INFESTATION INTENSITY OF PAPAYA MEALYBUG *(Paracoccus marginatus)* IN FARMER'S FIELD AND ITS MANAGEMENT

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CERTIFICATE

This is to certify that the thesis entitled, **"INFESTATION INTENSITY OF PAPAYA MEALYBUG (*Paracoccus marginatus*) IN FARMERS FIELD AND ITS MANAGEMENT''** submitted to the Department of Entomology, Sher-e-Bangla Agricultural University, Dhaka, in the partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE (MS) in Entomology,** embodies the result of a piece of *bona fide* research work carried out by **Md. Motiour Rahman Shimul,** registration No. **11-04527** 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, received during the course of this investigation has been duly acknowledged and style of this thesis have been approved and recommended for submission.

Dated: June, 2017
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Dedicated To

My Beloved Parents & Respected Research Supervisor

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ABSTRACT

Information was collected from papaya growers and DAE personnel of ten districts namely, Dhaka, Rajshahi, Kustia, Gazipur, Pabna, Norsindhi, Tangail, Joypurhat, Natore and Bogura during November 2017 to December 2018 to assess the diversity of insect pests of papaya and its management practices used by growers. Descriptive statistics, Pearson product moment correlation coefficient, were used for analysis. Four insect pests namely mealybug, fruit fly, ant and mite were reported by the growers as well as DAE personnel. Among the papaya growers most (98%) of them were male and only 2% were female. Majority of them (40.67%) were middle aged (41-50 years) farmers compare to old aged (51-60 years) which occupied 34.67%. Most of the papaya growers 65.33% could not read or write but could sign only. Highest experience category of papaya growers were medium category (86.67%) followed by low category (12.0%). For seed use, the highest percentage of the farmers 50.33%) used their own seed followed by 23.67% and 21.33% were used seeds of company and neighbor, respectively. In case of pest occurrence in the papaya field 48.15% respondents expressed that papaya mainly infested by mealybug followed by whitefly (27.45% farmers), mite (20.39% farmers) and ant (4.01% farmers). Among the pests, mealybug and ant were reported to infest leaf, stem, flower and fruits but whitefly and mites were reported as leaf infesting pests. Low (8.70%), medium (47.83%) to high level (43.48%) severity of infestation was reported by the farmers and majority of the farmers (55.56%) reported medium severity of whitefly infestation. All farmers (100%) reported mealybug as a major pest of papaya, followed by 35.23% and 24.76% farmers reported whitefly and mite, respectively as major pests of papaya. Farmers used Marshal 20EC, Sumithion 50EC, imitaf 20SL or tido 20SL 3-4 times for controlling mealybug,

imitaf 20SL or tido 20SL and aktara 20WG 1-2 times for controlling whitefly and sunmectin 1.8EC/ acamite 1.8EC / vertimec 1.8EC for controlling mite.Most of the farmers (65.27%) opined that mealybug infested in the papaya plant at fruiting stage and infestation occurred on leaf, stem, flower and fruit with medium to high severity of infestation but maximum infestation was reported from fruit (36.31% farmers opinion) followed by flower infestation (34.24% farmers opinion). Majority of the farmers (96.42%) applied insecticides to control mealybug and marshal 20EC, sumithion 50EC, imitaf or tido 20SL and caught 10EC were used 3-4 times by the farmers. But majority of the farmers (47.52%) sprayed imitaf 20SL/tido 20SL 3-4 times for controlling mealybug. In responding effectiveness of insecticides, most of the farmers (93.33%) reported that mealybug was controlled by insecticides spraying and 6.67% farmers reported ineffectiveness of insecticides. Most of the papaya growers (96.67%) were conscious about hazardous effect of chemical insecticides and most of them (96.93%) reported health hazards.

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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 (Heu *et al.* 2007,

Muniappan *et al.* 2006, Meyerdirk *et al.* 2004). 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 (*Plumeriaa cuminata*) 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).

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 and Kauffman, 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.

Only a few researches have so far been conducted research on farmers' management practices against mealy bug of papaya in Bangladesh. Consequently, large amount of production is hampered and farmers face economic losses due to mealy bug insect pest attacks. The focal point of the research work was to explore the trends of mealy bug insect pest infestation assessment and management practices for papaya. This is why the following objectives were framed out in order to provide an appropriate track to the research work:

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

a. To assess the pest status and infestation intensity of mealybug in major papaya growing districts of Bangladesh.
b. To find out the management practices used by the farmers for controlling mealybug of papaya.

CHAPTER II

REVIEW OF LITERATURE

2.1 Bioecology of papaya mealybug

Taxonomic position

Kingdom:	Animalia
Phylum:	Arthropoda
Class:	Insecta
Order:	Hemiptera
Suborder:	Sternorrhyncha
Superfamily:	Coccoidea
Family:	Pseudococcidae
Genus:	*Paracoccus*
Species:	*P. marginatus*

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 Belizum, 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 following14 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.

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). They also worked on the incidence and damage potential of this noxious pest.

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 adages, 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 (0.30 mm). 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.

Papaya varieties

Two varieties of papaya red lady and locals, are cultivated throughout the country. But demand of the hybrid variety is very high in the local markets as those are large in size and sweetened with thick flesh. There are more varieties of papaya in Bangladesh namely, Bombai, Deshi, Shahi (Yellow) and Shahi (Red).

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 and 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.

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. Spalgiusepius 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 and 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

Methodology plays a significant role in a scientific research. To perform the objectives of the study, a researcher should be very cautious while formulating methods and procedures in conducting the research. The detailed methods and operational measures followed in conducting the study were selection of study area, sampling procedures, instrumentation, categorization of variables, gathering of data, measurement of the variables and statistical measurements. A sequential explanation of the methods followed in conducting this research work has been presented in this chapter.

3.1 Research design

A research design is detailed plan of investigation. It is the blueprint of the detailed procedure of testing the hypothesis and analysis of the obtained data. The research design followed in this study was *ex-post facto,* because of uncontrollable and non-manipulating variables. This is absolute descriptive and diagnostic research design. A descriptive research design is used for fact findings with adequate interpretation. Diagnostic research design, on the other hand, is concerned with testing the hypothesis for specifying and interpreting the relationship of variables.

3.2 Study area

The present study was conducted in ten different districts of Bangladesh (Table 3). The districts are Kustia, Gazipur, Pabna, Norsindhi, Tangail, Joypurhat, Natore, Bogra, Rajshahi and Dhaka. The study area was taken with three upazila of each districts (Table 1) where the area were covered with papaya cultivation.

Table 1. List of district and upazila of study area for mealybug survey

Sl. No.	Districts	Upazila
01	Dhaka	Dhamrai Savar Kernigonj
02	Kustia	Mirpur Daluatpur Veramara
03	Gazipur	Joydevpur Tongi Kaliakair
04	Pabna	Sadar Atghoria Ishwardi
05	Norsindhi	Polash Sadar Balabo
06	Tangail	Modhupur Shokhipur Mirzapur
07	Joypurhat	Sadar Kalai Khetlal
08	Natore	Sadar Lalpur Bagatipara
09	Bogura	Sadar Dhunat Sherpur
10	Rajshahi	Puthia Charghat Bagha

3.3 Unit of analysis

The unit of analysis of the study was the people who engaged papaya production (farmers).

3.3.1 Population and sampling

People who permanently reside in the selected upazila constituted the active population of this study. As all population of the study area could not possible to measure, head of the farm families of selected blocks of upazila (segmented by the Department of Agriculture Extension under the Ministry of Agriculture) of ten different districts were the population of the study. However, representative sample from the population were taken for collection of data following purposive sampling technique. One farmer (who operated farming activities of the family) from each farm family was considered as the respondent. Updated lists of all farm families of papaya producers of the selected blocks were prepared with the help of SAAO and local leader. Farm families who engaged in papaya production and who provided the extension service to the papaya growers were considered as the study group. A purposive sampling procedure was followed to select ten districts from the all over Bangladesh, and a random sampling method was used to select the Upazila. Random sampling was also used to select the blocks of Upazila as the study group. The total number of individuals under study was estimated 300 in the study area which is shown in the following Table 3. We collected data from 300 farmers (10 districts x 30 farmers).

Table 2. Papaya farmers selected under the study area

Sl No.	Districts	Upazila	No. of papaya farmers
01	Dhaka	Dhamrai	530
		Savar	563
		Keranigonj	876
02	Kustia	Mirpur	456
		Daluatpur	654
		Veramara	457
03	Gazipur	Joydevpur	657
		Tongi	456
		Kaliakair	567
04	Pabna	Sadar	546
		Atghoria	456
		Ishwardi	765
05	Norsindhi	Polash	654
		Sadar	564
		Balavo	456
06	Tangail	Modhupur	543
		Shokhipur	765
		Mirzapur	464
07	Joypurhat	Sadar	750
		Kalai	765
		Khetlal	544
08	Natore	Sadar	562
		Lalpur	652
		Bgatipara	654
09	Bogura	Sadar	654
		Dhunat	344
		Sherpur	543
10	Rajshahi	Tanor	564
		Godagari	543
		Bagha	544

3.3.2 Study Group (SG) Sampling

There are several methods for determining the sample size; here, I used Yamane's (1967) formula for study group:

$$\mathbf{n} = \frac{Z^2 P(1-P)N}{Z^2 P(1-P)+N((e)^2}$$

Where,

n = Sample size;

N, Population size = 17548;

e, The level of precision = 7%;

z = the value of the standard normal variable given the chosen confidence level (e.g., z = 1.96 with a confidence level of 95 %) and

P, The proportion or degree of variability = 5%;

The sample size (n) is = 300

3.4 Variables and their measurement techniques

In a descriptive social research, selection and measurement of the variable is an important task. A variable is any characteristics which can assume varying or different values are successive individuals' cases (Ezekiel and Fox, 1959**)**. An organized research usually contains at least two identical elements i.e. independent and dependent variable. An independent variable is a factor which is manipulated by the researcher in his attempt to ascertain its relationship to an observed phenomenon. A dependent variable is a factor, which appears, disappears or varies as the experimenter introduces, removes or varies the independent variables (Townsend, 1953). According to the relevance of the research area, the researcher

selected 16 characteristics of the respondents as the independent variables (e.g. gender, age, education, agricultural farming experience, papaya cultivated land size, number of papaya trees, experience in papaya cultivation, information received about insecticides usage, insecticides sources, training exposure on papaya cultivation, organizational participation, harmful effects for chemical insecticides usages). On the other hand, insect pests management practices was dependent variable consisted of two dimensions i.e. chemical management practices. The following sections contain procedures of measurement of dependent and independent variables of the study along with the assessment of insect pest of papaya.

3.4.1 Measurement of independent variables

The independent variables of the study were gender, age, education, agricultural farming experience, papaya cultivated land size, number of papaya trees, experience in papaya cultivation, information received about insecticides usage, insecticides sources, training exposure on papaya cultivation, organizational participation. The procedure followed in measuring the independent variables have been discussed in the subsequent sections.

3.4.1.1 Gender

Gender of the respondent was measured in terms of actual condition from their birth to the time of the interview, which was found on the basis of the response of the rural people. A score of one (1) was assigned for male and score two (2) was assigned for female.

3.4.1.2 Age

Age of the respondent was measured in terms of actual years from their birth to the time of the interview, which was found on the basis of the verbal response of the rural people. A score of one (1) was assigned for each year of one's age. This variable appears in item number A.2 in the interview schedule as presented in APPENDIX-I. Based on the available information cited by the respondents, they were classified into three categories according to the Ministry of Youth and Sports, Government of the Peoples Republic of Bangladesh.

Category	Years
Young age	≤ 35
Middle age	36 to 50
Old age	≥ 51

3.4.1.3 Education

Education was measured by assigning score against successful years of schooling by a respondent. One score was given for passing each level in an educational institution (Amin, 2004).

For example, if a respondent passed the final examination of class five or equivalent examination, his/her education score has given five (5). Each respondent of can't read & write has given a score of zero (0). A person not knowing reading or writing but being able to sign only has given a score of 0.5. If a farmer did not go to school but took non-formal education, his educational status was determined as the equivalent to a formal school student. This variable appears in item number A.3 in the interview schedule as presented in APPENDIX-I. Based on the available information cited by the respondents, they were classified into five categories.

Category	Education (Year of schooling)
Can't read, write and sign only	0.5
Primary education	1 to 5
Secondary education	6 to 10
Above secondary	> 10

3.4.1.4 Agricultural Farming Experience

Experience in agricultural farming of a respondent was measured on the basis of his/her duration of agricultural farming in terms of years. The experience of a respondent was measured by counting the period of time of agricultural farming. A score of one (1) was assigned for each year of agricultural farming. It was measured in complete years as reported by a respondent. Question regarding this variable appears in item number A.4 in the interview schedule as presented in Appendix-I.

3.4.1.5 Papaya Cultivated Land Size

It refers to the area of land owned by a farmer on which papaya growing activities are carried out. However, it was estimated in terms of hectare. Data obtained in response to questions under item number A.5 in the interview schedule (APPENDIX-I) formed the basis for determining papaya cultivation area of the respondent.

3.4.1.6 Experience in papaya Cultivation

Experience in papaya cultivation of a respondent was measured on the basis of his/her duration of papaya cultivation in terms of years. The experience of a respondent was measured by counting the period of time of papaya cultivation. A score of one (1) was assigned for each year of papaya cultivation. It was measured

in complete years as reported by a respondent. This variable appears in item number A.8 in the interview schedule as presented in Appendix-I.

3.4.2 Measurement of dependent variable

Insect pest assessment for papaya is one of the dependent variable. To reveal this insect pest assessment for papaya, the researcher considered four (02) components: insect pest occurrence in papaya field, insect pest infestation status in papaya field, insect pest attack part in papaya field and insect pest infestation severity in papaya field. All the major components were measured with the help of identified subcomponents. Each subcomponent was measured against the identified items, collected through the process of review of relevant literature, focused discussion with the officials, experts, experienced farmers.

3.4.2.1 Insect pest diversity assessment for papaya

3.4.2.1.1 Insect pest occurrence in papaya orchard

Insect pest occurrence in papaya field was assessed by providing score. Score one was provided for yes and score zero was provided for no answer. Data obtained in response to item number B.1.1 of the interview schedule as presented in APPENDIX-I.

3.4.2.1.2 Insect pest infestation status in papaya orchard

Insect pest infestation status in papaya orchard was assessed by providing score. Score one was provided for minor answer and scores two was provided for major answer. Data obtained in response to item number B.1.2 of the interview schedule as presented in APPENDIX-I.

3.4.2.1.3 Insect pest infestation severity in papaya orchard

Insect pest attack part in papaya orchard was assessed by providing score. Score one was provided for very low infestation severity. Data obtained in response to item number B.1.4 of the interview schedule as presented in APPENDIX-I.

3.4.3.2 Insect pest management practices

Insect pest management practices are the dependent variable. To reveal this management practices, the researcher considered two (02) components: cultural and chemical control. All the major components were measured with the help of identified subcomponents. Each subcomponent was measured against the identified items, collected through the process of review of relevant literature, focused discussion with the officials, experts, experienced farmers. Insect pest management practices (IPMP) was calculated by using the formula:

$$IPMP = CP + MP + CC$$

Where, IPMP = Insect pest management practices

CP = Cultural Practices

MP = Mechanical Practices

CC = Chemical Control

3.4.2.2.1 Cultural control

Cultural control of a respondent was determined by providing score. Score one was provided for very low practices. Data obtained in response to item number C.1.1 of the interview schedule as presented in APPENDIX-I.

3.4.2.2.2 Mechanical control

Mechanical control of a respondent was determined by providing score. Score one was provided for very low chemical use. Data obtained in response to item number C.1.2 of the interview schedule as presented in APPENDIX-I.

3.4.2.2.3 Chemical control

Chemical control of a respondent was determined by providing score. Score one was provided for very low chemical use. Data obtained in response to item number C.1.3 of the interview schedule as presented in APPENDIX-I.

3.5 Insecticide usages by the papaya growers

What type insecticide usages by the papaya growers were assessed by providing score? Score one was provided for yes and score zero was provided for no answer. Data obtained in response to item number D.1 of the interview schedule as presented in APPENDIX-I.

3.6 Harmful effects of chemical insecticides usage

Harmful effects of chemical insecticides usage referred to the harmful effects due to usages of chemical insecticides. It was expressed in score. In measuring this variable, a score of one was given for low effects. This variable appears in item number D.2 in the interview schedule as presented in APPENDIX-I.

3.7 Instrument for collection of data

In order to collect reliable and valid information from the respondents, an interview schedule was prepared for collection of data from respondents keeping the objectives of the study in mind. The schedule was prepared in Bangla for a clear understanding to the respondents. The Bengali version of interview schedule

was used to collect data. The question and statements contained in the schedule were simple, direct and easily understandable by the respondents. Simple and direct question, different scales, closed and open form statements and questions were included in the interview schedule to obtain necessary information. The draft interview schedule was prepared in accordance with the objective of the study. The interview schedule was pretested with 10 respondents of the papaya growers in the study area.

The draft interview schedule was pretested in actual field situation before finalizing it for collection of data. The pre-test was helpful to identify inappropriate questions and statements in the draft schedule. Necessary addition, alternation and adjustments were made in the schedule on the basis of the experience of the pretest. The interview schedule was then cyclostyled in its final form for the collection of data. The interview schedule was then printed in its final form. An English version of the interview schedule has been shown in APPENDIX-I.

3.8 Data collection

Data were collected personally through personal interview schedule from the sampled papaya growers of the selected blocks. A rapport was established with the rural people so that they feel easy to answer the questions. A possible care was taken to establish rapport with the respondents so that they would not feel any indecision while starting the interview. Very good cooperation was obtained from the UAO (Plate 1 and Plate 4), field extension workers (Plate 3 and Plate 6) and growers (Plate 2 and Plate 5) of the study area. No serious difficulty was faced

during the collection of data. Questions were asked in different ways so that the respondents could easily understand the questions. Whenever a respondent faced difficulty in understanding any questions, care was taken to explain the same clearly with a view to enabling him to answer it properly.

3.9 Compilation of data

After completion of field survey, data recorded in the interview schedules were coded, compiled, tabulated and analyzed in accordance with the objectives of the study. In this process, all the responses in the interview schedule were given numerically coded values. Local units were converted into standard units and qualitative data were converted into quantitative ones by means of suitable scoring whenever necessary. All the collected data were checked and crosschecked before transplanting to the master sheets. To facilitate tabulation, the collected data were properly coded and transferred from interview schedule to a master sheet. Tabulation and cross tabulation was done on the basis of categorization developed.

3.10 Statistical analysis

Data collected from the respondents were analyzed and interpreted in accordance with the objectives of the study. The analysis of data was performed using statistical treatment with SPSS (Statistical Package for Social Sciences) computer program, version 20. Statistical measures as a number, range, mean, standard deviation and person’s product moment correlation (r) were used in describing the variables whenever applicable.

CHAPTER IV

RESULTS AND DISCUSSION

Information obtained from respondents by interview were measured, analyzed, tabulated and statistically treated according to the objectives of the study. This chapter has been discussed in five sections such as personal characteristics of the papaya growers, information about papaya cultivation, pests of papaya and information about mealybug.

4.1 Personal characteristics of the papaya growers

Three characteristics of the papaya growers were selected to describe and to find out their basic information. These characteristics were gender, age and education.

4.1.1 Gender

The field survey was conducted among 300 papaya growers in the 10 different districts like Rajshahi, Natore, Narshindghi, Gazipur, Dhaka, Joypurhat, Pabna, Kushtia, Bogura and Tangail with three upazila each. Among the papaya growers most (98%) of them were male while only 2% papaya growers participated in the study were female (Figure 1).

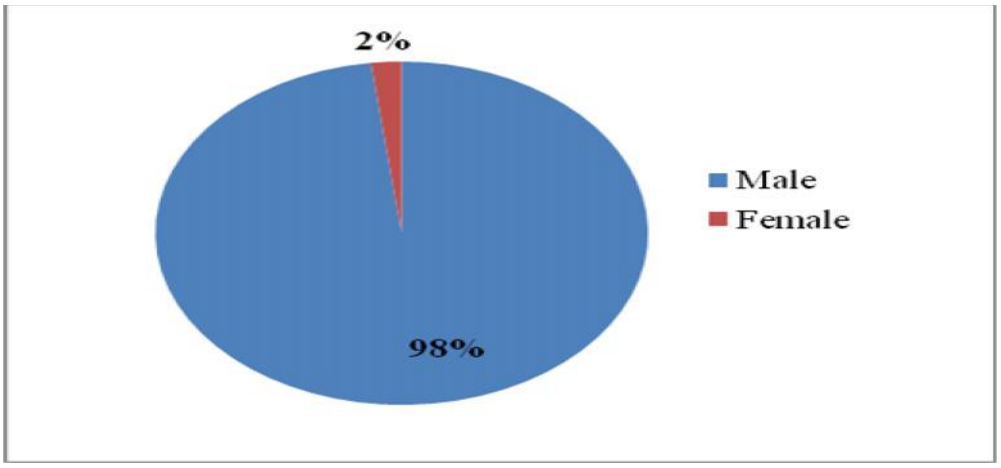

Figure 1. Gender of the papaya growers participated in the field survey.

4.1.2 Age of the papaya growers

The age of the papaya growers ranged from 25 to 76 years. The average was 50.48 with the standard deviation of 9.31. The respondents were classified into six categories according to their age (Table 3) of which highest frequency (40.67%) were occupied by 41-50 years age followed by 34.67% under 51-60 years age.

Table 3. Age distribution of the papaya growers of ten major papaya growing districts in Bangladesh

Age distribution of papaya growers	Frequency	%
25-30	6	2.00
31-40	44	14.67
41-50	122	40.67
51-60	104	34.67
61-70	23	7.67
71-80	1	0.33
Minimum	25	
Maximum	76	
Average	50.48	
Sd	9.31	

4.1.3 Education

The education status of the farmers was varied from no education to higher secondary. Most of the farmers (65.33%) had no formal education that could not read and write but could sign only and 1.67% farmers had higher secondary or (Table 4). However, 26.0% farmers had primary education and 7.0% farmers had secondary level education. This information indicates that most of the farmers involved in papaya production were illiterate.

Table 4. Distribution of the papaya growers according to their education

Category	Respondents	
	Number	**Percent**
Can't read and write but sign only	196	65.33
Primary education	78	26.00
Secondary education	21	7.00
Higher secondary	5	1.67
Total	**300**	**100**

4.2 Information about papaya cultivation

Papaya cultivation experience of the growers, land, seed sources and varieties of papaya are discussed herein.

4.2.1 Papaya cultivation experience

Experience in papaya cultivation of the respondents was measured in terms of actual years of papaya producing and in the present study that ranged from 3 to 12. On the basis of experience in papaya cultivation, the respondents were divided into three categories such as low, medium and high as shown in Table 5. Data in expressed that papaya growers under medium experience category constituted the highest proportion (86.67%) compared to low (12.00 %) and high (1.33%) experience categories.

Table 5. Distribution of the papaya growers according to their experience of papaya cultivation

Category	Scoring (Years)	Respondents	
		Number	Percent
Low	≤5	36	12.00
Medium	6 – 10	260	86.67
High	> 10	4	1.33
Total		300	100
Minimum experience	**3**	**2**	
Maximum experience	**12**	**4**	

4.2.2 Total land area of the papaya growers

The respondents were classified into five categories on the basis of their farm size (Table 6) following DAE (Department of Agricultural Extension). Data in the Table 6 revealed that more than two-third (77.67%) of the total respondent had medium farmers and no respondents were landless and marginal, small and large farmers were 13.00% and 9.33% respectively.

Table 6. Distribution of the papaya growers according to their total land size

Category	**Score (ha)**	**Respondents**	
		Number	Percent
Landless	≤ 0.02	0	0
Marginal	0.021 - 0.20	0	0
Small	0.21 – 1.0	39	13.00
Medium	1.0- 3.0	233	77.67
Large	> 3.0	28	9.33
Total		**300**	**100**

4.2.3 Papaya cultivation area

Papaya cultivated land size of the growers varied from 0.10 to 0.66 decimal with an average of 42.09 decimal and standard deviation of 10.06. Data in the Table 7 revealed that 35.0% farmers had 31-40 decimal papaya cultivation area followed by 26.67% farmers had 41-50 decimal papaya land. A remarkable farmer (18.67%) had < 20.0 decimal of papaya cultivation land and only 4% farmers had > 60 decimal papaya cultivation land.

Table 7. Distribution of the papaya growers according to their papaya land size

Papaya cultivation land (Decimal)	Frequency	%
< 20	56	18.67
31-40	105	35.00
41-50	80	26.66
51-60	47	15.67
> 60	12	4.00
Total	**300**	**100**
Minimum	**10**	
Maximum	**66**	
Average	**42.10**	
Sd	**10.06**	

4.2.3 Seed source for papaya cultivation

According to the opinion expressed by the papaya growers, out of 300, most of the papaya growers (50.33%) reported that they used their own seeds which was followed by 23.67% of the papaya growers used seeds of different companies (Figure 2). Whereas 21.33% growers used papaya seed from different companies and 2.67% of them collected papaya seed from BADC seed dealer.

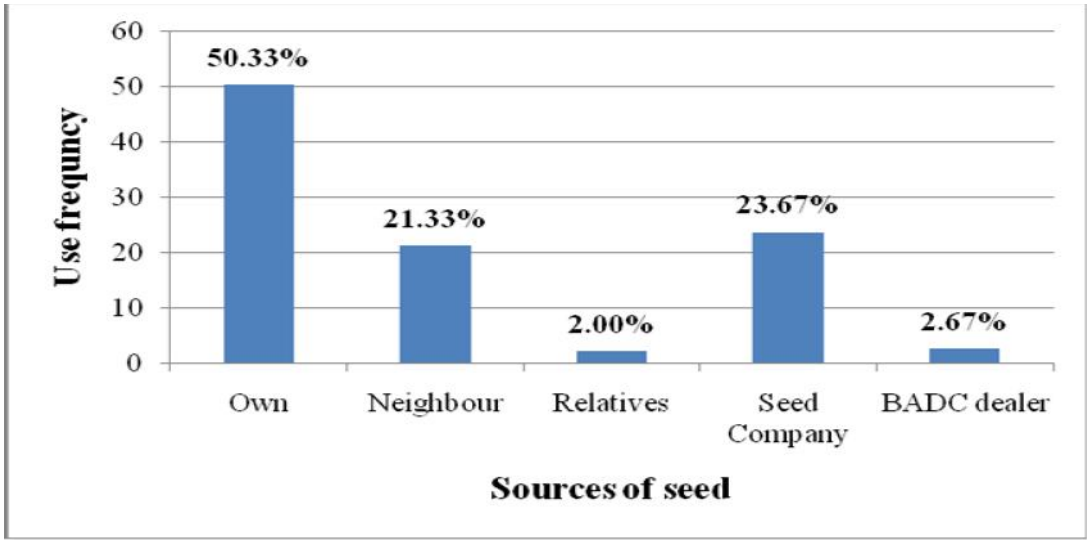

Figure 2. Response of the papaya growers on seed sources.

4.2.4 Cultivated papaya varieties

Papaya growers cultivated three varieties viz. local, shahi and red lady. Of which majority of the farmers (53.31%) used shahi variety followed by 30.91% and 15.77% farmers used local and red lady varieties respectively (Table 8).

Table 8. Farmer's response on cultivated papaya varieties

Papaya varieties	Frequency [N=300]	Percent response
Local	98	30.91
Shahi	169	53.31
Red lady	50	15.77
Multiple response		100.00

4.3 Pest's infestation on papaya

4.3.1 Pest's occurrence in papaya orchard

According to the opinion expressed by the growers, papaya was infested by mealybug, whitefly, ant and mite in the orchard. Out of 300, all the papaya growers (100%) reported that papaya was infested in the field by mealybug. In case of multiple responses, 171 farmers (27.45%) reported whitefly, 25 farmers (4.01%) reported ant and 127 farmers (20.39%) reported mite as pests of papaya in their field (Table 9).

Table 9. Response of the papaya growers on incidence of insect pest on papaya

Name of pests	Farmer's response (N = 300)	Percent response (%)
Mealybug	300	48.15
Whitefly	171	27.45
Ant	25	4.01
Mite	127	20.39
Multiple response		100.00

4.3.2 Pest's infestation on stages of papaya

Four pests viz., mealybug, whitefly, ant and mites were reported by papaya growers of which whitefly, ant and mite infestations were reported from vegetative, growing and

seedling stage of the papaya (Table 10) but whitefly infestation was reported form vegetative stage of the papaya. Highest infestation of mealybug, whitefly and ant (>80.0%) was reported at fruiting stage but maximum mite infestation (50.45%) was reported from vegetative stage.

Table 10. Response of the papaya growers on pest infestation status at different stages of papaya

Name of insect pests	Response on infestation plant stage (%)		
	Seedling stage	Vegetative stage	Fruiting stage
Mealybug	4.01	15.87	80.12
Whitefly	0.0	7.24	92.76
Ant	5.25	14.10	80.65
Mites	34.87	50.45	14.68

4.3.3 Farmers response on infested plant parts of papaya

According to papaya grower's leaf (17.83% farmers), stem (11.62% farmers), flower (34.24% farmers) and fruits (36.31% farmers) were infested by mealybug. Ant infestation was also reported from all plant parts (Table 11). But whitefly and mite infestation were reported from papaya leaves only.

Table 11. Farmers' information on infested plant parts of papaya by different pests

Name of insect pests	Farmers response on pests' infestation on plant parts (%)			
	Leaf	Stem	Flower	Fruits
Mealybug	17.83	11.62	34.24	36.31
Whitefly	100.0	-	-	-
Ant	32.00	12.00	20.00	36.00
Mite	100.0	-	-	-

4.3.4 Farmers' information on severity of infestation of different pests

High severity of mealybug was reported by 43.83% growers and 47.83% reported medium severity of infestation on papaya. All the farmers 100% reported low severity of ant on papaya. High severity of whitefly and mite were also reported by 9.36% and 9.44%

farmer's respectively (Table 12). Most of the farmers opined medium severity of whitefly (55.56%) and mite (59.06%) infestation on papaya.

Table 12. Response of the papaya growers on severity of infestation of four pests of papaya

Name of insect pests	Response on status of four pests (%)		
	Low	Medium	High
Mealybug	8.70	47.83	43.83
Whitefly	35.08	55.56	9.36
Ant	100.0	0.0	0.0
Mite	31.50	59.06	9.44

4.3.5 Farmers' information on status of insect pests of papaya

In responding status of four pests of papaya, 100% farmers reported mealybug as major damaging pest of papaya (Table 13). Whitefly and mites were also reported as major pests by 35.23% and 24.76% growers respectively. Ant was reported as minor insect pest of papaya by all farmers.

Table 13. Response of the papaya growers on status of different pests' infestation in papaya orchard

Name of insect pests	Response on status of four pests (%)	
	Major	Minor
Mealybug	100.0	0.00
Whitefly	35.23	64.77
Ant	0.0	100.00
Mite	24.76	75.24

4.3.6 Control measures of pests of papaya

Out of 300 respondents, all expressed their opinion that they controlled different pests by application of chemical pesticides. None of the farmers used cultural or biological pest control methods.

4.3.6.1 Insecticides uses against pests of papaya

According to the opinion expressed by the papaya growers, they sprayed Marshal 20EC (23.76%) and sumithion 20EC (18.36%) @ 2.0 ml/L water, imitaf 20SL/tido 20SL (47.52%) @ 0.50 ml/L water and caught 10EC (10.36%) @ 1.0 ml/L water 3-4 times for controlling papaya mealybug (Table 14). They also applied imitaf 20SL/tido 20SL (70.18%) 0.50 ml/L water and aktara 20WG (29.82%) 0.50 g/L water 1-2 times against whitefly. Sunmectin 1.8EC (30.00% farmers), acamite 1.8EC (18.03% farmers) and vertimec (51.97% farmers) @ 2.0 ml/L were used 2-3 times against mite pest of papaya. Majority of the papaya growers used imitaf 20SL/ tido 20SL (Imidacloprid) for controlling mealybug and whitefly infesting papaya.

Table 14. Response of the papaya growers on insecticide use in papaya orchard

Name of pests	Insecticides and their doses used against pests of papaya			Used frequency
	Insecticides	% response	Dose	
Mealybug	Marshal 20EC	23.76	2.0 ml/L	3-4
	Sumithion 50EC	18.36	2.0 ml/L	
	Imitaf 20SL / Tido 20SL	47.52	0.50 ml/L	
	Caught 10EC	10.36	1.0 ml/L	
Whitefly	Imitaf 20SL/ Tido 20SL	70.18	0.5 ml/L	1-2
	Aktara 20WG	29.82	0.5 g/L	
Ant	No inseciticide	100.0	-	-
Mite	Sunmectin 1.8EC	30.00	2.0 ml/L	2-3
	Acamite 1.8EC	18.03	2.0 ml/L	
	Vertimec 1.8EC	51.97	2.0 ml/L	

4.4 Farmers information on mealybug infestation on papaya

Out of 300 respondents, all expressed their opinion that that their papaya plant infested by mealybug. The details about mealybug infestation and control measures are discussed herein.

4.4.1 Mealybug infestation stage

According to farmers' information, mealybug infestation occurred from seedling stage to mature plants. Majority of farmers (65.27%) opined that mealybug infestation occurred at fruiting stage of papaya followed by 24.78% reported growing plant infestation and 9.96% reported seedling infestation of papaya (Table 15).

Table 15. Response of the papaya growers on plant stage of mealybug infestation in papaya orchard

Plant stage of infestation	Farmer's response [N=300]	Percent response (%)
Seedling	45	9.96
Growing plant	112	24.78
Fruiting stage	295	65.27
Multiple response		100.00

4.4.2 Mealybug infested parts of papaya

Papaya growers opined that all parts of papaya plants viz. leaf, stem, flower and fruits were infested by mealybug. Majority of the farmers (36.31%) reported fruit infestation followed by flower, leaf and stem infestation as reported by 34.24%, 17.83% and 11.62% farmers respectively (Table 16).

Table 16. Farmers' information on infested parts of papaya by mealybug

Infested part of papaya	Farmer's response [N=300]	Percent response (%)
Leaf	112	17.83
Stem	73	11.62
Flower	215	34.24
Fruit	228	36.31
Multiple response		100

4.4.3 Severity of mealybug infestation

Papaya growers reported low to high level of mealybug infestation on papaya. Majority of the farmers (47.83%) reported medium level of mealybug infestation followed by 43.83% farmers reported high severity of mealybug infestation. Few farmers (8.70%) reported low severity of mealybug infestation (Table 17).

Table 17. Farmers' information on severity of mealybug infestation on papaya

Severity of mealybug infestation	Farmer's response [N=300]	Percent response (%)
Low	30	8.70
Medium	165	47.83
High	150	43.48
Multiple response		100

4.4.4 Time of mealybug infestation

According to farmers information, mealybug infestation occurred throughout the year. However majority of them (63.72%) reported mealybug infestation occurred at rainy season followed by winter season as reported by 30.28% farmers. Few farmers (5.99%) reported mealybug infestation during rainy season (Table 16) .

Table 18. Farmers' information on time of mealybug infestation on papaya

Season of mealybug infestation	Farmer's response [N=300]	Percent response (%)
Summer	202	63.72
Rainy	19	5.99
Winter	96	30.28
Multiple response		100.00

4.4.5 Control methods against mealybug

Farmers used cultural (clean cultivation), mechanical (hand collection and destruction) and chemical control against papaya mealybug. However majority of farmers (96.42%) used chemical insecticides for controlling mealybug. Few farmers used cultural (1.95%) and mechanical (1.63%) methods for mealybug control (Figure 3).

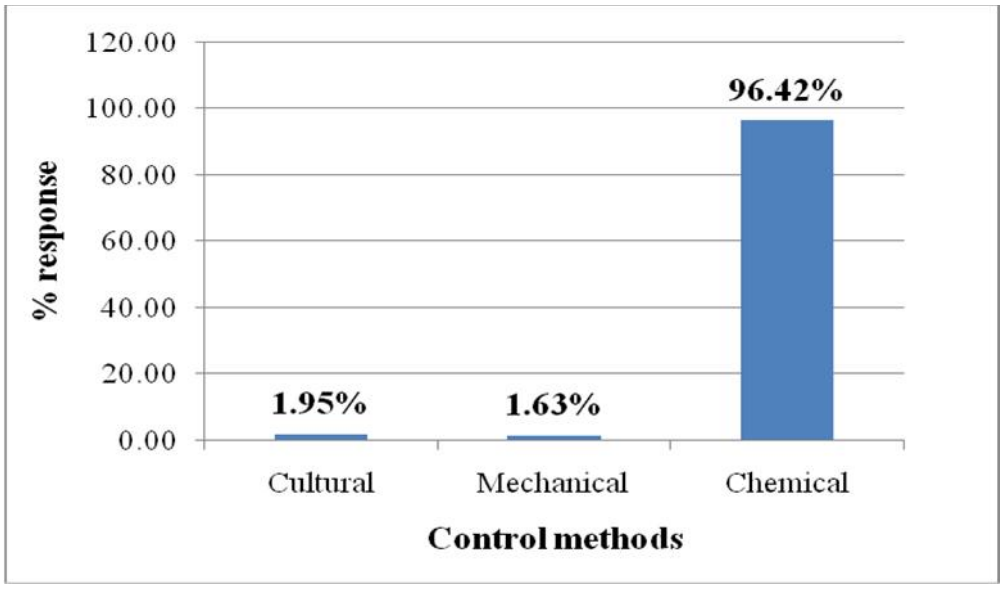

Figure 3. Farmer's response on control methods against papaya mealybug.

4.4.6 Insecticide use for controlling mealybug

Out of 300, most (47.52%) of the papaya growers reported that they used imitaf or tido 20SL which was followed by marshal 20EC (23.76%), sumithion 50EC (18.36%) and caught 10EC (10.76%) as chemical control against papaya mealy bug (Table 18). Sometimes they had applied the insecticide as cocktail from by blending of more insecticides together.

Table 19. Farmers' information on chemical insecticides used against papaya mealybug

Name of insecticides	Farmer's response [N=300]	Percent response (%)
Marshal 20EC	110	23.76
Sumithion 50EC	85	18.36
Imitaf 20SL/Tido 20SL	220	47.52
Caught 10EC	48	10.36
	Multiple response	100.00

4.4.7 Insecticide spray frequency for controlling mealybug

Farmers sprayed chemical insecticides 3-4 times for controlling papaya mealybug. Majority of the farmers (58.92%) sprayed insecticides 3 times but 41.08% of them sprayed insecticides 4 times (Figure 4).

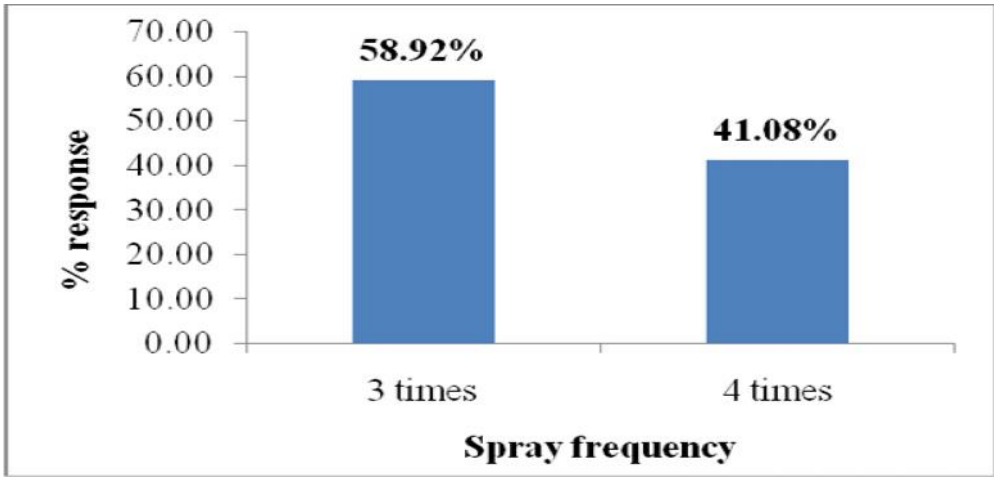

Figure 4. Farmers response on frequency of insecticides spray for controlling papaya mealybug.

4.4.8 Effectiveness of insecticides for controlling mealybug

In responding effectiveness of insecticides against papaya mealybug, 93.33% farmers reported that papaya mealybug was controlled after insecticides spray. Only 6.67 % farmers opined that papaya mealybug was not controlled by insecticides spray (Figure 12).

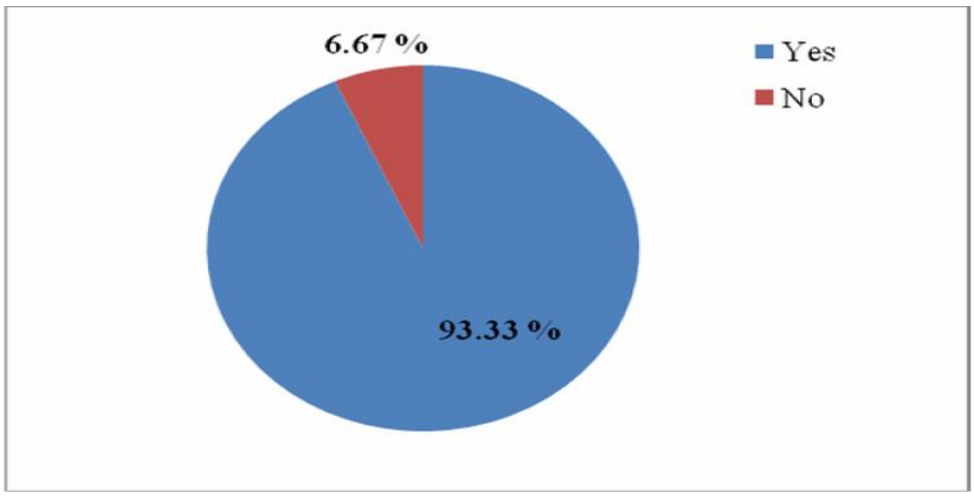

Figure 5. Farmer's response on effectiveness of insecticides against papaya mealybug.

4.4.6 Harmful effect of insecticides

Out of 300 papaya growers, 97.67% (292) opined that insecticides had harmful effect and only 2.33% (8) farmers were not conscious about side effect of insecticides (Figure 6). In responding hazardous effect of insecticides, 96.93% farmers informed that insecticides caused health hazard on human and 3.07% papaya growers reported harmful effect of insecticides on environment (Figure 7).

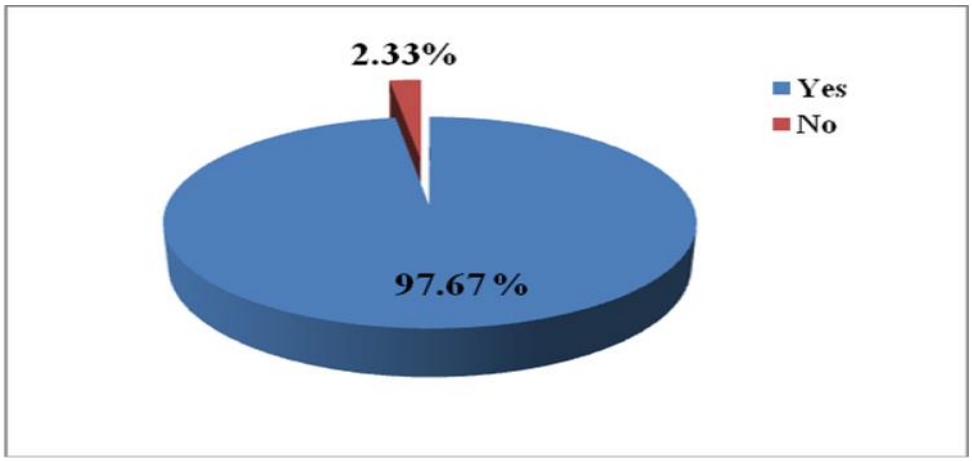

Figure 6. Farmers response on harmful effect of insecticides.

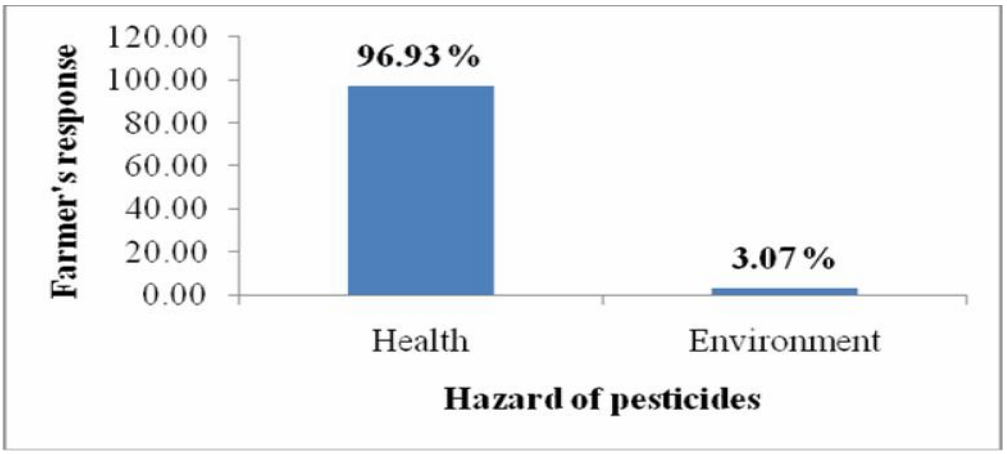

Figure 7. Farmer's response on hazards of insecticides on human health and environment.

CHAPTER V

SUMMARY AND CONCLUSION

Survey was conducted in the 30 upazilas of ten districts of Bangladesh where papaya is produced on a large scale during November 2017 to January 2018 to study the pest status and infestation intensity of mealybug in major papaya growing districts of Bangladesh and to find out the management practices used by the farmers for controlling mealybug of papaya. Information was collected from 300 papaya growers in ten districts using pre-designed and pretested questionnaire. The findings of this study have summarized herein.

Most of the papaya growers (98%) were male and their age ranged from 25-76 years. Majority of them (40.67%) were middle aged (41-50 years) farmers compare to old aged (51-60 years) which occupied 34.67%. Most of the papaya growers 65.33% could not read or write but could sign only.

Highest experience category of papaya growers were medium category (86.67%) followed by low category (12.0%). For seed use, the highest percentage of the farmers 50.33%) used their own seed followed by 23.67% and 21.33% were used seeds of company and neighbor, respectively. For variety use, the majority of them (53.31%) cultivated shahi variety followed by 30.91% and 15.77% farmers used local and red lady, respectively.

In case of pest occurrence in the papaya field 48.15% respondents expressed that papaya mainly infested by mealybug followed by whitefly (27.45% farmers), mite (20.39% farmers) and ant (4.01% farmers). Among the pests, mealybug and ant were reported to infest leaf, stem, flower and fruits but whitefly and mites were reported as leaf infesting pests. Low (8.70%), medium (47.83%) to high level (43.48%) severity of infestation was reported by the farmers and majority of the farmers (55.56%) reported medium severity of whitefly infestation. All farmers (100%) reported mealybug as a major pest of papaya,

followed by 35.23% and 24.76% farmers reported whitefly and mite, respectively as major pests of papaya. Most of the farmers reported that they control pests by spraying chemical insecticides. Farmers used Marshal 20EC, Sumithion 50EC, imitaf 20SL or tido 20SL 3-4 times for controlling mealybug, imitaf 20SL or tido 20SL and aktara 20WG 1-2 times for controlling whitefly and sunmectin 1.8EC/ acamite 1.8EC / vertimec 1.8EC for controlling mite.

Most of the farmers (65.27%) opined that mealybug infested in the papaya plant at fruiting stage and infestation occurred on leaf, stem, flower and fruit with medium to high severity of infestation but maximum infestation was reported from fruit (36.31% farmers opinion) followed by flower infestation (34.24% farmers opinion). Majority of the farmers (96.42%) applied insecticides to control mealybug and marshal 20EC, sumithion 50EC, imitaf or tido 20SL and caught 10EC were used 3-4 times by the farmers. But majority of the farmers (47.52%) sprayed imitaf 20SL/tido 20SL 3-4 times for controlling mealybug. In responding effectiveness of insecticides, most of the farmers (93.33%) reported that mealybug was controlled by insecticides spraying and 6.67% farmers reported ineffectiveness of insecticides. Most of the papaya growers (96.67%) were conscious about hazardous effect of chemical insecticides and most of them (96.93%) reported health hazards.

CONCLUSION

Four pests were reported to attack papaya in farmer's field of which mealybug was reported as major pests. Mealybug was reported to infest leaf, stem, flower and fruit of papaya from seedling to mature plant with medium to high severity of infestation. Farmers mainly used marshal 20EC (Carbosulfan), sumithion 50EC (fenitrothion), imitaf 20SL/ tido 20SL (imidacloprid) and caught 10EC (cypermethrin) insecticides for controlling mealybug. Majority of the farmers applied imitaf 20SL/ tido 20SL (imidacloprid) 3-4 times for controlling mealybug.

CHAPTER VI

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Appendix-1

মিলিবাগ সম্পর্কে পেঁপে চাষীদের মতামত জরিপের প্রশ্নবলী

কোড নং-..... মোবাইল নং.....

১। কৃষকের ব্যক্তিগত তথ্যাবলী

ক) কৃষকের নামঃ .....

খ) গ্রামঃ..... গ) ব্লকঃ.....

ঘ) উপজেলাঃ..... ঙ) জেলাঃ.....

চ) বয়সঃ.....বছর ছ) লিঙ্গ ঃ(১=পুরুষ, ২=মহিলা) [ ]

জ) শিক্ষাগত যোগ্যতা ঃ (অশিক্ষিত = ১, প্রাথমিক = ২, মাধ্যমিক = ৩, উচ্চ মাধ্যমিক/তার বেশী = ৪) [ ]

ঝ) জমির পরিমান ঃ ..... শতাংশ

২। পেঁপে চাষ সংক্রান্ত তথ্যাবলী

২.১ কত বছর যাবত পেঁপে চাষ করেন?..... বছর

২.২ পেঁপে চাষের উপর কোন প্রশিক্ষণ আছে কি না? [ ]

হ্যাঁ হলে প্রশিক্ষণের নাম বলুন।

১.....২.....৩.....

২.৩ এ বছর কতটুকু জমিতে পেঁপে চাষ করেছেন?..... শতাংশ

২.৪ এ বছর আপনি কোন কোন জাতের পেঁপে চাষ করেছেন?

১.....২.....৩.....

২.৫ পেঁপে চাষে আপনার বীজের উৎস কী কী? (নিজস্ব = ১, প্রতিবেশী = ২ আত্মীয় = ৩, এনজিও = ৪, কোম্পানী = ৫, বিএডিসি=৬ বিএডিসি ডিলার =৭, খুচরা ডিলার=৮, বাংলাদেশ কৃষি গবেষণা ইনষ্টিটিউট =৯ অন্যান্য=১০) [ ]

২.৬ পেঁপে চাষে আপনি কি কি সমস্যার সম্মুখীন হন?

১.....২.....৩.....৪.....৫...

.....

৩. পেঁপের পোকা আক্রমন সংক্রান্ত তথ্যাবলী

৩.১ আপনার পেঁপেতে কখন কোন কোন পোকার আক্রমন হয় এবং আক্রমন ধরন কি রকম?

পোকার নাম	কখন আক্রমন হয় (১=চারা, ২=বাড়ন্ত গাছ, ৩= ফলজ গাছ)	গাছের কোন অংশ আক্রান্ত হয় (১=পাতা, ২= কান্ড, ৩=ফুল, ৪=ফল)	আক্রমনের তীব্রতা ১=কম, ২= মধ্যম, ৩=কম	পোকার ধরণ ১=মূখ্য, ২ গৌন
১।				
২।				
৩।				
৪।				
৫।				

৩.২ এ সকল পোকার জন্য কি কি দমন পদ্ধতি ব্যবহার করেন?

পোকার নাম	দমন পদ্ধতি ১=কালচারাল, ২=যান্ত্রিক, ৩= জৈবিক, ৪=রাসায়নিক, ৫=অন্যান্য	রাসায়নিক পদ্ধতি হলে কীটনাশকের নাম বলুন	কতবার কীটনাশক প্রয়োগ করেন	কিমাত্রায় কীটনাশক প্রয়োগ করেন
১।				
২।				
৩।				
৪।				
৫।				

৪। মিলিবাগ সংক্রান্ত তথ্যাবলী

৪.১ আপনার পেঁপেতে মিলিবাগ পোকার আক্রমন হয় কি না? (১=হ্যাঁ, ২=না) [ ]

৪.২ হ্যাঁ হলে পেঁপে গাছে মিলিবাগ পোকার আক্রমনের ধরন ও ক্ষতির পরিমাণ কেমন?

কখন আক্রমন হয় (১=চারা গাছ, ২=বাড়ন্ত গাছ, ৩= ফলজ গাছ)	গাছের কোন অংশ আক্রান্ত হয় (১=পাতা, ২= কান্ড, ৩=ফুল, ৪=ফল)	আক্রমনের তীব্রতা ১=কম, ২= মধ্যম, ৩=কম	পোকার ধরণ ১=মূখ্য, ২ গৌন	বছরের কোন সময় আক্রমণ বেশি হয়

৪.৩ মিলিবাগ পোকা দমন করার জন্য কি কি পদ্ধতি ব্যবহার করেন? (১=কালচারাল, ২=যান্ত্রিক, ৩= জৈবিক, ৪=রাসায়নিক, ৫=অন্যান্য) [ ]

৪.৪ কীটনাশক ব্যবহার করলে তার নাম ও কতবার, কিমাত্রায় প্রয়োগ করেন বলুন?

কীটনাশকের নাম	কতবার কীটনাশক প্রয়োগ করেন	কিমাত্রায় কীটনাশক প্রয়োগ করেন
১।		
২।		
৩।		
৪।		
৫।		

৪.৫ কীটনাশক প্রয়োগ করে মিলিবাগ সম্পূর্ণরূপে দমন হয় কি? (১=হ্যাঁ, ২=না) [ ]

নাহলে কি কারণে হয় না

১.....২.....৩.....[ ].....

৪.৬ মিলিবাগ পোকা পেঁপে ছাড়া অন্য কোন গাছকে আক্রমন করে কি না?

হ্যাঁ হলে সেগাছগুলোর নাম বলুন

১.....২.....৩.....

৪.৭ কীটনাশক ব্যবহার করলে কোন ক্ষতি হয় কি না? (১= হ্যাঁ, ২=না) [ ]

হ্যাঁ হলে কি ধরনের ক্ষতি হয়? (১= পরিবেশগত, ২= স্বাস্থ্যগত) [ ]

তথ্য সংগ্রহকারীর নাম ঃ

তারিখ ঃ

২