BANANA VALUE CHAIN ANALYSIS FOR DETECTING FACTORS RESPONSIBLE TO POST-HARVEST DISEASES

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CERTIFICATE

This is to certify that the thesis entitled**, "BANANA VALUE CHAIN ANALYSIS FOR DETECTING FACTORS RESPONSIBLE TO POST-HARVEST DISEASES"** submitted to the Department of Plant Pathology, Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka in partial fulfillment of the requirements for the degree of MASTER OF SCIENCE (MS) in PLANT PATHOLOGY embodies the result of a piece of bona fide research work carried out by Registration No. 18-09261 under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma elsewhere in the country or abroad.

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

Dated: JANUARY, 2021
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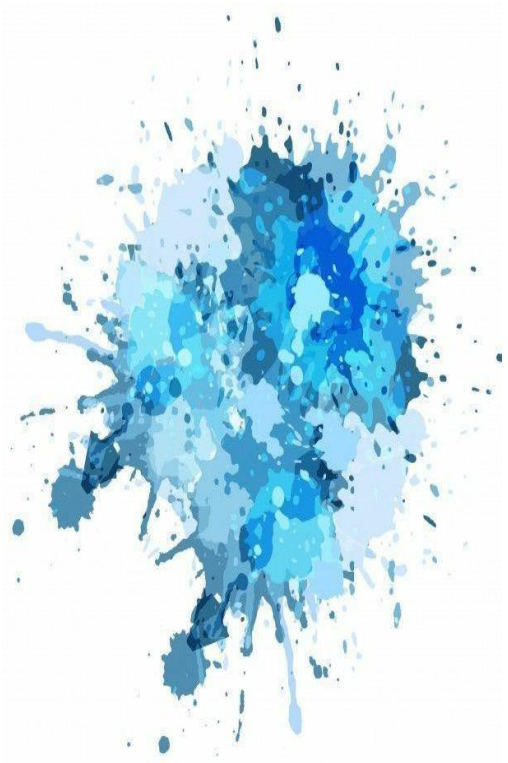

Dedicated
to
My Beloved Family

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BANANA VALUE CHAIN ANALYSIS FOR DETECTING FACTORS RESPONSIBLE TO POST-HARVEST DISEASES

ABSTRACT

A survey was conducted to analyze Banana value chain and to determine post-harvest problems at farmer and traders level. The survey was conducted during the periods of August, 2019 to February, 2020 in the Dinajpur district and three markets as well as 40 retailer shops of Dhaka city. Value chain was analyzed by the combination of qualitative and quantitative questionnaire methods that included primary survey focusses group discussions, answering questionnaire and informal interviews. Value chain analysis clearly revealed that Banana growing areas are increasing every year gradually and most of the orchards have 250-700 plants and the popular Banana varieties were Amrita Shagor, Sabri and Champa. Farmers used manure and fertilizers in Banana orchards in regular basis. All of the farmers were used to different type activities without maintaining any hygiene to harvest Bananas. Van and Nosimon are the most common transport for short distance carrying and Truck for long distant carrying. The common marketing channel is Grower> Paikar> Bepari> Retailer >Consumer. Lack of modern storage and transport, processing industries, high margin traders, no use of any packaging system, transport and production cost, and uncertainty of market price were also reported as difficulties in value chain of Bananas. Among intermediaries, the highest loss was recorded for Retailer (23.58%) followed by Piker (1.31%) and Bepari (5.85%). The highest incidence disease was observed for anthracnose 18.73% and crown rot 8.89% during August to October. The lowest incidence was observed for anthracnose 2.58% and crown rot 2.08% during November to February. The post-harvest loss of Banana was found 37.21% in total.

CHAPTER I

INTRODUCTION

Banana (*Musa sapientum*, family Musaceae) is one of the tallest of the herbaceous plants with a pseudo stem. It is possibly the world's oldest cultivated crop and it is a familiar fruit of Bangladesh (Rahman *et al*., 2006). From its native southwestern Pacific home, the Banana plant spreads to India by about 600 BC and later on it spreads all over the tropical world. Banana which is also known as Apple of Paradise is one of the major fruits of Bangladesh. It occupies an important position among the fruits of the country not only for its highest production among the fruits but also for its increasing popularity to farmers as an economic crop and to many people as a nutritious fruit. *Musa spp*., Banana and plantain, constitute the fourth most important staple food commodity of the world next to after rice, wheat and maize (Islam *et al*., 2016). Bananas are monocotyledonous plants that belong to the family Musaceae and the genus *Musa* originated in Southeast Asia (Ploetz, 2001). Banana is a major fruit crop of the tropical and subtropical regions of the world grown on about 8.8 million hectares (Mohapatra *et al.*, 2010). In Bangladesh, it is grown throughout the year but the production is still low as compared to other Banana producing countries of the world (FAO, 2008). Bangladesh produced 414000 tons of Bananas in 53609 hectares of land (BBS, 2012). Among the fruit crops grown in Bangladesh, Banana ranked third in terms of production by producing 0.80 million tons from 0.12 million acres of land (BBS, 2017). Banana is the only fruit crop available year round with the highest per capita consumption compared to the over 118 different fruits crops produced in the country (BBS, 2018). In 2018 Bananas production for Bangladesh was 8, 10,347 tons. Banana is considered “one of the finest fruits and the most important” in terms of food value, food security, food availability and above all, it is a crop that has a positive impact due to its profitability margins aimed at increasing household income and alleviating poverty. According to (FAO, 2019) available estimates indicate that average global Banana

production rose from 69 million tons in 2000-2002 to 116 million tons in 2017-2019, at an approximate value of 31 billion USD. Based on 2017 figures, the global Banana export industry generates around 12 billion USD per year. Rank of Bangladesh is 14 among the top 20 Banana producing countries in the world. Most importantly, the "super fruit" crop is not only economically important, but has the best nutritional value as well - all in one" (FAO, 2019). From the nutritional point of view, it has high caloric and nutritional values. It contains carbohydrate, crude fiber, protein, fat, ash, phosphorous, iron, β-carotene, riboflavin, niacin and ascorbic acid (Khader *et al.*, 1996). Banana is a rich source of calories, as well as most of the vitamins essential for human nutrition (Hossain, 2014). Bananas are also rich in carbohydrate, potassium and vitamins, including A, C and B6. They are a good source of fat-free dietary fiber. Banana is often the first solid food fed to infant. Ripe Banana mixed with rice and milk is the traditional dish for Bangladeshi. Varieties of Banana grown in Bangladesh are Amritasagar, Mehersager, Sabri, Champa, Chini Champa, Kabuli, Jahaji, Agnishwar, Basrai, Seeded Banana, Anaji or Kancha Kola and Singapuri, etc (Haque, 1988). Currently, three more varieties—Brikala-1, Barikala-2, Barikala-3 have been released by the Bangladesh Agricultural Research Institute (BARI). Ripe Banana mixed with rice and milk is the traditional dish for the Bangladeshis. Banana powder is used as the first baby food. It helps in reducing risk of heart disease when used regularly and is recommended for patients suffering from high blood pressure, arthritis, ulcer, gastroenteritis and kidney disorders (BBS, 2014; Fonsah and Chidebelu, 2012).

However, there are considerable problems with postharvest losses associated with storage and marketing. Such losses are prominent and laid in the range of 20–80% (Paull, 1993). Moisture loss by evaporation and transpiration together with losses due to postharvest disease levels are significant factors in determining grower profitability. Increased returns to Banana growers might come from conservation after harvest rather than from endeavors to boost up crop production. Reduction of

postharvest losses in Bananas by manipulating the normal postharvest physiological behavior and keeping postharvest disease levels under control are critical areas for research. A number of fungi and bacteria can cause postharvest decay of Bananas. Recent studies showed that the fungal species *Fusarium musae* is frequently found associated with Banana crown rot (Kamal *et al.*, 2016; Molnár *et al.*, 2015). *Colletotrichum musae* causes anthracnose and is one of the major spoilage organisms of Bananas.

Low temperature, heat treatment and modified atmospheres are often used extensively throughout the world to reduce postharvest losses in Bananas (Wills *et al*., 1989). Used judiciously, both heat treatment and low temperature storage may function to extend the shelf life of Bananas (Reyes *et al.*, 1998; Lizada, 1993). Chemical control of wastage organisms has also become an integral part of handling and successful marketing. The commonly used fungicides include thiabendazole, benomyl, imazalil, thiophanate-methyl and prochloraz (Tongthieng and Sangchote, 1993). These activities to increase storage life by suppressing disease development. Public reaction against food treated with chemicals is of increasing concern. Consequently, there is an expanding market in organically grown fruit and other food items. Growing Bananas in the wet tropics without the use of fungicides is always a risky business. Added to the field losses, postharvest losses are compounded by the increased colonization of fruit by latent fungi.

Banana is of considerable significance in the Bangladesh economy as one of the high value crops. A grower can earn a fair return from Banana production as it is grown in large quantity round the year. There exists scope for increasing the yield of Banana by improving the existing production practices. Banana is a perishable fruit and requires careful post-harvest handling and quick marketing. Infrastructure for postharvest management, transportation, storage and marketing has not yet been developed in the country for which sale of fruits at a reasonable price at a desirable time is a major problem under the existing inadequate marketing system. Poor

infrastructure for postharvest handling, storage and marketing contributes to a high proportion of spoilage which averages between 10-40% for horticultural crops (Ahmed, 2004). Despite the importance of Banana in the economy of Bangladesh, a few research works have been made on the postharvest handling and marketing of Banana. So, a systematic study on the postharvest handling and marketing of Banana could be of much importance which will help to improve the production process including postharvest management and marketing of this crop.

Nowadays, demand of Banana consumption is increasing day by day due to its high caloric and nutritional value, but non-availability of adequate postharvest storage facilities has posed a great threat to the commercial cultivation of Banana. Appropriate storage facilities and knowledge about storage are insufficient. As a result, considerable amount of Banana is spoiled every year. Banana is a perishable fruit and its postharvest loses range from 25-50% (Amiruzzaman, 1990). This loss occurs during transporting and marketing due to adverse physiological changes (loss of weight due to increased respiration and transpiration), softening of flesh and lack of resistance capacity against microbial attack.

The present study was conducted with a view to analyze postharvest losses in Banana value Chain in Bangladesh to promote, support and implement good practices in order to minimize postharvest losses and improve quality and safety in Banana value chain. Therefore, the study was conducted with the following objectives:

1. To identify the factors responsible for post-harvest losses in value chain;

2. To identify the pathogen(s) that cause post-harvest diseases of Banana in value chain.

CHAPTER II

REVIEW OF LITERATURE

Several researchers worked around the world on different aspects of Banana production, diseases at production, post-harvest losses and relevant literatures have been studied and constructed as follows:

BBS (2019) reported that the growers in Bangladesh cultivated Banana on 121,384 acres of land and the production was 810,347 MT in fiscal year 2017-18. The previous year, 807,104 MT of Banana were produced on 120,203 acres of land.

Jagana *et al.* (2017) reported that regular survey was conducted for three seasons of the year to record the extent of deterioration in Cavendish, Ney poovan and Sugandhi varieties of Banana in Hubballi and Dharwad markets. The mean disease incidence of Banana anthracnose was maximum during rainy season (17.53 % in Dharwad and 10.30 % in Hubballi) in all the varieties when compared to winter (7.16 % in Dharwad and 6.56 % in Hubballi) and very low incidence was observed during summer (2.25 % in Dharwad and 2.22 % in Hubballi). Disease severity (per cent disease index) of anthracnose was recorded maximum in rainy season which was more in Dharwad (20.56 %) compared to Hubblli (15.80 %). It is evident that disease incidence was more in rainy season in both the varieties when compared to winter season. This may be attributed to the favorable environmental conditions to pathogen prevailing such as temperature and relative humidity in rainy season.

Jagana *et al.* (2017) reported that crown rot disease was observed only during rainy season survey in all the varieties studied but not noticed in winter or summer in any of the variety. Among the varieties, Cavedish recorded more crown rot incidence (8.97 %) in Dharwad. While in Sugandhi 8.17 per cent incidence was recorded. Among the varieties, Cavendish recorded maximum disease severity of crown rot (31.42 %) which was observed during rainy season in Hubballi market. This may

be due to favorable environmental condition which might have resulted in the build-up of inoculums and thus more the severity in rainy season.

Kamel *et al*. (2016) and Lassois *et al*. (2010) stated that Crown rot was responsible for significant losses in Banana fruits. Predominantly, *Colletotrichum musae* and *Fusarium* spp. are its causative agents.

Kamel *et al*. (2016) and Molnar *et al*. (2015) stated that the fungal species *Fusarium musae* was frequently found associated with Banana crown rot.

Nath *et al*. (2015) reported seasonal variation on disease incidence and concluded that maximum disease incidence in fruit rot of Banana was recorded during the months September to June (37 %) in Navasari market of Gujarat. Reason behind the proneness of Cavendish to crown rot might be the mode of storage as it was stored or transported to short distances after the hands were separated from bunch at crown region. The injuries made during separation of hands paved the way for entry of crown rot pathogen.

Hossain (2014) reported that Bangladesh produces nearly 1.00 million tons of Banana annually.

Fonsah *et al*. (2012; 2007a; 2007b; 2007c) reported that the popularity of Banana was partially due to its "low price and multiple uses" as vegetable and as a dessert fruit. It is a rich source of carbohydrate and having plenty of vitamins particularly vitamin B. It is also a good source of potassium, phosphorus, calcium and magnesium

Indrakeerthi and Adikaram (2011) reported that all commercial cultivars of desert Bananas were known to be susceptible to crown rot. Crown rot, incited by a complex of fungi, was a major cause of postharvest losses in Banana. *Fusarium semitectum*, *Colletotrichum musae* and *C. gloeosporioides* were identified as the major crown rot causing fungi in Sri Lanka.

Hassan (2010) reported that the postharvest loss of Banana was 24.62% which accounts for 56.7 crore taka annually.

Rich *et al*. (2009) stated that value chain analysis was conducted through a combination of qualitative and quantitative methods. Primary survey focusses group discussions, participatory rapid appraisals (PRAs), informal interviews, and secondary data sourcing all form the basis for the analysis. The information helped to understand the linkages and structure of the value chain and served as the basis for identifying many of the key constraints and policy issues that required further exposition.

Lechaudal and Joas (2007) stated that pre-harvest factors affected fruit growth during development and fruit quality attributes during its storage by changing the concentration of water, dry matter and biochemical compounds.

Anonymous (2002) stated that Banana and plantain were highly perishable commodities. A combination of high perishability, high ambient temperatures, slow marketing systems and poor market condition lead to huge losses in quality Banana in Nigeria.

Flordaliza (2002) reported that in the Philippines, Banana growers' incurred a huge loss (30-40%) annually because of poor post-harvest techniques adopted by them.

Khan *et al*. (2001) reported that Crown rot of beheaded Banana was a major cause of losses during storage and marketing of Banana and considered as one of the most serious and frequent postharvest and post-packaging diseases.

Basal *et al*. (2002) and Hassan (2000) reported that Bananas are highly perishable fruits. Extended storage of Bananas could be obtained when ripening is not induced by a large ethylene exposure (exogenous or endogenous). Shelf life could be extended by different processes such as modified atmosphere packaging (MAP).

Haque (2001) stated that Bananas supply an appreciable amount of vitamins and minerals. One hundred gram of edible portion of Banana contains 70% water, 27% carbohydrate, 0.5% fiber, 1.2% protein, 0.3% fat, 0.9% ash, 290 ppm phosphorus, 80 ppm calcium, 6 ppm iron, 0.58 ppm, β carotene, 0.5 ppm riboflavin, 7.0 ppm Niacin and 120 ppm ascorbic acid.

Hadi (2001) reported that postharvest losses of fruits and vegetables in Pakistan is about 35%. According to him the factors responsible for post-harvest losses were adoption of poor pre harvest measures, insect pest and disease infestation and biotic stresses, low technique harvesting procedures, non- application of pre-harvest recommended treatments/ practices, harvesting at improper stage, improper care at harvest, non-removal of field heat, dumping procedure, moisture condensation causing pathogen infestation, packing in bulk without sorting and grading of produce improper transportation and storage and distant and time consuming market distribution.

Fakir (2001) stated that the climate of Bangladesh harbors plant pathogen and provides luxuriant environment for the growth and reproduction of large number of plant pathogens which caused hundreds of different diseases of crops.

Reyes *et al*. (1998) and Krauss *et al.* (2000) reported that Crown rot disease is considered to be the main export Banana postharvest disease and it affects export Bananas in all Banana-producing countries.

Jones (2000) stated that the symptoms on the fruit developed rapidly during shipping and ripening when the physiology undergoes modifications that facilitate fungal development.

Reyes *et al*. (1998) found that the quality of fruit was damaged following exposure to hot water for greater than 10 min at 55°C and by low temperature storage below 12.5°C.

Reyes *et al*., (1998) and Lizada (1993) reported that both heat treatment and low temperature storage may function to extend the shelf life of Bananas.

Nargis (1997) reported that during the period was September to December, 1996 per hectare costs of production of sole Banana were Tk. 121438 and Tk.92011, respectively considering full cost and cash cost. Per hectare cost of production of Banana with cucumber, Banana with Indian spinach and Banana with lady's finger based on full cost were Tk. 122896, Tk. 123328 and Tk. 123534 respectively per hectare net return of growing sole Banana was Tk.90032 and Tk. 119459 considering full cost and cash cost, respectively per hectare net return of growing Banana with cucumber, Banana with Indian spinach and Banana with lady's finger were Tk. 137974 Tk. 142482 Tk. 149676 respectively on the basis of full cost. Per hectare net return from Banana with cucumber, Banana with Indian spinach and Banana with lady's finger were Tk. 167909 Tk. 172499 and Tk. 179859 respectively considering cash cost.

Patel (1996) conducted a case study of Banana in Gujrat India to identify the emerging problems of marketing new crops with added focus on impact supply and to offer suggestion for possible improvement in the existing marketing, processing and impact supply system based on the findings of the study. The problems and prospectus relating to Banana marketing functions such as picking, grading, assembling, packing, transport etc., price received for product, supply of key inputs and price paid for inputs, were reported from a sample survey of Banana growers.

Chillet *et al*. (1996) stated that study on Banana in French found that described anthracnose is the main factor responsible for post-harvest decay of West Indian Banana.

Rahman (1995) conducted a study on marketing of Banana of Gabtali and Sariakandi thanas under Bogura district. Thirty five farmers and equal number of intermediaries were selected to determine the existing marketing system of Banana

in the selected areas. He estimated the costs and margins of Banana marketing. The study revealed that the marketing cost per 100 Bananas was the highest for large farmers (Tk.6.11) and was the lowest for medium farmers (Tk.4.15). Among the intermediaries, the marketing cost was the highest (Tk. 18.04) for aratdar and the lowest (Tk.9.22) for faria per 100 Bananas. The reported Banana marketing channel in the study areas was "Farmer—► Faria—►Bepari— ►Aratdar—► Retailer —► Consumer". The marketing margin for the channal was estimated at Tk. 102.90 per 100 Bananas.

Slabaugh and Slabaugh (1994) reported that in Caribbean, India, Taiwan and the Philippines, fully mature fruit was more susceptible to infection and the affected clusters ripen earlier. The disease developed faster during ripening and can spread to adjacent fingers.

Naqvi and Dass (1994) reported that in several districts of Maharashtra India, indicated that 43-47% of the total losses of mandarins in truck and train transport were due to postharvest diseases.

Paull (1993) reported that the Banana (*Musa sapientum*) was one of the most popular fruits of the world. However, there are considerable problems with postharvest losses associated with storage and marketing. Such losses were prominent and lie in the range of 20–80%.

Tongthieng *et al*. (1993) and Wade *et al*. (1993) reported that chemical control of wastage organisms has also become an integral part of handling and successful marketing. The commonly used fungicides include thiabendazole, benomyl, imazalil, thiophanate-methyl and prochloraz.

Kader (1992) reported that in Bangladesh postharvest losses of Banana due to environmental drivers (high temperature and humidity) ranged from 25-40% and it is only 5-25% in developed countries.

Prusky and Plumbley (1992) reported that Anthracnose of Banana was caused by the *Colletotrichum* species and was one of the most serious diseases of ripe Banana. Symptoms of anthracnose include black and sunken lesions with spore masses or acervuli in the lesion. Infection on the Banana usually started during the development of the fruit but remains quiescent until the fruit ripens; symptoms often manifest during storage and marketing.

Eckert (1991) noted that fresh fruits are susceptible to attack by many plant pathogens after harvest because they are rich in nutrients and have lost most of the intrinsic resistance that has protected them during their development while attached to the plant.

Bairagi (1990) conducted a study to determine the profitability of Banana production in Jhenaidah district of Bangladesh. His survey period was September, 1989 to October, 1989. The relative economic advantage of Banana and sugarcane and the factors that affect Banana production and marketing of Banana were also analyzed in his study. He found that per hectare cost and returns of Banana production were Tk.53, 714.50 and Tk. l 16678.84 respectively.

Sapiah *et al*. (1990) stated that postharvest diseases of Banana fruits were considered as a major threat to the Banana industry. Fruit rot occupies leading position among the post-harvest diseases.

Amiruzzaman (1990) indicated that nowadays, demand of Banana consumption was increasing day by day due to its high caloric and nutritional value, but non-availability of adequate postharvest storage facilities has posed a great threat to the commercial cultivation of Banana. Appropriate storage facilities and knowledge about storage were insufficient. As a result, considerable amount of Banana was spoiled every year. Banana was a perishable fruit and its postharvest loses ranged from 25-50%. This loss occurred during transporting and marketing due to adverse physiological changes (loss of weight due to increased respiration and

transpiration), softening of flesh and lack of resistance capacity against microbial attack.

Rawal (1990) reported that plant disease play an important role in reducing yield of horticultural crops in the tropics. It has been estimated that production could be increased at least by 28% if the crop could be confined against various diseases and many of these diseases have been reported to be transmitted through the planting material.

Danials (1990) reported 20-40% post-harvest losses of fruits and vegetables in the tropical countries.

Rahman and Akbar (1989) conducted a study on Banana marketing in Narsingdi district. Their survey period was October 1987. They reported that the farmer's share of the consumer's taka spent on Bananas varied between 44 and 62 percent. The farmer's share was however, found to be inversely related with the size of the channel; the shorter the channel, the higher was the share. The intermediaries appropriated a marketing margin of 38 to 56 percent in the form of marketing cost and profit. The profit component in the margin for all groups of intermediaries was higher than the cost component. Although the net margin taken by the retailers was reportedly larger, their 10 overall turnover was considerably less than that of other intermediaries. The intermediaries engaged in marketing of Bananas were faria, paiker, aratder and retailer. The problems faced by the farmers in the production and marketing of Bananas were lack of capital, diseases, natural calamities, thievery, poor communication, high transportation cost, delay in sale and lack of physical facilities in the market.

Wills *et al*. (1989) and Liu *et al*. (1997) reported that *Colletotrichum musae* caused anthracnose and was one of the major spoilage organisms of Bananas. Low temperature, heat treatment and modified atmospheres were often used extensively throughout the world to reduce postharvest losses in Bananas.

Gerini (1988) in his study observed 5% mean weight loss of Banana due to mechanical damage and fungal disease.

Haque (1988) conducted a research at Bangladesh Agricultural University, during October 1987 to November 1988. He examined the economic performance of Banana production. He found that per hectare cost and net returns of Banana production were Tk. 1, 03,614.88 and Tk. 1, 61,386.12 respectively. According to Haque, net return from Banana cultivation was much higher than any other field crops.

Subramanyam (1986) described that in India the postharvest losses of fruits and vegetables in developing countries have been reported to vary between 15 and 50% with an estimated minimum loss of 20% at different stages of marketing.

Salunkhe and Desai (1984) observed that Postharvest losses to fruits in developing countries had been estimated to be in the range of 5-50% or more of the harvest.

Rao (1979) stated that proper harvesting was also important. Bananas should be harvested at appropriate stage of maturity for transport, handling and storage. It was necessary to delay ripening for distant markets and then enhance ripening for retail sale.

NAS (1978) stated in USA post-harvest losses took a heavy toll on the harvested Banana; which may vary from 20-80%.

Kader *et al*. (1985) and Sommer (1982) stated that the extension of marketing periods by storing fruits and vegetables affect the physiological life of the stored products and may create additional disease problems.

Anonymous (1976) made a case study in Kenya on postharvest losses of Bananas and reported that the major factors responsible for the losses were mechanical damage and in transit ripening. Overall the losses from the defingering, bruising, broken fruits and in transit ripening were in the order of 22, 29, 15 and 30%

respectively. The position of the fruits in the truck affected the degree of damage with the total losses from the top, middle and bottom being 21, 31 and 44% respectively. Estimates of postharvest loss of Musa crops in the traditional marketing systems ranged from 20-80%.

Peacock (1973) reported that Crown rot affected the fruit quality because of the development of necrosis on the fruit, and it could also trigger early ripening of Bananas during shipping.

Stover (1972) reported that finger rot was one of the most common rots of Bananas that were in transit in boxes for more than 14 days. However, it rarely occurs in fruit transported for 10 days or less.

Scott *et al*. (1971) mentioned that the ripening of Banana is delayed when stored in sealed polythene cover and the minimal fruit losses were recorded in sealed polythene along with KMnO4.

Peacock *et al*. (1974) and Daundasekera *et al*. (2003) reported that ripening may be caused by ethylene released by stressed and necrotic tissues x; but also by ethylene produced by mycalia of fungi such as *Colletotrichum musae*

CHAPTER III

MATERIALS AND METHODS

3.1. Survey on the practices followed by the Banana growers during Banana production and marketing.

3.1.1. Sampling procedure

Primary data were collected through a questionnaire from key actors like producers, pikers, beparies and retailers in the Banana value chain. The Banana postharvest handling system from Dinajpur to Dhaka marketing channel was investigated to have a clear understanding. Survey study targeted Banana producers and Banana marketing actors in Dinajpur. The data collection tools included: Open and closed type questionnaire- key informant interviews; and market visits. In questionnaire survey, the Banana farmers and retailers were directly interviewed.

3.1.2. Survey of Banana orchard

Dinapur, one of the important Banana growing districts of Bangladesh, was selected for this study. Three Upazillas of Dinajpur viz. Bochaganj, Kaharole and Sadar Upazilla were selected. Seven Banana orchards in every upazilla were randomly selected for survey study. In an average, 250-350 plantations were counted in each Banana orchard. The Banana growers were categorized into three categories viz. large farmer, medium farmer and small farmer according to their farm size. The farmers, who have more than 700 Banana plants are categorized large farmers, who have 250-700 plants are categorized medium farmers, who have 10-250 plants are categorized small farmers and who have less than 10 plants are consumers.

3.1.3. Survey on Banana market

Three wholesale Banana markets viz, Kawranbazar wholesale market of Dhaka, Mohammadpur Krishi market and Mirpur-1 Banana market at Dhaka district were selected. Each market was visited three times from August, 2019 to February, 2020.

Data were collected on types of packaging, mode of transportation marketing cost and diseased Banana from each Banana market. In the wholesale markets, 10 bunches (having 90-110 Bananas) were observed and in the retailer shops 30 Bananas were observed for each time.

3.2. Prevalence of disease

3.2.1. Assessment of disease incidence

Disease incidence was assessed as percentage of fruits infected with at least one spot or visible symptom. The total number of Banana and the number of infected Bananas were counted to calculate the disease incidence. Percent disease incidence (PDI) was calculated using the formula:

$$\textbf{(\%) Disease incidence} = \frac{\textbf{Number of infected Bananas}}{\textit{Total Number of Bananas}} \textbf{ X 100}$$

These numbers were divided by the total numbers observed Bananas and multiplied by 100 so as to find out the parentage of loss due to diseases. Total loss in each market of different districts was also calculated.

The following state of Banana were considered to calculate and estimate the loss in market conditions such as,

a) Total number of infected Bananas

b) Injured Banana

Then percentage of fungal (Anthracnose, Crown rot) diseases were calculated in market and in laboratory.

3.3. Isolation and identification of pathogen.

3.3.1. Collection of samples

Bananas were collected from Kawranbazar Banana market, Mohammadpur Krishi market and Mirpur wholesale market. Diseased fruits were collected from the

wholesale market and 40 retailer shops at Dhaka city. Bananas were taken randomly from each market. The collected fruit samples were brought to the laboratory, Department of Plant Pathology, Sher-e-Bangla Agriculture University for further experiment.

3.3.2. Observation of the symptoms

Symptoms of the disease were studied by visual observation as per standard procedure described by Guerber *et al*., (2003).

3.3.3. Isolation and identification of fungal diseases in laboratory

3.3.3.1. Preparation of potato dextrose medium

Potato dextrose agar is a common microbiological growth media often abbreviated "PDA". It is one of the most widely used media for growing fungi. Potato Dextrose Agar consists of potato infusion, agar and dextrose. The dextrose provides a fast easily utilized energy source and stimulant while Potato infusion provides a more complex nutrient base. Both together allow for a nutritionally balanced medium growth of most fungi. Potato Dextrose Agar (PDA) medium was used to isolate fungus from diseased Banana.

To prepare potato infusion, boil 200 gm sliced, unpeeled potatoes in 1-liter distilled water for 30 min.

3.3.3.2. Isolation of fungus

Infected fruits were collected using sterilized polythene bags and the samples were washed thoroughly under running tap water and surface sterilized with 4% NaOCl. Three pieces of sterile blotting paper were placed in sterilized glass petri dishes and moistened with sterilized distilled water so that a little amount of surplus water was left on the surface of paper. The non-disinfected fruits were placed on three layered water-soaked blotter papers at the laboratory, Department of Plant Pathology, Sher-e-Bangla Agriculture University. After 3-5 days, small portions of rotted tissues

were isolated aseptically from the glass petridish to PDA media. Pure colony cultures were obtained by sub-culturing the fungal growth in separate petri-dishes containing the same medium and kept at 4 ºC for preservation and further use.

3.3.3.3. Identification of fungus

The pure cultures were allowed to grow aseptically within the laboratory covering the petri dish with aluminum foil paper followed by tightening with plastic tape. After 8-12 days, the fungal cultures on PDA media were observed. The developed colonies were identified according to Mordue (1971). Then the pathogens were identified by their morphological, cultural characteristics and physiological structures under microscopic observation.

CHAPTER IV

RESULTS

Value chain of Banana from production to consumption were evaluated to analyze the factors responsible for deterioration of produce in the handling procedure by stakeholders. Total 21 Banana farms, one local market and three whole sale market in Dhaka city were surveyed and the results have been presented in this chapter:

4.1. Status of area under Banana cultivation during 2019-20

Among the 21 respondents, 10 respondents increased their Banana cultivating area by converting their agricultural land, while 8 respondents had no change in their Banana growing area and only 3 respondents' decreased cultivation area.

Table 1. Present status of Banana cultivation by the Banana farmers

Present status of Banana cultivation						
Issues	**Increased**		**Decreased**		**No change**	
	No. of farmers	%	No. of farmers	%	No. of farmers	%
Area under Banana cultivation	10	47.62	3	14.28	8	38.0

4.2. Farm size

Among 21 respondents, the highest 61.90% was found as medium farmers followed by 28.57% large farmers and 9.52% small farmers. Farm size were determined on the basis of farmer having more than 700 trees are classified as large farmers, more than 250 trees are medium farmers and farmers occupying more than 10 trees but less than 250 trees are classified as small farmers. The persons who has less than 10 trees are termed as consumer assuming that they cultivated Banana for their own consumption and not count in this survey.

Table 2. Farm size of Banana farmers

Types of Farmer	No. of plants	Area (Bigha)	No. of farmers	% of farmers
Large farmer	>700	>2	6	28.57
Medium farmer	250-700	1-2	3	61.90
Small farmer	<250	<1	2	9.52

4.3. Experience in production of Banana growers

The experience of the respondent growers in Banana production ranged from 3 to 22 years. The highest 47.62% respondents were of having 7 to 15 years of experience. The second highest 38. 90% respondents were of having less than 7 years of experience. Only 14.29 % respondents were of having more than 15 years of experience. (Figure 1.)

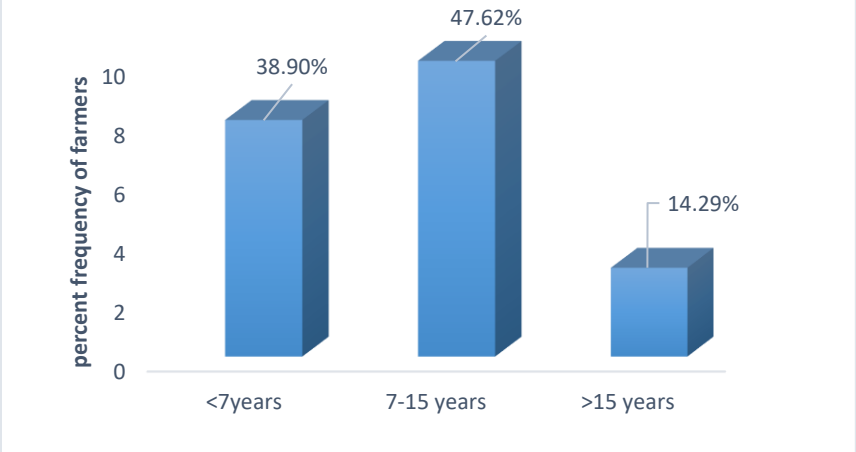


Figure 1. Frequency of Banana growers under three categories having different years of experience

4.4. Varieties of Banana

During the survey, the respondents reported that the most popular varieties in Dinajpur district were Amrita Shagor, Sabri, Champa and Kachkola.

Plate 1: Different varieties of Banana cultivated at Dinajpur area

Among all 21 respondents highest no of them cultivated Amrita Shagor (43%) followed by Sabri (38%), Champa (14%) and Green Banana (5%). (Figure 2.).

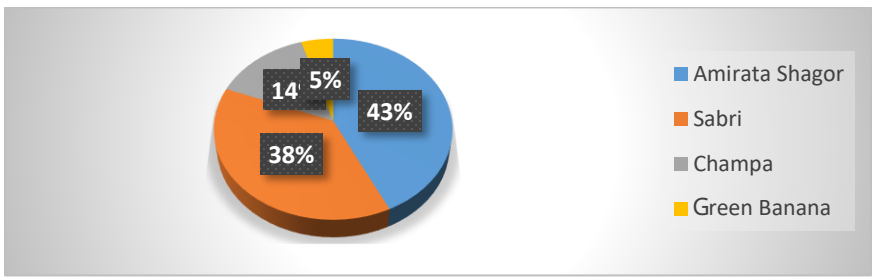


Figure 2: Distribution of Banana varieties according to cultivation by growers

4.5. Fertilizers used for Banana production

During interviewing, all of the responding Banana growers (100%) reported that they applied ashes and cow dung for soil preparation every year. The highest 61.90% growers used TSP and MoP. The second highest 23.81% growers used TSP and DAP. The lowest 14.29% respondents used MoP and Gypsum during production period. The grower used to fertilizer every three months interval. (Table3)

Table 3: Fertilizer used for Banana production in study area

Inputs	No. of farmers	% of farmers
No fertilizer	0	0.00
Urea, MoP, Gypsum	3	14.29
Urea, TSP, DAP	5	23.81
Urea, TSP, MoP	13	61.90
Total	21	100

4.6. Use of Pesticides

Farmers reported that they used Tilt 250 EC (Propiconaozole), Avance 25 EC (Propiconaozole), Azonil 56 SC, Nativo 75WP (Azoxistobin) and Contaf 5 EC (Hexaconazole) at Banana cultivation period for pest management. Hexaconazole+Mancozeb, Propiconazole and Tebuconazole + Trifloxistrobin groups of fungicides applied by 19.05%, 47.62% and 33.33% of the respondents respectively. All of them used Aktara 25 WG for the management of insect infestation.

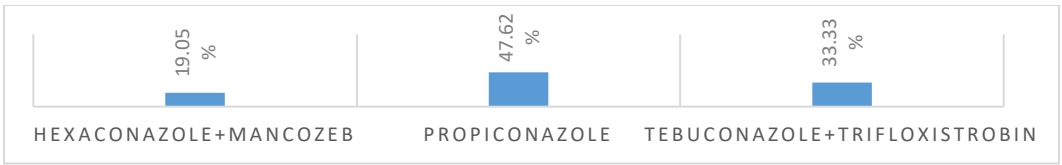


Figure 3. Frequency of Banana growers used pesticides

4.7. Harvesting procedure of Banana in orchards

Farmers determined the maturity stage for harvesting of Banana on the basis of finger angularity, fullness of fingers, color of fingers, or age. Farmers used knives (locally called “Kaste”) to harvest Banana bunches and except for small plants, they cut first the pseudo-stems and then cut bunches as the pseudo-stem bend to the ground. After harvesting farmers sorted damaged, diseased and rotten fruits manually. Subsequently, they carried them on the shoulders to intermediate collection points near the farm where they pile or put them side by side for a few hours. Most of the Banana producers were not aware of the dangers of poor sanitation in the fields.

Plate 2: Harvesting procedure of Banana in orchards (A). Knife used in harvesting and sorting (B). Accumulation of Banana bunches in the field (C). Banana plant after harvesting

4.8. Sorting and accumulation procedure of Banana

The survey revealed that sorting and accumulation were done for three times in the marketing channel of Banana. Firstly growers sorted bunches and heap them in the field. Then harvested Banana bunches were transported to the intermediate collection points of Piker where they pile or put them side by side for a few hours to one day long. After that, bunches were loaded on Truck to transport to distant market channels. After unloading, the Bananas were again sorted out by Bepari intermediaries and accumulated for traditional Kerosine smoking system.

Plate 3: Sorting and accumulation procedure of Banana (A). Sorting of Bananas by farmers (B). Piled Bananas after harvesting by farmers (C). Piled Bananas at Piker market

Plate 4. Loading and unloading of Banana for distant market channel (A) Loading of Banana (B) Unloading of Banana

4.9. Banana ripening process

The ripening process was done through the traditional kerosene smoking system inside airtight and non-ventilated chambers commonly called “chela” or “muket” houses. Ripening was done on piled bunches took for 24-48 hours depending on different Banana varieties. All wholesalers/ripeners also explained both immature and over matured fruits as regularly being part of the post-harvest loss they incur. The immature fruits either completely failed to ripe or ripped unevenly, the over mature ones often tend to be caked due to over ripening and cracked during ripening.

Plate 5: Kerosine smoking system (A). Bowl and Saw-dust used in smoking system (B) Banana smoking preparation (C) During smoking

4.10. Mode of Transportation

The survey study revealed that, the use of vehicles varied from traders to traders and the length of destination markets.

Figure 4. Transportation and traders channel

Trucks were used for Banana transportation by the Beparies (100%) from the assemble markets to the destination wholesale markets. Majority of the Pikers (60%) used Nosimon (5 wheeler local vehicle) to transport and 20% used mini truck and 20 % Piker used Van. In case of retailer, highest frequency (60%) used van, 20% used Local carts and 20% used Baskets(manually) to transport Banana. In the channels of transportation poor sanitation, recklessness and improper handling of Bananas was observed.

Table.4. Frequency of vehicles in marketing channel

Intermediaries	**Use of Vehicles (%)**				
	Truck	Nosimon	Van	Local carts	Baskets
Piker	20	60	20	0	0
Bepari	100	0	0	0	0
Retailer	0	0	60	20	20

Plate 6: Different Mode of Transportation (A) Banana transportation manually (B)Transport by Van (C) Transport by Bamboo Truk (D) Transport by Local carts (E)Transport by Jhuri (F) Transport by Baskets (manually)

4.11. Storage condition in the market

Beparies trade at major regional and central market outlets. They bought the Bananas in bulk from Piker and ripen and sold them to individual and institutional retailing business operators (green grocers, supermarkets, street and open market, etc.). After the Bananas were unloaded upon arrival, they were sorted, weighed and treated for ripening initiation for 1 to 2 days, depending on the locality or prevailing

temperature. After ripening, bunches were beheaded and sold to various retailers in their respective localities either in green-ripen or yellow-ripen forms. (Plate. 7)

Plate 7: Storage condition (A). Before kerosine smoking (B). After ripening (C). Sorting and preparing for selling

4.12. Postharvest Loss of Banana at Farm Level

The survey study revealed that total loss at farm level was 6.47%. On an average, the postharvest loss of Banana at farm level in the peak season was 7.06% and in the lean season was 5.88%. (Table. 5) The loss was occurred due to harvesting untimely, harvesting practices and disease infestation. Most of the Banana producers were not aware of the dangers of poor sanitation in the fields and they tend to be reckless in handling the soft fruit leading to physical damage. In every bunch contained 90-100 Bananas.

Table 5. Postharvest losses of Banana at farmers' level

Reasons	Peak season		Lean season		Average Loss	
	Quantity (pcs/bunch)	% of total	Quantity (pcs/bunch)	% of total	Quantity (pcs/bunch)	% of total
Physical Damage	3	3.53	2	2.35	2.5	2.94
Diseased & Blemish	3	3.53	3	3.53	3	3.53
Total	6	7.06	5	5.88	5.5	6.47

* The peak and lean seasons are ranged from Aug to Sept and Oct to July, respectively

4.12.1. Postharvest Loss at Traders' Level

As a result of the operation were done in the traders channel rough unloading, weighing, ripening, and dehanding practices, Bananas were heavily liable for impact, compression, bruising, abrasion, puncturing, direct breakage and overheating damages. In this survey study for 700 bunches of Banana (one truck) it was found that the postharvest loss at trader's level was estimated at (30.74%) which consisted of completely damaged Banana (29.74%) and partial damaged Banana (1.00%). Among intermediaries, the highest loss was recorded for Retailer (23.58%) followed by Piker (1.31%) and Bepari (5.85%). Every bunches contained 90-110 Bananas.(Table. 6)

Table 6. Total postharvest losses of Banana at traders' level

Key players	Complete damage		Partial damage		Total damage	
	Quantity (pcs/700 bunches)	% of total	Quantity (pcs/700 bunches)	% of total	Quantity (pcs/700 bunches)	% of total
Piker	820	1.17	100	0.14	4300	1.31
Bepari	4000	5.71	100	0.14	4100	5.85
Retailer	16,000	22.86	500	0.72	16500	23.58
Total	20,820	29.74	700	1.00	24,900	30.74

4.13. Problems in Banana value chain

In the survey the highest reported problem was delayed sale (46.6%) following by lack of buyers (30.0%) and Transportation delay (23.4%) among these three problems. It was found that, farmers and retailers faced delayed sale and lack of buyers, these two problems to a great extent compared to Piker and Bepari.

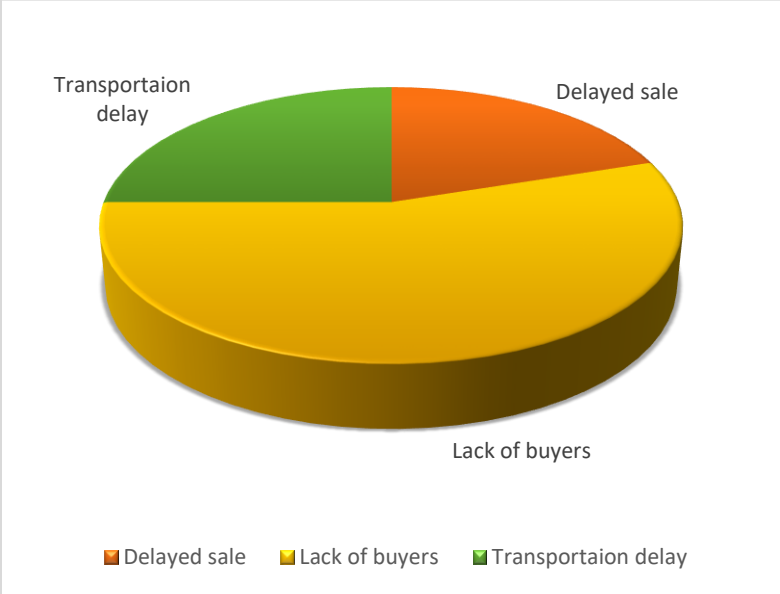


Figure 5: Different problems in Banana value chain in study areas

4.14. Assessment of the current Banana post-harvest handling system

The activities of a standard post-harvest system and surveyed actors activities have been analyzed. The actors of the value chain were involved in different type activities. The actors in the value chain as producers, pikers, beparies and retailers were questioned about their activities and problems they faced. It was observed that variation between previous standard post-harvest system and post-harvest practices at the surveyed value chain. The observations are given at Table. 7.

Table 7. Assessment of the current Banana post-harvest handling system

Activity	Observations at Value chain
Pre-harvest activities; tagging, propping, bagging and deflowering	No producers practiced pre-harvest activities
Reaping (harvesting)	It was done without maintaining hygiene
Transit of Bananas from field to packing house (Local market)	Carry on shoulders with hatter or by local vehicles; Nosimon, Mini truck and Van
De-handing	This practice was not done by any producers
Washing	This practice was not done by any producers
Air drying and storage	No facilities was seen
Grading	Grading was not done in a proper way
Packing	No packing system was practiced
Loading and transportation from producer to consumer	Loading was done manually. Transportation was done by truck, nosimon, van and local carts.
Receiving	It was done manually
Ripening in the cold rooms	Ripening was done in conventional process. There were no adequate and functional temperature management or tracking systems.
Packaging	No packaging
Market, distribution and respective price	Beparies distributed to the local retailers. Retailer's selling price varied from 600TK to 800TK. per 100pcs of Banana

4.15. Buying and Selling Price of Banana

Producers sold their Bananas to traders including Pikers, Beparies and Retailers worked in the marketing channel. The highest and lowest selling price of farmers are 260 and 185 TK, respectively. The highest and lowest selling price of retailers are 800 and 600 TK, respectively. The highest price was for good quality Bananas at lean season because of unavailability.

Table 8. Buying and selling price of Banana in the study areas

Season	Traders	Low quality Bananas			Good quality Bananas		
		Purchase price(Tk/ 100pc)	Selling price(Tk /100pc)	% increased	Purchase price(Tk/ 100pc)	Selling price(Tk/ 100pc)	% increased
Peak season(Aug-Oct)	Piker	185	205	10.81	250	280	12.00
	Bepari	205	320	51.22	280	425	51.78
	Retailer	320	600	87.50	425	800	88.23
Lean season (Nov-July)	Piker	190	215	13.16	260	290	11.53
	Bepari	215	335	55.81	290	440	51.72
	Retailer	340	650	91.18	440	800	81.82

4.15.1. Monthly Price Variation of Banana

The highest value was for Sabri at the month March to July and lowest price was for Champa variety at November to February. Price for 100 pieces Amrita Sagar varied 240 to 260 for different months. (Table. 9)

Table 9: Monthly price variation of different Banana varieties

	Amrita Shagor (Tk/100 pc)	Sabri (Tk/100 pc)	Champa (Tk/100 pc)	Kachkola (Tk/100 pc)
November-February	240	245	150	200
March-July	260	265	170	220
August-October	250	250	175	000

4.16. Marketing Margins and Costs

The highest gross margin was estimated for Retailer (Tk. 365/100 pcs) followed by Bepari (Tk. 145) and Piker (Tk. 30)). Again, Retailer received the highest net profit (Tk. 365.79) and Piker received the lowest net profit (Tk. 26.72) for 100 pcs of Banana. (Table. 10)

Table 10. Marketing margin and profit of different intermediaries

Trader type	Average purchase price(Tk/100 pcs)	Average sale price (Tk/100pcs)	Gross margin (Tk/100pcs)	Average marketing cost (Tk/100pcs)	Net profit (Tk/100pcs)
I	II	III	IV=(III-II)	V	VII=(IV-V)
Piker	250	280	30	3.28	26.72
Bepari	280	425	145	17.58	127.42
Retailer	425	800	375	9.21	365 .79

In this survey it was found that, among different traders, Bepari incurred the highest average marketing cost of Tk. 18.57 per 100pc followed by Piker (Tk. 3.28/100pc) and retailer (Tk.9.21/100pc). Beparis informed that, they incurred the highest costs due to transportation (Tk.14.29/100pc). (Table. 11)

Table 11. Marketing cost of Banana at trader's level

Cost headings	**Piker**		**Bepari**		**Retailer**	
	Amount (Tk/100 pcs)	Percent	Amount (Tk/100 pcs)	Percent	Amount (Tk/100 pcs)	Percent
1.Arathdar commission	--	--	2.1	9.60	--	--
2.Transportation	0.85	25.92	18.57	84.95	6.66	72.32
3.Loading & unloading	0.08	2.44	0.50	2.29	--	--
4. Cleaning & Smoking	0.05	1.52	0.50	2.29	--	--
5. Shop rent	--	--	0.09	0.41	2.50	27.14
6. Market toll	2.30	70.12	0.06	0.27	0.05	0.54
7.Electricity charge	--	--	0.04	0.18	--	--
Total cost	3.28	100	21.86	100	9.21	100

* Transport Bananas from Dinajpur to Dhaka for Bepari and then to Retailer

4.17. Prevalence of disease incidence

Incidence of anthracnose and crown rot of Banana varied appreciably from season to season as well as market to market. The highest incidence was observed for anthracnose 18.73 % and crown rot 8.89% both, at retailers- the Tong dokans of Dhaka at the duration August to October. The lowest incidence was observed for anthracnose 2.58 % and crown rot 2.08%, at the piker- Doshmile Banana market of Dinajpur at the duration November to February. The incidence of disease was increased time being and changed of trader's channel.

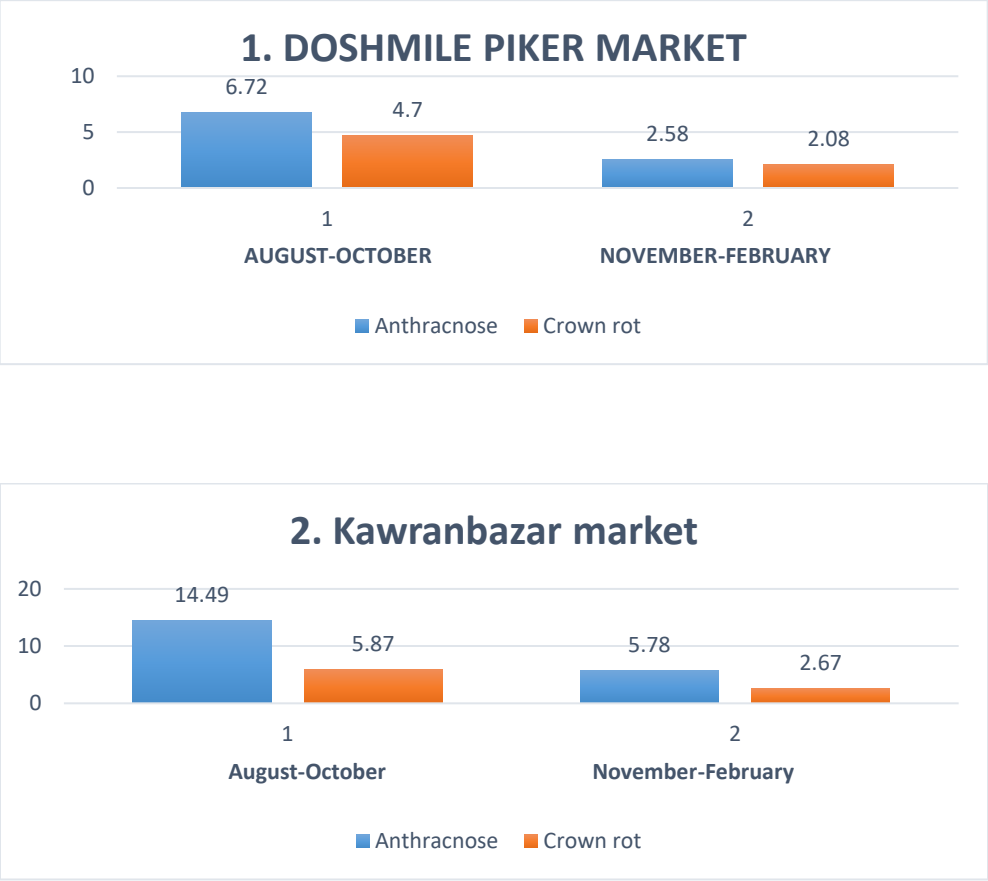
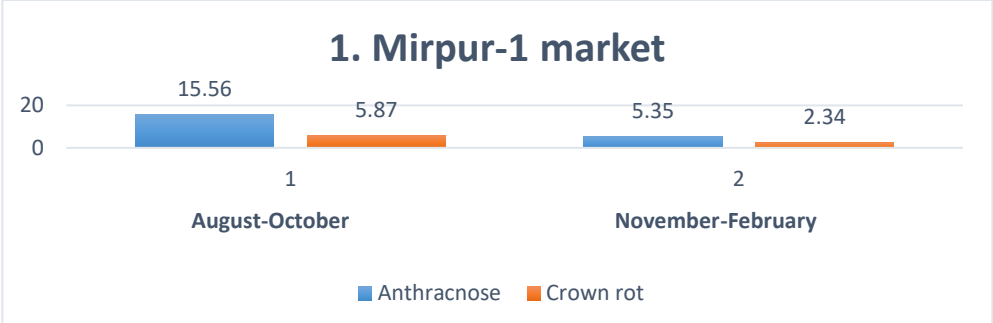
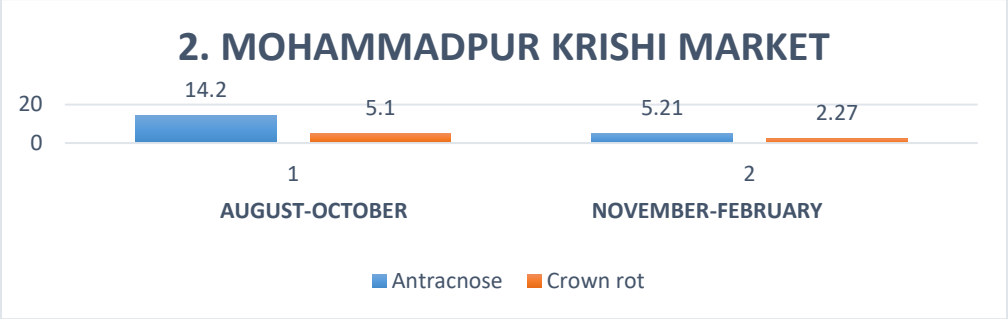


Figure 6. Incidence of disease (anthracnose and stem end rot) of Banana in different data recording times at 1. Doshmile piker market Dinapur and 2. Karwanbazar Banana market in Dhaka.





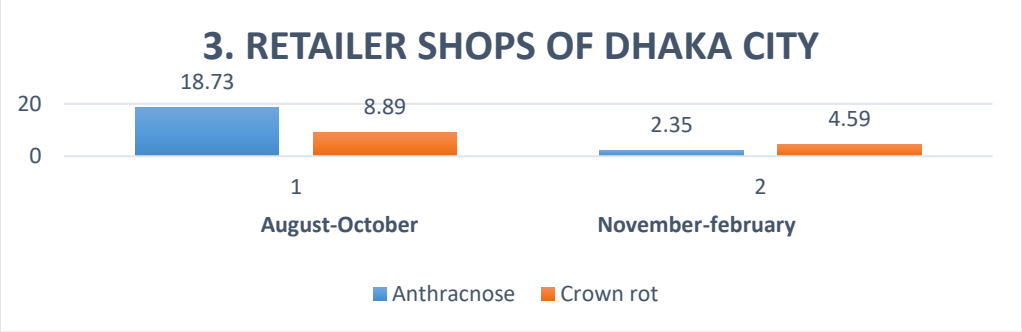


Figure 7. Incidence of disease (Anthracnose and Crown rot) of Banana in different data recording times at (1) Mirpur-1 market, (2) Moahmmadpur Krishi market and (3) 40 Retailer shops of Banana in Dhaka city

4.18. Identifying the causal agents of post-harvest diseases of Banana

4.18.1. Identification of fungus

The fungi grown on PDA media were identified by their colony and morphological characteristics. Colony characters and morphological characters were observed under microscope through preparing slide using either glycerin or lacto phenol cotton blue.

4.18.1.1. Identification of *Colletotrichum musae* by cultural and morphological characteristics

After 8 days growth on PDA media, it was observed that the culture was growing rapidly. Colonies on potato dextrose agar were grayish white to dark gray. Acervulus was irregular in shape and setae were present. Conidia were hyaline, unicellular and cylindrical. They formed on faintly brown conidiophores

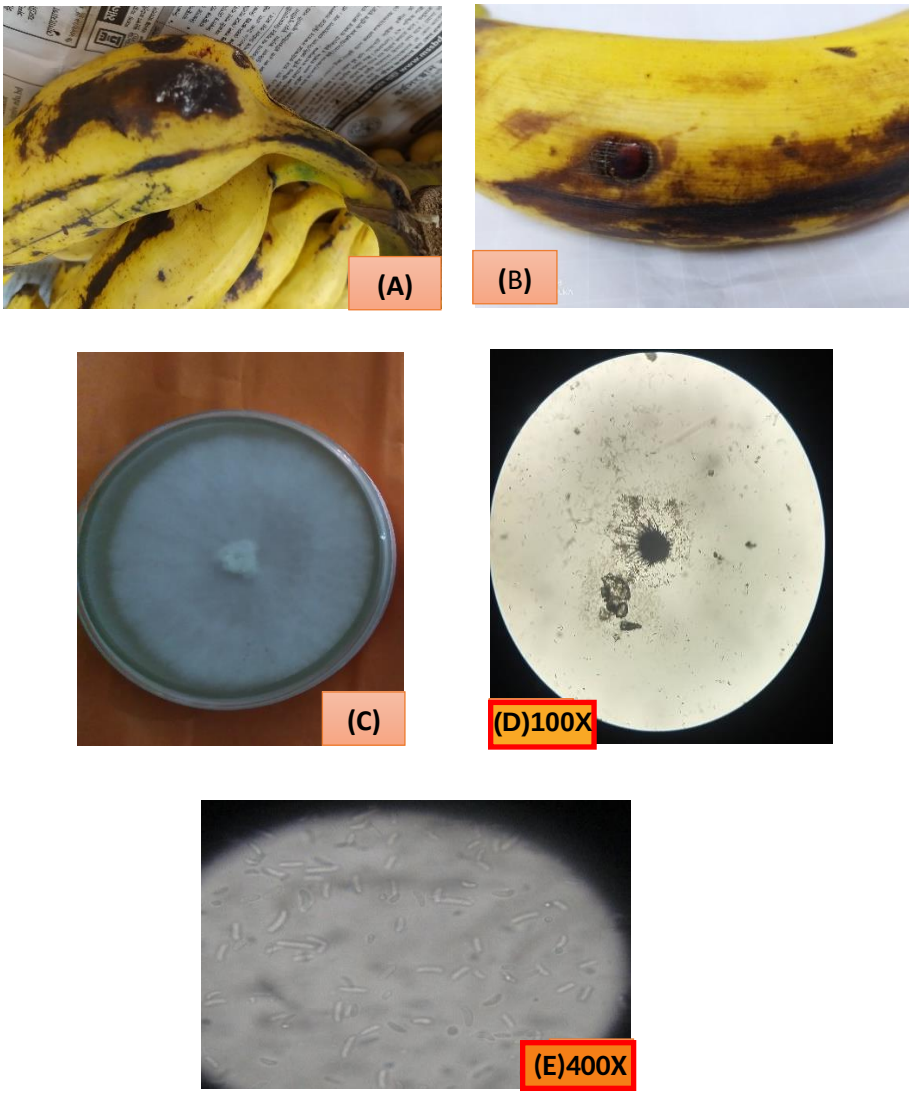


Plate 8. Cultural and morphological view of *C. masae* (A). Banana fruit showing anthracnose (B) Banana fruit showing anthracnose (C) Growth of *Colletotrichum masae* on PDA media (D) Acervulus and Setae of *C. musae* (E) Conidia of *C. musae* isolated from diseased Banana fruit.

4.18.1.2. Identification of *Fusarium spp*. by cultural and morphological characteristics

After 12 days growth on PDA media, it was seen that the culture was growing rapidly. Colonies on potato dextrose agar were greyish black to blackish grey. Mycelia were hyaline. Conidia were dark walled, one septate.

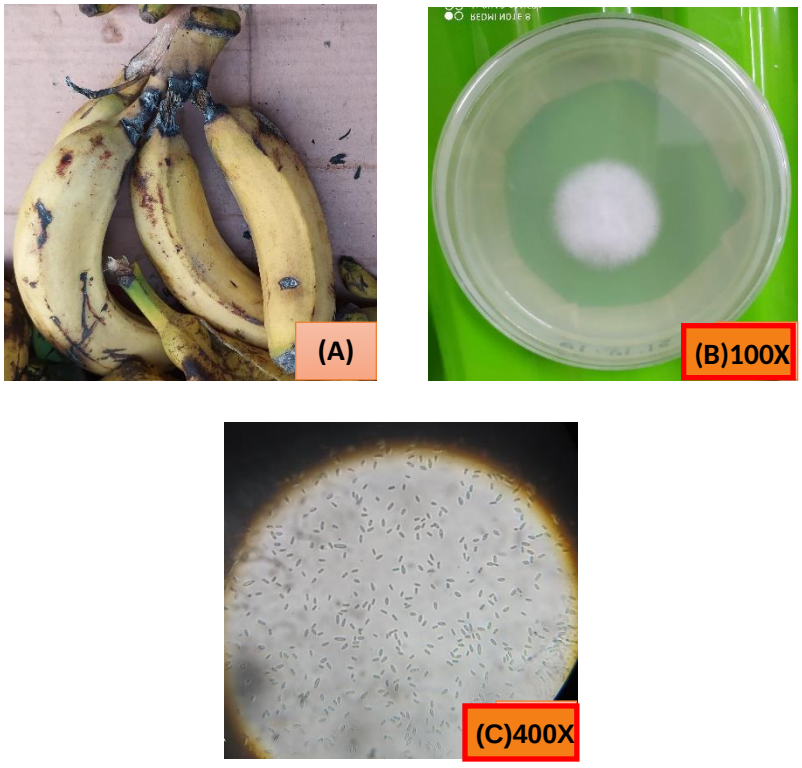


Plate 9. Cultural and morphological view of *Fusarium spp.* (A) Banana fruit showing crown rot (B) Growth of *Fusarium spp.* on PDA media (C). Conidia of *Fusarium spp.* isolated from crown of Banana fruit

CHAPTER V

DISCUSSION

A survey was conducted to analysis banana value chain in order to determine the causes of post-harvest deterioration of produce at farmers and traders level through questionnaire, key informant interview and focus group discussion. Similar survey study on banana cultivation practice and post-harvest value chain were conducted by many other workers around the world; Rahman and Akbar (1989); Rao (1979); Anonymous (2002); Brighton *et al* (2016); Latiffah *et al*. (2013); Flordeliza (2002); (Paull, 1993); Sarkar *et al*. (2009); Nath *et al*. (2015); Jagana *et al*. (2017); Kamel *et al*. (2016); Molnar *et al*. (2015) and Reyes *et al*. (1998). Rich *et al*. (2009) analyzed value chain of banana in combination of qualitative and quantitative methods that included primary survey, focusses group discussions, participatory rapid appraisals (PRAs) and informal interviews. Present study revealed that cultivation area of banana were increased by 47.62% of 21 respondentes in the survey area. According to BBS (2018), in the year 2017-18, banana were cultivated on 121,384 acres of land while it was 120,203 acres of land in the year 2016-17. The production was 807,104 MT in the fiscal year 2016-17 and increased to 810,347 MT in fiscal year 2017-18. This data indicates the gradual increase of production area in Bangladesh. The survey revealed that of the farm size were mostly of 1-2 bigha area and the farmers had 3 to 23 years of experience in Banana cultivation. They cultivated Amritashagor, Sabri, Champa and Kachkola varieties in their farm. Haque (1988) reported that Amritasagar, Mehersager, Sabri, Champa, Chini Champa, Kabuli, Jahaji, Agnishwar, Basrai, Seeded banana, Anaji or Green Banana and Singapure are the most cultivated varieties of Bangladesh. The farmers used Urea, MoP, Gypsum, DAP, MoP as fertilizer during banana cultivation. The highest 61.90% growers used TSP and MoP. The respondents applied Hexaconazole+Mancozeb, Propiconazole and Tebuconazole+Trifloxistrobin groups of fungicides by 19.05%, 47.62% and 33.33%

of respectively. Rao (1979) stated that proper harvesting is also important. Bananas should be harvested at appropriate stage of maturity for transport, handling and storage. It is necessary to delay ripening for distant markets and then enhance ripening for retail sale. Banana producers were not aware of the dangers of poor sanitation in the fields and they tend to be reckless in handling the soft fruit leading to physical damage. The banana bunch management practice in the field such as bagging, tagging, propping were not done by the producers. It was revealed that there is no packaging practices in banana traders. The survey study revealed that, the use of vehicles varied from traders to traders and the length of destination markets. The use of vehicles varied from traders to traders and most of the traders used Local carts, Baskets, van, nosimon and truck. Farmers transported banana by using different local low-cost carriers like rickshaw and van. In the survey we found that, the operations were done in the trader's channel rough unloading, weighing, ripening, and dehanding practices, bananas are heavily liable for impact, compression, bruising, abrasion, puncturing, direct breakage and overheating damages. Poor sanitation, recklessness and improper postharvest handling of bananas were occurred in the channels. In this survey study for 700 bunches of banana (one truck), it was found that the postharvest loss at trader's level was estimated at (30.74%) which consisted of completely damaged banana (29.74%) and partial damaged banana (1.00%). Among intermediaries, the highest loss was recorded for Retailer (23.58%) followed by Piker (1.31%) and Bepari (5.85%). The post-harvest loss of banana at farm level and traders was in total 37.21%.This result was supported by the research Flordeliza (2002) in the Philippines, banana growers incured a huge loss (30-40%) annually because of poor post -harvest techniques adopted by them. Surveys made by Naqvi and Dass (1994) in several districts of Maharashtra India, indicated that 43-47% of the total losses of mandarins in truck and train transport were due to postharvest diseases. Paull (1993) stated that there are considerable problems with postharvest losses associated with storage and marketing. Such losses were prominent and lie in the range of 20–80%. Among

intermediaries, the highest loss was recorded for Retailer (23.58%) followed by Paiker (1.31%) and Bepari (5.85%) in this research area and marketing channel. The result was supported by Slabaugh and Slabaugh (1994) reported that in Caribbean, India, Taiwan and the Philippines, fully mature fruit is more susceptible to infection and the affected clusters ripen earlier. The disease develops faster during ripening and can spread to adjacent fingers. Hassan (2010) reported that the postharvest loss of banana is 24.62% which accounts for 56.7 crore taka annually. The highest reported problem was delayed sale (46.6%) following by lack of buyers (30.0%) and Transportation delay (23.4%) among these three problems. Anonymous (2002) stated that banana and plantain were highly perishable commodities and a combination of high perishability, high ambient temperatures, slow marketing systems and poor market condition lead to huge losses in quality banana in Nigeria. In this survey it was found that, among different traders, Bepari incurred the highest average marketing cost of Tk. 17.58 per 100pcs followed by Faria (Tk. 3.28/100pc) and retailer (Tk.9.21/100pc). Beparis informed that, they incurred the highest costs due to transportation (Tk.14.29/100pc).The highest gross margin was estimated for Retailer (Tk. 365/100 pcs) followed by Bepari (Tk. 145) and Paiker (Tk. 30)). Rahman (1995) conducted a study on marketing of banana of Gabtali and Sariakandi thanas under Bogura district. He estimated the costs and margins of banana marketing. Among the intermediaries, the marketing cost was the highest (Tk. 18.04) for aratdar and the lowest (Tk.9.22) for faria per 100 bananas. The reported banana marketing channel in the study areas was "Farmer—► Faria—►Bepari—►Aratdar—► Retailer —► Consumer". The marketing margin for the channel was estimated at Tk. 102.90 per 100 bananas.

In the survey it was reported that Retailer received the highest net profit (Tk. 365.79) and Paiker received the lowest net profit (Tk. 26.72) for 100 pcs of banana. Rahman and Akbar (1989) conducted a study on banana marketing in Narsingdi district. Their survey period was October 1987. They reported that the profit component in

the margin for all groups of intermediaries was higher than the cost component. The net margin taken by the retailers was reportedly larger. In the survey it was revealed that two major post-harvest diseases called anthracnose by *Colletotricum musae* and banana crown rot by *Fusariem spp.* Chillet *et al*. (1996) stated that in their study on banana found that described anthracnose is the main factor responsible for post-harvest decay of West Indian banana. *Colletotrichum musae* causes anthracnose and is one of the major spoilage organisms of bananas. Wills *et al*. (1989) and Liu *et al*. (1997) also reported that in banana predominant diseases identified were anthracnose caused by *Colletotrichum musae* and crown rot caused by *Fusarium semitectum*. The highest incidence disease was observed for anthracnose 18.73% and crown rot 8.89% at the Retailer shops of Dhaka at the duration August to October. The lowest incidence was observed for anthracnose 2.58% and crown rot 2.08%, at the Doshmile banana market of Dinajpur at the duration November to February. The result was supported by the survey conducted by Jagana *et al*., (2017) for three seasons of the year to record the extent of deterioration in Cavendish, Ney poovan and Sugandhi varieties of banana in Hubballi and Dharwad markets. The mean disease incidence of banana anthracnose was maximum during rainy season (17.53 % in Dharwad & 10.30 % in Hubballi) in all the varieties when compared to winter (7.16 % in Dharwad & 6.56 % in Hubballi) and very low incidence was observed during summer (2.25 % in Dharwad & 2.22 % in Hubballi). Disease severity (per cent disease index) of anthracnose was recorded maximum in rainy season which was more in Dharwad (20.56 %) compared to Hubblli (15.80 %). It is evident that disease incidence was more in rainy season in both the varieties when compared to winter season. This may be attributed to the favorable environmental conditions to pathogen prevailing such as temperature and relative humidity in rainy season. These findings are in harmony with survey reports of Sarkar *et al*. (2009) who concluded that maximum disease incidence of banana fruit rot was observed during August to February. Jagana *et al*. (2017) stated that Crown rot disease was observed only during rainy season survey in all the varieties studied but not noticed

in winter or summer in any of the variety. Among the varieties, Cavedish recorded more crown rot incidence (8.97 %) in Dharwad. While in Sugandhi 8.17 per cent incidence was recorded. Among the varieties, Cavendish recorded maximum disease severity of crown rot (31.42 %) which was observed during rainy season in Hubballi market. This may be due to favorable environmental condition which might have resulted in the build-up of inoculums and thus more the severity in rainy season. Nath *et al*. (2015) reported that seasonal variation in disease incidence was demonstrated and concluded that fruit rot of banana was recorded maximum disease incidence during the months September to June (37 %) in Navasari market of Gujarat. Reason behind the proneness of Cavendish to crown rot might be the mode of storage as it is stored or transported to short distances after the hands were separated from bunch at crown region. The injuries made during separation of hands paves the way for entry of crown rot pathogen. Modification of temperature, relative humidity and atmospheric conditions during pre-storage, storage and transportation are significantly important to control postharvest rots (Kader, 2002; Spotts, 1984). Exposure and storage of banana hands to low temperature i.e. 18ºC significantly reduced the development of all post-harvest rots viz. crown rot, anthracnose and cigar end rot. However, at higher temperatures the fruit became subjected to higher disease severity (%) and grade.

CHAPTER VI

SUMMARY AND CONCLUSION

The study investigated the current banana postharvest handling system in Bangladesh and revealed that the system is lagging behind against global trends. The present research work has been designed considering the following objects:

1. To identify the factors responsible for post-harvest losses in value chain;

2. To identify the pathogen(s) that cause post-harvest diseases of banana in value chain.

Survey study targeted banana producers and banana marketing actors in Dinajpur. Primary data were collected through a questionnaire from key actors like producers, pikers, beparies and retailers in the banana value chain. The banana postharvest handling system from Dinajpur to Dhaka marketing channel was investigated to have a clear understanding. The data collection tools included: Open and closed type questionnaire- key informant interviews; and market visits. In questionnaire survey, the banana farmers and retailers were directly interviewed. Seven banana orchards in every upazilla were randomly selected for survey study. In an average, 250-350 plantations were counted in each banana orchard. The banana growers were categorized into three categories viz. large farmer, medium farmer and small farmer according to their farm size. Each market was visited three times from August, 2019 to February, 2020. Data were collected on types of packaging, mode of transportation marketing cost and diseased banana from each banana market. In the wholesale markets, 10 bunches (having 90-110 bananas) were observed and in the retailer shops 30 bananas were observed for each time. Disease incidence was assessed as percentage of fruits infected with at least one spot or visible symptom. The total number of banana and the number of infected bananas were counted to calculate the disease incidence. Then percentage of fungal (Anthracnose, Crown rot) diseases were calculated in market and in laboratory. The collected fruit samples

were brought to the laboratory for further experiment. Pure colony cultures were obtained by sub-culturing the fungal growth in separate petri-dishes containing the same medium and kept at 4 ºC for preservation and further use. Then isolation and identification of fungal diseases was done in laboratory.

Two fungi viz. *Colletotrichum musae* and *Fusarium spp.* were identified as causal agents of anthracnose and crown rot of banana respectively. The disease incidence of anthracnose 5.78-18.73% and crown rot were 2.34-8.89% in different season. Disease incidence were higher in the months August-October than November-February. The post-harvest loss of banana at farm level and traders was in total 37.21%. The highest reported problem was delayed sale (46.6%) and lack of buyers (30.0%) for unstable supply followed by Transportation delay (23.4%). In value chain analysis constraints like post-harvest losses and storage problem, handling at transportation were identified.

Based on findings of the present survey the following conclusions may be drawn:

- Value chain analysis clearly revealed that banana growing areas are increasing every year.
- The most of the orchards have 250-700 plants and the popular banana varieties grown in Dinajpur district are Amrita Shagor, Sabri and Champa.
- Farmers regularly use manure and fertilizers in banana orchards.
- The respondents applied fungicides from the groups of Hexaconazole, Mancozeb, Propiconazole, Tebuconazole and Trifloxistrobin of fungicide.
- All of the farmers were used to different type activities without maintaining any hygiene to harvest bananas.
- Van and Nosimon are the most common transport for short distance carrying and Truck for long distant carrying.
- The common marketing channel is Grower> Piker> Bepari> Retailer >Consumer.

- Price of banana is dependent on banana varieties and season of harvest.
- Lack of modern storage and transport, processing industries, high margin traders, no use of any packaging system, transport and production cost, and uncertainty of market price were also reported as difficulties in value chain of bananas. The post-harvest loss of banana at farm level and traders was in total 37.21%
- The highest incidence disease was observed for anthracnose 18.73% and crown rot 8.89% during August to October. The lowest incidence was observed for anthracnose 2.58% and crown rot 2.08% during November to February.

To reduce banana postharvest losses several steps might be taken such as more widespread training; awareness-raising amongst value chain actors on the causes of postharvest losses; better infrastructure to connect farmers to markets; more effective value chains that provide sufficient financial incentives at the producer level as well as opportunities to adopt collective marketing and including better technologies.

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CHAPTER VII

APPENDICES

Appendix I. English version Questionnaire used for collection of data from banana farmers

Name: - ----------.

Address: - Vill---------- Upazilla---------- Dist.----------.

(Please help by answering the following questions to collect data about banana production in our country. Give tick (√) marks more than one place, if necessary.)

1. Banana orchard-

Own ☐ Contract ☐

2. Area/ farm size-

a) Increased ☐ b) Decreased ☐ c) No change ☐

3. How many banana plants in your orchard?

a)>10 ☐ b) >50 ☐ c)>250 ☐ d) >700 ☐

4. Which varieties of banana plants are in your orchards?

a. Amrita Shagor ☐ b.Sabri ☐

c. Champa ☐ d. Nepali ☐

e. Deshi ☐ f Any other ☐ (specify)----------

5. Experience in Banana farming: - ----------(years).

6. What kind of pesticides and fertilizers do you use in production season?

i) ----------

ii) ----------

iii) ----------

iv) ----------

7. How many days do you stop using pesticides before harvesting banana?
---------- (days).

8. Generally in which stage, do you pluck banana?

i) Pre-matured ☐ ii) Matured ☐ iii) Over matured ☐

9. How do you pluck the bananas from the plants?
Ans……

10. Which strategy do you follow for packaging Bananas?

(specify)----------

11. Did you grade the bananas before sellig?

Yes ☐ No ☐

12. Which following diseases have you observed in your banana garden?

Anthracnose ☐ Crown rot ☐ Any others ☐

13. What is your selling price?

Ans…….

13. What is your opinion about cultivation of banana?

Date:…… Name and signature

Researcher

Appendix II. English version questionnaire used for collection of data from banana traders

Name: - ----------.

Market Address: - Upazilla---------- Dist.----------.

(Please help by answering the following questions to collect data about banana production in our country. Give tick (√) marks more than one place, if necessary.)

1. Which varieties of banana do you sell?

a. Amrita Shagor ☐ d. Sabri ☐

b. Champa ☐ c. Any other ☐ (specify)------

2. Experience in Banana business: - ----------(years).

3. Write down the availability and price of different mango varieties according to following table:

Banana varieties	Times of availability (Months)	Buying Price (Per 100 pcs)	Selling Price (Per 100 pcs)
Amrita Shagor			
Sabri			
Champa			
Kachkola			

4. Which factors influencing in banana price variation?

a) ---------- d) ----------

b) ---------- e) ----------

c) ---------- f) ----------

5. Which mode of transportation do you use during transporting Bananas?

a) Trucks ☐

c) Pickup ☐

d) Any other ☐ (specify)----------

6. Did you grade the bananas before sell?

Yes ☐ No ☐

7. What are the major Problems in banana value chain?

a)---------- c)----------

b)---------- d)----------

8. Which following diseases have you observed in your mango storage?

i) Anthracnose ☐ ii) Stem end rot ☐ iii) Any others ☐

9. What is your opinion about mango business?

Good Business ☐ Medium ☐ Not good ☐

Date:……. Name and signature

Researcher