *The Mango: Botany, Production and Uses.* CAB International, Wallingford, UK: 97–169pp.

Dean, G. J. 1978. Insects found on economic plants other than rice in Laos. *Int. J. Pest Mang.* 24(2):129-142.

Devi Thangam, S. 2014. *Ecological modelling, biodiversity studies, geographical mapping of mango hopper (Hemiptera: cicadellidae) populations in mango ecosystems of South India. Ph.D thesis,*Kuvempu University, p182.

Devi, M. B., Joymati, L., Kananbala, A., Binarani, A. and Manoj, K. 2011. Predatory behaviour of *Mantid religiosa* against Mango hopper. *Ann. Plant Protect. Sci.* 19(2): 457-458.

Divya, B., Navi, S., Sugeetha, G., Vijaykumar, L., Kumar, S., Somu, G. and Patel, V. N. 2019. Evaluation of newer molecules for the management of pink bollworm, *Pectinophora gossypiella* (Saunders) (Lepidoptera: Gelechiidae) in cotton (*Gossypium* spp.) *J. Entomol. Zool. Stud.* 8(1): 383-386.

Dwivedi, P., Kumar, G. and Srivastava, R. P. 2018. Contact Toxicity of some newer insecticides against mango mealy bug, *Drosicha mangiferae* (Green). *J. Entomol. Res.* 42(4): 569-574.

Ghauri, M. S. K. 1967. New Mango Leafhoppers from the Oriental and Austro-oriental regions (Homoptera: Cicadelloidea). *Proc. Royal Entomol. Soc. London.* 36 (12): 159-166.

Ghosh, S. K. 2013. Sustainable management of mango hopper (*Amritodas atkinsony* Leth and *Idioscopus niveosparsus* Leth) by using insect growth regulator (IGR), buprofezin 25 SC. *Uttar Pradesh J. Zool.* 33(2): 119-128.

Godse, S. K. 2003. Mango mealy bug fauna of Konkan Region of Maharashtra. *Insect Environ.* 9: 1-157.

GOI (Government of India). 2018. Horticulture statistics ta a glance 2018. Horticulture statistics Division, Department of Agriculture, Cooperation & Farmer's Welfare, Ministry of Agriculture & Farmer's Welfare Government of India. 490 pp.

Grove, T. and De Beer, M. S. 2015. Insect pests affecting the production of mango in South Africa. *Int. Mango Symp.* 1183: 297-304.

Gundappa, P. D., Jayanthi, K., and Varghese, A. 2014. Migratory behaviour of mango hoppers, *Idioscopus* spp. in relation to host plant flowering phenology: a synchronous shift. *Bioscan*. 9(2): 639-641.

Harris, K. M. and Schreiner, I. H. 1992. A new species of gall midge (Diptera: Cecidomyiidae) attacking mango foliage in Guam, with observations on its pest status and biology. *Bull. Entomol. Res.* 82(1): 41-48.

Hussain, S. I., Saleem, M. A. and Freed, S. 2012. Toxicity of some insecticides to control mango mealy bug, *Drosicha mangiferae*, a serious pest of mango in Pakistan. *Pakistan J. Zool.* 44(2):353-359.

Jayanthi, P. D., Nagaraja, T., Raghava, T., Kempraj, V., Mala, B. R. and Shashank, P. R. 2018. Lepidopterans found aggressively devouring mango panicles: A paradigm shift in pest status. *Pest Manag. Hortic. Ecosyst.* 24(2): 96-100.

Jiji, T., Praveena, R., Naseema, A., Anitha, N. and Simna, T. 2008. Entomopathogenic fungus *Beauveria bassiana* (B.) for the management of key pests of vegetables. *Green Farm.* 1: 54-56.

Jiron, L. S. and Hedstrom, T. 1985. Pollination ecology of mango. *Turnalba,* 35(3): 269-277.

Johnson, J., Lethika, P., Visalakshi, A. and Nalinakumari, T. 1980. A lycaenid Rapala manea Hewitson as a new pest of mango in Kerala. *Entomon,* 5(3):171-172.

Joshi, M., Gaur, N. and Pandey, R. 2018. Compatibility of entomopathogenic fungi *Beauveria bassiana* and *Metarhizium anisopliae* with selective pesticides. *J. Entomol. Zool. Stud.* 6: 867-872.

Juliano, J. B. 1934. Origin of embryos in the strawberry mango. *Philippine J. Sci.* 54:553-563.

Kangale, G. K., Kadam, D. R., Jadhao, P. B. and Jadhav, R. D. 2019. Efficacy of insecticides against mango hoppers and their predatory coccinellids. *Indian J. Entomol.* 81(2): 277-279.

Kannan, M. and Rao, N. V. 2006. Seasonal incidence and population fluctuation of Dipteran, Isopteran, Hymenopteran and Thysanopteran pests of mango. *J. Plant Prot. Environ.* 3(1): 50-55.

Kannan, M., Umamaheshwari, T. and Rao, V. 2002. Incidence of flower pests on mango. *Insect Environ*. 7(4): 151.

Kapadia, M. N. 2003. Insect pests of mango and their management. In : *National Seminar on Mango,* June14-15 2003 ,GAU, Junagadh.

Karar, H. A., Arif, M. J., Sayyed, H. A., Ashfaq, M. and Khan, M. A. 2010. Comparative efficacy of new and old insecticides for the control of mango

mealybug *(Drosicha mangiferae* G.) in mango orchards. *Int. J. Agric. Biol.* 12(3): 443-446.

Karar, H., Arif, M. J., Ali, A., Hameed, A., Abbas, G. and Abbas, Q. 2012. Assessment of yield losses and impact of morphological markers of various mango (*Mangiferae indica*) genotypes on mango mealybug (*Drosicha mangiferae* Green) (Homoptera: Margarodidae). *Pakistan J. Zool.* 44(6).

Kaushik, D. K. 2009. Relative preference of different mango varieties by major insect pests with special reference to mango hopper and its management through new insecticide molecules. Ph. D thesis, Indira Gandhi Krishi Vishwavidyalaya, Raipur, 211p.

Kaushik, D. K., Sharma, S., Sharma, D. and Baraiha, U. 2014. Efficacy of insecticides against hopper complex on langra mango in Chhattisgarh. *Pesticide Res. J.* 26 (1): 6-11.

Kavitha, K., Lakshmi, K. V., and Anitha, V. 2005. Mango leaf Webber Orthaga euadrusalis Walker (Pyralidae : Lepidoptera) in Andhra Pradesh. Insect Environ. 11(1): 39-40.

Khan, M. G. R., Inayatullah, M., Rafi, M. A. and Ashfaque, M. 1999. Species composition, distribution and host plants of predatory coccinellids (Coccinellidae: Coleoptera) in District Bagh, Azad Jammu and Kashmir. *Pakistan J. Entomol.* 14: 1-4.

Kirti, J. S. and Sidhu, A. K. 2015. Insect diversity of India. In: Sobti, R.C., Jaiswal, K. and Misra, S. (eds) *Faunal diversity in India,* Narendra Publishing House, New Delhi, India, 203-218.

Kishor, M. R. 2020. Bio-Efficacy of Some New Insecticides on Spotted Pod Borer, *Maruca vitrata* (Geyer) in Clusterbean. *Int. J. Agric. Sci.* 975-3710.

Krishnamoorthy, A. and Visalakshi, P. G. 2012. Record of thrips on mango. *J. Hortic. Sci.* 7(1): 110-111.

Krishnamoorthy, A. and Visalakshi, P. G. 2012. Record of thrips on mango. *J. Hortic. Sci.* 7(1): 110-111.

Krull, S. M. E. 2004. Studies on the Mango Ecosystem in Papua New Guinea with Special Reference to the Ecology of *Deanolis sublimbalis* Snellen (Lepidoptera, Pyralidae) and to the Biological Control of *Ceroplastes Rubens* Maskell (Homoptera, Coccidae). Ph. D thesis, Justus-Liebig-Universitat Gieben, 190p.

Kudagamage, H. L., Rajapakse, Z., Rajapakse, R. H. S. and Ratnasekara, N. A. 2001. Population dynamics and insecticidal control of three leaf hoppers, *Amritodus brevistylus* Leth. *Idioscopus niveosparus* Leth. and *Idioscopus clypealis* Leth. (Homoptera: Cicadellidae) in mango. *J. Entomol. Res.* 25(2): 121-125.

Kumar, N. 2019. High Density Planting System in Mango-Prospects and Problems. *Int. J. Innovative Hortic.* 8(2): 101-107.

Kumar, V., Reddy, P.V. R., Anal, A. K. D. and Nath, V. 2014. Outbreak of the looper, *Perixera illepidaria* (Lepidoptera: Geometridae) on litchi, *Litchi chinensis* (Sapindales: Sapindaceae)-a new pest record from India. *Florida Entomol*. 97(1): 22-29.

Landry, J. F. and Landry, B. 1994. A technique for setting and mounting microlepidoptera. *J. the Lepidopterists' Soc., 48*(3): 205-227.

Lewis, T. 1973. *Thrips, their biology, ecology and economic importance.* London Academic press, UK, 349p.

Mani, M. and Shivaraju, C. 2016. *Mealybugs and their management in agricultural and horticultural crops*. Berlin, Germany, Springer, 653p.

Manjunatha, R. 2015. Population dynamics of mango leaf hoppers and their management. Ph. D. (Ag.) thesis, University of Agricultural sciences, Dharwad. 166p

Matos, S. T. S. D., Andrade, D. J. D., Zanata, R. M. P., Azevedo, E. B. D. and Lima, É. F. B. 2019. New records of thrips species on mango and natural enemies associated. *Revista Brasileira de Fruticultura*, 41(1).

McGregor, S. E. 1976. *Insect Pollination of Cultivated Crop Plants*. US Department of Agriculture, Agriculture Handbook, pp. 496.

Meena, R. K., Meena, R. K., Anokhe, A., Singh, U., Meena, M. L., Meena, B. L. and Meena, M. K. 2020. Evaluation of Insecticides against Bihar hairy caterpillar, *Spilosoma obliqua* Walker in Clusterbean. *Ann. Plant Prot. Sci.* 28(1): 25-28.

Mehta, I. 2017. History of Mango – King of Fruits. *Int. J. Eng. Sci. Invention*, 6(7): 20-24

Mia, M. R., Amin, M. R., Rahman, H. and Miah, M. G. 2019. Scenario of insect pests, predators and pollinators associated with crop plants in an agroforestry in Bangladesh. *SAARC J. Agric.* 17(1): 13-22.

Misra, A. K., Shukla, P. K. and Pandey, B. K. 2012. Diseases of mango. In: Misra, A. K., Chowdappa, P., Sharma, P. and Khetrapal, R. K. (eds.), *Diseases of fruit crops.* Indian Phytopathological Society. New Delhi, pp.278-335.

Moorthi, V. P., Balasubramanian, C. and Murugan, K. 2015. Efficacy of *Beauveria bassiana* (Balsamo) Vuillemin isolates against mango leaf webber, *Orthaga exvinacea* Hampson (Pyralidae: Lepidoptera*). Malaya J. Biosci.* 2(1): 50-56.

Nadaf, A. M. 2017. Bio efficacy of newer insecticides against anar butterfly, *Deodorex isocrates* Fab. on pomegranate. *J. Entomol. Zool. Stud.* 5(3): 1655-1657.

Natikar, P. K. and Balikai, R. A. 2015. Oviposition deterrent activity of newer insecticide molecules to *Spodoptera litura* (Fabricius) on soybean. *J. Exp. Zool*. 18(2): 923-925.

Nebapure, S. M. and Sagar, D. 2019. Efficacy of some insecticides against pod borers and blister beetle in pigeon pea. *Indian J. Entomol.* 81(4): 837-840.

Nebie, K., Nacro, S., Dabire, R. A. and Otoidobiga, L. C. 2018. Compared effects of *Metarhizium anisopliae* ICIPE 69 and Chlorpyriphos-ethyl on the mango mealybug, *Rastrococcus invadens* Williams (Homoptera: Pseudococcidae) and its parasitoids in western Burkina Faso. *Int. J. Biol. Chem. Sci.* 12(6): 2738-2752.

Nitin, R., Balakrishnan, V. C., Churi, P. V., Kalesh, S., Prakash, S. and Kunte, K. 2018. Larval host plants of the butterflies of the Western Ghats, India. *J. Threatened Taxa*. 10(4): 11495-11550.

NMD [National Mango Database]. 2017. [on-line] Available at: http:// mangifera.res.in/ indianstatus.php [Accessed 7 Jan. 2019].

Pandey, R. M. 1988. Physiology of flowering in mango. *Acta Hortic*. 23(1): 361-380.

Pandey, R. M. 1988. Physiology of flowering in mango. *Acta Hortic*. 23(1): 361-380.

Panse, V. G. and Sukhatme, P. V. 1967. Statistical methods of agricultural workers. *ICAR Publication, New Delhi, India*, 381.

Patel, D. N. and Patel, D. R. 2020. Efficacy of insecticides against diamond back moth in cauliflower. *Indian J. Entomol.* 82(1):131-133.

Patel, J. R., Patel, M. B., Radadia, G. C., Shah, A. A. and Pandya, H. V. 1997. Insect pest management in mango nursery. *J. Appl. Hortic. Navsari*, 3:125-128.

Pawar, S. A., Wagh, B. M., Datkhile, R. V. and Bhalekar, M. N. 2016. Evaluation of newer insecticide molecules against pests of Tomato. *Ann. Plant Protec. Sci.* 24(2) : 303-306.

Pena, J. E. 1992. Pests of mango in Florida. *Int. Mango Symp.* 341 : 395-406.

Pena, J. E. 2002. Integrated pest management and monitoring techniques for mango pests. *Int. Mango Symp*. 645:151–161.

Pena, J. E., Duncan, R. E. and Meister, C. W. 2006. Chemical control of flowering thrips infesting tropical fruits. *Proc. Fla State Hort. Soc.* 119: 21-24.

Pena, J. E., Mohyuddin, A. I. and Wysoki, M. 1998. A review of the pest management situation in mango agroecosystems. *Phytoparasitica*, 26(2): 129.

Peng, R. and Christian, K. 2005. *Integrated pest management for mango orchards using green ants as a major component: a manual for conventional and organic mango growers in Australia*, Charles Darwin University, 453p.

Phartale, N. N., Shinde, A., Gyananath, G. and Kadam, J. A. 2014. Diversity and abundance of spiders in mango fields of Latur district, Maharashtra state. *J. Entomol. Res.* 38(4): 295-300.

Prabhakara, M. S., Ghosh, S. K. and Chaudhary, M. 2011. Field efficacy of Myco-jaal, an oil based commercial formulation of *Beauveria bassiana* (Deuteromycotina: Hyphomycetaceae) against mango inflorescence hopper, *Idioscopus nitidulus* (Walker). *Pest Manag. Hortic. Ecosyst.* 17(2): 140-143.

Prakash, K.V., Sudarshan, M. R. and Radhika, N. S. 2002. Studies on insect pests of vanilla in Karnataka. In: *Proceedings of the 15th Plantation Crops Symp. Placrosym XV,* Mysore, India, 10-13 December, 2002 (pp. 592-595). Central Coffee Research Institute, Coffee Research Station.

Prasad, A. and Syed, N. 2010. Evaluating prospects of fungal biopesticide *Beauveria bassiana* (Balsamo) against *Helicoverpa armigera* (Hubner): An ecosafe strategy for pesticidal pollution. *Asian J. Exp. Biol. Sci*. 1(3): 596-601.

Preetha, L. *Shoot Feeders of mango and their management*. M. Sc. (Ag.) thesis, Department of Agricultural Entomology, Kerala Agricultural University, Thrissur, 118p.

Purohit, M. S. and Kumar, S. 2008. The spiders: an important predator of mango hopper, *Amritodus atkinsoni* in South Gujarat - a survey. *Entomon.* 5 (2): 20-21.

Radha, T. and Nair, S. R. 1999. Status of mango cultivation in Kerala. *Int. Symp. Mango* 509: 117-122.

Ramasubbarao, V. and Thammiraju, N. B. 1994. New record of blossom thrips *Megalurothrips distalis* on mango (*Mangifera indica*). *Indian J. Agric. Sci.* 64(6): 417-418.

Reddy, P. V. R., Gundappa, B. and Chakravarthy, A. K. 2018. *Pests of mango*. Springer, Singapore, 440p

Robinson, G. S., Ackery, P. R., Kitching, I. J., Beccaloni, G.W. and Hernández, L. M. 2010. *HOSTS-a database of the world's Lepidopteran host plants*. Natural History Museum, London, 150p.

Rocha, F.H., Infante, F., Quilantán, J., Goldarazena, A. and Funderburk, J. E., 2012. 'Ataulfo'Mango Flowers Contain a Diversity of Thrips (Thysanoptera). *Florida Entomol. 95*(1):171-178.

Salem, H. A., Sabry, K. H. and Aref, N. B. 2011. Evaluation the activity of certain insecticidal, time and number of application in controlling white mango scale, *Aulacaspis mangiferae* (New.) in mango orchards. *Bull NRC*. 36: 271-286.

Sarode, B. R. and Mohite, P. B. 2016. Seasonal incidence and biorational management of mango hopper, *Amritodus atkinsoni* Leth. *J. Agric. Vet. Sci.* 9(1): .29-31.

Satyanarayana, C. and Arunakumara, K. T. 2016. Biology and management of guava bark eating caterpillar (*Indarbela tetraonis* Moore). *Agric. Sci. Digest. Res. J.* 36(3): 197-201.

Shahidi, F., Janitha, P. K. and Wanasundara, P. D. 1992. Phenolic antioxidants. *Crit. Rev. Food Sci. Nutr.* 32: 67-103.

Sharanabasappa, P. H. and Adiveppar, M. M. N. 2018. Efficacy of different newer insecticides against mango leaf hoppers. *J. Entomol. Zool. Stud*. 6(1): 834-837.

Shivamurthy, 2016. Population dynamics and management of shoot webber and hoppers infesting mango using safer molecules. M. Sc. (Ag.) thesis, Kerala Agricultural University, Thrissur, 110p.

Singh, G. 1978. The mango shoot gall psyllid *Apsylla cistellata* Buckton and its control. *Pesticides Ind.* 12(9): 15-16.

Singh, G. 1985. Management of major mango insects affecting flowering and fruiting with some newer insecticides. *Int. Symp. Mango* 231 : 607-611.

Singh, J. and Mukherjee, I. N. 1989. Pest status of phytophagous mites in some northern states of India. In : *Proceedings of the 1st Asia-Pacific conference of entomology (APCE), the Entomolgy and Zoology Association of Thailand* : 169-185.

Singh, L. B. 1960. *The Mango: Botany, Cultivation and Utilization*. Leonard Hill Press, London. 438 pp.

Singh, S. and Kaur, G. 2014. Diversity of pestiferous borers of mango in Punjab. *Indian J Appl. Entomol*. 28(2): 125-127.

Singh, G., Kumar, A. and *Everrett, T. R. 1975. Biological observations* and *control* of *Apsylla cistellata Buckton* (*Psyllidae*: *Homoptera*). *Ind. J. Entomol.* 37: 46–50.

Soomro, A. H. 1988. Integrated control of mango insect pests in Sindh. (2nd annual research report). PL-480 project. Dept. Entomololgy Sindh Agri.Uni. Tandojam, Pakistan, 289 pp.

Soumya, B. R., Verghese, A. and Jayanthi, P. K. 2017. Diversity and economic status of Lepidopteran insect-pest on two major varieties of mango. *J. Entomol. Zool. Stud.* 5: 838-843.

Srivastava, R. P. 1997. *Mango insect pest management* (No. Ed. 1). International Book Distributing Co. , Lucknow, 272 p.

Srivastava, R. P. 1998. Pests of mango. *Mango Cultivation. International Book Distribution company,* Lucknow, pp.175-299.

Srivastava, R. P. and Verghese, A. 1989. Chemical control of the mango hopper *Idioscopus clypealis* Lethierry. *Indian J. Entomol.* 51(3): 358-359.

Srivatava, R. P., Tandon, P. L. and Lal, B. 1979. Natural control of important insect pests of mango. Research Report on mango workers Meeting held at Panaji, Goa, May 2-5, 275-277.

Sturrock, T. T. 1966. The mango inflorescence. *Proc. of Florida State Hortic. Soc.*79p.

Sundararaju, D. 2009. Species composition, yield loss and management of lepidopteran flower and fruit pests in cashew. *J. Plant. Crops*. 37(1):21-25.

Sushil, K., Nair, A. G. and Bhatt, R. I. 2002. Evaluation of promising and released mango hybrids for multiple pest resistance. *J. Appl. Zool. Res.* 13(1): 66-68.

Tandon, P. L. and Verghese, A. 1985. *World list of insect, mite and other pests of mango.* Technical Document, Indian Institute of Horticultural Research, 22pp.

Tandon, P. L. and Verghese, A. 1987. New insect pests of certain fruit crops. *Indian J. Hortic.* 44(2): 121-122.

Tewari G. C. and Krishnamoorthy P. N. 1985. Selective toxicity of some synthetic pyrethroids and conventional insecticides to aphid predator, *Menochilus sexmaculatus* Fabricius. *Indian J Agric. Sci*. 55: 40-43.

Tharanathan, R. N., Yashoda, H. M. and Prabha, T. N. 2006. Mango (*Mangifera indica* L.),"The king of fruits"—An overview. *Food Re. Int.* 22(2): 95-123.

Valvi, A. S., Mohite, P. B. and Tarate, S. P. 2018. Efficacy of various entomopathogenic fungi against mango hopper (*Amritodus atkinsoni* Leth.). *J. Pharmacognosy and Phytochem.* 7(5): 1847-1851.

Veeresh, G. K. 1985. Pest problems in mango—world situation. In *Int. Symp. Mango* 231 : 551-565.

Verghese, A. and Jayanthi, P. D. K. 1999. Lepidopteran pest complex on mango inflorescence. *Insect Environ.* 5(2): 51-52.

Verghese, A., Jayanthi, P. D. K. 2001. Integrated pest management in fruits. In: Reddy, P. P., Verghese, A. and Krishna Kumar, N. K. (eds.), *Pest*

Management in Horticultural Ecosystems. Capital Publishing Company, New Delhi, pp. 1–23.

Verma, K. S. 2020. Toxicity of some insecticides against *Agrotis* spp. infesting cabbage. *Indian J. Entomol.* 82(1): 139-142.

Viraktamath, C. A. and Murphy, D. H. 1980. Description of two new species with notes on some Oriental Idiocerinae (Homoptera: Cicadellidae). *J. Entomol. Res.* 4(1): 83-90.

Viraktamath, S. and Viraktamath, C. A. 1985. New species of *Busoniomimus* and *Idioscopus* (Homoptera-Cicadellidae-Idiocerinae) Breeding on mango in South-India. *Entomon* 10(4): 305-311.

Waite, G. K. 2002. Pests and pollinators of mango. *Tropical Fruit Pests and Pollinators.* CAB International, Queensland, Australia, pp.103-129.

Whitwell, A. C. 1992. The pest/predator/parasitoid complex on mango inflorescences in Dominica. *Int. Mango Symp.* 341 : 421-432.

Williams, D. J. 2004. *Mealybugs of southern Asia.* The Natural History Museum/BHD, London/Southdene SDN/Kuala Lumpur, 896 p.

Wysoki, M. 1996. Present status of arthropod fauna in mango orchards in Israel. *Int. Mango Symp.* 455: 805-811.

Wysoki, M., Ben-Dov, Y., Swirski, E. and Izhar, Y. 1992. The arthropod pests of mango in Israel. *Int. Mango Symp.* 341: 452-466.

Wysoki, M., Kuslitzky, W., Zur Strassen, R., Israeli, Y., Rosen, D., Rene, S., Ofek, G. and Izhar, Y. 1995. *Mango pests survey, population dynamics and natural enemies*. Mango Pest Research Report Agricultural Research Center, pp. 1-32

Yadav, E. S., Bangarwa, K. S., Dhankhar, S. S. and Pannu, R. K. 2014. Major insect pests of fruit crops and their management. *Entomol. Nematol.* 4(1):169.

Yapo, M. L., Yeboue, K. E., Coulibaly, T. and Kouassi, P. 2019. Contribution to the identification of the insect visitors of mango (*Mangifera indica* L.) flowers in

Korhogo (Northern Cote D'ivoire). *J. Adv. Stud. Agric. Biol. Environ. Sci.* 6(3): 9-14.

Zhao, D. X., Gao, J. L., Lu, F. P., Wang, A. P. and Zhu, M. S. 2013. A comprehensive survey of spider species present in mango orchards in Hainan Island, China. *Acta Hortic.* 99 (2): 475-478.

INCIDENCE AND MANAGEMENT OF INSECT PESTS INFESTING INFLORESCENCE OF MANGO

by

J. NAYANATHARA

(2018-11-069)

Abstract of the thesis
Submitted in partial fulfilment of the
requirement for the degree of

MASTER OF SCIENCE IN AGRICULTURE

Faculty of Agriculture

Kerala Agricultural University

DEPARTMENT OF AGRICULTURAL ENTOMOLOGY

COLLEGE OF AGRICULTURE

VELLAYANI, THIRUVANANTHAPURAM-695 522

KERALA, INDIA

2020

ABSTRACT

Mango inflorescence hosts a varied complex of insect and non insect population. This has resulted in poor fruit set and yield of mango. In the study entitled "Incidence and management of insect pests infesting inflorescence of mango"; the documentation of various insect pests attacking mango inflorescence was conducted in the three different blocks of Thiruvananthapuram district *viz.,* Nemom, Athiyannur and Parassala whereas the field experiment for the management of insect pests infesting mango inflorescence was done during the period 2018-2020 in an orchard located at Kollengode of Palakkad district.

The collected specimens included pests, floral visitors and natural enemies from the nine different orders including Araneae. Insect pests from 15 different families of five different orders were identified with the assistance of expert taxonomists.

Hoppers posed a serious threat to the mango ecosystem in its vegetative and reproductive phase. The commonly noticed species during the field visits in Palakkad was *Idioscopus* sp. Mealy bugs and scales were the other common hemipterans recorded during the documentation studies. They were mainly from the families of Pseudococcidae and Monophlebidae consisting of *Crisicoccus hirsutus, Rastrococcus iceryoides, Ferrisia virgata Formicococcus mangiferacola, Icerya* sp. and *Rastrococcus* sp. Cowbugs were also noticed from the panicle and some in association with ants like; *Camponotus compressus.* The thrips were from the families of Phlaeothripidae *ie., Gynaikothrips* sp. and *Haplothrips* sp. Chrysomelids from the tribe Alticini included *Nonartha* sp. and *Monolepta* sp were found feeding on mango inflorescence. The weaver ant *Oecophylla smaragdina* made nests on mango inflorescence by mild to severe webbings on the panicle.

The commonly recorded lepidopterans from the mango panicle were included in the family, Geometridae, Noctuidae, Lycaenidae, Torticidae, Nolidae and Erebidae. Around 17 species were identified; comprising of *Comostola laesaria, Chlumetia transversa, Anthene lycaenina lycaenina, Rapala manea , Archips micaceana, Nanaguna breviuscula, Gatesclarkeana erotias, Bombotelia jocosatrix, Perixera*

illepidaria, Eublemma abrupt, Thalassodes sp., *Lymantria* sp., *Eublemma versicolor, Aetholix flavibasalis* and *Eublemma* sp. ; along with nearly 17 more unidentified species.

The regularly noticed floral visitors were from the families of Syrphidae, Calliphoridae and Sarcophagidae and the identified species were *Eristalinus arvorum , Lucilia sericata* and *Parasarcophaga dux.* Apart from these there were presence of several other bugs, ants (*Camponotus compressus*), unidentified neuropterans and mantids (*Odontimantis pulchra*). The documented spider diversity from inflorescence consisted of *Thomisus s*p., *Tetragnatha viridorufa, Cyrtophora cicatrosa,* and *Tetragnatha* sp.

A field experiment was carried out at Kollengode area of Palakkad district to evaluate the efficacy of *Beauveria bassiana* (ITCC6063) WP 2%, fish –jaggery mixture 0.5%, azadirachtin 1%, buprofezin 25% EC 62.5 g a.i. ha^{-1}, novaluron 10% EC 100 g a.i. ha^{-1}, chlorantraniliprole 18.5%SC 30 g a.i. $ha^{-1}$and *Metarhizium anisopliae* (Ma4) 20 g l^{-1}, to suppress the pest attack on the inflorescence with a major focus on the caterpillar complex.

Single spray of each treatment was done on the selected mango trees and observations were recorded from the tagged inflorescence on fifth, tenth and fifteenth day after spraying. All the treatments were effective in reducing the pest. However, chlorantraniliprole 18.5% SC 30 g a.i. ha^{-1} was the superior treatment in reducing the pest population (4.11) followed by novaluron 10% EC 100 g a.i. ha^{-1} (5.22) and buprofezin 25% EC 62.5 g a.i. ha^{-1} (5.33) on five, ten and fifteen days after spraying. Among the biocontrol agents entomopathogenic fungi like *Beauveria bassiana* (ITCC6063) WP 2% (7.89) followed by *Metarhizium anisopliae* (Ma4) 20 g l^{-1}(7.94), were found effective. Azadirachtin 1% (7.72) was also an effective treatment among the biorationals and gave maximum pest suppression at 15^{th} day of spraying. Chlorantraniliprole 18.5%SC 30 g a.i. ha^{-1} recorded maximum fruit set per panicle (24.33) during the peanut stage followed by Novaluron 10% EC 100 g a.i. ha^{-1} (23.33) however, they were on par with each other.