EVALUATUON OF PLANT EXTRACT AND MECHANICAL BAND AGAINST MANGO MEALYBUG (*DROSICHA MANGIFERAE*)

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CERTIFICATE

This is to certify that thesis entitled, "**EVALUATUON OF PLANT EXTRACT AND MECHANICAL BAND AGAINST MANGO MEALYBUG (*DROSICHA MANGIFERAE*)"** 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 result of a piece of *bona fide* research work carried out by SHAH MD. ASHRAFUL ISLAM bearing Registration No. 09-03350 under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

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

Dated: JUNE, 2015
Dhaka, Bangladesh

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(DR. Mst. Nur Mohal Akhter Banu)
Supervisor

DEDICATED

TO

MY BELOVED PARENTS

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ABSTRACT

The experiment was conducted at the Entomology laboratory and mango orchard at Sher-e-Bangla Agricultural University campus, Dhaka during the period from November, 2013 to May, 2014 to study the effect of some plant extracts and mechanical bands against mango mealybug. In laboratory seven plant extractsleaf of (neem, korobi, marigold, nishinda,tobacco,tomatoand neem seed kernel)were used to evaluate against 1^{st},2^{nd}, 3^{rd} instar nymph and adult female of mango mealybug. In field different mechanical bands(cotton, white plastic sheet, black plastic sheet, only grease, red cloth, black cloth, white cloth, cotton with insecticide, white plastic sheet with grease, black plastic sheet with grease) were used.In case of 1^{st} instar mango mealybug at dipping and spraying neem seed kernel extract gave the highest mortality at 24 h, 48 h, 72 h, 96 h and 120 h resulted 5%, 10%, 15%, 13.3% and 5%, 11.67%, 13.33%, 16.67% and 8.33% respectively. Similar trend was found at 2^{nd} and 3^{rd} instar mango mealybug nymph in both dipping and spraying method. Neem seed kernel gave the highest mortality from 24 h to 120 h of post treatment. Treatment with all plant extracts following both spraying and dipping methods did not show any effect on the mortality of adult female of mango mealybug.Regarding the mechanical bands in field, black plastic sheet with grease gave the maximum reduction resulted 71.33%, 83.00%,and 84.70% in inflorescence, stem and leaf respectively at the 1^{st}instar nymph.At 2^{nd} instar 79.25%, 71.33% and 86.33% reduction was found in inflorescence, stem and leaf respectively. At 3rd instar 87.33%, 86.67% and 94.33% reductionwas found in inflorescence, stem and leaf, respectively.

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LIST OF ACRONYMS

AEZ	=	Agro-Ecological Zone
et al.	=	And others
RCBD	=	Randomized complete block design
Kg	=	Kilogram
SAU	=	Sher-e-Bangla Agricultural University
No.	=	Number
LSD	=	Least Significant Difference
^{0}C	=	Degree Celsius
Max	=	Maximum
Min	=	Minimum
%	=	Percentange
CV%	=	Percentage of coefficient of variance

CHAPTER I

INTRODUCTION

Mango (*Mangiferaindica* L.) belongs to the family Anacardiacee is one of the most popular and delicious fruits grown throughout the tropics and sub-tropics of the world. It was thought to be originated in the region of Indo-Bangladesh, Myanmar,Malaysia. Mango is being cultivated for more than 4000 years (Candole, 1984). It is considered as the class one fruit in the country. Popenoe (1964) mentioned mango as “the king of the oriental fruits”. It is widely grown all over Bangladesh; while the quality mangoes solely concentrated in the north-west areas, especially greater Rajshahi, Dinajpur and Rangpur (karim, 1985). It ranks third among the tropical fruits grown in the world with a total production of 28.85 million tons (FAO, 2012). In Bangladesh, mango ranks second fruit in terms of area cultivated and third in production. Mango mealybug (*Drosichamangiferae*), is a pest of mango crops in Asia. The nymphs and females suck plant sap from inflorescences, tender leaves, shoots and fruit peduncles. As a result, the infested inflorescences dry up, affects the fruit set, causing fruit drop. These bugs also exude honey dew over the mango tree leaves, on which sooty mold fungus develops reducing the photosynthetic efficiency of the tree. It is a polyphagous pest and is found on over 60 other plant species.

Variation in population density of phytophagous insects among conspecific trees is known to be very high (Price *et al.,* 1980). In tropical forests, for instance, a strong correlation was observed between renewal of foliage (flushing) and abundance of herbivores, especially Homoptera(Wolda, 1978).

Cultural control has long been observed to slow the spread of mealybug infestations in ochards. Work in mealybug infested orchards should be scheduled such that once pruners or harvesters are done with work in the orchards, they are finished for the day. Alternatively, workers should be asked to shower and change their clothes before entering an uninfested orchard. Showering and change of clothing’s are necessary because all life stages of mealybug (particularly, crawlers) can be carried on the workers’ skin, clothing and hair.Mealybugs have many natural enemies, including parasitic wasps, arthropod predators and entomopathogenic fungi. However, parasitoid encyrtids (Hymenoptera, Encyrtidae) and predatory lady beetles (Coleoptera, Coccinellidae) are the most common natural enemies of mealybugs. Mealybug-parasitizing encyrtids are primary endoparasitoids; most of them undergo solitary development. Their host specificity is not a clear issue.Chemical control of mealybugs with conventional insecticides is difficult as with all mealybugs due to protection of the adults by a waxy covering (Dean *et al*., 1971; French and Reeve, 1979; Greathead, 1986; Panis, 1986; Kosztarab 1996; Franco *etal*., 2009; Joshi *et al*., 2010). Systematic insecticides do not seem to be effective because the ovipositing females do not feed, yet continue to produce viable offspring beyond the active life of chemicals (Islam, 1993). Early, chemical control efforts against *P.solenopsis*proved unsatisfactory in Texas, United States (Fuchs *et al*., 1991). The use of insecticides makes the pest more devastating and has been reported damaging plants other than mango. Application of insecticides (Dimethoate 0.05% and Monocrotophos 0.05%) failed to control the mealybug on crossandra (Mani and Krishnamoorthy, 2007).

Keeping in view the above information, present studies were conducted in laboratory and field on control of mango mealybug. Present research work was primarily focused on that were the vast arena to research about mango mealybug and further study may be needed to find out the appropriate measures to control the mango mealybug.More botanical extracts should be included for future study as sole or different combination to make sure the better performance.

Objectives

Considering the above facts the research program was designed with the following objectives-

1. to evaluate the effectiveness of some plant extracts against different stages of mango mealybug.
2. to study the effect of some mechanical bands against mango mealybug in orchard.

CHAPTER II

REVIEW OF LITERATURE

Mango mealybug is one of the major insect pests of mango. The review and literature works about mango mealybug are presented in following the headings and subheadings-

2.1 .1 Biology of mango mealybug

Mango mealybug (*Drosicha mangiferae*), is a pest of mango crops in Asia. The nymphs and females suck plant sap from inflorescences, tender leaves, shoots and fruit peduncles. As a result, the infested inflorescences dry up, affects the fruit set, causing fruit drop. These bugs also exude honey dew over the mango tree leaves, on which sooty mold fungus develops reducing the photosynthetic efficiency of the tree. It is a polyphagous pest and is found on over 60 other plant species.

Most mealybug species reproduce sexually, and lay eggs (Gullan and Kosztarab, 1997; Kosztarab and Kozár, 1988). The more common corresponds to a particular type of haplodiploidy, known as paternal genome elimination, in which both males and females develop from fertilized eggs; the male develops from a zygote containing one haploid genome from his mother and one haploid genome from his father, but only the maternal genome is transmitted to the offspring via the sperm, because the set of chromosomes of the trees.paternal origin becomes heterochromatic and genetically inactive (Normark, 2003; Nur, 1990).

In Pakistan, *Drosicha mangiferae* is a total lifecycle of 78–135 days. Between April and May, purple-colored eggs are laid in egg-sacs consisting of a mass of wax threads, in the loose soil around (within 2–3 m radius) the infested mango trees. Eggs hatch in December–January and nymphs start ascending the trees to succulent shoots and the bases of fruiting parts. Nymphs go through stages of 1st instar (45–71 days), 2nd instar (18–38 days) and 3rd instar (15–26 days).

Female and male appearance starts during March–April. Males are winged and short-lived after mating, and do not cause damage to

2.1.2 Economic importance of mealybugs

All mealybug pests are phytophagous and often invasive species with great economic importance around the world. For exmple in the USA, there are 350 species of mealybug of which approximately 70% of the 66 mealybug species that are considered as pests are invasive (Miller *et al.*, 2002). In New Zealand, most of the known 114 species of mealybugs are found only on native plants. Three cosmopolitan and invasive *Pseudococcus* species are frequently occurring pests of horticultural crops in the country, where they account for more than 99% of the mealybug fauna in orchards and vineyards (Charles, 1993). In Israel, only one among 13 mealybug pests may be considered native (Franco, 2009). In France, scale insects, including mealybugs, represent 31% (Streito and Martinez, 2005) of newly introduced species in recent years, although all mealybug pests on grapevine are native (Sforza, 2008; Sforza, 2008). Rather few narrow host-range plant mealybugs are considered major pests on an international scale, as in the case of the cassava mealybug *Phenacoccus manihoti* (Matile-Ferrero, 1977; Williams and Granara de Willink, 1992; Zeddies *et al.,* 2001). However, the most notorious species are polyphagous and have become serious pests of different crops under different environments. Many of them are cosmopolitan species belonging to the genera *Pseudococcus* and *Planococcus*; they spread between continents through international trade. Several members of the genus *Pseudococcus*, for example, *P. calceolariae* (Maskell), *P. longispinus* (Targioni-Tozzetti), and *P. viburni* (Signoret), are important pests of apple, pear and vineyards in New Zealand (Charles, 1993), whereas around the Mediterranean they are considered mainly as pests of citrus, persimmon and several other subtropical fruit trees (Franco *et al.,* 2004). The citriculus mealybug, *P. cryptus* Hempel is a major pest of citrus in the east Mediterranean region and it attacks coffee roots in Asia and South America (Ben-Dov, 1994; Blumberg *et al.,* 1999; Williams and Granara de

Willink, 1992). Two members of the genus *Planococcus* are among the best known pests of the family: on an international scale, the vine mealybug, *P. ficus* (Signoret) damages mainly vines (Ben-Dov, 1994; Daane *et al.,* 2006a; Gutierrez *et al*., 2008; Walton *et al.,* 2004; Zada *et al*., 2008), whereas the citrus mealybug, *P. citri* (Risso), attacks mainly subtropical fruit trees under Mediterranean climate conditions and ornamental plants in interior landscapes in cooler zones (Ben-Dov, 1994; Franco *et al*., 2004). Polyphagous mealybugs pose a serious threat because of their tendency to adopt new host plants easily. The citrus mealybug has become a key pest in the mint and tarragon industry in Israel and another example that indicates the high economic importance of a polyphagous mealybug is the pink hibiscus mealybug, *Maconellicoccus hirsutus*. This mealybug is indigenous to southern Asia, and actually is considered a potentially serious pest in the United States, because of its extremely broad range of economically important hosts, including citrus, ornamentals, vegetables and native American flora. It was first reported in the Western Hemisphere in Hawaii in 1984, and later in Grenada in 1994; subsequently it has spread rapidly through the Caribbean islands and to southern California (1999) and Florida (2002). Without control, the economic impact of the hibiscus mealybug to U.S. agriculture was estimated at $750 million per year (Hall *et al*., 2008; Roltsch *et al.,* 2006; Vitullo et al., 2007; Zhang *et al.,* 2006). The solanum mealybugs, *Phenacoccus solani* Ferris and *P. solenopsis* Tinsley are examples of invasive pests of annual crops; they cause devastating damage to green pepper in Israel and cotton in the Indian sub-continent (Ben-Dov, 2005; Hodgson *et al*., 2008; Nakahira and Arakawa, 2006).

Recently, mango infestation in Africa has been reported by two invasive mealybug species of Asian origin, i.e. *R. invadens* and *R. iceryoides* causing serious damage to fruit trees especially mango and citrus (Agounké *et al*., 1988). The former devastated mango production in West and Central Africa with yields of mango and citrus plummeted, effectively to about zero in areas with longest exposure to the insect. The accounts of yield losses are largely not quantified, but can be estimated to range between 50-80% (Neuenschwander, 2003). Factors responsible for the lack of statistics on fruit losses caused by this insect pest can be attributed to the traditional nature of horticulture in the regions, which hampers the collection of statistical data as people's reaction towards *R. invadens* led to control measures such as trimming, and in case of desperation, felling of infested trees as result of general panic generated by the proliferation of the pest. The damage caused by mealybugs is linked to sap uptake, honeydew secretion and associated sooty mold development, toxin injection and virus transmission, although the presence of the insects may itself lead to economic losses (McKenzie, 1967; Panis, 1969 Franco *et al*., 2000; Gullan and Martin, 2003). The typical injury includes: (a) leaf and fruit discoloration; (b) defoliation, flower and fruit drop; (c) reduction of fruit growth rate; (d) distortion of leaves, new shoots and fruits; (e) aborted plant shoots; (f) development of cork tissue on fruit peel; (g) soiling of fruits with mealybugs and honeydew, which encourage the development of sooty mould *Capnodium mangiferum* Cooke & Broome (Capnodiaceae) known to also raise the leaf temperature of infected mango seedlings; and (h) reduction of plant vigor (Franco *et al.,* 2000, Sagarra, *et al*., 2001, Gullan and Martin, 2003; Franco *et al*., 2004; Hodges and Hodges, 2004). High densities or annually repeated infestations can even kill perennial plants (Hodges and Hodges, 2004; Walton *et al*., 2004; Walton *et al.,* 2006). Indirect damage can result from trophic interactions between mealybugs and other insect pests that are attracted by honeydew, such as, (Mexia, 1999; Franco *et al.,* 2000; Mittler and Douglas, 2003; Silva and).

Several mealybug species are vectors of viral diseases of various crops: banana (Thomson *et al.,* 1996; Kubiriba *et al.,* 2001; Watson and Kubiriba, 2005), black pepper (Bhat *et al.,* 2003), cocoa (Dufour, 1991; Entwistle and Longworth, 1963; Hall, 1945), grapevine (Cid *et al.,* 2007; Sforza *et al*., 2003; Tsai *et al.,* 2008; Zorloni *et al*., 2006), pineapple (Sether and Hu, 2002; Sether and Hu, 2002; Sether *et al.*, 2005), rice (Abo and Sy, 1998), and sugarcane (Lockhart *et al.*, 1992). In such cases, mealybugs may be economic pests even at low densities. For example, several mealybug species are responsible for GLRaV-3 (Grapevine Leaf Roll associated Virus-3) transmission to grapevine, which has been shown by the strong positive correlations between mealybug numbers and infection levels in the following season. The virus infection was predicted to spread rapidly within the vineyard within the economic impact of GLRaV-3 infection in sensitive varieties exceeding $10,000 per ha annually and profitability was sufficiently affected to justify replanting (Walker *et al.,* 2004).

2.2.3 Feeding process

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).

2.2.4 Defense system

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 Kozár, 1988). This cryptic behavior of mealybugs may originate a spatial refuge from natural enemies and harsh environmental conditions (Berlinger and Golberg, 1978; Gutierrez *et al.,* 2008). 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.

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 trialkylglycerols 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 mealybugs 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 (Gullan and Kosztarab, 1997).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 mealybugs 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). Major parasitism in mealybugs involves members of the wasp family Encyrtidae. The encyrtids are koinobiont endoparasitoids, so that the parasitized mealybug continues to live for a few days, to grow and even to reproduce to some extent. This time gap between parasitization and deterioration of the physiological condition enables the mealybug to confront the immature individual parasitoid by encapsulation. The encapsulation is a common immune defense mechanism that involves the formation of a capsule around the parasitoid egg or larva; it is usually composed of host blood cells and the pigment melanin. The capsule may kill the parasitoid and thus prevent successful parasitism (Blumberg, 1997).

Various levels of encapsulation have been shown to occur in different mealybug species, in response to parasitism by encyrtids (Blumberg, 1997; Blumberg *et al.,* 1995; Blumberg *et al.,* 2001; Blumberg and van Driesche, 2001; Chong and Oetting, 2007; Giordanengo and Nenon, 1990; Sagarra *et al.,* 2000) and stress conditions (Blumberg, 1997; Blumberg *et al*., 2001; Calatayud *et al.,* 2002).

2.2.5 Behavior

Mango mealybug (*Drosicha mangiferae*,Homoptera:Margarodidae) isimportant adventive Kumar *et al.,* 2009), dimorphic (Chandra *et al.,* 1987), destructive (Karar *et al.,* 2009, 2010, 2012) polyphagous (Tandon *et al.,* 1978), and highly fecund (Nair, 1975) pest covered with waxy layer which makes the chemical control difficult (Ashfaq *et al.,* 2005). After it invades and becomes established in orchard it is very difficult for the growers to control. Unlike some species of scale insects, the mealybugs have well-developed legs that allow them to remain mobile throughout their life. Plant damage occurs by piercing-sucking mouthparts which consequently lowers plant photosynthesis resulting in decreased respiration curling, yellowing and leaf drop. Malformation, dwarfing, decreasing food production, and even plant death occur from feeding pressure (Karar *et al.,* 2010). Sooty mold which develops on honey dew produced by the insect, inhibit photosynthesis and quality of plant. Pakistan was the second world producer of mango, Mangifera indica L., in 1978 and was reduced by insect pest and disease infestations resulting in lower yield (Usman *et al*., 2003), and a lower worldwide ranking (6th) (Government of Pakistan, 2011). Due to high pest attack in many orchards in southern Punjab some growers have uprooted their orchards in Pakistan. Cardinal directions of plant influence the insect flight, movement, and dispersal pattern. Most of insects move towards east west axis than south north axis (Bancroft, 2005). This dispersal habit of insects helps in particular monitoring and recommendation methods for pest control. Insects on the basis of habitat requirement try to settle on branches that meet their optimum requirements for obtaining heat, sunshine and humidity. Monitoring from these sites helps in formulation of earlier pest management approaches.

2.2.6 Population dynamic

Variation in population density of phytophagous insects among conspecific trees is known to be very high (Price *et al.,* 1990). This variation in susceptibility may be genetic, or phenotypic due to differences in environmental factors such as the nutritional status of the soil (Dale, 1988) or air pollution (Riemer and Whittake, 1989), as well as variation in plant age or seasonal phenology (Marino and Cornell, 1993). In tropical forests, for instance, a strong correlation was observed between renewal of foliage (flushing) and abundance of herbivores, especially Homoptera (Wolda, 1978). Temperature and relative humidity have been reported to play an important role in development of *D. stebbingi* (Singh, 1946; Yousuf and Gaur, 1993; Yadav *et al.,* 2004). However Matokot *et al.,* (1992) have shown that fluctuations in populations of mango mealybug (*Rastrococcus. invadens* Williams.*)* on mango are linked to the physiological and phenological characteristics of the host plant than to climatic factors. Seasonal changes play an important role on population fluctuations of mango mealybug (*Rastrococcus invadens* Williams.) its population, which decreased during the rainy season and peaked during dry season (Bovida and Neuenschwander, 1995; Dwivedi *et al.,* 2003).

Drosisha mangiferae abundance is affected by several factors, especially microclimate created by irrigation methods and distance between trees. Pruning the trees can also reduce infestations (Bakr *et al*, 2009).

Meteorological data viz., mean monthly maximum temperature, minimum temperature, morning and evening relative humidity affects population of coccids (Sundaraj and Muthukrishan, 2011). *D. mangiferae* females lay eggs in May to June, egg hatching is influenced by temperature and precipitation (Ashfaq, *et al.*, 2005). During May returning to ground is dependent with average temperature. Temperature and moisture effect mealybug growth, development hatching and other life parameters (Kumar, 2009). Changes in climate can induce changes in species dynamics and this requires extensive attention in focusing on the role of changing climate on altering distribution, abundance, seasonality of individual species.

2.2.7 Host plants

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 (Poaceae) and composites (Asteraceae) (Kosztarab and Kozár, 1988;Ben-Dov, 2006).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 (or monophagous) while others are polyphagous (Kosztarab and Kozár, 1988;Ben-Dov, 2006). However, such a characterization is problematic as most of the economically important species are known to be associated with long lists of hosts, and their performance varies widely, ranging from development of high population density, which eventually would kill the host plant, to poor development that renders the survival of the population for several generations questionable. Plant growth conditions may strongly affect the success of the population: under irrigation and fertilization plant species become favorable hosts of mealybugs, whereas in different environments the performance is usually poor. During laboratory studies many of the mealybug pest species easily could be reared on alternative hosts, such as potato sprouts or squashes, which are not colonized by mealybugs in the field. For example, the citrus mealybug has been found on plants from 70 botanical families, 60% of which are characterized as non-woody plants, whereas on the international scale this mealybug is a pest of subtropical and tropical crops, such as citrus

(*Citrus* spp.), persimmon (*Diospyros kaki* Thunberg), banana (*Musa paradisiacal* L.), and custard apple (*Annona* spp.), or it damages various types of plant species in interior landscapes, greenhouses in particular. Another example of the apparent contradiction between the long lists of host plants and the narrow ranges of damaged crops is the case of the citriculus mealybug, *P. cryptus*; although this mealybug is known from 35 host plant families (Ben-Dov, 2006), in Israel it causes damage only to citrus trees.Under low pressure of natural enemies, for example, when they spread in new environments, mealybugs are observed on relatively large numbers of host plants, in contrast with the situation when there is effective biological control.

2.2.8 Dispersal

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 Kozár, 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 Kozár, 1988). Among arthropods, ants have also been reported to disperse some mealybug species (Gullan and Kosztarab, 1997; Malsch *et al*., 2001; 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 (Nestel *et al.,* 1995;Gullan and Kosztarab, 1997).

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)

2.2.9 Management of mealybug

2.2.9.1 Cultural control

Cultural control has long been observed to slow the spread of mealybug infestations in ochards. The following tactics can be applied in mealybug infested mango orchards:

Work in mealybug infested orchards should be scheduled such that once pruners or harvesters are done with work in the orchards; they are finished for the day. Alternatively, workers should be asked to shower and change their clothes before entering an uninfested orchard. Showering and change of clothing are necessary because all life stages of mealybug (particularly, crawlers) can be carried on the workers' skin, clothing and hair. These mealybug life stages can survive for eight to 24 hours and therefore can lead to new infestaion in uninfested orchards, if the cleaning protocol is not followed. The pruning from an infested orchards can be treated in one of the following ways, Pruning of infested plant parts should be taken out of the orchards and burnt immediately. The pruning should be shredded and mulched in the middle of the row away from the mango stem. Although, shredding makes very small pieces out of the pruning, mealybug crawlers can still survive on pieces of sticks about one to two inches in length. Therefore, shredding should be bagged in heavy-duty construction disposal bags, and the sealed bag taken away from the zone of the mango stem shortly after pruning (Gross *et al.,* 2001).

2.2.9.2 Mechanical control

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 2nd and 3rd instar nymphs of *D. mangiferae* but less effective against the nymphs of 1st 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).

2.2.9.3 Biological Control

Mealybugs have many natural enemies, including parasitic wasps, arthropod predators and entomopathogenic fungi. However, parasitoid encyrtids (Hymenoptera, Encyrtidae) and predatory lady beetles (Coleoptera, Coccinellidae) are the most common natural enemies of mealybug. Mealybug-parasitizing encyrtids are primary endoparasitoids; most of them undergo solitary development. Their host specificity is not a clear issue. Franco et al. (2000) compiled, from published literature, about 70 encyrtid parasitoid species

that were reared from the citrus mealybug, whereas only four species were considered to be principle parasitoids of this mealybug. *Coccidoxenoides, Gyranusoidea, Leptomastidea, Leptomastix, Pseudaphycus*, and *Tetracnemoidea* are examples of encyrtid genera of mealybug parasitoids (Rosen, 1981; Charles, 1993; Hayat and Noyes, 1994; Franco *et al*. 2000s). The most up-to-date assessment of parasitoids attacking *R. iceryoides* in its native home is provided by Noyes and Hyat (1994).The most important parasitoids of *R. iceryoides* in India are *Anagyrus chryos*, *A. sabas, An. agraensis, A.mirzai, Leptomastrix nigrocoxalis* and *Praleurocerus viridis*. Coccinellids accept a wide range of food. Other important groups of predators are brown lacewings (Neuroptera; Hemerobiidae) and predatory gallmidges (Diptera; Cecidomyiidae). The most important predators of *R. iceryoides* in India include: *Aponephus lentiformis* gen. *Cryptolaemus montrouzieri* Mulsant, *Scymnus coccivora* Ayyar and *Spalgis epeus* Westwood. Only a few species of entomopathogenic fungi were reported to be associated with mealybugs and confirmed to be pathogenic; they include *Aspergillus parasiticus* Speare,
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. Noyes and Hayat (1994) reviewed the use of encyrtids for biological control of pest mealybugs, and found that out of a total of 385 importations of encyrtids, targeting 22 mealybug species, about 24 and 7% were considered to give partial or successful control in the field and in greenhouses, respectively.

With regard to predators, Moore (1988) analyzed the use of *C. montrouzieri* separately from that of other mealybug predators. This lady beetle has been used many times against at least 10 different species of mealybugs and was considered to give substantial or partial control in about 19% of the introductions; on some occasions it has been regarded as an outstanding biological control success. Of the other 46 predator species mostly coccinellids, but also cecidomyiids, chrysopids, hemerobiids and lycanids used in biological control of mealybugs, only the cecidomyiid *Kalodiplosis pseudococci* Felt was regarded as having given significant control, when used against *Dysmicoccus brevipes* (Cockerell) in Hawaii in conjunction with two parasitoids. The lack of adequate food resources for natural enemies within or near to agroecosystems may limit the performance of biological control agents against mealybugs. For example, Davies *et al.* (2004) observed that the survival and reproduction of *Coccidoxenoides perminutus* Girault, a parasitoid of the citrus mealybug, *P. citri*, was significantly influenced by the nature of the nectar on which the parasitoid was fed. In light of these results, it was suggested that habitat management, for example, by providing suitable nectar sources for adult parasitoids, might be a means to conserve and enhance *C. perminutus* activity in the field.

2.2.9.4 Botanical control

Use of only insecticides is not sufficient to control the pest (Yousuf and Ashraf, 1987). Use of insecticides may cause environmental pollution and destruction of natural beneficial insects (Peng *et al.*, 2010). Considerable efforts are being made in various parts of the world to minimize the over use of insecticidal chemicals and increased the use of Integrated Pest Management techniques. Available reports reveal that botanicals are effective to control mealybugs (Mangoud *et al.*, 2012). Botanical are broad spectrum materials which are used in pest control and they are safe to apply, unique in action and can easily be processed. Locally available plant materials have been widely used in the past to protect the damage caused by insects (Golob and Webly, 1980). The main advantage of botanicals is that they are easily available and safe to apply. They are cheaper and hazard free in comparison to chemicals (Saxena *et al.* 1996).

2.2.9.5 Chemical control

Karar *et al.*(2009) worked on comperative 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 2^{nd} and 3^{rd} instar, Decis and Curacron gave maximum mortality 71 and 70, 24 hrs 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.

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, Côte 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 (Yousuf and Ashraf, 1987; Khan and Ahsan, 2008). 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). 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, insecticides 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 1^{st} and 2^{nd} instar mango mealybug.

CHAPTER III

MATERIALS AND METHORDS

This chapter described the materials and methods that were used in carrying out the experiment. It included a description of management of mealybug in mango plant.The materials and methods that were used for conducting the experiment are presented under the following headings-

3.1 Experimental site

The experiment was conducted at the mango orchad near by the central Mosque of Sher-e-Bangla Agricultural University; Dhaka, Bangladesh during the period from November 2013 to May, 2014 to study the management of mealybug in mango plant. The experimental area was situated at 23°46' N latitude and 90°22'E longitude at an altitude of 8.6 meter above the sea level. The experimental field belongs to the Agro-ecological zone of "The Madhupur Tract". This was a region of complex relief and soils developed over the Madhupur clay, where floodplain sediments buried the dissected edges of the Madhupur Tract leaving small hillocks of red soils as `islands' surrounded by floodplain.

3.2 Climate

The climate is subtropical in nature with moderate temperature and scanty rainfall. The soil of the experimental land belongs to the Madhupur tract and was silty clay in nature having pH ranging from 5.5 to 6.

3.3 Characteristics of soil

The soil of the experimental area belongs to the Madhupur Tract under AEZ No. 28. It had shallow red brown terrace soil. The selected plot was medium high land and the soil series was Tejgaon.

3.4 Treatments

3.4.1 Laboratory Experiment

The experiment was conducted at the Entomology laboratory of Sher-e -Bangla Agricultural University(SAU), Dhaka during November 2013 to May, 2014.

3.4.2 Evaluation of botanicals against mango mealybug under laboratory condition

Seven botanicals namely leaf of tobacco, neem , kernel of neem, marigold , tomato , korobi, and nishinda, were evaluated in the laboratory for their efficacy against mango mealybug under laboratory conditions.

The name of botanicals including the plant parts used along with the doses are shown in Table 1.

Table 1. Plant extracts and their doses used in experiment against mealybug

Treatments	Extracts	Plant parts used	Concentration
T_1	Neem	Leaf	25g/500ml
T_2	Kobori	Leaf	25g/500ml
T_3	Merigold	Leaf	25g/500ml
T_4	Nishinda	Leaf	25g/500ml
T_5	Tobacco	Leaf	25g/500ml
T_6	Tomato	Leaf	25g/500ml
T_7	Neem Seed Kernel	Seed kernel	25g/500ml
T_8	Control	Water	500ml

3.4.3 Preparation of neem seed kernel extracts (NSKE)

Neem seed kernel were collected from the Krishimarket, Dhaka, thoroughly with running tap water till the adhered fruit particles were removed. Four hundred milliliter of water was added to the neem seed kernel and ground well in a blender to make a suspension. The suspension was left undisturbed overnight, filtered through fine cloth and poured into a volumetric flask. Fresh water was added to make the volume 500 ml.

3.4.4 Preparation of various leaves extracts

Various kinds of leaves such as korobi, nishinda, tomato, tobacco, marigold and neem were collected from different location from SAU campus. All of leaves were weighted 25 g separately by electrical balance and thoroughly washed with running tap water and chopped with a knife. Four hundred milliliter of water was added with chopped leaves and ground well with a blender. The mixture was kept undisturbed overnight, filtered through fine cloth and poured into a volumetric flask (500 ml) and water was added to make the volume 500 ml.

3.4.5 Treatments for Field Experiment

3.4.5.1 Infestation intensity

In natural condition mealybug population were counted in mango, papaya and jack fruit trees. The intensity of infestation was counted by observed the insects number per 2 cm^2 of leaf, 2 cm^2 of stem and 2 cm^2 of inflorescence of mango, papaya and jack fruit at different dates.

3.4.6 Mechanical bands

In mechanical barrier, tree trunk was tightly wrapped with a 30 cm width white plastic sheet, black plastic sheet, white cloth, black cloth, cotton, grease etc. above 45 cm height from the soil surface. A thin layer of grease (7 cm) was applied surrounding the middle portion of the plastic sheet during November 2013 to April 2014.The barrier inhibits the crawling of nymphs to cross the band and reach the plant canopy. As a result, the nymphs gathered near the lower edge of the plastic barrier. Selected trees under untreated control were kept without any treatment of mechanical bands. Mango plant of variety Amrupali grafted from five years old tree were planted in earthen pots one plant per pot. Three old plant were collected from Anower Nursery, Savar, Dhdka.The experiment was laid out in randomized complete block design (RCBD).

Eleven treatments including an untreated control were evaluated with a view to suppress the mealybug infestation in Mango plants are as follows

T_1 = Cotton

T_2 = White plastic sheet

T_3 = Black plastic sheet

T_4 = Grease

T_5 = Red cloth

T_6 = Black cloth

T_7 = White cloth

T_8 = Cotton with Insecticide

T_9 = White plastic sheet with grease

T_{10} = Black plastic sheet with grease

T_{11} = Control

3.5 Collection of insects

Mango mealybug of different development stages were collected from infested mango trees in early morning in a jar with the help of an aspirator. Fresh mango leaves were provided in the jars as food for the crawler nymphs.

3.6 Bioassay under laboratory conditions

The efficacy of the botanicals were evaluated under laboratory conditions against 1st, 2nd,3rd instars and adult females of mango mealybug following foliar spray and insect dipping methods.

3.7 Foliar spray method

In spray method, freshly collected mango leaves were cut into 4 cm long pieces and sprayed with each botanical with a hand sprayer. Leaf pieces under control were sprayed only water. After air drying,the treated leaf pieces were placed in Petri dishes (12cm diameter) containing moist filter paper to avoid desiccation of the leaves .Thereafter, twenty active crawler nymphs of the 1st and 2ndinstars were placed on the treated leaves in each Petri dish with the help of fine camel hair brush. In case of 3rdinstar nymph and adult female ten insects were placed on the treated leaves in each Petri dish. Petri dishes were kept on the laboratory desk at an ambient temperature of maximum of 30 degree and minimum 25 degree. The relative humidity was 65%. Experiment was laid out in Completely Randomized Design(CRD) with three replications. Data on mortality of mealybug were recorded at 24, 48, 72, 96 and 120 h after treatment.

3.8 Insect dipping method

In insect dipping method, insects were kept in a small sieve and dipped into each botanicals suspension for 10 seconds. For control treatment, the insects were dipped in plain water for same period. After airs dried the treated insect were placed in Petri dishes (12 cm×2 cm) containing fresh mango leaves as food for the nymphs. Moisten filter paper was placed in each Petri dish to avoid desiccation of the leaves. Petri dishes were placed on the laboratory at an ambient temperature of maximum 30 degree and minimum relative humidity.

The percent mortality was calculated according to the following formula:

$$\%\text{Mortality} = \frac{\text{Number of dead nymph}}{\text{Total number of nymph}} \times 100$$

3.9 Statistical analyses

The data obtained from the experiment on various parameters were statistically analyzed by MSTAT-C computer program. The mean values for all the parameters were calculated and the analysis of variance for the characters was accomplished by Duncan's Multiple Range Test (DMRT) at 5 % levels of probability.

CHAPTER IV

RESULTS AND DISCUSSIONS

The results on the effect of some plant extracts and mechanical bands against mango mealybug have been presented and possible interpretations are made in this sections.

4.1 Infestation intensity of mango mealybug in mango, jackfruit and papaya

Infestation intensity of mango mealybug on mango, jackfruit and papaya during January to April are discussed here.

4.1.1 Infestation intensity of mango mealybug on mango tree

In mango tree population variation was observed at different dates on stem, leaf and inflorescence. In stem, the highest number of mealybug was found on 23/02/14 after that the population was declined. Similar trends were found in leaf and inflorescence (Figure 1). However the highest number of mealybug was observed on leaf compared to stem and inflorescence. The order of infestation intensity on different parts of mango was tree inflorescence > leaf > stem.

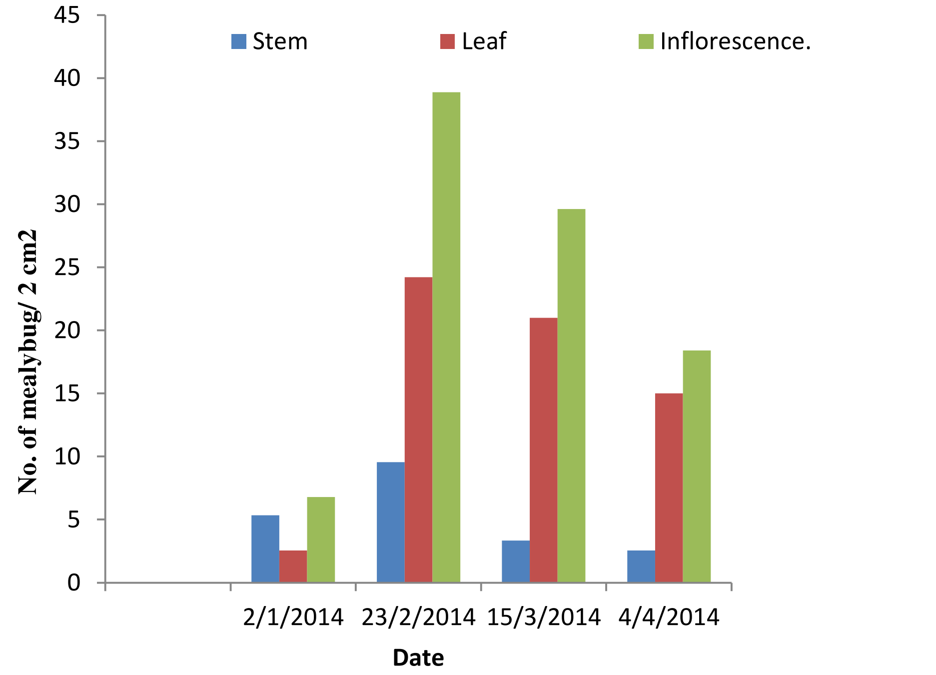

Figure 1. Infestation intensity of mealybug in mango tree space.

4.1.2 Infestation intensity of mango mealybug on jack fruit tree

In case of jack fruit tree the number of insect was 19.33/ $2cm^2$ on 2/1/2014. The number of insects were increased up to 15/ 3/2014. The number of insects were decreased on 4/3/2014.

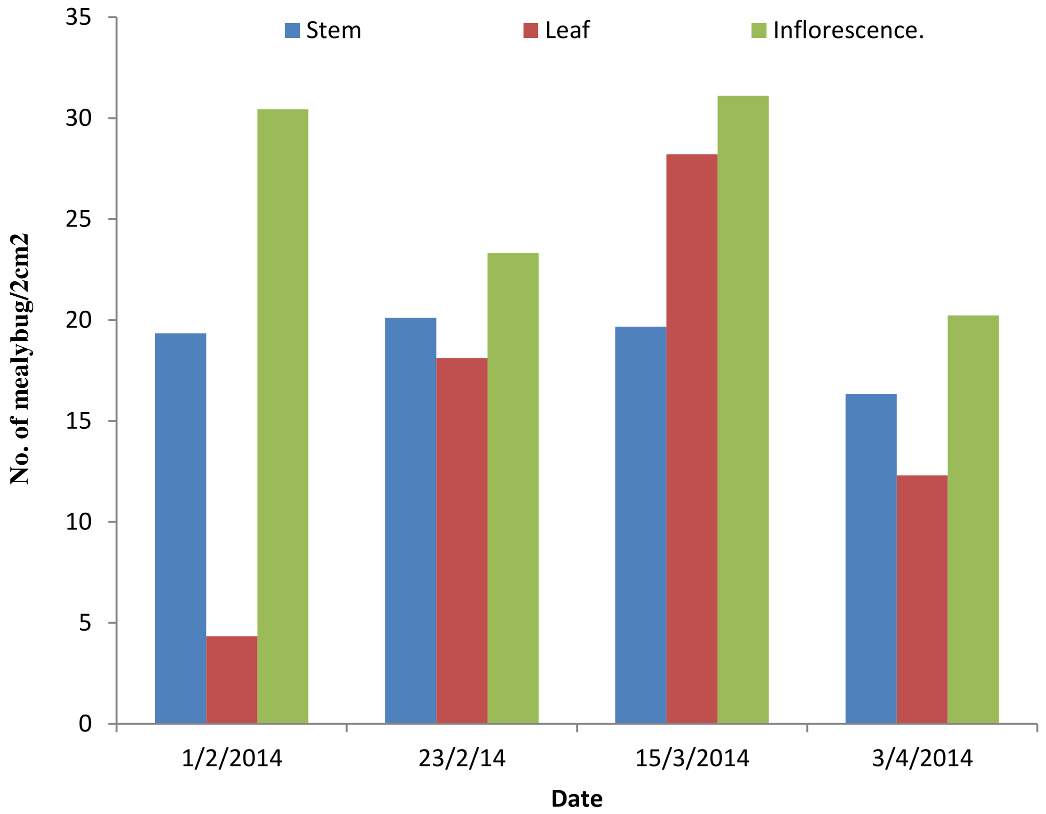

Figure 2. Infestation intensity of mealybug in jackfruit tree space.

4.1.3 Infestation intensity of mango mealybug on papaya tree

In papaya tree, population variation was observed at different dates on stem, leaf and inflorescence. In stem, the highest number of mealybug was found on 15/03/2014 after that the population was declined. Similar trends were found in case of leaf and inflorescence (Figure 3). However, the highest number of mealybug was recorded on leaf and stem compared to inflorescence.

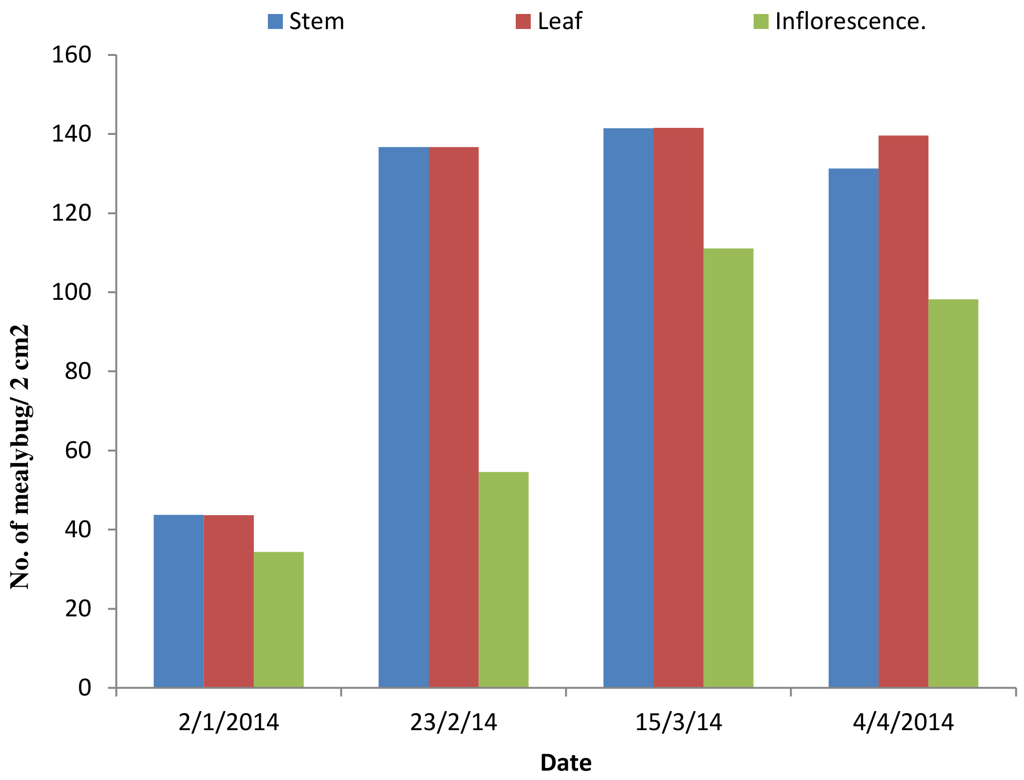

Figure 3. Infestation intensity of mealybug in papaya

4.2 Effect of some plant extracts against different nymphal instars of mango mealybug

The results of the effect of plant extracts against nymphs and adult female of mango mealybug are discussed here.

4.2.1 Mortality of 1st instar nymphs of mango mealybug at different intervals after dipping in plant extract

The data pertaining to the mortality percentage of 1st instar nymph of mango mealybug at 24 h of post treatment interval are shown in Table 2. The highest mortality (5%) was found in neem seed kernel which was statistically similar to neem leaf extract after 24 h of post treatments. After 48 h (10%) mortality of the insect was found in neem seed kernel extract followed by neem leaves (6.67%). After 72 h of treatment neem seed kernel gave highest mortality of 1st instar nymph of mango mealybug resulted with (15%) mortality followed by neem leaves (11.67%). This result supports the findings of Sadre *et al.* (1983) and Satti *et al.* (2010) reported that neem seed extract is most effective in the laboratory condition.The lowest mortality (0.00%) was found in tobacco leaf. Neem seed kernel extract followed the same trend up to 120 h of post treatment. After 120 h of treatments (8.33%) mortality was found in neem leaf which was statistically similar to tobacco leaf extract.

Table 2. Percent mortality of 1st instar nymph of mango mealybug at different intervals after dipping in plant extracts

Treatments	Mortality at different interval (%)				
	24 h	48 h	72 h	96 h	120 h
T_1	5.00a	6.67b	11.6b	10.0b	8.33b
T_2	3.33b	3.20d	5.50d	5.00d	4.67d
T_3	1.57c	3.00d	7.67c	6.67c	6.67c
T_4	1.67c	3.33d	8.00c	5.00d	5.00d
T_5	1.60c	5.00 c	8.33c	7.00c	8.33b
T_6	0.00d	1.67e	5.0de	3.33e	6.67c
T_7	5.00a	10.0a	15.0a	13.3a	10.0a
T_8	0.00d	1.60 e	0.00e	0.10e	1.33e
LSD $_{(0.05)}$	**0.35**	**0.39**	**1.07**	**1.12**	**1.01**
CV (%)	**8.7**	**5.11**	**7.5**	**9.61**	**9.08**

In a column, means having same letter(s) are not significantly different at 5% level of probability by DMRT.

Treatments

T_1=Neem leaf | T_2=Korobi leaf
T_3=Marigold leaf | T_4=Nishinda leaf
T_5=Tobacco leaf | T_6=Tomato leaf
T_7 =Neem seed kernel | T_8= Control

4.2.2. Mortality of 1st instar nymphs of mango mealybug at different intervals after spraying by plant extract

The data pertaining to the mortality percentage of 1st instar nymph of mango mealybug at different intervals of post treatment are shown in (Table 3). The results reveal significant differences among the treatments. Neem seed kernel extract was found to be the most effective resulted in maximum mortality (5%) which was statistically similar to tomato leaf extract followed by neem leaves (3.33%). After 48 h (11.67%) mortality of the insect was found in neem seed kernel followed by neem leaves (8.33%), tobacco leaves (6.67%). After 72 h of treatment neem seed kernel was found most effective botanical for the control of 1st instar mango mealybug resulted with (13.33%) mortality followed by neem leaves (11.67%), tomato leaves (10%). After 120 h neem seed kernel extract gave maximum mortality (10%) followed by neem leaves (6.67%). This result supports the findings of Sadre *et al.* (1983) and

Satti *et al*. (2010) reported that neem seed extract is most effective in the laboratory condition.

Table 3. Percent mortality of 1st instar nymph of mango mealybug at different intervals after spraying by plant extracts

Treatments	Mortality at different interval (%)				
	24 h	**48 h**	**72 h**	**96 h**	**120 h**
T_1	3.33b	8.33b	11.67b	11.67b	6.67b
T_2	1.67d	5.00d	6.67d	8.33d	3.33d
T_3	1.53d	5.00d	8.67c	6.67e	3.27d
T_4	3.33b	5.00d	6.67d	5.00f	5.00c
T_5	3.00c	6.67c	10.00c	10.00c	5.00c
T_6	5.00a	5.00d	5.00e	5.00f	5.93b
T_7	5.00a	11.67a	13.33a	16.67a	8.33a
T_8	0.00e	1.67e	0.00f	0.00g	0.00e
LSD $_{(0.05)}$	**0.27**	**0.64**	**1.61**	**1.48**	**0.88**
CV (%)	**5.38**	**6.04**	**11.26**	**10.11**	**10.71**

In a column, means having same letter(s) are not significantly different at 5% level of probability by DMRT.

Treatments

T_1=Neem leaf T_2=Korobi leaf
T_3=Marigold leaf T_4=Nishinda leaf
T_5=Tobacco leaf T_6=Tomato leaf
T_7 =Neem seed kernel T_8= Control

4.2.3 Mortality of 2nd instar nymphs of mango mealybug at different intervals after dipping in plant extract

At 24 h of treatment neem seed kernel extract was the most effective to kill (8.33%) followed by neem leaves (6.67%) and tobacco leaf (5%). No significant difference was found in mortality of the insect in treatment with nishinda leaves. After 48 h (25%) mortality of insect was found in neem seed kernel extract followed by neem leaves (13.33%) and tobacco leaves (11.6%). This result supports the findings of Sadre *et al.* (1983) and Satti *et al*. (2010) reported that neem seed extract is most effective in the laboratory condition. After 72 h of treatment neem seed kernel was found the most effective botanical for the control of 2nd instar mango mealybug resulted with (18.33%) mortality followed by neem leaves (11.6%) and tobacco leaves (10.0%). After 96 h and 120 h highest mortality was found in neem seed kernel extract and lowest effect was found in korobi leaves extract.

Table 4. Percent mortality of 2nd instar nymph of mango mealybug at different intervals after dipping in plant extracts

Treatments	Mortality at different interval(%)				
	24 h	48 h	72 h	96 h	120 h
T_1	6.67b	13.3b	11.6b	21.67a	6.00b
T_2	1.67e	6.00e	6.50c	10.00d	3.00de
T_3	3.33d	4.67f	3.33d	15.0bc	2.67de
T_4	1.87e	6.00e	3.00d	13.33c	2.33ef
T_5	5.00c	11.6c	10.0b	16.67b	5.00c
T_6	4.67c	9.00d	4.33d	10.00d	3.33d
T_7	8.33a	25.0a	18.3a	23.33a	10.00a
T_8	1.67e	0.00g	0.00e	0.00e	0.00 g
LSD $_{(0.05)}$	**0.51**	**1.05**	**1.85**	**3.30**	**0.75**
CV (%)	**7.05**	**6.04**	**13.96**	**12.77**	**10.13**

In a column, means having same letter(s) are not significantly different at 5% level of probability by DMRT.

Treatments

T_1=Neem leaf T_2=Korobi leaf
T_3=Marigold leaf T_4=Nishinda leaf
T_5=Tobacco leaf T_6=Tomato leaf
T_7 =Neem seed kernel T_8= Control

4.2.4. Mortality of 2nd instar nymphs of mango mealybug at different intervals after spraying by plant extract

At 24 h of treatment neem seed kernel extract was the most effective to kill (3.33%) followed by neem leaves and korobi leaves (1.67%). After 48 h (23.33%) mortality of insect was found in neem seed kernel extract followed by neem leaves (18.3%) which was statistically similar to tobacco leaves (16.6%). Up to 120 h of treatment highest mortality was found in neem seed kernel extract followed by neem leaf extract.

Table 5. Percent mortality of 2nd instar nymphs of mango mealybug at different intervals after spraying by plant extracts

Treatments	Mortality at different interval (%)				
	24 h	48 h	72 h	96 h	120 h
T_1	1.67b	18.3b	11.67b	13.33b	11.67b
T_2	1.67b	8.33e	5.00c	8.33d	6.67e
T_3	1.33c	13.3 d	10.0b	7.67d	8.33d
T_4	1.67b	15.0cd	11.6b	12.67b	3.00f
T_5	1.67b	16.6bc	18.3a	10.00c	10.0c
T_6	0.00d	8.33e	5.00c	8.33d	6.67e
T_7	3.33a	23.33a	16.6a	15.00a	13.3 a
T_8	0.00d	0.00f	0.00d	0.00e	1.67g
LSD $_{(0.05)}$	**0.32**	**2.54**	**2.23**	**1.22**	**1.24**
CV (%)	**13.06**	**10.65**	**12.48**	**6.95**	**9.23**

In a column, means having same letter(s) are not significantly different at 5% level of probability by DMRT.

Treatments

T_1=Neem leaf
T_2=Korobi leaf
T_3=Marigold leaf
T_4=Nishinda leaf
T_5=Tobacco leaf
T_6=Tomato leaf
T_7 =Neem seed kernel
T_8= Control

4.2.5. Mortality of 3rd instar nymphs of mango mealybug at different intervals after dipping by plant extract

The data pertaining to the mortality at 24 h of treatment neem seed kernel extract was the most effective to kill the 3rd instar showing the highest mortality (8.33%) followed by neem leaves (6.67%). Korobi leaf extract was found least effective and showed no effect against 3rd instar mango mealybug. Up to 120 h of treatment, neem seed kernel showed best performance and gave the highest mortality followed by neem leaves.

Table 6. Percent mortality of 3rd instar nymphs of mango mealybug at different intervals after dipping in plant extracts

Treatments	Mortality at different interval(%)				
	24 h	**48 h**	**72 h**	**96 h**	**120 h**
T_1	1.67e	8.33b	5.00b	6.67c	6.67b
T_2	0.00f	5.00c	3.33c	5.00d	5.00c
T_3	3.33d	3.33d	3.33c	5.33d	1.67e
T_4	5.00c	5.00c	1.67d	6.67c	5.33c
T_5	6.67b	5.00c	6.67a	8.33b	3.33d
T_6	5.00c	3.33d	5.00b	5.00d	3.33d
T_7	8.33a	10.0a	5.00b	10.0a	8.33a
T_8	0.00f	1.67e	1.04e	3.33e	1.12f
LSD $_{(0.05)}$	**0.42**	**0.46**	**0.63**	**0.73**	**0.55**
CV (%)	**6.59**	**5.02**	**9.09**	**6.59**	**7.17**

In a column, means having same letter(s) are not significantly different at 5% level of probability by DMRT.

Treatments

T_1=Neem leaf
T_2=Korobi leaf
T_3=Marigold leaf
T_4=Nishinda leaf
T_5=Tobacco leaf
T_6=Tomato leaf
T_7 =Neem seed kernel
T_8= Control

4.2.6. Mortality of 3rd instar nymphs of mango mealybug at different intervals after spraying by plant extract

At 24 h of treatment neem seed kernel extract was found the most effective to kill (5%) which was statistically similar to tobacco leaf followed by neem leaves (3.33%). After 48 h (11.67%) mortality of insect was found in neem seed kernel extract followed by neem leaves extract (8.33%), and tobacco leaves (6.67%). After 72 h, 96 h, and 120 h of treatment highest mortality was found in neem seed kernel extract followed by neem leaf extract. Lowest performance was found in korobi leaf up to 120 h of post treatment.

Table 7. Percent mortality of 3rd instar nymphs of mango mealybug at different intervals after spraying by plant extracts

Treatments	Mortality at different interval(%)				
	24 h	48 h	72 h	96 h	120 h
T_1	3.33b	8.33b	8.33b	6.33b	10.0 b
T_2	0.00d	3.33e	6.67c	5.00c	1.67f
T_3	0.00d	3.47e	6.67c	6.00b	3.33e
T_4	1.67c	5.00d	6.57c	6.33b	3.23e
T_5	5.00a	6.67c	8.33b	6.67b	8.33c
T_6	1.67c	6.53c	6.56c	3.33d	5.00d
T_7	5.00a	11.67a	10.0a	8.33a	11.67a
T_8	0.00d	1.67f	3.33d	0.00e	0.00g
LSD $_{(0.05)}$	**0.29**	**0.70**	**0.84**	**0.68**	**0.75**
CV (%)	**9.92**	**6.87**	**6.84**	**7.43**	**7.93**

In a column, means having same letter(s) are not significantly different at 5% level of probability by DMRT.

Treatments

T_1=Neem leaf
T_2=Korobi leaf
T_3=Marigold leaf
T_4=Nishinda leaf
T_5=Tobacco leaf
T_6=Tomato leaf
T_7 =Neem seed kernel
T_8= Control

4.2.7. Efficacy of plant extract against adult mango mealybug female

Treatment with all botanicals following both spraying and dipping methods did not show any effect on the mortality of adult female of mango mealybug (Appendix 4).

4.2.8. Effect of mechanical bands against different stages of mango mealybug

The results on effectiveness of ten mechanical bands on the infestation of stem, inflorescence and leaves at different stages of mango mealy bug are given below

4.2.3.1 Effect of mechanical bands on the1st instar nymph of mango mealybug in field

The data regarding the reduction percentage in inflorescence infestation, the black plastic sheet with grease gave the maximum (71.33%) reduction (Table 7) which was statistically similar to only grease (67.67%), white plastic sheet (66.25%), cotton with insecticide (65.00%) and black cloth (65.00%). In stem maximum reduction was showed at black plastic sheet with grease (83.00%) followed by red cloth (68.67%) which was statistically similar to the cotton with insecticide (66.00%) and black cloth (66.67%). In leaf, the maximum reduction was showed in black plastic sheet with grease (84.70%) followed by white plastic sheet (75.32%), cotton (75.28%) (Table 7). In case of inflorescence the result supported by the results Karar *et al.*, (2007) but contradict with the reduction percentage of mealybug in stem and leaf. He 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.

4.2.3.2 Effect of mechanical bands on 2nd instar nymph of mango mealybug in field

The data regarding the reduction percentage in inflorescence black plastic sheet with grease showed maximum (79.25%) reduction which was statistically similar to black plastic sheet (79.07%). In stem maximum reduction was showed at black plastic sheet with grease (71.33%) followed by only grease (67.67%) and cotton with insecticide (65.0%) which was statistically similar to white cloth (63.33%) and white plastic sheet (66.25%). In leaf, the maximum reductionof infestation (Table 8) was showed in black plastic sheet with grease (86.33%) followed by black plastic sheet (71.33%), white cloth (42.67%) and black cloth (38.33%).

Table 8. Effect of mechanical bands to control 1st instar nymphs of mango mealybug

Treatments	Mealybug no./different plant parts					
	Inflorescence ($2cm^2$)	Reduction over control (%)	Stem ($2cm^2$)	Reduction over control (%)	Leaf ($2cm^2$)	Reduction over control (%)
T_1	2.33b	37.33d	0.67c	32.27e	0.33 b	75.28b
T_2	1.00d	66.25a	1.67a	14.67f	0.33 b	75.32b
T_3	1.06d	36.33d	0.67c	33.33e	0.33 b	75.86b
T_4	0.33e	67.67a	0.00e	58.33c	0.33 b	73.17b
T_5	1.67c	55.33bc	0.33d	68.67b	0.00 c	72.68b
T_6	1.06d	65.00a	0.33d	66.67b	0.33 b	73.06b
T_7	1.67c	63.33ab	1.00b	44.0d	0.33 b	72.85b
T_8	1.67c	65.00a	0.33d	66.0b	1.00 a	36.65c
T_9	2.33b	51.67c	1.00b	33.33e	1.00 a	22.80d
T_{10}	3.67a	71.33a	0.00e	83.00a	0.33 b	84.70a
T_{11}	0.67de		1.00b		1.00 a	
LSD $_{(0.05)}$	**0.40**	**8.88**	**0.11**	**6.52**	**0.09**	**7.09**
CV (%)	**14.85**	**8.41**	**10.46**	**6.91**	**10.6**	**9.90**

In a column, means having same letter(s) are not significantly different at 5% level of probability by DMRT.

Treatments

T_1 = Cotton
T_2 = White plastic sheet
T_3 = Black plastic sheet
T_4 = Only Grease
T_5 = Red cloth
T_6 = Black cloth
T_7 = White cloth
T_8 = Cotton with insecticide
T_9 = White plastic sheet with grease
T_{10} = Black plastic sheet with grease
T_{11} = Control

Table 9. Effect of mechanical bands to control 2nd instar nymphs of mango mealybug

Treatments	Mealybug no./different plant parts					
	Inflorescence ($2cm^2$)	Reduction over control (%)	Stem ($2cm^2$)	Reduction over control (%)	Leaf ($2cm^2$)	Reduction over control (%)
T_1	5.67c	42.73c	2.00a	37.33d	1.00c	16.00g
T_2	2.00f	41.06c	0.00f	66.25ab	1.00c	23.00f
T_3	4.33d	79.25a	0.67d	36.33d	0.33e	71.33b
T_4	1.33fg	20.84d	0.33e	67.67ab	1.33b	39.00cd
T_5	3.33e	59.23b	1.67b	55.33c	0.67d	34.33d
T_6	1.67f	39.67c	1.68b	65.00ab	1.00c	38.33cd
T_7	3.00e	58.67b	1.34c	63.33b	0.67d	42.67c
T_8	1.67f	38.67c	2.00a	65.00ab	1.00c	15.33g
T_9	14.00a	23.67d	0.00f	51.67c	0.33e	28.00d
T_{10}	0.67g	79.07a	1.33c	71.33a	1.33b	86.33a
T_{11}	9.00b	-	1.33c	-	1.67a	-
LSD $_{(0.05)}$	**0.92**	**5.92**	**0.13**	**7.96**	**0.09**	**4.88**
CV (%)	**12.77**	**8.87**	**6.84**	**8.00**	**6.24**	**7.92**

In a column, means having same letter(s) are not significantly different at 5% level of probability by DMRT.

Treatments

T_1 = Cotton
T_2 = White plastic sheet
T_3 = Black plastic sheet
T_4 = Only Grease
T_5 = Red cloth
T_6 = Black cloth
T_7 = White cloth
T_8 = Cotton with insecticide
T_9 = White plastic sheet with grease
T_{10} = Black plastic sheet with grease
T_{11} = Control

4.2.3.3 Effect of mechanical bands on 3rd instar nymph of mango mealybug in field

The data regarding the reduction percentage in inflorescence black plastic sheet with grease gave maximum reduction (87.33%) followed by white cloth (78.0%) which was statistically similar to black plastic sheet (76.0%). In stem maximum reduction was showed at black plastic sheet with grease (88.67%) followed by cotton with insecticide (84.44%), white plastic sheet (84.33%). In leaf, the maximum reduction was showed in black plastic sheet with grease (94.33%) which was statistically similar with black plastic sheet (92.33%) and red cloth (91.67%).

Table 10. Effect of mechanical bands to control 3rd instar nymphs of mango mealybug

Treatments	Mealybug no./different plant parts					
	Inflorescence ($2cm^2$)	Reduction over control (%)	Stem ($2cm^2$)	Reduction over control (%)	Leaf ($2cm^2$)	Reduction over control (%)
T_1	10.67b	30.67se	1.67b	28.89d	2.00b	66.67d
T_2	2.67e	64.67c	0.67d	84.33ab	1.00c	84.67bc
T_3	5.33c	76.00b	0.33e	68.78c	0.67d	92.33ab
T_4	3.67d	64.67c	0.67d	68.33c	1.00c	84.67bc
T_5	3.67d	65.00c	0.33e	75.51bc	1.00c	91.67ab
T_6	3.00de	58.33d	0.67d	77.18bc	1.00c	85.33bc
T_7	1.67f	78.00b	4.67a	17.78e	0.63d	64.00d
T_8	13.33a	65.00c	0.67d	84.44ab	1.00c	79.33c
T_9	1.33f	65.33c	0.33e	83.11ab	0.33e	10.33e
T_{10}	2.67e	87.33a	1.67b	88.67ab	1.00c	94.33a
T_{11}	10.67b	-	1.00c	-	2.67a	-
LSD $_{(0.05)}$	**0.93**	**5.66**	**0.12**	**10.85**	**0.20**	**7.79**
CV (%)	**10.21**	**10.35**	**6.04**	**6.68**	**10.48**	**5.58**

In a column, means having same letter(s) are not significantly different at 5% level of probability by DMRT.

Treatments

T_1 = Cotton
T_2 = White plastic sheet
T_3 = Black plastic sheet
T_4 = Only Grease
T_5 = Red cloth
T_6 = Black cloth
T_7 = White cloth
T_8 = Cotton with insecticide
T_9 = White plastic sheet with grease
T_{10} = Black plastic sheet with grease
T_{11} = Control

CHAPTER V

SUMMARY AND CONCLUSION

SUMMARY

The experiment was conducted at the Entomology laboratory and mango orchard at Sher-e-Bangla Agricultural University campus Dhaka during the period from November, 2013 to May, 2014 to study the effect of some plant extracts mechanical bands against mango mealybug. In laboratory, some plant extracts such as neem, korobi, marigold, nishinda, tobacco, tomato and neem seed kernel extracts were used to evaluate their efficacy on infestation against 1^{st}, 2^{nd}, 3^{rd} instar nymph and adult female of mango mealybug. In field, different mechanical bands (cotton, white plastic sheet, black plastic sheet, only grease, red cloth, black cloth, white cloth, cotton with insecticide, white plastic sheet with grease, black plastic sheet with grease) were used as mechanical control.

In case of 1^{st} instar mango mealybug at dipping method highest mortality (5%) was found in neem seed kernel which was statistically similar to neem leaf extract after 24 h of post treatments. After 48 h (10%) mortality of the insect was found in neem seed kernel extract followed by neem leaves (6.67%). No effect was found in case of tomato leaf extract. After 72 h of treatment neem seed kernel gave highest mortality of 1^{st} instar nymph of mango mealybug resulted with (15%) mortality followed by neem leaves (11.67%). In spraying method up to 120 h similar trend was found like dipping method. After 72 h of treatment neem seed kernel was found most effective botanical for the control of 1^{st} instar mango mealybug resulted with (13.33%) mortality followed by neem leaves (11.67%), tomato leaves (10%). After 120 h neem seed kernel extract gave maximum mortality (10%) followed by neem leaves (6.67%).

In case of 2^{nd} instar at the dipping method after 24 h of treatment neem seed kernel extract was the most effective to kill (8.33%) followed by neem leaves (6.67%) and tobacco leaf (5%). No significant difference was found in mortality of the insect in treatment with nishinda leaves. After 48 h (25%) mortality of insect was found in neem seed kernel extract followed by neem leaves (13.33%) and tobacco leaves (11.6%). After 72 h of treatment neem seed kernel was found the most effective botanical for the control of 2nd instar mango mealybug resulted with (18.33%) mortality followed by neem leaves (11.6%) and tobacco leaves (10.0%). After 96 h and 120 h highest mortality was found in neem seed kernel extract and lowest effect was found in korobi leaves extract. In spraying method up to 120 h of treatment highest mortality was found in neem seed kernel extract followed by neem leaf extract.

In case of 3rd instar in dipping method after 24 h of treatment neem seed kernel extract was the most effective and gave highest mortality (8.33%) followed by neem leaves (6.67%). Korobi leaf extract was found least effective and showed no effect against 3rd instar mango mealybug. Up to 120 h of treatment, neem seed kernel showed best performance and gave the highest mortality followed by neem leaves. In spraying method after 24 h, 48 h, 72 h, 96 h, and 120 h of treatment highest mortality was found in neem seed kernel extract followed by neem leaf extract. Lowest performance was found in korobi leaf up to 120 h of post treatment. Treatment with all plant extracts following both spraying and dipping methods did not show any effect on the mortality of adult female of mango mealybug.

In field at the 1st instar mango mealybug black plastic sheet with grease gave the maximum (71.33%) reduction which was statistically similar to only grease (67.67%), white plastic sheet (66.25%), cotton with insecticide (65.00%) and black cloth (65.00%) which was observed in inflorescence. In stem maximum reduction was showed at black plastic sheet with grease (83.00%) followed by red cloth (68.67%) which was statistically similar to the cotton with insecticide (66.00%) and black cloth (66.67%). In leaf, the maximum reduction was showed in black plastic sheet with grease (84.70%) followed by white plastic sheet (75.32%), cotton (75.28%).

In case of 2nd instar nymph of mango mealybug percent reduction of insect number was observed in inflorescence and found that black plastic sheet with grease showed maximum (79.25%) reduction which was statistically similar to black plastic sheet (79.07%). In stem maximum reduction was showed at black plastic sheet with grease (71.33%) followed by only grease (67.67%) and cotton with insecticide (65.0%) which was statistically similar to white cloth (63.33%) and white plastic sheet (66.25%). In leaf, the maximum reduction (Table 8) was showed in black plastic sheet with grease (86.33%) followed by black plastic sheet (71.33%), white cloth (42.67%) and black cloth (38.33%).

In case of 3rd instar nymph black plastic sheet with grease gave maximum reduction (87.33%) followed by white cloth (78.0%) which was statistically similar to black plastic sheet (76.0%) in inflorescence. Similar trend was observed both stem and leaf. Maximum reduction was showed at black plastic sheet with grease (88.67%) followed by cotton with insecticide (84.44%), white plastic sheet (84.33%) in stem. In leaf, the maximum reduction was found in black plastic sheet with grease (94.33%) which was statistically similar with black plastic sheet (92.33%) and the red cloth (91.67%).

CONCLUSION

Based on finding of the study the following conclusion are drawn

Among all the plant extract neem seed kernel extract showed the maximum mortality against 1^{st}, 2^{nd}, 3^{rd} and adult female mango mealybug in the laboratory. In field experiment black plastic sheet with grease gave the highest reduction of 1^{st}, 2^{nd} and 3^{rd} instar nymph of mango mealybug.

RECOMMENDATIONS

The following recommendations may be suggested from the present study-

1. Further study may be needed to find out the appropriate dose of plant extract to control the mango mealybug.
2. More plant extracts should be included for future study as sole or different combination to make sure the better performance.

CHAPTER VI

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APPENDIX TABLE 1. Infestation intensity of mango mealybug in mango tree.

Date	No. of insect/ $2cm^2$ stem	No. of insect/ $2cm^2$ leaf	No. of insect/ $2cm^2$ inflo.
01-02-2014	5.33	2.55	6.78
23-02-2014	9.56	24.22	38.89
15-03-2014	3.33	21	29.62
04-04-2014	2.55	15	18.4

APPENDIX TABLE 2. Infestation intensity of mango mealybug in jack fruit tree.

Date	No. of insect/ $2cm^2$ stem	No. of insect/ $2cm^2$ leaf	No. of insect/ $2cm^2$ inflo.
02-01-2014	19.33	4.33	30.44
23-02-2014	20.11	18.11	23.33
15-03-2014	19.67	28.21	31.11
04-03-2014	16.33	12.3	20.22

APPENDIX TABLE 3. Infestation intensity of mango mealybug in papaya tree.

Date	No. of insect/ $2cm^2$ stem	No. of insect/ $2cm^2$ leaf	No. of insect/ $2cm^2$ inflo.
01-02-2014	43.72	43.7	34.33
23-02-2014	136.72	136.72	54.55
15-03-2014	141.5	141.52	111.11
04-04-2014	131.32	139.59	98.24

APPENDIX 4. Efficacy of plant extract against adult mango mealybug female

Treatments	%Mortality at different interval of data collection after spraying and dipping				
	24hrs	48hrs	72hrs	96hrs	120hrs
T_1	0.00	0.00	0.00	0.00	0.00
T_2	0.00	0.00	0.00	0.00	0.00
T_3	0.00	0.00	0.00	0.00	0.00
T_4	0.00	0.00	0.00	0.00	0.00
T_5	0.00	0.00	0.00	0.00	0.00
T_6	0.00	0.00	0.00	0.00	0.00
T_7	0.00	0.00	0.00	0.00	0.00
T_8	0.00	0.00	0.00	0.00	0.00