Seasonal Incidence and Integrated Management of Mango Mealy Bug, *Drosicha mangiferae* (Green)

By

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(J-08-D-97-A)

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IN

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Main Campus, Chatha, Jammu 180009

2012

CERTIFICATE – I

This is to certify that the thesis entitled "**Seasonal incidence and integrated management of mango mealy bug, *Drosicha mangiferae* (Green)**" submitted in partial fulfillment of the requirements for the degree of **Doctor of Philosophy in Entomology** to the Faculty of Post-Graduate Studies, Sher-e-Kashmir University of Agricultural Sciences and Technology of Jammu is a record of bonafide research carried out by **Ms. Bandana Bhau**, Registration No. **J-08-D-97-A** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma. It is further certified that such help and assistance received during the course of investigation have been duly acknowledged.

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Date: 28/12/12

Bandana Bhau

Dedicated

To

My Parents

ABSTRACT

Title of the thesis	: **Seasonal Incidence and Integrated Management of Mango Mealy Bug, *Drosicha mangiferae* (Green)**
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The studies were conducted to determine "Seasonal incidence and integrated management of mango mealy bug, *Drosicha mangiferae* (Green)". To achieve it, an extensive field survey and observations were conducted during 2009 and 2011 which showed that mango mealy bug (*Drosicha mangiferae*) was invariably found on cultivated fruit and vegetable crops as well as on wild host crops growing in and around the fruit and vegetable crop ecosystem. In this context, over 70 plants including vegetables, shade trees, fruit trees, forest trees, ornamental plants, weeds and shrubs were examined wherein, more than more than 30 host plants from 24 families were infested with four (4) mealy bug species (in four genera) identified in the Jammu region.

Seasonal fluctuations in the mango mealy bug population during 2009-10 at Udheywalla (SKUAST-J) ranged from 1.33 to 23.33. Infestation was first observed after hatching of eggs and emergence of tiny nymphs (crawlers) as the temperature started rising in the month of early January. i.e., from 1^{st} standard week with an initial population of 3.00 nymphs per plant till 16^{th} standard week in which recording a maximum of 23.33 nymphs per plant. The trend in seasonal incidence of mango mealy bug nymphal population in both the experimental sites was observed to be more or less similar with slight variation in population fluctuations. A highly significant positive correlation existed between weekly mean minimum and maximum temperature and mealy bug nymphal density and non-significant negative correlation with relative humidity (morning and evening) and non-significant correlation with rainfall, respectively. The value of linear regression equations for the three locations were calculated to be $Y = 14.971 - 3.906\ X_1$, $Y_1 = 26.346 - 1.470X1$ and $Y_1 = 14.971\text{-}3.906\ X_1$ at different experimental sites of Udheywalla, Akhnoor and Miran Sahib, respectively. These equations showed the increasing trend of mealy bug nymphal incidence due to increase in temperature, preferably to some extent. The values of coefficient of variation also varied from 72.4 to 78.4 per cent which indicated a variation in the population density with an increasing trend. The overall impact of weather factors on population build up above mealy bug was 72.4 per cent at Udheywalla, 72.4 per cent at Akhnoor and 78.4 per cent at Miran Sahib. Almost similar trend were observed with a bit aberration during the second year of experimentation.

Biology and duration of various life/developmental stages revealed that the first instar nymph took mean time of 51.1±2.64 (range 39 to 60) days for its development. This period differed significantly from the developmental period of rest of the instars including adults. The second and third instars completed their development in relatively lesser period of 22.7± 2.08 (range 13 to 32) days and 32.9±1.15 (range 16 to 45) days, respectively. The pupal period of male lasted for 6.1 ±

1.00 (range 5 to 9) days. The eggs laid in the soil cracks and cravices remain in diapause from June to the next season in January.

Among all the predatory species recorded on mango, mealy bug in orchard, *Rodolia amabilis Kapur* was found to be the most abundant coccinellid predator during the two years of study at all the experimental sites. Its highest abundance (61.64 %) was recorded in Udheywalla followed by Miran Sahib (59.70 %) and Akhnoor (54.99 %). *C. septempunctata* was the second most abundant predator with 13.91 to 19.13 per cent abundance followed by *C. sexmaculata* (12.03 to 13.99 %) at different experimental sites.

The overall impact of various treatments when observed individually after the 2nd spray applications, the average of all counts of mealy bug nymphal population per plant was low with sand application, imidacloprid, metasystox and sticky barrier, respectively. The impact of different treatments on mealy bug nymphal population observed during 2011, nymphal population counts was similar to that observed in previous years of experimentation. The overall mean impact of IPM modules after first treatment/application revealed the following descending order of performance of treatments was as follows:

Module 4 (Soil raking + ploughing followed by irrigation +Sticky band+ Soil application (methyl parathion dust 2%) + Imidacloprid 1 spray; metasystox 1 spray) (0.667) > Module 3 (Sand application, soil racking +sticky band) (2.333) > Module 5 (Existing package and practices (soil raking+soil application 1.5% lindane dust + sticky band) (2.667) > Module 2 (Sand application + Methyl parathion 2% dust + imidacloprid 0.0025% 2 sprays) (5.333) > Module 1 (Methyl parathion 2% dust; metasystox 0.03% 2 spray + soil raking and ploughing followed by irrigation) (3.000 mean mealy bug nymphs).

Almost similar trend with little aberration in reference to impact of different IPM modules on mean mealy bug pest population was also observed during 2011 During 2011, the overall effect of all the five modules after two sprays was found to be maximum again with module 4 (1.267) and minimum with module 1 (5.133) (Methyl parathion 2% dust; metasystox 0.03% 2 spray + soil raking and ploughing followed by irrigation) and the order of performance of all the five modules in terms of effect in reducing the mean number of mango mealy bug pest population after 2nd treatments was same as observed during 1st treatment in the same year of study.

Signature of Major Advisor 28/12/12

Signature of Student 28/12/12

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INTRODUCTION

Chapter- 1

Introduction

India is bestowed with a wide variety of agro-climatic conditions and unique comparative advantage for growing almost all horticultural crops. Our country is the second largest producer of fruits in the world and the major producing areas are distributed in Sub-tropical and tropical parts of the country and a limited area have been harnessed in the temperate region. The total area under fruit is 5.77 million hectares, total production is 63.50 million tonnes which accounts for 11 per cent of the world total fruit production (Anonymous, 2011). The total area during 2005-06 under the fruit crops in the Jammu and Kashmir state was 2.83 lakh hectares with a production of 1504.01 thousand metric tonnes. Almost 45 per cent of economic returns under agriculture sector are contributed by horticulture, thereby adding 7 per cent to the Gross State Domestic Product (Anonymous, 2007). Jammu and Kashmir state is generally mountainous with tiny valleys having diverse topography occupies central place in Asian continent. The diversity of climates, consequently alters favourable chances for crops including fruits. It is located within the northern hemisphere between 32.17 and 58 northern latitude,76.26 and 80.30 east longitude and 80 east of greenwhick out of different kinds of fruits grown in the state, wherein, mango ranks at the top in Jammu divison.

Mango (*Mangifera indica* Linnaeus) is known as 'king of fruits' and belongs to family Anacardiaceae (Singh, 1968; Litz, 1997). It is an important tropical fruit, which is being grown in more than 100 countries of the world (Sauco, 1997). Mango is the most popular fruit amongst millions of people in the Oriental region, particularly in Indo-Pakistan Sub-continent. India is the largest mango producer in the world (10.0 million tonnes) with 15 per cent share in the world mango market (http://www.panhwar.com/ Article79. htm). Mango accounts for 40 per cent of the national fruit production *viz.*, 13792.1 thousand tonne, 42 per cent of the land under its cultivation *viz.*, 2205.6 thousand hectares, 40 per cent of the fruit exports from the country (Anonymous, 2008). The main constituents of mango fruits are carbohydrates, proteins, organic acids, minerals and vitamins. It also contains carotenoids, carbohydrates from a major portion which have simple sugars, starchs, cellouse, pectic substances and tannins. The protein content in Indian varieties ranges from 0.50 to 1.0 per cent content unripe fully developed mango of pickling variety contains oxalic acids, citric, malic and succinic acids. It ranges from 0.67 to 3.36 per cent green fruits and 0.18 to 0.56 per cent in ripe fruits. Mango contains considerable amount of vitamin C when it is green and tender with a values high as 348.5 mg per 100 grams of edible part. The mango is a natural source of vitamin A and it varies in different varieties. The ash content of mango varies from 0.26 to 1.66 per cent and show the presence of calcium, magnesium, copper. The mango fruit is utilised at all stages of its development i,e from immature to mature stage. The unripe fruits are used for making pickles and chutney. Mango juice is served as soft drink and ripe fruits are being used in preparing squash, jam, custard powder, baby fruit, mango leather and toffee. The stone of mango is used for medicinal purposes (Jain, 1961). Its leaves form an important component at some religious rituals in the countryside and timber as an important raw materials for furniture industry. Its importance as a foreign exchange earner is very well established.

Mango is grown in vast range of agro climatic conditions and attacked by over 500 species of insect pests (Tandon and Lal, 1981;Tandon and Varghese, 1985) where 21 species are most important pests particularly in oriental region (Tandon, 1978). Mango is usually attacked by four to five key pests damaging the crop to a considerable extent causing severe losses which includes fruit flies, stone weevils, mango hoppers, mealy bugs, scale insects and tree shoot borers. However, only a few important species are of major concern in Jammu region. Among the insect pest listed as above, fruit flies (*Bactrocera dorsalis* and *B. zonata*), mango mealy bug (*Drosicha mangiferae* Green) and mango hoppers (*Amortiodus atkinsoni* Leth and *Idoscopus* sp.) are most destructive. Most of the mango producing countries are located in fruit fly infested areas, and growers suffer significant direct and indirect economic losses resulting from fruit fly damage (Aluja, 1994; Drew and Hancock, 1994; Hill, 1975; Singh, 1991).The area under the occupation of this crop during 1989-90 was 3.33 millon hectare with an estimated production of 28.24 millon tonnes (Koul, 1993). Several insect pest cause considerable damage to mango crop every year. Irrespective of the cropping intensity, mangos in West Africa are threatened by three major pests, namely, termites (Isoptera: Termitidae), mealybugs (Homoptera: Pseudococcidae), and fruit flies (Diptera: Tephritidae) (Vannie`re *et al.,* 2004). Mango fruit flies are quarantine pests in many parts of the world, including the European Union and the United States. The latter currently prohibits imports of West African mangos. Apart from export restrictions, of the 1.9 million metric tons of mangos produced in Africa annually, ~ 40% is lost due to damage caused by fruit flies (Lux *et al.,* 2003).

Mango mealy bugs (*Drosicha mangiferae, Drosicha stebbingi* and *Rastrococcus iceryoides*) (Hemiptera: Pseudococidae), the polyphagous pests of mango in India are recorded as serious pests from Asia on several host crops (Tandon and Verghese, 1985; Tandon, 1978). The newly hatched nymphs ascend the trees, settle on inflorescence and feed by sucking sap and thereby causing flower drop and affecting fruit set. Serious attack by this insect follows drying of the leaves, terminal shoots, premature fruit fall. The occurrence of honey dew and sooty mould may reduce the market value of product such as fruits. In India, it is a major pest of grapes, reducing yield 50 to 100 per cent yield losses on the crops, such as jute and mesta ranges up to 70 per cent. Yields losses due to infestations and damage caused by mealybug on mango plant can rise up to 80 per cent (Entomological Society of Nigeria, 1991; Moore, 2004; Karar *et al.,* 2007). The damage due to mealybug could be as high as 80 percent of all losses (Nwanze, 1982). Similarly, Tobih (2002) observed that the infestation due to mango mealybug caused significant loss in size and weight of fresh mango fruits. Mealy bugs are known to bribe ants with their sugary secretion (Honey dew) and in return ants help in spreading of mealy bug and provide protection from predators like ladybird beetle, parasitoides and other natural enemies.

Earlier, mealy bug were considered to be minor pest in several crops have gained the status of major pest especially in cotton, vegetables and fruit crops. During last few year, mealy bug has become a major problems in several crops. Gujarat and Punjab have faced serious infestation of mealy bug in cotton since last few years. The vast range of climatic conditions and agro-ecosystems in which mango is grown subject to attack of insect pest. The damage due to mealy bug as high as 60 per cent (Tandon *et al.*, 1978). The management is difficult particularly in view of its behaviour and polyphagous nature. There has been a consistent interest to evolve cultural and biological methods. The mealy bug being sessile insects are more amenable to biological control in which parasitoids and predators effectively reduce mealy bug population. Chemicals are generally recommended only as a last resort in the integrated package of control measures and have been inefficient (Tandon & Lal, 1980; Yousuf & Ashraf, 1987). There has been consistent interest to evolve cultural and biological control methods. Yousuf (1993) reported use of polyethylene bands for effective control of mealy bug. Several predators of mango mealy bug have been identified (Syed *et al.*, 1970; More & Cross, 1993; Boavida *et al.*, 1995; Bokonon & Neuenschwander, 1995). The major problem with the management is related to their mode of life. Mealy bug live in protected area such as cracks and crevices of bark at base or leaf are protected by waxy secretion of ovisac are almost impossible to reach with insecticides. Late instars nymph and adults of female mealy bug are not affected by foliar application since they are covered with waxy coating. Evidently, a combination of all suitable techniques is required for their management. There are numerous species of mealy bugs (Green, 1908) infesting damage to the fruit crops and vegetables. Mango mealybug (*Drosicha mangiferae*), a polyphagous pest infesting almost all fruit crops like mango, citrus, guava, litchi, anar, papaya, phalsa, cotton, mash etc. and many forest trees and agricultural crops. The spatial distribution of polyphagous mealy bug infesting leaves, flowers and fruits was studied by Boavida *et al.* (1992), who developed binomial sampling plans for estimating population levels. Another species of mealy bug infesting vegetable crops are *Planococcus solenopsis* has been recorded for the first time in Jammu (Shankar *et al.*, 2010) causing damage by sucking the sap from the leaves, tender shoots, and the fruits.

In view of the economic importance of the mango cultivation in Jammu and the magnitudes of the damage caused by the mealy bug, it becomes mandatory to keep continuous watch on their incidence, life cycle, natural enemies and management studies which will pave the building block for development of effective pest management strategies against mango mealy bug. Further, the review of literature showed meagre information on seasonal incidence, life cycle and natural enemy and management of mealy bug infesting mango in Jammu, therefore, present investigations has been planned with the following objectives:

1. To study the seasonal incidences of mango mealy bug
2. To study the life cycle of mango mealy bug, *Drosicha mangiferae*
3. To record the natural enemy fauna of mango mealy bug
4. To develop management for mango mealy bug

REVIEW OF LITERATURE

Review of Literature

The mango mealy bug, *Drosicha mangiferae* Green is one of the serious insect pests of mango occurring mainly in the Northern and the Central parts of India. In recent past, efforts have been made to give thrust to integrated strategies which comprises cultural, biological and insecticidal methods for the management of mango mealy bug, *D. mangiferae*. The relevant information pertinent to the present investigation on seasonal pest incidence, life cycle, activity of natural enemies of mealy bug is reviewed as under-

2.1 Host ranges of different types of mealy bug

Host plant has great effect on the fecundity and survival of *R. invadens* (Bovida and Neuenschwander, 1995). Latif (1940) observed the wandering habits of nymphs of mealy bugs and described the taxonomic status and identified *D. stebbingi* Green and *D. mangiferae* Green. Dietz and Harwood (1960) reported the host range and damage by the Grass mealy bug, *Heterococcus graminicola* on 67 species representing 23 genera. They have recorded sixty four mealy bug species from Brazil. Haq and Akmal (1960) observed the attack of giant mango mealy bug on a variety of other fruit trees like peach (*Prunus persica*), plum (*P. domestica*), papaya (*Carica papaya*) and all guava species etc. During heavy infestation, it has been observed attacking many forest trees. Huge number of mature females has been seen crawling down via stem of *Dalbergia sisso, Ficus religiosa, Bombyx ceiba, Populus abla* etc.

Mango mealybug (*Drosicha mangiferae*) is one of the destructive pests attacking the fruit trees in India (Prassad and Singh, 1976). Tandon and Verghese, 1985 reported that *D. mangiferae* is dangerous for mango crop. It is not only pest of mango but it attacks more than 70 other host plants (Tandon and Lal, 1978; Narula, 2003). Mango mealybug *Drosicha mangiferae* Green is a pest of mango and 12 other orchards, known as giant mealybug (Sternorrhyncha: Coccoidea: Monophlebidae).

Tandon *et al.* (1978) recorded the host range of *Drosicha mangiferae* and *Drosichia stebbingi* feeding on 62 host plants under 51 genera and 28 families, which included fruits crops, forest trees , ornamental plants and weeds. Shah *et al.* (1980) recorded ber a new host of mango mealy bug, *Nipaecoccus vastator* Maark) in Gujarat and observed that the mealy bug infested ber trees by way of clustering upon the leaves and terminal shoot.

Though this insect is mainly a pest of mango tree, however in the areas of heavy populations, it has the tendency to attack a variety of other fruit trees like peach (*Prunus persica*), plum (*P. domestica*), papaya (*Carica papaya*) and all citrus species etc. (Khan, 2001). During heavy infestation, the giant mango mealy bug has been observed attacking many forest trees. Huge number of mature females has been seen crawling down via stem of *Dalbergia sisso, Ficus religiosa, Bombyx ceiba, Populus abla* etc.

Arif *et al.* (2002) showed that the mealy bug species cause considerable economic damage to agricultural and horticultural plants. Santa-Cecília *et al.* (2002) documented the presence of two species of mealy bug which need additional survey and taxonomic studies on coffee in Brazil. Worldwide, at least nine species of mealy bug have been recorded as pests of papaya, of which five occur in Brazil. Culik *et al.* (2003) recorded the host range of the mealy bug which includes grape, fig, date palm, apple, avocado, banana, citrus, okra, tomato, brinjal, cotton and a few ornamentals. *Hibiscus rosa-sinensis* is a typical host which is frequently attacked by *Maconellicoccus hirsutus*. Host records of *M. hirsutus* extend to 76 families and over 200 genera, including beans, *Chrysanthemum*, citrus, coconut, coffee, cotton, corn, *croton*, cucumber, grape, guava, *Hibiscus*, peanuts, pumpkin, rose, and mulberry. In its native range, *M. hirsutus* has been recorded causing economic damage to many crops. In India, losses have been reported for cotton; the fibre crops *Hibiscus sabdariffa*, *Hibiscus cannabinus* and *Boehmeria nivea*; grapevine; mulberry; pigeonpea; *Zizyphus mauritiana*. Presumably, many ornamental woody plants are also affected, but populations and damage may be limited by natural enemies.

Godse *et al.* (2003) found seven species of mealy bugs on mango (*Perissopneumon* sp. *Ferrisia virgata, Planococcoides robustus, Rastrococcus invadens, Planococcus* sp., *Cataenococcus* sp. and *Icerya aegyptiaca*) in Maharashtra, India. Of these, *Ferrisia virgata* and *Perissopneumon* sp. were observed causing considerable economic damage.

Kannan *et al.* (2006) determined the occurrence of pests during the new flush, twig expansion, matured leaf and fruit maturity stages of 0 to 5, 5 to 15 and > =15 year-old mango cv. Neelum trees. Trees 15 years old and above were preferred by the pests *Procontarinia matteiana, Amradiplosis ecinogalliperda, Orthaga exvinacea, Amritodus atkinsoni, Idioscopus niveosparsus, Thrips hawaiiensis, Drosicha mangiferae, Sternochaetus mangiferae, Bactrocera dorsalis, Conogethes punctiferalis* and *Batocera rufomaculata*.

Various species of mealy bugs have started appearing in serious proportions on field crops, vegetables, fruits and ornamentals (Tanwar *et al.*, 2007). In fact, mealy bugs have become indicator insects for the current ecosystem alterations due to slow changes in climate during the period from 2002 to 2005. Among these, *Phenacoccus solenopsis* Tinsley on cotton and *Paracoccus marginatus* Williams and Granara de Willink on papaya have become quite serious. The papaya mealy bug, *P. marginatus,* has become quite alarming in Tamil Nadu, challenging the pesticides or other IPM measures. *Maconellicoccus hirsutus* (Green) causes extensive damage to ornamentals, though its host range extends to 76 families and over 200 genera, including beans, *Chrysanthemum*, citrus, coconut, coffee, cotton, *croton*, cucumber, grape, groundnut, guava, *Hibiscus*, maize, mulberry, pumpkin and rose (Tanwar *et al.*, 2007; Rajendran, 2009).

The severity of pest problems has been changing with the developments in agricultural technology and modifications of farming practices. The pest scenario in cotton ecosystem is changing fast and is assailed by multitude of pests as it evolves through various production levels. American and spotted bollworms attained secondary pest status, and tobacco caterpillar, pink bollworm, mirids and mealy bugs are emerging as major pests. While there is a decline in the pest status of bollworms; the sap feeders, viz. aphids, jassids, mirids and mealy bugs are emerging as serious pests (Vennila, 2008).

Anonymous (2008) reported that there are apprehensions about mealy bug inflicting more damage on cotton in the 2008–09 season after a sizable loss of Rs 159 corers from Punjab on cotton and the reports of a range of severity from other cotton growing States during 2007-08 season.

Sharma *et al.* (2009) identified six mealy bug species, viz. *Planococcus citri* (Risso), *Planococcus lilacinus* (Cockerell), *Ferrisia virgata* (Cockerell), *Nipaecoccus viridis* (Newstead), *Maconellicoccus hirsutus* (Green) and *Drosicha mangiferae*

(Green) active on various fruit crops in Punjab. *P. citri* attacked citrus, guava, pomegranate, sapota, jamun, aonla and ber fruit plants. Its infestation was found on leaves, twigs and branches of all these fruit crops. *D. mangiferae* was the most serious mealy bug species of mango from February to April and its attack was also observed on sapota and litchi. *P. lilacinus*, *F. virgata*, *N. viridis* and *M. hirsutus* are reported for the first time on fruit crops in Punjab. Chlorpyriphos (0.075%), acephate (0.075%), thiamethoxam (0.008%) and profenophos (0.075%) were found effective against mealy bugs on citrus, guava and grapes.

The host range of the mealy bug includes grape, fig, date palm, apple, avocado, banana, citrus, okra, tomato, brinjal, cotton and a few ornamentals. *Hibiscus rosa-sinensis* is a typical host which is frequently attacked by *Maconellicoccus hirsutus*. Host records of *M. hirsutus* extend to 76 families and over 200 genera, including beans, *Chrysanthemum*, citrus, coconut, coffee, cotton, corn, *croton*, cucumber, grape, guava, *Hibiscus*, peanuts, pumpkin, rose, and mulberry. In its native range, *M. hirsutus* has been recorded causing economic damage to many crops. In India, losses have been reported for cotton; the fibre crops *Hibiscus sabdariffa*, *Hibiscus cannabinus* and *Boehmeria nivea*; grapevine; mulberry; pigeonpea; *Zizyphus mauritiana*. Presumably, many ornamental woody plants are also affected, but populations and damage may be limited by natural enemies. In India, it is a major pest of grapes, reducing yields 50 to 100 per cent. Yield losses on other crops, such as jute and mesta range up to 75 per cent. Mealy bug are known to bribe ants with their sugary secretion (honeydew) and in return ants help in spreading of mealy bug and provide protection from predator ladybird beetle, parasites and other natural enemies. The giant mango mealy bug (*Dorsicha stebbingi)* though is mainly a pest of mango tree (Birat, 1964; Bindra *et al.* 1970; Bindra and Sohi, 1974; Haq and Akmal,1960; Khan, 1989), however in the areas of heavy populations, it has the tendency to attack a variety of other fruit trees like peach (*Prunus persica*), plum (*P. domestica*), papaya (*Carica papaya*) and all guavaspecies etc. During heavy infestation, the giant mango mealy bug has been observed attacking many forest trees. Huge number of mature females has been seen crawling down via stem of *Dalbergia sisso, Ficus religiosa, Bombyx ceiba, Populus abla* etc. in the area of Buloke, Gatwala and Bhaget Plantations (Khan and Ashfaq, 2004).

During 2006, *P. solenopsis* appeared for the first time on cotton crop in Punjab and caused severe losses in some pockets of Ferozepur, Muktsar and Bhatinda districts (Dhawan and Saini, 2009). Since then this pest has spread to several states like Haryana, Rajasthan, Maharashtra and Gujarat and southern states (Atwal and Dhaliwal, 2009; Nagrare *et al.,* 2009). Besides cotton, *P. solenopsis* has been recorded on several economic crops like okra, tomato, brinjal, chilli, grape, fig, datepalm, apple, avocado, banana, citrus, etc. (Mohindru *et al.,* 2009).

Franco *et al.* (2009) Mealybugs (Hemiptera: Pseudococcidae) are small, soft-bodied plant sap-sucking insects that constitute the second largest family of scale insects (Hemiptera: Coccoidea), with more than 2,000 described species and ca. 290 genera (Downie and Gullan, 2004). Their common name is derived from the mealy wax secretion that usually covers their bodies (Kosztarab, 1996). Mealybugs are severe agricultural pests. According to Miller *et al.* (2002), 158 species of mealybugs are recognized as pests worldwide. These species most frequently originate from the Palearctic region (ca. 29%), followed by the Nearctic (17%), Neotropical (16%), Oriental (15%), Afrotropical (12%) and Australasian (11%) regions. Approximately 22% of the mealybug pests are polyphagous, 20% occur on grasses (e.g., sugar cane), 16% on citrus and tropical fruits, and 6% on coffee.

Wih and Billah (2012) reported that the fruit flies and mealybugs have been observed as major threats to mango and other crops in the Upper West Region. Nine fruit fly species and four mealybug species (*Pseudococcus longispinus*, *Paracoccus marginatus*, *Rastrococcus invadens* and *Icerya* sp.) were identified during the survey. While mango was dominated by *R. invadens*, the ornamental plants were mostly affected by *Icerya* sp., papaw by *P. marginatus*, and *Jatropha* species infested by *P. longispinus*. The mealybug species were fairly common in the region. In certain cases, other pest species such as aphids and whiteflies were found in close association (in complex mixtures) with the mealybugs.

2.1.1 Seasonal incidence of mango mealy bug on mango

The mango mealy bug is a polyphagous insect, which has been recorded to feed on numerous plant species. There are numerous species of mealy bugs (Green, 1908). Variation in population density of phytophagous insects and variation in susceptibility may be genetic, or phenotypic due to differences in environmental factors such as the nutritional status of the soil (Dale, 1988) or air pollution (Riemer and Whittake, 1989), as well as variation in plant age or seasonal phenology (Marino and Cornell, 1993).

Temperature and relative humidity have been reported to play an important role in development of *D. stebbingi* (Singh, 1946; Yousuf and Gaur, 1993; Yadav *et al.*, 2004). However Matokot *et al.,* (1992) have shown that fluctuations in populations of mango mealybug (*Rastrococcus. invadens* Williams.*)* on mango are linked to the physiological and phenological characteristics of the host plant than to climatic factors. Seasonal changes play an important role on population fluctuations of mango mealybug (*Rastrococcus invadens* Williams.) its population, which decreased during the rainy season and peaked during dry season (Bovida and Neuenschwander, 1995; Dwivedi *et al.*, 2003).

In earlier studies, Rehman and Latif (1944) while working at Layallpur observed the descending of females to ground during the months of May and June. Sen and Prasad (1956) at Bihar and Pruthi and Batra (1960) at Gwalior have recorded the descending in the months of April and May. But at Sirsa the descending of females has been noted from end of March to end of May (Butani, 1964 and 1979).

There has been a consistent interest to evolve cultural and biological methods (Chandra *et al.*, 1991). Several predators and Parasitiod of mealy bug species has been identified (Boavida *et al.,* 1995). More than 1300 mealy bug and their natural enemies have been reported across the world. The mealy bug being sessile insects are more amenable to biological control in which parasitiods and predators effectively reduce mealy bug population.

Neuenschwander (1996) mango mealy bug (*Rastrococcus invadens* Williams), is effectively kept under check by hymenopterous parasitoids and coccinellids. Recent survey conducted in Delhi (India) in July and August, 2008 indicated the presence of a hymenopterous parasitoid, *Aenasius* sp. (Chalcidodea: Aphelinidae) on *Phenacoccus solenopsis* infesting *Parthenium hysterophorus*, *Xanthium strumarium* and *Achyranthes aspera* plants. Its parasitisation on these weeds ranged from 20-70%. A survey conducted in five tehsils of Parbhani (Maharashtra) indicated the presence of another hymenopterous parasitoid, *Promuscidea unfasciati* Girault (Chalcidodea: Encyrtidae) parasitizing *P. solenopsis* on cotton and *P. hysteropus* plants in four tehsils out of five surveyed.

Mealy bug species cause considerable economic damage to agricultural and horticultural plants (Atwal, 1976; Arif, *et al.,* 2002; McKenzie, 1967; Williams and Granara de Willink, 1992; Miller *et al.*, 2002 and 2005). Plant damage by mealy bug results from the direct effects of sap removal and injection of toxins, as well as indirectly by honeydew contamination and associated sooty mould growth that decreases photosynthesis (Mibey, 1997), and occasionally from the effects of transmitted plant viruses. Feeding damage may cause leaf yellowing, defoliation, reduced plant growth, and death of plants.

About 5000 species of mealy bug have been recorded from 246 families of plants throughout the world. Among these, 56 species have been reported from 15 genera of family Malvaceae, including cotton and many other plants of economic importance (Ben- Dov, 1994). A new species of mealy bug, *Phenacoccus solenopsis* Tinsley, appeared on cotton during the year 2005 and attained the status of a serious pest in the cotton growing areas of Punjab and Sindh Provinces of Pakistan. It attacked many other plants including crops, weeds and those of ornamental and medicinal value. Dietz and Harwood (1960) reported the occurrence of grass mealy bug (*Heterococcus gramincola*) on 67 species representing 23 genera. Sixty four mealy bug species recorded from Brazil (Ben-Dov *et al.*, 2005).

Bokonon-Ganta *et al.* (2002) demonstrated the negative impact of the pest (*Rastrococcus invadens* Williams (Homoptera: Pseudococcidae) on plant production and the positive impact of the introduced natural enemy (parasitic wasp, *Gyranusoidea tebygi* Noyes) based on production estimates by producers. Interviewed mango producers gained on average US$ 328 per year by the biological control programme. Extrapolated to all producers of Benin, a yearly gain of US$ 50 million in mango production can be estimated. The present value of accrued benefits is estimated at US$ 531 million over a period of 20 years. The total cost of the biological control of mango mealy bug is estimated at US$ 3.66 million, which includes initial costs in other African countries and the introduction of the natural enemy from India, resulting in a benefit–cost ratio of 145:1 for benefits in Benin alone.

Santa-Cecília *et al.* (2002) documented the presence of two species of mealy bug that had not previously been known to occur on coffee in Brazil, and noted the need for additional survey and taxonomic studies on such pests in this area. Worldwide, at least nine species of mealy bug have been recorded as pests of papaya, of which five occur in Brazil (Culik *et al.*, 2003).

Dwivedi *et al.* (2003) recorded the seasonal incidence of insect pests of mango mealy bug in relation to mean temperature and humidity. The population of mealy bug (*Drosicha mangiferae*) was highest (84.6) at the base of the tree trunk in February and lowest (0.58) in December. Leaf hopper (*Amritodus atkinsoni*) appeared in March and reached its peak (87.9/10 leaves) in June. The incidence of (*Inderbella quadrinatala*) ranged from 1.2 (July) to 8.6 ribbons/plant (January). Gall formation by *Apsylla cistellata* started in July and gradually increased during August, September and October. Fruit fly (*Dacus dorsalis* [*Bactrocera dorsalis*]) was first observed in April with 3% infestation, gradually increased in May (8.2%) and June (9.8%) and slightly declined in July (8.3%). The maggots fed on fruit pulp, resulting in premature fruit falling.

Yadav *et al.* (2004) studied the population density of mealy bug (*D. mangiferae*) 2000 in cv. Amrapali orchard in Meerut, India. The average number of mealy bugs was recorded and correlated with abiotic factors, i.e. average temperature, relative humidity and rain. The highest population (17.50) of mango mealy bug was recorded on April 2000 at an average temperature and relative humidity of 27.43 °C and 46.57%, respectively. A decreasing population trend, i.e. 8.25 and 4.75, was observed on ending April and May 2000 at an average temperature of 31.31 and 31.55 ° C and relative humidity of 48.35 and 49.80%, respectively, due to increasing temperature and relative humidity. The lowest population (1.50) of mango mealy bug was recorded on ending May 2000 at an average temperature and relative humidity of 33.03 °C and 56.75%, respectively. No infestation was recorded on 31 May 2000 due to an increase of temperature (33.55 °C) and relative humidity (63.05%).

During the last few years, mealy bug (Homoptera: Pseudococcidae) has become a major problem in several crops such as cotton, vegetables and fruits. Several states such as Punjab, Rajasthan, Maharashtra and Gujarat have faced serious infestation of mealy bug in cotton. Recently in India the cotton crop in Punjab, Rajasthan, Maharashtra and Gujarat is being seriously infested with mealy bug. There are apprehensions about mealy bug inflicting more damage on cotton in the 2008–09 seasons after a sizable loss of Rs 159 corers reported from Punjab on cotton and the reports of a range of severity from other cotton growing States during 2007–08 season (Anonymous, 2008).

Suresh and Kavitha (2008) found that five scale insect pest species such as *Phenacoccus solenopsis* Tinsley, *Coccidohystrix insolita* Green,*Rastrococcus iceryoides* Green, *Cerococcus indicus* Maskell and *Saissetia coffeae* Walker on parthenium, cotton, hibiscus and crotons in Coimbtore, Tamil Nadu. They showed that mealybugs were most abumdant during May, the cerococcid population was present between October and February, while *S. coffeae* was present throughout the year but most abundant in February and March. Studies correlating the seasonal incidence of each species with weather factors found that, for mealy bugs, abundance was negatively correlated with rainfall and evening humidity.

Pandey and Kumar (2009) observed the population dynamics of mango mealy bug nymphs, *Drosicha mangiferae* Green on the basis of seasonal abundance. Canopy in selected area were pin marked as Tree-A, Tree-B and Tree-C and the number of nymphs of insect present on the tree trunk, terminal twigs or on inflorescences was recorded at an interval of a week. Population of insect was seen to be decreasing thereafter from mid February till last May on three trees. From the visual observations, it reveals that nymphs of mealy bug seen on trunks in the beginning were identified as first instar till mid February.

Karar (2010) conducted a study on bio-ecology and management of mango mealybug, *Drosicha mangiferae* (Green) in mango orchards of Punjab Pakistan and concluded that among various insect pest of mango, mango mealybug was found to be the major pest followed by hoppers, fruit fly, scales, mango leaf galls *Amaraemyia* spp. and midges. The farmers also reported that mango mealybug caused 25-100% loss. Further the respondents indicated that 'Chaunsa' cultivar was the most susceptible to mango mealybug followed by 'Fajri', 'Langra' and 'Black Chaunsa, whereas 'Dusehri' was resistant. Irrigation was the major source of flare up of the pest as viewed by the majority of the respondents. The practices like hoeing, ploughing, irrigation, removal of weeds, grease bands and insecticides were adapted by the respondents with variable results. The maximum peak population of mango mealybug was observed to be 26.6 per 30-cm branch at maximum temperature of 24.6°C, minimum temperature of 10.4°C and RH 78.9%. Among twelve cultivars under study, the 'Chaunsa' cultivar of mango showed maximum population of mango mealybug in both the study years (104.9 and 69.8 during 2005-2006 and during 2006-2007, respectively as well as on an average of both study years (87.4), whereas 'Tukhmi' cultivar was found comparatively resistant with minimum population of mango mealybug i.e. 14.2, 15.9 and 18.2.

Singh *et al.* (2010) found that the maximum incidence mealy bug and mango leaf hopper was observed during first fortnight of March when maximum and minimum temperature, morning and evening relative humidity were 26.4 °C and 14.0 °C, 90.3 and 53.7% respectively. After second fortnight of April, males were not observed when maximum and minimum temperature, morning and evening relative humidity were 37.3 °C, 22.1 °C, 61.6% and 18.9%, respectively. Leaf hoppers exhibited increasing trend from second fortnight of March and starts decreasing from August. Incidence of mealy bugs/twig had a highly significant positive correlation with maximum temperature (0.964) and minimum temperature (0.938) and negative correlation with morning relative humidity (-0.740) and evening relative humidity (-0.910).

Hala *et al.* (2011) observed that the populations of mango mealybug (*Rastrococcus invadens*) were affected mainly by rainfall and temperature variations and to a lesser extent by humidity. The level of live and dead insects is positively correlated with rainfall in contrast to temperature variations. With only 17.95% of parasites developed by *G. tebygi* and *A. mangicola* on mealybug, their impact seems weak on the pest. *Gyranusoidea tebygi* and *Anagyrus mangicola* are attacked in their turn by several seems weak on the pest. Mass production of *G. tebygi* and *A. mangicola* and their release is considered to control *R. invadens* from March to April.

2.2 Life cycle of mango mealy bug on mango

The nymphs and female scales suck sap from shoots, tender leaves and fruit peduncles but prefer to feed on inflorescence (Tandon and Lal, 1979). The affected panicles shrivel and dry. Severe infestation affects the fruit set and causes fruit drop (Khan, 1989) and this ultimately affects the yield.

The mango mealybug (*D. mangiferae*) nymphs started to hatch out at end of Dec. or beginning of Jan. (Chandra *et al.*, 1987; Mohyuddin, 1989). A single female lays up to 400-500 eggs (Haq and Akmal, 1960). The duration of 1st instar vary from 45-71 days; second 18-38 days; third instar for female 15-26 days, whereas duration for males 5-10 days. The total duration 77-135 days for female and 67-119 days for male and 78-135 for females and 77-134 days for males on mango (Rahman and Latif, 1944; Haq and Akmal, 1960) whereas, on citrus the total duration was 169-304 days for female and 165-290 days for male (Saxena and Rawat, 1968). A female took 7-16 days to lay its full quota of eggs (Rahman and Latif, 1944; Chandra *et al.*, 1987). First instars of mango mealybug *D. stebbingi* crawled a distance of about 40 ft and 2nd instars 150 ft. as reported by Latif (1940). Males have ability to reconstruct the cocoon if it is damaged in any way. The copulation time of male with female was 4-10 minutes (Rahman and Latif, 1944) and the ratio of males to females was 1:19 (Chandra *et al.*, 1987).

The pseudococcid fruit tree mealybug, *Rastrococcus invadens* Williams, is a serious pest of several crops, including mango. It has become a serious pest of mango in West Africa (Agounk'e *et al.*, 1988). Mealybugs feed on leaves and fruits. Females have three moults and males have four moults. The entire life cycle can be completed in 31-84 days. The mealybugs weaken plants by puncturing the tissues and consuming sap, but the major damage is caused by the production of large amounts of honeydew upon which saprophytic fungi develop. The resultant thick black layer of sooty mould causes a drastic reduction in photosynthetic efficiency, resulting in premature leaf drop. *R. invadens* severely reduces fruit production in some areas of Africa (Moore and Cross, 1992).

Ashfaq *et al.* (2005) reported that the mango fruits of the Indian subcontinent is badly damaged by giant mango mealy bug (*Dorsicha stebbingi).* This insect pest is hardly controlled by pesticides due to white waxy body coating. Life cycle of mango mealy bug starts with egg laying in loose soil around effected trees. The nymphs emerge with the rise in temperature during January and travel up the trees via stem to feed on cell sap, adjacent to the fruiting parts. Resultantly heavy immature fruit falling occurs. During May, the flying males emerge to mate with the flightless mature females while crawling down to the ground for egg laying.

2.2.1 Egg laying

The giant mango mealy bug (*Dorsicha stebbingi)* is the most familiar dimorphic insect pest of mango trees (Bindra *et al.*1970, Bindra and Sohi 1974, Ali 1980, Anonymous 1996). It lays egg in loose soil within radius of 2-3 meter around the infested trees. Hatching of their eggs starts with rise in temperature during January and the newly emerging nymphs crawls up via tree stem to reach the succulent shoots and base of fruiting parts (Atwal, 1963; Birat, 1964; Atwal, 1976). Being dull coloured, this tiny creature is hard to detect at emergence.

At later stages, the insects can be seen adhering around the entire peduncle of inflorescence and other tender shoots to suck the sap. Their feeding process steadily weakens the branches, which leads to falling of flowers and the immature fruits. The honeydew exuded by developing mealy bugs induces appearance of sooty mould near the affected region and cause necrosis of the affected parts (Latif, 1941; Atwal, 1976; Khan, 1989).

Further, Latif (1940) has documented that the eggs remain embedded in the silken pouch (ovisac) in the subsoil upto depth of 15-20 cms. In Punjab, contrary to these observations the females after reaching the ground are stated to lay the eggs in *craks* and crevices of the soil (Rehman and Latif, 1944). The egg laying between 5-15 cms has been observed at Layallpur (Rehman and Latif, 1944), Bihar (Sen and Prasad, 1956), Punjab (Pruthi and Batra, 1996) and Sirsa (Butani, 1964). Srivastava *et al.* (1973) hae, however, noted the egg laying upto a depth of 16 cms in U.P.

2.2.1.1 Egg measurments

The measurement of an egg of this insect do not exhibit notable variations at different places as is evinced from its length of 0.9 – 1.10mm and breadth of 0.65-0.75mm recorded both at Bihar and Punjab Sen and Prasad (1956). Butani (1964) have also documented similar morphomeasurements of an egg Sirsa and Atwal *et al.* (1969 and 1986) at Punjab.

2.2.1.2 Fecundity

Beason (1941) documented 300-400 eggs being laid by a female who gradually shrink until finally the dry dead shriveled body is left by the side of egg mass. Rehman and Latif (1944) have recorded average of 372 eggs per female within 7-16 days while San and Prasad (1956) noted 250-300 eggs and Atwal (1961) from 400-500 eggs within over 16 days. Pruthi (1969), however, recorded 400-500 eggs being laid in sac like pouches early summer. A single female is reported to have laid an average number of 300 eggs within a period of 7-12 days in U.P. (Srivastava *et al.*, 1973).

2.2.1.3 Shape and Colour of Eggs

Rehman and Latif (1944) have observed that the oval eggs and yellow at the time of laying which later turn deep orange yellow to reddish brown. The shape and colour patterns of the eggs noted in Bihar by Sen and Prasad (1956) have not been different from those found in Layallpur by the above workers. The colouring patterns of eggs dot not seem to vary under varying agroeco situations. The initial shiny pink colour of an egg is recorded to have changed later to yellow in Punjab (Singh, 1960 Atwal, 1961) and Delhi (Pradhan, 1969 and Chandra *et al.*, 1987).

2.2.1.4 Diapause

Sen and Prasad (1956) have found the eggs to remain in diapauses in the soil from May to mid December. The observations of Atwal (1963) with regard to diapause of eggs in Punjab have not been in any way different from that of above workers. Srivastava *et al.* (1973) have, however, observed the diapause sometimes extending upto January. Prasad and Singh (1976) while working at Sabour and

Sandhu *et al.* (1979) at Punjab have also recorded the diapauses form May to mid December. This period has, however, been noted to last only from June to November at Ludhiana (Lakra *et al.,* 1980).

2.2.2 Newly emerging nymphs

The newly emerging nymphs measure 1/8" in Bihar (Sen and Prasad, 1956) and Punjab (Atwal, 1963). The breadth of the newly emerging reddish coloured tiny insect (Srivastava *et al.,* 1973) is reported as ½" (Rehman and Latif, 1944).

2.2.2.1 First Instar nymph

The moulting takes place after 38-80 days and ecdysis completed within 2-5 days near the midrib on the underside of the leaf (Rehman and Latif, 1944). Its colour at this stage is brown, matching the soil surroundings it (Sen and Prasad, 1956). Chandra *et al.* (1987) have ratified the observations on moulting and colour of first instar nymph made by earlier workers.

2.2.2.2 First instar nymph

The first instar is recorded to measure 1.31-2.30mm in length and 0.70-1.90mm in breadth (Rehman and Latif, 1944).

2.2.2.3 Second instar female nymph

The second instar female nymphs measure 2.9-4.7mm in length and 1.7-2.6mm in breadth (Rehman and Latif, 1944).

2.2.2.4 Second instar male nymph

These measure 6 mm in length and 4 mm at their pupal stage (Srivastava *et al.,* 1973).

2.2.2.5 Second and third instar nymph

The colour of the nymphs, immediately after entering into second instar is reddish brown which turns light black within some days. The body length is more than the breadth at this stage and the mealy powder starts appearing on its surface. The second instar nymphs move upto a maximum distance of 10 cms. In a zig-zag direction at a speed of 0.27m (Rehman and Latif, 1944) or 9-10 cms (Chandra *et al.*, 1987). The second instar nymphs predominate the population of this bug around the middle of March. The development of this instar is completed in about 39 days and it takes 4-5 days for moulting and entering into third instar (Chandra *et al,*. 1987).

2.2.2.6 Third instar nymph

Rehman and Latif (1944) have expressed the third nymphal female instar to measure 4.55-7.7mm in length and 2.5 – 3.7mm in breadth.

2.2.3 Pre-pupa and Pupa

The reddish brown pre-pupa spin silken mass (cocoon) around its body to form a Pupa and remains in that stage for 9-10 days (Rehman and Latif, 1944) or the period may get extended to 50-57 days (Srivastava *et al,*. 1973).

2.2.4 The adult male

The adult male is reddish in colour with small black wings, legs and long feathery light brown antennae (Chandra *et al.,* 1987). These workers have also reported that the males do not feed and live for 4-6 days and the females on the other hand live for 18-51 days. Rehman and Latif (1944) have recorded the longevity of male and females as 5-10 and 16-26 days respectively. The sex ratio between male and female reported as 1: 1: 8 by Atwal *et al.* (1969) is much different from the ratio of 1:19 documented by Chandra *et al.* (1987).

Ashfaq *et al.* (2005) observed that during May, smoky winged and dark red bodied male bugs emerge and fly out to copulate the adult females adhering tender shoots and crawling down on tree stem. On reaching the ground, these large, white, soft-bodied egg carrying females enter the loose soil for egg laying. The eggs are deposited 2-6 inches or even more deep, in clusters of 300-400, enclosed in silky sacs within about 7- 15 days after which the females die. Egg hatching is chiefly influenced by the temperature and humidity of the soil. The females pass through three nymphal instars, while the males have an addition pupae stage before reaching maturity.

2.2.4.1 Adult male and female

The adult males measure (length × breadth) 4.6mm × 1.6mm and females 14.0 × 16.5mm (Rehman and Latif, 1944). Lal (1952) has, however, reported the length of female adults as 1/2" and its breadth1/4". The largest sized females measuring 3/4" in length have also been observed in Punjab (Atwal, 1963).

2.3 Natural enemy fauna of mango mealy bug

Swlrski *et al.* (1980) recorded the heavy infestation and damage caused by the long-tailed mealybug *Pseudococcus longispinus* Targioni Tozzetti in Avocado plantations neighbouring cotton fields in Israel. Drift of pesticides from the aerial sprays of those cotton fields upset the biological equilibrium and resulted in outbreaks of the mealybug population. Avocado plantations in the vicinity of deciduous fruit trees, vines and citrus orchards treated with non-selective pesticides were also damaged, but to a lesser degree. The annual peak of the long-tailed mealybug population occurs in late spring and early summer, declines from autumn to winter, and is at ebb usually in April. The parasitic wasp *Hungariella peregrina* Compere, the most important natural enemy in Israel of the long-tailed mealybug, was released in the striken areas. *Anagyrus fusciventris* Girault was introduced from Australia and well established in citrus and avocado plantations. Lady beetle, *Cryptolaemus montrouzieri* Muls. did not become established in avocado plantations. Lacewings were less important than parasites as biocontrol agents. Control of ants did not affect markedly the fluctuations in the mealybug populations. As a result of limitations of aerial sprays of cotton near avocado, as well as of release of natural enemies in afflicted plantations, the long-tailed mealybug population and its damage were reduced greatly.

Andrews *et al.* (1992) pointedout, taking farmers out of the technology transfer equation in these programmes may be a positive advantage in the eyes of scientists, since it avoids many risks and complications while farmers receive the benefit. Certainly the introduction of the parasitoid *Epidinocarsis lopezi* (De Santis) (Hym., Encyrtidae), distributed by aeroplane drops across thousands of square kilometres in Africa, for control of the cassava mealybug *Phenacoccus manihoti* Matile-Ferrero (Hom.: Pseudococcidae) was a universally acclaimed success carried out by international and national research bodies with minimal participation of cassava growers. On the other hand, both the cassava case and the contemporary introduction of two parasitoids for control of the mango mealybug, *Rastrococcus invadens* Williams (Hom.: Pseudococcidae) in Central and West Africa provide clear examples of the need for close collaboration between research organizations, governments, extension services and donors for such a project to be successful (Neuenschwander, 1993). Moore and Cross (1992) also reported that the parasitoid *Gyranusoidea tebygi* Noyes, introduced into West Africa, is providing excellent control of this pest.

Neuenschwander (1996) evaluating the efficacy of biological control of three exotic homopteran pest in tropical Africa. Mango mealy bug (*Rastrococcus invadens* Williams), is effectively kept under check by hymenopterous parasitoid.

Several predators of mango mealy bug have been identified (Syed *et al.*, 1970; More and Cross, 1993; Boavida *et al.*, 1995; Bokonon and Neuenschwander, 1995). In the Caribbean, for example, the classical biocontrol programme against the hibiscus mealybug, *Maconellicoccus hirsutus* (Green) (Hom.: Pseudococcidae), which arrived in Grenada in 1993-94 and rapidly spread to neighbouring islands, has included a public education campaign in the media about the pest and its introduced natural enemies, the encyrtid wasp *Anagyrus kamali* Moursi (Hym.: Encyrtidae) and the coccinellid mealybug predator *Cryptolaemus montrouzieri* Mulsant (Col., Coccinellidae) (IIBC, 1997). The mealybug attacks a very wide range of commercial and garden fruit, timber trees, vegetables and ornamentals, hence the programme aims to raise awareness among farmers and the public about the dangers of reliance on chemical control, emphasizing the IPM options for pest control.

Gautam and Tesfaye (2002) found that the common green lacewing, *C. carnea*, is a potential predatory biological control agent that can be used in augmentation programmes for sustainable crop pest suppression, however, the predatory potential of the predator was found to vary depending on the prey species.

Culik *et al.* (2003) reported the losses in cotton; the fibre crops such as *Hibiscus sabdariffa*, *Hibiscus cannabinus* and *Boehmeria nivea*; grapevine; mulberry; pigeonpea; *Zizyphus mauritiana*. Further, they observed that many ornamental woody plants are also affected, but populations and damage may be limited by natural enemies.

Bhagat (2004) revealed the infestation of mango mealy bug, *Drosicha mangiferae* on the foliage. The grubs of *Suminus renardi* [*Sumnius vestita*] and 2 unidentified spider species were found preying upon the mealy bug nymphs infesting the host plant. Adults of *Cryptochaetum* [*Cryptochetum*] sp. were also recovered from the parasitized nymphs of *D. mangiferae*.

Hala *et al.* (2004) found that mango mealybug, *Rastrococcus invadens* causes 53% of mango yield losses as a result of bug infestations. On farm lands, 100% yield losses could be reached so that infested orchards were destroyed by farmers. Both physical and chemical control procedures practiced by farmers have been ineffective. It was observed that the mealybug is closely related to a complex of natural enemies as parasitoids *Gyranusoidea tebigy* [*Gyranusoidea tebygi*] and *Anagyrus mangicola*, is suggested for a biological control programme.

Mani *et al.* (2007) reported that coccinellid predator *Cryptolaemus montrouzieri* provided effective control of pink mealy bug (*Maconellicoccus hirsutus*) on ber (*Zizyphus mauritiana*).

Pandey and Kumar (2009) studied the population dynamics of mango mealy bug nymphs, *Drosicha mangiferae* Green on the tree trunk, terminal twigs or on inflorescence at weekly intervals and found that population of insect started decreasing from mid February till last May.

Recently, a nymphal parasitoid, *Aenasius bambawalei* Hayat, of *P. solenopsis* has been recorded (Hayat, 2009), which caused upto more than 80 per cent parasitization on cotton (Ram *et al.*, 2009) and 30 per cent on tomato (Mohindru *et al.*, 2009).

Dinesh and Venkatesha (2011) determined the daily prey consumption and preference for prey stages by different larval instars of apefly, *Spalgis epius* (Westwood) (Lepidoptera: Lycaenidae) reared on *Maconellicoccus hirsutus* (Green) (Hemiptera: Pseudococcidae) in the laboratory. During the 8-day larval development period with four larval instars of *S. epius*, the daily prey consumption increased from the first to the seventh day and decreased on the eighth day prior to the prepupal stage. Generally, there was a significant difference in the prey consumption on different days. The 1st to 4th instar larvae of *S. epius* consumed, respectively, a mean of 181.3, 679.1, 1770.4 and 4333.0 eggs or 19.1, 67.7, 153.0 and 639.0 nymphs or 2.72, 6.26, 13.8 and 32.1 adults of *M. hirsutus*. When an *S. epius* larva was fed on *M. hirsutus* eggs, nymphs and adults separately, it consumed a mean of 6952.6 eggs, 878.8 nymphs or 53.9 adults during its entire development. A single larva of *S. epius* consumed 2358.3 eggs, 151.2 nymphs and 34.3 adults of *M. hirsutus* during its entire development when the prey stages were offered all together. The study revealed that *S. epius* is a voracious predator of *M. hirsutus* and thus could be utilized as a potential biological control agent.

2.4 Management of mango mealy bug

The management of mealy bug is difficult owing to its polyphagous and hardy nature. Many workers after carrying out detailed investigations have recommended maneurvability of cultural practices for destruction of egg masses, application of banding materials around the tree trunks for arresting the ascending and descending nymphs, insecticidal sprays and biological methods for the containment of the pest. Various control methods, including banding tree trunks with various materials to prevent nymphs from climbing (Lakra *et al.*, 1980; Srivastava, 1981) and dusting chlorinated hydrocarbons on the soil (Srivastava, 1981) have been tried with little success. In Pakistan the mango mealybug was controlled by hoeing or ploughing the soil and conservation of the predator, *Sumnius renardi* Weise, by wrapping burlap around the trunks of the trees (Mohyuddin and Mahmood, 1993).

2.4.1 Raking and Scrapping of Soil

The digging of the soil around the trees has been found to help destruction of eggs at Pusa (Fletcher, 1917) and elsewhere in Delhi (Dutt, 1925).

Destruction of eggs of mango mealy bug by digging them out with spades from the soil is not an encouraging practice (Rahman and Latif, 1944), whereas this way of destroying the eggs is an effective practice as reported by (Singh, 1947; Mohyuddin and Mahmood, 1993). Similarly the use of burlap band, burning of gravid females and removal of soil contaminated with eggs of mango mealybug gave complete control of mango mealy bug without the use of pesticides (Sial, 1999). Burning of rubbish, scraping of soil at the bases of fruit trees and root opening are very useful practices for the destruction of eggs (Haq and Akmal, 1960). Also pruning of trees (Sandhu *et al.,* 1980) and cutting down of damaged trees and their destruction (Agricola *et al.,* 1989) were the most effective practices for the control of mango mealy bug. Further, it was suggested that a 30 cm deep trench dug in a radius about 50 cm around tree trunk filled with decoys vegetation ideal for egg laying of *Drosicha corpulenta* (Hemiptera: Margarodidae) and should be destroyed in autumn (Xu *et al.,* 1999).

The raking of soil and exposure of the eggs to sun, birds, ants and other predators has been found to yield encouraging results (Sen, 1955 and Pruthi and Batra, 1960), Butani (1964) advocated scrapping of soil to a depth of about 150mm and placement of the scrapped soi as litre, underneath the cattle to ensure complete destruction of the eggs lying within the scrapped soil. Singh (1978) has demonstrated effective control by the exposure of the *rak*ed soil to sun during May and June. Maximum control of insects has been achieved by Chandra *et al.* (1989) by raking the soil followed by irrigating the fields in the months of May, June, August and October. Atwal (1963) observed that the flooding in the month of October often destroys the eggs buried in the soil and remaining eggs are exposed to sun heat by ploughing in the November. Polyethylene bands of 400 μ gauge and 25 cm width fastened around the tree trunk are another effective way of managing mealy bug ascent to the trees. The sticky bands with grease material or slippery bands with alkathene or plastic sheets around the trunk at about one meter above ground level in 2nd week of December could also prevent the upward movement of nymphs.

The turning over of the soil in mango orchards in Jammu in the months of May-June with a furrow turning plough has been suggested to expose most of the egg masses for destruction by summer heat (SKUAST, 1993).

Lakra et al. (1980) reported that sand was also used as barrier for upward migrating nymphs of *D. mangiferae.* Srivastava *et al.* (1982) suggested a band width of 25-30 cms ideally suiting in preventing ascend of nymphs. Chandra *et al.* (1991) recorded mechanical control of mango mealy bug *Drosichia mangiferae (Green)* by tree trunk banding. There has been a consistent interest to evolve cultural and biological methods. Further several predators and parasitiod of mealy bug species has been identified.

2.4.2 Evaluation of banding materials

Different types of banding materials have been tried for its control but with varying success. Stebbing (1903) after evaluation of grease coaltar, grease, coaltar, coaltar glue and coaltar rosin bands concluded that none of these are effective in stopping the ascend of nymphs statifactorily. Lal (1919) obtained very effective results when he used well carded cotton band for stopping the ascend of the insect at Lahore. Sticky bands of rosin and castor oil have also proved effective in checking the upward movement of the insect at Pusa (Fletcher, 1927). Similarly, rosin + Toria oil ban 1:1 is, recorded b Chopra (1928) to be very promising. Effectiveness of rosins neem oil and Vaseline band has been confirmed by Richards *et al.* (1934). Rehman and Latif (1944) obtained satisfactory results after using "Namhar' band at Layallpur. The ordinary sannhemp fibre or hessian cloth dipped in equal quantities of crude oil emulsion and coaltar has also been proved a successful method of control (ICAR Bulletin, 1951). Lal (1952) tried grease band and castor oil + rosin at Delhi and Mazid (1954) observe the ostico band yielding encouraging results. Amongst various types of bands tried at Punjab and Bihar ostico band has been rated as the best for checking the ascend of the nymphs (Sen, 1955). Sen and Prasad (1956) and Atwal (1963) confirmed the superiority of ostico band for effective arrest of the ascend of nymphs. Bindra *et al.* (1970) at Punjab has ratified the view of above mentioned workers. Bindra (1967) while working at Hissar observed the coaltar + grease band effective for two weeks. The results on the evaluation of different types of stickly coaltar 1:2 as the most effective treatment.

Srivastava (1980) observed the maximum number of nymphs congregated at the level (L) in case of alkathene band while comparing the previously used alkathene band with presently used ostico and Esso fruit grease band. Randhawa (1974) has suggested that Esso fruit tree grease of slippery alkathene sheet does help in checking the upward movement of crawlers. Superiority of alkathene has also been determined at Delhi (Srivastava, 1976) and Punjab (Lakra *et al.* 1980). Polythene band dusted with Methyl parathion has proved equally effective in Punjab (Sadhu *et al.* 1979). Srivastava *et al.* (1972) suggested a band width of 25-30 cms ideally suiting in preventing ascend of nymphs. Bindra and Sohi (1933) recommended tree banding with 30cm wide polythene sheet over a mud plaster.

Polyethelene bands of 400 mil gauge and 25 cm width fastened around the tree trunk are another effective way of managing mealy bug ascent to the trees. The sticky bands with grease material or slippery bands with alkathene or plastic sheets around the trunk at about one meter above ground level in 2nd week of Dec. could also prevent the upward movement of nymphs (Atwal, 1963). Similarly Tandon and Verghese (1995) suggested that exposure of eggs to sun, removal of alternative host plants and conservation of natural enemies by using garlic oil or neem seed extract around the trunk of trees and application of alkathane bands could also eliminate mango mealybug population.

Bajwa and Gul (2000) reported that *Drosicha stebbingii* could be managed through destruction of eggs, banding of trees and spray of insecticides v.z., Bulldock 25EC, Endon 35EC and Mepra 50EC on trees of *Paulownia tomentosa* and *Paulownia fortunei.* Whereas, Jia *et al.*, (2001) achieved good control of *Drosicha corpulenta, a* walnut pest through dusting parathion in micro capsules form or phoxim on the ground before the soil freezes in winter, painting mixture of 1 kg omethoate + 5 kg mineral oil and spraying 300 times, solution of Bt (*Bacillus thuringiensis*) or a 2000- times solution of 20% fenpropathrin from mid Feb. to mid Mar. for the control of nymphs.

There has been consistent interest to evolve cultural and biological control methods. Yousuf (1993) reported use of polyethylene bands for effective control of mealy bug. Ishaq *et al.* (2004) tested several treatments developed as an IPM strategy against mango mealy bug and fruit fly. The sticky bands along with burning and burying treatments significantly reduced the incidence of infestation by mango mealy bug (0.00-15.79%). Burlap bands reduced population of mango mealy bug nymphs by 78.98%. Methyl eugenol traps were extremely effective to trap and kill fruit fly. Stem injection could achieve a very high level of mortality of sucking insects (98%). The mortality rates achieved with insecticide sprays were up to 55%. The nonchemical methods have been found superior in mealy bug and fruit fly control.

Ashfaq *et al.* (2005) reported that since mango mealy bug are hard to control by pesticides therefore two non-chemical techniques have been tried and compared for efficacy. The new technique "funnel type slippery trap (FTST)" and the old technique slippery band (SB) were tested and evaluated for four year. On the basic pest control efficacy, FTST was declared to be the complete two way control of the menace. The funnel of the new trap was observed to arrest the upward crossing of the nymphs and successfully entrap the egg carrying females while coming down the tree for egg laying. Being environment friendly this technique is highly safe and provide effective control of this prolific pest. The trap is cheap to prepare and easy to install on tree stem.

Karar *et al.* (2007) tested nine tree bands to check the upward movement of mango mealybug (*D. mangiferae)* and found a new band named *Haider's band* (plastic sheeting having a layer of 3.8 cm of grease in middle) proved most effective for the preventing insects reaching the tree canopies.

Karar *et al.* (2010) Studied that different bands significantly stopped the upward movement of overwintering and surviving populations of *D. mangiferae*. To augment the bands' results, mounding the tree with debris on a plastic sheet once a year was the most effective technique to control the upward movement of newly hatched nymphs on trees crossed plastic sheets, polyethylene sheets and funnel bands are used and suggested that employing cultural practices and bands together could reduce the need for insecticide treatments and offer a sustainable method for *D. mangiferae* control.

2.4.3 Evaluation of various insecticides and combination strategy

Chemical control methods for mealy bug and fruit fly have been inefficient (Tandon and Lal, 1980; Yousuf and Ashraf, 1987). Despite the annual investment of US $35,000 for the application of there million metric tonnes of pesticides, plus the use of various biological and other non-chemical controls worldwide, global crop losses remain a matter of concern (Pimentel, 2007, 2009).

Srivastava (2008) tested the field efficacy of 3, 2 and 1% ether and alcoholic extracts of neem products for three years against nymphs of mealy bug *D. mangiferae* Green during 1997-98 to 1999-2000 on c.v Mallika and revealed that all the concentrations were found significantly superior over the control in the effective pest management.

The spray of fish soil rosin soap emulsion (240z in 4 gallons of water) was suggested earlier at Delhi (Dutt, 1925) and Punjab (Rehman, 1940) for control of this insect. Morrill *et al.* (1947) for control of this insect. Morrill *et al.* (1947) obtained 83 per cent kill of the insect with a single spray of DDT emulsion comprising 20 per cent DDT, 65 per cent xylene and 10 per cent triton × - 100 whereas the second spray on the plants showing infestation offered cent per cent of the mealy bugs in phillippines. Kenneth (1952) while working at Yakima valley on grape mealy bugs drenched the infested plants once with parathion spray solution and obtained excellent control. Sen (1955) while determining the effectivity of BHC 50 percent, DDT 10 percent Toxaphene 10 percent, Chlordane 2.5 percent, methyl parathion dust 0.5 per cent potassium permagnate, kerosene oil emulsion and calomel as soil applicants observed that none of these pesticides could offer my satisfactory control of the nymphs of mealy bug. Sen and Prasad (1956) observed that percentage of mortality of the first instar nymphs was 100 percetn with folidol E- 605 (0.03 percent) treatment, 56.6 percent with pyrocolloid and 61 percent with BHC (Hortex) treatment within six days. The percentage of mortality of second instar nymphs was 93 per cent of Folidol E-605 (0.04 per cent), 26.3 per cent in case of pyrocolloid (0.25 per cent) and 29.7 per cent in case of BHC (0.1 per cent) within the above stated period and none of these chemicals was found to be much effective against the third instar nymphs.

Pradhan *et al.* (1956) carried out bioassay tests in the laboratory and found melathion to be more toxic than P'-P DDT and within the commercial preparations. Parathion. Demeton and Diazinon proved more toxic than DDT. Trehan, Gangoli *et al.* (1957) advocated BHC dust for its effective control. Singh (1957) recorded 98.98 percent check in the population ascent of first instar nymphs when Diazinon 0.33 percent was applied on trunk and application of the same chemical at same concentration on foliage yielded 96.2 to 100 percent mortality of second instar nymphs. Singh (1960) recommended a spray of the infested trees with a mixture of nicotine sulphate 0.1 percent sesame oil 1.25 percent soft soap 0.25 percent washing soda 0.3 percent in water and ethylalcohal 0.3 percent for effective control of the pest. He has further argued that Diazinon 0.06 percent has also shown promise.

Atwal (1963) observed that first and second instar nymphs could be effectively killed in Punjab by spraying the tree with Endrin or Parathion 0.04 percent or dusting with 10 percent BHC or DDT and the third instar nymphs with Diazinon 0.04 percent sprays. Birat (1963) after carrying out comparative efficacy studies of organophosphorous insecticides has found Diazinon 0.06 percent superior to melathion and parathion. Bhatia and Gauba (1964) have also reported Diazinon to be effective against the pest.

Atwal *et al.* (1969) found 0.1 percent Fomothion or methylparathion most promising and these were followed by parathion 0.05 percent, 0.10 percent Formothion or Zectran in their effectively for the control of first and second nymphal instars. They also obtained equally successful control of third instar nymphs with parathion (0.05 percent, 0.10 percent) formothion (0.10 percent) Methyl parathion (0.10 percent), trichlorophan, (0.1 per cent) and Zectran (0.1 percent).

Reddy (1968) experimented spraying the trees with Diazinon 0.04 percent or Malathion 0.08 percent and concluded that all the three yield encouraging results for controlling the nymphs and adults. Sexena *et al.* (1968) obtained effective control at Jabalpur when they sprayed the infested trees with parathion 0.06 percent emulsion or melathion 0.07 percent to 0.08 percent emulsion. Pradhan (1969) recommended strong organophosphrous insecticidal sprays against young nymphs. Vevai (1969) found dimethoate 30 percent 12-20ml with 50 gms sulphur (80 W.P.) in 15-20 litres of water and spray mango fruits and flowers only. Cent percent mortality of mealy bugs collected below the bands and sprayed with malathion emulsion (30ml of 50 EC in 10 Litre of water was observed by (Bindra *et al.,* 1974). The nymphs and adults are also reported to be satisfactorily controlled by spraying 0.03 percent Monocrotophos or Dimecron, Endosulfan 0.05 percent and Dimethoate (0.03%) (Srivastava *et al.,* 1973).

Tandon (1969) obtained maximum reduction of mealy bug population with monocrotophos (0.05 percent) carabaryl (0.1 percent) and synthetic garlic oil (0.75 percent) which behaved at par whereas the second best was methyl parathion and quinalphos, each applied at 0.05 percent concentration.

Pushpa (1973) recorded the mealy bug (*Maconellicoccus hirsutus* Green) on mesta (*Hibiscus cannabinus*) were controlled effectively through the application of roger (dimethoate) or metasystox (methyl demeton). High volume application of insecticides was very important to ensure coverage and reach the mealy bugs in crevices and *crak*s on the bark, for example diazinon, quinalphos and parathion-methyl have been shown to suppress the pest quite effectively both at nymph and adult stages.

Batra *et al.* (1979) revealed that Quinalphos was the most effective insecticide on terminals followed by monocrotophos but when the chemicals were sprayed on branches and stem only 25 and 35 percent morality upto 7 days was recorded respectively and amongst the dusts methyl parathion offered best results.

Lakra *et al.* (1980) obtained 97.04, 93.50 and 93.80 percent mortality of the clustering second instar nymphs on mango trees with Quinalphos (0.75 per cent) Diazinon (0.05 per cent) and methyl parathion (0.05 per cent), respectively. The chemicals like diazinon, quinalphos and parathion-methyl (methyl parathion) were highly effective against 1^{st} instar nymphs that were gathered below the bands.

Dalaya *et al.* (1983) observed that fenitrothion (0.1 percent) is the most effective the followed by phosolone (0.07 percent), Quinalphos (0.05 percent), Monocrotophos (0.04 percent), Methyl parathion (0.05 percent) and Bromophos ethyl (0.07 percent) and Phosphomidon (0.03 percent) and the chemicals viz. Phenthoate (0.05 percent) dimethoate (0.03 percent) and Melathion (0.1 percent) and Melathion (0.1 percent) proved less effective against mango mealy bug.

Dhingra (1990) evaluated ten insecticides as the alternative chemical for successful control of the mango mealy bug. He further observed that lamda cyhalothrin, alphamethrin, decamethrin, cypermethrin, methyl parathin, fenvalerate, monoctophos, endosulfan whose LC_{50} value was calculated as 0.0024, 0.0196, 0.0209, 0.0292, 0.0385, 0.0454, 0.2357 and 0.9303 respectively offered promise result. He further noted that lindane and malathion proved ineffective even at as high as 1 per cent concentration.

Joubert *et al.* (2000) studied several insect pests being important in the production of mangoes in South Africa. The mango scale, *Aulacaspis tubercularis*, mango seed weevil, *Sternochetus mangiferae*, and the fruit flies *Ceratitis capitata*, *Drosichia mangiferae* ,*Ceratitis rosa* and *Ceratitis cosyra* arekey pests and have to be controlled regularly and alternative control measures were evaluated. A monitoring system was developed for the important pests and the more judicious use of insecticides now facilitates IPM on mangoes in South Africa.

Karar *et al.* (2010) evaluated eleven formulation of insecticides for the control of mango mealy bug under field conditions and found that the maximum mortality of 1st instar mango mealybug was observed in those treatments, where Mospilan were applied with 80, 85 and 91% after 24, 72 and 168 h of spray. However, in case of 2nd and 3rd instar, Decis and Curacron gave maximum mortality

71 and 70, 24 h after spray. After 72 and 168 h Mospilan proved best with 78 and 81% mortality. Supracide the most effective insecticides for the control of adult female at all the post treatment intervals i.e., 60, 72 and 73% mortality under field conditions.

Mansour *et al.* (2010) evaluated the three insecticides, imidacloprid, Prev-Am® and spirotetramat with reference to methidathion to improve management strategies for the Vine Mealybug (VM), *Planococcus ficus* (Signoret). The systemic insecticide spirotetramat (Movento® 150 OD) provided the greatest control performance of the VM populations, compared to the contact insecticide methidathion, the systemic insecticide imidacloprid applied through furrow irrigated system, and to Prev-Am®, a new contact biopesticide. Three weeks after treatment, VM eggs and adult females were missing from spirotetramat-treated vines. Additionally, spirotetramat supplied a long-residual activity against VM populations and prevented further spread of these insects on vine leaves. Therefore, this new systemic insecticide could be incorporated in an Integrated Pest Management program for VM control in Tunisian vineyards. Despite its short-residual activity, Prev-Am® was shown to be more effective than both methidathion and imidacloprid, mainly on VM eggs and L3 nymphs, and resulted in the highest level of VM L1-L2 nymph decrease on vine trunks. Hence, this biopesticide might prove useful for VM management in vineyards.

Srivastava (1976) recommended the spraying of diazinon, monocrotophos and Chloropyriphos for achieving good control. Prasad *et al.* (1976) opined that the protions of the infested tree trunksk above the applied tree bands, and the foliage if sprayed with chemicals viz. Melathion 0.04 percetn (3-4 sprays) or Dimethoate 0.03 percent or Phosphomidon 0.04 percent or Diazinon 0.04 percent or Thilometon 0.04 percent or Diazinon 0.04 percent or Thiometon 0.04 percent (3 sprays) during January on tree trunks can offer a very satisfactory control of mealy bugs. Stem injection is also suggested as a means of effective control of the insect at its earlier stages. The monocrotophos injected in the trunk has proved more effective than fenitrothion (Sandhu *et al.*, 1979). Monocrotophos (0.05 percent), carbaryl (0.1 percent) and synthetic garlic oil (0.75 percent) have been rated at par but effective for the control of insects at their nymphal stages (Tandon et al, 1979). Tandon (1969) obtained maximum reduction of mealy bug population with monocrotophos (0.05 percent) carabaryl (0.1 percent) and synthetic garlic oil (0.75 percent) which behaved at par whereas the second best was methyl parathion and quinalphos, each applied at 0.05 percent concentration.

Batra *et al.* (1979) revealed that Quinalphos was the most effective insecticide on terminals followed by monocrotophos but when the chemicals were sprayed on branches and stem only 25 and 35 percent morality up to 7 days was recorded respectively and amongst the dusts methyl parathion offered best results. Lakra *et al.* (1980) obtained 97.04, 93.50 and 93.80 percent mortality of the clustering second instar nymphs on mango trees with Quinalphos (0.75 percent) Diazinon (0.05 percent) and methyl parathion (0.05 percent) respectively

Siddique *et al.* (1982) noted that diazinon (0.04 percent) methyl demeton (0.1 percent), phosphomidon (0.04 percent) and ethyl parathion (0.04 percent) offered 99 percent insect kill in the laboratory studies whereas the chemicals viz. diazinon (0.06 percent) methyldemeton (0.15 and 0.1 percent) phsophamidon (0.06 percent) and ethyl parathion (0.06 percent) under field studies offered insect mortality of 98 percent. Dalaya *et al.* (1983) after undertaking a field trial in Maharashtra observed that fenitrothion (0.1 percent) is the most effective the followed by phosolone (0.07 percent), Quinalphos (0.05 percent), Monocrotophos (0.04 percent), Methyl parathion (0.05 percent) and Bromophos ethyl (0.07 percent) and Phosphomidon (0.03 percent) and the chemicals viz. Phenthoate (0.05 percent) dimethoate (0.03 percent) and Melathion (0.1 percent) and Melathion (0.1 percent) proved less effective.

Nayer *et al.* (1986) advocated application of aldrin (5 percent dust around the base of the tress and spraying of aerial parts with Parathion (0.05 percent) or Melathion (0.05 percent) for the effective control of early instar nymphs. Methyl demeton (0.05 percent) Dimethoate (0.05 percent) and Dichloros (0.1 percent) have been proved equally effective when used as foliar sprays (Kirpal Singh *et al.* 1988). Tandon (1988) observed the spray of Monocrotophos (0.05 percent) or Chloropyrphos yielding good results when bugs settle on inflorescene panicles. Khurana and Verma (1988) at Sirsa evaluated the efficiency of Phosalne, Dicrotophos each at (0.05 percent) Carbaryl, Tetrachlorvenphos, Trichlorphan each at (0.1 percent) and found these effective against second instar nymphs under field conditions. Ahad *et al.* (1988) opined that Phorate was ineffective in suppressing the infestation on the aerial plant parts but soil applications were very effective and Quinalphos, Monocrotophos, Dimethoate when used as soil drenches or aerial sprays significantly reduced the pest population above and below ground. Gaffar (1989) while carrying out field trials at

Srinagar against *Drosicha dalbergeae stebbengi.* On almond observed quinalphos (0.1 percent) as most effective as soil drench.

Treatment of the bosins in January and February with BHC 10 percent dust @ 25-30 Kg/hac or 30-40 kg per hectare or 5 percent Aldrin or Chlorodan dust has also been suggested as an effective measure of control for bugs. The nymphs already settled on the growing points can be checked by spray of BHC (50 WP) 1000 grams or Endosulfan (35 EC) 100ml or Dichlorovos (100 EC) 500ml or Carbaryl (50 WP) 1000 gms in 500 litres of water at the end of February followed by second spray at the end of March. Use of Dimethoate (30EC) 750ml or Methyl demeton (25EC) 800ml or monocrotophos (36EC) 60ml in 500 litre water is recorded to give equally effective control of the bug (SKUAST, 1993).

Ishaq *et al.,* (2004) worked on the management of mango mealybug *(D. stebbingi)* and concluded that the mortality only with insecticide sprays were up to 55 per cent, whereas sticky bands along with burying and burning treatments significantly reduced the extent of infestation by mango mealybug (0.00-15.79 percent) and burlap bands reduced population of mango mealybug nymphs by 78.98 percent. So it was concluded that for the control of mealybug integration of insecticides with bands along with burning and burying treatments gave good control.

Insecticides are generally recommended only as a last resort in the integrated package of control measures. Chemical control methods for mealy bug have been insufficient. (Tandon and Lal, 1980). The eggs of this pest hibernate in the soil. The cryptic habit of some mealy bug species (*P. viburni*) makes it difficult to control (Geiger *et al.*, 2001). Mango mealy bug tend to aggregate on the fruit and cover themselves with a thick layer of mealy wax. Since spray coverage on large fruit is difficult and the guavamealy bug 's waxy secretions interfere with spray penetration, control with contact insecticides is difficult. Sajo *et al* (2006) evaluated the effect of two formulations of imidacloprid, Confidor Forte 200 SL and Winner, to control *Pseudococcus longispinus* and their impact on *Neoseiulus californicus* in avocado trees and concluded that imidacloprid applied to the foliage as Confidor Forte 200 SL was efficient in controlling *P. longispinus*. Applications to the trunk were not efficient against long-tailed mealy bug, apparently due to the reduced absorption and translocation in the trees at both locations. Nevertheless, populations of *N. californicus* were not affected.

Karar (2010) tested a combination of mounds on the plastic sheet, Haider's band and application of acetamiprid and found that the combination of these treatments to be the most effective resulted in 98% reduction of first instars of mango mealybug. It is further stated that the Haider's band was the most effective and cheaper which was a new addition in the mechanical control management of mango mealybug on mango trees. The males of mango mealy bug were attracted to mercury light and no males were attracted to yellow, green, red, blue lights. Male preferred to pupate in wet places near the 'kacha' (mud) water which can be exposed to sunlight by hoeing. This research project demonstrates the complete management programme for the control of mango mealy bug under field condition for mango growers.

MATERIALS AND METHODS

MATERIALS AND METHODS

The materials employed and methodology adopted during the entire course of investigation to study various objectives viz., seasonal incidences, life cycle of mango mealy bug, its natural enemy fauna and to develop management against mango mealy bug, *Drosicha mangiferae* Green are given in this chapter. The details of methods used in recording the observations are as given below-

Details of the experiments

3.1.1 Location and site of the experimental orchards for studying the seasonal incidence of mango mealy bug

The studies on the seasonal incidence of mango mealy bug in relation to abiotic factors and record of natural enemies' fauna (especially parasitoids and predators) in mango ecosystem were carried out at three locations i.e., Farmers' orchard at Miran Sahib, Udheywalla mango orchard (SKUAST-Jammu), Akhnoor farmers' mango orchard during 2009 to 2011. Jammu is situated an altitude of 300 m above sea level. Miran Sahib is situated 10 km away from the main Campus of the University. Udheywalla is situated 18 km away from the Main Campus Chatha and forms the constituent of SKUAST-J whereas, Akhnoor is situated around 40 km away from Main Campus, respectively. Akhnoor is located in kandi (rainfed) area and surrounded by the land where other fruiting trees such as guava, citrus and aonla for rainfed areas are grown (Plate 1). The orchard includes a variety of mango plants such as dashehari, Bombay green, summer bahist chaunsa, amrapalli, mallika and desi mango of more than 300 plants.

3.1.2 Topography soil and climatic conditions of the experimental location

Jammu and Kashmir State having diverse topography occupies almost central place in Asian continent. The elastic diversity, namely arid, semi-arid, temperate, intermediate and sub-tropical, has been bestowed to the state due to its geographical

Plate 1
Overview of experimental orchard

(A) Overview of mango orchard at Akhnoor

(B) Overview of mango orchard at Miran Sahib

(C) Overview of mango orchard at Udheywalla

(D) Heavy infestation of mealy bug during fruiting

(E) Exudation of honey dew by mealy bugs

(F) Association of mealy bug with ant

position. The diversity of alginates, consequently offers favourable chances for the growth and cultivation of a variety of agricultural crops including fruits. It is located within the Northern hemisphere between 32 ^{0} 17' and 58 ^{0} Northern Latitude, 76 ^{0} 26' and 80 ^{0} 30' East longitude and 81 ^{0} East of Greenwich. Out of 45 different kinds of fruits grown in the state, mango (*Mangifera indica* Linnaeus) ranks at the top in Jammu Division. Mango thrives well up to 1400 m above mean sea level provided locality is frost free and there is no high humidity or rains during flowering. The favourable temperature is 24^{0} C to 27^{0} C, however, it can tolerate temperature as high as 48^{0}C provided that trees are getting regular irrigation. Mango has been found to grow on a wide range of soils. However, deep and well-drained loam to sandy loam soils are most suitable for mango cultivation. Heavy black cotton, alkaline and water soils should be avoided. The ideal range of soil pH for mango cultivation is 5.5 to 7.5.

3.1.3 Layout of the Experiment

Crop	:	Mango (Mangifera indica L.)
Variety	:	Amrapali
Design	:	Randomised Block Design (RBD)
Treatments	:	9
Replications	:	3

Each treatment shall consist of 3 plants

3.1.4 Cultural Operations

Cultural operations were done according to the package of practices for fruit crops of SKUAST-J (2007).

3.2 Seasonal incidence of mango mealy bug on mango

Five plants of mango about ten to twelve years old and of equal vigour and size were selected at random in orchards at three different locations for recording seasonal incidence of mango mealy bug. The observations were recorded at weekly intervals starting from 1st SW up to 20th SW during 2010 and 2011 at three different experimental sites. The data on seasonal incidence of different insect pests was compiled and correlated with weather factors viz., minimum and maximum temperature, morning and evening relative humidity and rainfall. During the course of observations, seasonal incidence of mango mealy bug was recorded as per the method given by Mani *et al.* (2007). The meteorological data for the period of experimentation (2010 and 2011) was obtained from the Agro-meteorological observatory, Sher-e-Kashmir University of Agricultural Sciences and Technology, Chatha, Jammu for calculating the correlation matrix and linear regression at three experimental locations i.e., Miran Sahib, Udheywalla and Akhnoor (Appendix I).

3.2.1 Host range of different types of mealybug on cultivated and wild crops

Field observations conducted during 2009 and 2011 revealed that the different types of mealybugs was invariably found on cultivated as well as wild host plant growing in the vicinity of the main mango orchards and acting as a pest reservoir (Table2). These plants offer shelter to the mealybugs and maintain its population round the year. Observation on infestation by the mealybugs were recorded on twenty randomly selected infested plants.

3.3 The life cycle of mango mealy bug, *Drosicha mangiferae*

The life cycle of mango mealy bug *Drosicha mangiferae* were conducted under laboratory conditions. For this purpose plants were maintained in pots in the laboratory. The observations on the various developmental stages of mealy bug were recorded in the pots and number of days taken for each development stage was recorded separately.

3.3.1 Mass culture of mango mealy bug

The soil sample containing egg masses of mango mealy bug were dug out with the help of garden shovel and khurpa from the depth of 10-15 cms around a mango tree from udehywalla orchard. Precautions were taken not to disturb the egg lying inside the soil samples. These samples were collected on first week of December during 2009. The collected egg masses were placed in the pots covered with muslin cloth with the help of rubber band. A small quantity of water was sprinkled as and when required over the soil samples, in each pot in order to ensure optimum moisture condition. The samples were kept under observation for determation of date of hatching of eggs emergence of nymphs. The emerging nymphs were transferred in the first week of January 2010 with the help of brush on other pots containing mango plants.

3.3.2 Nymphl stage

Freshly emerging nymphs were lifted in the first week of January 2010 on mango plants in pots. Ten such nymphs were individually placed in separate pots each representing a replicate. For proper sanitation and health of the nymphs was cleaned every day the nymphs were reared in the pots up to their first moulting where after they were transferred to another pot covered with net placed with rubber band. The nymphs from second instar onwards were continued to be reared in the pots till adult emergence. The maintenance of sanitation and provision fresh food to the development stages of individual replicate was ensured in the same manner s in case of first instar nymphs. Right from the date of placement of newly hatched nymph to the date of emergence of adults each developing insect in each replicate was kept under constant observation. Every change observed during process of development of the nymph was recorded. The time taken from hatching to first moulting and subsequently to second and third moulting was recorded in each case. The period between hatching and moulting or between the two successive moults was considered as the developmental period of the particular instar. The time taken by the particular individual newly hatched nymph to reach or pupal stage, in case of female and male insect, respectively was considered as its nymphl period .

3.3.3 Pre -pupal stage

The developing male insects were found to remain somewhat sluggish and virtually stop feeding In the later part of their instar , the time taken from second moulting i.e., entering into thirds instar to the time of formation of pupa was considered as the pre- pupal period.

3.3.4 Pupal stage

In case of male insects the nymhs started formation of coccon in the later period of pre-pupal stage. The time taken from formation of pupa to the emergence of adult was considered as the period of pupal stage.

3.3.5 Adult stage

The period during which the adult male and female survive from the time of their emergence was recorded as their period of longevity

3.3.6 Sex ratio

The sex ratio was determined on the basis of the number of insects entering the pupal stage and emerging directly adults after third moulting. The former group represented the males while latter one the females. The ratio between males and females was accordingly calculated from the data collected.

3.3.7 Morpho measurements

The length and breadth measurements of freshly emerging nymphs and eggs were computed with the help of an Lieca microscope.

3.3.8 Freshly emerging nymphs

Ten freshly emerging nymphs were selected at random from mass culture, anaesthesized in 70 per cent alcohol and measured individually with help of Lieca microscope. Longitudinally from their body was measured from anterior to the posterior end while breadth measurements were recorded horizonatally from end to end at middle of the body. The procedure described by Varshney (1985) was adopted for anaesthesizzing the insect.

3.3.9 Developing nymphs

Ten nymphs from each developing instar were similarly selected at random, from mass culture, at the corresponding developmental stage. The measurements (length x breath) were recorded where utilised for computation and determination of the mean length and breadth of each instar.

3.3.10 Eggs

The randomly selected eggs were examined under a microscope and measured longitudinally with the help of an Lieca microscope. These measurement were suggestive of the egg length and its breadth was determined by recording end to end measurements at the middle . These measurements were records were further used for couputation and determination of the mean length and breadth of an egg. Ten specimens in each case (freshly emerging nymphs, developing nymphs and eggs) represented ten replicates.

3.4 Natural enemies' fauna against mango mealy bug on mango

Survey was also conducted at three different locations viz., Miran Sahib, Udheywalla and Akhnoor to record the natural enemy fauna prevalent in the mango orchard. For recording natural parasitization by the biological control agents in the field, the visually infected insects were collected and brought to the laboratory for further emergence of parasitoid and their identification.

3.4.1 Parasitoids

For recording the parasitization, mealy bug encountered on mango trees were collected manually from the field and brought to the laboratory for adult emergence. These were kept in glass jars (10×15×20 cm) providing them their preferred host food along with the streak of honey through cotton swabs and were examined for emergence of parasites. The infested twigs were also brought to the laboratory and counted number of infested mealybug nymphs and adult (20) was kept in glass jars for emergence of parasitoids.

3.4.2 Predators

Predators observed preying upon the mealy bug stages in the field condition were also collected and brought to the laboratory to confirm their predation behaviour and potential of predation. Predation by the dominant predators on mango mealy bug was determined in the laboratory using collected predators from mango orchards. Per cent relative abundance of a predator species was calculated as:

$$\frac{\text{Total number of adults of a predator species}}{\text{Total number of adults of all species of predators recorded}} \times 100$$

Predation by *R. amabilis*, which is a dominant predator, on mealy bug nymphs was determined in the laboratory using different stages of coccinellids collected from mango orchard of the experimental sites. The *R. amabilis* were put separately in mesh cages of size 25 x 25 x 25 cm at different densities of 1, 2, 4 and 6 and the mealy bug nymphs were released into these cages after 12 h of starvation of the adult and grub beetle. All the different treatments involving different densities of the predator population were replicated thrice. In each replication the mealy bug nymphs densities released were 20. Number of nymphs consumed was recorded daily for 7 days and the mealy bug nymph density in each replication of different treatments was maintained by daily replacement.

The killing efficiency of *R. amabilis* collected from various locations at different densities was calculated by using the formula given by Hessell (1971) -

$$K = \log_e \frac{Ni}{Nf}$$

Where, Ni = initial population of host density

Nf = final population of host density

3.5 Management of mango mealy bug

For conducting the study of management practices, the experiments were carried out at Udhewalla orchard SKUAST-Jammu. The following insecticides were selected for the present investigation (Table 1).

Table 1 List of insecticides/chemicals used during the experimentation

S. No.	Common name	Group	Concentration (%)	Name of the manufacture
1	Chlorpyrifos 20 EC	Organophoshates	1.5% dust	Dow Agro Science India Limited
2	Methyl parathion 50EC	Organophosphates	2.0% dust	Bayer India Limited
3	Metasystox 25 EC	Organophosphates	0.03%	Bayer India Limited
4	Imidacloprid 17.8 SL	Neonicotinoid	0.0025%	East Grace Corporation, China

General management practices adopted for controlling mango mealy bug

3.5.1 Pre-emergence treatments

Pre-emergence treatments comprising cultural control, soil raking, ploughing followed by irrigation, Mechanical barrier, sticky barrier and sand application and chemicals as soil treatment as a general management practices adopted for controlling mango mealy bug.

3.5.1.1 Cultural Control

(a) Soil raking

For the pre- emergence treatments soil digging shall be done in the month of June .Soil digging around the tree trunk upto 1 meter diameter having 8-10 cm depth to expose the eggs of mango mealy bug

(b) Ploughing followed by irrigation.

After raking the second treatment was ploughing followed by irrigation in this treatment the field was ploughed deeply and irrigated by water to wash away the eggs of the mealy bug in order to minimize the population

3.5.1.2 Chemical as soil treatment

For soil treatment, the soil around the tree trunk was treated with Chlopyriphos 1.5% dust in the mango orchard in the first week of December . Similarly in the second treatment soil around the selected plants was digged and treated with Methyl parathion 2.0% dust in the first week of December to minimize the population.

3.5.1.3 Mechinacal barrier

T wo type of mechanical barrier was used in the experiment

3.5.1.4 Sitcky barrier and sand application

Sitcky barriers of alkthane band 15-20 cm wide (400gauge) shall be tied around the tree trunk ½ meter above the ground before the eggs start hatching in the month of December.

3.5.1.5 Sand application

In the month of ending December a heap of sand was kept around the tree trunk to avoid crawling of the insect to reach the stem and twigs of the plant and during the crawling maximum insect found dead in the next day

3.5.2 Post emergence treatment

3.5.2.1 Chemical treatment

Pre count of mango mealy bug infesting trees shall be taken before the application of insecticide. Two chemical are selected for spray i.e Metasystox 0.003% and Imidacloprid 0.0025%. First spray of metasystox was done at early stage of panicale formation .Similarly the first spray of Imidacloprids done at panicale formation after that observations was recorded at 1,3,7,14,and 21 days after application of each insecticide. Second spray of insecticide was done 21 days of first spray. After that observation shall be recorded at 1, 3, 7, 14, and 21 day after spray. The population present on three twigs of 10 cm length per plant were counted. The mean population was calculated by dividing the total population of tree plant by number of plants observed.

Based on the effectiveness of treatments, the different IPM modules were developed and evaluated for their efficacy against mango mealy bug in mango orchard during both the years of experimentation. They are as follows-

Module	Cominations of different treatments
Module 1	Methyle parathion 2% dust;Metasystox 0.03% 2 spray + soil raking and ploughing followed by irrigation
Module 2	Sand application + methyl parathion 2% dust+2 spray of Imidacloprid 0.0025%
Module 3	Sand application, soil raking + sticky band
Module 4	Soil raking + ploughing followed by irrigation+sticky band+(Methyle parathion dust 2%) + Imidacloprid 1 spray; Metaystox 1 spray
Module 5	Existing package and practiceses(soil raking + soil application of Lindane 1.5 % dust+ sticky band)

Statistical analysis

The data have been subjected to analysis of variance as per the standard statistical techniques followed for randomized block design. Critical difference for treatments was computed at 5 per cent level of significance. Statistical analysis was done by using SPSS-14 Software and SAS 9.4 software.

RESULTS

Chapter 4

RESULTS

In the present investigation an effort was made to understand the pest incidence in relation to abiotic factors on mango commonly grown in this region. The seasonal activity of parasitoid and predatory fauna of mealy bug, their relative abundance and predation performance of potential predator, impact of management strategies and finally efficacy of various IPM modules were also evaluated against mango mealy bug, *Drosicha mangiferae* Green on mango. The results obtained are presented under following sub-heads:

4.1 Host ranges and species diversity of different types of mealy bug in Jammu

Field survey and observations conducted during 2009 and 2011 showed that the mealy bugs insect pest in general and mango mealy bug in particular (*Drosichia mangiferae*) were invariably found on cultivated fruit and vegetable crops as well as on wild host crops growing in and around the fruit and vegetable crop ecosystem. Secondary sources or the wild host plants serving as insect pest reservoir for the multiplication and dispersal of mealy bugs on main cultivated crops (Table 2). These wide ranges of host plants offer shelter to the different types of mealy bugs and maintain their population for some more time than the usual around the year. The host range of mealy bug pest were recorded on cultivated host plants such as tomato (*Lycopersicon esculentum*); okra (*Abelmoschus esculentus*); bottle gourd (*Lagenaria siceraria*); cucumber (*Cucumis sativus*); brinjal (*Solanum melongena*); chillies (*Capsicum annum*); bitter gourd (*Momordica charantia*); ridge gourd (*Luffa cylindrica*); water melon (*Cucumis melo);* Ashwagandha (*Rawlfia serpentia);* Datura (*Datura stromonium*); Husk tomato (*Physalis maxima*); parthenium (*Parthenium hysterophorus*); china rose (*Hibiscus rosachinensis*); nerium (*Nerium indica*); black gram (*Vigina mungo*); mango (*Mangifera indica*); guava (*Psidium guaja*); lemon

Table 2. Different species of mealy bugs recorded on various host crops during 2010 and 2011

S.No.	**Host plants**	**Botanical Name**	**Family**
1.	Tomato	*Lycopersicon esculentum*	**Solanaceae**
2.	Okra	*Abelmoschus esculentus*	Malvaceae
3.	Bottle gourd	*Lagenaria siceraria*	**Cucurbitaceae**
4.	Cucumber	*Cucumis sativus*	**Cucurbitaceae**
5.	Brinjal	*Solanum melongena*	**Solanaceae**
6.	Chillies	*Capsicum annum*	**Solanaceae**
7.	Bitter gourd	*Momordica charantia*	**Cucurbitaceae**
8.	Ridge gourd	*Luffa cylindrica*	**Cucurbitaceae**
9.	Water melon	*Cucumis melo*	**Cucurbitaceae**
10.	Ashwagandha	*Rawllfia serpentia*	**Solanaceae**
11.	Dhatura	*Datura stromonium*	**Solanaceae**
12.	Husk tomato	*Physalis maxima*	**Solanaceae**
13.	Parthenium	*Parthenium hysterophorus*	Asteraceae
14.	China rose	*Hibiscus rosa-sinensis*	Malvaceae
15.	Bell flower	*Tecoma grandiflora* L.	Bignoniaceae
16.	Nerium	*Nerium indica*	Apocynaceae
17.	mulberry	*Morus alba*	**Moraceae**
18.	Lantana	*Lantana camera*	Verbenaceae
19.	Pipal	*Ficus religiosa* L.	**Moraceae**
20.	Tur	*Cajanus cajan* (L.) Millsp.	Fabaceae
21.	Black gram	*Vigina mungo*	Legumeaeouceae
22.	Mango	*Mangifera indica*	Anacardiaceae
23.	Guava	*Psidium guajava*	Myrtaceae
24.	Aonla	*Emblica officinalis*	Euphorbiaceae
25.	Lemon	*Citrus limon*	Rutaceae
26.	Grape	*Vitis vinifera*	Vitaceae
27.	Papaya	*Carica papaya*	Caricaceae
28.	Pomegranate	*Punica granatum*	Punicaceae
29.	Loquat	*Eribotrya japonica*	Rosaceae
30.	Custard Apple	*Annona squamosa* L.	Annonaceae
31.	Imli	*Tamarindus indica* L.	Caesalpinaceae
32.	Ber	*Zizyphus mauritiana*	Rhamnaceae
33.	Sweet orange	*Citrus sinensis*	Rutaceae
34.	Litchi	*Litchi chinesis*	Sapindaceae
35.	Peach	*Prunus persica*	Rosaceae
36.	Banana	*Musa paradisica*	Musaceae
37.	Jack fruit	*Artocarpus heterophyllus*	**Moraceae**

(*Citrus limon*); Aonla (*Emblica officinalis*); grape (*Vitis vinifera*); papaya (*Carica papaya*); pomegranate (*Punica granatum*); loquat (*Eribotrya japonica*); ber (*Zizyphus mauritiana*); sweet orange (*Citrus sinensis*); litchi (*Litchi chinesis*); peach (*Prunus persica*); banana (*Musa paradisica*) and Jack fruit (*Artocarpus heterophyllus*), respectively (Plate 2 and 3). Four (4) mealybug species (in four genera) were identified in the region. These included *Phenacoccus solenopsis* (solanaceous mealybug), *Pseudococcus longispinus* (Long-tailed mealybug on mango), *Drosicha mangiferae* (Mango mealybug) and *Icerya* sp. (Cottony cushion scale on aonla and mango). Over 70 plants, including vegetables, shade trees, fruit trees, forest trees, ornamental plants, weeds and shrubs were examined. Out of which more than 30 plants from 24 families were infested with mealybugs (Table 2). The highest number of plant species infested was from the family solanaceae (6). This was followed by cucurbitaceae (5), moraceae (3), rosaceae (2), malvaceae (2), and the 19 remaining families contributing few species each. Severe infestation of mango and ornamental plants were by *D. mangiferae* and *P. solenopsis*, respectively. Moreover, some crops were affected by several species of the suborder Homoptera other than mealy bugs; at times these other species were found co-existing on the same plant parts, forming complexes of different species of mealy bugs, Jassids, aphids, and white flies that made the level of infestation more and degree of damage enhanced.

4.1.2 Seasonal incidence of mango mealy bug, *D. mangiferae*

The seasonal incidence of mango mealy bug on mango was observed during the two consecutive years of experimentation viz., 2010 and 2011, respectively. The observations on natural infestation of mealy bug were recorded at weekly intervals starting from 1st standard week i.e., soon after the hatching of crawlers in the month of early January, till 20th standard week i.e., last week of May during every proceeding year on different parts of mango trees (Plate 4). The relationship of seasonal incidence of mango mealy bug population per plant with mean temperature, relative humidity and rainfall in three different localities viz., Udheywalla (SKUAST-J) Miran Sahib and Akhnoor mango orchard during 2009-10 and 2010-11, were studied and presented here under.

4.1.2.1 Seasonal incidence of mango mealy bug during 2009-10

The data on seasonal fluctuations in the mango mealy bug population during 2009-10 at different experimental sites on mango have been presented in Table 3. During 2009-10, the

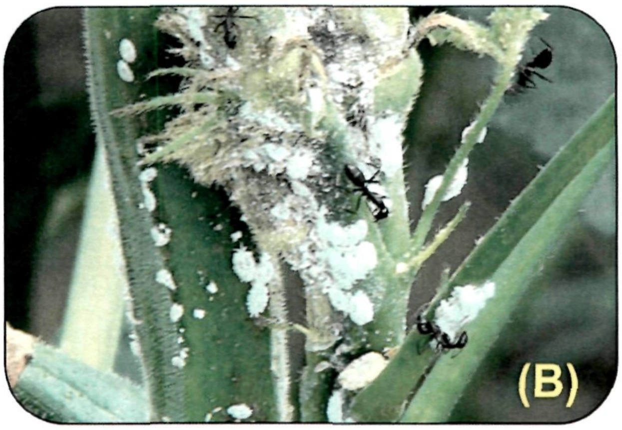
Table 3. Seasonal incidence of mango mealy bug at different locations during 2010

S. No	SW	Mean mango mealy bug popoulation			Temperature °C		Relative Humidity %		Rainfall (in mm)
		Locations							
		Udheywalla	Akhnoor	Miransahib	Min.	Max	Mor	Eve`	
1	1	3..00	1.33	1.333	3.1	17.1	85.0	40.1	0.0
2	2	4.00	2.66	2.66	4.2	18.0	85.1	42.0	0.0
3	3	1.66	1.33	1.33	4.5	19.1	87.0	43.1	0.1
4	4	8.00	5.66	5.66	5.5	20.1	88.1	55.1	0.1
5	5	8.66	7.66	7.66	6.1	21.1	89.1	69.5	0.0
6	6	9.66	8.00	8.00	7.5	22.1	91.1	65.1	0.0
7	7	11.33	8.33	8.33	8.1	23.0	93.2	63.1	0.0
8	8	7.33	5.00	5.00	9.1	24.1	90.2	62.0	0.7
9	9	9.66	8.00	5.33	9.9	25.2	89.1	48.5	0.0
10	10	12.33	5.00	6.66	10.5	26.1	85.2	46.0	0.6
11	11	15.00	4.33	4.66	11.7	27.1	83.5	45.1	0.6
12	12	16.00	15.33	14.00	15.2	28.6	82.1	43.5	0.0
13	13	11.66	12.00	13.66	16.2	29.1	80.1	42.1	0.0
14	14	19.33	16.33	14.00	17.1	30.1	79.1	40.0	0.0
15	15	20.00	19.33	18.33	18.1	31.0	75.1	38.1	0.0
16	16	23.33	22.00	21.00	19.0	32.2	71.2	35.0	0.0
17	17	17.66	16.00	15.66	19.1	33.1	70.1	40.0	0.8
18	18	14.00	12.33	11.00	20.0	34.1	65.2	50.1	0.6
19	19	8.66	7.00	6.00	20.5	35.0	64.0	55.1	0.0
20	20	3.66	3.00	2.33	21.5	36.1	63.0	60.0	0.0

Plate 2

Different types of mealy bugs encountered on various horticultural and wild plants

(A) Mealy bug, *Phenacoccus solenopsis* infestation on brinjal



(B) Mealy bug, *Phenacoccus solenopsis* infestation on okra

(C) Mealy bug, *Phenacoccus solenopsis* infestation on tomato

(D) Mealy bug, *Drosicha mangiferae* infestation on kidney bean

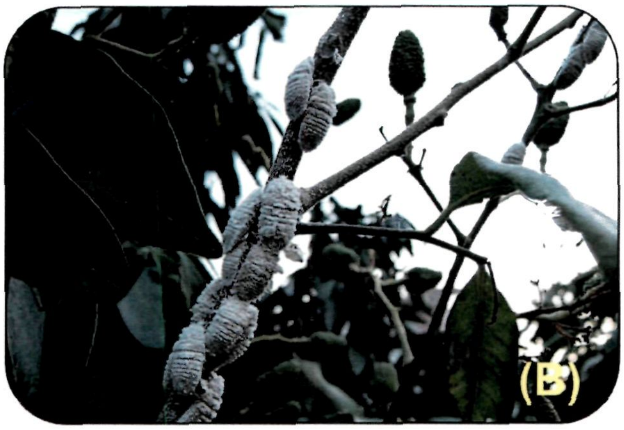
(E) Mealy bug, *Maconellicoccus hirsutus* infestation on china rose

(F) Mealy bug, *Phenacoccus solenopsis* infestation on *Parthenium hysteroforum*

Plate 3

Different types of mealy bugs encountered on various horticultural and wild plants

(A) Long tailed mealy bug, *Pseudococcus longispinus* infestation on mango



(B) Mealy bug, *Drosicha mangiferae* infestation on litchi

(C) Mealy bug, *Drosicha mangiferae* infestation on citrus

(D) Mealy bug, *Drosicha mangiferae* infestation on guava

(E) Mealy bug, *Drosicha mangiferae* infestation on papaya

(F) Mealy bug, *Drosicha mangiferae* infestation on *Nerium indica*

Photo courtesy: Dr. Uma Shankar

Plate 4

Infestation of mango mealy bug on different parts of mango tree

(A) Mealy bug infestation at base of mango tree

(B) Mealy bug on tree trunk of mango tree

(C) Mealy bug, *Drosicha mangiferae* infestation on inflorescence

(D) Mealy bug, *Drosicha mangiferae* infestation on tender twigs

(E) *Drosicha mangiferae* infestation on fruits

(F) Symptoms showing the dried and shrivelled mango fruit mango mealy bug population per plant at Udheywalla (SKUAST-J) ranged from 1.33 to 23.33. Infestation was first observed after hatching of eggs and emergence of tiny nymphs (crawlers) as the temperature started rising in the month of early January *i.e.*, from 1st standard week with an initial population of 3.00 nymphs per plant. The mean weekly temperature (minimum and maximum), relative humidity (morning and evening) and rainfall during the period were recorded to be 3.1°C, 17.1°C; 85.0, 40.1 per cent and 0.0 mm, respectively. The nymphal population was observed to be increasing gradually with some fluctuations till 16th standard week recording a maximum of 23.33 nymphs per plant. The nymphal population of mango mealy bug then decreased till 20th standard week on the same crop up to 3.66 nymphs per plant. During this period, the weekly mean temperature (minimum and maximum), relative humidity (morning and evening) and rainfall (in mm) were observed 21.5°C, 36.1°C; 63.0, 60.0 per cent and 0.0 mm, respectively. Thus, there was one peak of mango mealy bug nymphal population build-up observed during April on mango.

The trend in seasonal incidence of mango mealy bug nymphal population in both the experimental sites was observed to be more or less similar with slight variation in population fluctuations. However, infestation was observed to start at 1st standard week) with an initial load of 1.33 nymphs per plant at Akhnoor and 1.33 at Miran Sahib, respectively. Mango mealy bug nymphal population build-up observed on mango at both the sites were observed in 16th standard week recording a maximum of 22.00 and 21.00 nymphs per plant in Akhnoor and Miran sahib, respectively. The nymphal population then decreased continuously up to 3.00 and 2.33 mean nymphs per plant by 20th standard week.

Table 4 shows the relationship of mango mealy bug nymphal incidence on mango with mean temperature, relative humidity and rainfall at different experimental sites during 2010. A highly significant positive correlation existed between weekly mean minimum and maximum temperature and mealy bug nymphal density and non-significant negative correlation with relative humidity (morning and evening) and non-significant correlation with rainfall, respectively.

The value of linear regression equations for the three locations were calculated to be $Y = 14.971 - 3.906\ X_1$, $Y_1 = 26.346 - 1.470X1$ and $Y_1 = 14.971\text{-}3.906\ X_1$ at different experimental sites of Udheywalla, Akhnoor and Miran Sahib, respectively (Table 5). These equations showed the increasing trend of mealy bug nymphal incidence due to increase in temperature, preferably to some extent. The

Table 4. Correlation matrix of mango mealy bug in relation to population and abotic factors on mango during 2010 at different loacations

Locations	Temperature		Relative Humidity		Rainfall
	Min.	Max.	Morn.	Even.	
Udheywalla	0.605**	0.563**	-300	-431	0.170
Akhnoor	0.643**	0.572**	-375	-414	-048
Miran sahib	0.616**	0.544**	-344	-416	0.075

** Correlation is significant at the 0.05 level (2-tailed)
** Correlation is significant at the 0.01 level (2-tailed)

Table 5. Regression equation & coefficient of multiple determination (R) of mango mealy bug in relation to abotic factors at different locations

S.No	Locations	Regression equation	R^2
1	Udheywalla	$Y= 14.971 - 3.906 X_1 + 4.867 X_2 + 4.63 X_3 - 0.06 X_4 + 2.793 X_5$	0.724
2	Akhnoor	$Y= 26.346 - 1.470X_1 + 2.721 X_2 + 0.618 X_3 -0.150 X_4 + 3.317 X_5$	0.724
3	Miransahib	$Y=14.971-3.906 X_1 + 4.867 X_2 + 0.463 X_3 -0.006 X_4 + 2.793 X_5$	0.784

corresponding correlation co-efficient of multiple determination (R^2) values worked out to be 0.724 for Udheywalla and Akhnoor, 0.784 for Miran Sahib and was found statistically significant at 5% level of significance (Table 5). The linear regression equations calculated from different locational sites also showed that with change in mean minimum temperature from 3.1 to 21.5°C and mean maximum temperature from 17.1 to 36.1°C, the values of coefficient of variation also varied from 72.4 to 78.4 per cent which indicated a variation in the population density with an increasing trend. The overall impact of weather factors on population build up above mealy bug was 72.4 per cent at Udheywalla, 72.4 per cent at Akhnoor and 78.4 per cent at Miran Sahib (Table 5).

4.1.2.2 Seasonal incidence of mango mealy bug during 2010-11

Table 6 represents the seasonal incidence of the nymphal population of mango mealy bug on mango at all the experimental locations during 2010-11. The mean nymphal population of mango mealy bug per plant at Udheywalla (SKUAST-J) ranged from 1.00 to 23.33. Infestation was first recorded in 1st standard week with an initial population of 2.00 nymphs per plant. The mean weekly temperature (minimum and maximum), relative humidity (morning and evening) and rainfall during the period were recorded to be 2.2°C, 16.1°C; 84.0, 39.0 per cent and 0.0 mm, respectively. The nymphal population was observed to be increasing gradually with some aberration till 16th standard week recording a maximum of 23.33 nymphs per plant. Thereafter, the nymphal population of mango mealy bug then decreased till 20th standard week on the same crop up to 3.66 nymphs per plant. During this period, the weekly mean temperature (minimum and maximum), relative humidity (morning and evening) and rainfall (in mm) were observed to be 21.1°C, 37.1°C; 63.0, 60.0 per cent and 0.2 mm, respectively. Thus, there was one peak of mango mealy bug nymphal population build-up observed during April on mango.

Seasonal incidence of mango mealy bug nymphal population in rest of the two experimental sites was observed to be more or less similar with slight variation in population fluctuations. However, infestation was observed to start at 1st standard week) with an initial load of 1.33 nymphs per plant at Akhnoor and 1.22 at Miran Sahib, respectively. Mango mealy bug nymphal population build-up observed on mango at both the sites were observed in 16th standard week recording a maximum of 20.00 nymphs per plant in Akhnoor and Miran Sahib, respectively. The nymphal

Table 6. Seasonal incidence of mango mealy bug at different locations during 2011

S.No	SW	Mean Mealy bug population			Temperature °C		Relative Humidity%		Rainfall (in mm)
		Locations							
		Udheywalla	Akhnoor	Miransahib	Min	Max	Mor	Eve	
1	1	2.00	1.33	1.22	2.2	16.1	84	39	0.0
2	2	3.00	3.22	2.66	3.1	17.2	86	40	0.0
3	3	1.00	1.00	1.11	4.5	19.1	87	42	0.1
4	4	6.66	5.66	4.11	5.5	20.1	88	54	0.0
5	5	8.66	7.22	7.66	6.1	21.1	89	69	0.0
6	6	9.66	8.11	7.33	6.7	22.1	90	66	0.0
7	7	12.33	9.11	8.22	7.5	22.5	92	63	0.0
8	8	6.33	5.00	5.00	8.1	23.2	93	62	0.5
9	9	8.33	7.00	6.00	9.9	24.1	88	49	0.0
10	10	4.33	5.00	3.00	10.1	25.5	86	47	0.3
11	11	6.00	4.33	5.11	11.7	27.1	85	46	0.0
12	12	16.22	15.33	14.00	14.3	28.6	82	45	0.0
13	13	12.66	15.11	13.00	16.2	29.1	80	42	0.0
14	14	19.33	16.33	14.00	17.0	30.1	78	40	0.0
15	15	19.22	18.11	17.11	18.3	31.1	76	39	0.0
16	16	23.33	20.00	20.00	19.1	31.3	71	36	0.0
17	17	16.22	15.00	14.11	20.1	32.2	70	39	0.3
18	18	14.00	13.00	10.00	21.1	34.1	65	55	0.0
19	19	9.11	4.00	4.00	22.1	35.1	64	55	0.0
20	20	3.66	1.22	2.33	21.1	37.1	63	60	0.2

population then decreased continuously up to 1.22 and 2.33 mean nymphs per plant by 20th standard week.

Table 7 shows the relationship of mango mealy bug nymphal incidence on mango with mean temperature, relative humidity and rainfall at different experimental sites during 2011. A positive significant correlation existed between weekly mean minimum and maximum temperature and mealy bug nymphal density and non-significant negative correlation with relative humidity (morning and evening) and non-significant negative correlation with rainfall, respectively.

The value of linear regression equations for the three locations were calculated to be $Y_1 = -11.600 - 3.141\ X_1$, $Y_1 = -14506 - 2.983X_1$ and $Y_1 = -13.896 -2.588\ X_1$ at different experimental sites of Udheywalla, Akhnoor and Miran Sahib, respectively (Table 8). These equations showed the increasing trend of mealy bug nymphal incidence due to increase in temperature, preferably to some extent. The corresponding correlation co-efficient of multiple determination (R^2) values worked out to be 0.801 for Udheywalla and 0.794 for Akhnoor, 0.766 for Miran sahib and was found statistically significant at 5% level of significance. The linear regression equations calculated from different locational sites also showed that with change in mean minimum temperature from 2.2 to 21.1°C and mean maximum temperature from 16.1 to 37.1°C, the values of coefficient of variation also varied from 76.6 to 80.1 per cent which indicated a variation in the population density with an increasing trend. The overall impact of weather factors on population build up above mealy bug was 80.1 per cent at Udheywalla, 79.4 per cent at Akhnoor and 76.6 per cent at Miran Sahib (Table 8).

4.2 Biology of mango mealy bug, *D. mangiferae*

Biology and duration of various life/developmental stages are presented in Table 9 (Plate 5) which revealed that the first instar nymph took mean time of 51.1 ± 2.64 (range 39 to 60) days for its development. This period differed significantly from the developmental period of rest of the instars including adults. The second and third instars completed their development in relatively lesser period of 22.7 ± 2.08 (range 13 to 32) days and 32.9 ± 1.15 (range 16 to 45) days, respectively. These two instars did not exhibit any significant difference in terms of their period of development is concerned. The third instar nymph of male represent its pre-pupal stage which completed its development within a mean period 6.8 ± 0.58 (range 4 to 9) days. The pupal period of male lasted for 6.1 ± 1.00 (range 5 to 9) days.

Table 7. Correlation matrix showing relationship between mealybug in realation to population and abotic factors on mango 2011 at different locations

Locations	Temperature		Relative Humidity		Rainfall
	Min.	Max.	Morn.	Even.	
Udheywalla	0.623**	0.546*	-370	-271	-236
Akhnoor	0.557*	0.472*	-293	-358	-209
Miran sahib	0.570**	0.489*	-311	-349	-197

**** Correlation is significant at the 0.05 level (2-tailed)**
**** Correlation is significant at the 0.01 level (2-tailed)**

Table 8. Regression equation & coefficient of multiple determination (R) of mango mealy bug in relation to abotic factors at different location

S.no	Location	Regression equation	R
1	Udheywalla	$Y = -11.600 - 3.141\ X_1 + 4.256\ X_2 + 0.623\ X_3 + 0.52\ X_4 - 9.131\ X_5$	0.801
2	Akhnoor	$Y = -14506 - 2.983X_1 + 4.054\ X_2 + 0.663\ X_3 - 0.20\ X_4 - 7.149\ X_5$	0.794
3	Miransahib	$Y = -13.896 - 2.588\ X_1 + 3.574\ X_2 + 0.590\ X_3 - 0.020\ X_4 - 6.376\ X_5$	0.766

Table 9. Biology and duration of various life/ develometnal stages of mealy bug, *D. mangiferae*

Life Stage	Duration days		Temperature				Relative humidity			
	Generation1	Generation2	Generation1		Generation2		Generation1		Generation2	
			Max	Min.	Max.	Min.	Morg.	Even.	Morg.	Even.
Eggs	Diapause from 1st June to 3rd Jan .	Diapuse from 1st June to 1st Jan								
1st instar	51.1±2.64 (39-60)	52.2±1.00 (41-61)	17.2±1.5	4.25±1.3	17±1.2	4.1±1.2	90±3.1	58±3	91±2.1	57±1.2
2nd instar	22.7±2.08 (13-32)	22.6±2.52 (13-31)	22.3±1.4	9.95±1.8	21.1±1.2	8.85±1.8	83.5±4.5	48.5±3.5	82.4±1.2	47.5±2
3rd instar	32.9±1.15 (16-45)	32.4±1.16 (16-44)	34.4±2.1	15.2±1.5	34±1.2	14.5±1.5	77±3.1	38 .0±2.0	76±1.5	38.5±1.5
Adult female	49.8±1.13 (39-69)	44.7±4.04 (25-53)	38 .0±2.0	21±1.5	39±1.5	21.5±1.5	55±2	20.5±2	56±2.5	38.0±2
1st instar	51.1±2.64 (39-60)	52.2±1.00 (41-61)	17.2±1.5	4.25±1.3	17±1.2	4.1±1.2	90±3.1	58±3	91±2.1	57±1.2
2nd instar	22.7±2.08 (13-32)	22.6±2.52 (13-31)	22.3±1.4	9.95±1.8	21.1±1.2	8.85±1.8	83.5±4.5	48.5±3.5	82.4±1.2	47.5±2
3rd instar Pre pupa	6.8± 0.58 (4-9)	6-7 ± 0.88 (5-9)	22±2.1	9.5±1.5	21±2.1	8±1.5	82±2.1	48.5±3.5	82.4±1.2	47.5±2
Pupa	6.1±1.00 5-9	6.2±0.58 6-8	22.1±2.1	9.5±1.5	21±2.1	8±1.5	82±2.1	48.5±3.5	82.4±1.2	47.5±2
Adult male	6.8±0.58 (6-8)	6.2±0.58 (6-9)	38 .0±2.0	21±1.5	39±1.5	21.5±1.5	55±3.1	20.5±2	56±2.5	38.0±2
C.D(≤0.05)	5.20	4.31								
S.E(m)	1.72	1.43								

Total period of activity of female =125.5 ± 10.17, Range=103 – 190 days
Total period of activity Male=110.5 ± 10.01, Range=75-130 day

The male insects at their pre-pupal, pupal and adult stage did not show any significant difference in between the periods of their development. The female nymphal development completed within a period of 125.5 ± 10.17 (range 103 to 190) days, whereas male took less period of 110.5 ± 10.01 (range 75 to 130) days only. Adult longevity in case of female was recorded as 49.8 ± 1.13 (range 39 to 69) days which was significantly different from that of male in which case it was noted as 6.8 ± 0.58 (range 6 to 8) days.

The seasonal activity of mango mealy bugs were recorded from 1st standard week up to 20th standard week thereafter the gravid female come/strolled down and entered inside the cracks and cravices for laying the eggs. The eggs laid in the soil cracks and cravices remain in diapause from June to the next season in January. With the increase in temperature the eggs were hatched and newly emerged nymphs/crawlers started climbing on trees and crops and settled on tender twigs. The total period of activity (pooled data of two generation) from hatching of eggs to adult mortality was computed s 125.5 ± 10.17 (range 103 to 190) days and 110.5 ± 10.01 (range 75 to 130) days in case of females and males, respectively. The nymphs passed through three instars during the course of development while having only one generation in a year.Similar observations were also recorded in generation 2 (Table 9).

4.2.1 Mean morphometric measurements of various developmental stages of *D. mangiferae*

The data on measurements of length and breadth of eggs, developing nymphs and adults (male and female) of mango mealy bug are presented in Table 10.

4.2.1.1 Eggs

The mean length × breadth of an egg (Plate -5) recorded and computed as 1.9 ± 0.31 × 0.8 ± 0.4 (range 1-3 × 0-1) mm.

4.2.1.2 Nymphs

The mean body length × breadth of first instar nymph was 1.3±0.4 × 0.7±0.4 (range 1.2 × 0-2) mm. The second instar female and male nymph measured 2.7±1.6 × 2.1±0.4 (range 1-3 × 1-3) mm, respectively. The third instar female and male nymph measured 4.1±1.6 × 2.0±0.7 (range 2-4 × 2-4) mm, respectively. The male pupa measured 4.6±1.7 × 3.0±0.9 (range 3-5 × 3-6) (Table 10).

4.2.1.3 Adults

Table 10. Mean morphometric measurements of various life/ developmental stages of *D. mangiferae*

Sex	Developmental Stage	Length × Breadth	Range
	Egg	1.9±0.31 × 0.8±0.4	(1-3) × (0-1)
Female	First instar nymph	1.3±0.4 × 0.7±0.4	(1.2) ×(0-2)
	Second instar nymph	2.7±1.6 × 2.1±0.4	(1-3) × (1-3)
	Third instar nymph	4.1±1.6 × 2.0±0.7	(2-4) × (2-4)
	Adult	4.7±1.8 × 1.5±0.5	(6-10) × (2-5)
Male	First instar nymph	1.3±0.4 × 0.7±0.4	(1.2) × (0-2)
	Second instar nymph	2.7±1.6 × 2.1±0.4	(1-3) × (1-3)
	Third instar nymph	4.1±1.6 × 2.0±0.7	(2-4) × (2-4)
	Pupa	4.6±1.7 × 3.0±0.9	(3-5) × (3-6)
	Adult	4.5±1.7 × 1.5±0.5	(4-8) × (2-5)

The adult female and male measured 4.7±1.8 × 1.5±0.5 (range 6-10 × 2-5) mm and 4.5±1.7 × 1.5±0.5 (range 4-8 × 2-5) mm, respectively.

4.2.1.4 Fecundity

The data on fecundity collected on showed that the eggs were laid in a mass in a silken pouch. In some cases, the egg pouches were observed to be attached to the posterior side of the dead females below the surface of the soil. The mean number of eggs laid per female was recorded as 122.2 ± 22.70 (range 85-133). The laying period continued for about 20-25 days. The eggs were initially light pink and later turned to reddish brown in colour.

4.2.1.5 Diapause

The eggs laid earlier in the previous season were noted to be available up to a depth of 20 cm in the soil around the mango trees in the experimental orchard. This behaviour coupled with observations recording hatching of eggs and time of laying from end of May to June suggests that the insect remains in diapause, in egg stage, from June to early late December under Jammu conditions.

4.2.1.6 Period of activity and generations

First appearance of nymphs in generation 1was observed on 1st week of new year in the fields which was synchronized with the minimum and maximum temperature of 4.25°C and 17.2°C respectively and the relative humidity of 90 per cent (0830h) and 58 per cent (1730h). The insect was recorded to have only one generation during the entire year as evinced by the mortality of adult male and female in the ending May, respectively. In generation 2, similar observations were also recorded. After third instar, the numphs of mealy bug could not moult in the laboratory.

4.3 Natural enemy complex of mango mealy bug

Field survey was conducted at three experimental mango orchards of Jammu to record natural enemies of mango mealy bug, *Drosicha mangiferae* during 2009-11. Predators were observed active throughout the mango crop season. Different natural enemies recorded from mealy bug colonies on mango included three coccinellid predators (*Rodolia amabilis, Coccinella septempunctata, Cheilomenes sexmaculata)*, spider (*Oxyopes* sp.), chrysopid (*Chrysoperla carnea*), yellow jacket wasp (*Vespa orientalis*), preying mantis and their details are presented in Table 11 (Plate 6). Among these, ladybird beetle, *Rodolia amabilis* was the most abundant. Its highest abundance (61.64 %) was recorded in Udheywalla followed by Miran Sahib (59.70 %) and Akhnoor (54.99 %). *C. septempunctata* was the second most abundant

Table 11. Seasonal activity and abundance of natural enemy recorded against mango mealy bug, *D. mangiferae*

S. No.	Scientific name	Activity period	Order	Family	Udheywalla	Miran Sahib	Akhnoor
					Relative abundance of predator species (%)*		
1	*Rodolia amabilis*	March-May	Coleoptera	Coccinellidae	61.64	59.70	54.99
2	*Coccinella septempunctata*	March-May	Coleoptera	Coccinellidae	18.11	19.13	13.91
	Cheilomenes sexmaculata	March-May	Coleoptera	Coccinellidae	12.20	12.03	13.99
3	*Chrysoperla carnea*	March-May	Neuropetera	Chrysoidae	4.62	4.91	8.57
4	Yellow jacket wasp	March-May	Hymenoptera	Vespidae	1.57	1.92	3.99
5	*Oxyopes* spider	February-April	Arachinidae	Icaraneae	1.88	2.31	4.54

***Mean of three replications**

Table 12. Performance of *Rodolia amabilis Kapur* at different densities in terms of percent predation of mango Mealybug per day

Rodelia amabilis **population density**	*** Mean percentage (%) predation by adults of *Rodolia amabilis* per day**	***Killing efficiency (K) of adult predator**	***Mean percentage (%) predation by grub per day**	***Killing efficiency (K) of grubs of *Rodolia amabilis* predator**
1	8.33	0.088	13.33	0.1434
2	11.66	0.1245	18.33	0.2029
4	21.66	0.2446	28.33	0.3336
6	18.33	0.2029	23.33	0.2661

***Mean of three replications**

Plate 6

Natural enemy fauna of mango mealy bug

(A) Green lace wing feeding on mango insect pests

(B) *Coccinella septumpunctata* feeding on mealy bug

(C) *Cheilomenes sexmaculata* feeding on mealy bug

(D) *Rodolia amabilis* feeding on mealy bug

(D) Predatory paper wasp feeding on mealy bug

(D) Preying mantis probing for host on mango predator with 13.91 to 19.13 per cent abundance followed by *C. sexmaculata* (12.03 to 13.99 %) at different experimental sites. Remaining predatory fauna were also found intermittently predating upon the mealy bug populations.

4.3.1 Performance of *Rodolia amabilis* Kapur in terms of predatism of mango mealy bug per day

Among all the predatory species recorded on mango mealy bug in orchard, *Rodolia amabilis Kapur* was found to be the most abundant coccinellid predator during the two years of study at all the experimental sites. Thus, the studies were further extended from field to laboratory to study the performance of *R. amabilis* in terms of predatism of mango mealy bug per day in laboratory conditions and the results obtained were presented in Table 12 (Plate 7). The predatory coccinellids collected from different experimental sites were pooled to study the predatism performance.

Mean per cent predation and killing efficiency of *R. amabilis* was worked out at different stages (adults and grubs) of predator density i.e., 1, 2, 4 and 6. The maximum mean per cent predation was observed to be 21.66 per cent by adults and 28.33 per cent predation per day by grubs on mealy bug nymphs at 4 beetle density of *R. amabilis*. The corresponding value of killing efficiency was 0.2446 and 0.3336, respectively (Table 12). The given number of mealy bug nymphs (n = 20) were maintained every day after consumption by replacing that many nymphs of mango mealy bug. At all density levels, per cent consumption increased with time and prey density. But, the killing efficiency of the predator (adults and grubs) decreased with increasing the density of mealy bug nymphs. The killing efficiency of the predator was maximum when the one predator was released, recording 0.8761 and 0.6989 with mealy bug nymphs. From the results obtained it was evident that the mean per cent predation was recorded to be maximum in case of grubs on mealy bug nymphs than the adults.

4.4. Management of *D.mangiferae* Green

4.4.1 Effect of different management practices on the pest population of mango mealy

An experiment was conducted to determine the effect of different management practices on the pest population of mango mealy was studied during 2010-2011 (Tables 13-16, Plate 8). The data represented in these tables revealed that all the

Plate 7

Predation potential of *Rodolia amabilis* against mango mealy bug

(A) Laboratory evaluation of predation potential of *Rodolia amabilis* against mealy bug

(B) Predators released in caged condition of infested twigs

(C) Close up view of infested twigs

(D) Adult Rodolia amabilis feeding on mealy bug

(E) Grubs of *Rodolia* feeding on mealy bugs

(F) Pupae of *Rodolia amabilis* on mango

Plate 8

Various types of management practices against mango mealy bug

(A) Soil raking around the mango tree

(B) Tree banding with alkathene sheets

(C) Tree banding with alkathene sheet and greese

(D) Taking observation in sand heap methods

(E) Overview of sand heap methods in mango orchard

(F) Slipping of mealy bugs on sand heap

treatments proved significantly more or less superior over control in protecting the crop from the target pest during first and second treatments.

In the field trials conducted during 2010, the mean pest population of mango mealy bug varied from 7.900 to 9.167 per plant initially i.e., a day prior to the management practices (Table 13). After first management treatments, the mean pest population of mango mealy bug varied from 2.000 to 7.33 per plant 1st day after treatments (DAT) after 1st treatment. After first insecticidal treatments, the mean mango mealy bug nymphal population in plant receiving sand application was low (1.667 per plant) when observed after third days of treatment followed by Imidacloprid 0.0025%, Metasystox 0.03%, which recorded of 2.667 and 3.000 mealy bug nymphs per plant, respectively. The mean nymphal population in the plants receiving sticky barrier, chloripyriphos dust 1.5%, methyl parathion 2% dust, ploughing followed by irrigation and soil racking treatments was observed to be high recording 4.000, 5.000, 5.333, 7.000 and 5.667 nymphs per plant, respectively after third days in 1st treatment and significant difference was observed between sand application and imidacloprid and between imidacloprid and metasystox at 5 per cent level of significance. However, on the seventh day after application, the mean mealy bug nymphal population in the treatment receiving sand application followed by imidacloprid was low and at par with metasystox treatments having 1.000, 2.333 and 2.667 nymphs per plant, respectively. A mean of 2.333 nymphs per plant recorded in sticky barrier treated plants after 7 days of spray which was again found to be on par with imidacloprid and metasystox treatment. The nymphal population was observed to be high in Ploughing followed by irrigation treated plants recording 6.333 nymphs per plant and were significantly differed from rest of all the insecticidal and controlled treatments. On the 14th day after treatment, the lowest mean number of mealy bug nymphal population was recorded in sand application and metasystox treated plants recording 0.667 and 2.333 nymphs per plant, respectively. After 21st days of application, the effectiveness of sand application was quite high and the population recorded in these treatment was low recording 0.667 mealy bug nymphal poppulation followed by Imidacloprid (1.333) and Metasystox (2.000), respectively. Overall, after first treatment, the mean value showed that the treatment receiving sand application (1.200 nymphs per plant) was found to be the best treatment in controlling the mean nymphal mealy bug population followed by imidacloprid (2.533) and metasystox (2.800).

Table 13. Effect of different management practices on the pest population of mango mealy bug after 1st treatment during 2010

S.No	Name of treatments	Pre Count	Days After Treatments (DAT)					Mean
			1	3	7	14	21	
1	Soil Racking	8.667 (3.108)	7.000 (2.936)	5.667 (2.570)	5.000 (2.426)	3.333 (2.061)	3.000 (2.000)	4.800 (2.374)
2	Ploughing followed by irrigation	8.567 (3.093)	7.333 (2.879)	7.000 (2.775)	6.333 (2.426)	5.667 (2.061)	3.667 (2.157)	6.000 (2.616)
3	Methyl parathion 2% dust	8.433 (3.070)	6.333 (2.570)	5.333 (2.515)	4.667 (2.378)	4.667 (2.378)	6.000 (2.646)	5.400 (2.525)
4	Chloripyriphos dust 1.5%	8.233 (3.038)	6.333 (2.505)	5.000 (2.426)	4.000 (2.229)	4.000 (2.229)	6.000 (2.641)	5.067 (2.446)
5	Sticky barrier	8.167 (3.027)	4.333 (2.229)	4.000 (2.229)	2.333 (1.821)	2.000 (1.732)	1.667 (1.626)	2.867 (1.942)
6	Sand application	7.900 (2.983)	2.000 (1.626)	1.667 (1.626)	1.000 (1.414)	0.667 (1.276)	0.667 (1.276)	1.200 (1.462)
7	Metasystox 0.03%	8.167 (3.027)	4.000 (2.229)	3.000 (1.989)	2.667 (1.911)	2.333 (1.805)	2.000 (1.688)	2.800 (1.924)
8	Imidacloprid 0.0025%	8.767 (3.125)	3.333 (1.955)	2.667 (1.883)	2.333 (1.821)	3.000 (2.000)	1.333 (1.520)	2.533 (1.849)
9	Control	9.167 (3.188)	15.000 (4.007)	18.333 (4.295)	20.000 (4.561)	25.000 (5.083)	26.667 (5.239)	21.000 (4.629)
SEM ±		**0.044**	**0.214**	**0.290**	**0.155**	**0.154**	**0.164**	
CD at 5 %		**N.S.**	**0.64**	**0.878**	**0.469**	**0.466**	**0.495**	

A day before commencement of second management practices, the mean mealy bug nymphal population number ranged from 8.567 to 9.100 nymphs per plant as observed after 21 days of the first treatment (Table 14). A day after second treatment, the lowest mean mealy bug nymphal population was recorded in sand application (2.000 nymphs/plant) and was closely followed by imidacloprid and metasystox treated plants. No difference in nymphal population at 5 per cent level of significance was observed between Chloripyriphos dust 1.5% and Methyl parathion 2% dust treatments and also between soil racking and ploughing followed by irrigation, respectively. The maximum mean nymphal population number was recorded in plots receiving in controlled treatments. On third day after application of second insecticidal spray, the nymphal population recorded in all the treated plants receiving different treatments was significantly lower than controlled plots. The mean mealy bug nymphal population per plant in the plants receiving sand application (1.667) was low followed by imidacloprid (2.667), metasystox (3.000) and sticky barrier (4.000).

On 7th day after application of 2nd insecticidal spray, except sand application and imidacloprid, metasystox and sticky barrier, the rest of all the treatments recorded significantly high nymphal number per plant ranging from 4.000 to 6.333. The nymphal population observed in sand application, imidacloprid, metasystox and sticky barrier treated plants were significantly differed from chloripyriphos dust, methyl parathion dust, ploughing followed by irrigation and soil racking treatments.

After 14th day of application also the population recorded in sand application, sticky barrier, metasystox, and imidacloprid treated plants was low recording 0.667, 2.000,2.333 and 3.000 nymphs per plant, respectively and was found statistically different from population recorded on plants receiving chloripyriphos dust, methyl parathion dust, ploughing followed by irrigation and soil racking treatments. Though the mean mealy bug nymphal population was high in the plots receiving chloripyriphos dust, methyl parathion dust, ploughing followed by irrigation and soil racking treatments but significantly differed with the nymphal population recorded on controlled plots. The overall impact of various treatments when observed individually

Table 14. Effect of different management practise on the pest population of mango mealy bug after 2nd treatment during 2010

S.No	Name of treatments	Pre Count	Days After Treatments (DAT)					Mean
			1	3	7	14	21	
1	Soil Racking	8.833 (3.136)	7.000 (2.183)	5.667 (2.570)	5.000 (2.426)	3.333 (2.061)	3.000 (2.000)	4.800
2	Ploughing followed by irrigation	8.633 (3.103)	7.333 (2.879)	7.000 (2.775)	6.333 (2.688)	5.667 (2.580)	3.667 (2.157)	6.000
3	Methyl parathion 2% dust	8.533 (3.087)	6.333 (2.707)	5.333 (2.515)	4.667 (2.378)	4.667 (2.378)	6.000 (2.646)	5.400
4	Chloripyriphos dust 1.5%	8.833 (3.136)	6.333 (2.707)	5.000 (2.426)	4.000 (2.229)	4.000 (2.229)	6.000 (2.641)	5.067
5	Sticky barrier	8.567 (3.093)	4.333 (2.300)	4.000 (2.229)	2.333 (1.821)	2.000 (1.732)	1.667 (1.626)	2.867
6	Sand application	9.033 (3.167)	2.000 (1.715)	1.667 (1.626)	1.000 (1.414)	0.667 (1.276)	0.667 (1.276)	1.200
7	Metasystox 0.03%	8.567 (3.093)	4.000 (2.229)	3.000 (1.989)	2.667 (1.911)	2.333 (1.805)	2.000 (1.688)	2.800
8	Imidacloprid 0.0025%	8.900 (3.146)	3.333 (2.020)	2.667 (1.883)	2.333 (1.821)	3.000 (2.000)	1.333 (1.520)	2.533
9	Control	9.100 (3.178)	15.000 (3.966)	18.333 (4.295)	20.000 (4.561)	25.000 (5.083)	26.667 (5.239)	21.000
SEM ±		**0.028**	**0.218**	**0.290**	**0.155**	**0.154**	**0.164**	
CD at 5 %		**N.S.**	**0.658**	**0.879**	**0.469**	**0.466**	**0.495**	

(Table 14) after the 2nd spray applications, the average of all counts of mealy bug nymphal population per plant was low with sand application, imidacloprid, metasystox and sticky barrier, respectively.

Almost, similar findings were recorded in both the treatments during 2011 (Table 15 & 16). After 1st management treatments, the mean mealy bug nymphal population varied from 0.733 to 21.200 per plant during 2011 (Table 15). During this year also, the more effect on nymphal population was observed with sand application at the later dates of observations even after 21 days after treatment sand application *(0.333) followed by imidacloprid (1.333), sticky barrier (1.333) and metasystox* (2.000), respectively.

The overall impact of these treatments (1st and 2nd) showed that after 2nd treatment, the mean number of mealy bug nymphal population per plant in plants receiving ploughing followed by irrigation treatment was maximum (5.733) and all the treatments were statistically significant at 5% level when compared with the controlled treatments (Table 16). The impact of different treatments on mealy bug nymphal population observed during 2011, nymphal population counts was similar to that observed in previous years of experimentation.

4.4.2 Imapact of different IPM Modules on mean mealy bug pest population

The experimental findings on impact of different IPM modules on mean bug population during 2010-11 for managements of mango mealy bug in the present studies, are presented in tables 17 -20, respectively.

Table 17 showed the impact of different IPM Modules on mean mealy bug pest population after 1st treatment during 2010. A day after application of different types of IPM modules, the pest population of mango mealy bug ranged from 7.833 to 8.100 mean bugs nymphal population per plant. The maximum impact of IPM modules was recorded with module 4 (Soil raking + ploughing followed by irrigation +Sticky band+ Soil application (methyl parathion dust 2%) + Imidacloprid 1 spray; metasystox 1 spray) after a day of treatment (1.333 mean mealy bug pest population) and was followed by module 3 (sand application, soil racking +sticky band) and module 5 (existing package and practices (soil raking+soil application 1.5% lindane dust + sticky band) which showed 4.000 mean mealy bug pest population in each modules, respectively. The minimum impact of IPM modules was recorded with module 1 (Methyl parathion 2% dust; metasystox 0.03% 2 spray + soil raking and

Table 15. Effect of different management practise on the pest population of mango mealy bug after 1st treatment during 2011

S.No	Name of treatments	Pre Count	Days After Treatments (DAT)					Mean
			1	3	7	14	21	
1	Soil Racking	8.700 (3.114)	7.000 (2.825)	6.000 (2.641)	4.667 (4.295)	4.333 (2.307)	3.000 (2.000)	5.000
2	Ploughing followed by irrigation	8.567 (3.093)	6.667 (2.764)	6.667 (2.745)	6.000 (2.378)	5.000 (2.444)	3.667 (2.157)	5.600
3	Methyl parathion 2% dust	8.800 (3.130)	5.667 (2.570)	5.333 (2.515)	4.667 (2.627)	4.000 (2.236)	5.333 (2.515)	5.000
4	Chloripyriphos dust 1.5%	8.733 (3.120)	5.000 (2.449)	4.667 (2.373)	4.333 (2.378)	4.333 (2.307)	5.000 (1.449)	4.667
5	Sticky barrier	8.900 (3.146)	4.000 (2.236)	3.333 (2.079)	2.667 (2.307)	2.333 (1.821)	1.333 (1.520)	2.733
6	Sand application	8.733 (3.120)	1.333 (1.520)	1.000 (1.414)	0.667 (1.911)	0.333 (1.138)	0.333 (1.138)	0.733
7	Metasystox 0.03%	8.867 (3.141)	4.000 (2.229)	4.000 (2.236)	2.333 (1.276)	2.000 (1.688)	2.000 (1.688)	2.867
8	Imidacloprid 0.0025%	8.400 (3.065)	3.000 (1.955)	2.667 (1.883)	2.000 (1.821)	2.333 (1.821)	1.333 (1.520)	2.267
9	Control	8.433 (3.071)	16.667 (4.161)	18.333 (4.295)	19.333 (1.715)	25.000 (5.083)	26.667 (5.239)	21.200
SEM ±		**0.030**	**0.204**	**0.258**	**0.244**	**0.163**	**0.166**	
CD at 5 %		**N.S.**	**0.618**	**0.780**	**0.738**	**0.492**	**0.503**	

Table 16. Effect of different management practise on the pest population of mango mealy bug after 2nd treatment during 2011

S.No.	Name of treatments	Pre Count	Days After Treatments (DAT)					Mean
			1	3	7	14	21	
1	Soil Racking	8.333 (3.054)	7.667 (2.936)	6.667 (2.768)	5.333 (2.505)	4.333 (2.307)	3.000 (2.000)	5.400 (2.503)
2	Ploughing followed by irrigation	8.400 (3.066)	7.333 (2.879)	(6.333) 2.664	6.000 (2.627)	5.333 (2.515)	3.667 (2.157)	(5.733) 2.568
3	Methyl parathion 2% dust	8.033 (3.005)	5.667 (2.570)	5.333 (2.515)	4.333 (2.307)	4.000 (2.229)	5.667 (2.580)	5.000 (2.440)
4	Chloripyriphos dust 1.5%	8.500 (3.082)	5.333 (2.505)	(5.000) 2.426	4.333 (2.307)	4.000 (2.229)	5.333 (2.515)	4.800 (2.396)
5	Sticky barrier	8.200 (3.033)	4.000 (2.229)	3.667 (2.157)	2.667 (1.911)	2.000 (1.732)	1.667 (1.626)	2.800 (1.931)
6	Sand application	8.467 (3.077)	1.667 (1.626)	1.333 (1.520)	1.000 (1.382)	1.000 (1.414)	0.667 (1.276)	1.133 (1.444)
7	Metasystox 0.03%	8.476 (3.076)	4.000 (2.229)	3.667 (2.157)	2.333 (1.821)	2.333 (1.805)	2.000 (1.688)	2.867 (1.940)
8	Imidacloprid 0.0025%	8.367 (3.060)	3.000 (1.955)	2.667 (1.883)	2.000 (1.715)	2.333 (1.821)	1.333 (1.520)	2.267 (1.779)
9	Control	8.600 (3.098)	15.333 4.007	18.333 (4.295)	19.000 (4.459)	25.000 (5.083)	26.667 (5.239)	20.867 (4.617)
	SEM ±	**0.035**	**0.214**	**0.290**	**0.161**	**0.133**	**0.159**	
	CD at 5 %	**N.S.**	**0.647**	**0.875**	**0.488**	**0.403**	**0.482**	

Table 17. Impact of different IPM Modules on mean mealy bug pest population after 1st treatment during 2010

S.No.	Different types of IPM Modules	Pre Count	Days After Treatments (DAT)					Mean
			1	3	7	14	21	
1	Methyl parathion 2% dust; metasystox 0.03% 2 spray + soil raking and ploughing followed by irrigation	8.033 (3.005)	7.000 (2.825)	6.000 (2.641)	4.667 (2.378)	4.333 (2.307)	3.000 (2.000)	5.000
2	Sand application + Methyl parathion 2% dust + imidacloprid 0.0025% 2 sprays	8.100 (3.017)	5.667 (2.570)	5.333 (2.515)	4.667 (2.378)	4.000 (2.236)	5.333 (2.515)	5.000
3	Sand application, soil racking +sticky band	7.967 (2.994	4.000 (2.229)	4.000 (2.236)	2.333 (1.821)	2.000 (1.688)	2.000 (1.688)	2.867
4	Soil raking + ploughing followed by irrigation +Sticky band+ Soil application (methyl parathion dust 2%) + Imidaclोprid 1 spray; metasystox 1 spray	8.100 (3.016)	1.333 (1.520)	1.000 (1.414)	0.667 (1.276)	0.333 (1.138)	0.333 (1.138)	0.733
5	Existing package and practices (soil raking+soil application 1.5% lindane dust + sticky band)	7.833 (2.972	4.000 (2.229)	3.667 (2.157)	2.667 (1.911)	2.000 (1.732)	1.667 (1.626)	2.800
6	Control	7.900 (2.983)	16.667 (4.161)	18.333 (4.295)	19.333 (4.494)	25.000 (5.083)	26.667 (5.239)	21.200
	SEM ±	**0.027**	**0.178**	**0.273**	**0.137**	**0.189**	**0.193**	
	CD at 5 %	**N.S**	**0.569**	**0.872**	**0.436**	**0.602**	**0.615**	

ploughing followed by irrigation) treated plants a day after treatment (7.000 mean mealy bug pest population).

However, the observations after 3rd days in 1st IPM module treatment showed that the effect of module in reducing the mealy bug population ranged from 1.000 (module 4) to 6.000 (module 1) excluding the control treatment. The maximum impact of IPM modules in lowering the mealy bug populations was recorded with module 4 (1.000 mean number of mealy bug) followed by module 5 (3.667 mean number of mealy bug). The remaining three modules such as module 1, 2 and 3 performed intermediate effects in reducing the mealy bug population.

On 7th days after application of IPM modules, the effect of module 4 (0.667 mean mealy bug nymphs) was observed to be more followed by module 3 (2.333) and module 5 (2.667 mean mealy bug nymphs). Once again the Impact of IPM modules was reported to be minimum in case of module 1 and 2 (4.667 mean mealy bug nymphs in each), respectively. On 21 day after application of IPM module treatments, the maximum effect was recorded again with *module 4 with* 0.333 mean mealy bug nymphs. Module 5 (1.667 mean mealy bug nymphs) was closely followed by module 3(2.000 mean mealy bug nymphs). The minimum of 5.333 and 3.000 mean mealy bug nymphs was recorded in plants receiving module 2 and module 1 treatments, respectively.

The overall mean impact of IPM modules after first treatment/application revealed the following descending order of performance of treatments was as follows:

Module 4 (Soil raking + ploughing followed by irrigation +Sticky band+ Soil application (methyl parathion dust 2%) + Imidacloprid 1 spray; metasystox 1 spray) (0.667) > Module 3 (Sand application, soil racking +sticky band) (2.333) > Module 5 (Existing package and practices (soil raking+soil application 1.5% lindane dust + sticky band) (2.667) > Module 2 (Sand application + Methyl parathion 2% dust + imidacloprid 0.0025% 2 sprays) (5.333) > Module 1 (Methyl parathion 2% dust; metasystox 0.03% 2 spray + soil raking and ploughing followed by irrigation) (3.000 mean mealy bug nymphs).

One day after application of second IPM modules treatments, the mean pest population of mango mealy bug during pre count ranged from 7.767 to 8.267 per plant (Table 18). However, on third day the mean mango mealy bug population

Table 18. Impact of different IPM modules on mean mealy bug pest population after 2nd treatment during 2010

S.No.	Different types of IPM Modules	Pre Count	Days After Treatments (DAT)					Mean
			1	3	7	14	21	
1	Methyl parathion 2% dust; metasystox 0.03% 2 spray + soil raking and ploughing followed by irrigation	8.000 (2.999)	7.000 (2.825)	6.000 (2.641)	4.667 (2.378)	4.333 (2.307)	3.000	5.000
2	Sand application + Methyl parathion 2% dust + imidacloprid 0.0025% 2 sprays	8.267 (3.044)	6.667 (2.764)	6.667 (2.745)	6.000 (2.627)	5.000 (2.444)	3.667 (2.000)	5.600
3	Sand application, soil racking +sticky band	7.967 (2.994)	4.000 (2.229)	3.667 (2.157)	2.667 (1.911)	2.000 (1.732)	1.667 (2.157)	2.800
4	Soil raking + ploughing followed by irrigation +Sticky band+ Soil application (methyl parathion dust 2%) + Imidacloprid 1 spray; metasystox 1 spray	8.100 (3.016)	1.667 (1.626)	1.333 (1.520)	1.000 (1.382)	0.667 (1.276)	0.667 (1.626)	1.067
5	Existing package and practices (soil raking+soil application 1.5% lindane dust + sticky band)	7.833 (2.972)	3.000 (1.955)	2.667 (1.883)	2.000 (1.715)	2.333 (1.821)	1.333 (1.276)	2.267
6	Control	7.767 (2.961)	15.333 (4.007)	18.333 (4.295)	19.000 (4.459)	25.000 (5.083)	26.667 (5.239)	20.867
	SEM ±	**0.029**	**0.753**	**1.004**	**0.591**	**0.363**	**0.515**	
	CD at 5 %	**N.S**	**0.236**	**0.327**	**0.185**	**0.114**	**0.161**	

was recorded to be high in plants receiving with module 2 (Sand application + Methyl parathion 2% dust + imidacloprid 0.0025% 2 sprays) (6.667 mean nymphs) and was followed by module 1 (Methyl parathion 2% dust; metasystox 0.03% 2 spray + soil raking and ploughing followed by irrigation) (6.000 mean nymphs), respectively. The minimum number of mean mango mealy bug population was recorded in plants receiving module 4 (Soil raking + ploughing followed by irrigation +Sticky band+ Soil application (methyl parathion dust 2%) + Imidacloprid 1 spray; metasystox 1 spray) (1.333 mean bug nymphs).

On the seventh day, the maximum mean number of mango mealy bug population was recorded in plants receiving Module 2 (6.000) and module 1 (4.667) treatments, respectively. Again the minimum mean number of bug population was recorded in module 4 (1.000) closely followed by module module 5 and module 3. On 14th days after treatments of second treatment the mean number of bug population was recorded minimum in module 4 (0.667) which was found significantly different from other modules in controlling the bug nymphs in plants receiving with module 5 and module 3, followed by module 1 and module 2, respectively. After 21st days, the effect of module in the same order in mitigating the mean number of mealy bug populations. Considering the overall impact of IPM modules of all the post treatment counts after second treatment, the descending order of performance of treatments was as follows:

Module 4 (1.067 mean mealy bug) > module 5 (2.267) > module 3 (2.800) > module 1 (5.000) > module 2 (5.600 mean mealy bug)

A similar trend with little aberration in reference to impact of different IPM modules on mean mealy bug pest population was also observed during 2011 (Table 19) on the 1st, 3rd, 7th , 14th and 21st days after treatments of first and second treatments. The overall effect of different IPM modules after 1st treatment was observed to be maximum with module 4 (1.200) followed by module 5 (2.533), module 3 (2.800), module 2 (2.867) and module 1 (5.067) treatments.

Table 20 also shows the of different IPM modules against mango mealy bug pest population on mango during 2011. Initial maximum effect after one day of treatment was recorded in plants receiving with module 4 (Soil raking + ploughing followed by irrigation +Sticky band+ Soil application (methyl parathion dust 2%) + Imidacloprid 1 spray; metasystox 1 spray), module 5 (Existing package

Table 19 . Imapact of different IPM Modules on mean mealy bug pest population after 1st treatment during 2011

S.No.	Different types of IPM Modules	Pre Count	Days After Treatments (DAT)					Mean
			1	3	7	14	21	
1	Methyl parathion 2% dust; metasystox 0.03% 2 spray + soil raking and ploughing followed by irrigation	7.833 (2.972)	6.333 (2.707)	5.000 (2.426)	4.000 (2.707)	4.000 (2.307)	6.000 (2.000)	5.067
2	sand application + Methyl parathion 2% dust + imidacloprid 0.0025% 2 sprays	8.067 (3.011)	4.333 (2.300)	4.000 (2.229)	2.333 (2.300)	2.000 (2.444)	1.667 (2.157)	2.867
3	Sand application, soil racking +sticky band	7.933 (2.989)	4.000 (2.229)	3.000 (1.989)	2.667 (2.229)	2.333 (1.276)	2.000 (1.276)	2.800
4	Soil raking + ploughing followed by irrigation +Sticky band+ Soil application (methyl parathion dust 2%) + Imidacloprid 1 spray; metasystox 1 spray	7.967 (2.994)	2.000 (1.715)	1.667 (1.626)	1.000 (1.715)	0.667 (1.732)	0.667 (1.626)	1.200
5	Existing package and practices (soil raking+soil application 1.5% lindane dust + sticky band)	7.900 (2.983)	3.333 (2.020)	2.667 (1.883)	2.3333 (2.020)	3.000 (1.821)	1.333 (1.520)	2.533
6	Control	7.967 (2.994)	15.000 (3.966)	18.333 (4.295)	20.000 (3.966)	25.000 (5.083)	26.667 (5.239)	21.000
	SEM ±	**0.025**	**0.241**	**0.278**	**0.241**	**0.114**	**0.161**	
	CD at 5 %	**N.S**	**0.770**	**0.887**	**0.770**	**0.363**	**0.515**	

Table 20. Imapact of different IPM Modules on mean mealy bug pest population after 2nd treatment during 2011

S.No.	Different types of IPM Modules	Pre Count	Days After Treatments (DAT)					Mean
			1	3	7	14	21	
1	Methyl parathion 2% dust; metasystox 0.03% 2 spray + soil raking and ploughing followed by irrigation	8.100 (3.016)	6.667 (2.768)	5.000 (2.426)	4.333 (2.294)	4.000 (2.236)	5.667 (2.580)	5.133
2	sand application + Methyl parathion 2% dust + imidacloprid 0.0025% 2 sprays	8.033 (3.005)	4.667 (2.365)	4.000 (2.229)	2.667 (1.911)	2.333 (1.821)	2.000 (1.715)	3.133
3	Sand application, soil racking +sticky band	7.933 (2.989)	4.000 (2.229)	3.333 (2.061	3.000 (1.989)	2.667 (1.883)	2.333 (1.805	3.067
4	Soil raking + ploughing followed by irrigation +Sticky band+ Soil application (methyl parathion dust 2%) + Imidacloprid 1 spray; metasystox 1 spray	8.167 (3.028)	2.000 (1.715)	1.667 (1.626)	1.333 (1.520)	0.667 (1.276)	0.667 (1.276)	1.267
5	Existing package and practices (soil raking+soil application 1.5% lindane dust + sticky band)	8.167 (3.028)	3.333 (2.020)	3.000 (1.955)	2.667 (1.900)	2.333 (1.805)	1.667 (1.626)	2.0600
6	Control	8.000 (3.000)	16.667 (4.161)	23.333 (4.767)	30.000 (5.556)	36.667 (6.117)	38.333 (6.169)	29.000
	SEM ±	**0.020**	**0.247**	**0.366**	**0.130**	**0.222**	**0.363**	
	CD at 5 %	**N.S**	**0.788**	**1.169**	**0.416**	**0.707**	**1.159**	

and practices (soil raking+soil application 1.5% lindane dust + sticky band))and module 3 (Sand application, soil racking +sticky band) treatments. However, the overall effect of all the five modules after two sprays was found to be maximum again with module 4 (1.267) and minimum with module 1 (5.133) (Methyl parathion 2% dust; metasystox 0.03% 2 spray + soil raking and ploughing followed by irrigation) and the order of performance of all the five modules in terms of effect in reducing the mean number of mango mealy bug pest population after 2nd treatments was same as observed during 1st treatment in the same year of study.

4.4.3 Pooled data of management of mango mealy bug

Pooled data (Table 21) was analyzed to determine the overall effects of different management practices on the suppression of pest population of mango mealy. The mean pest population of mango mealy bug varied from 7.900 to 9.167 per plant initially i.e., a day prior to the management practices. After first management treatments, the mean pest population of mango mealy bug ranged from 1.667 to 7.000 per plant 1st day after treatments (DAT) excluding the control treatment. On the 14th day after treatment, the lowest mean number of mealy bug nymphal population was recorded in sand application (0.500) followed by metasystox and sticky barrier treated plants recording (2.167) nymphs per plant and both were found to be at par in controlling the mealy bug population. After 21st days after treatment, the effectiveness of sand application was quite high and the population recorded in these treatment was low recording 0.500 mealy bug nymphal poppulation followed by sticky barrier (1.500).

A day before commencement of 2nd management treatment (after 21 days), the mean mealy bug nymphal population number was ranged from 8.400 to 8.900 nymphs per plant (Table 21). On 7th days after treatment, the lowest mean mealy bug nymphal population was recorded in sand application (1.000 nymphs/plant) and was followed by sticky barrier and metasystox treated plants (2.500 nymphs/plant in each). Sticky barrier and metasystox treated plants were found to be at par in managing the mango mealy bug nymphal population and no significant difference was observed between them. After 21 days of treatment, the population recorded in metasystox, sand application and imidacloprid treated plants was low recording 0.667, 1.667 and 2.000

Table 21. Pooled data of management of mango mealy bug during 2010 and 2011

S. No.	Name of treatment	Mean number of mealy bug /twig*											
		Pre Count	1st treatment					Pre Count	2nd treatment (after 21 day)				
			1	3	7	14	21		1	3	7	14	21
1	Soil Racking	8.667 (3.108)	7.000 (2.813)	5.833 (2.570)	4.833 (2.426)	3.833 (2.061)	3.000 (2.000)	8.700 (3.114)	7.000 (2.813)	6.167 (2.570)	5.167 (2.426)	3.833 (2.061)	3.000 (2.000)
2	Ploughing followed by irrigation	8.567 (3.093)	7.000 (2.879)	6.833 (2.775)	6.167 (2.688)	5.333 (2.580)	3.667 (2.157)	8.567 (3.093)	7.333 (2.879)	6.667 (2.775)	6.167 (2.688)	5.500 (2.580)	3.667 (2.157)
3	Methyl parathion 2% dust	8.433 (3.070)	6.000 (2.707)	5.333 (2.515)	4.667 (2.378)	4.333 (2.378)	5.667 (2.646)	8.800 (3.130)	7.333 (2.707)	5.333 (2.515)	4.500 (2.378)	4..333 (2.378)	3.000 (2.646)
4	Chloripyriphos dust 1.5%	8.233 (3.038)	5.667 (2.707)	4.833 (2.426)	4.167 (2.229)	4.167 (2.229)	5.500 (2.641)	8.733 (3.120)	6.000 (2.707)	5.000 (2.426)	4.167 (2.229)	4.000 (2.229)	3.667 (2.641)
5	Sticky barrier	8.167 (3.027)	4.167 (2.300)	3.667 (2.229)	2.500 (1.821)	2.167 (1.732)	1.500 (1.626)	8.900 (3.146)	4.167 (2.300)	3.833 (2.229)	2.500 (1.821)	2.000 (1.732)	5.833 (1.626)
6	Sand application	7.900 (2.983)	1.667 (1.715)	1.333 (1.626)	0.833 (1.414)	0.500 (1.276)	0.500 (1.276)	8.733 (3.120)	1.8333 (1.715)	1.500 (1.626)	1.000 (1.414)	0.833 (1.276)	1.667 (1.276)
7	Metasystox 0.03%	8.167 (3.027)	4.000 (2.229)	3.500 (1.989)	2.500 (1.911)	2.167 (1.805)	2.167 (1.688)	8.867 (3.141)	4.000 (2.229)	3.333 (1.989)	2.500 (1.911)	2.333 (1.805)	0.667 (1.688)
8	Imidacloprid 0.0025%	8.767 (3.125)	3.167 (2.020)	2.667 (1.883)	2.167 (1.821)	2.667 (2.000)	2.667 (1.520)	8.400 (3.065)	3.167 (2.020)	2.667 (1.883)	2.167 (1.821)	2.667 (2.000)	2.000 (1.520)
9	Control	9.167 (3.188)	15.8333 (3.966)	18.333 (4.295)	19.667 (4.561)	25.000 (5.083)	26.667 (5.239)	8.433 (3.071)	15.167 (3.966)	18.333 (4.295)	19.500 (4.561)	25.000 (5.083)	26.667 (5.239)
	SEM ±	**0.044**	**0.218**	**0.290**	**0.155**	**0.154**	**0.164**	**0.030**	**0.218**	**0.290**	**0.155**	**0.154**	**0.164**
	CD at 5 %	**N.S**	**0.658**	**0.878**	**0.469**	**0.466**	**0.495**	**N.S**	**0.658**	**0.878**	**0.469**	**0.466**	**0.495**

***Mean of three replications**

nymphs per plant, respectively and was found statistically different from population recorded among all treatments.

On the basis of pooled data obtained the overall effect of treatments after both the treatments the mean value showed that the treatment receiving metasystox (0.667 nymphs per plant) was found to be the best treatment in controlling the mean nymphal mealy bug population followed by sand application (1.667) and imidacloprid (2.000).

4.4.4 Pooled data of different IPM Modules against mango mealy

The experimental findings on pooled data on impact of different IPM Modules on bug pest populations are analyzed and presented in Table 22. The pre count of different types of IPM modules ranged from 7.833 to 8.100 mean bugs nymphal population per plant. Third days after treatment, the maximum impact of IPM modules was recorded with module 4 (Soil raking + ploughing followed by irrigation +Sticky band+ Soil application (methyl parathion dust 2%) + Imidacloprid 1 spray; metasystox 1 spray) (2.000 mean mealy bug pest population) and was followed by module 3 (sand application, soil racking +sticky band) (2.833) and module 5 (existing package and practices (soil raking+soil application 1.5% lindane dust + sticky band) treatments which showed 3.167 mean mealy bug pest population, respectively. The minimum effect of IPM modules was recorded with module 1 (Methyl parathion 2% dust; metasystox 0.03% 2 spray + soil raking and ploughing followed by irrigation) treated plants 3rd day observation (5.500 mean mealy bug pest population).

However, the observations after 7th days, effect of different modules in reducing the mealy bug population ranged from 1.667 (module 3 and 4) to 4.333 (module 1) excluding the control treatment. The maximum impact of IPM modules in lowering the mealy bug populations was recorded with module 4 (1.167 mean number of mealy bug) followed by module 3 (1.333 mean number of mealy bug) and were not significantly different with each other after 21 days of treatment. The remaining two modules such as modules 1 and 2 were found intermediary in reducing the mealy bug population. The overall mean impact of IPM modules after first treatment revealed the following descending order of performance of treatments was as follows:

Module 4 (Soil raking + ploughing followed by irrigation +Sticky band+ Soil application (methyl parathion dust 2%) + Imidacloprid 1 spray; metasystox 1 spray) (1.167 mean number of mealy bug) > Module 3 (Sand application, soil racking +sticky band) (1.333 mean number of mealy bug) > Module 5 (Existing package and

Table 22. Pooled data of different IPM Modules against mango mealy bug during 2010 and 2011

S.No.	Different types of IPM Modules	Mean number of mealy bug /twig*											
		Pre Count	1st treatment					Pre Count	2nd treatment (After 21 day)				
			1	3	7	14	21		1	3	7	14	21
1	Methyl parathion 2% dust; metasystox 0.03% 2 spray + soil raking and ploughing followed by irrigation	8.033 (3.005)	6.667 (2.825)	5.500 (2.641)	4.333 (2.378)	4.167 (2.307)	4.500 (2.000)	7.833 (2.972)	6.833 (2.825)	5.500 (2.641)	4.500 (2.378)	4.167 (2.307)	4.333 (2.000)
2	sand application + Methyl parathion 2% dust + imidacloprid 0.0025% 2 sprays	8.100 (3.017)	5.000 (2.570)	4.667 (2.515)	3.500 (2.378)	3.000 (2.236)	3.500 (2.515)	8.067 (3.011)	5.667 (2.764)	5.333 (2.745)	4.333 (2.627)	3.667 (2.444)	2.833 (2.515)
3	Sand application, soil racking +sticky band	7.967 (2.994)	3.000 (2.229)	2.833 (2.236)	1.667 (1.821)	1.333 (1.688)	1.333 (1.688)	7.933 (2.989)	3.000 (2.229)	2.667 (2.157)	2.000 (1.911)	1.333 (1.732)	1.167 (1.688)
4	Soil raking + ploughing followed by irrigation +Sticky band+ Soil application (methyl parathion dust 2%) + Imidacloprid 1 spray; metasystox 1 spray	8.100 (3.016)	2.667 (1.520)	2.000 (1.414)	1.667 (1.276)	1.333 (1.138)	1.167 (1.138)	7.967 (2.994)	2.833 (1.626)	2.333 (1.520)	2.000 (1.382)	1.667 (1.276)	1.500 (1.138)
5	Existing package and practices (soil raking+soil application 1.5% lindane dust + sticky band)	7.833 (2.972)	3.667 (2.229)	3.167 (2.157)	2.500 (1.911)	2.500 (1.732)	1.500 (1.626)	7.900 (2.983)	3.167 (1.955)	2.833 (1.883)	2.333 (1.715)	2.333 (1.821)	1.500 (1.626)
6	Control	7.900 (2.983)	15.833 (4.161)	18.333 (4.295)	19.667 (4.494)	25.000 (5.083)	26.667 (5.239)	7.967 (2.994)	16.000 (4.007)	20.833 (4.295)	24.500 (4.459)	30.800 (5.083)	32.500 (5.239)
	SEM ±	**0.027**	**0.178**	**0.273**	**0.436**	**0.189**	**0.193**	**0.025**	**0.236**	**1.044**	**0.185**	**0.363**	**0.193**
	CD at 5 %	**N.S**	**(0.506)**	**0.872**	**0.137**	**0.602**	**0.615**	**N.S**	**0.753**	**0.327**	**0.591**	**0.114**	**0.615**

***Mean of three replications**

practices (soil raking+soil application 1.5% lindane dust + sticky band) (1.500 mean number of mealy bug) > Module 2 (Sand application + Methyl parathion 2% dust + imidacloprid 0.0025% 2 sprays) (3.500 mean mealy bug) > Module 1 (Methyl parathion 2% dust; metasystox 0.03% 2 spray + soil raking and ploughing followed by irrigation) (4.500 mean mealy bug nymphs).

One day after treatment of 2nd modules, the mean pest population of mango mealy bug during pre count ranged from 7.833 to 8.067 per plant (Table 22). However, on third day the mean mango mealy bug population was recorded to be low in plants receiving with module 4 (Soil raking + ploughing followed by irrigation +Sticky band+ Soil application (methyl parathion dust 2%) + Imidacloprid 1 spray; metasystox 1 spray) (2.333 mean nymphs) and was followed by module 3 (Sand application, soil racking +sticky band) (2.667 mean nymphs). On the seventh day, the minimum mean number of mango mealy bug population was recorded in plants receiving Module 3 and 4 (2.000 mean nymphs in each). Again the maximum mean number of bug population was recorded in module 1 (4.500) closely followed by module module 2 (4.333). After 14th days of treatment, the mean number of bug population was recorded minimum in module 3 (1.333) which was found non-significantly with module 4 (1.667 mean bugs) in controlling the mealy bug nymphs.

After 21st days, the effect of IPM module was found to be significantly different from rest of the modules whereas, module 4 and 5 were found at par in their effect to reduce the mean number of mealy bug populations. Considering the overall impact of IPM modules of post treatment counts after 2nd treatment, the descending order of performance of treatments was as follows: Module 3 (1.167 mean mealy bugs) > module 4 and 5 (1.500) > module 2 (2.833) > module 1 (4.333 mean mealy bugs).

DISCUSSION

Chapter 5

DISCUSSION

The mango mealy bug, *D. mangiferae,* is one of the most destructive pest of several fruits, vegetables and plantation crops throughout the world. Indiscriminate and continuous use of synthetic insecticides on mealy bug has eventually led to insecticide resistance and failure of their control. This phenomenon has adversely affected their control by natural enemies, especially parasitoids. These reasons are believed to be major causes for their sudden outbreak and attaining serious pest status in most part of the tropical countries, including India. To overcome this situation, the study were conducted to determine pest incidence in relation to abiotic factors of mango mealy bug on mango, seasonal activity and abundance of natural enemy fauna and evaluating the impact of some promising insecticides and different types of IPM modules against mango mealy bugs were considered. The results obtained are discussed as under:

5.1 Host range and species diversity of mealy bug in Jammu

In both the years of study, the pest population densities had a tendency to fluctuate as a result of their inherent characteristics as influenced by the ecological factors, such as, abiotic and biotic. The foremost important and crucial factor is the availability of host plants. The interaction of these factors governs the population size of a given test organism irrespective of straight generations in which the population of a test species go on changing from egg to adult stage. The understanding of such changes in any set of agro-climatic conditions is a must so that the critical pest stage and key mortality factors are identified and exploited in managing the pest population.

In general, the abundance of insect pests is governed by the food plants. In case, when such host(s) plants are available throughout or even for prolonged period in a year and other environmental factors becomes favourable, the pest is bound to pose threat to the crop cultivation and production. Under such agro-ecological conditions a minor pest could become major pest and diamondback moth is one of such important examples which assumed the status of major pest on several crops in India (Bindra *et al.* 1970; Atwal and Dhaliwal, 2009; Nagrare *et al.*, 2009; Mohindru *et al.*, 2009) and around the tropical and sub-tropical world (Miller *et al.*, 2002; Downie and Gullan, 2004; Franco *et al.*, 2009;), wherever the crops are grown. The behavioural knowledge of mealy bug insect pests with particular reference to their life activities provides the better understanding of seasonal incidence and also explores the suitable, timely and locally developed management practices in the prevailing situations. Unfortunately such information in terms of area specific management strategies is lacking against mango mealy bug.

The present experimentation showed that mango mealy bug (*Drosichia mangiferae*) was observed infesting on cultivated fruits and vegetables and on wild host crops growing in different types of crop ecosystem.These wide ranges of host plants offer shelter to the different types of mealy bugs and maintaining their population round the year. Over 70 plants including vegetables, shade trees, fruit trees, forest trees, ornamental plants, weeds and shrubs were examined wherein, more than more than 30 host plants from 24 families were infested with four (4) mealy bug species (in four genera) identified in the Jammu region. The present findings are in conformity with the results obtained by Suresh and Kavitha (2008) found that five scale insect pest species such as *Phenacoccus solenopsis* Tinsley, *Coccidohystrix insolita* Green,*Rastrococcus iceryoides* Green, *Cerococcus indicus* Maskell and *Saissetia coffeae* Walker on parthenium, cotton, hibiscus and crotons in Coimbtore, Tamil Nadu. Further, Godse *et al.* (2003) found seven species of mealy bugs on mango (*Perissopneumon* sp. *Ferrisia virgata, Planococcoides robustus, Rastrococcus invadens, Planococcus* sp., *Cataenococcus* sp. and *Icerya aegyptiaca*) in Maharashtra, India. Furthermore, Haq and Akmal, 1960; Prassad and Singh, 1976; Tandon and Lal, 1978; Tandon *et al.*, 1978; Shah *et al.*, 1980; Tandon and Verghese, 1985; Khan, 2001; Narula, 2003; Culik *et al.*, 2003; Tanwar *et al.*, 2007; Rajendran, 2009; Dhawan and Saini, 2009; Atwal and Dhaliwal, 2009; Nagrare *et al.*, 2009 and Wih and Billah, 2012 were established the similar records and stated that mango mealybug (*Drosicha mangiferae* G.) attack on a variety of other fruit trees and dangerous for mango crop.

5.1.1 Seasonal incidence of mango mealy bug, *D. mangiferae*

During the course of investigation, the mango mealy bug pest population showed the tendency to fluctuate by the influence of abiotic and biotic factors. It was observed that the mealy bug activities followed a similar trend in both the crop seasons of 2009-10 and 2010-11. The studies revealed that four species of mealy bugs were associated and causing damage to crops including vegetables, fruits, ornamentals, herbs and shrubs etc. and found throughout the years. (Table 2). The seasonal incidence of mango mealy bugs were recorded from 1st standard week up to 20th standard week thereafter the gravid female stroll down and enter inside the cracks and cravices for laying the eggs. The maximum number of mealy bug nymphal population were recorded in 17th standard week.

These findings are in conformity with those reported from India and other parts of Asia by Culik *et al.*, 2003; Dwivedi *et al.*, 2003; Yadav *et al.*, 2004; Ben-Dov *et al.*, 2005; Kannan *et al.*, 2006; Tanwar *et al.*, 2007; Suresh and Kavitha, 2008; Pandey and Kumar, 2009; Rajendran, 2009; Sharma *et al.*, 2009 ; Karar, 2010; Singh *et al.*, 2010; Hala *et al.*, 2011 who reported a high build-up of mealy bug nymphal population during second week of March to early April. While studying the seasonal incidence of this pest Sen and Prasad (1956) at Bihar and Pruthi and Batra (1960) at Gwalior had also reported and recorded the descending in the months of April and May. But at Sirsa (Haryana) the descending of females has been noted from end of March to end of May (Butani, 1964 and 1979).

In the present study, the high nymphal population of the test insect was observed could be mainly due to high temperature and relative humidity that reflects dry climatic conditions in this zone, from a safe threshold level of the insect. Our findings were also agree with those reported by Dwivedi *et al.*, 2003 who recorded the seasonal incidence of insect pests of mango mealy bug in relation to mean temperature and humidity. The population of mealy bug (*Drosicha mangiferae*) was highest (84.6) at the base of the tree trunk in February and lowest (0.58) in December. Further, Yadav *et al.* (2004) observed that the highest population (17.50) of mango mealy bug was recorded on April 2000 at an average temperature and relative humidity of 27.43 ° C and 46.57%, respectively. A decreasing population trend from 8.25 to 4.75, was observed on ending April and May 2000 at an average temperature of 31.31 and 31.55 ° C and relative humidity of 48.35 and 49.80%, respectively, due to increasing temperature and relative humidity. The lowest population (1.50) of mango mealy bug was recorded on ending May 2000 at an average temperature and relative humidity of 33.03 degrees C and 56.75%, respectively. No infestation was recorded on 31st May 2000 due to an increase of temperature (33.55 ° C) and relative humidity (63.05%).

Our results on impact of temperature and relative humidity on mealy bug nymphal population build-up coincide with the studies reported earlier by Singh *et al.* (2010) who found that the maximum incidence mealy bug was observed during first fortnight of March when maximum and minimum temperature, morning and evening relative humidity were 26.4° and 14.0° C, 90.3 and 53.7% respectively. After second fortnight of April, males were not observed when maximum and minimum temperature, morning and evening relative humidity were 37.3 °C, 22.1° C, 61.6% and 18.9%, respectively. Incidence of mealy bugs/twig had a highly significant positive correlation with maximum temperature (0.964) and minimum temperature (0.938) and negative correlation with morning relative humidity (-0.740) and evening relative humidity (-0.910). Whereas, Hala *et al.* (2011) observed the mango mealybug (*Rastrococcus invadens*) populations were affected mainly by rainfall and temperature variations and to a lesser extent by humidity. The level of live and dead insects is positively correlated with rainfall in contrast to temperature variations.

5.2 Biology of mango mealy bug, *D. mangiferae*

The present findings on biology and duration of various life/developmental stages are presented in Table 9 (Plate 5) which revealed that the first instar nymph took mean time of 51.1 ± 2.64 (range 39 to 60) days for its development. This period differed significantly from the developmental period of rest of the instars including adults. The second and third instars completed their development in relatively lesser period of 22.7 ± 2.08 (range 13 to 32) days and 32.9 ± 1.15 (range 16 to 45) days, respectively. These two instars did not exhibit any significant difference in terms of their period of development is concerned. The third instar nymph of male represent its pre-pupal stage which completed its development within a mean period 6.8 ± 0.58 (range 4 to 9) days. The pupal period of male lasted for 6.1 ± 1.00 (range 5 to 9) days. The observed longevity of adult females for a period of 46.3+3.4 and that of males for 6.7+1.41 days is similar to the findings of Chandra *et al.*(1987) who have recorded the life of males and females as 4-6 and 18-51 days respectively. The females lived much longer life which was six times the longevity period of males. The nymphs of both male and female bugs were seen to become most active in their looks and behaviour after entering the second stage of their development following their first moulting.

The current results are in conformity with the Rehman and Latif, 1944; Atwal *et al.*,1969; Srivastava *et al.*, 1973; Bindra and Sohi, 1974; Atwal, 1976; Tandon and Lal, 1979; Sandhu *et al.*, 1979 and Ashfaq *et al.*, 2005. The observation on the studies related to the number of generations revealed that the insect is univoltine which retified the reports of Chandra *et al*. (1987), Atwal (1963), Srivastava *et al*. (1973), Ashfaq *et al.* (2005). who have also documented one generation in case of mango mealy bug in Punjab, Bihar and Uttar Pradesh.

5.3 Natural enemy complex of mango mealy bug

The present results showed that the predators were observed active throughout the mango crop season. Different types of natural enemies recorded from mealy bug colonies on mango included three coccinellid predators (*Rodolia amabilis, Coccinella septempunctata, Cheilomenes sexmaculata)*, spider (*Oxyopes* sp.), chrysopid (*Chrysoperla carnea*), yellow jacket wasp (*Vespa orientalis*), preying mantis and their details are presented in Table 11 (Plate 6). Among these, ladybird beetle, *Rodolia amabilis* was the most abundant. Its highest abundance (61.64 %) was recorded in Udheywalla followed by Miran Sahib (59.70 %) and Akhnoor (54.99 %). *C. septempunctata* was the second most abundant predator with 13.91 to 19.13 per cent abundance followed by *C. sexmaculata* (12.03 to 13.99 %) at different experimental sites. However, it is necessary to improve the communication system, develop messages and plan campaigns for the effective control of insect pests of mango especially mango mealybug to improve the knowledge of the farmers for perception of pest and natural enemies identification and their potential in suppressing the pest (Syed *et al.*, 1970; More and Cross, 1993; Boavida *et al.*, 1995; Bokonon and Neuenschwander, 1995; Gautam and Tesfaye (2002).

Performance of *Rodolia amabilis* Kapur in terms of predatism and killing efficiency of *R. amabilis* was worked out at different stages (adults and grubs) of predator density i.e., 1, 2, 4 and 6. The maximum mean per cent predation was observed to be 21.66 per cent by adults and 28.33 per cent predation per day by grubs on mealy bug nymphs at 4 beetle density of *R. amabilis*. The corresponding value of killing efficiency was 0.2446 and 0.3336, respectively (Table 12). Nevertheless, according to Okada (1991) the per cent mortality of eggs, nymphs and pupae of mealy bugs were mostly affected by some biotic factors such as parasitoids, predators and diseases along with abiotic natural factors. This envisages that the weather factors of this agro-climatic conditions jointly influence the life activity, infestation level and population growth of mealy bugs, besides host availability which is almost throughout the year. Similar records were observed by Gautam *et al.* (2007) who reported five predators, viz., *B. lineatus*, *B. suturalis*, *C. sexmaculata*, *N. regularis* and *S. coccivora* from the field population of *P. solani* Ferris (probably *P. solenopsis*) infesting different plant species. Ram and Saini (2010) in a survey conducted during 2008 & 2009 in cotton belt of Haryana recovered *Brumoides suturalis* (Fabricius) and *Nephus regularis* Sicard as the most abundant predators from the mealy bug infested colonies. *Chrysoperla carnea* was recorded for the first time preying on *M. hirustus* in vine yards by Krishnamoorthy and Mani (1989) and they further collected eggs, pupae and larvae of lacewings from mealy bug infested citrus and guava orchards and in vineyards. Based on surveys in different experimental sites for recording the natural enemies of *D.. mangiferae* it was found that no parasitoids were recovered from the field condition and the coccinellid, *Rodolia amabilis* Kapur were the predominant natural enemies of the mango mealy bugs under Jammu conditions. However, several workers have reported more than 50 per cent (Mahmood, 2008), 20-70 per cent (Tanwar *et al.,* 2008) and 37.6 -72.3 per cent (Ram *et al* 2009) parasitism of *P. solenopsis* by *Aenasius* sp. on cotton and other host plants. Thus, it appears that the predatory fauna played a crucial role to regulate the mealy bug nymphal pest population by its abundance and predation throughout the crop growing season.

5.4 Management of mango mealy bug

The results indicated that the lack of knowledge about the pest among the farmers, was the main constraint for the formulation of effective IPM strategy. The present findings agree with the earlier investigators (Tendon, 1969; Bindra *et al.*,1974; Batra *et al.*, 1979; Lakra *et al.*, 1980; Siddique *et al.*, 1982; Dhingra, 1990; Saeed et al., 2007; Pushpa, 1973; Srivastava *et al.*, 1973; Srivastava, 2008; Dhawan et al., 2008; Mansour *et al.*, 2010; Karar et al., 2010) who evaluated various insecticides as the alternative chemical for successful control of the mango mealy bug and cotton mealy bug. They further observed that most of the potent chemicals such as lamda cyhalothrin, alphamethrin, decamethrin, cypermethrin, methyl parathin, fenvalerate, monoctophos, endosulfan, respectively offered promising result in controlling mealy bugs.

5.4.1. **Effect of different management practices on the pest population of mango mealy**

The effect of different management practices on the pest population of mango mealy was studied during 2010-2011. The mean pest population of mango mealy bug varied from 7.900 to 9.167 per plant initially i.e., a day prior to the management practices during 2010. After 21st days of application, the effectiveness of sand application was quite high and the population recorded in this treatment was low recording 0.667 mealy bug nymphal poppulation followed by Imidacloprid (1.333) and Metasystox (2.000), respectively. Overall, after first treatment, the mean value showed that the treatment receiving sand application (1.200 nymphs per plant) was found to be the best treatment in controlling the mean nymphal mealy bug population followed by imidacloprid (2.533) and metasystox (2.800). The overall impact of various treatments when observed individually after the 2nd spray applications, the average of all counts of mealy bug nymphal population per plant was low with sand application, imidacloprid, metasystox and sticky barrier, respectively. The impact of different treatments on mealy bug nymphal population observed during 2011, nymphal population counts was similar to that observed in previous years of experimentation. Pooled data was analyzed to determine the overall effects of different management practices on the suppression of pest population of mango mealy. On the basis of pooled data obtained the overall effect of treatments after both the treatments the mean value showed that the treatment receiving metasystox (0.667 nymphs per plant) was found to be the best treatment in controlling the mean nymphal mealy bug population followed by sand application (1.667) and imidacloprid (2.000). Tandon (1988) observed that the spray of Monocrotophos (0.05 percent) or Chloropyrphos yielding good results when bugs settle on inflorescene panicles. Ahad *et al.* (1988) opined that Phorate was ineffective in suppressing the infestation on the aerial plant parts but soil applications were very effective and Quinalphos, Monocrotophos, Dimethoate when used as soil drenches or aerial sprays significantly reduced the pest population above and below ground. Nayer *et al.* (1986) advocated application of aldrin (5 percent dust around the base of the tress and spraying of aerial parts with Parathion (0.05 percent) or Melathion (0.05 percent) for the effective control of early instar nymphs. Methyl demeton (0.05 percent) Dimethoate (0.05 percent) and Dichloros (0.1 percent) have been proved equally effective when used as foliar sprays (Singh et *al.* 1988). Similarity in the proportion of insect mortality by this chemical (Dimethoate) at higher concentration (0.15 per cent) observed in the present studies and at lower concentration (0.03 percent) recorded by above workers may be due to higher toxic effect of the chemical on the insect immediately after spraying and later on its transformation into a less toxic product. This finding leads us to summarize that evaluation of systemic products for management of a sucking type insect like mealy bug merits detailed investigation. The insect knockdown with Dimethoate (0.05 percent) and oxydemeton methyl (0.05 percent) has ranged between 59.88 and 49.20 percent at 2 and 6 DAT respectively (Table 7). These chemicals have not evinced any better performance over contact insecticides even when used as foliar applicants. Relatively much less proportion of insect motility observed in our studies testify the findings of Batra *et al* (1979) who have recorded 38.7 percent mortality with Oxydemeton methyl at 7 DAT even at a higher concentration of 0.1 percent. The observations of Prasad *et al* (1976), however, differ as they have recorded 81.07 percent mortality with Dimethoate (0.03 percent). The reason for variability in the proportion of mortality is not fully understood. The variations in the size of population may, however, be due to variations in the size of sample unit as also the variations in the population pressure.

5.4.2 **Impact of different IPM Modules on mean mealy bug pest population**

Insecticides are generally recommended only as a last resort in the integrated package of control measures. Chemical control methods for mealy bug have been insufficient. (Tandon and Lal, 1980). The current findings on impact of different IPM modules showed the impact of different IPM Modules on mean mealy bug pest population after 1st treatment during 2010.

The overall mean impact of IPM modules after first treatment/application revealed the following descending order of performance of treatments was as follows: Module 4 (Soil raking + ploughing followed by irrigation +Sticky band+ Soil application (methyl parathion dust 2%) + Imidacloprid 1 spray; metasystox 1 spray) (0.667) > Module 3 (Sand application, soil racking +sticky band) (2.333) > Module 5 (Existing package and practices (soil raking+soil application 1.5% lindane dust + sticky band) (2.667) > Module 2 (Sand application + Methyl parathion 2% dust + imidacloprid 0.0025% 2 sprays) (5.333) > Module 1 (Methyl parathion 2% dust; metasystox 0.03% 2 spray + soil raking and ploughing followed by irrigation) (3.000 mean mealy bug nymphs).

Almost similar trend with little aberration in reference to impact of different IPM modules on mean mealy bug pest population was also observed during 2011 on the 1st, 3rd, 7th, 14th and 21st days after treatments of first and second treatments. The overall effect of different IPM modules after 1st treatment was observed to be maximum with module 4 (1.200) followed by module 5 (2.533), module 3 (2.800), module 2 (2.867) and module 1 (5.067) treatments.

During 2011, the overall effect of all the five modules after two sprays was found to be maximum again with module 4 (1.267) and minimum with module 1 (5.133) (Methyl parathion 2% dust; metasystox 0.03% 2 spray + soil raking and ploughing followed by irrigation) and the order of performance of all the five modules in terms of effect in reducing the mean number of mango mealy bug pest population after 2nd treatments was same as observed during 1st treatment in the same year of study. Pooled data on impact of different IPM Modules on bug pest populations portrayed the overall mean impact of modules after first treatment with the following descending order of performance:

Module 4 (Soil raking + ploughing followed by irrigation +Sticky band+ Soil application (methyl parathion dust 2%) + Imidacloprid 1 spray; metasystox 1 spray) (1.167 mean number of mealy bug) > Module 3 (Sand application, soil racking +sticky band) (1.333 mean number of mealy bug) > Module 5 (Existing package and practices (soil raking+soil application 1.5% lindane dust + sticky band) (1.500 mean number of mealy bug) > Module 2 (Sand application + Methyl parathion 2% dust + imidacloprid 0.0025% 2 sprays) (3.500 mean mealy bug) > Module 1 (Methyl parathion 2% dust; metasystox 0.03% 2 spray + soil raking and ploughing followed by irrigation) (4.500 mean mealy bug nymphs). Considering the overall impact of IPM modules of post treatment counts after 2nd treatment, the descending order of performance of treatments was as follows: Module 3 (1.167 mean mealy bugs) > module 4 and 5 (1.500) > module 2 (2.833) > module 1 (4.333 mean mealy bugs).

The literature available on IPM modules for managing mango mealy bug are meagre however, the present finding are bit supported by Karar (2010) who tested a combination of mounds on the plastic sheet, Haider's band and application of acetamiprid and found that the combination of these treatments to be the most effective resulted in 98% reduction of first instars of mango mealy bug. It is further stated that the Haider's band was the most effective and cheaper which was a new addition in the mechanical control management of mango mealy bug on mango trees.

In this context, Ishaq *et al.*, 2004 also concluded that the mortality only with insecticide sprays were up to 55 per cent, whereas sticky bands along with burying and burning treatments significantly reduced the extent of infestation by mango mealy bug (0.00-15.79 percent) and burlap bands reduced population of mango mealy bug nymphs by 78.98 percent. So it was concluded that for the control of mealy bug integration of insecticides with bands along with burning and burying treatments gave good control.

SUMMARY AND CONCLUSION

SUMMARY AND CONCLUSION

The studies were conducted to determine "Seasonal Incidence and Integrated Management of Mango Mealy Bug, *Drosicha mangiferae* (Green)". To achieve it, an extensive field survey and observations were conducted during 2009 and 2011 which showed that mango mealy bug (*Drosichia mangiferae*) was invariably found on cultivated fruit and vegetable crops as well as on wild host crops growing in and around the fruit and vegetable crop ecosystem. These wide ranges of host plants offer shelter to the different types of mealy bugs and maintaining their population round the year. In this context, over 70 plants including vegetables, shade trees, fruit trees, forest trees, ornamental plants, weeds and shrubs were examined wherein, more than more than 30 host plants from 24 families were infested with four (4) mealy bug species (in four genera) identified in the Jammu region. The highest number of plant species infested was from the family solanaceae (6). This was followed by cucurbitaceae (5), moraceae (3), rosaceae (2), malvaceae (2), and the 19 remaining families contributing few species each. Severe infestation of mango and ornamental plants were by *D. mangiferae* and *P. solenopsis*, respectively. Moreover, some crops were affected by several species of the suborder Homoptera other than mealy bugs; at times these other species were found co-existing on the same plant parts, forming complexes of different species of mealy bugs, Jassids, aphids, and white flies that made the level of infestation more and degree of damage enhanced.

Seasonal fluctuations in the mango mealy bug population during 2009-10 at Udheywalla (SKUAST-J) ranged from 1.33 to 23.33. Infestation was first observed after hatching of eggs and emergence of tiny nymphs (crawlers) as the temperature started rising in the month of early January. i.e., from 1^{st} standard week with an initial population of 3.00 nymphs per plant till 16th standard week in which recording a maximum of 23.33 nymphs per plant. The nymphal population of mango mealy bug then decreased till 20th standard week on the same crop up to 3.66 nymphs per plant. The trend in seasonal incidence of mango mealy bug nymphal population in both the experimental sites was observed to be more or less similar with slight variation in population fluctuations.

The relationship of mango mealy bug nymphal incidence on mango with mean temperature, relative humidity and rainfall at different experimental sites during 2010. A highly significant positive correlation existed between weekly mean minimum and maximum temperature and mealy bug nymphal density and non-significant negative correlation with relative humidity (morning and evening) and non-significant correlation with rainfall, respectively. The value of linear regression equations for the three locations were calculated to be $Y = 14.971 - 3.906\ X_1$, $Y_1 = 26.346 - 1.470X1$ and $Y_1 = 14.971-3.906\ X_1$ at different experimental sites of Udheywalla, Akhnoor and Miran Sahib, respectively. These equations showed the increasing trend of mealy bug nymphal incidence due to increase in temperature, preferably to some extent. The values of coefficient of variation also varied from 72.4 to 78.4 per cent which indicated a variation in the population density with an increasing trend. The overall impact of weather factors on population build up above mealy bug was 72.4 per cent at Udheywalla, 72.4 per cent at Akhnoor and 78.4 per cent at Miran Sahib.

The seasonal incidence of the mean nymphal population of mango mealy bug per plant at Udheywalla (SKUAST-J) ranged from 1.00 to 23.33 during 2010-11. Infestation was first recorded in 1st standard week with an initial population of 2.00 nymphs per plant till 16th standard week recording a maximum of 23.33 nymphs per plant. Thus, there was one peak of mango mealy bug nymphal population build-up observed during April on mango.

A positive significant correlation between weekly mean minimum and maximum temperature and mealy bug nymphal density and non-significant negative correlation with relative humidity (morning and evening) and non-significant negative correlation with rainfall, respectively during 2011. The value of linear regression equations for the three locations were calculated to be $Y_1 = -11.600 - 3.141\ X_1$, $Y_1 = -14506 - 2.983X_1$ and $Y_1 = -13.896 -2.588\ X_1$ at different experimental sites of Udheywalla, Akhnoor and Miran Sahib, respectively. The linear regression equations revealed the overall impact of weather factors on population build up above mealy bug was 80.1 per cent at Udheywalla, 79.4 per cent at Akhnoor and 76.6 per cent at Miran Sahib, respectively.

Biology and duration of various life/developmental stages revealed that the first instar nymph took mean time of 51.1±2.64 (range 39 to 60) days for its development. This period differed significantly from the developmental period of rest of the instars including adults. The second and third instars completed their development in relatively lesser period of 22.7± 2.08 (range 13 to 32) days and 32.9±1.15 (range 16 to 45) days, respectively. These two instars did not exhibit any significant difference in terms of their period of development is concerned. The third instar nymph of male represent its pre-pupal stage which completed its development within a mean period 6.8 ± 0.58 (range 4 to 9) days. The pupal period of male lasted for 6.1 ± 1.00 (range 5 to 9) days. The eggs laid in the soil cracks and cravices remain in diapause from June to the next season in January. With the increase in temperature the eggs were hatched and newly emerged nymphs/crawlers started climbing on trees and crops and settled on tender twigs. The total period of activity (pooled data of two generation) from hatching of eggs to adult mortality was computed s 125.5 ± 10.17 (range 103 to 190) days and 110.5 ± 10.01 (range 75 to 130) days in case of females and males, respectively. The nymphs passed through three instars during the course of development while having only one generation in a year.

In the present investigation of predatism of mango mealy bug by three coccinellid predators and others and their seasonal abundance were extensively surveyed under natural field conditions. Among all the predatory species recorded on mango mealy bug in orchard, *Rodolia amabilis Kapur* was found to be the most abundant coccinellid predator during the two years of study at all the experimental sites. Its highest abundance (61.64 %) was recorded in Udheywalla followed by Miran Sahib (59.70 %) and Akhnoor (54.99 %). *C. septempunctata* was the second most abundant predator with 13.91 to 19.13 per cent abundance followed by *C. sexmaculata* (12.03 to 13.99 %) at different experimental sites. The predatory coccinellids collected from different experimental sites were pooled to study the predatism performance. The maximum mean per cent predation was observed to be 21.66 per cent by adults and 28.33 per cent predation per day by grubs on mealy bug nymphs at 4 beetle density of *R. amabilis*.

The effect of different management practices on the pest population of mango mealy was studied during 2010-2011. The mean pest population of mango mealy bug varied from 7.900 to 9.167 per plant initially i.e., a day prior to the management practices during 2010. After 21st days of application, the effectiveness of sand application was quite high and the population recorded in this treatment was low recording 0.667 mealy bug nymphal poppulation followed by Imidacloprid (1.333) and Metasystox (2.000), respectively. Overall, after first treatment, the mean value showed that the treatment receiving sand application (1.200 nymphs per plant) was found to be the best treatment in controlling the mean nymphal mealy bug population followed by imidacloprid (2.533) and metasystox (2.800). The overall impact of various treatments when observed individually after the 2nd spray applications, the average of all counts of mealy bug nymphal population per plant was low with sand application, imidacloprid, metasystox and sticky barrier, respectively. The impact of different treatments on mealy bug nymphal population observed during 2011, nymphal population counts was similar to that observed in previous years of experimentation.

The experimental findings on impact of different IPM modules showed the impact of different IPM Modules on mean mealy bug pest population after 1st treatment during 2010.

The overall mean impact of IPM modules after first treatment/application revealed the following descending order of performance of treatments was as follows:

Module 4 (Soil raking + ploughing followed by irrigation +Sticky band+ Soil application (methyl parathion dust 2%) + Imidacloprid 1 spray; metasystox 1 spray) (0.667) > Module 3 (Sand application, soil racking +sticky band) (2.333) > Module 5 (Existing package and practices (soil raking+soil application 1.5% lindane dust + sticky band) (2.667) > Module 2 (Sand application + Methyl parathion 2% dust + imidacloprid 0.0025% 2 sprays) (5.333) > Module 1 (Methyl parathion 2% dust; metasystox 0.03% 2 spray + soil raking and ploughing followed by irrigation) (3.000 mean mealy bug nymphs).

Almost similar trend with little aberration in reference to impact of different IPM modules on mean mealy bug pest population was also observed during 2011 on the 1st, 3rd, 7th , 14th and 21st days after treatments of first and second treatments. The overall effect of different IPM modules after 1st treatment was observed to be maximum with module 4 (1.200) followed by module 5 (2.533), module 3 (2.800), module 2 (2.867) and module 1 (5.067) treatments.

During 2011, the overall effect of all the five modules after two sprays was found to be maximum again with module 4 (1.267) and minimum with module 1

(5.133) (Methyl parathion 2% dust; metasystox 0.03% 2 spray + soil raking and ploughing followed by irrigation) and the order of performance of all the five modules in terms of effect in reducing the mean number of mango mealy bug pest population after 2nd treatments was same as observed during 1st treatment in the same year of study.

Pooled data was analyzed to determine the overall effects of different management practices on the suppression of pest population of mango mealy. On the basis of pooled data obtained the overall effect of treatments after both the treatments the mean value showed that the treatment receiving metasystox (0.667 nymphs per plant) was found to be the best treatment in controlling the mean nymphal mealy bug population followed by sand application (1.667) and imidacloprid (2.000).

Pooled data on impact of different IPM Modules on bug pest populations portrayed the overall mean impact of modules after first treatment with the following descending order of performance:

Module 4 (Soil raking + ploughing followed by irrigation +Sticky band+ Soil application (methyl parathion dust 2%) + Imidacloprid 1 spray; metasystox 1 spray) (1.167 mean number of mealy bug) > Module 3 (Sand application, soil racking +sticky band) (1.333 mean number of mealy bug) > Module 5 (Existing package and practices (soil raking+soil application 1.5% lindane dust + sticky band) (1.500 mean number of mealy bug) > Module 2 (Sand application + Methyl parathion 2% dust + imidacloprid 0.0025% 2 sprays) (3.500 mean mealy bug) > Module 1 (Methyl parathion 2% dust; metasystox 0.03% 2 spray + soil raking and ploughing followed by irrigation) (4.500 mean mealy bug nymphs). Considering the overall impact of IPM modules of post treatment counts after 2nd treatment, the descending order of performance of treatments was as follows: Module 3 (1.167 mean mealy bugs) > module 4 and 5 (1.500) > module 2 (2.833) > module 1 (4.333 mean mealy bugs).

The conclusion drawn during present investigation is summarized below:

- Mango is an important fruit crops grown in Jammu region which harbours a large magnitude of insect pests. Among them, mango mealy bug is one such problematic pest causing huge damage to several fruit, vegetable and other crops including mango. The host range studies revealed that more than 30 species were severely infested with mealy bugs in the Jammu region.

- Predatory insects like Coccinellid beetles, chrysoperla, wasps and spiders were the dominantly found in the fruit crop ecosystem for suppressing the insect pest population. Further their mass rearing and multiplication at larger scale may opens a new vistas in bio-intensive IPM strategies.
- Effect of different management practices for the management of mango mealy showed that an integrated approach of various methods such as with sand application, imidacloprid, metasystox and sticky barrier will be quite beneficial in suppression of mango mealy bug population.
- In addition to the different management practices, different types of IPM modules will add some extra edge in regulating the mango mealy bug population well in time.

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APPENDIX

Annexure-I

Standard Meteorological Week data for the Year 2009

Met. Week (1)	Date & month (2)	Met. Week (1)	Rainy days (4)	RH1 (Mor) (5)	RH2 (After noon) (6)	Max Temp (⁰C) (7)	Min Temp (⁰C) (8)	Mean Evapo ration (mm) (9)	Solar Radiation $MJm^{-2}d^{-1}$ (10)
1	1-7 Jan	1	1	95	64	17.4	5.4	1.2	12.25
2	8-14	2	0	94	53	19.9	5.3	1.4	13.33
3	15-21	3	3	90	66	21.2	8.6	1.1	13.03
4	22-28	4	2	90	69	20.6	9.3	1.3	12.30
5	29-4 Feb	5	0	92	51	22.0	6.6	1.8	15.60
6	5-11	6	2	89	60	21.0	9.2	1.5	14.80
7	12-18	7	1	93	48	22.7	8.4	2.2	17.55
8	19-25	8	0	91	43	24.5	10.7	2.2	16.46
9	26-4 Mar	9	0	88	45	25.8	8.7	2.8	18.43
10	5-11	10	0	88	34	27.3	10.3	2.6	17.86
11	12-18	11	0	87	38	29.9	10.8	2.6	19.57
12	19-25	12	2	82	39	28.2	13.0	2.5	17.82
13	26-1 Apr	13	3	82	45	26.9	13.5	2.5	18.23
14	2-8	14	2	76	42	29.0	15.1	2.6	19.22
15	9-15	15	1	79	34	31.9	15.2	3.1	21.43
16	16-22	16	0	68	20	35.6	16.9	4.1	22.76
17	23-29	17	0	59	14	38.0	17.8	5.1	23.91
18	30-6 May	18	1	50	22	38.0	19.8	5.0	21.66
19	7-13	19	0	55	19	36.6	18.7	5.1	23.48
20	14-20	20	0	55	21	41.0	21.6	6.5	24.53
21	21-27	21	0	46	18	40.4	22.3	8.0	23.54
22	28-3 Jun	22	0	46	22	39.9	22.7	9.1	24.46
23	4-10	23	0	46	18	40.5	22.1	10.2	24.11
24	11-17	24	1	53	25	38.4	23.2	9.7	22.27
25	18-24	25	0	51	20	42.3	21.6	9.6	24.73
26	25-1 July	26	1	59	41	40.6	26.3	10.2	22.41
27	2-8	27		60	27	40.2	23.3	9.1	23.76
28	9-15	28	2	75	45	37.3	24.7	7.8	22.48
29	16-22	29	3	80	51	37.2	25.2	6.8	23.43
30	23-29	042.0	3	87	68	32.5	25.3	5.4	20.82

31	30-5 Aug	235.9	5	92	68	33.7	24.0	6.0	20.62
32	6-12	091.6	5	89	67	34.7	24.6	5.4	20.37
33	13-19	066.2	3	89	77	31.7	25.2	3.0	17.93
34	20-26	001.8	0	87	60	33.4	23.2	3.9	22.89
35	27-2 Sep	000.0	0	89	59	33.7	23.9	3.4	20.23
36	3-9	027.8	1	79	60	31.8	21.4	3.4	20.98
37	10-16	000.0	0	88	62	32.9	22.9	3.5	19.87
38	17-23	000.0	0	87	59	33.8	23.0	3.2	19.21
39	24-30	000.0	0	88	55	34.5	24.3	3.1	17.58
40	1-7 Oct	004.2	1	86	55	32.8	21.1	2.5	18.26
41	8-14	000.0	0	76	39	32.2	15.7	2.8	19.13
42	15-21	000.0	0	79	32	31.3	13.2	2.4	18.91
43	22-28	000.0	0	82	25	30.2	9.9	2.1	18.44
44	29-4 Nov	000.0	0	85	34	29.9	10.9	2.1	16.78
45	5-11	000.0	0	83	40	27.6	10.9	1.6	15.33
46	12-18	001.0	0	83	39	25.2	10.5	1.6	14.31
47	19-25	000.0	0	81	33	24.8	6.4	1.7	15.62
48	26-2 Dec	000.0	0	85	44	22.9	6.1	1.5	12.71
49	3-9	000.0	0	88	45	22.7	6.9	1.5	13.79
50	10-16	000.0	0	89	42	21.3	7.1	1.3	11.53
51	17- 23	000.0	0	87	43	20.1	4.2	1.1	12.62
52	24-31	000.0	0	92	42	19.4	2.8	1.0	12.79

Standard Meteorological Week data for the Year 2010

Met. Week (1)	Date & month (2)	Rainfall (mm) (3)	Rainy days (4)	RH1 (Mor) (5)	RH2 (After noon) (6)	Max Temp (^0C) (7)	Min Temp (^0C) (8)	Mean Evapo-ration (mm) (9)
1	1-7 Jan	000.0	0	85	40.1	17.1	3.1	0.4
2	8-14	000.0	0	85.1	42	18	4.25	0.3
3	15-21	000.1	1	87	43.1	19.1	4.5	0.6
4	22-28	000.1	1	88.1	55.1	20.1	5.5	1.1
5	29-4 Feb	000.0	0	89.1	69.5	21.1	6.1	1.5
6	5-11	000.0	0	91.1	65.1	22.1	7.5	1.4
7	12-18	000.0	0	93.2	63.1	23	8.1	2.0
8	19-25	000.7	1	90.2	62	24.1	9.1	2.2
9	26-4 Mar	000.0	0	89.1	48.5	25.2	9.9	2.4
10	5-11	000.6	0	85.2	46	26.1	10.5	2.3
11	12-18	000.6	0	83.5	45.1	27.1	11.7	3.1
12	19-25	000.0	0	82.1	43.5	28.6	15.2	3.5
13	26-1 Apr	000.0	0	80.1	42.1	29.1	16.22	4.5
14	2-8	000.0	0	79.1	40	30.1	17.1	5.6
15	9-15	000.0	0	75.1	38.1	31	18.1	6.3
16	16-22	000.0	0	71.2	35	32.2	19	7.4
17	23-29	000.8	1	70.1	40	33.1	19.1	9.3
18	30-6 May	000.6	1	65.2	50.1	34.1	20	10.2
19	7-13	00.0	10	64	55.1	35	20.5	8.0
20	14-20	000.0	0	63	60	36.1	21.1	11.2
21	21-27	000.0	0	46	12	43.9	22.8	12.1
22	28-3 Jun	024.0	2	53	19	39.8	22.2	10.4
23	4-10	012.2	2	60	26	36.6	21.9	8.7
24	11-17	000.0	0	47	22	39.4	22.8	10.2
25	18-24	007.4	2	47	22	43.0	25.5	11.4
26	25-1 July	052.2	2	69	46	36.9	23.6	8.9
27	2-8	021.8	1	68	46	36.6	24.4	7.8
28	9-15	073.2	3	79	54	36.1	23.4	6.5
29	16-22	173.4	5	90	70	33.1	23.5	4.8
30	23-29	039.5	3	84	74	33.2	24.9	4.9
31	30-5	098.4	3	81	67	34.7	25.1	5.9

	Aug							
32	6-12	136.8	5	89	79	32.2	23.9	5.0
33	13-19	087.6	4	86	74	33.3	24.7	4.8
34	20-26	201.2	6	93	71	32.0	22.9	2.5
35	27-2 Sep	011.4	1	88	63	34.1	25.1	3.9
36	3-9	011.4	2	89	69	33.3	23.7	3.1
37	10-16	000.8	0	91	63	32.3	22.5	3.2
38	17-23	021.6	1	84	61	31.9	20.9	2.7
39	24-30	000.0	0	88	55	32.8	20.2	2.9
40	1-7 Oct	000.0	0	85	49	33.5	20.4	3.1
41	8-14	002.0	0	84	47	32.5	19.3	2.4
42	15-21	000.0	0	80	54	32.1	20.5	2.6
43	22-28	024.2	1	88	46	27.5	13.3	1.9
44	29-4 Nov	000.0	0	91	40	28.6	12.8	2.1
45	5-11	000.0	0	91	37	28.9	11.9	2.1
46	12-18	000.0	0	91	38	27.4	9.7	1.7
47	19-25	001.0	0	93	40	25.2	9.2	1.6
48	26-2 Dec	000.0	0	94	39	24.3	8.1	1.4
49	3-9	000.0	0	95	37	23.0	5.2	1.5
50	10-16	007.2	1	96	53	20.1	5.2	1.1
51	17- 23	000.0	0	97	41	20.6	2.9	1.1
52	24-31	067.4	2	94	58	18.7	4.5	1.1

Standard Meteorological Week data from Jan to June- 2011

Met. Week (1)	Date & month (2)	Max Temp (^{0}C) (3)	Min Temp (^{0}C) (4)	RH1 (Mor) (5)	RH2 (After noon) (6)	Rainfall (mm) (9)	Rainy days	Mean Evapo-ration (mm) (9)
1	1-7 Jan	16.1	2.2	84	39.1	0	0	0.8
2	8-14	17.2	3.1	86	40	0	0	0.5
3	15-21	19.1	4.5	87	42.1	0.1	1	1.0
4	22-28	20.1	5.5	88.1	54	0	0	1.2
5	29-4 Feb	21	6.1	89.1	69.5	0	0	1.2
6	5-11	22	6.7	90.1	66	0	0	1.2
7	12-18	22.5	7.5	92.1	63.1	0	0	1.0
8	19-25	23.2	8.1	93.1	62	0.5	1	1.3
9	26-4 Mar	24.1	9.9	88.3	49	0	0	1.2
10	5-11	25.5	10.1	86.2	47	0.3	1	2.5
11	12-18	27.1	11.7	85	46	0	0	3.8
12	19-25	28.6	14.3	82.1	45.1	0	0	4.0
13	26-1 Apr	29.1	16.22	80.1	42.1	0	0	3.9
14	2-8 .	30.1	17	78.1	40.1	0	0	5.0
15	9-15	31	18.3	76	39.2	0	0	4.8
16	16-22	31.3	19.1	71.2	36	0	0	4.6
17	23-29	32.2	20	70.1	39	0.3	1	6.5
18	30-6 May	34.1	21	65.2	55	0	0	7.5
19	7-13	35	22	64	55.1	0	0	7.4
20	14-20	37.1	21.1	63	60	0.2	1	8.7
21	21-27	39.1	22.2	65	30	5.8	2	7.8
22	28-3 Jun	37.1	22.5	73	33	15.6	2	7.0
23	4-10	39.6	23.2	58	27	4.4	1	8.4
24	11-17	37.4	23.7	72	42	11.4	2	9.0
25	18-24	36.0	24.6	76	54	16.2	1	5.5
26	25-1 July	32.3	22.8	89	70	129.6	5	4.1

VITA

VITA

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Bachelors degree	B. Sc. Agriculture
University	C. C . S. University, Meerut, Uttar Pradesh
Year of award	2001
OGPA	66. 06%/100.00
Master's degree specilization in	M.Sc. (Plant Protection with Entomology)
University	C. C. S. University, Meerut, Uttar Pradesh
Year of award	2003
OGPA /Percentage	79.7 % /100.00
Ph. D	Entomology
OGPA/Percentage	7.7 5/ 10.00