

**SURVEY ON PAPAYA VIRAL DISEASES IN MAJOR PAPAYA GROWING DISTRICTS IN  
BANGLADESH**

**MD. AHAMEDUL KABIR**



**DEPARTMENT OF PLANT PATHOLOGY**

**SHER-E-BANGLA AGRICULTURAL UNIVERSITY  
DHAKA -1207**

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GROWING DISTRICTS IN BANGLADESH**

**BY**

**MD. AHAMEDUL KABIR**

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**Approved by:**

---

**Dr. Fatema Begum**  
Associate Professor  
Department of Plant Pathology  
SAU, Dhaka  
Supervisor

---

**Abu Noman Faruq Ahmmed**  
Associate Professor  
Department of Plant Pathology  
SAU, Dhaka  
Co-Supervisor

---

**(Dr. Md. Belal Hossain)**  
Associate Professor  
Chairman  
Examination Committee  
Department of Plant Pathology



**Department of Plant Pathology**  
**Sher-e Bangla Agricultural University**  
**Sher-e-Bangla Nagar**  
**Dhaka-1207**

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***CERTIFICATE***

*This is to certify that thesis entitled, "SURVEY ON PAPAYA VIRAL DISEASES IN MAJOR PAPAYA GROWING DISTRICTS IN BANGLADESH" submitted to the Department of Plant Pathology, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of MASTER OF SCIENCE in Plant Pathology, embodies the result of a piece of bona fide research work carried out by MD. AHAMEDUL KABIR, Registration No. 09-03507 under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.*

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

.....  
**Dated:**  
**Place: Dhaka, Bangladesh**

.....  
**Dr. Fatema Begum**  
Associate Professor  
Department of Plant Pathology  
Sher-e-Bangla Agricultural University  
**Supervisor**

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*The Author*

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## **ABSTRACT**

A survey was conducted at 10 upazilas of selected 6 major papaya growing districts of Bangladesh to investigate the papaya viral diseases. The study area were in upazila Kapasia and Sreepur under Gazipur district, Narshingdi Sadar under Norsinghdi district, Jhikargacha, Monirampur and Keshobpur upazila under Jessore district, Magura Sadar and Sripur upazila under Magura district, Kaliganj upazila under Jhinaidah district and Modhukhali upazila under Faridpur district. With the assistance of DAE, 20 farmers from each upazila were selected for interview on the incidence and severity of viral diseases of papaya crop in the field at seedling, flowering and fruiting stage. Direct personal interview approach was adopted for collection of primary data. Collected data were compiled, analysis and summarized by SPSS Software. Results exhibits that identified 3 different viral symptoms from all over working area at three distinct growth stage were selected for sample data collection. Ringspot, mosaic and leaf curl symptoms were found as common symptoms which cause severe damage to papaya. Experiment results revealed that from both at farmers level information and field survey inspection papaya ringspot symptoms were much destructive and cause severe losses of farmers papaya field. After papaya ringspot, papaya mosaic and papaya leaf curl were ranked, respectively and all of them were also serious in papaya growing investigated areas. It was observed that ringspot in fruit, leaf curl in leaves and in seedlings, mosaic in fruit and leaves were most destructive.

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## ABBREVIATIONS AND ACRONYMS

AEZ	=	Agro-Ecological Zone
BBS	=	Bangladesh Bureau of Statistics
BCSRI	=	Bangladesh Council of Scientific Research Institute
cm	=	Centimeter
CV %	=	Percent Coefficient of Variation
DAS	=	Days After Sowing
DMRT	=	Duncan's Multiple Range Test
<i>et al.</i> ,	=	And others
e.g.	=	exempli gratia (L), for example
etc.	=	Etcetera
FAO	=	Food and Agricultural Organization
g	=	Gram (s)
i.e.	=	id est (L), that is
Kg	=	Kilogram (s)
LSD	=	Least Significant Difference
m <sup>2</sup>	=	Meter squares
ml	=	MiliLitre
M.S.	=	Master of Science
No.	=	Number
SAU	=	Sher-e-Bangla Agricultural University
var.	=	Variety
°C	=	Degree Celceous
%	=	Percentage
NaOH	=	Sodium hydroxide
GM	=	Geometric mean
mg	=	Miligram
P	=	Phosphorus
K	=	Potassium
Ca	=	Calcium
L	=	Litre
µg	=	Microgram
USA	=	United States of America
WHO	=	World Health Organization

## 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 break down the meat fibers. Papaya is one of the major fruit crops cultivated in tropical and sub-tropical zones. Worldwide over 6.8 million ton of fruit were produced in 2004 on about 389990 ha (FAO, 2004). Of this volume, 47% was produced in Central and South America (mainly in Brazil), 30% in Asia, and 20% in Africa (FAO, 2004). In Bangladesh, 38 thousand acres of land was under papaya cultivation and 489 thousand ton papaya was produced in 2014-15 (BBS, 2016) which is very low compared to neighboring countries like India, Srilanka and Pakistan.

Diseases are the most important limiting production problems of papaya. Although the plant is classified botanically as perennial, virus diseases have reduced the effective crop life to 1-2 years. Insect pest and diseases caused serious damage to papaya crops in our country. About 70% crop loss and sometimes 100% crop loss may occur due to insect and diseases infestation. It is urgently needed to protect this fruit crop against insect pest and diseases infestation. Every year in Bangladesh, about 25% papaya damage was found from insect pest infestation where 30-40% damage was found from disease

infestation and only 10% damage was observed from transportation of papaya for marketing (BBS, 2000).

The papaya viral disease may show peculiarity in their prevalence and symptom development throughout the year. Sometimes, masking of the symptom occur in the infected plants depending upon the seasons (Kiranmai *et al.* 1998)

The papaya plant may get infected by PRSV-P at any stage of the growth (seedling to maturity) and yield loss might reach even upto 100% very often (Purcifull *et al.* 1984). For causing devastating disease which severely interfere with economic papaya production *Papaya ringspot virus*-Papaya strain (PRSV-P) is well recognized in all papaya growing countries of tropic and sub-tropic (Gonsalves, 1998). Akhter and Akanda (2008) stated that all seven symptoms namely mild mosaic (MM), mosaic (MO), severe mosaic (SM), leaf distortion (LD), fern leaf (FL), vein clearing (VC), chlorotic leaf spot (CS) all are reacted positively in DAS-ELISA against the antisera of papaya ringspot virus- papaya strain (PRSV-P).

Papaya viruses cause diseases of international importance with serious reductions in fruit production that may even totally destroy affected orchards. Until now, more than ten different viruses have been reported in papaya worldwide. Nevertheless, the most important viruses that affect papaya are the *Papaya ringspot virus* (PRSV), the *Papaya leaf distortion mosaic virus* (PLDMV), the *Papaya lethal yellowing virus* (PLYV) and the *Papaya mosaic virus* (PapMV) which have been known to cause serious damage to the crop production throughout the world. PRSV causes the most destructive viral disease of papaya crop, the papaya ringspot, and has been found in many tropical and subtropical areas where papaya is grown, including the USA, South America, Mexico and Japan (Azad *et al.*, 2014). PLDMV was first reported in 1954 on the island of Okinawa, Japan. PLDMV emergence in PRSV-resistant papaya transgenic lines was considered as an emerging threat to papaya culture in China (Bau *et al.*, 2008). PLYV is restricted to Brazil and

its increasing spread reaching high incidence rates (Daltro *et al.*, 2012). PapMV was first reported in 1962 in Florida, USA. The disease has spread to other countries, reaching Bolivia, Peru, Venezuela and Mexico. In Mexico, PRSV and PapMV occurred in single or mixed infections and a synergistic interaction between the two independent viruses in the same host can occur and lead to increased symptoms and virus accumulation (Noa-Carrazana *et al.*, 2006).

The economic production of papaya needs efficient management of the disease caused by papaya viruses. Severe attempts were made like roughing, controlling of insect vectors by spraying mineral oil and insecticides, mulching, inter-cropping with barrier crop (corn), protecting young seedlings with plastic bag, developing papaya varieties resistant to papaya viral disease for managing the disease (Yeh *et al.* 1988) but none of the measure gave satisfactory results.

Although reports on different virus symptoms of papaya are found elsewhere, reports on those of the papaya are not available in Bangladesh. Thus the present research work was undertaken to fulfill the following objectives:

### **Objective of the study**

1. To study the virus infection (disease incidence) of papaya in Bangladesh.
2. To study the distribution of different virus symptoms in major papaya growing districts of Bangladesh.
3. To observe the intensity of damage (disease severity) caused by different virus of papaya.

## CHAPTER II

### REVIEW OF LITERATURE

The papaya is believed to be native to southern Mexico and neighboring Central America. It is currently cultivated in Florida, Hawaii, Eastern British Africa, South Africa, Sri-Lanka, India, Canary Islands, Malaysia and Australia. It is now present in every tropical and subtropical country.

Papaya is a large herbaceous tropical plant grown for its melon-like fruit. Diseases are the most important limiting production problems of papaya. Although the plant is classified botanically as perennial, virus diseases have reduced the effective crop life to 1-2 years. Many types of papaya viral diseases are found in Bangladesh and also all over the world. A few viral diseases are found in Bangladesh which is more severe. Among them Papaya ringspot virus, Papaya mosaic virus, papaya leaf curl virus and papaya malaria virus are very important.

Literature and review under such diseases are limited. The following presentations were done on common viral diseases of papaya in Bangladesh under the following headings:

#### **2.1 General information on papaya viral diseases**

Papaya (***Carica papaya***) is a tropical fruit having commercial importance because of its high nutritive and medicinal value. Papaya cultivation had its origin in South Mexico and Costa Rica. Total annual world production is estimated at 6 million tons of fruits (FAOSTAT, 2014). India leads the world in papaya production with an annual output of about 3 million tons. Other leading producers are Brazil, Mexico, Nigeria, Indonesia, China, Peru, Thailand and Philippines.

In Bangladesh and also many other countries, viral diseases of papaya is a great problem. A considerable amount of papaya is damaged by viral diseases in every year. Plant viruses cause many diseases of international importance and

are responsible for huge losses of crop production and quality in all parts of the world. The production is impaired due to the susceptibility of the plants to the viruses.

Brazil is one of the main papaya producers; in 2012, the country produced 1.52 million tons, which was approximately 12.2% of the world supply. The production area was 31.3 thousand hectares with an average yield of 48.5 t/ha, and the production value estimated at \$ 786 million (FAOSTAT, 2014). Mexico, on the other hand, is the main exporter to the USA. In 2013, it cultivated approximately 16,368 hectares, with a production of 764,514 tons (SIAP, 2014). The economic importance of this crop for both countries, besides the high levels of fruit exportation, is that this crop is the source of income for hundreds of smallholder farmers.

Papaya viruses cause diseases of international importance with serious reductions in fruit production that may even totally destroy affected orchards. Until now, more than ten different viruses have been reported in papaya worldwide. Nevertheless, the most important viruses that affect papaya are the Papaya ringspot virus (PRSV), the Papaya leaf distortion mosaic virus (PLDMV), the Papaya lethal yellowing virus (PLYV), the Papaya mosaic virus (PapMV) and the Papaya meleira virus (PMeV), which have been known to cause serious damage to the crop production throughout the world (FAOSTAT, 2014).

PRSV causes the most destructive viral disease of papaya crop, the papaya ringspot, and has been found in many tropical and subtropical areas where papaya is grown, including the USA, South America, Mexico and Japan (Azad *et al.*, 2014). PLDMV was first reported in 1954 on the island of Okinawa, Japan. PLDMV emergence in PRSV-resistant papaya transgenic lines was considered as an emerging threat to papaya culture in China (Bau *et al.*, 2008). PLYV is restricted to Brazil and its increasing spread reaching high incidence rates (Daltro *et al.*, 2012). PapMV was first reported in 1962 in Florida, USA. The disease has spread to other countries, reaching Bolivia, Peru, Venezuela

and Mexico. In Mexico, PRSV and PapMV occurred in single or mixed infections and a synergistic interaction between the two independent viruses in the same host can occur and lead to increased symptoms and virus accumulation (Noa-Carrazana *et al.*, 2006).

In Brazil, the percentage of plants eradicated with papaya ringspot is about 2% per year in well-managed orchards. In traditional orchards, the losses may reach 80% (Ventura *et al.*, 2004). In Mexico, PRSV causes severe damage in the main papaya production states with crop losses of up to 85% (Teliz *et al.*, 1991). The PMeV infects at least 20% of the plants during the economic cycle of crop. In some orchards, where rouging of sticky diseased plants was not carried out, an incidence of the disease of up to 100% and cause total yield losses (Ventura *et al.*, 2003).

## **2.2 Common papaya virus symptoms and damage status**

### **2.2.1 Papaya ringspot symptoms**

It is the most destructive disease of papaya in all over the world. Linder (1945) has published about PRSV and brought it in literature for the first time. An investigation was done by Jensen (1949) about the virus infecting papaya in Hawaii and named the virus as *Papaya ring spot virus* (PRSV).

In 1945, for the first time it was reported about the presence of PRSV in Taiwan, where most of the plant was destroyed by virus in the commercial orchard (Wang *et al.*, 1978). In Japan, *Papaya leaf distortion mosaic virus* was first reported by Maoka *et al.* (1995) as a distinct member of genus *Potyvirus* that was later proved to be an isolate of PRSV.

Gonzalvez *et al.* (1997) established that PRSV caused three types of leaf symptom on papaya which are mosaic, yellowing and deformation. In Andhra Pradesh of India, in commercial plantation papaya plants with severe mosaic, leaf distortion and filiform leaves were suspected to be infected with PRSV reported by Kiranmai *et al.* (1998).



PRSV is described as a typical member of *Potyvirus* and grouped PRSV into PRSV-P i.e. *Papaya ringspot virus*- papaya strain which infect papaya and cucurbitis and PRSV-W i.e. *Papaya ringspot virus*- watermelon strain which infects cucurbits but not papaya (Purcifull, 1984). He also described that PRSV-P is radially transmitted by mechanical inoculation using sap of infected plants and host range is limited to the members of Caricaceae, Chenopodiaceae and Cucurbitaceae. PRSV caused with different symptoms but typical ringspot symptom occurs on fruits of infected plants (Yeh *et al*, 1988). The virus was proved to be a non-persistently transmitted by a number of aphid species. Among all of the species *Aphis gossypii* is the most common.

The most renowned papaya viral disease is PRSV-P in the world. In Hawaii, Florida, the Caribbean Countries, South America, Australia and the Far East it was reported that PRSV-P is the major limiting factor in papaya growing areas (Purcifull *et al*. 1984). The distribution of PRSV-P in many areas was of the world including USA, Mexico, Caribbean Countries, Germany, France, Italy, India, Taiwan, Middle East and South Africa was reported by Brunt *et al*. (1990).

### **2.2.2 Papaya leaf curl symptom**

The disease is characterized by severe curling, crinkling and deformation of leaves. Mostly the young leaves are affected. They show vein clearing, reduced size, inward rolling of the leaves, and thickening of the veins. The petioles are twisted. The diseased leaves become leathery and brittle. The plants are stunted and in advanced stages defoliation was observed. The fruits developed are of abnormal size and have no commercial value. Papaya leaf curl disease caused by PLCV is one of most serious threat to papaya cultivation in most of papaya-growing countries. Papaya leaf curl disease is caused by bipartite geminivirus (Goodman, 1981). The vector associated with disease is identified as whitefly (*Bemisia tabaci*) (Nariani, 1956).

### **2.2.3 Papaya mosaic symptom**

Papaya mosaic virus is one of the most important virus of papaya in the world. It causes leaf mosaic and stunting in papaya. The disease was observed on papaya plants of all age groups, but it was most serious on young plants. The top young leaves of the diseased plants were much reduced in size and showed blister like patches of dark green tissue alternating with yellowish green lamina, and puckering. The leaf petiole was of reduced in length and the top leaves assume upright position. The infected plant showed degeneration and marked reduction in growth. The fruits on diseased plants developed circular water soaked lesions with central solid spots. It is transmitted by several species of Aphids (Zettler, Edwardson and Purcifull, 1968).

### **2.3. Economic importance of papaya virus symptom**

Eighty three viruses, nine mycoplasma and two virus/mycoplasma complex diseases were reported in thirty two different crops which included 1 cereal. 8 pulse, 5 oilseed, 3 tuber crops, 12 vegetables, 1 spices and 2 fruit crops (Muqit and Akanda, 2007).

Papaya is a very testy and demanding fruit in the world with various purposes like as a fruit and vegetable. It has high nutritional, medicinal value. It has a great economical contribution in the world. But the papaya viral disease causes great hamper in papaya production both in quality and quantity. It reduces the production and effect on commercial papaya production.

Jensen (1949) stated that PRSV destroyed the papaya industry in Hawaii and shifted the papaya cultivation from Hawaii to Oahu. On the other hand its destructive effect forced Brazilian papaya industry to move from Sao-Paulo and Rio-De-Zaneiro states to more remote northern state Espiritu-Santo and Bahia (Costa *et al.* 1969). From 1973-78 Sao-Paulo and Rio-De-Zeneiro accounted 90% of the total papaya acreage but 27% in 1984 due to PRSV prevalence over there (Costa *et al.* 1969)

*Papaya ringspot virus* (PRSV) destroyed most of the papaya plant in commercial orchard along the West Coast of Taiwan, reported by Wang *et al.* (1978). The total yield of papaya dropped from 41,595t in 1974 to 18,950 in 1977. *Papaya ringspot virus* disease has been reported as a destructive disease causing severe economic loss of papaya production by Yeh *et al.* (1988) and Gonsalves (1989). The virus was designed as a major obstacle to wide scale planting of papaya. Chan and Doon (1990) described PRSV as a potential threat to the local papaya industry in Malaysia.

Akanda (1991) reported that *Papaya ringspot virus* - papaya strain causes 70-100% yield reduction of papaya depending upon the stage of infection in Bangladesh. Yon (1994) determined that papaya cultivation of 17170 ha of land in 1982 was clopped down to less than 6000 ha in 1991 in Indonesia due to severe prevalence of PRSV.

Gonzalez *et al.* (1997) recorded that *Papaya ringspot virus* –type P (PRSV-P) is the most harmful viral disease of papaya in Mexico. It causes losses in fruit yield and quality and at least three types of leaf symptoms (mosaic, yellowing and leaf deformation). Result showed that leaf deformation may cause the highest reduction in photo assimilate synthesis and fruit growth.

PapMV infection initiated at the seedling stage on pawpaw (*Carica papaya*) results in a slightly stunted plant with leaf mottle, still able to produce fruit with no significant reduction on size or yield. Other species of the Caricaceae family are also subject to infection by PapMV which, in some, is lethal. Mixed infections of viruses in pawpaw induce disease symptoms that can be more serious than those associated with a single infection. Severe leaf mottle and malformation, shortened petioles and rapid decline may occur. PapMV alone causes symptoms of minor concern, as do milder strains of *Papaya ringspot virus*, but a combination of the two viruses can result in lethal decline (Conover, 1964).

## CHAPTER III

### MATERIALS AND METHODS

#### 3.1 Duration of the study

The surveys, interviews, group discussion with relevant respondents of major papaya growing areas in Bangladesh were conducted during April 2016 to August, 2016.

#### 3.2. Study area

An extensive survey was conducted at 10 upazilas of selected 6 major papaya growing districts of Bangladesh to collect the information and present status of different viral symptoms of papaya in field. The survey area under 6 districts and 10 upazilas are presented in Table 1.

Table 1. List of districts and upazilas selected for survey of viral diseases of papaya in Bangladesh

Sl. No.	District	Upazila
01	Gazipur	Kapasia
		Sreepur
02	Narsinghdi	NarshingdiSadar
03	Jessore	Jhikargacha
		Monirampur
		Keshobpur
04	Magura	MaguraSadar
		Sripur
05	Jhinaidah	Kaliganj
06	Faridpur	Modhukhali

Primary data were collected from the standing papaya of the selected farmers from each upazila and recorded the incidence and severity of different virus symptoms available in the field.

#### 3.3 Respondents of the study

Field activities included interview with Sub-Assistant Agriculture Officer (SAAO), Upazila Agriculture Officer (UAO) and the Deputy Director (DD), Department of Agricultural Extension (DAE) and also concern scientists of

BARI research stations using structured questionnaire to record the present status of disease on papaya crop.

### 3.4 Sample size

With the assistance of DAE, 20 farmers from each upazila were selected for interview on the incidence and severity of viral diseases of papaya crop in the field at seedling, flowering and fruiting stage. Primary data were collected from the standing papaya farmers field of each upazila and recorded the incidence and severity of different virus symptoms available in the field. Additional information on the area of papaya cultivation and production in the selected districts were collected from the DAE office. The total sample size was 275 as shown in Table 2.

Table 2. Sample respondents of the field survey

<b>Respondents</b>	<b>Sample size</b>
District level officials of DAE	5
Upazila level officials of DAE	10
Sub-Assistant Agriculture Officer (SAAO) of DAE	50
Papaya farmers	200
BARI scientists	10
<b>Total</b>	<b>275</b>

### 3.5 Study related indicators

Several study related indicators were selected for field data collection and as follows:

- a) Name of symptoms in papaya field
- b) Diseases (viral) incidence (%) in papaya field
- c) Damage status and severity of diseases in the field

### 3.6 Preparation of study questionnaire

The draft questionnaires were prepared based on the objectives of the work and indicators for the study. The draft questionnaires were pre-tested in the selected

study location and finalized with due care to be able to include appropriate questions for collection of necessary information from different levels and types of respondents to reflect the indicators relevant to the objectives of the study.

### **3.7 Methods of data collection**

Two types of data were collected for the study such as primary data and secondary data. The methods of data collection used in the study are discussed below:

#### **3.7.1 Primary data collection**

Primary data were collected by direct personal interview and field survey.

##### **3.7.1.1 Data collection by direct personal interview**

Direct personal interview approach was adopted for collection of primary data. Personal contact was done with the respondents and obtained desired information by explaining the objectives of the study to the respondents. Reaching the target area, a respondent was selected and made self-introduction. Then purpose of the interview and objectives of the study were described to the farmers. Colored photograph of different disease symptoms were shown to the farmers for identification of diseases. Lastly data sheet was filled up discussing with the respondents. After completion of filling up one questionnaire from one respondent, then moved to another respondent for fulfill the target respondents. The data were recorded only after fully being satisfied that the respondent was able to understand the question and offering any of the probable answers in his own perception. The investigators had been made all efforts to have a friendly and open-minded interaction with the respondent instead of asking question like a school teacher to his students. All question had to ask one by one and data sheets were filled up on the spot by districts. As per sample design the 275 survey respondents had been interviewed for sampled 10 upazilas of 6 major papaya growing districts.

### **3.7.1.2 Field survey**

Personal field survey was made and collected necessary information based on questionnaire and format from the farmers and concerned officials of 6 major papaya growing districts. Reaching the target areas virus symptoms of papaya was identified through careful observation of papaya leaves and fruits. Percent infection/severity of papaya virus symptoms was measured based on diseases symptoms on leaf and fruit with degrees of infection.

Data were taken from 5 randomly selected plants. Severity of infection was measured based on percentage of infection. Severity was classified as low (below 4.00 percent of infection), medium (above 4.00 to 8.00 percent of infection) and high (above 8.00 percentage of infection).

### **3.7.2 Secondary Data Collection**

The secondary information on virus symptoms of papaya was collected from Bangladesh Agricultural Research Institute (BARI proceedings, 2007), published reports and internet. The Internet searching was done to collect information on virus symptoms of papaya worldwide.

### **3.7.3 Data collection technique**

Information gathered through secondary sources, three (3) viruses symptoms were selected to take information. On the basis of diseases severity; papaya ringspot, mosaic and leaf curl symptoms were selected to observe infection status for the study.

Data were taken into two ways as farmer's level information and direct field inspection. Data were presented in the table and expressed as major and minor for disease status in both at farmer's level and field survey data (Wakiluzzaman, 2014). Disease severity status was measured by infection status obtained from field survey data. Considering field survey data, scoring and analysis; percent (%) infection of papaya, classified into two categories as major and minor infection and score ranged with 0 - 3 = minor infection status

with low disease severity, 3 – 6 = minor infection status with medium disease severity and 6 – above = major infection status with high disease severity.

### **3.8 Measurement of %disease incidence and severity**

Percent (%) disease incidence was measured from collected data through questionnaire (Appendix I) for both at farmer's information and personal field observation. According to the questionnaire, % disease incidence (based on % infection by virus symptoms) it was classified into four categories as 'no and/or very low % disease incidence', 'low % disease incidence', 'moderate % disease incidence' and 'major % disease incidence and score was given by 1, 2, 3 and 4 respectively for data collection. The information taken on first three status ('no and/or very low % disease incidence', 'low' % disease incidence' and 'moderate % disease incidence') were considered as minor infestation. The score was given for selected three major papaya virus symptoms. According to the questionnaire, the possible highest score was 12.00. The score of 12.00 was divided into two groups as 'minor' and 'major'. So, the score of 0-6 was grouped as 'minor' % infestation and score of 6-12 or above 6 was grouped as 'major' % infestation.

Percent (%) disease severity was measured from collected data through questionnaire (Appendix I) for both at farmer's information and personal field observation. According to the questionnaire, % disease severity was classified into three categories as 'low % disease severity', 'medium % disease severity' and 'high % disease severity' and score was given by 1, 2 and 3 respectively for data collection. The score was given for selected three major papaya virus symptoms. According to the questionnaire, the possible highest score was 9.00. The score of 9.00 was divided into three groups as 'low', 'medium' and 'high'. So, the score of 0-3 was grouped as 'low', 3-6 was grouped as 'medium' and 6-9 or above 6 was grouped as 'high'% disease severity.

So, data presentation in Table for disease incidence and severity, scoring combination was done as 0-3 = minor infestation status with low disease



severity, 3-6 = minor infestation status with medium disease severity and 6–above = major infestation status with high disease severity. Here, it can be mentioned that obtained score from individual disease incidence and severity were converted comparing highest score respectively by analytical software and presented in Table of Result and Discussion Chapter.

### **3.9 Virus identification on the basis of symptomology**

Three distinct symptoms were identified during survey from 10 upazilas of 6 districts in Bangladesh. They were papaya ringspot (PRSV), papaya mosaic (PapMV) and papaya leaf curl (PLV) symptoms. The symptoms of papaya virus symptoms are presented in Fig. 1, 2 and 3 respectively.



Fig.1. Symptoms of PRSV (Papaya ring spot) on papaya fruit



Fig.2. Symptoms of papaya mosaic



Fig.3.Symptoms of papaya leaf curl

### **3.10 Data analyses and interpretation of results**

The collected data on virus infection of papaya from different locations were analyzed using the computer software SPSS Package Program. Results were interpreted with the aim to find out variations in respect of incidence, status and severity of virus symptoms of papaya.

## CHAPTER IV

### RESULTS

In Bangladesh various types of virus symptoms are found in papaya. Generally all growth stages of papaya and also all papaya plant parts (seedling, leaves, and fruits) are affected by virus symptoms. Major 3 virus symptoms were selected that were known and generally found in Bangladesh. Viral infection status and disease severity of papaya growing areas are described under the following heading and sub-headings:

#### 4.1 Area under papaya cultivation in study area

The area visited for survey on status of symptoms of papaya, the data under papaya cultivation area was recorded (Table 3). It was observed that the total land area of selected 20 farmers under papaya cultivation was highest at Monirampur upazilla of Jessore district where the lowest was in Kapasia, Gazipur.

Table 3. Average area under cultivation of papaya by the respondents

Sl. No.	Name of district	Name of upazila	No. of respondents	Papaya cultivated area (Decimal)
1.	Gazipur	Kapasia	20	2080
2.		Sreepur	20	2840
3.	Narsinghdi	Narshingdi Sadar	20	2400
4.	Jessore	Jhikargacha	20	3200
5.		Monirampur	20	3440
6.		Keshobpur	20	3120
7.	Magura	Magura Sadar	20	2880
8.		Sripur	20	3040
9.	Jhinaidah	Kaliganj	20	3280
10.	Faridpur	Modhukhali	20	2440
Total			200	28720

## 4.2 Incidence of papaya virus symptoms and general severity level in Bangladesh

Information about six (6) common papaya virus symptoms were measured from secondary data source (BARI) and presented in Table 4.

Table 4: List of severe viral diseases of papaya found in Bangladesh

Sl. No.	Diseases	Categories of symptoms	Diseases severity
1.	Apical necrosis of papaya	<i>Papaya apical necrosis</i>	Low
2.	Droopy necrosis of papaya	<i>Papaya droopy necrosis</i>	Low
3.	Feather leaf of papaya	<i>Unknown</i>	Low
4.	Leaf curl of papaya	<i>Leaf curl</i>	High
5.	Mosaic of papaya	<i>Papaya mosaic</i>	Medium
6.	Papaya ringspot	<i>Papaya ringspot</i>	High

Source: Baker *et al.* (2007)

## 4.3 Diversity incidence and severity of papaya virus symptom

The recorded symptoms of papaya at 10 upazillas of 6 districts with their incidence percent and severity are discussed below:

### 4.3.1 Diversity, incidence and severity of papaya virus symptom in Kapasia, Gazipur

#### 4.3.1.1 Virus symptoms in seedlings

Two virus symptoms of papaya were recorded in Kapasia, Gazipur with their percent of incidence and severity in papaya seedling. The recorded papaya symptoms were papaya mosaic and papaya leaf curl. The percent infection of leaf curl was found highest with high level of severity (farmer's information 11.00 percent and field survey data 10.00 percent) (Table 5). The incidence of mosaic was minor (farmer's information 3.00 percent and field survey data 3.00 percent) with low level of severity which was found lowest.

#### **4.3.1.2 Virus symptoms in leaves**

Three virus symptoms of papaya were recorded in Kapasia, Gazipur with their percent of damage and severity in papaya leaves. The recorded papaya symptoms were papaya ringspot, mosaic and papaya leaf curl. The percent infection of leaf curl was found highest with high level of severity (farmer's information 10.00 percent and field survey data 11.00 percent) (Table 5). Percent incidence of ringspot was also major with high level of severity where mosaic incidence was lowest and showed minor incidence with low level of severity.

#### **4.3.1.3 Virus symptoms in fruit**

Two virus symptoms of papaya were recorded in Kapasia, Gazipur with their percent of damage and severity in papaya fruit. The recorded papaya symptoms were papaya ringspot and mosaic. The percent infection of ringspot was found highest and infection status was major with high level of severity (farmer's information 10.00 percent and field survey data 11.00 percent) (Table 5). Percent incidence of mosaic was lowest and incidence status was minor (farmer's information 2.00 percent and field survey data 2.50 percent) with low level of severity.

Table 5. Symptoms of papaya with their incidence and severity in Kapasia, Gazipur

Common name	Categories of symptoms	Farmer's information		Field survey data		Severity level
		% incidence	Status	% incidence	Status	
<b><i>Virus infection in seedlings</i></b>						
Papaya Ringspot	<i>Papaya ringspot</i>	--	--	--	--	--
Papaya Mosaic	<i>Papaya mosaic</i>	3.00	Minor	3.00	Minor	Low
Papaya Leaf curl	<i>Papaya leaf curl</i>	11.00	Major	10.00	Major	High
<b><i>Virus infection in leaves</i></b>						
Papaya Ringspot	<i>Papaya ringspot</i>	8.00	Major	8.00	Major	High
Papaya Mosaic	<i>Papaya mosaic</i>	2.00	Minor	2.50	Minor	Low
Papaya Leaf curl	<i>Papaya leaf curl</i>	10.00	Major	11.00	Major	High
<b><i>Virus infection in fruit</i></b>						
Papaya Ringspot	<i>Papaya ringspot</i>	11.00	Major	9.00	Major	High
Papaya Mosaic	<i>Papaya mosaic</i>	2.00	Minor	2.50	Minor	Low
Papaya Leaf curl	<i>Papaya leaf curl</i>	--	--	--	--	--
Average						

0 – 3 = minor infection status with low disease severity,  
 3 – 6 = minor infection status with medium disease severity  
 6 –above = major infection status with high disease severity

### **4.3.2 Diversity, incidence and severity of papaya virus symptom in Sreepur, Gazipur**

#### **4.3.2.1 Virus infection in seedlings**

Two virus symptoms of papaya were recorded in Sreepur, Gazipur with their percent of damage and severity in papaya seedling (Table 6). The recorded papaya virus symptoms were papaya mosaic and papaya leaf curl. The percent infection of leaf curl was found highest and infection status was minor (farmer's information 7.00 percent and field survey data 6.50 percent) with medium level of severity where percent infection of mosaic was lowest and infection status was minor with medium level of severity.

#### **4.3.2.2 Virus infection in leaves**

Three virus symptoms of papaya were recorded in Sreepur, Gazipur with their percent of damage and severity in papaya leaves (Table 6). The recorded papaya virus symptoms were papaya ringspot, papaya mosaic and papaya leaf curl. The percent infection of papaya mosaic was found highest and infection status was minor (farmer's information 5.00 percent and field survey data 4.00 percent) with medium level of severity. Percent infection of ringspot was lowest and also showed minor infection with low level of severity.

#### **4.3.2.3 Virus infection in fruit**

One virus symptom of papaya was recorded in Sreepur, Gazipur with their percent of damage and severity in papaya fruit. The recorded papaya virus symptom was papaya mosaic (Table 6). The percent infection of mosaic was minor with low level of severity (farmer's information 2.00 percent and field survey data 2.00 percent).



Table 6. Symptoms of papaya with their incidence and severity in Sreepur, Gazipur

Common name	Categories of symptoms	Farmer's information		Field survey data		Severity level
		% incidence	Status	% incidence	Status	
<b><i>Virus infection in seedlings</i></b>						
Papaya Ringspot	<i>Papaya ringspot</i>	--	--	--	--	--
Papaya Mosaic	<i>Papaya mosaic</i>	5.00	Minor	6.00	Minor	Medium
Papaya Leaf curl	<i>Papaya leaf curl</i>	7.00	Minor	6.50	Minor	Medium
<b><i>Virus infection in leaves</i></b>						
Papaya Ringspot	<i>Papaya ringspot</i>	3.00	Minor	2.00	Minor	Low
Papaya Mosaic	<i>Papaya mosaic</i>	5.00	Minor	4.00	Minor	Medium
Papaya Leaf curl	<i>Papaya leaf curl</i>	3.00	Minor	3.00	Minor	Low
<b><i>Virus infection in fruit</i></b>						
Papaya Ringspot	<i>Papaya ringspot</i>	--	--	--	--	--
Papaya Mosaic	<i>Papaya mosaic</i>	2.00	Minor	2.00	Minor	Low
Papaya Leaf curl	<i>Papaya leaf curl</i>	--	--	--	--	--

0 – 3 = minor infection status with low disease severity,

3 – 6 = minor infection status with medium disease severity

6 – above = major infection status with high disease severity

### **4.3.3 Diversity, incidence and severity of papaya virus symptom in Narshingdi Sadar, Narsinghdi**

#### **4.3.3.1 Virus infection in seedlings**

Three virus symptoms of papaya were recorded in Narshingdi Sadar, Narsinghdi with their percent of damage and severity in papaya seedling. The recorded papaya virus symptoms were papaya ringspot, papaya mosaic and papaya leaf curl. The percent infection of leaf curl was major and found highest with high level of severity (farmer's information 11.00 percent and field survey data 10.00 percent) (Table 7). The infection and severity of ringspot was minor and found lowest with (farmer's information 1.00 percent and field survey data 1.00 percent) low level of severity.

#### **4.3.3.2 Virus infection in leaves**

Two virus symptoms of papaya were recorded in Narshingdi Sadar, Narsinghdi with their percent of damage and severity in papaya leaves. The recorded papaya virus symptoms were papaya ringspot and mosaic. The percent infection of papaya ringspot was minor and found highest with medium level of severity (farmer's information 5.00 percent and field survey data 5.00 percent) (Table 7). Percent infection of mosaic was lowest and showed minor infection with low level of severity.

#### **4.3.3.3 Virus infection in fruit**

One virus symptom of papaya was recorded in Narshingdi Sadar, Narsinghdi with their percent of damage and severity in papaya fruit. The recorded papaya virus symptom was papaya mosaic. The percent infection of mosaic was minor with medium level of severity (farmer's information 4.00 percent and field survey data 5.00 percent) (Table 7).

Table 7. Symptoms of papaya with their incidence and severity in Narshingdi Sadar, Narsinghdi

Common name	Categories of symptoms	Farmer's information		Field survey data		Severity level
		% incidence	Status	% incidence	Status	
<b><i>Virus infection in seedlings</i></b>						
Papaya Ringspot	<i>Papaya ringspot</i>	1.00	Minor	1.00	Minor	Low
Papaya Mosaic	<i>Papaya mosaic</i>	5.00	Minor	6.00	Minor	Medium
Papaya Leaf curl	<i>Papaya leaf curl</i>	11.00	Major	10.00	Major	High
<b><i>Virus infection in leaves</i></b>						
Papaya Ringspot	<i>Papaya ringspot</i>	5.00	Minor	5.00	Minor	Medium
Papaya Mosaic	<i>Papaya mosaic virus</i>	3.00	Minor	3.00	Minor	Low
Papaya Leaf curl	<i>Papaya leaf curl</i>	--	--	--	--	--
<b><i>Virus infection in fruit</i></b>						
Papaya Ringspot	<i>Papaya ringspot</i>	--	--	--	--	--
Papaya Mosaic	<i>Papaya mosaic</i>	4.00	Minor	5.00	Minor	Medium
Papaya Leaf curl	<i>Papaya leaf curl</i>	--	--	--	--	--

0 – 3 = minor infection status with low disease severity,

3 – 6 = minor infection status with medium disease severity

6 – above = major infection status with high disease severity

#### **4.3.4 Diversity, incidence and severity of papaya virus symptom in Jhikargacha, Jessore**

##### **4.3.4.1 Virus infection in seedlings**

Two virus symptoms of papaya were recorded in Jhikargacha, Jessore with their percent of damage and severity in papaya seedling (Table 8). The recorded papaya virus symptoms were papaya ringspot and papaya mosaic. The percent infection of mosaic was minor and found highest with medium level of severity (farmer's information 3.00 percent and field survey data 4.00 percent) where infection of papaya ringspot was found lowest and showed minor infection with low level of severity (farmer's information 3.00 percent and field survey data 3.00 percent).

##### **4.3.4.2 Virus infection in leaves**

Two virus symptoms of papaya were recorded in Jhikargacha, Jessore with their percent of damage and severity in papaya leaves. The recorded papaya virus symptoms were papaya mosaic and papaya leaf curl. The percent infection of mosaic was major and found highest with high level of severity (farmer's information 6.00 percent and field survey data 7.00 percent) (Table 8). Percent infection of leaf curl was found lowest and showed minor infection with low level of severity.

##### **4.3.4.3 Virus infection in fruit**

Two virus symptoms of papaya were recorded in Jhikargacha, Jessore with their percent of damage and severity in papaya fruit. The recorded papaya virus symptoms were papaya ringspot, mosaic (Table 8). The percent infection of ringspot was major and found highest with high level of severity (farmer's information 11.00 percent and field survey data 10.00 percent). Percent infection of mosaic disease was also major and found lowest with high level of severity (farmer's information 9.00 percent and field survey data 10.00 percent).

Table 8. Symptoms s of papaya with their incidence and severity in Jhikargacha, Jessore

Common name	Categories of symptoms	Farmer's information		Field survey data		Severity level
		% incidence	Status	% incidence	Status	
<b><i>Virus infection in seedlings</i></b>						
Papaya Ringspot	<i>Papaya ringspot</i>	3.00	Minor	3.00	Minor	Low
Papaya Mosaic	<i>Papaya mosaic</i>	3.00	Minor	4.00	Minor	Medium
Papaya Leaf curl	<i>Papaya leaf curl</i>	--	--	--	--	--
<b><i>Virus infection in leaves</i></b>						
Papaya Ringspot	<i>Papaya ringspot</i>	--	--	--	--	--
Papaya Mosaic	<i>Papaya mosaic</i>	6.00	Minor	7.00	Major	High
Papaya Leaf curl	<i>Papaya leaf curl</i>	4.00	Minor	3.00	Minor	Low
<b><i>Virus infection in fruit</i></b>						
Papaya Ringspot	<i>Papaya ringspot</i>	11.00	Major	10.00	Major	High
Papaya Mosaic	<i>Papaya mosaic</i>	9.00	Major	10.00	Major	high
Papaya Leaf curl	<i>Papaya leaf curl</i>	--	--	--	--	--

0 – 3 = minor infection status with low disease severity,

3 – 6 = minor infection status with medium disease severity

6 – above = major infection status with high disease severity

### **4.3.5 Diversity, incidence and severity of papaya virus symptom in Monirampur, Jessore**

#### **4.3.5.1 Virus infection in seedlings**

Three virus symptoms of papaya were recorded in Monirampur, Jessore with their percent of damage and severity in papaya seedling (Table 9). The recorded papaya virus symptoms were papaya ringspot, papaya mosaic and papaya leaf curl. The percent infection of leaf curl was found highest and infection status was major with high level of severity (farmer's information 11.00 percent and field survey data 10.00 percent). The infection and severity of papaya ringspot was minor and was found lowest with low level of severity.

#### **4.3.5.2 Virus infection in leaves**

Three virus symptoms of papaya were recorded in Monirampur, Jessore with their percent of damage and severity in papaya leaves. The recorded papaya virus symptoms were papaya ringspot, papaya mosaic and papaya leaf curl. The percent infection of leaf curl was major and found highest with high level of severity (farmer's information 9.00 percent and field survey data 10.00 percent) (Table 9). Percent infection of ringspot was also major with high level of severity where papaya mosaic infection was minor and was found lowest with low level of severity.

#### **4.3.5.3 Virus infection in fruit**

One virus symptom of papaya was recorded in Monirampur, Jessore with their percent of damage and severity in papaya fruit. The recorded papaya virus symptom was papaya mosaic (Table 9). Percent infection of mosaic was found as minor with low level of severity (farmer's information 2.00 percent and field survey data 1.50 percent).

Table 9. Symptoms of papaya with their incidence and severity in Monirampur, Jessore

Common name	Categories of symptoms	Farmer's information		Field survey data		Severity level
		% incidence	Status	% incidence	Status	
<b><i>Virus infection in seedlings</i></b>						
Papaya Ringspot	<i>Papaya ringspot</i>	2.50	Minor	3.00	Minor	Low
Papaya Mosaic	<i>Papaya mosaic</i>	6.00	Minor	5.00	Minor	Medium
Papaya Leaf curl	<i>Papaya leaf curl</i>	11.00	Major	10.00	Major	High
<b><i>Virus infection in leaves</i></b>						
Papaya Ringspot	<i>Papaya ringspot</i>	7.00	Major	8.00	Major	High
Papaya Mosaic	<i>Papaya mosaic</i>	2.00	Minor	2.50	Minor	Low
Papaya Leaf curl	<i>Papaya leaf curl</i>	9.00	Major	10.00	Major	high
<b><i>Virus infection in fruit</i></b>						
Papaya Ringspot	<i>Papaya ringspot</i>	--	--	--	--	--
Papaya Mosaic	<i>Papaya mosaic</i>	2.00	Minor	1.50	Minor	Low
Papaya Leaf curl	<i>Papaya leaf curl</i>	--	--	--	--	--

0 – 3 = minor infection status with low disease severity,  
3 – 6 = minor infection status with medium disease severity  
6 – above = major infection status with high disease severity

### **4.3.6 Diversity, incidence and severity of papaya virus symptom in Keshobpur, Jessore**

#### **4.3.6.1 Virus infection in seedlings**

Two virus symptoms of papaya were recorded in Keshobpur, Jessore with their percent of damage and severity in papaya seedling. The recorded papaya virus symptoms were papaya ringspot and papaya mosaic (Table 10). The percent infection of papaya ringspot was major and found highest with high level of severity (farmer's information 8.00 percent and field survey data 7.00 percent). The infection and severity of papaya mosaic was minor and found lowest with low level of severity.

#### **4.3.6.2 Virus infection in leaves**

Two virus symptoms of papaya were recorded in Keshobpur, Jessore with their percent of damage and severity in papaya leaves. The recorded papaya virus symptoms were papaya mosaic and papaya leaf curl (Table 10). The percent infection of papaya leaf curl was minor and found highest with medium level of severity (farmer's information 4.00 percent and field survey data 5.00 percent). Percent infection of papaya mosaic was also minor and was found lowest with low level of severity.

#### **4.3.6.3 Virus infection in fruit**

One virus symptom of papaya was recorded in Keshobpur, Jessore with their percent of damage and severity in papaya fruit. The recorded papaya virus symptom was papaya ringspot (Table 10). The percent infection of ringspot was minor with medium level of severity (farmer's information 4.00 percent and field survey data 5.00 percent).



Table 10. Symptoms of papaya with their incidence and severity in Keshobpur, Jessore

Common name	Categories of symptoms	Farmer's information		Field survey data		Severity level
		% incidence	Status	% incidence	Status	
<b><i>Virus infection in seedlings</i></b>						
Papaya Ringspot	<i>Papaya ringspot</i>	8.00	Major	7.00	Major	High
Papaya Mosaic	<i>Papaya mosaic</i>	4.00	Minor	3.00	Minor	Low
Papaya Leaf curl	<i>Papaya leaf curl</i>	--	--	--	--	--
<b><i>Virus infection in leaves</i></b>						
Papaya Ringspot	<i>Papaya ringspot</i>	--	--	--	--	--
Papaya Mosaic	<i>Papaya mosaic</i>	2.00	Minor	2.50	Minor	Low
Papaya Leaf curl	<i>Papaya leaf curl</i>	4.00	Minor	5.00	Minor	Medium
<b><i>Virus infection in fruit</i></b>						
Papaya Ringspot	<i>Papaya ringspot</i>	4.00	Minor	5.00	Minor	Medium
Papaya Mosaic	<i>Papaya mosaic</i>	--	--	--	--	--
Papaya Leaf curl	<i>Papaya leaf curl</i>	--	--	--	--	--

0 – 3 = minor infection status with low disease severity,  
 3 – 6 = minor infection status with medium disease severity  
 6 – above = major infection status with high disease severity

### **4.3.7 Diversity, incidence and severity of papaya virus symptom in Magura Sadar, Magura**

#### **4.3.7.1 Virus infection in seedlings**

Three virus symptoms of papaya were recorded in Magura Sadar, Magura with their percent of damage and severity in papaya seedling (Table 11). The recorded papaya virus symptoms were papaya ringspot, papaya mosaic and papaya leaf curl. The percent infection of papaya ringspot was major and found highest with high level of severity (farmer's information 9.00 percent and field survey data 10.00 percent). The infection status of papaya leaf curl was also major with high level of severity where infection status of papaya mosaic was minor and found lowest with medium level of severity.

#### **4.3.7.2 Virus infection in leaves**

Two virus symptoms of papaya were recorded in Magura Sadar, Magura with their percent of damage and severity in papaya leaves (Table 11). The recorded papaya virus symptoms were papaya ringspot and papaya leaf curl. The percent infection of leaf curl was minor and found highest with low level of severity (farmer's information 4.00 percent and field survey data 3.00 percent). Percent infection of ringspot was also minor and found lowest with low level of severity.

#### **4.3.7.3 Virus infection in fruit**

Two virus symptom of papaya were recorded in Magura Sadar, Magura with their percent of damage and severity in papaya fruit. The recorded papaya virus symptoms were papaya ringspot and papaya mosaic (Table 11). The percent infection of papaya ringspot was major and was found highest with high level of severity (farmer's information 7.00 percent and field survey data 8.00 percent). Percent infection of papaya mosaic was minor and found lowest with low level of severity.

Table 11. Symptoms of papaya with their incidence and severity in Magura Sadar,  
Magura

Common name	Categories of symptoms	Farmer's information		Field survey data		Severity level
		% incidence	Status	% incidence	Status	
<b><i>Virus infection in seedlings</i></b>						
Papaya Ringspot	<i>Papaya ringspot</i>	9.00	Major	10.00	Major	High
Papaya Mosaic	<i>Papaya mosaic</i>	6.00	Minor	7.00	Major	Medium
Papaya Leaf curl	<i>Papaya leaf curl</i>	8.00	Major	10.00	Major	High
<b><i>Virus infection in leaves</i></b>						
Papaya Ringspot	<i>Papaya ringspot</i>	3.00	Minor	2.00	Minor	Low
Papaya Mosaic	<i>Papaya mosaic</i>	--	--	--	--	--
Papaya Leaf curl	<i>Papaya leaf curl</i>	4.00	Minor	3.00	Minor	Low
<b><i>Virus infection in fruit</i></b>						
Papaya Ringspot	<i>Papaya ringspot</i>	7.00	Major	8.00	Major	High
Papaya Mosaic	<i>Papaya mosaic</i>	2.00	Minor	1.50	Minor	Low
Papaya Leaf curl	<i>Papaya leaf curl</i>	--	--	--	--	--

0 – 3 = minor infection status with low disease severity,

3 – 6 = minor infection status with medium disease severity

6 – above = major infection status with high disease severity

### **4.3.8 Diversity, incidence and severity of papaya virus symptom in Sripur, Magura**

#### **4.3.8.1 Virus infection in seedlings**

Three virus symptoms of papaya were recorded in Sripur, Magura with their percent of damage and severity in papaya seedling (Table 12). The recorded papaya virus symptoms were papaya ringspot, papaya mosaic and papaya leaf curl. The percent infection of leaf curl was major and found highest with high level of severity (farmer's information 7.00 percent and field survey data 7.00 percent). The infection and severity of papaya ringspot was minor and with low level of severity. Again, the infection and severity of papaya mosaic was minor and found lowest with low level of severity.

#### **4.3.8.2 Virus infection in leaves**

Three virus symptoms of papaya were recorded in Sripur, Magura with their percent of damage and severity in papaya leaves. The recorded papaya virus symptoms were papaya ringspot, papaya mosaic and papaya leaf curl. The percent infection of leaf curl was minor and found highest with low level of severity (farmer's information 4.00 percent and field survey data 3.00 percent) (Table 12). Percent infection of papaya mosaic was minor and found lowest with high level of severity.

#### **4.3.8.3 Virus infection in fruit**

Two virus symptoms of papaya were recorded in Sripur, Magura with their percent of damage and severity in papaya fruit (Table 12). The recorded papaya virus symptoms were papaya ringspot and papaya mosaic. The percent infection of papaya ringspot was minor and found highest with medium level of severity (farmer's information 4.00 percent and field survey data 4.00 percent). The percent infection of mosaic was also minor and found lowest with low level of severity (farmer's information 2.00 percent and field survey data 1.5 percent).

Table 12. Symptoms of papaya with their incidence and severity in Sripur, Magura

Common name	Categories of symptoms Causal organism	Farmer's information		Field survey data		Severity level
		% incidence	Status	% incidence	Status	
<b><i>Virus infection in seedlings</i></b>						
Papaya Ringspot	<i>Papaya ringspot</i>	5.00	Minor	4.00	Minor	Medium
Papaya Mosaic	<i>Papaya mosaic</i>	3.00	Minor	4.00	Minor	Low
Papaya Leaf curl	<i>Papaya leaf curl s</i>	7.00	Major	7.00	Major	High
<b><i>Virus infection in leaves</i></b>						
Papaya Ringspot	<i>Papaya ringspot</i>	3.00	Minor	2.00	Minor	Low
Papaya Mosaic	<i>Papaya mosaic</i>	2.00	Minor	2.50	Minor	Low
Papaya Leaf curl	<i>Papaya leaf curl</i>	4.00	Minor	3.00	Minor	Low
<b><i>Virus infection in fruit</i></b>						
Papaya Ringspot	<i>Papaya ringspot</i>	4.00	Minor	4.00	Minor	Medium
Papaya Mosaic	<i>Papaya mosaic</i>	2.00	Minor	1.50	Minor	Low
Papaya Leaf curl	<i>Papaya leaf curl</i>	--	--	--	--	--

0 – 3 = minor infection status with low disease severity,

3 – 6 = minor infection status with medium disease severity

6 – above = major infection status with high disease severity

### **4.3.9 Diversity, incidence and severity of papaya virus symptom in Kaliganj, Jhinaidah**

#### **4.3.9.1 Virus infection in seedlings**

Two virus symptoms of papaya were recorded in Kaliganj, Jhinaidah with their percent of damage and severity in papaya seedling. The recorded papaya virus symptoms were papaya ringspot and papaya leaf curl (Table 13). The percent infection of papaya leaf curl was found highest and infection status was major with high level of severity (farmer's information 10.00 percent and field survey data 11.00 percent). The percent infection of papaya ringspot was found lowest and infection status was minor with medium level of severity (farmer's information 5.00 percent and field survey data 6.00 percent).

#### **4.3.9.2 Virus infection in leaves**

Two virus symptoms of papaya were recorded in Kaliganj, Jhinaidah with their percent of damage and severity in papaya leaves. The recorded papaya virus symptoms were papaya ringspot and papaya mosaic (Table 13). The percent infection of ringspot was minor and was found highest with low level of severity (farmer's information 3.00 percent and field survey data 2.00 percent). The percent infection of papaya mosaic was minor and was found lowest with low level of severity (farmer's information 2.00 percent and field survey data 2.50 percent).

#### **4.3.9.3 Virus infection in fruit**

One virus symptoms of papaya was recorded in Kaliganj, Jhinaidah with their percent of damage and severity in papaya fruit. The recorded papaya virus symptom was papaya ringspot (Table 13). The percent infection of ringspot was major with high level of severity (farmer's information 9.00 percent and field survey data 10.00 percent).

Table 13. Symptoms of papaya with their incidence and severity in Kaliganj, Jhinaidah

Common name	Categories of symptoms Causal organism	Farmer's information		Field survey data		Severity level
		% incidence	Status	% incidence	Status	
<b><i>Virus infection in seedlings</i></b>						
Papaya Ringspot	<i>Papaya ringspot</i>	5.00	Minor	6.00	Minor	Medium
Papaya Mosaic	<i>Papaya mosaic</i>	--	--	--	--	--
Papaya Leaf curl	<i>Papaya leaf curl</i>	10.00	Major	11.00	Major	High
<b><i>Virus infection in leaves</i></b>						
Papaya Ringspot	<i>Papaya ringspot</i>	3.00	Minor	2.00	Minor	Low
Papaya Mosaic	<i>Papaya mosaic</i>	2.00	Minor	2.50	Minor	Low
Papaya Leaf curl	<i>Papaya leaf curl</i>	--	--	--	--	--
<b><i>Virus infection in fruit</i></b>						
Papaya Ringspot	<i>Papaya ringspot</i>	9.00	Major	10.00	Major	High
Papaya Mosaic	<i>Papaya mosaic</i>	--	--	--	--	--
Papaya Leaf curl	<i>Papaya leaf curl</i>	--	--	--	--	--

0 – 3 = minor infection status with low disease severity,  
 3 – 6 = minor infection status with medium disease severity  
 6 – above = major infection status with high disease severity

#### **4.3.10 Diversity, incidence and severity of papaya virus symptom in Modhukhali, Faridpur**

##### **4.3.10.1 Virus infection in seedlings**

Three virus symptoms of papaya were recorded in Modhukhali, Faridpur with their percent of damage and severity in papaya seedling (Table 14). The recorded papaya virus symptoms were papaya ringspot, papaya mosaic and papaya leaf curl. The percent infection of papaya leaf curl was major and found highest with high level of severity (farmer's information 10.00 percent and field survey data 9.00 percent). The infection and severity of papaya mosaic was minor with medium level of severity. The percent infection of papaya ringspot was minor and found lowest with medium level of severity (farmer's information 3.00 percent and field survey data 5.00 percent) (Table 14).

##### **4.3.10.2 Virus infection in leaves**

Three virus symptoms of papaya were recorded in Modhukhali, Faridpur with their percent of damage and severity in papaya leaves (Table 14). The recorded papaya virus symptoms were papaya ringspot, papaya mosaic and papaya leaf curl. The percent infection of mosaic was found highest with high level of severity (farmer's information 10.00 percent and field survey data 11.00 percent). Percent infection of ringspot was minor and found lowest with low level of severity (farmer's information 3.00 percent and field survey data 2.00 percent).

##### **4.3.10.3 Virus infection in fruit**

Two virus symptoms of papaya were recorded in Modhukhali, Faridpur with their percent of damage and severity in papaya fruit. The recorded papaya virus symptoms were papaya ringspot and papaya mosaic (Table 14). The percent infection of papaya ringspot was minor and found highest with low level of severity (farmer's information 3.00 percent and field survey data 3.00 percent).



The percent infection of mosaic was also minor and found lowest with low level of severity (farmer's information 2.00 percent and field survey data 1.50 percent).

Table 14. Symptoms of papaya with their incidence and severity in Modhukhali, Faridpur

Common name	Categories of symptoms	Farmer's information		Field survey data		Severity level
		% incidence	Status	% incidence	Status	
<b><i>Virus infection in seedlings</i></b>						
Papaya Ringspot	<i>Papaya ringspot</i>	3.00	Minor	5.00	Minor	Medium
Papaya Mosaic	<i>Papaya mosaic</i>	6.00	Minor	5.00	Minor	Medium
Papaya Leaf curl	<i>Papaya leaf curl</i>	10.00	Major	9.00	Major	High
<b><i>Virus infection in leaves</i></b>						
Papaya Ringspot	<i>Papaya ringspot</i>	3.00	Minor	2.00	Minor	Low
Papaya Mosaic	<i>Papaya mosaic</i>	10.00	Major	11.00	Major	High
Papaya Leaf curl	<i>Papaya leaf curl</i>	4.00	Minor	3.00	Minor	Low
<b><i>Virus infection in fruit</i></b>						
Papaya Ringspot	<i>Papaya ringspot</i>	3.00	Minor	3.00	Minor	Low
Papaya Mosaic	<i>Papaya mosaic</i>	2.00	Minor	1.50	Minor	Low
Papaya Leaf curl	<i>Papaya leaf curl</i>	--	--	--	--	--

0 – 3 = minor infection status with low disease severity,

3 – 6 = minor infection status with medium disease severity

6 – above = major infection status with high disease severity

#### 4.4 Average virus infection at different growth conditions

Severe virus infection was found at seedling stage, in leaves and in fruits (Table 15). Results indicated that at all conditions of papaya were affected seriously by papaya ringspot, papaya mosaic and papaya leaf curl. It was found that the highest infection was found in seedling stage and lowest was observed in fruit (Fig. 4). Virus infection in seedling, leaves and fruits were major with high level of severity (Table 15 & Fig 4).

Table 15. Average virus infection in seedling, leaves and fruits

Sl. No.	Virus infection at different conditions	% Infection (Mean)		Severity	Status
		Farmer's information	Field survey data		
01	Seedlings	15.25	15.55	High	Major
02	Leaves	11.10	10.95	High	Major
03	Fruit	7.40	7.45	High	Major

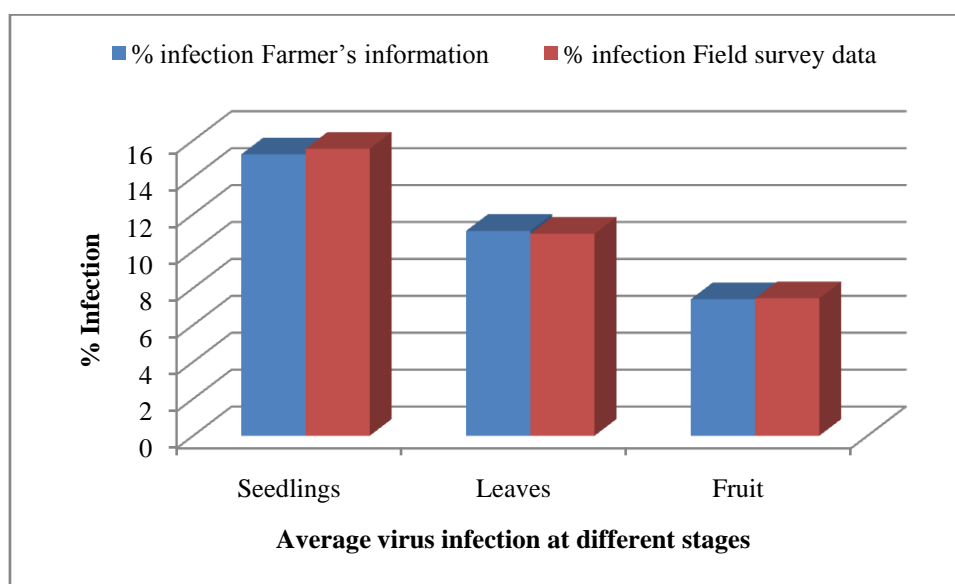


Fig. 4. Average virus infection in seedling, leaves and fruits

#### 4.5 Average virus infection at different locations in Bangladesh

Viral infection at different selected areas of Bangladesh was observed (Fig. 5). It was found that considerable infection was occurred in selected papaya growing areas of Bangladesh (Table 16). Among the different study area in Bangladesh; major virus infection was observed in Kapasia, Gazipur and Jhikargacha, Jessore with high level of severity. Minor virus infection with medium level of severity was also found in Sreepur, Gazipur, Narshingdi Sadar, Monirampur, Jessore, Keshobpur, Jessore, Magura Sadar, Kaliganj, Jhinaidah and Modhukhali, Faridpur. Minor virus infection with low level of severity was observed in Sripur, Magura (Table 16 Fig. 5)).

Table 16. Average virus infection at selected areas in Bangladesh

Location	% Infection		Severity	Status
	Farmer's information	Field survey data		
Kapasia, Gazipur	6.71	6.57	High	Major
Sreepur, Gazipur	4.17	3.92	Medium	Minor
Narshingdi Sadar	4.83	5.00	Medium	Minor
Jhikargacha, Jessore	6.00	6.17	High	Major
Monirampur, Jessore	5.64	5.71	Medium	Minor
Keshobpur, Jessore	4.40	4.50	Medium	Minor
Magura Sadar	5.57	5.93	Medium	Minor
Sripur, Magura	3.75	3.50	Low	Minor
Kaliganj, Jhinaidah	5.80	6.30	Medium	Minor
Modhukhali, Faridpur	5.13	4.94	Medium	Minor

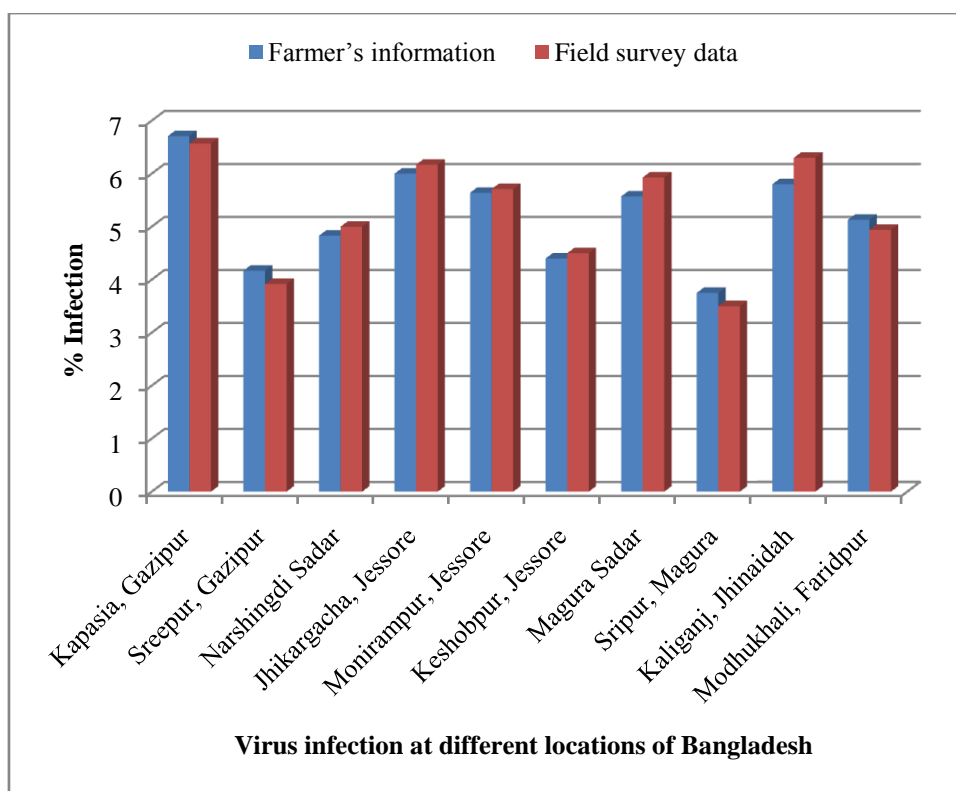


Fig. 5. Average virus infection at selected areas in Bangladesh

#### 4.6 Distribution, diversity, infection and severity in Bangladesh

About six virus symptoms were identified in 10 Upazila of 6 districts. Among them three are identified as common papaya virus symptoms in growing areas. Three virus symptoms have been identified but there was variation in infection percent, severity and distribution (Table 17 & Fig. 6). Individually each selected papaya affected seriously which was proved by the present study (Table 17). At different location same virus symptoms played as major disease and minor disease. Papaya ringspot was recorded as major virus symptoms with high level of infection (farmer's information  $12.05 \pm 1.62$  percent and field survey data  $11.90 \pm 1.27$  percent of infection) and severity. In case of papaya mosaic, it was also recorded as major virus symptoms of papaya with high level of infection (farmer's information  $10.00 \pm 0.86$  percent and field survey data  $10.60 \pm 1.18$  percent of infection) and severity. Considering papaya leaf curl was also found as major papaya virus symptoms with high severity

(farmer's information  $11.70 \pm 1.16$  percent and field survey data  $11.45 \pm 0.84$  percent of infection).

Table 17. Infection and severity of papaya virus symptoms in Bangladesh

Sl. No.	Common Name	Infected plant parts	% Infection (Mean $\pm$ SD)		Severity	Status
			Farmer's information	Field survey data		
01	Ringspot	Seedlings, leaves, fruit	$12.05 \pm 1.62$	$11.90 \pm 1.27$	High	Major
02	Mosaic	Seedlings, leaves, fruit	$10.00 \pm 0.86$	$10.60 \pm 1.18$	High	Major
03	Leaf curl	Seedlings, leaves	$11.70 \pm 1.16$	$11.45 \pm 0.84$	High	Major

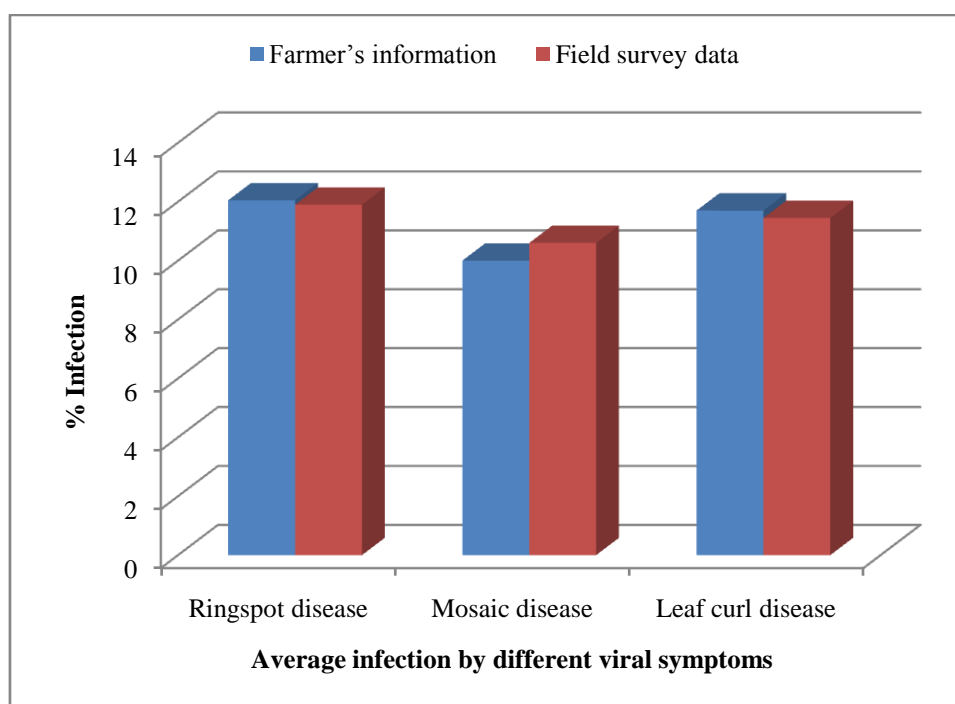


Fig. 6. Infection and severity of papaya virus symptoms in Bangladesh

## CHAPTER V

### DISCUSSION

Papaya is one of the major fruit crops cultivated in tropical and sub-tropical zones. Worldwide over 6.8 million tons of fruit were produced in 2004 on about 389990 ha (FAO, 2004). Of this volume, 47% was produced in Central and South America (mainly in Brazil), 30% in Asia, and 20% in Africa (FAO, 2004). In Bangladesh, 38 thousand acres of land was under papaya cultivation and 489 thousand tons papaya was produced in 2014 – 15 (BBS, 2016) which is very low compared to neighboring countries like India, Srilanka and Pakistan.

The most important virus symptoms that affect papaya are the Papaya ringspot (PRSV), the Papaya leaf distortion mosaic (PLDMV), the Papaya lethal yellowing (PLYV) and the Papaya mosaic (PapMV), which have been known to cause serious damage to the crop production throughout the world. PRSV causes the most destructive viral disease of papaya crop, the papaya ringspot, and has been found in many tropical and subtropical areas where papaya is grown, including the USA, South America, Mexico and Japan (Azad *et al.*, 2014).

In this survey, ten locations of six districts in Bangladesh were selected to see the virus symptoms incidence and severity of PRSV-P. Akhter and Akanda (2008) has shown effect of *Papaya ringspot-* papaya strain (PRSV-P) on growth and yield on papaya. Same survey was done by Md. Shamim Akhter (2007). He showed the reduction percentage of growth and yield of the plant due to infection of PRSV-P in different location in Bangladesh. Under the present study, it was found that the diseases incidence and severity in studied areas were versatile in character. All kinds of virus are not destructive for all levels of plant growth. It was observed that the ringspot in fruit, leaf curl in leaves and in seedlings, mosaic in fruit and leaves were more destructive.

Seedling show prominent vein clearing and downward cupping of the young leaves stated by Conover (1964).Gonzalvez *et al.* (1997) established that PRSV caused three types of leaf symptom on papaya which are mosaic, yellowing and deformation. Rahaman (2003) also found similar symptom during investigation about PRSV-P. He showed there are seven symptoms are visible in the infected plants. Mowlick (2003) also showed the reduction percentage of different characters of papaya due to PRSV-P infection. He described on different parameter like as plant height, flower per plant, fruit per plant fruit weight and fruit yield. In every parameter there was remarkable reduction due to PRSV-P infection.

Papaya is a very tasty and demanding fruit in the world with various purposes like as a fruit and vegetable. It has high nutritional, medicinal value. It has a great economical contribution in the world. But the papaya virus symptom causes great hamper in papaya production both in quality and quantity. It reduces the production and effect on commercial papaya production. In Andhra Pradesh of India, in commercial plantation papaya plants with severe mosaic, leaf distortion and filiform leaves were suspected to be infected with PRSV reported by Kiranmai *et al.* (1998).Papaya leaf curl caused by PLCV is one of most serious threat to papaya cultivation in most of papaya-growing countries. Papaya leaf curl is caused by bipartite Gemini virus (Goodman, 1981).The vector associated with disease is identified as whitefly (*Bemisia tabaci*) (Nariani, 1956).Papaya mosaic is one of the most important virus of papaya in the world. It causes leaf mosaic and stunting in papaya. The virus symptom was observed on papaya plants of all age groups, but it was most serious on young plants. The infected plant showed degeneration and marked reduction in growth. The fruits on diseased plants developed circular water soaked lesions with central solid spots. It is transmitted by several species of Aphids (Zettler, Edwardson and Purcifull, 1968).

It was also observed that under the present study, papaya was affected by certain viral diseases which had tremendous effect on growth and yield of

papaya and sometimes resulted 100% crop losses. It was found that the diseases incidence and severity in studied areas were versatile in character. All kinds of virus are not destructive for all levels of plant growth such as the ringspot in fruit, leaf curl in leaves and in seedlings, mosaic in fruit and leaves were more destructive.



## CHAPTER VI

### SUMMARY AND CONCLUSION

An extensive survey was conducted at 10 upazilas of selected 6 major papaya growing districts of Bangladesh to collect the information and present status of different virus symptoms of papaya in field. The study area were in upazila Kapasia and Sreepur under Gazipur district, Narshingdi Sadar upazila under Narsinghdi district, Jhikargacha and Monirampur and Keshobpur upazila under Jessore district, Magura Sadar and Sripur upazila under Magura district, Kaliganj upazila under Jhainadah district and Modhukhal iupazila under Faridpur district.

Primary data were collected from the standing papaya of the selected farmers from each upazila and recorded the incidence and severity of different virus symptoms available in the field. Field activities included interview with Sub-Assistant Agriculture Officer (SAAO), Upazila Agriculture Officer (UAO) and the Deputy Director (DD), Department of Agricultural Extension (DAE) and also concern scientists of BARI research stations using structured questionnaire to record the present status of insect pests on papaya.

With the assistance of DAE, 20 farmers from each upazila were selected for interview on the incidence and severity of virus symptoms of papaya crop in the field at seedling, flowering and fruiting stage. Primary data were collected from the standing papaya farmers field of each upazila and recorded the incidence and severity of different viral diseases available in the field. Direct personal interview approach was adopted for collection of primary data. Personal contact was done with the respondents and obtained desired information by explaining the objectives of the study to the respondents. Collected data were compiled, analysis and summarized by SPSS Software.

Results exhibits that identified 6 virus symptoms from all over working area three were selected for sample data collection. Ringspot, mosaic and leaf curl

were selected as common disease which cause severe damage. Results revealed that from the present study, all studied papaya symptoms were severe and destructive in papaya field and it's damage severity were in all stages of papaya plant. Among three major virus symptoms, papaya ringspot ranks first to its severity and damage status. Both at farmers level information and field survey inspection it was proved that papaya ringspot was very much destructive and cause severe loss of farmers. After papaya ringspot; papaya mosaic and papaya leaf curl were ranked and all of them were also serious. It was also observed that the ringspot in fruit, leaf curl in leaves and in seedlings and mosaic in fruit and leaves was more destructive.

From the above consideration, it can be concluded that papaya virus in Bangladesh is great threat for papaya production and three common papaya virus symptoms viz. Ringspot, mosaic and leaf curl, presence in the field may also occur crop failure.

## CHAPTER VII

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## APPENDICES

### Appendix I. Questionnaire

#### Questionnaire for collecting information from the farmers

**A. Farmers Interview** Date of Interview: .....

1. Name of Farmer: .....

Village: Union: Upazila: District:

2. Male/Female: 1= Male: ..... 2= Female: .....

3. Agricultural Farming Experience (No. of years.): Years: .....

4. Area of papaya crop cultivated by you? (in decimal): .....

5. Did any virus attack your papaya crops and what percent of disease incidence and severity you observed?

**i) Disease incidence (% infestation)**

Name of papaya virus symptom	Minor			Major
	No and/or very low % disease incidence	low % disease incidence	moderate % disease incidence	
	(1)	(2)	(3)	
Total				

**ii) Disease severity**

Name of papaya virus symptom	Low	Medium	High
	(1)	(2)	(3)
Total			

**B. DAE/BARI personnel interview**

Date:

.....

Name of the DAE/BARI Officials:

.....

Designation:

Name of Upazila: District:

1. Total Area under papaya crops in your upazila/district. Area (ha):

.....

2. Name of major papaya virus symptom in your upazila/district:



