MANAGEMENT OF MEALYBUG (*PARACOCCUS MARGINATUS*) IN PAPAYA PLANT

A THESIS

By

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CERTIFICATE

This is to certify that thesis entitled, “MANAGEMENT OF MEALYBUG IN PAPAYA PLANT” 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 MD. SHAHEDUZZAMAN bearing Registration No. 06-02067 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:
Dhaka, Bangladesh

....

(Prof. Dr. Mohammed Ali)
Supervisor

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LIST OF ACRONYMS

AEZ	=	Agro-Ecological Zone
BARI	=	Bangladesh Agricultural Research Institute
BBS	=	Bangladesh Bureau of Statistics
ppm	=	Parts per million
et al.	=	And others
N	=	Nitrogen
TSP	=	Triple Super Phosphate
MP	=	Muriate of Potash
RCBD	=	Randomized complete block design
ha^{-1}	=	Per hectare
G	=	gram (s)
Kg	=	Kilogram
µg	=	Micro gram
SAU	=	Sher-e-Bangla Agricultural University
SRDI	=	Soil Resources and Development Institute
No.	=	Number
Wt.	=	Weight
LSD	=	Least Significant Difference
^{0}C	=	Degree Celsius
mm	=	millimeter
Max	=	Maximum
Min	=	Minimum
%	=	Percent
cv.	=	Cultivar
NPK	=	Nitrogen, Phosphorus and Potassium
CV%	=	Percentage of coefficient of variance
Hr	=	Hour
T	=	Ton
viz.	=	Videlicet (namely)

MANAGEMENT OF MEALYBUG IN PAPAYA PLANT

Abstract

The experiment was conducted at the Horticulture Farm of Sher-e-Bangla Agricultural University, Dhaka, Bangladesh during the period from September 2011 to May 2012 to study the management of mealybug in papaya plant. The experiment consists of ten treatments chemicals pesticide including control treatment for management of mealybug in papaya seedling viz. T_1 = Shobicron 425EC, T_2 = Imidacloprid (Admire) 200SL, T_3 = Semcap 50EC, T_4 = Cypermethrin 10EC, T_5 = Fighter 25EC, T_6 = Chloropyriphos 20EC, T_7 = Dimethoin 40EC, T_8 = Imidacloprid (Bumper) 200SL, T_9 = Decis 25EC and T_{10} = Control. The experiment consists of eight treatments including control treatment for management of mealybug in papaya plant viz. T_1 = Shobicron 425EC, T_2 = Imidacloprid 200SL, T_3 = Cypermethrin 10EC, T_4 = Deltamethrin 25EC, T_5 = Lambdacyhalothrin, T_6 = Semcap 50EC, T_7 = Neem seed kernel extract and T_8= Control. The experiment was laid out in Randomized Complete Block Design (RCBD) single factor with three replications. Significant differences were observed among different management practices in terms of seedling, plants, leaves and fruits infestation during the management of papaya mealy bug. Imidacloprid (Admire and Bumper) 200SL was the most effective on mealybug control as well as lowest number of infested seedling was recorded. The lowest number of infested plant, number of leaf infestation, number of infested fruits plant was recorded from Imidacloprid 200SL. The highest number of healthy plant per plot, number of healthy leaf per plant, healthy fruit was found in Imidacloprid treated plot. Imidacloprid gave the maximum protection of papaya in field from mealybug infestation.

CHAPTER I

INTRODUCTION

The papaya (*Carica papaya* L.) is one of the important delicious and popular fruit crops grown throughout Bangladesh. It is originated in Mexico and spread to almost all the corners of the tropical and subtropical parts of the world. It is a short duration and year round fruit in Bangladesh. It is usually cultivated in homestead area but presently farmers commercially cultivate in different regions of Bangladesh. As a raw fruit, it is popularly used as vegetable in cooking and some preparations. Papaya fruit is a rich source of minerals, vitamins, and enzymes. The papaya is an amazingly rich source of the proteolytic enzymes. These are the chemicals that enable the digestion of protein. Papain, which is the most important of these enzymes in the papaya, is extracted and dried as a powder for use to aid the digestion, and it is often used as a meat tenderizer, the enzyme partially breaking down the meat fibers.

In recent years, the production of papaya is greatly hindered by a nuisance insect pest, papaya mealybug in Bangladesh. The papaya mealy bug caused heavy infestation and reduced yield of papaya and devastated the crop throughout the country recently. The papaya mealybug, *Paracoccus marginatus* (Homoptera: Pseudococcidae) is a native of Mexico. The specimens of this mealybug were collected in 1955, but it was only described in 1992 (Williams and Willink, 1992). From 1992 until the year 2000, it spreads to the rest of Central America, the Caribbean Islands, Florida, and tropical South America. In the Pacific, it was recorded in Guam in 2002, Palau in 2003, and Hawaii in 2004 (Meyerdirk *et al.,* 2004; Muniappan *et al.,* 2006; Heu *et al.,* 2007). In Asia, it was reported from

Indonesia, India and Sri Lanka in 2008 (Muniappan *et al.,* 2009), Maldives and Bangladesh in 2009 and Thailand, Cambodia and the Philippines in 2010. It was also reported from the Reunion Island in the Arabian Sea and Ghana in West Africa in 2010 (Tanwar *et al.,* 2010).

The papaya mealybug is polyphagous pest and its host range includes more than 60 species of plants including papaya, hibiscus, avocado, citrus, cotton, tomato, eggplant, peppers, beans, peas, sweet potato, mango, cherry, and pomegranate. In Sri Lanka *P. marginatus* was said to be reported in about 30 families of host plants. However, papaya *(Carica papaya* L.*)* had been observed as the most preferred host while Manioc (*M.utilissima*) and temple trees (*Plumeria acuminata*) as the next preferred (Muniappan *et al.,* 2009; Thangamalar *et al.,* 2010).

The infestation of papaya mealybug appears on above ground parts on leaves, stem and fruits as clusters of cotton-like masses. Both nymph and adult of mealy bug suck the sap by inserting its stylets into the epidermis of the leaf, fruit and stem. While feeding, it injects a toxic substance into the leaves, resulting in chlorosis, plant stunting, leaf deformation or crinkling, early leaf and fruit drop, and death of plants. The honeydew excreted by the bug results in the formation of black sooty mould which interferes in the photosynthesis process and causes further damage to the crops. Heavy infestations are capable of rendering fruit inedible due to the buildup of thick white waxy coating (Meyerdirk *et al.,* 2004; Muniappan *et al.,* 2009; and Tanwar *et al.,* 2010).

The live adult female of mealybug (about 2.5 mm long and 1.5 mm wide) is evenly covered in powdery, white wax, without any longitudinal depressions. Short waxy filaments develop around the body margin including short caudal filaments. The body contents are yellow in life but turn black in less than one day after death, even when preserved in alcohol. In slide-mounted adult females from the Oriental region, this is the only species of *Paracoccus* that totally lacks oral rim ducts in the sub-median or median areas of the dorsum. There are three nymphal instars and no pupal stage in the wingless female, and eggs are laid in a small, white ovisac of woolly wax. The winged male has two nymphal stages, a pre-pupa and a pupal stage (Muniappan *et al.,* 2006). There are several generations per year.

The biology and seasonal abundance of papaya mealybug depends on the prevailing atmospheric condition. Temperature, rainfall and atmospheric humidity greatly influenced the population abundance and damage severity of this obnoxious pest. Heavy rainfall reduces its population and damage severity. Movement of crawlers through air, irrigation water or farm equipment helps in fast spread of the mealybug from infested field to healthy fields. Moreover, free movement of infested fruits, vegetables and other material among different regions causes spread of the pest. Long-distance movement is aided through transport of infested planting material and fresh fruits and vegetables from one end of a farm to the other or even across the country. Ants, attracted by the honeydew, have been seen carrying mealybugs from plant to plant (Tanwar *et al*., 2010).

Management of mealybugs is often difficult because plant protection products are of limited effectiveness against mealybugs because of the presence of waxy covering of its body. For management of mealybugs, it is important to know the species present as management programs for the various mealybugs may differ. Management of mealybug involves monitoring and scouting to detect early presence of the mealybug, pruning of infested branches and burning them, removal and burning of crop residues, avoiding the movement of planting material from infested areas to other areas, control of ant etc. Moreover, biological control agents like lady bird bettles, lace wings, hover flies plays an important role in reducing the population of mealybugs (Meyerdirk, 2001; Muniappan *et al.,* 2006; Tanwar *et al*., 2010). Therefore, it is needed to know the biology, pest status, seasonal abundance and damage severity of this pest in Bangladesh and to develop sustainable management practices for this pest.

Keeping the above points in view, present experiment was designed and planned with the following objectives:

a. To assess the pest status and damage severity of mealybug on papaya.
b. To develop suitable management practices for papaya mealybug control in Bangladesh.

CHAPTER II

REVIEW OF LITERATURE

2.1 Bioecology of papaya mealybug

Distribution

The papaya mealybug, *Paracoccus marginatus* is a hemipteran insect belonging to the family Pseudococcidae. The first specimen of this devastating mealybug was collected in Mexico during 1955. It was described in 1992 in the Neotropical region occupying Belize, Costa Rcia, Guatemala, and Mexico (Williams and Willink, 1992).

Walker *et al.,* (2003) stated that *Paracoccus marginatus* was recorded in the following 14 Caribbean countries i.e. St Martin, Guadeloupe, St Barthelme, Antigua, Bahamas, British Virgin Island, Cuba, Dominican Republic, Haiti, Puerto Rico, Montserrat, Nevis, St Kitts and the U.S. Virgin Islands since 1994.

Muniappan *et al.,* (2009) first reported the papaya mealybug *Paracoccus marginatus* in Indonesia (Java) and India (Tamil Nadu). He also worked on the incidence and damage potential of this noxious pest.

The papaya mealybug is believed to be native to Mexico and/or Central America. It has never gained status as a serious pest there, probably due to the presence of an endemic natural enemy complex. The first specimens were collected in Mexico in 1955. The papaya mealybug was described in 1992 from the Neotropical Region in Belize, Costa Rica, Guatemala, and Mexico (Williams and Willink, 1992). When the papaya mealybug invaded the Caribbean region, it became a pest there; since 1994 it has been recorded in the following 14 Caribbean countries: St. Martin, Guadeloupe, St. Barthelme, Antigua, Bahamas, British Virgin Islands, Cuba, Dominican Republic, Haiti, Puerto Rico, Montserrat, Nevis, St. Kitts, and the U.S. Virgin Islands. More recently, specimens have turned up in the Pacific regions of Guam and the Republic of Palau.

Specimens also have been intercepted in Texas and California, and it is expected that papaya mealybug could rapidly establish throughout Florida and through the Gulf states to California. It is possible that certain greenhouse crops could be at risk in areas as far north as Delaware, New Jersey and Maryland. It has already been identified on papaya plants in the Garfield Conservatory in Chicago, Illinois in late August of 2001. A biological control program was implemented in December of 2001 with very successful results.

Papaya mealybug infestations are typically observed as clusters of cotton-like masses on the above-ground portion of plants. The adult female is yellow and is covered with a white waxy coating. Adult females are approximately 2.2 mm long (1/16 inch) and 1.4 mm wide. A series of short waxy caudal filaments less than 1/4 the length of the body exist around the margin.

Eggs are greenish yellow and are laid in an egg sac that is three to four times the body length and entirely covered with white wax. The ovisac is developed ventrally on the adult female.

Adult males tend to be colored pink, especially during the pre-pupal and pupal stages, but appear yellow in the first and second instars. Adult males are approximately 1.0 mm long, with an elongate oval body that is widest at the thorax (0.3 mm). Adult males have ten-segmented antennae, a distinct aedeagus, lateral pore clusters, a heavily sclerotized thorax and head, and well-developed wings.

Miller and Miller (2002) give a complete description of all instars of both sexes of the papaya mealybug, as well as a complete description of characters used to distinguish the papaya mealybug from other closely related species. Two characteristics that are important in distinguishing *P. marginatus* adult females from all other species of *Paracoccus* are: the presence of oral-rim tubular ducts dorsally restricted to marginal areas of the body, and the absence of pores on the hind tibiae. Adult males may be distinguished from other related species by the presence of stout fleshy setae on the antennae and the absence of fleshy setae on the legs.

The papaya mealybug can easily be distinguished from *Maconellicoccus marginatus* (Green), the pink hibiscus mealybug because papaya mealybug females have eight antennal segments, in contrast to nine in the latter species. Specimens of papaya mealybug turn bluish-black when placed in alcohol, as is characteristic of other members of this genus.

Biology

Details on the biology and life cycle of the papaya mealybug are lacking. In general, mealybugs have piercing-sucking mouthparts and feed by inserting their mouthparts into plant tissue and sucking out sap. Mealybugs are most active in warm, dry weather. Females have no wings, and move by crawling short distances or by being blown in air currents. Females usually lay 100 to 600 eggs in an ovisac, although some species of mealybugs give birth to live young. Egg-laying usually occurs over the period of one to two weeks. Egg hatch occurs in about 10 days, and nymphs, or crawlers, begin to actively search for feeding sites. Female crawlers have four instars, with a generation taking approximately one month to complete, depending on the temperature. Males have five instars, the fourth of which is produced in a cocoon and referred to as the pupa. The fifth instar of the male is the only winged form of the species capable of flight. Adult females attract the males with sex pheromones. Under greenhouse conditions, reproduction occurs throughout the year, and in certain species may occur without fertilization.

According to Walker *et al.* (2003) Papaya mealybug infestations are typically observed as clusters of cotton-like masses on the above ground portions of plant, the adult female is yellow and covered with a white waxy coating, Adult females are approximately 2.2 mm long (1/16 inch) and 1.4 mm wide. A series of short waxy caudal filaments less than $1/4^{th}$ the length of the body exist around the margin. Adult males are approximately 1.0 mm long, with an elongate-oval body which is widest at the thorax (0.30mm). Adult males have ten segmented antennae and well developed wings. Details on the biology and life cycle of the papaya mealybug are lacking. In general mealybugs have piercing sucking mouth parts and feed by inserting their stylets into plant tissue and sucking out sap. Mealybugs are most active in warmer and dry weather. Females have no wings and move by crawling short distances of by being blown in air currents. Females usually lay 100 to 600 eggs in an ovisac, although some species of mealybugs give birth to Young. Egg lying usually accomplished in the period of one to two weeks, Egg is hatched in about 10 days and the nearly emerged nymphs or crawlers begin to actively search for feeding sites. Female crawlers have four instars, with a generation having approximately one month's duration for completing its life cycle depending on the other prevailing temperature and environmental conditions.

Tanwar *et al.* (2010) worked on the incidence and damaging valuve of papaya mealybug and its management strategies. Papaya mealybug is most active in warm and temperature weather. An individual female usually deposits 100 to 600 eggs. Eggs are greenish yellow and are laid in an ovisac which is about three to four times the body length and entirely covered with white wax. Eggs generally hatch at nearly 10 days and nymph or crawlers pass their times in search of feeding locations. Males have longer developmental time (27-30 days) than females (24-26 days) at 25± 1°C 65±2% RH and 12:12 (L:D) photoperiod. Aitken (1984) described papaya mealybug. *P. marginatus*, as an invasive pest from Central American countries. This mealybug has caused havoc in agricultural and horticultural crops in India ever since its first report from Coimbatore during 2007. The authors have reported that the adult females of *P. marginatus* laid eggs (approximately about 150 to 200 eggs) inside the egg-sacs. Eggs are pink colored, grain like measuring 0.120 cm in diameter.

Indra *et al.* (2008) carried out research work on *P. marginatus*. The female mealybug usually laid up to 600 eggs enclosed in an ovisac. *P. marginatus* was observed to complete the life cycle on papaya (*Carica papaya* L.) in 26 days and the life cycle was found to vary from 15 days to 32 days depending on the host plant species. It has the ability to develop, survive, and reproduce successfully between 18 to 30 °C which suggests that it has the ability to develop and establish in areas within these temperature range.

Host Plants

The papaya mealybug is polyphagous and has been recorded on >55 host plants in more than 25 genera. Economically important host plants of the papaya mealybug include papaya, hibiscus, avocado, citrus, cotton, tomato, eggplant, peppers, beans and peas, sweet potato, mango, cherry, and pomegranate (Walker *et al.*, 2003). The main host is papaw (Williams and Willink, 1992).

Miller and Miller (2002) worked on the incidence and developmental stage of *P. marginatus* in different host plants in USA. The genus *Paracoccus* includes some 79 species of varied distribution from the "Austro-Oriental, Ethiopian, Madagasian, Nearectic, Neotropical, Newzealand, Pacific, Palearetic and oriental regions" (Ben Dov, 1994). Although most assigned species have not been recognized as major economic pest there are two notable exceptions. *P. marginatus* is a polyphagous insect; it has recorded on about 55 host plants in more than 25 general.

Food is a component of the environment and may influence an animal's chance to survive and multiply by modifying its fecundity, longevity or speed of development (Andrewartha and Birch, 1954). The economically important host range of the papaya mealybug includes papaya, hibiscus, acalypha, plumeria, avocado, citrus, cotton, tomato, eggplant, pepper, beans and peas, sweet potato, mango, cherry and pomegranate (Miller and Miller, 2002). In addition, weed species such as *Parthenium hysterophorus* L. are also recorded as host plants of papaya mealybug (Miller and Miller, 2002). Infestations of papaya mealybug have been observed on papaya, plumeria, hibiscus and jatropha in Hawaii with the favored hosts appearing to be papaya, plumeria, and hibiscus (Heu *et al*., 2007).

However, insects may settle, lay eggs, and severely damage plant species that are unsuitable for development of immature (Harris, 1990). There is no specific information about the life history of papaya mealybug on different host plant species. Although, papaya is the dominant host plant species of papaya mealybug, it is important to find out how it can develop on popular ornamental plants such hibiscus, acalypha, and plumeria as well as on a commonly found invasive annual weeds such as parthenium.

Hibiscus, which is believed to be native to China, is a popular ornamental and landscape shrub, and widely grown in the tropics and subtropics (Ingram and Rabinowitz, 2004). Different hibiscus species are grown in many areas of the US (USDA, 2007). Hibiscus has been grown in Florida for many years (Ingram and Rabinowitz, 2004), and its potential planting range in the US includes some areas of Texas and California (Gilman, 1999). Hibiscus is widely grown in Hawaii. Hibiscus is sold nationwide as potted flower plants, and maintained in greenhouses around the country. Pink hibiscus mealybug, *Maconellicoccus hirsutus* (Green) (Hemiptera: Pseudococcidae) is another important mealybug species that was introduced to Florida in 2002, and has been identified as one of the most important insect pests of hibiscus (Goolsby *et al.*, 2002; Hoy *et al.*, 2006).

Damage

The papaya mealybug feeds on the sap of plants by inserting its stylets into the epidermis of the leaf, as well as into the fruit and stem. In doing so, it injects a toxic substance into the leaves. The result is chlorosis, plant stunting, leaf deformation, early leaf and fruit drop, a heavy buildup of honeydew, and death. Heavy infestations are capable of rendering fruit inedible due to the buildup of thick white wax. Papaya mealybug has only been recorded feeding on areas of the host plant that are above ground, namely the leaves and fruit.

Walker *et al.* (2003) conducted on the different ecological aspects *P. marginatus.* The papaya mealybug feeds on the sap of plants by inserting its stylets of beaks into the epidermis of the leaves, as well as into the unripe fruits and stems. In doing so, it infects a toxic or harmful substance into the leaves. The results are chlorosis, plant stunting, leaf deformation, early leaf and fruit drop, a heavy buildup of honeydew, and death of host plants. Heavy infestations are capable of rendering fruit inedible due to the aggregation of thick white waxy appearance papaya mealybug has only been recorded feeding on the areas of the host plant above ground parts including leaves and fruits of different host plants.

Factors Responsible for High Population Buildup

With rapid development, high survival rate, and enormous reproductive capacity, *P. marginatus* population could potentially reach a high level. Wax layer and waxy fibers over the ovisac and body of mealybug nymphs and adult females protect them from adverse environmental conditions and routine chemical pesticides. Availability of alternate hosts/weeds around fields not cared by cultivators, movement of crawlers through air, irrigation water or farm equipment helps in fast spread of the mealybug from infested field to healthy fields. No phytosanitation: free movement of infested fruits, vegetables and other material, Intensive cropping system. Wider acceptability of hosts by papaya mealybug and its subsequent adaptability on them. Ant association providing protection from parasitoids and predators and aiding in dispersal of the pest. In certain crops, stems which often carry mealybug infestation are stocked in the farm for propagation or other purposes. These stocks, near the newly planted crop act as reservoirs of papaya mealybug.

Healthy plants can be infested from mealybug infested plants as juvenile mealybugs can crawl from an infested plant to another plant. Small 'crawlers' get readily dispersed by wind, rain, irrigation water, birds, ants, clothing, and vehicle, etc. The wax, which sticks to each ovisac and nymphs, also facilitates passive dispersal by equipment, animals or human beings. The female mealybug is not active and unable to fly. In fact, human beings greatly facilitate in the transport of these mealybugs. Long-distance movement is aided through transport of infested planting material and fresh fruits and vegetables from a farm to the other or even across the country. Ants, attracted by the honeydew, have been seen carrying mealybugs from plant to plant.

Mealybugs are known to offer ants with their sugary excretion (honeydew) and in return ants help in spreading the mealy bugs and provide protection from predator ladybird beetles, parasites and other natural enemies. Species of ant, *Oecophylla smaragdina* has been found attending papaya mealybug, feeding on honeydew on papaya and other plants.

2.2. Management of Papaya Mealybug

Papaya mealybug, *Paracoccus marginatus,* the invasive pest from Central American countries has caused havoc in agricultural and horticultural crops in India ever since its first report from Coimbatore during 2007. The search for the effective parasitoids in India is still elusive. Attention has been focused on the conservation of native predators of the pest. *Spalgius epius* was recorded as a potential predator of different species of mealybugs and scales. As mulberry ecosystem provides a suitable niche for colonization of the predator owing to limited use of chemicals, investigations were taken up to explore the utility of this Lycaenid as a biological control agent of *P. marginatus* in mulberry. Photomicrograph aided investigations have thrown light on the peculiar feeding behaviour of the predatory larvae. Ex situ confinement studies have shown that the fifth instar larvae consumed as much as 18 to 26 (22.33±3.21) ovisacs and 112 to 132 (121.66 ± 8.86) nymphs and adults of the mealy bugs. During the whole larval period the predatory larvae devoured about 42 to 53 (48.15±4.08) ovisacs and 196 to 222 (210.99 ± 10. 77) nymphs and adults of *P.marginatus* (Thangamalar *et al*., 2010).

A hitherto unrecorded species of mealybug was discovered in early 2008 in the western provincial districts Colombo and Gampaha in Sri Lanka, infesting a large number of plant species. Investigations were done to identify the pest and to study its host range, nature of damage and distribution, and to design and implement control measures. The pest was identified as papaya mealybug, *Paracoccus marginatus* (Hemiptera: Pseudococcidae), an invasive alien species originating from Mexico and/or Central America.

The mealybug found to heavily infest more than 40 plant species including papaw, the major host, and several horticultural and floricultural crops like *Plumeria,* manioc, bread fruit, *Alstonia macrophylla* and *Jatropha* spp. By 2009 the pest had spread to other parts of the country including the North Western, Saba-ragamuwa, Southern, North Central, Central and Eastern provinces. As an immediate control measure, Imidacloprid 200SL, thiamethoxam 25%WG and Mineral oil were recommended for the control of this pest until biological control agents could be introduced (Galanihe *et al*., 2010).

The three most effective insecticides identified in the experiments were recommended for use as foliar sprays against the papaya mealybugs on cultivated crops: thiamethoxam 25%WG at the rate of 1g per liter; Imidacloprid 200g/l SL at the rate of 1ml per liter; and Mineral oil (Sparrow oil) at the rate of 5ml per liter (Galanihe, 2010).

Generalist predators such as larvae of ladybird beetles (Coleoptera: Coccinellidae) and green lace-wings (Neuroptera: Chloropidae) were found to have a low impact on papaya mealybug populations. The same predator groups including the commercially available mealybug destroyer, *Cryptolaemus montrouzieri* Mulsant (Coleoptera: Coccinellidae) have been reported from USA (Walker *et al.* 2003). In addition to predators, five efficient parasitoids (Hymenoptera: Encyrtidae) specific to papaya mealybug were identified by the United States Department of Agriculture (USDA) Animal and Plant Health Inspection Service (APHIS) and USDA Agricultural Research Service (ARS) in 1999: *Acerophagus papayae* Noyes and Schauff, *Anagyrus loecki* Noyes, *Anagyrus californicus* (Compere), *Pseudaphycus* sp. and *Pseudleptomastix mexicana* Noyes & Schauff (Walker *et al.*, 2003; Meyerdirk *et al.*, 2004).

The five parasitoid species have been efficient at controlling papaya mealybug in all the countries where they have been released. USDA-APHIS found that the five parasitoid species brought about a 99.7% reduction in papaya mealybug populations in the Dominican Republic, and a 97% reduction in Puerto Rico, with parasitism levels of 35.5-58.3% (Kauffman *et al.*, 2001; Meyerdirk and Kauffman, 2001). All five parasitoids have been observed at-tacking second and third instar *P. marginatus*. However, *Acerophagus* sp. emerged as the dominant parasitoid species in both Puerto Rico and the Dominican Republic (Meyerdirk and Kauffman, 2001).

According to Muniappan (2008), classical biological control approach of *P. marginatus* in an exotic or introduced pest in Asia and it is suitable for the classical biological control approach of releasing species-specific parasitoids. This approach has been successfully implemented against PMB (papaya mealybug) in several countries in the Caribbean, some islands in the pacific and in the states of Florida and Hawaii in the United States.

Organophosphate and carbamate insecticides such as dimethoate, malathion, carbaryl, chlorpyrifos, diazinone and acephate (Walker *et al*., 2003) were commonly used insecticides to control mealybugs. Currently neonecotinoid insecticides such as acetamiprid, clothianidin, dinotefuran, Imidacloprid, thiamethoxam, and insect growth regulators (IGR) such as pyriproxyfen are used to control scale insects and mealybugs (Buss and Turner, 2006). However, there is no specific insecticide currently registered for control of papaya mealybug (Walker *et al*., 2003).

Mealybugs are generally difficult to control chemically due to their thick waxy secretion covering the body, and their ability to hide in the damaged buds and leaves without being exposed to the insecticide. The adult mealybugs were more difficult to control than the young and repeated applications of chemicals targeting immatures were required in suppressing *P. madeirensis* (Townsend *et al*., 2000). In addition, with polyphagous insects such as papaya mealybug, it would be difficult to manage it with just insecticides and to achieve long-term control with the wide variety of host plants. Development of insecticide resistance and non-target effects of insecticides on natural enemies make chemical control a less feasible option for the long-term control of papaya mealybug (Walker *et al*., 2003). Because of these reasons, biological control was identified as a preferred method to control the papaya mealybug.

CHAPTER III

MATERIALS AND METHODS

The experiment was conducted at the Horticulture Farm of Sher-e-Bangla Agricultural University, Dhaka, Bangladesh during the period from September, 2011 to May, 2012 to study the management of mealybug in papaya 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 Horticulture farm of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka, Bangladesh. The location of the experimental site is $23^0 74'$N latitude and $90^0 35'$ E longitude and at an elevation of 8.2 m from sea level. Appendix-I.

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 6.2. Details of the meteorological data during the period of the experiment were collected from the Bangladesh Meteorological Department, Agargoan, Dhaka.

3.3 Characteristics of soil

The soil of the experimental area belongs to the Modhupur 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. Details of the recorded soil characteristics were presented in Appendix-II.

3.4 Treatments

3.4.1 Treatments for papaya seedlings

Ten treatments including an untreated control were selected with a view to suppress the mealy bug infestation in papaya seedlings are as follows:

T_1 = Shobicron 425EC @ 1ml/L of water at 7 days interval

T_2 = Imidacloprid (Admire) 200SL @ 1ml/L of water at 7 days interval

T_3 = Semcap 50EC @ 1ml/L of water at 7 days interval

T_4 = Cypermethrin 10EC @ 1ml/L of water at 7 days interval

T_5 = Fighter 25EC @ 1ml/L of water at 7 days interval

T_6 = Chloropyriphos 20EC @ 1ml/L of water at 7 days interval

T_7 = Dimethoin 40EC @ 1ml/L of water at 7 days interval

T_8 = Imidacloprid (Bumper) 200SL @ 1ml/L of water at 7 days interval

T_9 = Decis 25EC @ 1ml/L of water at 7 days interval

T_{10} = Control

3.4.2 Treatments for papaya plants in field

Eight treatments including an untreated control were selected with a view to suppress the mealy bug infestation in papaya plants are as follows:

T_1 = Shobicron 425EC @ 1ml/L of water

T_2 = Imidacloprid 200SL @ 1ml/L of water

T_3 = Cypermethrin 10EC @ 1ml/L of water

T_4 = Deltamethrin 25EC @ 1ml/L of water

T_5 = Lambdacyhalothrin @ 1ml/L of water

T_6 = Semcap 50EC @ 1ml/L of water

T_7 = Neem seed kernel extract @ 5g/L of water

T_8= Control

3.5 Design of experiment

The experiment was laid out in a randomized complete block design (RCBD) with three replications. The unit plot size was 2m × 2m. The distance between plots and blocks was 1m. Two pits were made in each plot.

3.6 Plant materials

Papaya was considered as test crop under the present study. Seedlings of Lal Teer variety was used for the experiment. It was an advanced winter variety. It was collected from Krishibid Upakaran Nursery, Sher-e-Bangla Nagar, Dhaka. Average yield of the variety is 35-40 t/ha.

3.7 Land preparation and fertilization

The experimental plot was ploughed thoroughly by a tractor drawn disc plough followed by harrowing. The land was then labeled prior to transplanting. During land preparation, cow dung was incorporated into the soil at the rate of 10 t/ha. Recommended doses of fertilizer such as urea, TSP and MP at the rate of 150, 125 and 100 kg/ha respectively were applied.

3.8 Transplanting of seedlings

Thirty days old healthy and uniform sized seedlings were transplanted into the experimental field on 17th October, 2011 in the afternoon and light irrigation was given around each seedling for their better establishment.

3.9 Intercultural operation

When the seedlings established in the beds it was always kept under careful observation. Various intercultural operations, thinning, weeding, top dressing was accomplished for better growth and development of papaya seedlings.

3.9.1 Gap filing

Dead, injured and weak seedlings were replaced by new vigor seedling from the stock kept on the border line of the experiment.

3.9.2 Weeding

Weeding was done three times in these plots where it was necessary.

3.9.3 Irrigation

Light irrigation was given just after transplanting the seedlings. A week after transplanting the requirement of irrigation was envisaged through visual estimation. Several numbers of irrigation were given with a hosepipe until the entire plot was properly wet.

3.9.4 Insect and pest control

The experimental crop was infested with mealy bug. They attacked at the seedling to reproductive stage. Various insecticides spray as water solution at 7 days interval as a treatment from seedling to harvesting period to control papaya mealybug.

3.9.5 Procedure of spray application

Selected insecticides for seedling and mature plant were sprayed in assigned plots and dosages by using Knapsack sprayer at 7 days interval to control the mealy bug.

3.10 Data collection and analysis

The effectiveness of each treatment was evaluated on the basis of some pre selected parameters. The following parameters were considered during data collection at each stage of reproduction.

3.10.1 Mealybug infestation in seedling

Total number of healthy and infested seedling was recorded at seedling stage. Infested seedling recorded at five seedlings were pooled and finally expressed in percentage. The damaged seedlings were spotted out by the presence of spot made by the mealybug.

The percentage of infested seedling was calculated using the following formula:

$$\text{\% mealy bug infested seedling} = \frac{\text{Number of infested seedling}}{\text{Total number of seedlings}} \times 100$$

Percent reduction over control was calculated using the following formula:

$$\text{Percent reduction over control} = \frac{\text{Value in untreated control plot} - \text{Value in treated}}{\text{Value in untreated control plot}}$$

x 100

Plate 1. Mealybug infested seedling of papaya

3.10.2 Mealybug infestation in plant

Total number of healthy and infested plant was recorded at 45, 90, 135 and 180 days after transplanting (DAT). Infested plants recorded at each observation were pooled and finally expressed in percentage. The damaged plant was spotted out by the presence of spot made by the mealybug.

The percentage of mealy bug infested plants was calculated using the following formula:

$$\text{\% mealy bug infested plant} = \frac{\text{Number of infested plant}}{\text{Total number of plants}} \times 100$$

Percent reduction over control was calculated using the following formula:

$$\text{Percent reduction over control} = \frac{\text{Value in untreated control plot} - \text{Value in treated}}{\text{Value in untreated control plot}} \times 100$$

Plate 2. Mealybug infested plant of papaya

3.10.3 Mealybug infestation in leaf

Total number of healthy and infested leaf was recorded at 45, 90, 135 and 180 days after transplanting (DAT). Infested leaves recorded at each observation were pooled and finally expressed in percentage. The damaged leaf was spotted out by the presence of spot made by the mealybug.

The percentage of mealy bug infested plants was calculated using the following formula:

$$\text{\% mealy bug infested leaf} = \frac{\text{Number of infested leaf}}{\text{Total number of leaves}} \times 100$$

Percent reduction over control was calculated using the following formula:

$$\text{Percent reduction over control} = \frac{\text{Value in untreated control plot} - \text{Value in treated}}{\text{Value in untreated control plot}} \times 100$$

Plate 3. Mealybug infested leaf of papaya

3.10.4 Mealybug infestation in fruit

Total number of healthy and infested fruit was recorded at 135 and 180 days after transplanting (DAT). Infested fruit recorded at each observation were pooled and finally expressed in percentage. The damaged fruit was spotted out by the presence of spot made by the mealybug.

The percentage of mealy bug infested fruits was calculated using the following formula:

$$\%\text{ mealy bug infested fruit} = \frac{\text{Number of infested fruit}}{\text{Total number of fruit}} \times 100$$

Percent reduction over control was calculated using the following formula:

$$\text{Percent reduction over control} = \frac{\text{Value in untreated control plot} - \text{Value in treated}}{\text{Value in untreated control plot}} \times 100$$

Plate 4. Mealybug infested fruit of papaya

3.11 Statistical analysis

The data obtained from experiment on various parameters were statistically analyzed in 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 (Gomez and Gomez, 1984).

CHAPTER IV

RESULTS AND DISCUSSION

The experiment was conducted to study the management of mealybug in papaya plant. The analysis of variance (ANOVA) of the data on infestation of papaya mealybug from seedling to harvesting stage was done. The results have been presented by using different tables and discussed with possible interpretations under the following headings and sub headings:

4.1 Number of seedling infestation

The effect of some chemical insecticides on infestation of papaya seedlings by mealybug has been presented in Table 1. The data indicate that the lowest number of infested seedling (1.0) was found in admire and bumper which were significantly higher than untreated control. However, no significant difference was observed among Admire, Bumper and Semcap. Similarly, percent seedling infestation was found lowest (20%) in admire and bumper followed by 30% in Semcap and 45% in Shobicron and Cypermethrin having significant difference among them. The maximum per cent seedling infestation (85%) was found in untreated control. It was also observed that admire and bumper showed the best performance by reducing 70.83% seedling infestation over untreated control. Dimethoin gave only 5% protection of seedling against mealybug infestation. The order of effectiveness of nine chemical insecticides used in this experiment for protection of papaya seedling infestation from mealybug is Admire/Bumper>Semcap>Cypermethrin/ Shobicron>Lambdacyhalothrin/Deltamethrin>Clorpyriphos>Dimethoin. These results indicate that Imidacloprid (Admire and Bumper) was the most effective insecticides and Dimethoin was the least effective insecticide for protection of papaya seedling from mealybug. Semcap gave intermediate level of protection of seedling from mealybug infestation. Although other insecticides reduced papaya seedling infestation their effectiveness was unsatisfactory.

Table 1. Effect of chemical insecticides on infestation of papaya seedlings by mealybug

Treatments	Number of infested seedling/5 seedling	Percent seedling infestation	Percent reduction over control
Shobicron 425EC	2.25 bc	45.00 bc	41.25 bc
Admire 200SL	1.00 c	20.00 c	70.83 a
Semcap 50EC	1.50 c	30.00 c	57.50 ab
Cypermethrin 10EC	2.25 bc	45.00 bc	41.25 bc
Fighter 25EC	3.00 ab	60.00 ab	25.00 cd
Chlorpyriphos 20EC	3.50 ab	70.00 ab	15.00 d
Dimethoin 40EC	4.00 a	80.00 ab	5.00 d
Bumper 200SL	1.00 c	20.00 c	70.83 a
Decis 25EC	3.00 ab	60.00 ab	25.00 cd
Control	4.25 a	85.00 a	-
LSD	1.261	25.21	21.30

In a column means having same letter(s) are statistically similar at 5.0% level of significance by Duncan's Multiple Range Test (DMRT).

4.2 Number of mealybug infested papaya plant

Data in Table 2 reveal the number of mealybug infested papaya plant in field at different days after transplanting under various treatments. It was observed that the lowest number of infested plant (0.33/plot) was recorded from Imidacloprid treated plot followed by Semcap treated plot (0.67/plot) at 45 DAT. However, no significant difference was found among the insecticide treatments. But all papaya plants (2.0/plot) were infested by mealybug in control plot which was significantly higher than Imidacloprid and Semcap treated plots. It was also observed that mealybug infested plant was gradually declined in insecticide treated plots starting from 45 DAT to 180 DAT. Considering average number of infested plant per plot, Imidacloprid treated plots had only 0.17 infested plant per plot. In contrast all plants (2.0/plot) were infested by mealybug in control plot. In case of per cent plant infestation, Imidacloprid spraying gave the best result having only 8.33% infestation followed by 25% in Semcap and 41.67% in Shobicron treated plots with no significant difference among them. However 100% plant infestation was recorded in control plot which was significantly higher than Imidacloprid, Semcap, Shobicron, Cypermethrin, Deltamethrin and Lambdacyhalothrin treated plots. Similarly maximum percent reduction of infested plant over control (91.67%) was found in Imidacloprid spraying field (Table 2). Thus, Imidacloprid spraying showed the best performance in reduction of plant infestation by mealybug during the cultivation period of papaya.

Table 2: Effect insecticides on infestation of papaya plant by mealybug at different days after transplantation in field

Treatments	**Number of mealybug infested papaya plant**				**Average number of plant infestation**	**Per cent plant infestation**	**Percent reduction over control**
	45 DAT	**90 DAT**	**135 DAT**	**180 DAT**			
Shobicron	1.00 ab	1.00 bcd	0.67 cde	0.67 bc	0.83 bcd	41.67 bcd	58.33 abc
Imidacloprid	0.33 b	0.33 d	0.00 e	0.00 d	0.17 d	8.33 d	91.67 a
Cypermethrin	1.33 ab	1.33 abc	1.00 bcd	1.00 b	1.17 bc	58.33 bc	41.67 bc
Deltamethrin	1.33 ab	1.33 abc	1.00 bcd	1.00 b	1.17 bc	58.33 bc	41.67 bc
Lambdalcyhalothrin	1.33 ab	1.33 abc	1.33 abc	1.00 b	1.25 abc	62.50 bc	37.50 bc
Semcap	0.67 b	0.67 cd	0.33 de	0.33 cd	0.50 cd	25.00 cd	75.00 ab
Neem seed kernel extract	1.33 ab	1.67 ab	1.67 ab	1.67 a	1.58 ab	79.17 ab	20.83 c
Control	2.00 a	2.00 a	2.00 a	2.00 a	2.00 a	100.00 a	-
LSD	1.089	0.896	0.728	0.604	0.741	37.00	40.50

In a column means having same letter(s) are statistically similar at 5.0% level of significance by Duncan's Multiple Range Test (DMRT).

4.3 Number of healthy plant

The data in Table 3 express the number of healthy plants per plot under different insecticide treated plots. Imidacloprid treated plots had the highest number of healthy plant per plot (1.835) having no significant difference with Semcap (1.50) and Shobicron (1.165) treatments. It was also observed that schedule spraying of all insecticides increased the healthy plant over untreated control. The best result was obtained by application of Imidacloprid which had 91.75% healthy papaya plants per plot and the control plot had no healthy plots at all. Therefore, insecticide spraying reduced mealybug infestation and increased production of healthy papaya plant in treated plots. Galanihe (2010) reported that the most effective insecticides identified in the experiments were recommended for use as foliar sprays against the papaya mealybugs on cultivated crops: Thiamethoxam 25%WG at the rate of 1g per liter; Imidacloprid 200g/l SL at the rate of 1ml per liter; and Mineral oil (Sparrow oil) at the rate of 5ml per liter.

Table 3: Effect of insecticides spraying on production of healthy papaya plant at different days after transplanting in field

Treatments	**Number of healthy plant**				**Average number of healthy plant**	**Per cent healthy plant**
	45 DAT	**90 DAT**	**135 DAT**	**180 DAT**		
Shobicron	1.00 ab	1.00 abc	1.33 bc	1.33 bc	1.165 abc	58.25 abc
Imidacloprid	1.67 a	1.67 a	2.00 a	2.00 a	1.835 a	91.75 a
Cypermethrin	0.67 bc	0.67 bcd	1.00 c	1.00 c	0.835 bc	41.75 bc
Deltamethrin	0.67 bc	0.67 bcd	1.00 c	1.00 c	0.835 bc	41.75 bc
Lambdalcyhalothrin	0.67 bc	0.67 bcd	0.67 c	1.00 c	0.752 bcd	37.63 bcd
Semcap	1.33 ab	1.33 ab	1.67 ab	1.67 ab	1.500 ab	75.00 ab
Neem seed kernel extract	0.67 bc	0.33 d	0.33 d	0.33 d	0.415 cd	20.75 cd
Control	0.00 c	0.00 d	0.00 d	0.00 d	0.000 cd	0.00 d
LSD	0.821	0.896	0.604	0.604	0.741	37.00

In a column means having same letter(s) are statistically similar at 5.0% level of significance by Duncan's Multiple Range Test (DMRT).

4.4 Number of infested leaf per plant

Application of different insecticides reduced papaya leaf infestation by mealybug in the field at different days after transplantation. The number of infested leaf was minimum (1.33/plant) in Imidacloprid treated plot as against maximum (8.00/plant) in untreated control plot at 45 DAT (Table 4). It is also observed that number of infested leaf was gradually decreased in insecticides treated plots starting from 45 DAT to 180 DAT except in neem seed kernel extract treatments. In contrast the number of infested leaf was increased in untreated control plot. The lowest percent of leaf infestation (2.11%) was obtained from Imidacloprid treated plot having no significant difference with Semcap treated plot (7.71%). While the highest per cent leaf infestation (83.98%) was observed in control plot which was significantly higher than all other insecticide treatments. The data (Table 4) also expressed that schedule spraying of Imidacloprid and Semcap reduced more than 90% leaf infestation over control which was significantly higher than all other treatments. More than 70% control was achieved by application Shobicron and Cypermethrin. Deltamethrin and Lambdacyhalothrin provided more than 60% reduction of leaf infestation of papaya by mealybug. Only 36.50% control was achieved by spraying of neem seed kernel extract which was significantly lower than all other treatements.

This result indicates that Imidacloprid and Semcap was the most effective and neem seed kernel extract was the least effective in reducing papaya leaf infestation by mealybug in field. This result agrees well with the finding of Tanwar *et al.* (2007). They found Imidacloprid was the most effective insecticide to control mealybug.

Table 4: Effect of insecticides spray on leaf infestation by mealybug at different days after transplanting in field

Treatments	**Number of infested leaf per plant**				**Average number of infested leaf**	**Percent leaf infestation**	**Percent reduction over control**
	45 DAT	**90 DAT**	**135 DAT**	**180 DAT**			
Shobicron	4.67 b	4.67 c	2.67 cd	2.67 de	3.67 c	18.54 d	77.90 b
Imidacloprid	1.33 c	0.67 d	0.00 d	0.00 f	0.50 d	2.11 e	97.49 a
Cypermethrin	5.33 b	5.33 c	4.00 c	3.33 cde	4.50 c	23.17 cd	72.42 bc
Deltamethrin	5.67 b	5.33 c	5.33 c	4.00 cd	5.08 c	27.03 c	67.78 c
Lambdalcyhalothrin	6.00 ab	6.00 c	5.33 c	5.33 c	5.67 c	28.94 c	65.48 c
Semcap	2.00 c	1.67 d	1.00 c	1.00 ef	1.42 d	7.71 e	90.80 a
Neem seed kernel extract	6.67 ab	10.00 b	10.67 b	10.67 b	9.50 b	53.30 b	36.50 d
Control	8.00 a	16.00 a	16.00 a	16.00 a	14.00 a	83.98 a	--
LSD	2.026	2.477	2.581	2.406	1.984	7.217	9.23

In a column means having same letter(s) are statistically similar at 5.0% level of significance by Duncan's Multiple Range Test (DMRT).

4.5 Number of healthy leaf per plant

The amount of healthy leaf per plant was highly influenced by spraying of insecticides. Data in Table 5 reveal that the number of healthy leaf per plant was increased with plant age under all insecticides treatments except in neem seed kernel extract where it was decreased.

However, it was also decreased in untreated control and no healthy leaf was found at 135 and 180 days after transplanting (Table 5). The highest number of healthy leaf per plant (20.08) was recorded from Imidacloprid treated plot having significant difference with other insecticides as against the lowest (3.17 per plant) in control which was significantly lower than all insecticide treatments. It is also found that more than 90% leaf was healthy in Imidacloprid and Semcap treated plots which were significantly higher than all other treatments. Only 16.02% leaf was found healthy in untreated control. Data further expressed that schedule spraying of all insecticides increased healthy leaf of papaya. However, Imidacloprid, Semcap and Shobicron increased more than 80% healthy leaf per plant over control and no significant variation was observed among Shobicron, Cypermethrin and Deltamethrin in terms of increase of healthy leaf per plant. Neem seed kernel spraying increased only 65.53% healthy leaf per plant. Thus, Imidacloprid and Semcap offered better performance in increasing healthy leaf of papaya against mealybug infestation. Currently Neonecotinoid insecticides such as Acetamiprid, Clothianidin, Dinotefuran, Imidacloprid, Thiamethoxam, and Insect Growth Regulators (IGR) such as Pyriproxyfen are used to control scale insects and mealybugs (Buss and Turner, 2006).

Table 5: Effect of insecticides on production of healthy leaf per plant against mealybug infestation in field

Treatments	Number of healthy leaf per plant				Average number of healthy leaf	Per cent healthy leaf	Percent increase over control
	45 DAT	90 DAT	135 DAT	180 DAT			
Shobicron	15.33 abc	15.33 bc	16.00 bc	16.00 bc	15.92 bc	81.46 b	80.33 bc
Imidacloprid	18.67 a	19.33 a	20.67 a	20.67 a	20.08 a	97.89 a	83.58 a
Cypermethrin	14.00 bc	14.00 c	15.67 bcd	16.00 bc	14.83 bc	76.83 bc	79.12 cd
Deltamethrin	13.67 bc	13.67 c	14.00 cd	13.67 d	13.75 c	72.97 c	78.00 cd
Lambdalcyhalothrin	14.33 bc	14.33 bc	13.33 d	14.00 cd	14.00 bc	71.06 c	77.32 d
Semcap	16.67 ab	17.33 ab	17.33 b	17.33 b	16.83 b	92.29 a	82.64 ab
Neem seed kernel extract	13.33 bc	10.00 d	6.00 e	5.33 e	8.75 d	46.7 d	65.53 e
Control	12.00 c	0.67 e	0.00 f	0.00 f	3.17 e	16.02 e	--
LSD	3.595	3.012	2.459	1.984	2.984	6.672	2.606

In a column means having same letter(s) are statistically similar at 5.0% level of significance by Duncan's Multiple Range Test (DMRT).

4.6 Number of mealybug per 2.0 cm^2 leaf area

Schedule spraying of insecticides on papaya field reduced incidence of mealybug on infested papaya leaf. Data in Table 6 clearly demonstrated that the lowest population of mealybug was recorded from Imidacloprid treatment at different days after transplanting followed by Semcap having no significant difference between them, however significant difference was observe with other insecticides. Consequently, average number of mealybug on 2 cm^{-2} leaf area was found lowest (0.50) in Imidacloprid treatment followed by Semcap (2.67) having no significant difference between them. Shobicron treated plot had intermediate level (4.17 cm^{-2} leaf area) of mealybug incidence. The highest population (9.75 2 cm^{-2} leaf area) was found in untreated control which was statistically similar with neem seed kernel extract treatment (7.83 cm^{-2} leaf area). Spraying Imidacloprid provided maximum protection (reduced 94.74% population of mealybug over untreated control) of papaya plant in field.

Other tested insecticides reduced population of mealybug however, they were failed to control standard level (80% reduction of population over control) of population. The lowest efficacy (19.45%) was found in case of neem seed kernel having no significant difference with Cypermethrin, Lambdacyhalothrin and Deltamethrin (Table 6). This result clearly revealed that Imidacloprid was highly effective; Semcap and Shobicron were moderately effective synthetic pyrethroids (Cypermethrin, Lambdacyhalothrin and Deltamethrin) were poorly effective against papaya mealybug in field. Galanihe (2010) reported that the most effective insecticides against the papaya mealybugs on cultivated crops: Imidacloprid 200SL at the rate of 1ml per liter.

Table 6: Effect of insecticides on incidence of mealybug on infested papaya leaf

Treatments	Number of mealybug per 2.0 cm^2 leaf area				Average number of mealybug per 2.0 cm^2 leaf area	Percent reduction of population over control
	45 DAT	90 DAT	135 DAT	180 DAT		
Shobicron	4.00 b	4.33 c	3.67 cd	4.67 bc	4.17 cd	57.51 bc
Imidacloprid	1.33 c	0.67 e	0.00 d	0.00 d	0.50 e	94.74 a
Cypermethrin	4.33 b	5.00 bc	6.67 bc	8.00 ab	6.00 bc	38.46 cd
Deltamethrin	4.67 b	5.00 bc	7.00 bc	8.00 ab	6.17 bc	36.86 cd
Lambdalcyhalothrin	5.33 b	6.33 ab	8.00 ab	9.67 a	7.33 b	24.67 d
Semcap	3.67 b	2.67 d	2.00 d	2.33 cd	2.67 d	72.64 ab
Neem seed kernel extract	5.33 b	6.33 ab	9.33 ab	10.33 a	7.83 ab	19.45 d
Control	7.67 a	7.33 a	11.67 a	12.33 a	9.75 a	--
LSD	1.991	1.437	3.702	4.258	1.987	22.29

In a column means having same letter(s) are statistically similar at 5.0% level of significance by Duncan's Multiple Range Test (DMRT).

4.7 Number of infested fruit per plant

Data on effect of insecticides spraying on fruit infestation by papaya mealybug in filed have been presented in Table 7. It was observed that Imidacloprid treated plots had no mealybug infested fruits. Although other insecticides treated plots had mealybug infested fruits but that was decreased gradually. Consequently, the average number of infested fruits plant was found 0.00 in Imidacloprid treatment having no significant difference with Semcap (1.67 infested fruit per plant. Considering per cent fruit infestation by mealybug, Imidacloprid gave the best result having no fruit infestation at all followed by 8.70% in Semcap. Shobicron treated plot had 26.12% fruit infestation which was significantly higher than Cypermethrin, Deltamethrin, Lamdacyhalothrin and Neem seed kernel. It was further observed that Imidacloprid provided 100% protection of fruit infestation against mealybug that was 91.30% in Semcap having no significant difference between them (Table 7). Shobicron gave 73.88% protection of fruit infestation over untreated control. More than 50% reduction of fruit infestation was obtained in case of Cypermethrin and Lambdalcyhalothrin.

Table 7: Effect of insecticides on papaya fruit infestation by mealybug

Treatments	Number of infested fruit per plant		Average number of infested fruit per plant	Per cent fruit infestation	Percent decrease over control
	135 DAT	180 DAT			
Shobicron	5.00 cd	3.67 cd	4.33 cd	26.12 c	73.88 b
Imidacloprid	0.00 e	0.00 d	0.00 d	0.00 d	100.00 a
Cypermethrin	10.00 ab	7.00 c	8.50 bc	49.99 b	50.01 c
Deltamethrin	10.33 ab	7.67 c	9.00 bc	55.99 b	44.01 c
Lambdalcyhalothrin	8.33 bc	7.67 c	8.00 bc	49.89 b	50.11 c
Semcap	2.00 de	1.33 d	1.67 d	8.70 cd	91.30 ab
Neem seed kernel extract	11.00 ab	13.33 b	12.17 b	68.22 b	31.78 c
Control	14.00 a	20.67 a	17.33 a	100.00 a	--
LSD	4.60	5.386	4.83	18.42	20.02

In a column means having same letter(s) are statistically similar at 5.0% level of significance by Duncan's Multiple Range Test (DMRT).

4.8 Number of healthy fruit per plant

The effect of insecticides spraying on production of healthy and mealybug free fruits have been presented in Table 8. It was clearly that all fruits were healthy in Imidacloprid treatment as against no health fruit was recorded untreated control. The average number of healthy and mealybug free papaya fruits were 22.33 per plant which was significantly higher than all other insecticide treated plots. The Semcap treated plots produced 18.17 healthy fruits per plant while Shobicron treated plots had 12.67 healthy and insect free fruits having significant difference between them. However, no significant difference was observed among Cypermethrin, Deltamethrin, Lambdacyhalothrin and need seed kernel treated plots in terms of production of healthy and mealybug infested fruits per plant. It was further observed that 100% per cent fruit was healthy and mealybug free in Imidacloprid treated plot followed by 91.30% in Semcap treatment having no significant difference between them. Statistically similar level of healthy fruit was found in Lambdacyhalothrin (50.12%), Cypermethrin (50.02%) and Deltamethrin (40.01%). Only 31.78% healthy fruit was observed in neem seed kernel treated plot. On the other hand control plot had no healthy and insect free fruits. In terms of production of fruit over control Imidacloprid gave the best result by increasing 100% healthy fruit over control followed by Semcap with 91.30% healthy fruit over control. However, no significant difference was found between them. Shobicron increased 73.88% production of healthy fruit over untreated control.

Table 8: Effect of insecticides on production of healthy papaya fruit per plant

Treatments	**Number of healthy fruit per plant**		**Average number of healthy fruit per plant**	**Percent healthy fruit**	**Percent increase over control**
	135 DAT	**180 DAT**			
Shobicron	12.67 b	12.67 c	12.67 c	73.88 b	73.88 b
Imidacloprid	20.67 a	24.00 a	22.33 a	100.00 a	100.00 a
Cypermethrin	8.00 c	9.00 cd	8.50 d	50.02 c	50.02 c
Deltamethrin	7.67 c	6.67 d	7.17 d	44.01 c	44.01 c
Lambdalcyhalothrin	8.33 c	7.67 d	8.00 d	50.12 c	50.12 c
Semcap	18.00 a	18.33 b	18.17 b	91.30 ab	91.30 ab
Neem seed kernel extract	6.00 c	5.00 d	5.50 d	31.78 c	31.78 c
Control	0.00 d	0.00 e	0.00 e	0.00 d	--
LSD	4.215	4.448	4.154	18.42	18.42

In a column means having same letter(s) are statistically similar at 5.0% level of significance by Duncan's Multiple Range Test (DMRT).

The above results of the present study indicate that schedule spraying of insecticides in papaya field during production reduced plant, leaf infestation and fruit infestation by mealybug and its incidence on papaya leaf, and increased production of healthy and insect free plant, leaf and fruit. However, the effectiveness of all tested insecticides was not similar. Imidacloprid gave the maximum protection of papaya in field from mealybug infestation; Semcap provided almost same level of protection and Shobicron showed the intermediate effectiveness against mealybug. The effectiveness of Cypermethrin, Lambdacyhalothrin and Deltamethrin against mealybug was no satisfactory. On the other hand spraying of neem seed kernel gave least and poorest effectiveness against papaya mealybug.

CHAPTER V

SUMMARY AND CONCLUSION

SUMMARY

The experiment was conducted at the Horticulture Farm of Sher-e-Bangla Agricultural University, Dhaka, Bangladesh during the period from September 2011 to May 2012 to study the management of mealybug in papaya plant. The experiment consists of ten treatments chemicals pesticide including control treatment for management of mealybug in papaya seedling viz. T_1 = Shobicron 425EC, T_2 = Imidacloprid (Admire) 200SL, T_3 = Semcap 50EC, T_4 = Cypermethrin 10EC, T_5 = Fighter 25EC, T_6 = Chloropyriphos 20EC, T_7 = Dimethoin 40EC, T_8 = Imidacloprid (Bumper) 200SL, T_9 = Decis 25EC and T_{10} = Control. The experiment consists of eight treatments including control treatment for management of mealybug in papaya plant viz. T_1 = Shobicron 425EC, T_2 = Imidacloprid 200SL, T_3 = Cypermethrin 10EC, T_4 = Deltamethrin 25EC, T_5 = Lambdacyhalothrin, T_6 = Semcap 50EC, T_7 = Neem seed kernel extract and T_8= Control. The experiment was laid out in Randomized Complete Block Design (RCBD) single factor with three replications.

Significant differences were observed among different management practices in terms of seedling, plants, leaves and fruits infestation during the management of papaya mealybug.

Among the treatments, Imidacloprid (Admire and Bumper) 200SL was more effective on mealy bug as well as lowest number of infested seedling (1.0) was recorded. Percent seedling infestation was found lowest (20%) in admire and bumper.

The seedling infestation reduction over untreated control was the highest (70.83%) under Imidacloprid (Admire and Bumper) 200SL and the lowest (5%) was in Dimethoin 40EC.

The lowest number of infested plant (0.33/plot) was recorded from Imidacloprid. The maximum percent reduction of infested plant over control (91.67%) was found in Imidacloprid. the highest number of healthy plant per plot (1.835) was found in Imidacloprid. The number of infested leaf was minimum (1.33/plant) in Imidacloprid treated plot. The lowest percent of leaf infestation (2.11%); highest number of healthy leaf per plant (20.08) lowest population of mealybug and the lowest number of infested fruits plant was found (0.00) in Imidacloprid treatment. All fruits were healthy in Imidacloprid treatment.

The above results of the present study indicate that schedule spraying of insecticides in papaya field during production reduced plant, leaf infestation and fruit infestation by mealybug and its incidence on papaya leaf, and increased production of healthy and insect free plant, leaf and fruit. However, the effectiveness of all tested insecticides was not similar. Imidacloprid gave the maximum protection of papaya in field from mealybug infestation; Semcap provided almost same level of protection and Shobicron showed the intermediate effectiveness against mealybug. The effectiveness of Cypermethrin, Lambdacyhalothrin and Deltamethrin against mealybug was not satisfactory. Spraying of neem seed kernel gave least performance against papaya mealybug.

CONCLUSION

From the above results investigated, it could be concluded that among the all applied chemical insecticides and botanical extract treatments in this study, Imidacloprid showed the best performance on management the mealybug of papaya. Whereas botanical treatment neem seed kernel showed the lowest performance on mealybug of papaya.

RECOMMENDATION

The following recommendation may be suggested from the present study-

1. Imidacloprid (Admire and Bumper) 200SL @ 1.0 ml/L water at 7 days interval may be applied for the management of papaya mealybug.

2. Considering environmental safety and health hazard botanical insecticidal treatments may be included for future study as sole or different combination to have better performance on mealybug management.

CHAPTER VI

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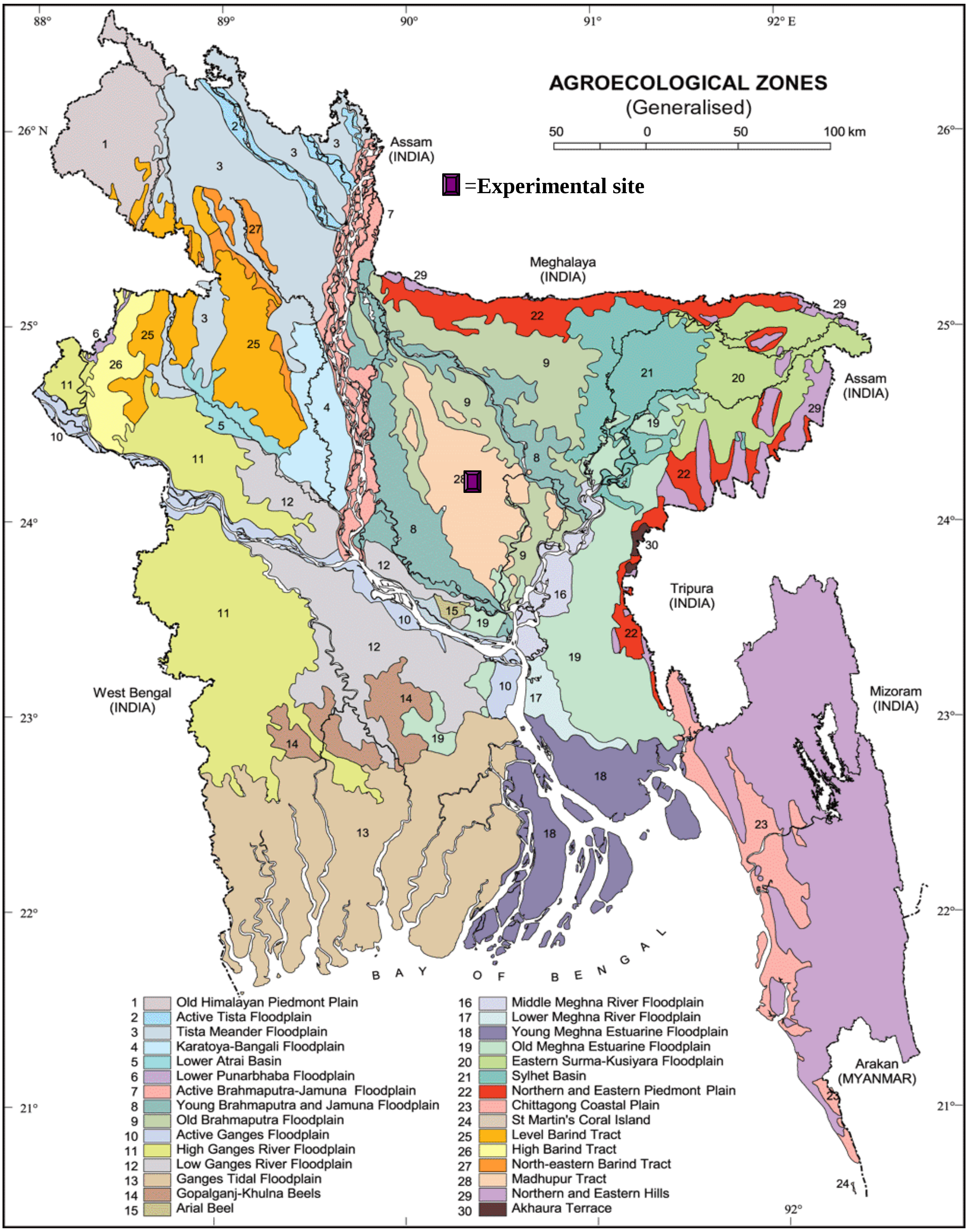
APPENDICES

Appendix I. Experimental location on the map of Agro-ecological Zones of Bangladesh



Appendix II. The physical and chemical characteristics of soil of the experimental site as observed prior to experimentation

(0-15 cm depth)

Constituents	**Percent**
Sand	26
Silt	45
Clay	29
Textural class	Silty clay

Chemical composition:

Soil characters	**Value**
Organic carbon (%)	0.45
Organic matter (%)	0.78
Total nitrogen (%)	0.07
Phosphorus	22.08 µg/g soil
Sulphur	25.98 µg/g soil
Magnesium	1.00 meq/100 g soil
Boron	0.48 µg/g soil
Copper	3.54 µg/g soil
Zinc	3.32 µg/g soil
Potassium	0.30 µg/g soil

Source: Soil Resources Development Institute (SRDI), Khamarbari, Dhaka