DISTRIBUTION, HOST PREFERENCE AND DAMAGE SEVERITY OF MANGO MEALYBUG IN DHAKA CITY AND ITS MANAGEMENT

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DISTRIBUTION, HOST PREFERENCE AND DAMAGE SEVERITY OF MANGO MEALYBUG IN DHAKA CITY AND ITS MANAGEMENT

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MY BELOVED PARENTS

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CERTIFICATE

This is to certify that thesis entitled, **"DISTRIBUTION, HOST PREFERENCE AND DAMAGE SEVERITY OF MANGO MEALYBUG IN DHAKA CITY AND ITS MANAGEMENT"** submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE IN ENTOMOLOGY,** embodies the results of a piece of bona fide research work carried out by **HOSNE ARA**, **Registration No.10-4059** under my supervision and guidance. No part of -the thesis has been submitted to any where for any degree or diploma.

I further certify that such help or source of information, as availed during the course of this investigation has duly been acknowledged.

Dated: December, 2015

Professor Dr. Md. Abdul Latif
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LIST OF ACRONYMS

AEZ	:	Agro-Ecological Zone
BARI	:	Bangladesh Agricultural Research Institute
BBS	:	Bangladesh Bureau of Statistics
cm	:	Centimeter
CV%	:	Percentage of coefficient of variance
EC	:	Emulsifiable Concentrate
et al.	:	And others
etc	:	Etcetera
g	:	Gram
h	:	Hour
ha	:	Hectare
IPM	:	Integrated Pest Management
J	:	Journal
kcal	:	Kilocalorie
kg	:	Kilogram
L	:	Liter
m	:	Meter
ml	:	Milliliter
mm	:	Millimeter
MP	:	Muriate of Potash
no.	:	Number
RCBD	:	Randomized Complete Block Design
SP	:	Soluble Powder
t	:	Ton
TSP	:	Triple Super Phosphate
%	:	Percent
@	:	At the rate of
^{0}C	:	Degree Celsius
a.i	:	Active Ingredient

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Date: December, 2015 **The author**

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ABSTRACT

The present study was conducted at the field of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka and 45 thanas of Dhaka city during the period from November, 2015 to May, 2016 to know the distribution, host preference, damage severity and management of mango mealybug. Four chemical insecticides and two mechanical bands were evaluated against mealybug at mango orchard of Sher-e-Bangla Agricultural University campus. Mango mealybug was recorded from six thanas out of 45 thanas in Dhaka city. Jackfruit was common host at all locations followed by mango. Comparatively higher infestation occurred on fruit of jackfruit compared to inflorescence and branch. In case of mango, more infestation occurred on inflorescences than branch and fruit. Severe infestation was observed on fruit for jackfruit and inflorescence of mango in most of the locations. Carbaryl was the most effective insecticide against mango mealybug which reduced maximum population of mango mealybug (86.70% after 7 days and 92.70% after 15 days of spray) followed by Thiamethoxam. Cotton band and polythene band with grease were found effective for reducing the mealybug populations of mango tree.

CHAPTER I

INTRODUCTION

Mango (*Mangifera indica* L.) is a member of the family Anacardiaceae. It is regarded and appreciated for its strong aroma, delicious taste and high nutritive value (Litz 1997, Singh 1968). This tropical fruit mango is being grown in more than 100 countries (Sauco 1997). Apart from that, it is also valuable ornamental and shade tree with medicinal virtues (D'Almeida 1995). Annually, about 12.5 million tones of mangoes from an area of 2021 thousand hectares of mango orchard are harvested in Indian sub-continent (Sekhar *et al.* 2013). Mango (*Mangifera indica* L) the king of all fruits is cultivated in about 7,50,000 hectares of land in Indian subcontinent. In Bangladesh, mango ranks first in terms of area and third in respect of production. According to BBS (2004), Bangladesh produces 190 thousand metric tons of mangoes per annum from 50.61 thousand hectares of land. The average yield of mango in Bangladesh is only 3.72 tons per hectares (BBS 2004). It is sold on local markets in Bangladesh and constitutes an important source of energy and nutrients (Vitamins A, C, and D, amino acids, carbohydrates, fatty acids, minerals, organic acids, proteins). Insect pests have been regarded as an important constrain to garden fruits throughout the centuries (Hill 2008). A number of insect pests are known to attack the mango trees, which have economic importance (Tandon *et al*. 1985, Herren 1981, Giani 1968).

Insect pests are the major threat to the mango production accounting for huge seasonal loss (Ishaq *et al.* 2004). Several insects attack mango from nursery stage to fruit maturity. Grossly 400 insects and non insect pests have been recorded from Indian subcontinents as pests. However, thirty are obnoxious and serious pests to mango orchard (Kapadia 2003). Among all of the mango insect pests, mealybug (*Drosicha mangiferae)* is one of the notorious and destructive pests rendering huge scale of fruit loss (Karar *et al.* 2006). Bhagat (2004) had mentioned that 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. Karar (2010) had opined that mealybug preferred mango varieties differentially. Mango mealybug became a serious pest of mango and citrus in West Africa which reduced mango fruit 50-90% and pest caused serious nuisance (Moore 2004). *D. mangiferae is* considered to be prime destructive mealybugs species of mangoes in subcontinent of South East Asia. *D. mangiferae* is the serious, dilapidating, polyphagus, dimorphic and notorious pest of mango orchards in Indian sub-continent (Rao *et al*. 2006).

Mealybug is a polyphagous pest which was reported to cause serious damage on various fruit trees particularly mango (Akinlosotu *et al*. 1994). The major host plants are mango (*Mangifera indica*), jackfruit (*Artocarpus heterophyllus*), citrus (*Citrus* spp.), frangipani (*Plumeria rubra*) and fig (*Ficus* spp.) (Ivbijaro *et al*. 1992). Mealybugs are sucking insects, soft bodied, oval shape and cottony in appearance found to attack on leaves, stems, roots and fruits which are covered like whitish powder. They suck a large amount of sap from all parts of the tree. They are found in moist warm climate and also act as a vector for several plant diseases. They attach themselves to the plant and secrete a powdery wax layer used for protection while they suck the plant juices. Some species of mealybug lay their eggs in the same waxy layer used for protection in the quantities of 50-100 other species are born directly from the female (Vogele *et al.* 1991). Juvenile mealybug can crawl from an infested plant to non-infested plant. The other mode of transfer is the small ‘crawlers’ are transferred by wind, rains, birds, ants, clothing and vehicles and settled on new plants. The female mealybug is unable to fly and not active. In fact, humans are great friends helping in transport of mealy bug. Ants attracted by the honeydew, have been seen carrying mealybug from plant to plant. Both the quality and the quantity of the food are greatly affected due to this infestation (Herren 1981). The nymphs and females of this bug suck sap from inflorescence, tender leaves, shoots and fruit peduncles. Affected panicles shrive and become died. Infested plants are affected by the sooty mould (Tandon *et al.* 1978). Severe infestation often leads to fruit drops or makes the fruit unfit for marketing (Karar *et al.* 2013). In general, *D. mangiferae* is found to infest almost all mango cultivars resulting severe fruit necrosis. Due to the growth of sooty mould on the leaves, photosynthetic activity is affected (Pruthi *et al*. 1960). Further the sooty mould of *D. mangiferae* provides an effective medium for rapid growth of black and sooty fungi which decolorizes the fruit and makes it unacceptable to consumer (CABI 2005).

All over the world scientists are working for development and establishment of plant based pesticide, usually called as phytopesticide, botanical pesticide, biopesticide or natural pesticides (Peng *et al*. 2005, Van Mele *et al*. 2000). Exposure of mealy bug 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 can eradicate mango mealybug population (Ekesi *et al*. 2009). Although, there are a number of chemical control strategies to overcome the yield losses in crop plants due to mealybug attack .The use of synthetic insecticides is extremely toxic to natural enemies of mealybugs. The efficacy of different synthetic insecticides and neem oil against mealybug was tested under laboratory and field conditions. Insecticides, Commando (97% DF), Confidor (20% SL), Lannate (40% SP), Actara (25 WG) were applied at field recommended doses. Azadirachtin and numerous other compounds derived primarily from *Azadirachta indica* have insecticidal, antifeedant, and toxicological properties for pest insects control (Nahed *et al*. 2014, Rashid *et al*. 2012, Aslam *et al*. 2004, Abbott *et al*. 1925). Plant derivatives can be used as an alternative approach to synthetic chemicals which are cost effective, easily available and safe to environment and bio control agents. Chemical control of mealybug is notoriously difficult because of their cryptic habit and the water-resistant waxy secretions covering both individual insects and colonies (Mckenzie 1967). Madsen and Westigard (1962) found that spraying just after bud burst gave better control than at other times. In addition, serious infestations have often followed the use of insecticides, mainly organophosphates for the control of Rutherglen bug (*Nysius vinitor*). On citrus, infestations of mealybug often occurred where organophosphate insecticides were used to control red scale. Similar outbreaks of mealybugs after the application of insecticides have been reported by De Bach (1947), Griffiths and Thompson (1947), Woglum *et al.* (1947), Bartlett (1953, 1963) and Whitehead and De Kock (1972). In all of these instances it is likely that the insecticides caused a greater mortality in natural enemies than in the mealybug. Thus the present study was undertaken to fulfill the following objectives-

OBJECTIVES

1. To survey the distribution of mango mealybug in different location of Dhaka city.

2. To record the host plants and infestation level of mango mealybug in the Dhaka city.

3. To develop management practices against mango mealybug.

CHAPTER II

REVIEW OF LITERATURE

This review is an overview of the literature on mango pests which focuses on the mealybug and its management practices. Literatures cited below under the following headings and sub-headings reveal some information about the present study.

2.1Mango pests

A number of insect pests are known to attack the mango trees, which have been studied in detail (Giani 1968, Herren 1981, Sen 1956, Tandon and Verghese 1985). Some of these are certainly responsible for causing considerable damage and become a limiting factor in many mango growing areas. To effectively monitor a mango orchard for insect pest outbreaks, growers must be first aware of the types of insect pests they are likely to encounter and should conduct the surveys on a regular basis (Patriquin *et al*. 1995).

According to Bokonon-Ganta *et al.* (2001) and several other entomologists and actors from the production and processing chains in the countries we surveyed damages by pests and diseases on mango in Africa in general and in West Africa in particular were of minor economic importance. It is only in the eighties that a mealybug later identified as *Rastrococcus invadens* Williams (Homoptera: Pseudococcidae) and a fruit fly identified as *Bactrocera invadens* were reported causing serious damage to various fruit trees, especially mango, in Benin, Togo and Ghana (Vayssieres 2005, Agounke *et al.* 1988).

Babu *et al.* (2001) recorded 18 species of insects at various stages of mango crop in an overlapping manner from August 1998 to July 1999 and August 1999 to July 2000 in Chittoor and Cuddapah regions of Andhra Pradesh, India, wherein they identified *Amritodus atkinsoni, Idioscopus* spp, *Procontarinia matteiana, Orthaga exvinacea, Sternochetus mangiferae* and *Bactrocera* spp. attaining major status or in a severe form whereas, three species, *Apoderus tranquebaricus, Coptosoma varigatum* and *Dasychira mendose* were recorded as stray pests. The remaining ten insect species appeared as minor pests without causing any severe and perceptible economic damage to the crop.

2.2 Mango mealybug (*Drosicha mangiferae)*

The main problem, mentioned by mango producers throughout the survey was the infestation of mango trees by the mango mealybug. All producers had some knowledge of the mango mealybug. The names given varied from insect to disease or both. One of the best definitions recorded for the pest was a white worm with black powder, producing honey like oil. All producers declared the mango mealybug a pest and 97% answered that it decreased fruit production. In 68% of all cases, the incidence of the pest was considered higher in the dry season than in the rainy season *R. invadens*is a native pest from Southeast Asia. It was introduced into western Africa through plant materials (Tobih *et al*. 2002).

It is a pest of more than 21 economically important plant species but mango is its major host plant. The pest has been reported causing 80% of mango yield losses in Ghana (Entomological society of Nigeria 1991), 53% to 100% reduction of total production in Cote d'Ivoire (Hala *et al* 2004), significant reduction in weight and size of fresh mango fruit in Nigeria, Togo and Benin (Ivbijaro and Udensi 1988, Ivbijaro *et al.* 1991 and Tobih *et al.* 2002). The insect affects the morphology and physiology of infested trees causing delays in flowering fall of floral spikes and leaves and slowing the emission of new branches.

Estimates by producers confirmed the negative impact of the pest on plant production and the positive impact of the introduced natural enemy. Production did not immediately return to pre-infestation levels, probably due to the effect of the residual sooty mould on trees following the releases of *G. tebygi*. A similar impact of the introduced natural enemy had been assessed in Togo based on estimation of the production of a limited number of trees grown from the main seedling nurseries (Vogele *et al.* 1991).

An increase beyond the original mango production is attributed to the fact that during the last 10 years many new mango orchards had been established and were coming into production. To what extent the second parasitoid *A. mangicola* which was established later (Neuenschwander *et al.* 1994, Neuenschwander 1996) contributed to the decline of the mealybug populations and increased mango production remains unknown.

Mealybugs feed by inserting their stylets through the plant tissue to suck up sap from either phloem or mesophyll or both. Males terminate their feeding towards the end of the second nymphal stage. Generally, stylet penetration is accomplished by secretion of solidified saliva that forms a sheath around the stylets. Similarly to other members of the suborder Sternorrhyncha, which includes scale insects, aphids, psyllids and whiteflies, mealybugs consume a diet containing mainly carbohydrates but also limited amounts of free amino acids and other nitrogen compounds (Franco *et al*. 2000, Gullan and Martin 2003, Silva and Mexia 1999, Tonkyn and Whitcomb 1987).

Thus, except for sucrose hydrolysis, food digestion is hardly necessary. However, organic compounds in phloem sap need to be concentrated before they can be absorbed and this occurs in the filter chamber, a specialized component of the digestive system, which enables the direct passage of water from the anterior midgut to the malpighian tubules, thereby concentrating food in the midgut (Terra and Ferreira 2003).

The residue of ingested phloem sap after digestion and assimilation in the insect gut is released from the anus as a sugar-rich material, the honeydew. Up to 90% of the ingested sugars may be egested in this way (Mittler and Douglas 2003).

Mealybugs developed several different defense mechanisms. Many of the species tend to establish themselves in protected sites such as cracks and crevices in bark, leaf axils, root crowns, nodes of grass stems, under fruit sepals and within fruit navels between touching fruits or fruits and leafs and in tunnels bored by insect larvae in roots and stems (Franco *et al.* 2000, Kosztarab and Kozar 1988).

This cryptic behavior of mealybugs may originate a spatial refuge from natural enemies and harsh environmental conditions. This type of plant colonization makes mealybugs practically invisible during the latent population phase. However, during outbreaks the population explodes from the refuge and becomes conspicuous (Berlinger and Golberg 1978, Gutierrez *et al.* 2008).

The waxy secretion is the most common conspicuous trait of the mealybug family. It is a complex system that serves different functions and which is produced by the epidermal wax glands and transported to the body surface via ducts, pores and secretory setae of various types (Foldi 1983, Gullan and Kosztarab 1997).

Zada *et al*. (2009) found that the main components of the wax of five mealybug species (*P. citri*, *P. ficus*, *P. vovae*, *P. cryptus* and *N. viridis*) were trialkyl glycerols and wax esters. The wax cover is believed to prevent water loss. The hydrophobic property of the wax enables the mealybugs to escape drowning or becoming swamped by water in their typical cryptic sites.

The ovisac which is also a wax secretion is considered to be an adaptation that protects the offspring from both wet and dry conditions and that may also provide an attachment to the host plant. Tubular ducts and multilocular disc pores, respectively, produce long hollow and shorter curled filaments which make up the ovisac and the male cocoon (Cox and Pearce 1983, Foldi 1983).

The white wax of mealybug is strongly light reflective and may reduce desiccation in some cases, the wax also serves to cover the honeydew droplets and to protect the mealybugs from contamination by their own honeydew and defensive exudates (Gullan and Kosztarab 1997).

The wax cover and the secretion process are involved in mealybug defense against natural enemies. It is hypothesized that the rarity of infestation by pathogens and nematodes is related to the wax shield. Stuart *et al.* (1997) found varied susceptibility of *Dysmicoccus vaccinii* Miller and *Polavarapu* to several nematode species, they showed that removal of the waxy coating from the mealybug did not influence their susceptibility to *Heterorhabditis bacteriophora* Poinar. The lateral wax protrusions protect the mealybug from predators and facilitate spacing of individuals within the colony.

The nymphs and adult females of most mealybugs possess two pairs of dorsal ostioles, located between the head and prothorax and on the sixth abdominal segment that discharge a globule of liquid when the insect is disturbed. This waxy liquid solidifies quickly on contact with air and is believed to have a defensive function (Eisner and Silberglied 1988, Gullan and Kosztarab 1997).

It was found for example, that this discharge negatively affect *Sympherobius fallax* Navas (Neuroptera: Hemerobiidae) larvae (Gillani and Copland 1999), green lacewings (Neuroptera: Chrysopidae) and the parasitoid *Leptomastidea abnormis* (Girault) (Hymenoptera: Encyrtidae) (Franco 1999).

Ostiolar secretions may have different functions in other mealybug species for example the highly developed condition of the dorsal ostioles in obligate ant attended mealybugs suggests that the released fluid may attract the ants (Gullan and Kosztarab 1997).

Nagrare (2014) revealed five mealybug species belonging to the Pseudococcidae and Monophlebidae families of Hemiptera order infesting cotton in India other than predominant mealybug species *Phenacoccus solenopsis* (Tinsley) and *Paracoccus marginatus* (Williams and Granara de Willink). These mealybug species were spherical mealybug *Nipaecoccus viridis* (Newstead), striped mealybug *Ferrisia virgata* (Cockerell), pink hibiscus mealybug *Maconellicoccus hirsutus* (Green), mango mealybug *Rastrococcus iceryoides* (Green) (Pseudococcidae) and ber (Zizyphus) mealybug *Perissopneumon tamarindus* from Monophlebidae (Green).

2.3 Seasonal abundance of mango mealybug

Adult males and newly emerged first instar nymphs or crawlers of most mealybug species display dispersal actively. Other nymphal stages and adult females may also move limited distances (Kosztarab and Kozar 1988) but similarly to most scale insects, crawlers are the mealybugs main dispersal agents.

There is evidence that this developmental stage of scale insects is dispersed passively by the wind, and may be carried for distances of a few meters to several kilometers or even more from the natal plant host, although mortality is very high (Gullan and Kosztarab 1997).

In contrast, Williams and Granara de Willink (1992) reported that mealybugs were believed to be distributed by air currents over only short distances. As well as wind, water, bed soil, humans, and domestic and wild animals may aid the passive dispersal of mealybugs (Kosztarab and Kozar 1988).

Among arthropods, ants have also been reported to disperse some mealybug species (Gullan and Kosztarab 1997, Malsch *et al*. 2001 and Ranjan 2006).

Nevertheless, if conditions are favorable, crawlers usually settle on the natal host plant, often close to their mother which leads to an aggregative distribution (Gullan and Kosztarab 1997, Nestel *et al*. 1995). Many species of mealybugs have been widely distributed by commercial traffic, mostly carried on imported plant material (Williams and Granara de Willink 1992).

Because of their cryptic habits and small size, mealybugs are difficult to detect at borders during quarantine inspections, especially if their population density on plants is low (Gullan and Martin 2003).

Sahito (2012) reported that eggs of mulberry mealybug are pink, minute and contained in an egg sack of white wax. Newly hatched nymphs are called crawlers since the nymphal stage is wingless.

Mani and Thontadarya (1988) showed that the maximum temperature tested had a positive correlation and relative humidity had negative correlation with mealybug populations. Higher temperatures shortened the incubation period, 5°C depression in temperature increased the life cycle duration two fold (Babu and Azam 1987).

Pitan (2000) discussed in his research paper that clear that there were reductions in the population levels of mango mealybug *Rastrococcus invadens* after the introduction *Gyranusoidea tebygi* in Nigeria. Similar reports have been made by Agricola *et al.* (1989), Agounke and Fischer (1993), Bokonon-Ganta and Neuenschwander (1995), Matokot *et al.* (1992) in their various studies.

The mealybug was located in the Paraguay River basin in the Santa Cruz de la Sierra are of eastern Bolivia. Mealybug populations were extremely low in all areas but there was a period of increase from August to December. Eighteen species of natural enemies were found attacking *P. manihoti* the most abundant and also most important were a solitary, internal parasitoid, *Epidinocarsis lopezi* (DeSantis) (Hymenoptera: Encyrtidae), *Hyperaspisnotata mulsant* and *Diomus* spp. (Coleoptera: Coccinellidae) and *Ocyptamus* spp. (Diptera: Syrphidae). Collections of a closely related mealybug, *Phenacoccus herreni* Cox & Williams yielded two additional encyrtid parasitoids, *Epidinocarsis diversicornis* (Howard) and *Aenasius* sp. but they did not survive on *P. manihoti.* Four parasitoids (*E. lopezi, E. diversicornis, Parapyrus manihoti* and *Allotropa* sp.) and four predators (*H. notata, Diomus* sp., *Sympherobius maculipennis* and *Exochomus* sp.) were sent for quarantine. Natural enemy species were forwarded to the International Institute of Tropical Agriculture at Ibadan, Nigeria for mass rearing and subsequent release (Lohr *et al.* 1990).

This experiment showed that after Survey for mealy bugs, natural enemies and ants were conducted in abandoned pineapple fields on the Hawaiian islands of Oahu and Maui. Whole plant samples were taken and mealy bugs and ants found were identified. Mealybug infested plant parts were isolated and held until natural enemies emerged from parasitized host material. Its densities ranged from a mean of 23 to 157 mealy bugs per plant, while in areas with mixed populations of this mealy bug and *Dysmicoccus neobrevipes* beardsley, densities ranged from a mean of 23 to 118 mealy bugs per plant. Ants were present at all sample sites and on all dates. *Pheidole megacephala* (F.) was the most common ant species found. *Anagyrus ananatis* Gahan was the most common parasitoid. It attacked only *D. brevipes* the dominant mealy bug in the pineapple fields surveyed. Percent parasitisation of *D. brevipes* by *A. ananatis* in the presence of ants ranged from 0.3 to 9.9%. Percent parasitization of *D. brevipes* and *D. neobrevipes* per plantby *Euryrhopalus propinquus* Kerrich ranged from 0.05 to 2.2%. Mean densities of the predators *Lobodiplosis pseudococci* (Felt), *Nephus bilucernarius* Mulsant and *Sticholotis ruficeps* Weise ranged from 0.05 to 5.75, 0.1 to 1.8 and 0.05 to 0.2 individuals per plant respectively (Hector *et al*. 1999).

2.4 Hosts of mango mealybug

Atwal (1976) found that the major hosts of mealy bug were papaya, silk cotton, papaya, cotton, shoe flower, jatropha, tapioca, mulberry, guava, tomato, turkey berry, brinjal, teak, country mallow, latjira, wild mustard, spider wort, chandvel, garden sprug, hazardani, dronapushpi, tulasi, congress grass, ghamra, pig weed. He also stated that nymph was highly mobile and in succulent small plant.

The pest has recently moved into the mango production areas of Burkina Faso in the provinces of Comoe, Leraba and Kenedougou in Western Mali in the region of Sikasso and in Guinea where it is causing alarming losses to mango production. Not only has the pest disrupted the production of mango and of many other fruits and ornamental trees but it is also a nuisance by causing accumulation of excreted honey dew that results in the formation of sooty mould which in turn arrests normal growth, photosynthesis, flowering and fruiting of the attacked plants (Pitan *et al.* 2000).

Kashid (2010) mentioned in is work that Sindhudurg district is highly favorable for growing a large number of fruits like mango, cashew nut, areca nuts etc. Fruits and vegetable in the study region play an important role in view of their export potentials as well as domestic requirement and employment generation.

In Guinea *R. invadens* was first observed in 2000 and later confirmed by IITA. Initially localized in one region, the pest rapidly infested the entire country. According to the scientific community and the majors groups of actors in the mango value chain, the bug infestations are causing serious damages to mango production in Guinea. Over the last few years, the infestations have a negative economic impact on producers and traders of this commodity. Although the rates of infestations are most important in urban areas than in orchards, the economic and social strain on farmers seem to be greater given the importance of the revenue of mango production, trade and consumption on farmer’s income and welfare. Indeed mango production plays a fundamental role in procuring extra income to farmers in rural areas all over Guinea.

Mango mealybug, *D. mangiferae* Green, is one of the most serious insect pests of mango in Pakistan due to its polyphagous nature (Green 1908). It lays egg in loose soil within radius of 2-3 meter around the infested trees. Hatching of the eggs starts with rise in temperature and the nymphs crawl to the succulent shoots and base of fruiting parts (Birat 1964 and Atwal 1976). The nymphs and female bugs suck sap from inflorescence, tender leaves, shoots and fruit peduncle. As a result, the affected inflorescences are shriveled and get dried. Rigorous infestation affects the fruit set and causes fruit drop. They exude honey dew over the leaves on which sooty mould is developed (Tandon and Lal 1978).

Until recently, damage by insect pests and diseases on mango in Africa was insignificant. In 1986, however, a mealybug later described as *Rastrococcus invadens* Williams (Homoptera: Pseudococcidae) of South East Asian origin (Williams 1986) was reported to cause serious damage to various fruit trees especially mango, in Benin, Ghana and Togo (Agounke *et al.* 1988).

Mealybugs feed on a variety of herbaceous and woody plants, including the angiosperm, gymnosperm and fern families. However, most of the species with known hosts develop on herbaceous plants, especially grasses and composites (Ben-Dov 2006, Kosztarab and Kozar 1988).

As expected, information on the host ranges of mealybugs is mainly derived from observations of species of economic importance. Most species are oligophagous or stenophagous while others are polyphagous (Ben-Dov 2006, Kosztarab and Kozar 1988).

It was found that more than 1300 mealybugs and their natural enemies were collected from six crops (apples, pears, nashi, citrus, persimmon and grapes). *Pseudococcus longispinus* and *P. calceolariae* were the commonest species in all crops, these three species accounted for more than 99% of all mealybugs collected. Mealybugs were attacked by 14 species of natural enemy.

Parectromoides varipes was newly identified as a primary parasitoid of mealy bugs and males of this species and *Gyranusoidea advena*, previously unknown were found. Both species together with *Tetracnemoidea sydneyensis*, *T. peregrina* and *T. brevicornis* and *Coccophagus gurneyi* (Aphelinidae) and two species of *Ophelosia* (Pteromalidae) were wide spread throughout the surveyed regions. Common predators included *Cryptolaemus montrouzieri* (Coccinellidae), *Cryptoscenea australiensis* (Neuroptera: Coniopterygidae) and *Diadiplosis koebelei* (Diptera: Cecidomyiidae). Five species of ants were recorded tending mealy bugs but none is known to be disruptive to mealy bug natural enemies. Data for biological control of mealy bug pests in horticultural crops concluded that *Pseudaphycus maculipennis* (Hymenoptera: Encyrtidae) should be introduced against *P. affinis*. The activity of existing species should be encouraged in future integrated pest management (IPM) programmes by for example, distributing *A. fusciventris* around the country and commercializing the mass rearing and release of *C. montrouzieri* (Charles *et al.* 2008).

2.5 Management of mango mealybug

All over the world scientists are working for development and establishment of plant based pesticide, usually called as phytopesticide, botanical pesticide, biopesticide or natural pesticides (Siddiqui 2009 and Yan-Zhang 2007).

Exposure of mealy bug 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 can eradicate mango mealybug population (Tandon 1985).

Biological activities of neem based insecticides are known for more than 400 pest insects, which have minimal toxicity to non target organisms such as parasitoids, predators and pollinators (Naumann 1996 and Lowery 1995).

Karar *et al*. (2009) worked on comparative effectiveness of old and new insecticides for the control of Mango Mealybug (*Drosicha mangiferae*) in Mango 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.

Ashfaq (2005) observed that old slippery band technique was hardly effective in controlling mango mealybug. But the new technique or funnel type slippery trap was found to effectively restrict upward movement of mango mealy bug nymphs due to fixed position on tree stem. Similarly it traps the egg carrying females crawling down or directly dropping down along tree stem and kills them entrapped.

The most common method used by local farmers to control *R. Invadens* is cutting down infested trees (Agricola *et al.* 1989). Investigations by National Research Services (NRS) have yielded little alternative control approaches to mitigate the threat caused by *R. invadens*. In Burkina Faso, Cote d'Ivoire and Mali, chemical control has been experimented but the technology has been poorly adopted by farmers because of little efficiency and fears that the use of insecticides will erase the organic nature of mango production of the region and expose mango export to pesticide Maximum Residue Limit restrictions in force in the European Union markets where most of the exported production is sold. Mango mealybug is difficult to control by insecticides and the use of chemicals has been inefficient (Khan and Ahsan 2008, Yousuf and Ashraf 1987).

The sticky bands along with burning and burying treatments significantly reduced the frequency of infestation of mango mealybug by 0.00-15.79%. Burlap bands reduced population of mango mealybug nymphs by 78.98%. Stem injection can achieve a very high level of mortality of sucking insects (98%). The mortality rates achieved with insecticide sprays were up to 55% (lshaq *et al.* 2004).

Paul Van Mele (2001) mentions in his work that in Vietnam, farmers manually remove larvae of the shoot and bark-borer. One farmer cuts flowers infested with scales or nymphs of hoppers (Homeoptera). The majority of farmers prune, mainly to control the shoot or twig borer. Nearly all farmers used insecticides. About half of them possess a knap-sack sprayer and the other half had a power sprayer. A total of 18 different fungicides were found to be used, including 11 different active ingredients. Major products used belonged to the group of systemic benzimidazoles, namely carbendazim (28.7%) and thiophanate-methyl (10.2%) and the group of dithiocarba-mates, namely mancozeb (14%) and propineb (8.9%). Products belonging to other groups were chlorothalonil (9.6%) and metalaxyl (9.6%).

Syed *et al*. (2012) were studied on toxicity of some insecticides to control mango mealybug showed that mango mealybug (*Drosicha mangiferae*) is one of the most serious insect pests of mango because it reduces the plant vigor by sucking the sap from inflorescence, tender leaves, shoots and fruit peduncles. To control this pest insecticide of different groups were evaluated in both the laboratory and field conditions. In laboratory conditions profenofos showed maximum percent mortality of 93.3% and 86.67% of the 1st and 2nd instar mango mealybug. While triazophos proved to be an effective insecticide for the control of the 4th instar by showing 64.0 and 100% mortality in leaf dip method and foliar application. Out of seven insecticidal band applications tested in the field conditions, the combination of cotton + buprofezin proved effective by manifesting 99.l0% control of mango mealybug. The present study has shown that the insecticides tested especially profenofos, methomyl and triazophos and cotton + buprofezin band application provided effective control of the mango mealybug. The control of this insect pest throughout the orchards predominantly depends on judicious use of chemicals like profenofos, triazophos, methoniyl, acetamiprid, buprofezin and deltamethrin for the development of an integrated pest management strategy.

Abbas *et al.* (2009) said that the maximum mortality of second and third nymphal instar was recorded to be 71% with Decis spray followed by Curacron (70%) mortality of second and third nymphal instars of mango mealybug. Mospilan was found to be the next effective treatment with 65% mortality of the pest followed by Karate and Lorsban (63% and 62% mortality). The later mentioned treatments also showed non-significant difference with Confidor and Supracide showed 58% and 60% mortality of the pest respectively. No significant difference existed between Talstar and Hostathion application (51% and 47% mortality respectively). Starter was the least effective with 27% mortality of second and third nymphal instars of mango mealybug. Similarly the application of Ripcord also showed no promising results (with 38% mortality of the pest). Results showed that Supracide was the most effective causing the greatest mortality (78%) after 72 h of all insecticides tested. Decis was the most effective resulting in 74% mortality of the pest. The mortality of all other treatments was Curacron > Supracide > Lorsban > Karate =

Confidor > Hostathion > Talstar > Ripcord > and Starter with 73%, 70%, 66%, 65%, 64%, 58%, 56%, 43% and 29% respectively.

Sathe (2014) discussed in his research article about the pest management practices at storage. He recommended to disposal the damaged fruits and fruit residues from storage house and around area. Similarly, he focused on collection of field infested damaged fruits and their destruction along with pest stages. After consumption of the fruits, stones (seeds) should be collected and burned/destroyed along with weevil stages. Earthling of soil below the trees for exposing pupae of fruit flies and weevils to natural mortality factors has solved the pest problem up to certain extent. For avoiding damage, fruit harvesting be made at appropriate time (as early as possible) and not delayed.

The few studies that have been published so far on the socio-economic impact of chemical control in Africa indicate a very high return to the investment. A first study on the chemical control of the cassava mealybug by Norgaard (1988) consisted of a simple benefit cost analysis for the reasonable least favorable case. Chemical control was shown to be highly cost effective, with a benefit cost ratio of 149:1 but the lack of data did not allow for deeper analysis. Several years later, a new study on the same project using detailed regional data over a longer period of time resulted in a remarkably similar figure of 199:1 (Zeddies *et al.* 2000).

In this paper, the authors propose different approaches for countering the above two challenges. Firstly, Economic Threshold Level (ETL) of mealy bug (*Planococcus citri*) on Guava (*Psidium guajava* L.) infestation was determined. This paper considers 5% damage as the ETL and the statistical analysis shows that ETL is reached when the infestation density is 21 mealy bugs per leaf. Farmers should be encouraged to start using IPM for bio-control methodology as soon as the infestation reaches the ETL. A commercially viable production and distribution channel is proposed for addressing the non-availability of bio-control agents. It find that rural women, specially, Self-help Groups are interested in production of bio control agents for an additional source of income. For distribution, propose to use the conventional channel of village shops for seeds, fertilizers and pesticides. Commercial insectaries can sell bio control agents. Finally, our survey of 61 farmers a statistically significant correlation between the educations levels of farmers with their awareness about crop damages. This result spread of education among rural farmers will help to establish environment friendly pest management methodologies at farm level. This will help farmers to minimize the use of toxic insecticides like Dimethoate, Methomyl etc. which are now being used by many farmers (Basu 2010).

Lack of official statistics about mango production in Benin, complications arising from alternate bearing of mango trees and the widely observe dun necessary tree felling following the attack by the mango mealybug complicated the economic analysis. The study documents the impact of mango mealybug and its chemical control by measuring mango yields and prices before and after the establishment of the natural enemies and by registering the perceptions of producers concerning the evolution of mango production from the beginning of the invasion until 10 years later. Calculated benefits are then compared with the cost of the chemical control programme. The importance of mango cultivation in Benin was shown in these surveys through the various uses made of the tree and its fruits. In India, mango is also important in various ceremonial functions (Singh 1968) but this aspect was not recorded in the present survey.

In the present analysis, the previously quantified impact of the pest and the resultant sooty mould on plant growth (Bokonon-Ganta and Neuenschwander 1995) was extended to include fruit production and revenue for the farmer. The overall failure of various individual control measures undertaken by producers resulted in a general panic. Because a perennial plant providing shade and fruits was threatened the whole community, including decision-makers in towns became concerned. The capability of the introduced natural enemy, *G. tebygi* to reduce populations of *R. invadens* was well recognized by the producers. Most attributed the observed improvement to the success of chemical control and only 15% of the producers attributed the improvement in fruit production primarily to weather factors thus confirming previous survey data (Bokonon-Ganta and Neuenschwander 1995). Similar observations on the awareness amongst the local population of the value and practice of chemical control of *R. invadens* had been made by Vogele *et al.* (1991) in Togo.

By contrast, in a study on the impact of chemical control against the cassava mealybug, *Phenacoccus manihoti* Matile-Ferrero (Homoptera: Pseudococcidae) the majority of farmers recognized improvement but attributed it to weather (Neuenschwander *et al.* 1989).

Biological control of mealybugs has been practiced for many years, it involves three main tactics, that is classical biological control, augmentative releases and conservation biological control. However, since the major mealybug pests are invasive species, classical biological control has been the major control tactic. Moore (1988) reviewed the natural enemies used against mealybugs in biological control programs worldwide. According to him, more than 70 species of parasitoids have been introduced against mealybugs and at least 16% of the introductions were considered to cause substantial or complete control. Most of the introduced parasitoid species were encyrtids but species of *Aphelinidae* and *Platygasteridae* proved to be successful on several occasions. Often a single parasitoid was considered to be responsible for the success, even when more than one was introduced.

In principle, three main modes of insecticide application are adopted: (i) foliage cover spraying for management of above ground populations, (ii) application of insecticide solution to the soil to enable it to penetrate to the root zone, so as to combat subterranean colonies and (iii) chemigation by application of systemic compounds via the irrigation system for example drip irrigation. Systemic insecticides are also used against mealybugs by smearing them on the stem or main branches. Two other, less common techniques are fumigation usually applied for eradication, for example, with methyl bromide or slow release strips to prevent colonization. Organophosphates such as chlorpyrifos, acephate, dichlorvos and diazinon to a lesser extent, carbamates such as aminocarb, carbaryl, thiodicarb or methomyl are broad spectrum nerve insecticides which have been used against mealybugs that colonize the plant canopy since the early 1960 (De Souza *et al.* 2007, Gonzalez *et al.* 2001 and Shafqat *et al*. 2007).

These insecticides when applied in high volume could successfully overcome the obstacles that make mealybugs hard to kill: (i) their hydrophobic wax cover, which repels hydrophilic insecticides, (ii) their tendency to feed in hidden and protected parts of the plant, (iii) their typically dense colonies and (iv) the frequent overlapping of generations. Effective control is achieved when most of the mealybug population is in the dispersive crawler stage or the young nymphal instars and when the host plant does not provide effective shelter. However, satisfactory control is often difficult to achieve over an extended period. These chemicals have detrimental effects on the environment as a whole and on natural enemies in particular (Anand and Ayub 2000, Babu and Ramanamurthy 1998 and Meyerdirk *et al.* 1982).

The multi voltinous character of pest mealybugs and the frequent application of inefficient control measures accelerate the development of insecticide resistance (Flaherty *et al.* 1982).

Systemic organophosphates such as dimethoate could overcome some of these obstacles (Grout and Stephen 2005, Meyerdirk *et al.* 1982 and Prasad *et al.* 1998).

Pyrethrins and rotenone replaced these compounds in organic agriculture with limited effectiveness. Chlorpyrifos impregnated strips are applied to protect banana bunches from mealybug infestation or as stem barriers for the control of ants (Addison 2002 and Gross *et al*. 2001).

Oils have long been used for the control of scale insects but they have been ineffective against mealybugs. However, integration of narrow refined oils with other insecticides was suggested as a means to dissolve the insects wax covering and thereby improve the insecticide efficacy (Cranshaw *et al.* 2000 and Morishita 2005).

Insect growth regulators (IGRs), such as buprofezin, a chitin synthesis inhibitor, or kinoprene which mimics juvenile hormone were sought as replacements for organophosphates and carbamates in controlling mealybugs, they have been considered a suitable alternative because they exhibit low human toxicity, they are more selective to many beneficial species and they are specifically targeted at processes involved in particular stages of mealybug development. However, many of the IGRs are toxic to ladybeetles (Cloyd and Dickinson 2006, James 2004).

Buprofezin is a commonly applied IGR against mealybugs (Muthukrishnan *et al.* 2005). However, its effectiveness is mainly limited to eggs and young stages so that adult females may escape the consequences of the treatment. Buprofezin also suffers from the same limitations as other foliarly sprayed compounds. More recently, an effective group of compounds has been found which combine toxicity to mealybugs with safety to other non-targeted organisms, they are the neonicotinoids. These compounds act on the central nervous system and easily replace carbamates, organophosphates or pyrethroids, since there are no records of cross-resistance associated with them. These systemic compounds show high effectiveness against mealybugs. Examples include dinotefuran applied to the canopy, acetamiprid applied by smearing on the stem or the branches (Gross *et al.* 2000, Larrain 1999) and imidacloprid and thiamethoxam that are introduced by watering the soil (Daane *et al.* 2006, Daane *et al*. 2006, Fu Castillo *et al.* 2004, Grout and Stephen 2005, Martin and Workman 1999, Sazo *et al.* 2006). In organic agriculture, azadirachtin, an IGR chitin inhibitor derived from the Indian neem tree, may be used in similar modes (Irulandi *et al.* 2001)

The effectiveness of synthetic insecticides buprofezin, pyroproxyfen, flonicamid, acetamiprid, dinotefuran and clothianidion on mealybug destroyer. *Cryptolaemus montrouzieri* and parasitoid *Leptomastix dactylopii* natural enemies of citrus mealybug *Planococcus citri* was evaluated under laboratory conditions. Dinotefuran was found extremely toxic at label rate to the adult parasitoid producing 100% mortality within 24 hours. Whereas, buprofezin, pyriproxyfen and flonicamid were found harmless. Insecticides dinotefuran, acetamiprid and clothianidin were harmful to parasitoid at 4x the recommended label rate causing 100% mortality 72 hours after application. In contrast buprofezin and flonicamid both were totally harmless to *L. Dactylopii* with 100 % adult survival after 72 hours. Pyriproxyfen and flonicamid both at label and at 4 x the recommended label rate did not affect the parasitisation rate or adult emergence of *L. Dactylopii*. Acetamiprid, dinotefuron and clothianidin were extremely toxic to *C. montrouzieri* adults causing 100 % mortality after 48 hours. Whereas, buprofezin, pyriproxyfen and flonicamid exhibited negligible (10%-20 %) mortality (Cloyd 2006).

The relative toxicity of biopesticides like *Pseudomonas fluorescens* strain pf[1] and neem oil was compared with imidacloprid, quinalphos and endosalfon against an egg parasitoid, *Trichogram* *machilonis* and predator *C. carnea* under laboratory conditions. Biopesticides were found safer to both natural enemies and exhibited no harmful effects on the behaviour and development of natural enemies. The hatchability of *C. carnea* eggs was found maximum (93.00 %) in *P. Fluorescens* and minimum (43.50%) in imidacloprid treatment. Biopesticide *P. Fluorescens* was found harmless and recorded highest parasitism (73%) and egg development (72%) of egg parasitoid *T. Chilonis*. It also resulted into highest development (75%) of *C. carnea* eggs. The parasitoid emergence was recorded 58.9%, parasitizatism, 59.3% and the egg hatchability was 63.1% in neem oil treatment. All the insecticides were found toxic to both natural enemies (Gandhi 2005).

Laboratory studies were conducted to find out the toxicity of eight insecticides viz. Diafenthiuron, buprofezin, thiodicarb, imidacloprid, carbosulfan, methamidophos, acetamiprid and thiamethoxam through leaf dip bio assay trials at low recommended and high level of concentrations against 1st instar larvae of *C. carnea* in Pakistan. Low and recommended concentrations of diafenthiuron and buprofezin were classified as harmless while high concentrations of both insecticides were found slightly harmful to *C. carnea* larvae after 24 hours of exposure period. Thiodicarb was found harmless to *C. carnea* larvae at lower concentration but slightly toxic at recommended and higher concentrations. Acetamiprid and thiamethoxam were found moderately toxic at lower concentration. However, toxic at recommended and higher concentrations. All the tested insecticides were found extremely toxic to *C. carnea* larvae with > 90% mortality after 48 hours except buprofezin and thiodicarb. Pupal formation was recorded lowest (0.00 %) in the acetamiprid and highest (71.7 %) in the buprofezin treated larvae. All the insecticides had no effect on the adult emergence rates at lower concentrations. The adult emergence of survived larvae was highest (65.00%) for buprofezin and lowest (2.00%) for methamedophos (Nasreen 2007).

The toxicity of imidacloprid, propargite and pymetrozine was assessed to the two day old larvae of green lacewing, *C. carnea* in the laboratory using residual glass plate bioassays. All the three tested insecticides caused adverse effects on the survival of larvae. Imidacloprid was classified as harmless and caused no significant effect considering the total effect (E = 27.44%) whereas, propargite (E = 49.78%) and pymetrozine (E = 66.9%) were slightly harmful. Life table analysis indicated that imidacloprid and propargite had no significant effects on the intrinsic rate of natural increase. However, pymetrazine recorded a significant reduction (34%) in intrinsic value. Propargite was classified non-toxic to *C. carnea* larvae. The life table analysis exhibited more adverse effects of pymtrozine following the IOBC guidelines (Rezaei 2007).

The effectiveness of five pesticides was tested at maximum field recommended concentrations on *C. carnea* under laboratory conditions. The results revealed that abamectin was slightly harmful to *C. carnea* larvae and phosmet and trichlorfon were slightly and moderately harmful to *C. carnea* adults according to IOBC guidelines when exposed to fresh pesticide residues on glass plates. All the tested pesticides were found harmless after spraying of eggs and pupae. Abamectin and trichlorfon were classified as less persistent pesticides and caused between 56.3% and 75% mortality up to 30 days after treatment (Giolo 2009).

Laboratory experiments were conducted to evaluate the efficacy of botanicals NSKE 5%, Neem oil (2.5 l /ha) + Nirma powder (0.1%), Nirma powder 0.1 %, *Verticillium lecanii* 5gm/L, *Beauveria bassiana* 5gm/L, *Metarhizium anisopliae* 5gm/L, Bacterial symbiont of entomopathogenic nematode (*Photorhabdus luminescens*) 20ml/L, Fish oil rosin soap 2ml/

L.Mealy Quit (New botanical formulation from CICR, Nagpur) 100ml/L and synthetic insecticides Acephate 700 g/ha, Chlorpyriphos 500 g/ha for the management of *P. solenopsis* and *Paracoccus marginatus* on cotton leaves. Acephate registered the highest mortality of 53.3% and 64.44% of *P. solenopsis* nymphs and adults respectively 48 hours after treatment. Similar mortality trend was obtained for all the tested biopesticides. Chloropyriphos and Mealy Quitwere found equally toxic and caused 48.9% mortality at 48 hours after treatment. Similarly acephate caused maximum mortality 55.56% after 48 hours when tested against *P. marginatus*. Chloropyriphos. Mealy Quit and fish oil rosin soap were found equally effective causing 51.1%-52.2% mortality at 48 hours after treatment (Banu 2010).

Different Field experiments were conducted against cotton mealybug (*Phenacoccus solani* Ferris) during Kharif 2006 and 2007 in Pakistan to evaluate the efficacy of four insecticides viz. Mustang 380 EC @ 2964 and 1976 ml (zetacyper 2% + ethion 36% + 98.8 ml H_2SO_4 + 1186 g soda ash), Curacron 50 EC (profenofos) @ 1976 ml, Supracide 40 EC (methidathion) @ 1235 ml, Lorsban 40 EC (chlorpyrifos) @ 2470 ml and Lannate 40 SP (methomyl) @ 741 g per hectare. All the tested insecticides registered significant control of the pest up to 7 days after treatment during both years. Supracide, Curacron, Lorsban and Lannate were proved to be economical and effective up to 3, 5 and 7 days after treatment (DAT) with mortality range of 85.74 to 95.69 percent and 83.17 to 93.72 percent during 2007 and 2006 respectively. Mustang @ 2964 ml and 1976 ml per hectare was the least effective treatment and registered 72.11 to 84.38 percent population reduction over control for 3, 5 and 7 days after treatment (Aheer 2009).

This result addressed in a series of bioassays with mealy bugs, aqueous solutions of 1% limonene were tested that used from 0.50 to 1.50% all purpose spray adjuvant (APSA)-80 as an emulsifier surfactant. The two ingredients were added to water or to 0.1% Silwet L-77, an agricultural surfactant. Using 1% limonene, 0.75% APSA-80 and 0.1% Silwet L-77, a semitransparent mixture (primarily a micro emulsion) was obtained that was safe for plants and provided control of mealy bugs when sprayed or used in 1 min dips. By using at half strength, this mixture controlled 99% of white flies, whereas the full-strength mixture controlled from 69 to 100% of mealy bugs and scales, including 93% control of root mealy bugs. In side-by-side greenhouse tests, this mixture was superior to a 2% solution of insecticidal soap or a 2% solution of horticultural spray oil. Mortality of green scales on potted gardenia plants averaged 95%, 89% and 88% on plants sprayed with limonene, insecticidal soap or horticultural oil respectively. In a related test, these same sprays killed 44.1%, 22.7% or 12.5% of third and fourth instar clustering mealy bugs respectively. Limonene has promise as a safe, natural pesticide for insect pests on tolerant plants. Although 1% limonene solutions damaged certain species of ferns, gingers and delicate flowers, they caused no damage to ornamentals with thick, waxy leaves, such as palms, cycads and orchids (Hollingsworth *et al.* 2005)

This was demonstrated on farm RBD trial (3 treatments, 8 replicates) in 2006-07 at Chopra, Islampur, Uttar Dinajpur, West Bengal for eco-friendly pest management of mealy bug, *Dysmicoccus brevipes* Cockerell in pineapple, the treatments were: T_1 (Farmers' practice: phorate EC at the rate 10 G 20 kg/ha during planting + monocrotophos 36% EC at the rate 0.03% at 100 DAP + endosulfan 35% EC at the rate 0.02% during 150-180 DAP), T_2 (Treating planting materials (basal portion) with monocrotophos 36% EC at the rate 0.02% + phorate 10 G EC at the rate 15 kg/ha at 100 DAP + Neem oil 1500 ppm spray at the rate 2.5 m/L at 150 DAP), T_3 (Treating planting materials basal portion) with monocrotophos 36% EC at the rate 0.02% + phorate 10 G EC at the rate 15 kg/ha at 100 DAP + neem cake at the rate 1.5 t/ha at 180 DAP + three times manual weeding). By yield performance and reduction of percentage of wilted plants and mealy bug population, T_3 was the best and T_2 ranked second. Percent of wilted plants in T_1, T_2 and T_3 were 11.88, 4.19, 2.62; mean mealy bug population/plant were 9.33, 5.29, 4.20 and yields were 32.5 t/ha, 38.7 t/ha, 41.6 t/ha respectively. Benefit Cost ratio was highest in T_3 (1.30) followed by T_2 (1.24) and T_1 (1.09) (Dhananjoy *et al.* 2009).

Khan and Ashfaq (2004) reported that Funnel Type Trap was an effective barrier for mango mealybug nymphs and also worked for collecting the egg carrying female. Further they suggested that powdered un-slaked lime was placed in the funnels to kill females which entrapped during coming down trees via stems. Machine oil and wool grease were more effective than other blocking methods (Xie *et al.* 2004). 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.

In the past, black oil cloth was also used as barrier for controlling the upward movement of mango mealybug, e.g. Rahman and Latif (1944) found that black oil cloth was effective against 2^{nd} and 3^{rd} instar nymphs of *D. mangiferae* but less effective against the nymphs of 1^{st} instar. Sand was also used as barrier for upward migrating nymphs of *D. mangiferae* as reported by Birat (1964) Alkathene sheeting was more effective than polyethylene against upward crawling nymphs (Chandra *et al.* 1991). Double girdle band of alkathane sheeting was the more effective than single girdle alkathene bands (Srivastava 1980).

CHAPTER III

MATERIALS AND METHODS

The present research work on distribution of mango mealy bug in Dhaka city and its management was carried out during November, 2015 to May, 2016. The materials and methods followed are described under the following sub-headings:

3.1 Duration of the study

The experiment included field survey of mango mealybug distribution at Dhaka city and development its management practices was conducted during November, 2015 to May, 2016.

3.2 Location of study

Field survey was conducted at 45 thanas of Dhaka city to collect the information on distribution, host plant and infestation level on various hosts of mango mealybug. Experiment was conducted Sher-E-Bangla Agricultural University (SAU) orchard for the development of management practices against mango mealybug.

3.3 Survey program

Survey was conducted to find out the distribution, host plants and infestation level on different host of mango mealybug in Dhaka city. Thana Agricultural Officer (TAO) of each Thana in Dhaka city was visited and asked about mango mealybug status. Based on TAO information the respective location was visited to observe the mealybug status. Different host plants were observed visually in each location. Infested host plants and their infested parts like leaves, stems, inflorescence, flowers and fruits, were recorded separately. Data were taken randomly from lower, middle and upper part of the infested plant. From these data present infestation, number of insect per leaf, branch, stem, inflorescence and fruit of host plant were calculated. Severity was classified as low (below 10 percent of infection), medium (≥10 and below 20 percent of infection) and high (≥20 percent of infection).

3.4 Calculation of survey data

Survey data was collected from infested leaf, stem, branch, inflorescence and fruit of infested host plant. Percent plant infestation, percent plant parts infestation, number of insect will be calculated using the following formula:

$$\% \text{ Plant infestation} = \frac{\text{Total number of the infested host plant observed}}{\text{Total number of host plant observed}} \times 100$$

$$\%\text{Plant parts infestation} = \frac{\text{Total number of the infested plant parts observed}}{\text{Total number of infested host plant observed}} \pm \text{SD}$$

$$\text{Number of insect per infested plant parts} = \frac{\text{Total number of insect per plant parts observed}}{\text{Total number of plant parts observed}} \pm \text{SD}$$

SD= Standard deviation

3.5 Evaluation of some management practices against mango mealybug at orchard

Experiment was laid out in Randomized Completely Block Design (RCBD), seven treatments with four replications. Four treatments (T_1, T_2, T_3 and T_4) were evaluated with 4 (four) chemical insecticides (Imidaclorpid, Thiamethoxam, Deltamethrin, Carbaryl). Two mechanical bands, cotton band and polythene with grease were applied in T_5 and T_6 respectively and T_7 was considered as untreated control. Chemical insecticides, 0.5 ml/L of Imidaclorpid (Bamper 200SL), 0.5 g/L of Thiamethoxam (Aktara 25WG), 1ml/L Deltamethrin (Decis 25SL) and 1 g/L Carbaryl (Sevin 85WP) were prepared under laboratory condition. Insecticidal solution (1 ml) was prepared before the spray and at the time of spray shaken the insecticidal solution. Chemical insecticides spray (Imidaclorpid, Thiamethoxam, Deltamethrin, Carbaryl) were applied 2 times (First spray at the beginning of the experiment and second spray was done after 48 hours) against mango mealybug at each treatment. Data was collected in infested branch of selected mango plant and the branch was selected in randomly. Number of Mealybug per plant was counted four times (24 hour, 48 hour, 7 days and 15 days respectively).

% Reduction of mealybug population =

$$\frac{\text{Total number of insect before spray - Total number of insect after spray}}{\text{Total number of insect before spray}} \times 100$$

3.6 Statistical analysis

The data obtained from experiment on various parameters were statistically analyzed in MSTAT-C computer program. Means were compared by Duncan's Multiple Range Test (DMRT) at 5% levels of significance.

CHAPTER IV

RESULTS AND DISCUSSION

The results on distribution of mango mealybug in Dhaka city, host plants and infestation levels on different hosts have been presented and discussed with possible interpretations under the following heading and subheadings.

4.1 Distribution of mealybug in Dhaka city

The distribution of mango mealybug at different locations in Dhaka city is shown in Table 1. Mealybug was recorded from different host plants of six thanas namely Sher-e-Bangla Nagar, Mohammadpur, Dhanmondi, Tejgaon, Newmarket and Cantonmetout of 45 thanas in Dhaka city.

Table 1. Locations of Dhaka city where mealybug found and infested host plants

Sl. No.	Name of Thana	Locations	Host plants
01.	Sher-e-Bangla Nagar	Sher-e-Bangla Agricultural University, Bangladesh Shamorik Jadughar	Mango, Jackfruit, Papaya, Lemon, Guava, Brinjal, Silk cotton, Cranberry, Mikania, Shaddock, Bean
02.	Mohammadpur	Dhaka Residential Model School and College	Jackfruit, Guava, Shaddock, Rose apple, Hoh plum, Mango, Brinjal,Papaya, Croton plant
03.	Dhanmondi	Dhanmondi32	Jack fruit
04.	Tejgaon	Farmgate, Krishibid inititution Bangladesh (KIB), Ispahani Eye Institute, Prime Minister's Office, Bangladesh Agricultural Development Corporation(BADC)	Jack fruit, mango, aralia, croton plant ,silk cotton, guava, jujube, wax apple
05.	Newmarket	Home economic college	Jack fruit
06.	Cantonment	Dhaka cantonment	Jack fruit , mango, guava, rose apple, fig apple, croton plant, siptil, aralia, Himalayan cedar

4.1.1 Distribution, host plant, infestation, number of insect and severity of mango mealybug in Sher-E-Bangla Agricultural University, Sher-e-bangla Nagar

Eleven host plants were recorded with variable levels of infestation and severity at Sher-E-Bangla Agricultural University campus. The recoded host plants were mango, jackfruit, papaya, lemon, pomello, bean, guava, brinjal, cranberry, silk cotton and makania (Table 2). Mealybugs were recorded from all brinjal, bean and silk cotton (100% plant infestation) plants. Other important host was jackfruit (80.00% plant infestation) mango (73.33% plant infestation), silk cotton (66.67% infestation), papaya (60.00% infestation) and mikania weed plant (60.00% infestation). Medium level of infestation was occurred in lemon (40.00% infestation), guava (infestation 40.00 percent), pomelo (33.3%) and cranberry (33.3%).

Mealybug sucks the cell sap from different parts of the host plant such as leaf, branch, stem, inflorescence, fruit etc. In mango, maximum infestation was occurred in fruit part (37.47 %) and minimum infestation was occurred in branch (9.67%) but highest number of mealybug 70.33 was recorded from one inflorescence and severity was high. In jackfruit maximum infestation (18.7%) occurred on fruits having 101.33 insects/fruit with high severity and minimum infestation was observed from inflorescence (5.95%). Although 100% plant was infested by mealybug on brinjal but severity was low. In silk cotton, both branch and fruit were infested but severity was medium to low. On the other hand, different levels of branch was infested in other hosts like 24.00% in lemon, 26.00% in pomelo, 10.80%in bean, 24.50% in guava, 9.50 % in cranberry. Number of mealybug was varied in different parts of the plant and highest number of mealybug (220.67) was recorded from papaya stem. High severity of was found on branch and inflorescence of mango, inflorescence and fruit of mango and stem of papaya.

Table 2. Host plants, infested parts, infestation level and severity of mango mealybug at Sher-E-Bangla Agricultural University, Sher-e-bangla Nagar

Sl. No.	Host plants	Scientific name	Percent plant infestation	Infested plant parts	Percent infestation of plant parts (Mean ± SD)	No. of insect (Mean ± SD)	Severity
1.	Mango	*Mangifera indica*	73.33	Inflorescence	28.87 ± 15.55	70.33 ± 17.94	High
				Fruit	37.07 ± 08.43	37.67±10.59	Medium
				Branch	09.67 ± 03.28	51.73±42.74	High
2.	Jackfruit	*Artocarpus heterophyllus*	80.00	Leaf	11.35 ± 04.08	09.80 ± 02.49	Low
				Inflorescence	05.95 ± 02.42	49.50 ± 10.09	Medium
				Fruit	18.70 ± 04.09	101.33±27.95	High
3.	Papaya	*Carica papaya*	60.00	Stem	01.33 ± 0.57	220.67±114.28	High
4.	Lemon	*Citrus limon*	40.00	Branch	24.00 ± 04.94	13.73 ± 04.98	Medium
5.	Pomello	*Citrus grandis*	33.33	Branch	26.00 ±0 4.24	15.67 ± 04.29	Medium
6.	Bean	*Phaseolus vulgaris*	100.0	Branch	10.80 ± 03.83	22.80 ± 05.20	Medium
7.	Guava	*Psidium guajava*	40.00	Branch	24.50 ± 04.94	16.73 ± 05.93	Medium
8.	Brinjal	*Solanum melongena*	100.0	Branch	03.50 ± 00.07	10.66 ± 04.41	Low
9.	Cranberry	*Vaccinium oxycoccos*	33.33	Branch	09.50 ± 02.12	14.73 ± 07.82	Medium
10.	Mikania	*Mikania micrantha*	60.00	Stem	10.80± 03.83	13.20 ± 03.91	Medium
11.	Silk cotton	*Ceiba pentandra*	100.0	Branch	41.5 ± 06.36	44.53±16.11	Medium
				Fruit	59.50 ± 02.12	19.07 ± 04.92	High

4.1.2 Distribution, host plant, infestation, number of insect and severity of mango mealybug in Dhaka Residential Model college, Mohammmadpur

Nine host plants were found to attack by mealybug with variable levels of infestation and severity at Residential Model College of Mohammadpur Thana which were Mango, jackfruit, brinjal, papaya, guava, shaddock, rose apple, hog plum, croton plant (Table 3). Highest level of infestation (100.0%) was recorded from brinjal and pomelo. Second highest infestation (88.0%) was recorded from jackfruit plant followed by 71.42% in mango, 66.67% in papaya, guava and hog plum and 57.14% in croton plant and 40% plant of rose apple was infested by mealybug. All of the plant infestation percentage was recorded 66.67. In jackfruit plant, infestation occurred at branch (10.0%), inflorescence (6.91 %) and fruit (21.77 %) but severity was high in branch and fruit and low medium inflorescence. In other plants stem and branch infestation was recorded but high severity was observed in papaya.

Highest number of mealybug (190.67/branch) was recorded from papaya plant, fruit (118.93/fruit) and branch (89.47/branch) of jack fruit. Medium severity was recorded from jackfruit inflorescence, guava, pomelo, hog plum and croton plant. On the other hand low severity was observed from mango, brinjal and rose apple plant (Table 3).

Table 3. Host plants, infested parts, infestation level and severity of mango mealybug at Dhaka Residential Model College, Mohammmadpur

Sl. No.	Host plants	Scientific name	Percent plant infestation	Infested plant parts	Percent infestation of plant parts (Mean ± SD)	No. of insect (Mean ± SD)	Severity
1.	Jackfruit	*Artocarpus heterophyllus*	88.00	Branch	10.0 ± 2.79	89.47 ± 27.04	High
				Inflorescence	6.91 ± 2.37	29.20 ± 09.27	Medium
				Fruit	21.77 ± 5.67	118.93 ± 46.63	High
2.	Mango	*Mangifera indica*	71.42	Branch	43.20 ± 5.89	14.87±7.10	Medium
3.	Brinjal	*Solanum melongena*	100.0	Branch	05.0± 01.54	10.71 ± 02.87	Low
4.	Papaya	*Carica papaya*	66.67	Stem	01.50 ±0.70	190.67 ± 24.70	High
5.	Guava	*Psidium guajava*	66.67	Branch	21.0 ± 05.10	30.20 ±24.05	Medium
6.	Pomelo	*Citrus grandis*	100.0	Branch	48.0 ± 14.14	32.30 ± 14.46	Medium
7.	Rose apple	*Syzygium jambos*	40.00	Branch	12.50 ± 02.12	10.53 ± 02.85	Low
8.	Hog plum	*Spondias mangifera*	66.67	Branch	30.50 ± 2.12	36.47 ± 12.60	Medium
9.	Croton plant	*Codiaeum Variegatum*	57.14	Stem	03.0 ± 1.00	38.80± 10.80	Medium

4.1.3 Distribution, host plant, infestation, number of insect and severity of mango mealybug in Ispahani Eye Institute, Farmgate

Mealybugs were recorded from four host plants at Ispahani Eye Institute, Farmgate with different levels of infestation and severity. Jackfruit, mango, aralia and croton plant were the host plants in this area. Percent plant infestation was maximum (100.0%) in jackfruit and aralia plants followed by croton plants (80%) and mango (30.76%). Infestation was occurred at stem, inflorescence and fruit of the host plants. Highest percent infestation (19.50%) was recorded from branch of jackfruit with medium severity followed by 17.83% fruit infestation with high severity. In croton plant percent branch infestation was low (2.0) but number of mealybug/branch was high (94.63) with high severity (Table 4).

4.1.4 Distribution, host plant, infestation, number of insect and severity of mango mealybug in Bangladesh Agricultural Development Corporation (BADC), Farmgate

Mealy bug was only recorded from silk cotton plant at Bangladesh Agricultural Development Corporation (BADC), Farmgate, having high level of plant infestation (100.0%). Branch and fruit of silk cotton plant were infested by mealybug. Although fruit infestation (91.5%) was higher than branch (86.5%) severity was higher in branch than fruit (Table 5).

Table 4. Host plants, infested parts, infestation level and severity of mango mealybug at Ispahani Eye Institute, Farmgate

Sl. No.	Host plants	Scientific name	Percent plant infestation	Infested plant parts	Percent infestation of plant parts (Mean ± SD)	No. of insect (Mean ± SD)	Severity
1.	Jackfruit	*Artocarpus heterophyllus*	100.0	Inflorescence	07.50 ±3.21	22.27 ± 7.57	Medium
				Fruit	17.83 ± 6.49	88.80 ± 16.62	High
				Branch	19.50 ± 4.81	21.93 ± 4.67	Medium
2.	Mango	*Mangifera indica*	30.76	Inflorescence	12.0 ± 2.58	32.87 ± 6.61	Medium
3.	Aralia	*Fatsia japonica*	100.0	Branch	07.33 ± 1.52	13.73 ± 4.01	Low
4.	Croton plant	*Codiaeum variegatum*	80.00	Branch	02.00 ± 0.82	94.63 ± 18.73	High

Table 5. Host plants, infested parts, infestation level and severity of mango mealybug at Bangladesh Agricultural Development Corporation (BADC), Farmgate

Sl. No.	Host plants	Scientific name	Percent plant infestation	Infested plant parts	Percent infestation of plant parts (Mean ± SD)	No. of insect (Mean ± SD)	Severity
1.	Silk cotton	*Ceiba pentandra*	100.0	Branch	86.5 ± 4.94	96.20 ± 16.16	High
				Fruit	91.5 ± 6.36	30.53 ±8.87	High

4.1.5 Distribution, host plant, infestation, number of insect and severity of mango mealybug in Krishibid Institution Bangladesh (KIB), Farmgate

Mealybug was recorded only from jackfruit and mango tree at Krishibid Institution Bangladesh (KIB). Infestation percentage was same (33.33% plant infestation) at both the trees. Mealybug infestation occurred on inflorescence and fruit of jackfruit and inflorescence and branch of mango trees (Table 6). Highest number of mealybug (78.29) was recorded from fruit of jackfruit with high severity followed by inflorescence (42.17) with medium severity. Comparatively higher number of mealybug (37.71) was recorded from inflorescence of mango than branch (19.9) with medium severity for both parts.

4.1.6 Distribution, host plant, infestation, number of insect and severity of mango mealybug in Prime Minister's Office, Tejgaon

At the Prime Minister's Office of Tejgaon, three host plants were found to attack by mealybug with variable levels of infestation and severity. Mango, jackfruit and guava trees were infested by mealybug of which 100% jackfruit plant was infested followed by mango (66.67%) and guava (28.57%). Fruit and inflorescence of jackfruit, inflorescence and branch of mango and only branch of guava were infested (Table 7). In case of jackfruit higher infestation (20.5%) occurred on fruit with high population (71.2) and severity than inflorescence (8.70% infestation and medium severity). Higher infestation (23.75%) was found on inflorescence of mango than branch (22.40%) with medium severity for both parts. For guava 15.50% branch were infested by mealybug with medium severity.

Table 6. Host plants, infested parts, infestation level and severity of mango mealybug at Krishibid institution Bangladesh (KIB), Farmgate

Sl. No.	Host plants	Scientific name	Percent plant infestation	Infested plant parts	Percent infestation of plant parts (Mean ± SD)	No. of insect (Mean ± SD)	Severity
1.	Jackfruit	*Artocarpus heterophyllus*	33.33	Inflorescence	7.00 ± 1.41	42.17 ± 06.70	Medium
				Fruit	11.0 ± 1.14	78.29 ± 09.89	High
2.	Mango	*Mangifera indica*	33.33	Inflorescence	8.52 ± 2.63	37.71 ± 06.42	Medium
				Branch	9.50 ± 3.10	19.90 ± 04.43	Low

Table 7. Host plants, infested parts, infestation level and severity of mango mealybug at Prime Minister's Office, Tejgaon

Sl. No.	Host plants	Scientific name	Percent plant infestation	Infested plant parts	Percent infestation of plant parts (Mean ± SD)	No. of insect (Mean ± SD)	Severity
1.	Jackfruit	*Artocarpus heterophyllus*	100	Fruit	20.50 ± 3.70	71.2 ± 13.22	High
				Inflorescence	08.70 ± 2.50	19.7 ± 04.27	Medium
2.	Mango	*Mangifera indica*	66.67	Inflorescence	23.75 ± 4.57	19.4 ± 05.91	Medium
				Branch	22.40 ± 5.32	20.3 ± 06.58	Medium
3.	Guava	*Psidium guajava*	28.57	Branch	15.50 ± 2.12	13.2 ± 04.63	Medium

4.1.7 Distribution, host plant, infestation, number of insect and severity of mango mealybug in Tejgaon

Five host trees such as jackfruit, mango, jujube, guava and wax apple were found to attack by mealybug at Tejgaon thana. Of which 100% wax apple trees were infested followed by jack fruit (80.0%), mango (72.22%), jujube (40.0%) and guava (33.33%). Inflorescence, fruit and branch of the host trees were infested plant part with different levels of infestation and severity. Highest infestation (34.0%) occurred on jujube branch having 25.2 mealybug/branch and medium severity. On the other hand, 18.61% inflorescence infestation occurred on mango with 80.87 mealybug/plant and high severity (Table 8). Mealybug population was found highest (109.6/fruit) on jackfruit fruit with high severity. Population of mealybug was low (13.33/branch) on wax apple tree and high on jackfruit and mango trees.

4.1.8 Distribution, host plant, infestation, number of insect and severity of mango mealybug in Dhaka Cantonment

Nine host trees such as jack fruit, mango, guava, rose apple, fig, croton, siptil, aralia and Himalayan cedar were identified as host of mealybug at Dhaka Cantonment area with different levels infestation and severity (Table 9). Among them 100% croton, siptil, aralia and Himalayan cedar plants were infested by mealybug followed by jack fruit (85%), mango (53.85%), rose apple (50%) and guava (44.44%). Branch and fruit of jackfruit, inflorescence of mango, branch and stem of other trees were infested. Higher infestation (18.61%) was observed on inflorescence of mango having 80.87 mealybug/inflorescence with high severity followed by branch (13.92% infestation) having 66.47 mealybug/branch with medium severity. More infestation of mealybug (14.41%) occurred on fruit having 109.06 mealybug/fruit with high severity compared to inflorescence of jackfruit. Medium severity was found on jujube and guava and that was low on wax apple.

Table 8. Host plants, infested parts, infestation level and severity of mango mealybug at Tejgaon

Sl.No.	Host plants	Scientific name	Percent plant infestation	Infested plant part	Percent plant part infestation (Mean ± SD)	No. of insect (Mean ± SD)	Severity
1.	Jackfruit	*Artocarpus heterophyllus*	80.0	Inflorescence	06.33 ± 3.14	64.27 ± 8.91	High
				Fruit	14.41 ± 5.16	109.6 ± 22.36	High
2.	Mango	*Mangifera indica*	72.22	Branch	13.92 ± 3.71	66.47 ± 14.56	High
				Inflorescence	18.61 ± 6.19	80.87 ± 14.81	High
3.	Jujube	*Zizypus jujuba*	40.00	Branch	34.00 ± 4.24	25.20 ± 10.33	Medium
4.	Guava	*Psidium guajava*	33.33	Branch	14.50 ± 2.12	27.58 ± 07.49	Medium
5.	Wax apple	*Syzygium samarangence*	100.0	Branch	08.0 ± 01.41	13.33 ± 04.06	Low

Table 9. Host plants, infested parts, infestation level and severity of mango mealybug at Dhaka Cantonment

Sl. No.	Host plants	Scientific name	Percent plant infestation	Infested plant part	Percent plant part infestation (Mean ± SD)	No. of insect (Mean ± SD)	Severity
1.	Jackfruit	*Artocarpus heterophyllus*	85.00	Branch	18.53 ± 5.80	49.30 ± 11.43	High
				Fruit	21.77 ± 5.67	93.93 ± 14.61	High
2.	Mango	*Mangifera indica*	53.85	Inflorescence	34.57 ± 6.37	49.00 ± 08.98	Medium
3.	Guava	*Psidium guajava*	44.44	Branch	20.25 ± 3.77	15.67 ± 04.43	Medium
4.	Rose apple	*Yzygium jambos*	50.00	Branch	11.00 ± 4.24	17.20 ± 05.53	Medium
5.	Fig	*Ficus carica*	100.0	Stem	15.50 ± 3.54	26.87± 08.09	Medium
6.	Croton	*Codiaeum Variegatum*	100.0	Stem	03.33 ± 1.21	101.8 ± 48.34	High
7.	Siptil		100.0	Branch	04.33 ± 1.52	108.5± 19.80	High
8.	Aralia	*Fatsia japonica*	100.0	Branch	12.25 ± 2.98	22.93 ± 7.98	Medium
9.	Himalayan cedar	*Cedrus deodara*	100.0	Branch	06.83 ± 2.86	09.93 ± 2.74	Low

4.1.9 Distribution, host plant, infestation, number of insect and severity of mango mealybug in Kakoli

Jackfruit and croton plant were found to attack by mealybug at Kakoli with variable levels of infestation and severity. All croton plants (100%) were infested by mealybug and only 40% jack fruit tree was infested by this pest (Table 10). Mealybug was observed only on fruit of jackfruit with 13.0% infestation and low severity. On the other hand 5.50% branch infestation was recorded from croton plant with 33.80 insects/branch and medium severity.

4.1.10 Distribution, host plant, infestation, number of insect and severity of mango mealybug at Bonani

Two host plants, viz jackfruit and white plumeria were found to attack by mealybug at Bonani. All white plumeria (100%) and 20% jackfruit tree were infested with medium severity for all (Table 11). Branch and fruit of jackfruit were infested but only branch of white plumeria was infested. For jackfruit 12.0% fruit infestation occurred with 68.10 mealybug/branch but 10.5% branch infestation was observed. In case of white plumeria, 20.50% branch infestation was observed with 29.4 mealybug/branch.

Table 10. Host plants, infested parts, infestation level and severity of mango mealybug at Kakoli

Sl. No.	Host plants	Scientific name	Percent plant infestation	Infested plant part	Percent plant part infestation (Mean ± SD)	No. of insect (Mean ± SD)	Severity
1.	Jackfruit	*Artocarpus heterophyllus*	40.00	Fruit	13.0 ± 5.66	15.87 ± 4.97	Medium
2.	Croton plant	*Codiaeum variegatum*	100.0	Branch	5.50 ± 2.12	33.80 ± 6.38	Medium

Table 11. Host plants, infested parts, infestation level and severity of mango mealybug at Bonani

Sl. No.	Host plants	Scientific name	Percent plant infestation	Infested plant part	Percent plant part infestation (Mean ± SD)	No. of insect (Mean ± SD)	Severity
1.	Jackfruit	*Artocarpus heterophyllus*	20.00	Branch	10.50 ± 3.54	22.20 ± 4.51	Medium
				Fruit	12.00 ± 1.41	68.10 ± 14.34	High
2.	White plumeria	*Plumeria rubra*	100.0	Branch	20.50 ± 3.54	29.4 ± 07.57	Medium

4.1.11 Distribution, host plant, infestation, number of insect and severity of mango mealybug at Home-Economics College, Dhanmondi 32 and Shamorik Jadughar (Sher-e-Bangla Nagar)

Only jackfruit tree was found as host tree of mango mealybug at Home Economics College, Dhanomondi 32 and Shamorik Jadughar. Branch, inflorescence and fruit were infested by mealybug of these three locations (Table 12, 13, 14). Percent fruit infestation was higher in all locations than inflorescence and branch. High severity was observed for fruit infestation at Home Economics College and Dhanmodi 32 and that was medium at Shamorik Jadughar location. Medium severity was found on inflorescence at Home Economics College and Dhanmodi 32 but low infestation was recorded on branch at Shamorik Jadughar location (Table 14).

Results on distribution of mealybug in Dhaka city, host plants, infestation level and severity indicate that mealybug was recorded from different host plants of six thanas out of 45 thanas namely Sher-e-Bangla Nagar, Mohammadpur, Dhanmondi, Tejgaon, Newmarket and Cantonmet. Jackfruit was common host at all locations followed by mango. Comparatively higher infestation occurred on fruit of jackfruit compared to inflorescence and branch. In case of mango, more infestation occurred on inflorescence than branch and fruit. High severity was observed on fruit for jackfruit and inflorescence of mango in most of the locations. This result agrees with the reports of Ben-Dov (2006) and Kosztarab and Kozar (1988) who reported that mealybug fed variety of herbaceous and woody host plants.

Table 12. Host plants, infested parts, infestation level and severity of mango mealybug at Home Economics College

Sl. No.	Host plants	Scientific name	Percent plant infestation	Infested plant part	Percent plant part infestation (Mean ± SD)	No. of insect (Mean ± SD)	Severity
1.	Jackfruit	*Artocarpus heterophyllus*	10.0	Fruit	18.5 ± 3.54	93.8 ± 17.57	High
				Inflorescence	07.0 ± 1.41	36.20 ± 09.87	Medium

Table 13. Host plants, infested parts, infestation level and severity of mango mealybug at Dhanmondi-32

Sl. No.	Host plants	Scientific name	Percent plant infestation	Infested plant part	Percent plant part infestation (Mean ± SD)	No. of insect (Mean ± SD)	Severity
1.	Jackfruit	*Artocarpus heterophyllus*	42.85	Inflorescence	06.67 ± 2.52	42.53 ± 13.10	Medium
				Fruit	14.33 ± 3.51	87.73 ± 16.96	High

Table 14. Host plants, infested parts, infestation level and severity of mango mealybug at Bangladesh Shamorik Jadughar, Sher-E-Bangla Nagar

Sl. No.	Host plants	Scientific name	Percent plant infestation	Infested plant part	Percent plant part infestation (Mean ± SD)	No. of insect (Mean ± SD)	Severity
1.	Jackfruit	*Artocarpus heterophyllus*	12.5	Branch	10.5 ± 2.12	16.60 ± 5.17	Low
				Fruit	15.5 ± 3.54	40.73 ± 8.45	Medium

4.2 Effect of some management practices against adult mango mealybug

The results on the effect of four chemical insecticides viz., Deltamethrin, Carbaryl, Imidacloprid and Thiamethoxam and other management practices against mango mealybug at mango orchard have been presented below:

4.2.1 Effect chemical insecticides on mango mealybug population at orchard

Spraying of chemical insecticide on mango tree significantly reduced the population of mealybug (Table 15). Treatment T_4 (Carbaryl) reduced 42.92% population of mealybug after 24 hour of spraying which was significantly higher than other chemical insecticides. After 48 hour of spraying T_2 (Thiamethoxam) gave maximum (70.47%) reduction of mealybug which was statistically similar with T_4 (Carbaryl) which reduced 67.65% population. Treatment T_4 (Carbaryl) reduced 86.70% and 92.70% population of mealybug respectively after 7 days and 15 days of spraying which was significantly higher than other treatments. Treatments T_1 (Imidacloprid) and T_2 (Thiamethoxam) reduced 86.68% and 89.76% population of mealybug after 15 days of spraying. Thus treatment T_4 (Carbaryl) was the most effective chemical insecticides against mealybug which gave maximum reduction of population after spraying. The order of effectiveness of four chemical insecticides against mealybug after application at orchard is T_4>T_2> T_1> T_3.

Table 15. Effectiveness of some chemical insecticides on mango mealybug population after spraying at mango orchard

Name of insecticides	Percent reduction of mealybug population by spraying chemical insecticides			
	24 hour	48 hour	7 days	15 days
T_1= Imidacloprid	36.40 c	55.23 b	76.39 c	86.68 c
T_2= Thiamethoxam	39.76 b	70.47a	82.60 b	89.76 b
T_3= Deltamethrin	31.36 d	45.11c	52.54 d	66.87 d
T_4= Carbaryl	42.92 a	67.65 a	86.70 a	92.70 a
LSD value	**0.81**	**7.32**	**1.40**	**1.61**
CV (%)	**2.47**	**14.11**	**2.16**	**2.20**

In a column, means having same letter(s) are statistically similar at 5% level of significance by DMRT.

4.2.3 Effect of some chemical insecticides and other management practices against mango mealybug at mango orchard

Significant variation was observed among different management practices against mealybug at mango orchard after application of treatments. The lowest number of mealybug/plant (10.0/plant) was recorded from T_4 (Carbaryl) and T_6treatments (10.00) after 7 days of treatment application. No significant variation was observed among $T_{4,}$ T_6, T_5 and T_2 in terms of number of adult/plant (Table 16). On the other hand the highest number of mealybug (68.75/plant) was recorded from T_7 (control) treatment which was significantly higher than all other treatments. After 15 days of treatment application, the lowest number of mealybug (5.50/plant) was recorded from T_4 (Carbaryl) having no significant difference with T_2 (8.25/plant). In contrast the highest number of mealybug (78.70/plant) was recorded from T_7 (control) treatment which was significantly higher than all other treatments. Number of mealybug was not significantly varied between T_5 (cotton band) and T_6 (polythene band with grease) after 15 days of treatment application. The order of effectiveness of six treatments against mealybug after 15 days of application at orchard is $T_4 > T_2 > T_1 > T_3 > T_6 > T_5$.

Table 16. Effect of different management practices against adult stages of mango mealybug

Treatments	Number of mealybug/plant after 7 days	Number of mealybug/plant after 15 days
T_1= Imidacloprid	21.25 c	12.00 cd
T_2= Thiamethoxam	14.00 d	08.25 de
T_3= Deltamethrin	39.75 b	27.75 b
T_4= Carbaryl	10.00 d	05.50 e
T_5 = Cotton band	10.50 d	15.25 c
T_6= Polythene with grease	10.00 d	16.00 c
T_7= Control	68.75 a	78.70 a
LSD value	**4.79**	**4.71**
CV (%)	**12.95**	**14.46**

In a column, means having same letter(s) are statistically similar at 5% level of significance by DMRT.

Result indicates that Carbaryl was the most effective insecticide against mango mealybug at orchard followed by Thiamethoxam. Cotton band and polythene band with grease significantly reduced the population of mango mealybug at orchard. The result agrees with the reports of Gonzalez *et al.*(2001) and Shafqat *et al*. (2007) who controlled mango mealybug by Carbaryl.

CHAPTER V

SUMMARY AND CONCLUSION

The present study was conducted at the field of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka during the period from November, 2015 to May, 2016 to know distribution, host preference, damage severity and management of mango mealybug. Field survey was done at 45 Thanas of Dhaka city to study the distribution, host preference and damage severity of mango mealybug. Four chemical insecticides and two mechanical bands (cotton band and polythene band with grease) were evaluated against mealybug at mango orchard of Sher-e-Bangla Agricultural University campus.

Mango mealybug was recorded from six thanas out of 45 thanas namely Sher-e-Bangla Nagar, Mohammadpur, Dhanmondi, Tejgaon, Newmarket and Cantonmet in Dhaka city. Mango mealybug is a polyphagous insect which attacked mango, jackfruit, papaya, lemon, pomelo, brinjal, cranberry, bean, silk cotton, rose apple, guava, hog plum, jujube, aralia, wax apple, wax apple etc. Jackfruit was common host at all locations followed by mango. Comparatively higher infestation occurred on fruit of jackfruit compared to inflorescence and branch. In case of mango, more infestation occurred on inflorescences than branch and fruit. High severity was observed on fruit for jackfruit and inflorescence of mango in most of the locations.

Carbaryl was the most effective insecticides against mango mealybug which reduced maximum population of mango mealybug (86.70% after 7 days and 92.70% after 15 days of spray) followed by Thiamethoxam. The order of effectiveness of four chemical insecticides against mango mealybug after application at orchard is $T_4 > T_2 > T_1 > T_3$.

The lowest number of mango mealybug (5.50/plant) was recorded from Carbaryl treated plant after 15 days of spraying compared to other chemical insecticides and mechanical bands. Thiamethoxam also gave the similar result having 8.25 mealybugs/plant. Cotton band and polythene band with grease reduced significant number of mealybug population.

Considering the above results it may be concluded that mango mealybug was recorded from different host plants of six thanas in Dhaka city where jackfruit and mango were the common host plants in all locations. Fruits of jack fruit and inflorescence of mango are the most preferable plant parts of mealybug. Carbaryl was the most effective chemical insecticides followed by Thiamethoxam. Cotton band and polythene band with grease might be effective protective measures of fruit trees.

Based on the results of the present study the following recommendations may be suggested-

1. Carbaryl could be applied for the management of mango mealybug. Cotton band and polythene band could also be used as protective measure.

CHAPTER VI

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APPENDICES

Appendix I. Mango mealybug infested host plants and plant parts

Figure 1. Infested mango inflorescence

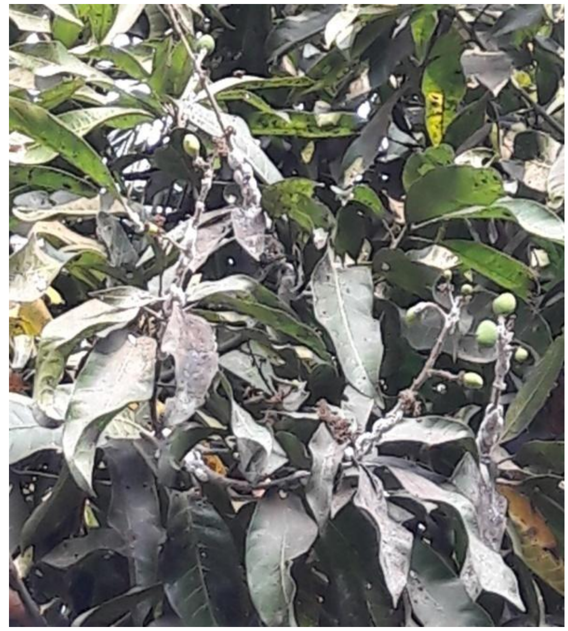


Figure 2. Infested mango fruit

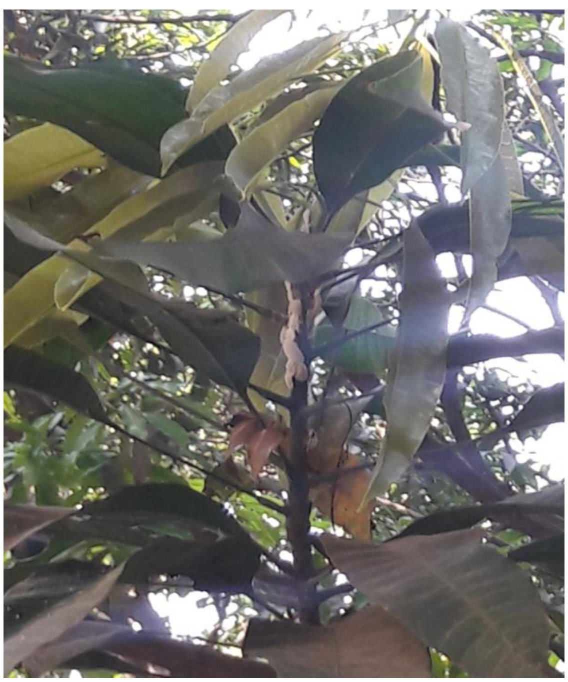


Figure 3. Infested mango branch

Figure 4. Infested jack fruit

Figure 6. Infested jack fruit branch

Figure 5. Infested jack fruit inflorescence

Figure 7. Infested lemon branch

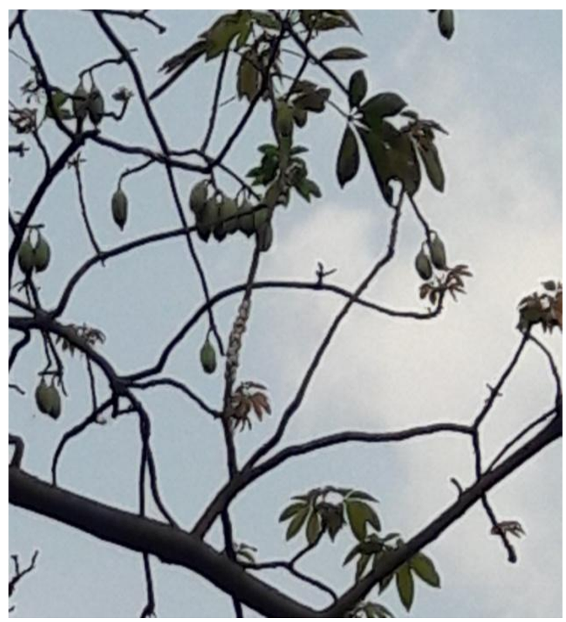


Figure 8. Infested branch of silk cotton

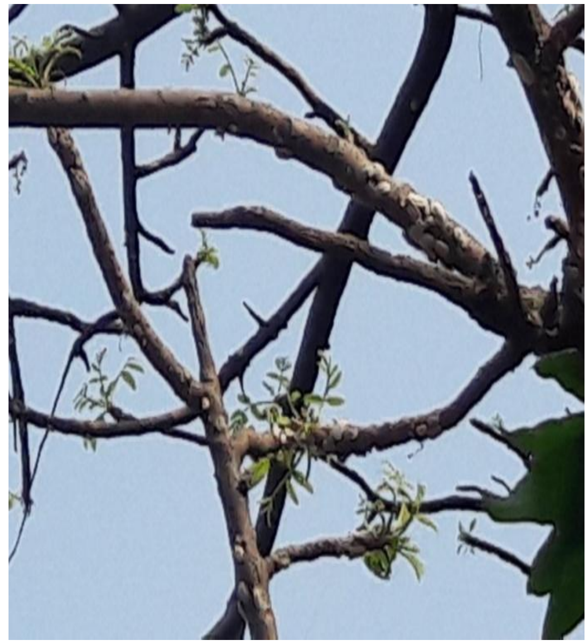


Figure 9. Infested guava branch

Figure 10. Infested hog plum branch

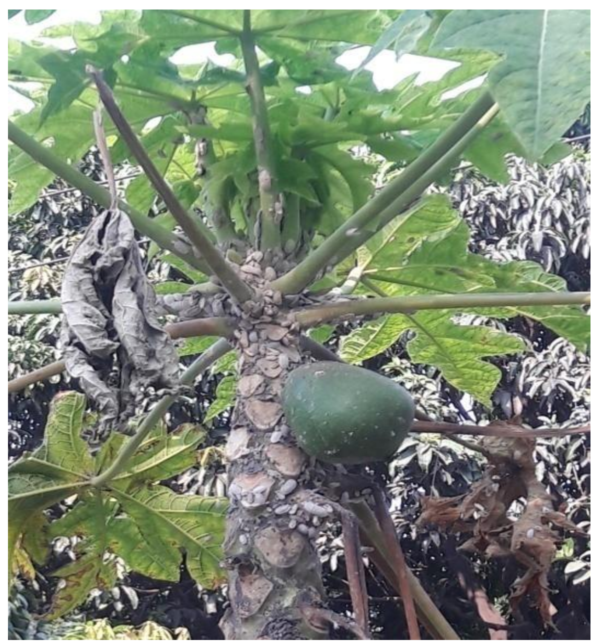


Figure 11. Infested shaddock branch

Figure 12. Infested papaya stem

Figure 13. Infested wax apple branch

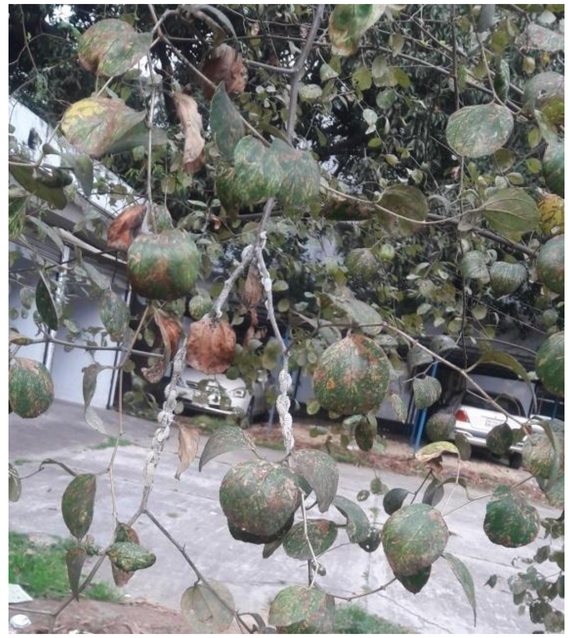


Figure 14. Infested jujubi branch

Figure 15. Infested aralia branch

Figure 16. Infested siptil branch

Figure 17. Infested himalayan ceder branch

Figure 18. Infested croton plant branch

Figure 19. Infested fig branch

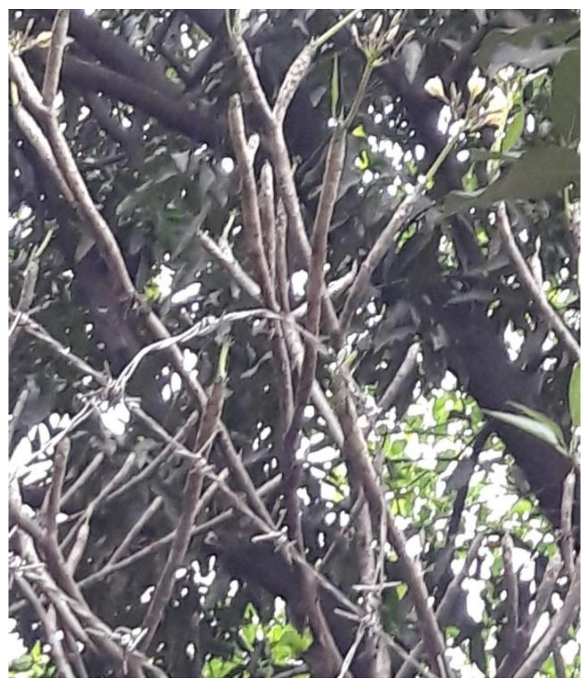


Figure 20. Infested white plumeria branch

Figure 21. Infested brinjal branch

Figure 22. Infested bean stem

Figure 23. Infested cranberry branch

Figure 24. Infested makania branch

Appendix II. Effectiveness and mortality after spraying of chemical insecticides against adult mango mealybug in field condition

Figure 25.Number of insect before Imidacloprid spray

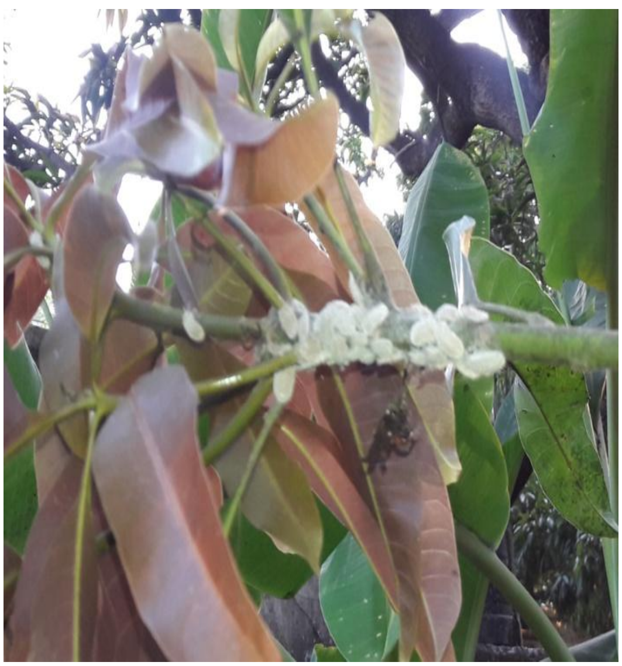
Figure 26. Number of insect after Imidacloprid spray

Figure 27. Number of insect before Carbaryl spray

Figure 28. Number of insect after Carbaryl spray

Figure 29. Number of insect before Thiamethoxam spray

Figure 30. Number of insect after Thiamethoxam spray



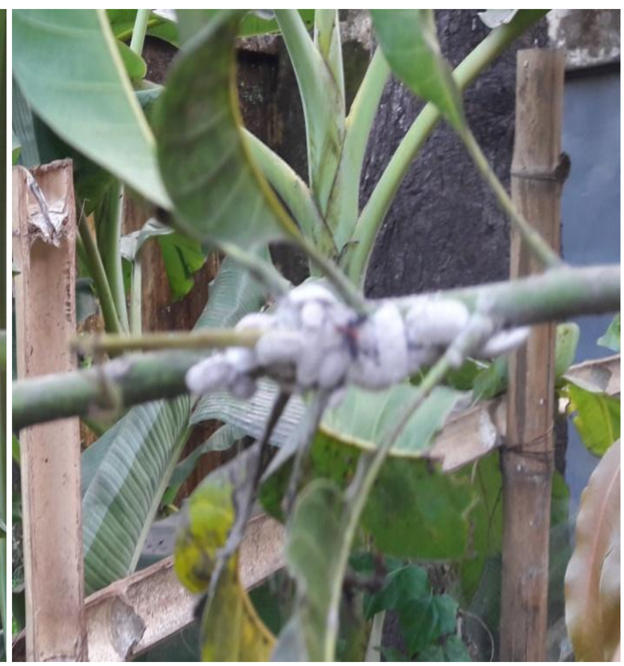


Figure 31. Number of insect before Deltamethrin spray

Figure 32. Number of insect after Deltamethrin spray

Figure 33. Number of insect before control treatment **Figure 34**. Number of insect aftre controltreatment

Figure 35. Polythene with grease

Figure 36. Cotton band