VALUE CHAIN ANALYSIS AND POST HARVEST DISEASES OF DIFFERENT CITRUS FRUITS

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CERTIFICATE

*This is to certify that the thesis entitled, "**VALUE CHAIN ANALYSIS AND POST HARVEST DISEASES OF DIFFERENT CITRUS FRUITS**" submitted to the Department of Plant Pathology, Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirement for the degree of **MASTER OF SCIENCE IN PLANT PATHOLOGY** embodies the results of a piece of bona fide research work carried out by bearing Registration No. **19-10341** 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 sources of information, as have been availed of during the course of this investigation has duly been acknowledged.

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Dedicated

to

My Beloved Parents and Supervisor

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The author

VALUE CHAIN ANALYSIS AND POST HARVEST DISEASES OF DIFFERENT CITRUS FRUITS

ABSTRACT

A survey study was conducted to analyze citrus value chain and identify different citrus diseases at farm level and trader level. The survey was conducted during the periods of August 2020 to February 2021 in the Sylhet and Dhaka district of Bangladesh. Three upazillas namely Jaintapur, Khadimnagar and Sylhet Sadar were selected for collection of information on farm practices and disease faced by those area's growers. Sylhet Kodomtoli wholesale market, Mohammadpur Krishi market, Karwan bazar and Retailer shops (Taltola, Mirpur 1, farmgate) at Dhaka city were studied for value chain at marketing. The survey revealed that citrus growing areas were increased. Most of the farmers were medium sized (46.66%) and farmers have 5-15 years' experience in citrus cultivation. The common varieties grown in that selected areas were Elachi lemon, Zara lemon, BARI malta and Orange (BARI Komla). For transportation harvested citrus fruits, Beparies mostly used mini trucks. Traders(retailer) used van (60%) and local carts (15%) for transporting their citrus in the marketing channel. Disease incidence varied from variety to variety and upazilla to upazilla. Highest canker incidence (52%) was found in khadimnagar in Elachi lemon and highest Citrus scab incidence (31%) was found at Jaintapur in BARI malta. At post-harvest stage, highest citrus blue mold incidence (12.3%) was found in retailer shops at Dhaka city and citrus green mold incidence (16.6%) was also found in retailer shops at Dhaka city. Citrus blue mold incidence (3%) was found lowest in kodomtoli wholesale market, Sylhet district and citrus green mold disease incidence (4.1%) was found lowest at karwan bazar market, Dhaka. In our study revealed that highest marketing margin gained by retailer level for BARI malta (1254.21tk/quintal)

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ABBREVIATION AND ACRONYMS

SAU	Sher-e-Bangla Agricultural University
BBS	Bangladesh Bureau of Statistics
USDA	United States Department of Agriculture
WHO	World Health Organization
FAO	Food and Agricultural Organization
MS	Master of Science
CRD	Completely Randomized Design
et al.,	And others
Viz.,	Namely
e.g.,	exempli gratia (L), for example
Etc.,	Etcetera
i.e.,	id est (L), that is
%	Percentage
°C	Degree Celsius
mg	Milligram
l	Liter
cm	Centimeter
ml	Milliliter
NA	Nutrient Agar
Kg	Kilogram (s)
No.	Number
PDA	Potato Dextrose Agar

CHAPTER I

INTRODUCTION

Citrus is the popular name for the edible fruits of this genus and is a flowering plant in the Rutaceae family. Numerous citrus species, including oranges, mandarins, lemons, grapefruits, limes, pummelos, kumquats , citrons and numerous hybrids that are also commercially significant, are grown all over the world (Strano *et al.*, 2017). Citrus is one of the most significant fruit crops in the world, grown in even more than 125 nations between latitudes 35° and 36°, where the environment is ideal and the temperature ranges from 4° to 50°C (Naz *et al.*, 2014). In Bangladesh, where the soil and environment are favorable for citrus fruit growth with lots of water and a humid climate, orange is considered one of the most promising citrus fruits. In Bangladesh, it is mostly grown in mountainous locations, while it is also grown in certain lower, well-drained places. Citrus (genus Citrus; family Rutaceae) is one of the most widely cultivated and consumed fruit crops globally (Denaro *et al*., 2020), and citrus fruit are abundant in a significant number of nutritional components that contribute to the human diet (Liu *et al.*, 2012). The most popular and lucrative citrus varieties include orange, lemon, lime, grapefruit, and tangerine (Liu *et al*., 2012). Citrus is cultivated in tropical and subtropical dry or humid climates with hot days and chilly nights, limited exposure to extended cold temperatures, or relatively little frost. These climates range in temperature from 248^0F to 388^0F on each side of the equator. (Melese Ashebre, 2015) said Citrus fruits are the most valuable in the global fruit trade and are grown over the biggest area of all horticulture crops. Citrus fruits are an abundant source of vitamins and minerals. Regular consumption of it helps to avoid the symptoms of the scurvy illness. Citrus fruits also have a high potassium content and a low nitrogen concentration (Gallasch *et al.,* 1984). Citrus juice's medicinal value is due to the extremely favorable potassium to nitrogen ratio (McHard *et al.,* 1980). The demand for copper is significantly better met by sweet orange juice than the requirement for zinc. Citrus fruits and products are clearly very helpful in achieving necessary

daily allowances and preventing even the preclinical symptoms of their deficiencies, as evidenced by the levels of vitamin C, B, and folic acid (Breeling 1971). Citrus fruits are a great source of bioactive chemicals including vitamin C, phenolic compounds like hydroxycinnamic acids and flavonoids, and vitamin A. Flavanones and anthocyanins are the two main types of flavonoids in citrus, and they are mostly found in the colored variety. The anthocyanins play a significant role in their pharmacological and antioxidant effects in addition to providing a vital sensory input. The benefit of eating fresh fruit is attributable to certain of these components' anti-autistic qualities, which are linked to lower risks of cancer, heart disease, and stroke (Chen *et al.*, 2019). There are also significant phytochemicals such as folacin, potassium, calcium, thiamine, niacin, synephrine, polyphenols, hesperidin flavonoid, and pectin in adequate amounts. By preventing cancer, arteriosclerosis, stomach ulcers, kidney stones, high blood pressure, and a decrease of cholesterol levels, these biologically active substances improve human health (Etebu & Nwauzoma, 2014).

Among the various varieties of citrus fruits grown in Bangladesh, the lemon is one of the most significant. It is one of the most expensive fruits in terms of global trade. Lemons thrive in areas with sufficient irrigation or rainfall to maintain growth, as well as mild enough winters to not injure the trees. In general, lemons contain a lot of citric acid, which ranges from 4.52 to 5.82 percent. Lemon is a member of the Rutaceae family and the genus *citrus*. In terms of productivity, citrus surpasses grape, apple, and banana as the most frequently cultivated fruit crop worldwide (Hasan *et al*., 2021). Around 24 million tons of the 121 million tons of citrus produced worldwide in 2015—mostly in the Mediterranean region, which includes Spain, Egypt, Turkey were largely headed for the fresh fruit market (Strano *et al.*, 2017). According to (Hasan *et al*., 2021), About 69132 M. tons of lime and lemon are cultivated in Bangladesh each year. In 2019, Bangladesh produced 165,327 tons of citrus fruit. Citrus output in Bangladesh has steadily increased in recent years. Citrus output increased by 2.3% year between 1992 and 2002, reaching over 110 million tons per year over an area of around 18.7 million acres, with lemon and lime

production accounting for 13.7 million tons of that total. From 1970 to 2019, Bangladesh's citrus fruit output climbed from 23,513 tons to 165,327 tons, expanding at an average yearly rate of 5.06%. According to Yearbook of Agricultural Statistics-2019 (BSS), Total Production of orange In 2016-17, 3372 (M.Ton), in 2017-18, 3315 (M.Ton), in 2018-19, 3393 (M.Ton) in the area, 1055 ,220650 and 45342 Acres respectively. Total Production of lemon In 2016-17,17-18 and 18-19 were 69132 M ton,67077 M.ton and 67077 M.ton with the area 6371, 4425 and 158842 Acres respectively. Again the highest production was found in Chattagram division with 15808, 16263, 16263 M.ton, respectively (BBS, 2020).

Year after year, citrus fruit output in Bangladesh increases significantly. Despite the fact that lemons may be cultivated well across the region, the majority of the output is centered in the districts of Sylhet, the Chittagong Hill Tracts, Chittagong, Rajshahi, and Maulavibazar (Hasan,2016). Tangail,The mountainous, well-drained regions of Panchgarh, Thakurgaon, and Gazipur in Cox's Bazar, as well as certain other places of Mymensingh, Narshindi, Sherpur, and Netrokona districts, show potential for citrus fruit development. Among them, the climate of the Tangail district is excellent for cultivating lemons. Delduar, Modhupur, and Mirzapur upazilas are widely recognized for producing high-quality lemons, claims Manik (Manik,2021). According to (USDA, 2020), due to excellent weather in Brazil and Turkey, global orange output is predicted to increase by 1.8 M. tons from the previous year to 49.0 M tons in 2021/22. Production in Brazil is anticipated to increase by 15% to 16.9 M.tons. Lemon is crucial in terms of nutrition, particularly in terms of vitamin C. Each person needs 30 milligrams of vitamin C every day. According to reports, 90.0% of Bangladesh's population lacks enough vitamin C (BARC,1995). According to (Ahmad *et al.*, 2018), the quality has been declining over the past several years as a result of a number of factors, including the uneven use of fertilizers, the presence of disease, and subpar post-harvest management. Most citrus diseases are spread via nurseries. The most detrimental ailment, according to them, was citrus canker. The lack of storage space, peak season oversupply and output, low-

quality seed, expensive inputs, afflicted by illnesses, insect infestation inadequate technological assistance lower production costs, The problems faced by citrus producers in Bangladesh include damage resulting from many causes and a lack of workers during harvest (Begum & Marium, 2022). Citrus fruit postharvest losses and deterioration can be brought on by infections that happen between blooming and fruit maturity or during harvesting and the subsequent handling and storage procedures (Ahmed, 2022). Losses during transit and storage are significantly higher in impoverished nations like Bangladesh where fresh fruit is not adequately handled or kept accounting for up to half of the generated fruit harvests. Due to their low pH, increased water content, and nutritional value, oranges are particularly susceptible to pathogenic fungus, which poses a significant impediment to their long-term production and storage (Ahmed, 2022). Post-harvest losses of fruits and vegetables, for instance, are estimated to be between 20 and 40% in developing countries (Ngowi, and Selejio,2019); for a number of fruits, such as apples, bananas, avocados, citrus, papayas, and grapes. Bangladesh they are estimated to be between 20 and 25 percent (Mollah *et al.*,2018). These losses for perishable fruits and vegetables might reach 40%. Poor packaging, a lack of quantity planning, and excessive handling by farmers, merchants, and consumers are the main sources of post-harvest losses in both developed and developing countries (Lebersorger, and Schneider,2014). Postharvest phytopathogens cause significant fruit and vegetable losses during storage and marketing, accounting for a sizable portion of the overall yield (Sanzani *et al.,* 2016). One of the most significant fruit crops in the world is citrus, and before they are ready for the market for fresh consumption after storage, they are especially vulnerable to postharvest damage (Moscoso-Ramirez and Palou, 2013). Fourteen citrus diseases with medium to higher prevalence and severity were discovered in Bangladesh out of the 25 citrus illnesses that exist worldwide (Uddin *et al*., 2014). However, the impact of bacterial diseases (citrus greening, citrus canker), fungal diseases (blue mold, scab, citrus black spot, powdery mildew), viral diseases (citrus tristeza, citrus

ringspot) as well as nematodes restrict citrus production, nutritional value, and market qualities (Etebu *et al*., 2014).

The present study was conducted to determine the disease incidence of major citrus disease both farm level and traders' level with a view to analyze postharvest losses in Citrus value Chain in Bangladesh to promote, support and implement good practices in order to minimize postharvest losses and improve quality and safety in Citrus value chain. Therefore, the study was conducted with the following objectives:

1. To study farmers' practices of citrus production in selected areas of Bangladesh.

2. To identify the post-harvest diseases and their causal agent of citrus in selected markets.

3. To analyze the causes of deterioration in post-harvest value chain.

CHAPTER II
REVIEW OF LITERATURE

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

Hanif & Ashari (2021) conducted survey study in 2017 in the Dau Subdistrict, Malang Regency, East Java, in order to understand citrus fruit losses and farmer views of marketing choices. This survey included 177 citrus producers in total. Food loss and waste among citrus producers was 34% of all activities. Farmers faced food loss and waste of 13%, 10%, 4%, and 7%, respectively, from the value chain activities performed by the majority of citrus farmers: production and harvesting, handling and storage, processing and packing, as well as distribution and markets. Farmers' opinions of selling citrus fruits, particularly pricing, cash payments, and the regularity of citrus fruit deliveries, had an impact on postharvest losses.

Ahmed *et al*. (2020) conducted a case study on at multiple citrus orchards in Sylhet, Bangladesh to determine the prevalence and severity of illnesses affecting several citrus species. In this study, 560 plants from 17 citrus species underwent careful observation to gather information on disease infection. The scab of citrus showed the maximum incidence in BARI satkara-1(50%). Elachilemon was found highly infected by canker of citrus showing 65% and 36% of incidence and severity, respectively.

BBS (2020) reported that the growers in Bangladesh cultivated 167104 tons in fiscal year 2019-20. In 2018-19, 165,327 tons of Citrus was produced.

According to Zacarias *et al*. (2020) throughout harvest, transportation, and post-harvest handling, some of the most significant post-harvest pathogens enter the fruit via rind wounds or lesions. *Penicillium digitatum* and *Penicillium italicum* which are two examples of these wound infections. They are the respective causes of blue and green mold.

According to Ahmed *et al.* (2020), rough lemon was found to be highly infected (95%) by greening. On the other hand, the percent disease index was the highest in BARI malta-1 (49%) followed by Jara lemon (37%) and the lowest was found in China lemon (3%).

According to Knoema (2019), Citrus production in Bangladesh has been gradually increasing over the years. In 2019, Bangladesh's citrus fruit production was 165.327 tons. Citrus fruit in Bangladesh grew from 23,513 tons, in 1970, to 165,327 tons, in 2019, with an annual average growth rate of 5.06%.

Lado *et al.* (2019) stated Citrus fruits are very susceptible to developing a variety of physiological peel problems, or peel blemishes, which are characterized by various morphological signs that may arise before or after harvest. Different pre- and post-harvest environmental conditions can damage fruit surfaces, which shows up as bruises, darkening of the cells, and browning. In fruits of the many citrus species and types, more than 70 distinct physiological abnormalities have been documented

Ahmad *et al*. (2018) stated that About 30–35% of the fruit is lost due to inadequate orchard management, which is followed by poor harvest and post-harvest procedures. The central markets that are governed by the government serve as the foundation of the conventional marketing systems in emerging nations The findings demonstrated that farmers cultivate citrus utilizing conventional techniques, such as the utilization of widely dispersed planting materials and minimal irrigation and chemical input. Fruits are frequently sold fresh since there is little value addition and processing is still a significant missing component. In general, there is a lack of trust among participants and poor coordination along the value chain. The availability of high-quality planting materials, processing for value addition, and the formation of commodity innovation platforms present prospects for enhancing the citrus value chain.

Usman *et al.* (2018) also reported the monopoly of the middleman, inadequate storage facilities for citrus fruits to extend their shelf life, late payments provided

by dealers once the produce is sold by the producer, a lack of and inadequate transportation facilities, disease, etc. are some additional marketing challenges that citrus grower have to deal with.

According to Porat (2018) up to one-third of the food produced worldwide is lost or destroyed through poor harvesting process, lack of post harvest knowledge and techniques, diseases etc.

Ullah *et al.* (2017) reported that Agriculture and horticulture goods are transported from producers to consumers via marketing channels. Depending on the quality that has to be transferred, the kind of customer demand, and the level of regional production specialization, the length of the channel varies from commodity to commodity. There are several market intermediates functioning at different marketing phases. Citrus must be harvested, packaged, stored, and processed at the suitable time and using the right procedures due to its perishable nature. The difference between the producer's income and the final consumer's price, known as the "marketing margin," is significant. Less money goes to citrus growers thanks to the larger marketing margin, while intermediaries who participate in citrus marketing get more. The expenses and profits incurred by the different market intermediaries participating in the citrus value chain must thus be determined

According to FAO (2016), Bangladesh ranked 52nd in the world, contributing about 0.1% of total citrus production.

According to Musasa *et al*. (2015) postharvest losses in the field, during transit, and at the market, respectively, totaled 36%, 3%, and 42%. All told, there were 81% post-harvest losses, with a monetary worth assessed at US$ 11.003.126.40. There was a strong correlation between the farmers' assessment of the prevalence of pests and diseases in their sweet orange crop and the reported postharvest losses

Montaigne *et al.* (2015) stated that ‘Fruit agriculture value chains' competitiveness in a global market is crucial. This is particularly true given that

plants are perennial, and changes occur gradually. These value chains are flexible and alter over time as a result of numerous restrictions and goals, primarily in export-related industries.

Iqbal & Kamal (2014) stated that Less utilization of high-quality citrus farming methods is the primary issue affecting the citrus supply chain. Instead of seeing orchards as a venture, farmers saw them as extra crops to be grown in the field. Because they intercrop diverse crops in citrus orchards, they are unable to meet the demand for kin now crops when they are needed, which results in negative losses for the citrus plants and productivity.

Musasa *et al.* (2013) stated that postharvest losses might happen at any point along the supply chain, it is necessary to look at the whole supply chain when estimating the losses. For farmers, postharvest losses for food lost after harvest can be measured in absolute terms and then estimated as a percentage based on the total quantity gathered It is less expensive to control and/or avoid postharvest losses than it is to produce an equivalent quantity of fruit loss. Another factor that contributed to postharvest losses, both qualitatively and quantitatively, was insect infestations. Citrus black aphids (Toxoptera aurantii Boyer de Fonscolombe), fruit flies (Tephritidae), leaf-miners (*Agromyzidae spp.),* and red weaver ants (*Oecophylla spp*.) were the pests that were identified (Hymenoptera: Formicidae). Fruit flies were the insect pests pointed out by 54% of the farmers interviewed as the worst issue in their orchards.

Haque (2012) stated that in the Value Chain Analysis (VCA), the term "value" is synonymous with "value added" since it describes the additional value of a product that is created after it has been processed. Value addition for agricultural goods may also occur through product diversification based on food safety and functionality. The cost of the finished product demonstrates its added value. The word "chain" refers to a supply chain, which describes the steps and participants in a product's life cycle from creation to disposal.

Neves & Trombin (2012) reported that there is little question that citrus disease is among the most significant hazards to Brazilian citrus farming. Four diseases—citrus canker, CVC, sudden death, and greening—accounted for the deaths of 39 million trees in the citrus belt during the course of the previous ten years. When taking into account an average productivity of two boxes per tree, this raised the mortalityrate from 4.5% to 7.3%, lowering yearly production in about 78 million boxes of 40.8 kg.

According to Nawaz *et al.* (2011) analysis, citrus producers believed that a lack of professional help, a lack of better varieties, a lack of irrigation facilities, disease attacks, and natural disasters (such as floods) were the main causes of their low output.

El-Otmani *et al.* (2011) stated that the majority of citrus fruit diseases that arise during post-harvest handling, storage, and management are brought on by bacteria, viruses, and virus-like organisms. These microbes cause fruit to become contaminated, and damaged plants may exhibit specific symptoms. *Pseudomonas syringae*, which causes extensive black pitting of fruit, and *Xanthomonas campestris*, the cause of citrus canker, one of the most damaging diseases in citrus, are the principal pathogenic bacteria infecting citrus fruits. The most common post-harvest diseases of citrus fruits are *Penicillium digitatum* (green mold) and *Penicillium italicum* (blue mold), which are both found globally. Blue mold is far more common than green mold, and depending on the situation, the losses caused by these fungi can account for up to 80% and 30% of the total post-harvest pathogen-related waste, respectively.

Pandey *et al.* (2011) studied marketing of sweet orange in Kumaon of Uttarakhand of India and found six types of marketing channels.

Channel I: Producer-village traders- primary wholesaler-Secondary wholesaler-retailer- consumer

Channel II: Producer- village trader- wholesaler- retailer- consumer

Channel III: Producer- wholesaler- retailer- consumer

Channel IV: Producer- wholesaler-consumer

Channel V: Producer- retailer- consumer

Channel VI: Producer- consumer

According to Joshi & Gurung(2009), Producers, processors, distributors, brokers, wholesalers, retailers, and consumers are typically included in value chains in groups of three or more, the value chain idea is viewed as an actor-oriented strategy that is particularly successful in tracking product flows, illuminating the phases of value addition, identifying key actors, and establishing connections with other actors in the chain. They also noted that the most significant issues in the citrus value chain are: (i) a large impact of pests and diseases, (ii) low yields, (iii) a poor input supply (seedlings, fertilizer, irrigation, agricultural chemicals), (iv) a lack of knowledge and skills resulting in poor management of orchards, (v) a lack of infrastructure (road networks, collection centers/packinghouses/grading facilities), and (vi) limited access to cr The majority of these restrictions are connected .

Palou (2009) noted that the level of physical damage to the fruit during harvest and subsequent handling, the efficiency of antifungal treatments, the postharvest environment, citrus variety, tree age and condition, and the region of production all have a role in the actual losses caused by these illnesses.

Reddy et al. (2008) said post-harvest illnesses are more likely to affect sweet oranges sold in stores. It was found that the level of damage in India ranged from 25.5% to 36.8% in acid lime and 29.9% to 43.8% in sweet orange.

Cadilhon *et al*. (2006) and Sagheer *et al.* (2009) highlighted the contributions made by different participants in the food value chain to product quality. Both studies demonstrate how decisions made at the farm level affect the quality of the farm product and, as a result, how it is marketed in international markets in accordance with the criteria necessary for marketing.

Lafuente and Zacaras (2006) stated that the most popular and effective method for extending citrus fruit's postharvest life is low-temperature storage. In addition, cold exposure below 2°C is necessary during quarantine procedures for export to a number of markets.

Dhakal *et al*. (2005) found following four types of marketing channel in the market survey of acid lime and hill lemon in Nepal which were

Channel 1. Producers- Retailers- Consumers

Channel 2. Producers- Wholesalers-Retailers-Consumers

Channel 3. Producers- - Commission agent- Wholesaler- Retailers-Consumers and

Channel 4. Producers- Collectors -wholesalers- Retailers- Consumers.

Malik *et al*.(2004) stated that Citrus is typically thought of as a less perishable fruit than mango, lychee, loquat, and fresh figs. However, in reality, the industry suffers significant post-harvest losses as a result of carelessness and improper handling during the processes of harvesting, storing, transporting, and marketing, which result in fruit bruises and injuries, various physiological disorders, and fruit decay throughout the chain of storage and marketing.

According to MDD (2001) agricultural marketing includes all processes from production to consumption, including harvesting, grading, packing, storage, price fixing, selling, and buying. By carrying out these tasks, the product gains value in terms of time, location, and farm utilities. It also discusses organizational structures, norms and regulations, market competition, and marketing costs.

Wilson *et al.* (1991) indicated that When fruits and vegetables are handled, packaged, stored, and transported improperly, bacteria can degrade and develop as a result of the fruits and vegetables' changing physiological states.

Grierson (1986) said the aging process known as SERB happens in the majority of citrus fruits. During storage, the skin around in the stem wilts & dries out in uneven, depressed, brown regions. It can show up in the field itself in overripe fruit. The lack of K and N in the orchard's nutrition may also make the fruit prone to this illness.

According to Grierson (1981) a number of pre- and post-harvest factors, such as nutritional deficiencies (Cu, B), sunburn, rind staining, wind blemish, puffiness, granulation, oleocellosis, peteca, stylar end breakdown, watery breakdown, chilling and freezing injury, among others, contribute to the development of various physiological disorders that affect citrus fruit quality.

Kanashiro *et al*. (2020) the fungus P. italicum is one of the principal pathogens responsible for post-harvest illnesses in oranges, according to It causes major declines in fruit output and has a direct impact on the economies of many nations, particularly Brazil, which is the world's largest producer and exporter of this good.

The results of Ahmed *et al*. (2020) revealed that the severity of the scab illness was moderate, with an incidence of 20 to 55% and a severity range of 3 to 22%. Sweetorange and Jaralemon had the lowest susceptibilities to the scab disease, whereas BARI lemon-1 had the most. Lime, Pomelo, Ashkorlemon, BARI Satkara-1, and other fruits and vegetables also shown comparably increased susceptibility. The species sweet orange and Jaralemon both had the lowest rates of infection, with a disease incidence of 15% and severity of (3%), compared to BARI lemon-1, which had a disease incidence of 55% and a disease severity of 11%. They also reported that Alachilemon has the greatest incidence of citrus canker disease (65%), followed by Jaralemon (60%), Lime (60%), Sweet orange (55%) and Long jaralemon (45%), while Chinalemon has the lowest disease incidence (17%) In terms of disease severity, Elachilemon was found to have the highest prevalence (36%) while BARI batabilemon-3 had the lowest prevalence

(3%), according to a study carried out in Sylhet, Bangladesh, in several citrus farms between November and December 2014.

Papoutsis *et al*. (2019) reported that blue mold disease causes affected rind tissue to lose smoothness, making it more susceptible to mechanical damage, and giving the fruit a watery, drenched look.

Sarker *et al.* (2017) reported that Citrus scab is a widespread issue around the world, especially in Asia's tropical and subtropical regions, depending on the environment. The ideal temperature range for the disease's infection is between 21 and 27 °C, while it may potentially live in a larger range (18 to 30 °C) (FFTC, 2018). Citrus scab has a strikingly negative impact on output, quality, and market value.

Melese Ashebre (2015) stated that *Penicillium italicum*, a fungus pathogen, is the culprit behind blue mold. Blue mold is caused by *P. italicum*, which infects citrus fruit through wounds. The abundance of blue spores that blue mold produces in rotting fruit makes it easy to identify. Initial lesions resemble green mold lesions, but the spores are blue and are encircled by a thin ring of white mycelium that is bordered by water-soaked rind. Green mold is frequently seen in mixed infections because it grows more slowly than blue mold does in ambient circumstances. Fruit kept in cold storage throughout the summer is more frequently affected by blue mold, which spreads more quickly in packed cartons than green mold. It occurs anywhere in the world that produces citrus.

According to Louw and Korsten (2015) *P. italicum* caused severe lesions on lemon fruit stored at room temperature also having the capacity to produce minor lesions under refrigeration conditions.

Spósito *et al.* (2011) stated that Citrus scab, which predominates in most humid citrus-producing regions, is a significant disease that causes fruit blemishes by growing lesions on citrus fruits, leaves, and twigs

Hyun (2009) reported that *Elsinoe fawcettii*, *S. fawcettii* var. *scabiosa*, and *E. australis* are three scab-causing organisms.

Palou *et al*. (2008) and Talibi *et al.* (2014) stated that the fungus *P. digitatum* and *P. italicum,* which produce the green and blue molds, respectively, are members of the Trichocomaceae family and the order Eurotiales.

Macarisin, D *et al. (2007)* reported that postharvest green mold, which is the main factor resulting in citrus fruit decay, leads to huge economic losses worldwide every year and can account for up to 90% of the total citrus postharvest losses, especially in arid zones and subtropical climates.

Das (2003) stated that citrus canker is one of the most destructive agricultural pests and illnesses that endanger citrus crops. Large parts of the nations that cultivate citrus across the world are affected by the illness, which is brought on by the bacterium *Xanthomonas axonopodis* pv. *citri*. The most harmful of them is the Asiatic type (Canker A), which damages the majority of the important citrus varieties. A severe disease infection causes a number of symptoms, such as defoliation, dieback, badly discolored fruit, decreased fruit quality, and early fruit drop. The illness is promoted by a warm, humid, gloomy climate, heavy rains, and high winds.

Agostini *et al.* (2003) stated that Citrus scab, which is brought on by *Elsinoe fawcettii,* results in surface flaws on citrus fruit and lowers the fruit's acceptability for the fresh market. Scab was much less severe at 17, 20, 30, or 32°C and more severe at temperatures between 23.5 and 27°C. Fresh leaves, twigs, and fruit are all affected. Scab normally has little impact on yield but has a significant impact on the fruit's outward look and therefore on its suitability for fresh market.

Schubert and Miller (2002) stated that Infestations of citrus canker-A have been documented in Florida since 1986, in the Gulf States about 1910, and in the Gulf States between 1986 and 1997. They also stated that Citrus-growing regions

with warm, muggy weather are those where citrus canker develops most frequently and severely.

Gottwald *et al.* (2002) Bacterial canker has been a limiting factor in profitable cultivation of acid lime in India. Recently the citrus canker pathogen and its impact has been reviewed comprehensively.

Civerolo (1994) stated that in tropical and subtropical regions when it is hot and rainy at the same time of year, citrus canker is most common. On the other hand, citrus canker has also spread to countries in southwest Asia, including Yemen, Iran, Iraq, Oman, Saudi Arabia, and the United Arab Emirates.

According to Vauterin *et al.* (1995) citrus canker disease is caused by three distinct pathovars and variations of the bacteria *Xanthomonas axonopodis*. Geographical distribution and the pathogen's host range are the primary factors used to differentiate these types (Stall and Seymour, 1983). The most prevalent type of canker is the one that occurs in Asia and is caused by *X. axonopodis* pv. *citri* (Hasse) Vauterin (Xac) commonly known as canker A (or true canker). False canker, also known as cancrosis B, is brought on by *X. axonopodis* pv. *aurantifolii* (Hasse).

According to Goto (1992) Citrus canker is a bacterial disease that affects the majority of commercial citrus species and cultivars as well as some citrus cousins. He also stated that the disease affects the leaves, twigs and fruits causing the leaves and fruits to drop before it ripens.

Mandal (1981) has reported from West Bengal that upto 35% loss due to Penicillium species alone in sweet orange

Whiteside (1975) discovered that 24 to 28°C was the ideal temperature for rough lemon leaf infection by canker in citrus.

According to Fawcett and Jenkins (1933), Findings point to the disease's tropical Asian origins, including South China, Indonesia, and India, where it is thought

that the citrus species originated and were spread to other citrus-growing regions in the form of budwood.

According to Fawcett (1921), *E. fawcettii* grows best at 21°C, while sporulation on sour orange leaves occurs best between 21 and 27°C.

There is debate concerning the citrus canker's geographic origin. According to Lee (1918), it may have originated in southern China, and the wild host plant is likely Fortunella hindsii. Citrus canker, however, was said to have originated in India and Java rather than other parts of the world.

CHAPTER III

MATERIALS AND METHODS

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

3.1.1 Survey period and sampling procedure

A survey was conducted during 2020-21 citrus production season to find out present status of cultivation practices, determine the major citrus diseases, marketing procedure and to analyze citrus value chain. For the survey, a deliberate sampling method was used to collect data on citrus yield and loss from post-harvest illnesses, a pre-designed open and closed type questionnaire was used. Direct interviews with citrus producer traders (Bepari, Wholesaler, retailer) was conducted as part of a questionnaire survey.

3.1.2 Survey on citrus orchard

The Sylhet District, which is well-known for cultivating citrus in Bangladesh, was chosen for this study. Three upazillas in the Sylhet district were chosen namely Jaintapur, Khadimnagar, and Sadar where five grower's field in each upazila were randomly chosen for the survey. In questionnaire survey data on Farm size, farm area increased or decreased, types of citruses under cultivation, types of diseases faced by farmers etc. were collected. In this survey study, 50 plants per orchard (15 orchard in total) were observed in Sylhet district for showed citrus canker and citrus scab disease infestation at the farm level (Plate 1).

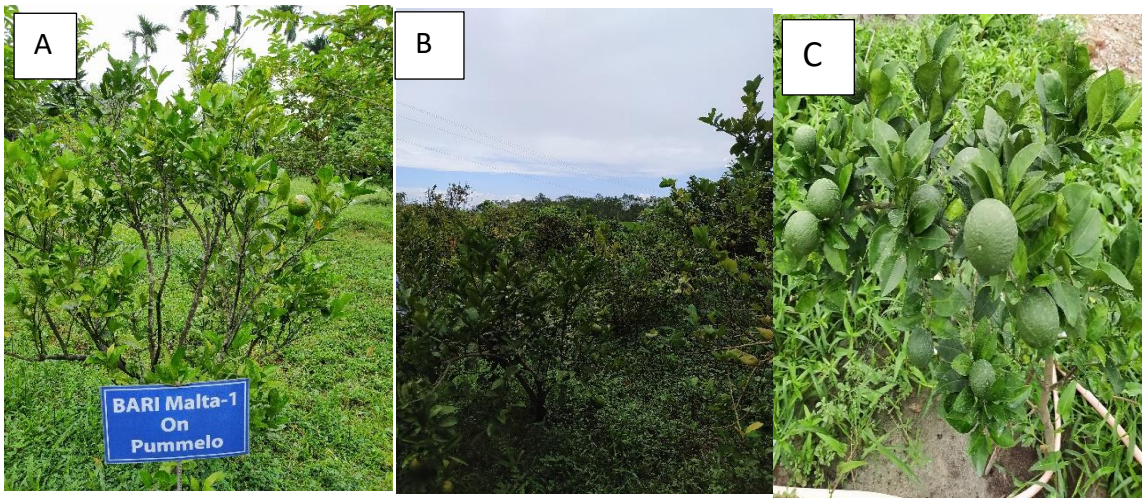


Plate 1. Citrus Orchard A. Jaintapur B. Khadimnagar. C. Sylhet sadar

3.1.3 Survey on Citrus Market

Three noted wholesale markets of Sylhet and Dhaka were surveyed for the study viz. Kodomtoli wholesale market at Sylhet, Kawranbazar Market, Mohammedpur Krishi Market as well as retailer's shop (Farmgate, Taltola, Mirpur 1 market) in the district of Dhaka. The survey was conducted between June 2020 and May 2021. From each market, information was gathered on the different forms of packaging, the cost of marketing, the mode of delivery, diseased citrus fruits etc. In the wholesale markets, average 20kg (110 pieces) citrus are observed for BARI komla and BARI Malta and for Elachi and Zara lemon (200) pieces in one small bag were observed. In the retailer shops average 50 fruits were observed randomly for both orange and lemon to identify citrus green and blue mold. For estimation of damaged fruit to healthy fruit, we observed approximately 50000 pieces of citrus in one truck where each cartoon contained 100-110 citrus fruits(oranges) and 45-50 cartoons in one truck (Plate 2).

Plate 2. Survey on citrus market at Local market (A, B, C) at Dhaka city

3.2 Assessment of Disease Incidence

The prevalence of the disease was calculated as the proportion of fruits with at minimum one visible spot or symptom. Number of infected citrus fruit and total number of citrus fruits were counted to estimate the disease incidence. By this formula Percent disease Incidence (PDI) was calculated

$$\% \text{ Disease incidence} = \frac{\text{Number of disease fruits}}{\text{Total no. of examined}} \times 100$$

3.3 Varieties of Citrus observed in field and traders' level (Table.1)

During the survey, the respondents reported that the most popular varieties in sylhet district were Zaralebu, Elachi lebu, Bari malta, BARI komla.

Variety	Caharcteristics
1. Zara Lemon	Average 500-600 gm per piece, in Bangladesh Jaintapur district is famous for its cultivation
2. Elachi Lemon	Elachi lemon is famous in our country for its smell, it is 2-4/5 inches in size
3. BARI Malta	It is a kind of grapefruit which originated in Bangladesh and now days its popularity becomes more in all over the country
4. BARI Komla	From mid-November, fruits can be harvested form this variety plant.

Plate 3. Different varieties of Citrus fruits Cultivated in Sylhet region. (A) Zara Lemon, (B) Elachi Lemon (C)BARI Malta (D) BARI Komla

3.4 Identification and confirmation of fungal diseases:

3.4.1 Collection of Samples

Citrus infected fruits were collected from field at Jaintapur, Khadimnagar and Sylhet sadar in Sylhet district at farm level and in traders level, Mohammadpur Krishi market, Karwan bazar, Retailer's shop (Farmgate, Taltola, Mirur 1 market) at Dhaka city Diseased fruits were collected from the wholesale market and 20 retailer shops at Dhaka city. Oranges and lemons were taken randomly from each market. For further experiment those collected fruit samples were brought to the laboratory, department of Plant Pathology, Sher-e Bangla Agricultural University (Plate 4).

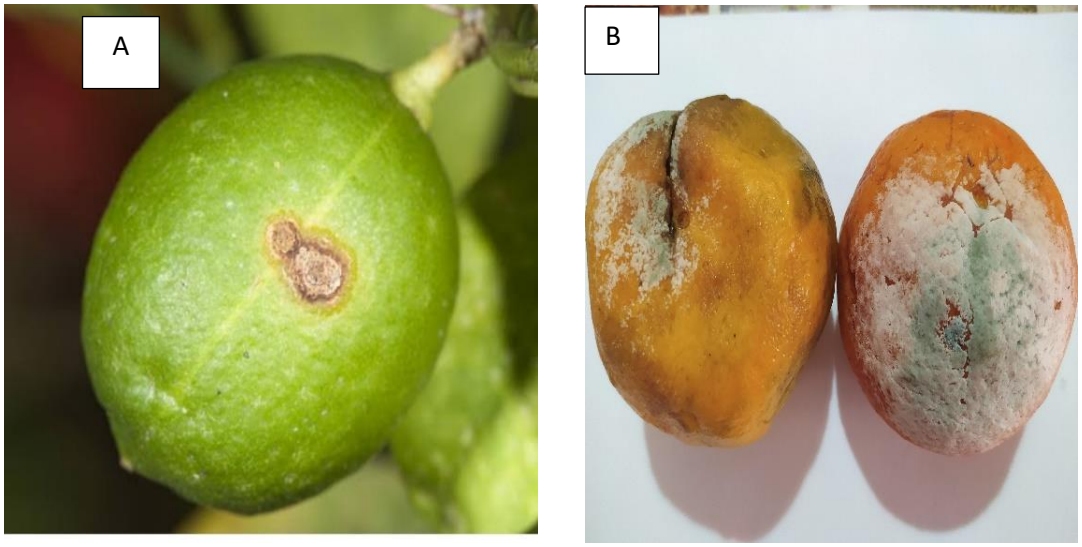


Plate 4. Diseased fruit collected from selected market both (A) & (B)

3.4.2 Observation of the Symptoms

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

3.4.3 Isolation of fungus

The diseased samples were washed thoroughly under running tap water cut into small pieces surface sterilized with 4% NaOCl and rinsed thrice with distilled

water. Three ply sterile moist blotting paper were placed on glass Petri dishes and surface sterilized citrus fruits were placed on Petri dishes and those Petri dishes were incubated at 25°C for 5 days. After 5 days of incubation a small portion of pure colony of fungi transferred to PDA plates. The pure Cultures ware allowed to grow for 12 days then the fungi was identified based on their morphological characteristics by using key book (Mordue,1971).

3.4.4 Preparation of Potato Dextrose Agar medium

Firstly, 200gm of finely chopped potatoes boiled in a one litter of distilled water for 30 minutes to make potato infusion. Saved effluent after being filtered through cheesecloth then mixed with 20gm dextrose and 20 gm Agar and autoclaved for 15 minutes for 121°C. Sterilized PDA was dispensed into sterile petri dishes at 20-25ml/dish (Plate 5).

Plate 5. Potato boiled in water(A), Agar & dextrose(B) and PDA media in volumetric flask(C)

3.5 Isolation and identification of bacterial disease in laboratory.

3.5.1 Preparation of Nutrient agar medium

The method for preparing nutrient agar medium was used by Schaad et al. (2001). First, 1000 ml of distilled water was added to an Erlenmeyer flask with 15 g of bacto agar. To make 1 liter of NA medium, 5 g of peptone plus 3 g of beef extracts were then incorporated into the mixture. The nutritional agar was

thoroughly shaken for a few minutes to ensure appropriate mixing. After that, it was autoclaved for 15 minutes at 121°C and 15 PSI of pressure.

3.5.2 Isolation and purification of canker pathogen of citrus

With sterilized distilled water, the infected citrus fruits were cleaned. The juvenile lesions with the green, healthy section of the diseased fruits were then chopped up. In order to surface sterilize them, they were submerged in a 0.1% sodium hypochlorite solution for 20–30 seconds. It was then cleaned three times using sterile water. After surface sterilization, the diseased fruit area were placed in a Petri dish and minced using a clean, sharp blade. It was placed in a test tube with 3–4 ml of sterilized water and left for 30 minutes to allow for microbial streaming and stock building. One milliliter of this stock solution was placed using a sterile pipette into the second test tube, which contained 9 ml of sterile water, and carefully shaken to produce a 10^{-1} dilution.

Likewise, the final dilution was increased to $10^{-4.}$ According to Goszczynska and Serfontein's (2000) instructions, three replications of 0.1 ml of each dilution were distributed over a NA plate that had been previously dried (to eliminate excess surface moisture). Glass rod that had been sterilized in an alcohol flame was used to disseminate the solution. The incubation chamber for inoculated NA plates was set to 30°C. It was noticed at 24 and 48 hours. Single unmerged colony produced over NA plate was re-streaked over another plate with the use of a sterile loop in order to obtain pure colony.

3.5.3 Growth on nutrient agar (NA) media

A sterile petri plate was filled with freshly made Nutrient Agar (NA) medium, which was then allowed to cool. A sterile transfer loop was used to streak inoculate a pure bacterial colony onto the plate. It was kept at 30°C in an incubator for at minimum 24 hours while the colony's characteristics were watched.

3.5.4 Preservation of *Xanthomonas axonopodis* pv. *Citri*

In order to conserve the bacteria for later use, a slant culture containing purified bacteria was performed on NA slant in little screw-cap test tubes, and it was preserved in the refrigerator at 4°C.

3.5.5 Identification of the pathogen

Based on an examination of the pathogen's morphological, biochemical, and cultural characteristics employing conventional microbiological techniques, the pathogen that causes citrus canker was identified.

3.5.5.i Morphological characters

The pathogen's morphological properties, including cell shape, gram's response, and pigmentation, were examined using the protocols established by Schaad (1992) and Gerhardt (1981).

3.5.5.i.a Gram’s staining

On a tidy microscope slide, one sterile drop of water was applied. A small amount of a juvenile colony (18–24 hours old) was removed from the nutrient agar medium using a cool, sterile loop, and also the bacteria were thinly spread across the slide. Air dried the thinly applied bacterial film. For the purpose of fixing the bacteria to the glass slide, the underside of the slide was heated by passing it four times through the flame of a spirit lamp. The slide was then submerged in a crystal violet solution for one minute after that. The slide was cleaned briefly under running water from the faucet, and any remaining water was blown off with air. Lugol's iodine solution was then poured over it and left

on for a minute. It was then decolored for 30 seconds with 95% ethanol, rinsed once more under running water, and allowed to air dry. It was then counterstained for 10 seconds with 0.5% safranine. It was briefly cleaned with running tap water, and any remaining water was blown away. The glass slide was then inspected using oil immersion at 40x and 100x magnification.

3.5.5.i.b KOH solubility test

On a glass slide, one droplet of 3% KOH (aqueous) was applied. Using a chilled, sterile loop, one loop full of a single colony (18–24 hr old) was removed from the NA plate and combined with KOH solution to create an equal suspension. According to Suslow et al., (1982). The loop was lifted a few centimeters off the glass slide then repeatedly stroked to create strands of viscous materials.

3.5.5.ii Biochemical characters

According to the procedures outlined by Schaad (1992) and Salle, biochemical tests such as the oxidase test, starch hydrolysis test, catalase test, and citrate utilization test were investigated.

3.5.5.ii.a Oxidase test

1ml 1% aqueous (w/v) solution of NNN‟Ntetramethyl-p-phenylene-diaminedihydrochloride solution was spread on the middle of filter paper and the paper placed on a petri dish. Then some colony part of the bacteria was picked with a sterile toothpick and smeared onto the moistened filter paper and observed up to 60 seconds whether it changed color to dark purple or not.

3.5.5.ii.b Starch hydrolysis test

Nutrient agar plate containing 0.2% soluble starch was spot inoculated with pure colony of bacterium. It was then incubated at 300C for at least 48 hours in incubation chamber. Then the plates were flooded with lugol‟s iodine solution and observed whether a clear zone appeared around the colony or not.

3.5.5.ii.c Catalase test

A few drops of freshly made 3% hydrogen peroxide were given to a pure culture of bacteria that had been growing on NA plates for 48 hours, and the outcome was tracked to see if bubbles appeared after a few seconds or not.

CHAPTER IV

RESULTS

4.1 Survey on present status of citrus cultivation

The findings of the study on the present status of citrus cultivation have been shown in (table 2). Study revealed that, among the 15 respondents, 5 respondents increased their citrus cultivating area by converting their agricultural land, while 3 respondents decrease and only 7 respondents had no change in their citrus growing area.

Table 2. Present status of citrus cultivation by the citrus farmers

Present Status of citrus cultivation						
Issues	Increased cultivation area		Decreased cultivation area		No Change in cultivation area	
	No. of farmers	% Farmer	No. of farmers	% Farmer	No. of farmers	% Farmer
Area Under Citrus Cultivation	5	33.33	3	20	7	46..66

4.2 Farm size

Among 15 respondents, the highest 46.66% % was found as medium farmers followed by 20% large farmers and 13.33% small farmers (Table 3). Farm size were determined on the basis of farmer having more than 500 trees are classified as large farmers, more than 200 trees are medium farmers and farmers occupying more than 20 trees, but less than 200 trees are classified as small farmers. The persons who has less than 20 trees are termed as consumer assuming that they cultivated Citrus for their own consumption and not count in this survey.

Table 3. Farm size of Citrus farmers

Types of farmers	No. of Plants	Area (Per Bigha)	No. Of Farmers	% of Farmers
Large farmer	≥500	≥2	3	20%
Medium farmer	200-500	1-2	7	46.66%
Small farmer	≤200	≤1	2	13.33%

4.3 Experience of growers in citrus production

In our study area with pre ready questionnaire we found that the experience of the respondent growers in citrus production ranged from 2 to 15 years. The highest 56.33 % respondents were of having 5 to 15 years of experience. The second highest 28.32.% respondents were of having less than 5 years of experience. Only 15.02 % respondents were of having more than 15 years of experience (Figure 1).

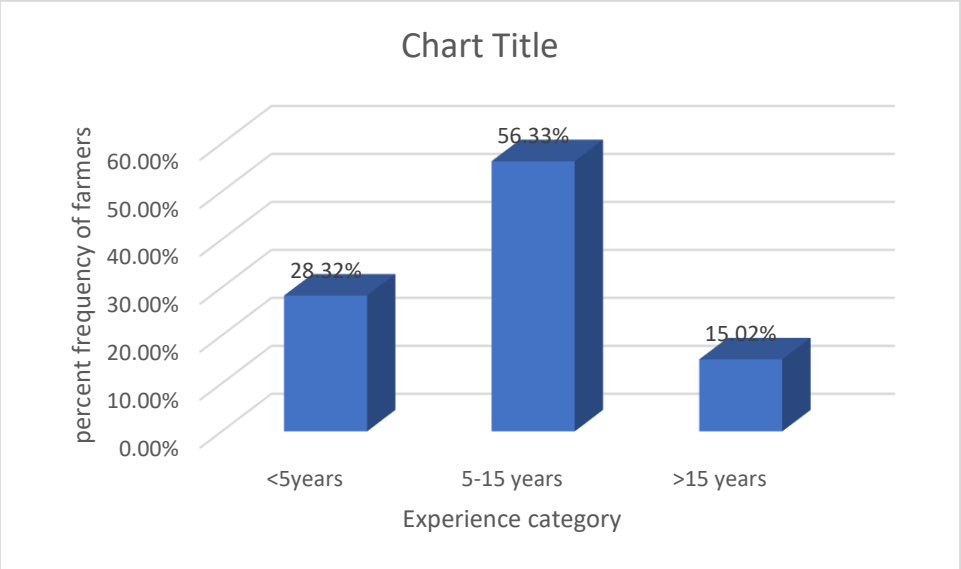


Figure 1. Frequency of Citrus growers under three categories having different years of experience

4.4 Distribution of Citrus Varieties according to cultivation by growers

Among all 15 respondents' highest number of them cultivated Zara lebu (25%), BARI Malta (23%) Shatkora (22%) Bari komla (13%) and Elachi lebu (17%) (Figure 2)

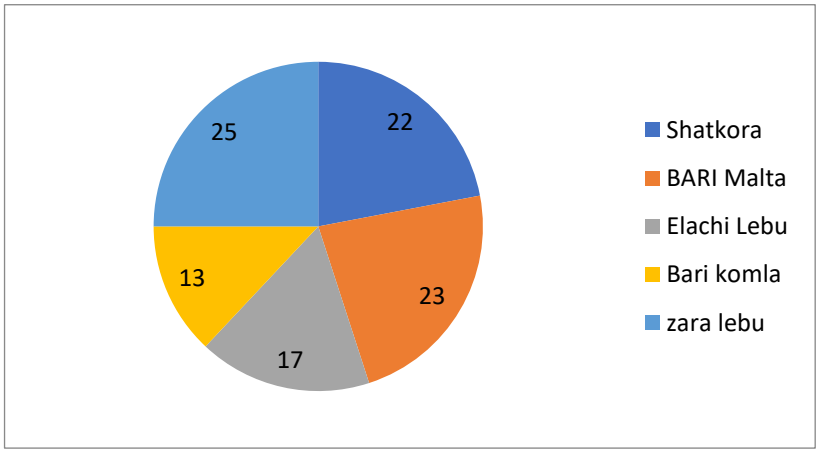


Fig 2. Distribution of Citrus Varieties according to cultivation by growers

4.5 Fertilizers used for Citrus production

During interviewing, all of the responding citrus growers (100%) reported that they applied FYM (cow dung) and super phosphate for soil preparation every year. The highest 53.33% growers used TSP and MoP. The second highest 26.66% growers used TSP and DAP. The lowest 20 % respondents used MoP and Gypsum during production period.

4.6 Use of Pesticides

Farmers reported that they used Furadan 5G(Carbofuran), Agromethrin 10 EC (Cyperme 39thrin), Decis 2.5Ec(Deltamethrin) and Sobicorn 425EC (profenofos+Cypermethrin) at citrtus cultivation period for pest management. Tebuconazol+Mancozeb, Mancozeb+Phenamidon, Flupyram+Trifoxitrobin groups of fungicides applied by 19.05%, 47.62% and 33.33% of the respondents respectively.

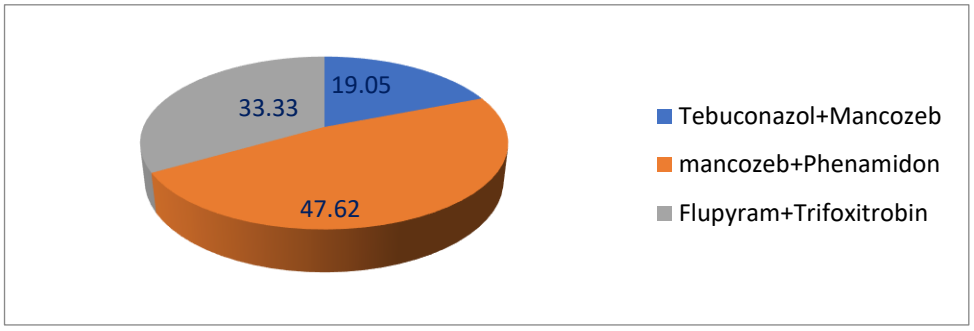


Figure 3. Frequency of citrus growers used pesticides

4.7 Key Stakeholders in Citrus Value chain

In our study we found key actors who are participated directly to complete the citrus value chain from production to consumption. These key stakeholders were Producer-Bepari-Arotdar-Retailer-Consumer. Producer were those who grew citrus in their field, Bepari were collected those citruses and sold to aratdar. From aratdar, retailer bought and re sold to consumer.

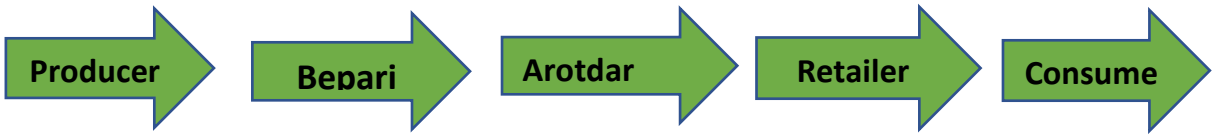


Figure 4. Key Stakeholders in citrus Value Chain

4.8 Mode of Transportation

The survey study revealed that, the use of vehicles varied from traders to traders and the length of destination markets. Trucks (also mini trucks) were used for Citrus transportation by the Beparies (100%) from the assemble markets to the destination wholesale markets. Majority of the Pikers (55%) used Nosimon (5wheeler local vehicle) to transport and 25% used mini truck and 15 % Piker used Van (Table 4). In case of retailer, highest frequency (60%) used van, 25% used Local carts and 15% used Baskets(manually) to transport orange and lemon.

Table 4. Frequency of vehicles in marketing channel

Intermediaries	Use of Vehicles (%)				
	Truck	Nosimon	Van	Local Carts	Busket
Piker	25	55	15	0	0
Bepari	100	0	0	0	0
Retailer	0	0	60	25	15

Plate 6. Different Modes of transportation. (A). Transport by Van. (B). Transport by Jhuri (C). Transport by hill truck, (D). Transport by Baskets (Manually)

4.9 Post Harvest Losses of Citrus fruits at Farmer Level

The Survey study was carried out at farm level to estimate percent damaged fruit compare to percent of healthy fruit. Three citrus varieties were considered where Zara lemon showed maximum no. of healthy fruits (84%), while BARI Malta-1 showed maximum no. of damaged fruit (25%) (Figure 5).

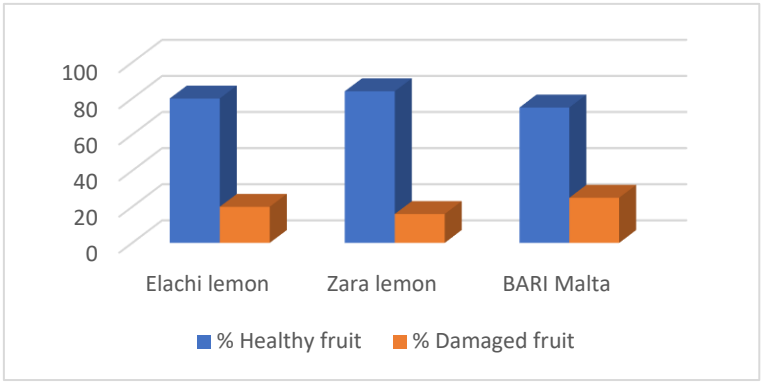


Figure 5. Post harvest losses of various citrus fruit at farm level

4.10 Post-harvest losses at Traders Level

In the trader channel due to rough unloading, weighting, unorganized packing practices leads a result of huge post-harvest loss,(Table-5). In this survey, an average of 50000 citrus and one transport (truck)was considered. In one truck 500 plastic cartoon and each cartoon had 110-120 citrus fruits were placed. It was found that the postharvest loss at traders' level was estimated at 30.31%. Among the channel stake holder's highest loss was recorded for Retailer (18.02%) followed by Aratdar (8.14%) and Bepari (4.15%). Normally the Bepari were non licensed traders and they handled relatively larger volume of citrus. On the other hand, Aratdar were licensed traders and they handled larger volume of citrus than the bepari and lastly retailer are those who have the last link I the marketing of citrus and they were directly connected with consumer.

Table 5. Post-harvest losses at trader's level.

Stakeholder	Complete Damage		Partial Damage		Total damage	
	Quantity (pieces/50000)	% of total	Quantity (pieces/50000)	% of total	Quantity (pieces/50000)	% of total
Bepari	1675	3.35	400	0.8	2075	4.15
Aratdar	3290	6.58	780	1.56	4070	8.14
Retailer	7230	14.46	1780	3.56	7530	18.02
Total	12195	24.39	2960	5.92	13675	30.31

4.11 Problems in Citrus Fruit Value Chain

In the survey the most severe reported problems which is first was delayed sale (47.2%) followed by lack of buyers (28.6%) and transportation delay (24.2%), (Figure-6). Delayed sale occurred due to lack of customer, weather condition. Lack of buyers which were showed second highest problem in our survey for value chain occurred due to unavailability of buyers like Bepari, Aratdar, Retailer also consumer. Transportation problems was also a serious factor in citrus value chain which showed the third problem identified in our study

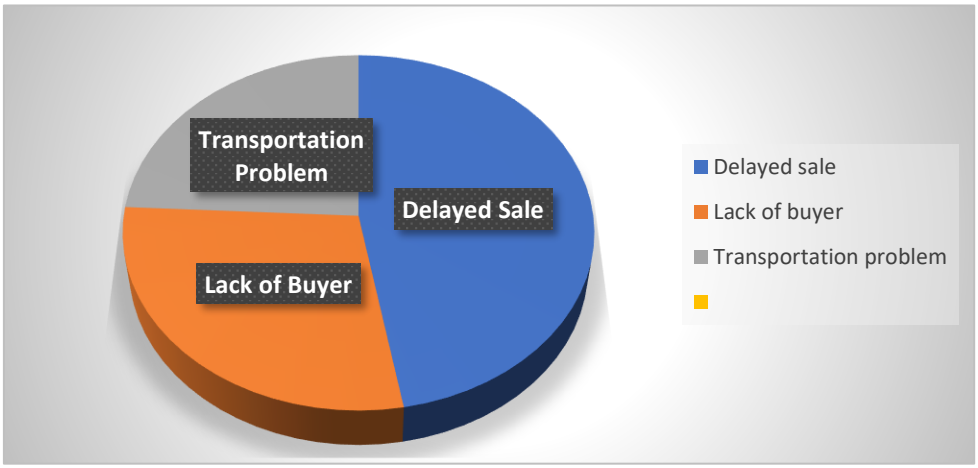


Fig 6. Problems identified in citrus value chain

4.12 Prevalence of Citrus Canker and Scab Disease

Incidence of Citrus canker disease varied from Place to place and variety to variety. In our study at Sylhet region, we have visited local farm level. Three spots named Jaintapur, Khadimnagar and Sylhet sadar Upazila were those and varieties of citrus were Elachi lemon, Zara lemon BARI komla and BARI malta 1. Canker disease were found mostly at khadimnagar(52%) for elachi lemon and lowest at Sylhet sadar upazila (28%) for zara lemon.

Table 6. Incidence of Canker Disease

Species	Jointapur (%)	Khadimnogor (%)	Sylhet sadar (%)
Elachi lemon	36	52	39
Zara lemon	32	40	28
BARI komla	38	32	26
BARI Malta	31	42	32

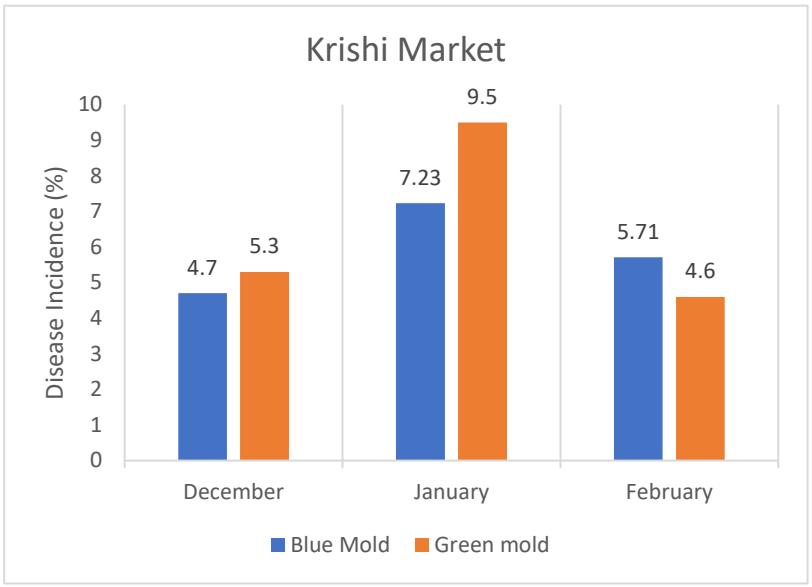
Incidence of Citrus Scab disease varied from Place to place and variety to variety. In our study at Sylhet region, we have visited local farm level. Three spots named Jaintapur, Khadimnagar and Sylhet sadar Upazila were those and varieties of citrus were Elachi lemon, Zara lemon, BARI komla and BARI malta 1. Scab disease were found mostly at Jaintapur(31%) for BARI malta 1 and lowest at also Jaintapur (15%) for BARI komla.

Table 7. Incidence of Scab Disease

Species	Jointapur (%)	Khadimnogor (%)	Sylhet sadar (%)
Elachi lemon	28	16	22
Zara lemon	21	24	28
BARI komla	15	18	20
BARI Malta	31	27	29

4.13 Disease Incidence of Citrus Blue mold and Citrus Green mold against different months and locations.

Incidence of citrus blue mold and green mold disease was showed in several market at different month. In this study we surveyed paikari market to retailer shop (Roadside shop, van). Highest disease incidence for citrus blue mold was observed in retailer shops at Dhaka city in the month of January (12.3%) and citrus green mold was also observed at retailer shops at Dhaka city in the month of February (16.6%). Disease incidence was lowest at kodomtoli wholesale market, Sylhet district for Citrus blue mold in the month of December (3%) and for citrus green mold disease incidence was found lowest at karwan bazar market (4.1) in the month of February.



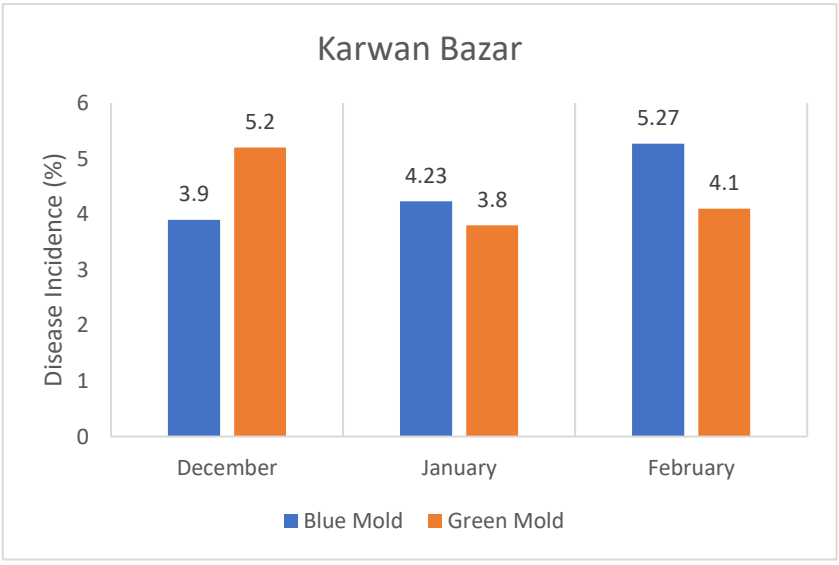
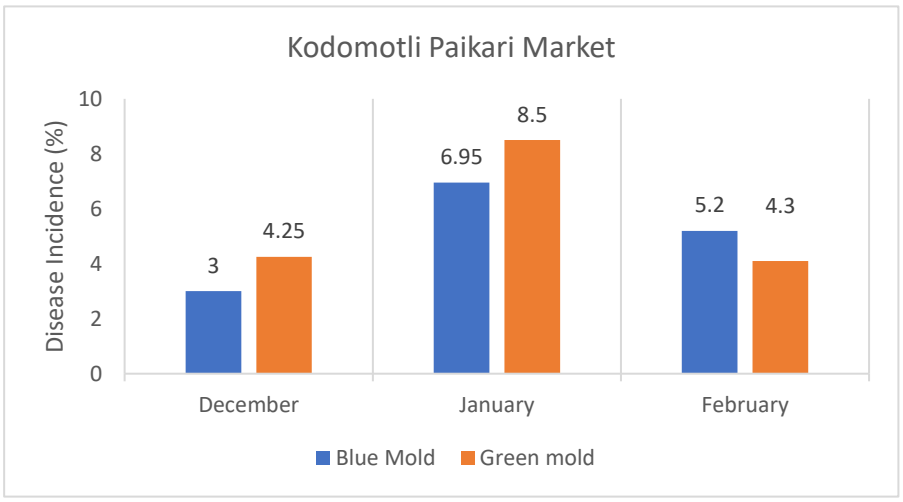


Figure 7. Incidence of Disease (Blue mold & green mold of citrus in different data recording times at Mohammadpur Krishi market & Karwanbazar Dhaka.



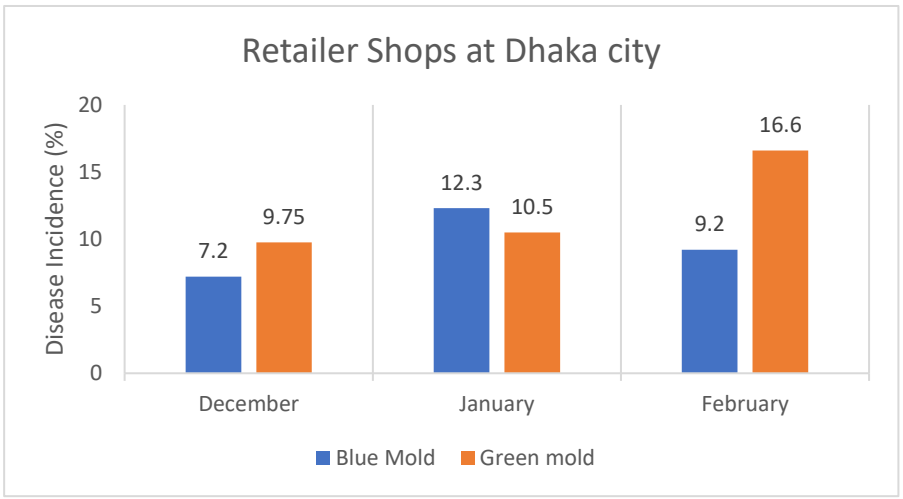


Figure 8. Incidence of Disease (Blue mold & green mold of citrus in different data recording times at Kodomtoli market and Retailer shops at Dhaka city.

4.14 The level of citrus fruit losses at different points of post-harvest chain

The study found that 25 percent of citrus fruits wasted during harvesting process, 29 percent lost during handling process, 30 percent of the fruits lost at storage places and 16 percent lost during transportation from farm to marketplaces.

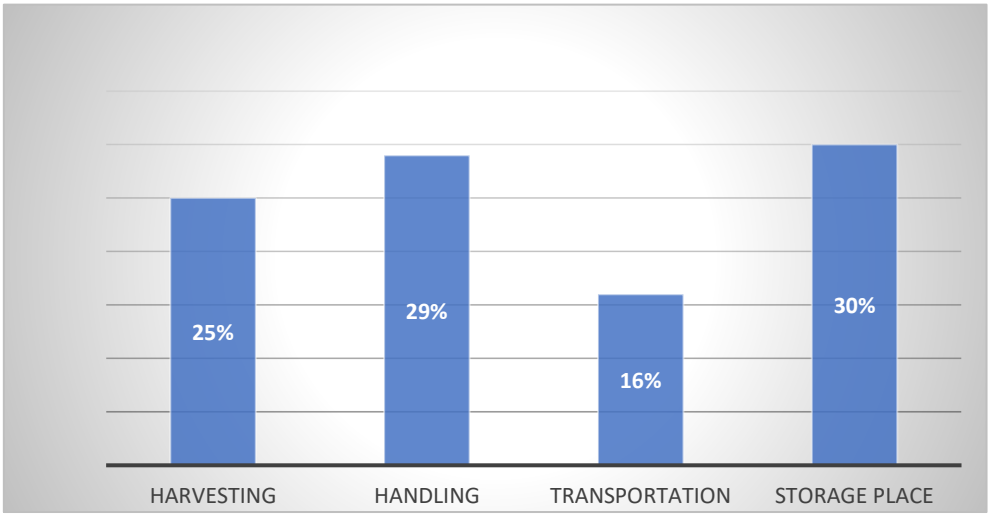


Figure 9. Indicates of the level of citrus fruit losses in percent in the study area

4.15 Buying and Selling Price of Citrus Fruit

Citrus producers sold their fruits to traders including Pikers, Beparies and Retailers existed in the marketing value channel. In our study we observed that value was added between traders' level by the difference between purchase price and selling price of citrus fruit. Our study showed that highest value was gained by retailer in case of all those citrus varieties, Orange (BARI komla), elachi lemon, Zara lemon and BARI Malta 1. After gaining gross marketing value there were some actors which incurred total marketing cost and deducting this marketing cost from gross marketing value, we have calculated the net profit margin by the intermediaries in the market channel. Marketing cost occurred sum of actors like Loading unloading, grading, transportation, wage and salaries, personal expenses, wastage, market toll.

Table 8. Buying and Selling Price of Orange (BARI komla) in the Study areas.

Traders	Purchase price (tk per Quintal)	Selling price (tk per Quintal)	Value Addition or Gross Marketing Margin
Bepari	7000	7800	800
Aratdar	7800	8500	700
Retailer	8500	10000	1500

Table 9. Buying and Selling Price of Elachi Lemon in the Study areas.

Traders	Purchase price (tk per 100 pieces)	Selling price (tk per 100 Pieces)	Value Addition or Gross Marketing Margin
Bepari	200	305	105
Aratdar	305	390	85
Retailer	390	500	110

Table 10. Buying and Selling Price of Zara Lemon in the Study areas.

Traders	Purchase price (tk per 100 pieces)	Selling price (tk per 100 Pieces)	Value Addition or Gross Marketing Margin
Bepari	1200	1420	220
Aratdar	1420	1800	380
Retailer	1800	2500	700

Table 11. Buying and Selling Price of BARI malta in the Study areas

Traders	Purchase price (tk per quintal	Selling price (tk per quintal)	Value Addition or Gross Marketing Margin
Bepari	6000	6500	500
Aratdar	6500	7200	700
Retailer	7200	9000	1800

4.16 Net marketing margin among the stakeholders at trader's level.

In our study we observed that highest net marketing margin was obtained by retailer for all varieties we have studied in this work. In case of orange retailer earned net marketing margin is 1194.45 tk per 1 quintal, for BARI malta 1, retailer got 1254.21tk/quintal. For calculating net marketing margin case of elachi lemon and Zara lemon retailer got the highest benefit 183.50tk and 544.50tk per 100 fruits.

Table 12. Marketing cost of citrus (BARI komla) spent by traders for different items

Trader	Item wise Cost (tk/100kg)							Total(tk/100kg)
	Aratdar Comission	Transpor-tation	Loading Unloading	Grading	Shop rent	Market toll	electricity	
Bepari	340	68.75	11	7.5	0.00	38	0.00	465.25
Aratdar	0.00	59.25	13.50	8.25	180	46	20.25	327.25
Retailer	0.00	69.25	0.0	0.0	135.45	51	49.75	305.45

Table 13. Marketing Cost and net marketing margin of different intermediaries for Orange (BARI komla)

Trader Type	Gross Margin (tk)	Marketing cost (tk)	Net Marketing Margin(tk)
Bepari	800	505.41	293.59
Aratdar	700	327.25	774.25
Retailer	1500	305.45	1194.45

Table 14. Marketing Cost and net marketing margin of different intermediaries for Elachi Lemon

Trader Type	Gross Margin(tk)	Marketing cost (tk)	Net Marketing Margin(tk)
Bepari	105	45.50	59.50
Aratdar	85	45.50	39.50
Retailer	110	22.50	87.50

Table 15. Marketing Cost and net marketing margin of different intermediaries for zara Lemon

Trader Type	Gross Margin(tk)	Marketing cost (tk)	Net Marketing Margin(tk)
Bepari	220	75.55	144.45
Aratdar	380	220	160
Retailer	700	155.50	544.50

Table 16. Marketing Cost and net marketing margin of different intermediaries for BARI Malta

Trader Type	Gross Margin (tk)	Marketing cost(tk)	Net Marketing Margin(tk)
Bepari	500	275.25	224.75
Aratdar	700	329.50	369.50
Retailer	1800	545.79	1254.21

4.17 Identifying the causal agents of post-harvest diseases of Citrus

4.17.1 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.

4.17.2 Identification of *Penicillium italicum* 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 bluish white to deep blue. Mycelia hyaline, branched. Conidiophore arising from the mycelium, septate branched near the apex, penicillate (small brush like)

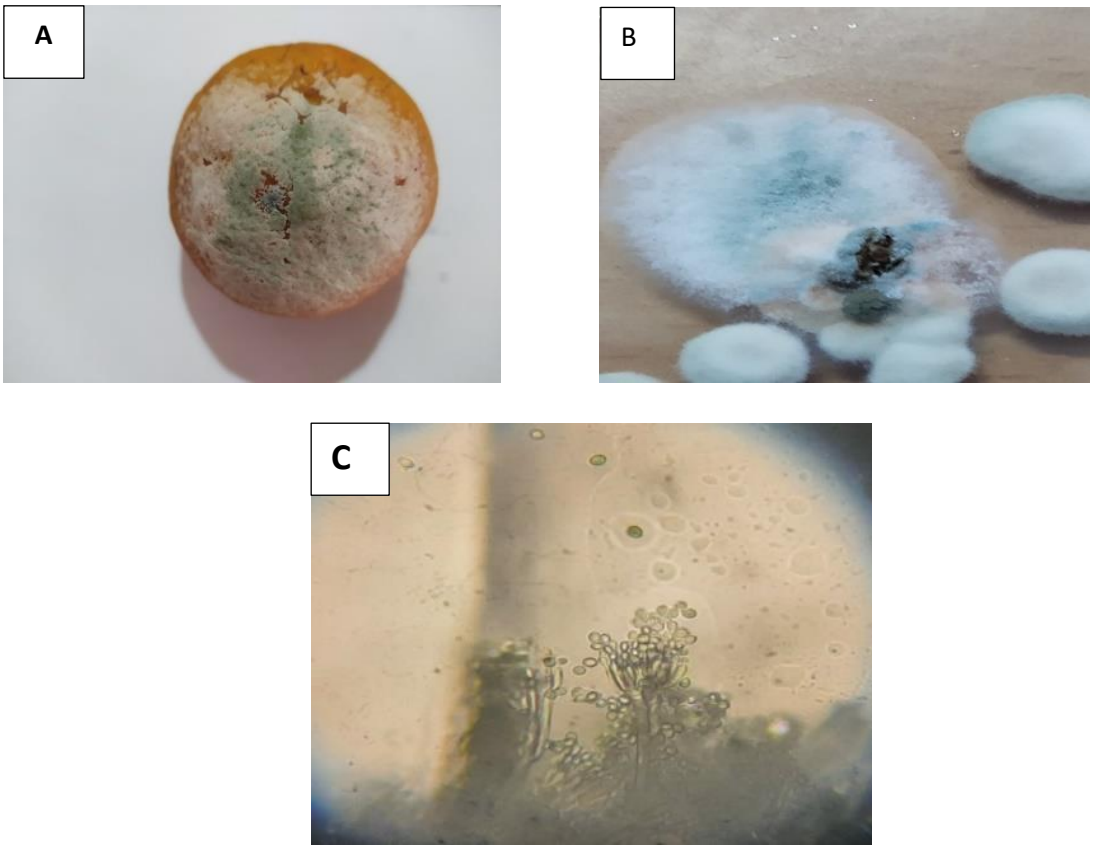


Plate 7. Diseased sample(A), Pure culture(B) and microscopic view(conidia)(C) (*Penicillium italicum)*

4.17.3 Identification of *Penicillium digitatum* by cultural and morphological characteristics

After 11 days growth on PDA media, it was observed that the culture was growing rapidly. Colonies on potato dextrose agar were bluish white to light green. Mycelia hyaline, branched. Conidiophore arising from the mycelium, septate branched near the apex, penicillate (small brush like)

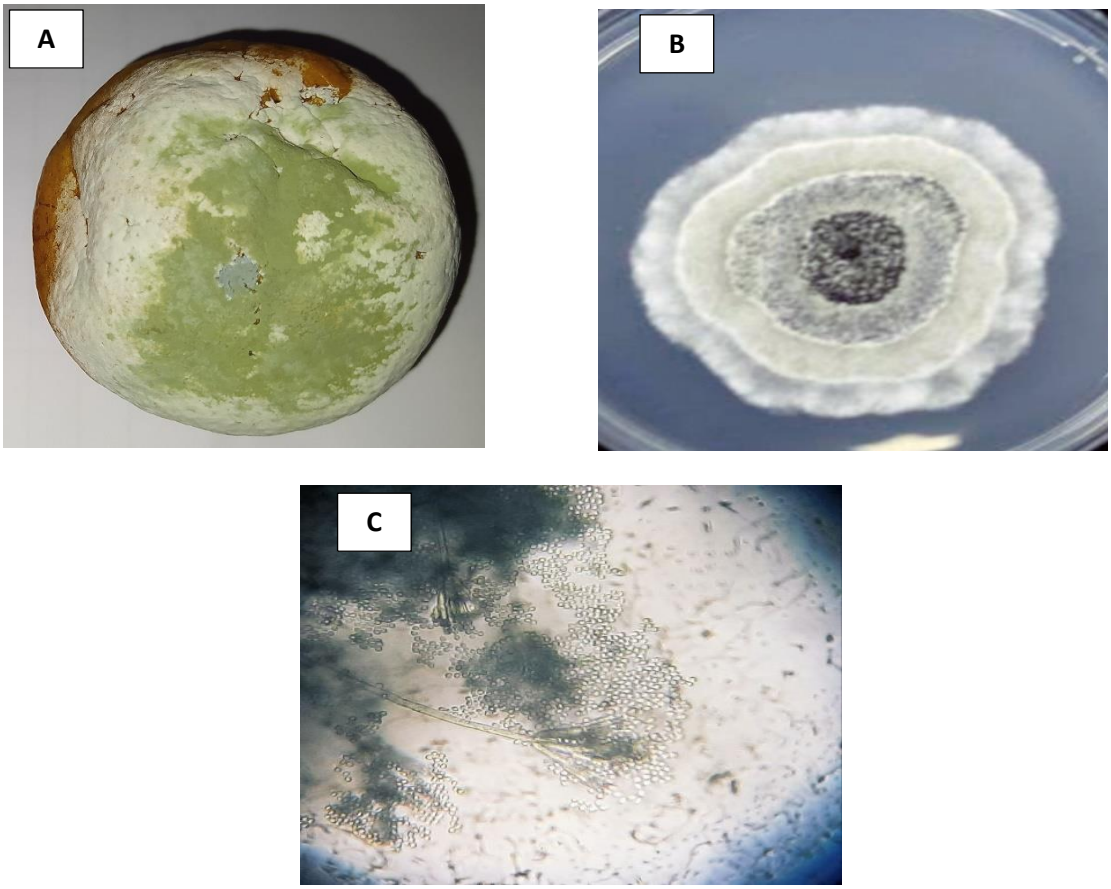


Plate 8. Diseased sample(A), Pure culture(B) and microscopic view(conidia)(C) (*Penicillium digitatum)*

4.18 Identification of *Elsinoe fawcettii* by cultural and morphological characteristics

After 21days growth on PDA media, it was observed that the culture was growing
rapidly. Colonies on potato dextrose agar were brownish hyaline conidia, spindle shape conidia of *E. fawcettii* produced.

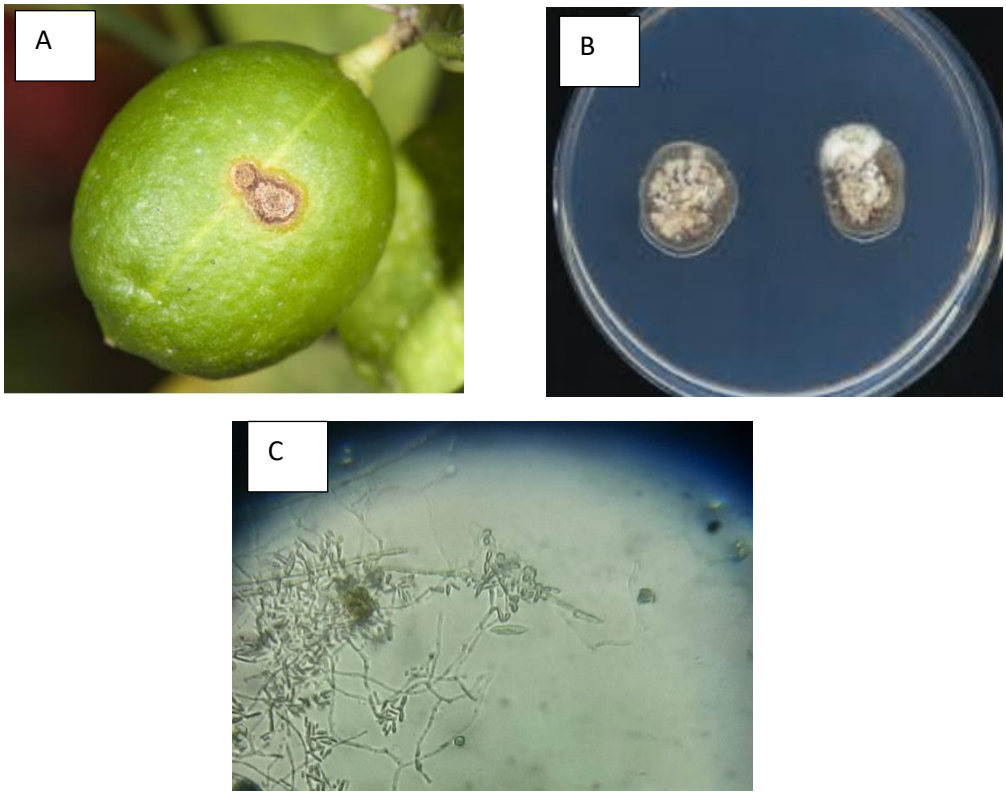


Plate 9. Diseased Sample(A), Colony growth (Pure Culture) (B), Spindle shape, hyaline Conidia of *Elsinoe fawcettii* (C)

4.19 Identification of *Xanthomonus axonopodis* pv.*citri* by cultural and morphological characteristics

4.19.1 Isolation of canker pathogen

The causal organism was isolated from the infected citrus fruits showing typical symptoms of citrus canker. Dilution plate method was used to isolate causal organism. Typical, yellow, convex, mucoid, colonies of bacterium on nutrient agar medium were found after 48 hours of incubation at 30^0C. Colonies were purified by re-streaking the isolated colony on nutrient agar plate.

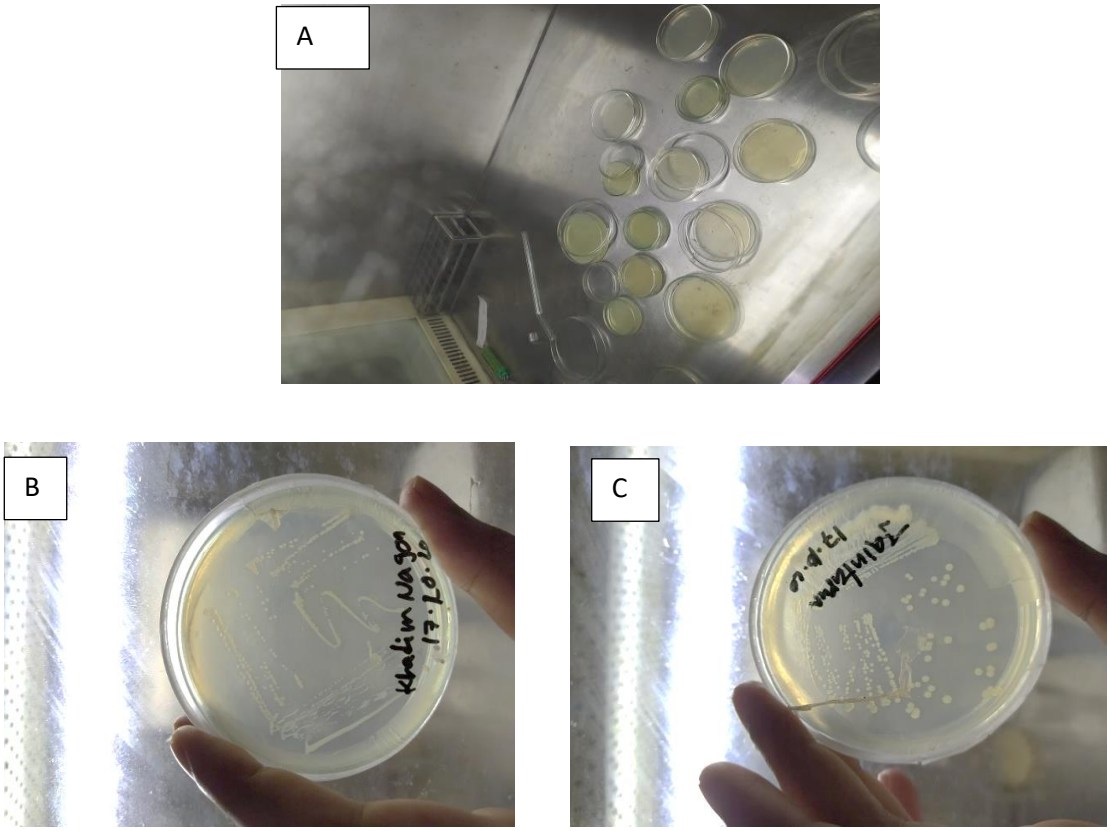


Plate 10. Inoculated canker pathogen into NA media(A) Yellow, convex, mucoid, colonies of pathogenic bacteria isolated from infected citrus fruits samples from khadimnagar(B), Jaintapur(C)

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4.19.2 Identification of the pathogen

The citrus canker pathogen was identified by studying morphological, biochemical and cultural characteristics of the pathogen as per standard microbiological procedures.

4.19.3 Morphological characters

The bacterium was rod shaped with rounded ends, cells appeared singly and also in pairs, gram negative (red color) and capsulated under the compound microscope at 100x magnification with oil immersion. The bacterium cells were stained with crystal violet.

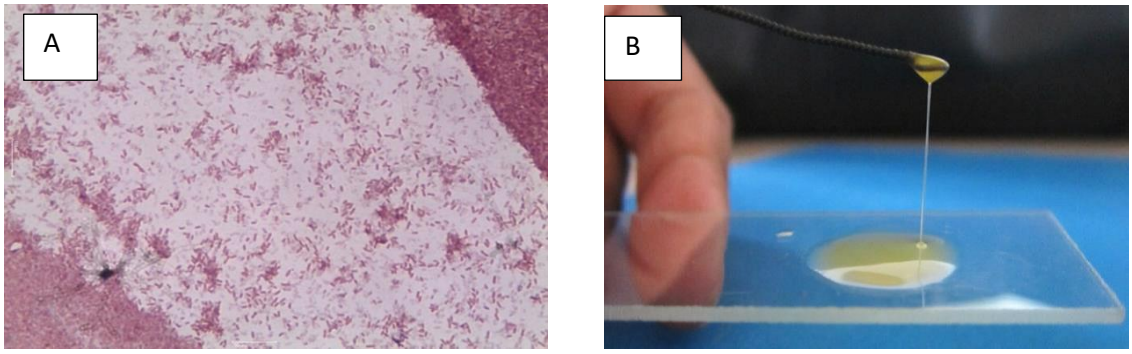

Plate 11. Microscopic view of pathogenic bacteria of citrus canker after gram's staining at 100x magnification(A), KOH Solubility test for *Xanthomonus axonopodis* pv. *Citri* (B)

4.19.4 Biochemical characters

Biochemical tests results for the pathogen are presented in Table 8

Table 7. Biochemical characteristics of pathogenic bacteria of citrus canker

Biochemical Tests	Results
Catalase test	Positive
Starch Hydrolysis Test	Positive
Oxidase Test	Negative

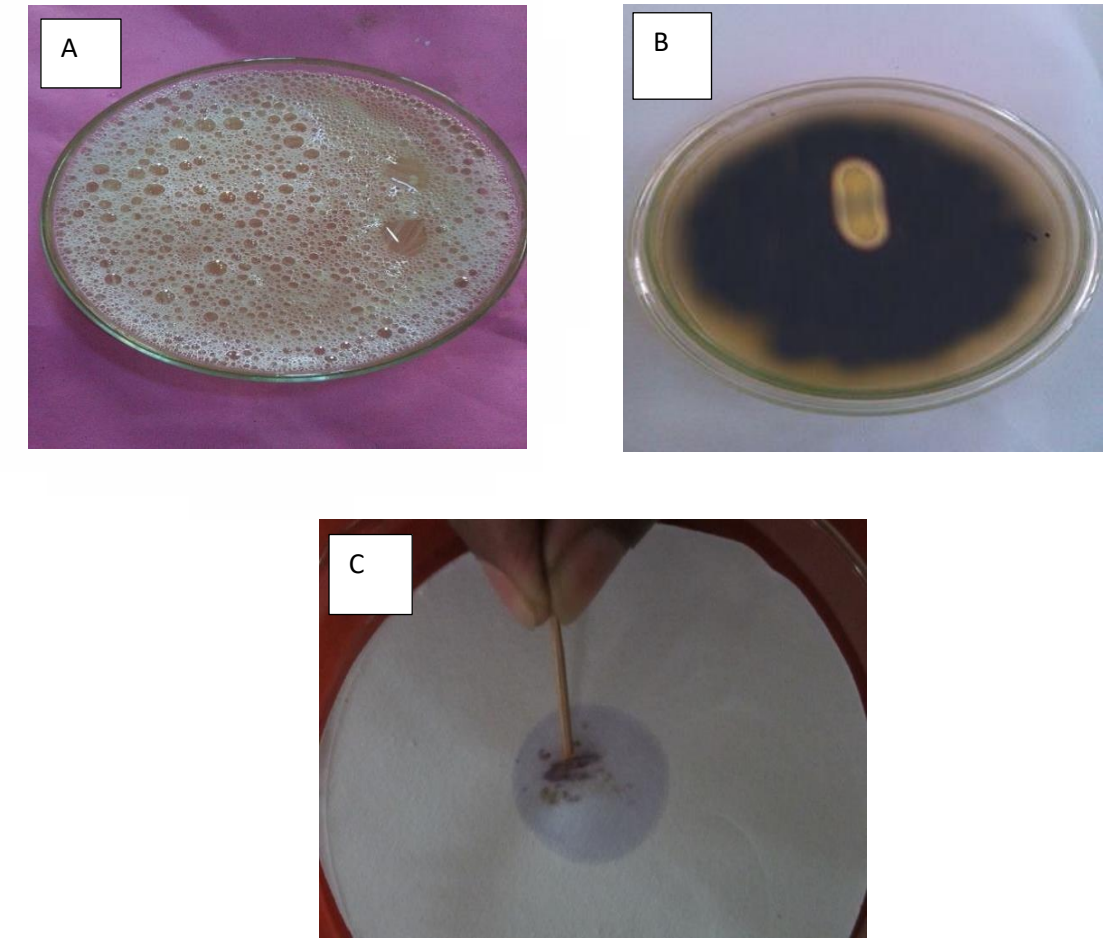

Plate 12. Biochemical tests results of canker pathogen (A) Catalase Test, (B) Starch Hydrolysis Test and (C) Oxidase Test

4.19.5 Preservation of canker pathogen: Purified bacterium on NA slant was kept in refrigerator at 4^0c in test tubes. It was served as a stock culture for further studies.

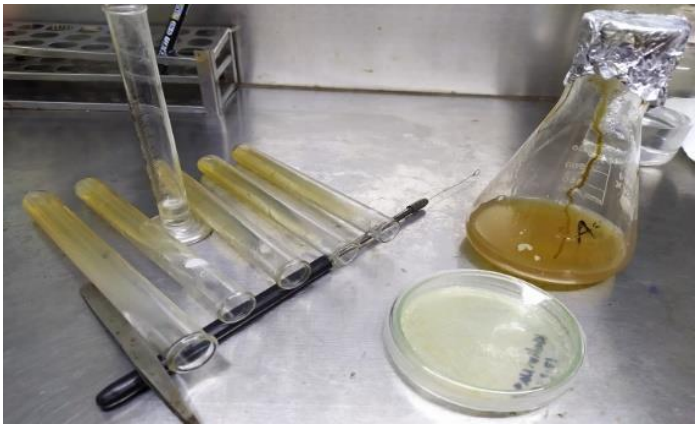

Fig 10. Slant culture of citrus pathogenic bacteria

CHAPTER V

DISCUSSION

A survey was conducted to value chain analyze and post harvest diseases of different citrus fruits through key informative interview, questionnaire and survey study at different market both Sylhet and Dhaka. Similar survey study on citrus cultivation practice and post-harvest value chain were conducted by many others researchers around the world; Ahmed and Muqit (2020); Begum (2016); Ezekiel, M. Z (2014); Musasa (2013) analyzed value chain for citrus fruit in combination of quantitative and qualitative methods that comprehended preliminary survey, open discussion with producer, market level stakeholder (Bepari, aratdar, retailer). Present status revealed that cultivation area of citrus fruits was increased by 33.33% of 15 respondents in the survey area. According to BBS (2019), in the year of 2017-18, citrus was cultivated on 225075 acres of land while it was 210560 acres of land in the year of 2016-17. This data indicates the gradual increase of production area in Bangladesh. In our study we found most of our respondent growers are medium categories farmer (46.6%) who have 1-2 bigha of citrus farm. Ahmad, B. (2018) reported a study in Pakistan who found 3 categories farmer in his studied area as large farmer(25≥ha), medium farmer (2-20 ha) and small farmer(5≤ha.) of land. He found most of their farmer in medium category (60%). The cultivated Zaralebu, shatkora, Elachi lebu, Bari malta 1, Orange (Bari komla) varieties in their farm. Ahmed (2020) reported that Elachi lebu, Jara lebu, Shatkora, BARI komla, BARI Malta are the most cultivated varieties in Bangladesh. In this study that the respondents applied Tebuconazol+Mancozeb, mancozeb+Phenamidon, Flupyram+Trifoxitrobin groups of fungicides by 19.05%, 47.62% and 33.33% respectively for disease management in their respective field. Similar study was conducted by Gurr, G. M (2004) where 1.0% Bordeaux mixture was used against citrus scab disease and 0.2% Streptomycin Sulphate 9% + Tetracycline Hydrocloride 1% SP Spray Streptocycline 50 to100 ppm solution against citrus canker disease.

In the present study it was observed after harvest citrus was traded in a chain which consists number of actors viz. "Producer- Bepari- Arotdar- Retailer-Consumer". Similar observation also described by Begum, M. (2016) where showed orange marketing chain involving six channels where 79.5% orange was distributed through this channel (Producer-Bepari-aratdar-wholesaler-Retailer-Consumer). The survey study revealed that the use of vehicles varied from traders to traders and most of the traders used local carts, Baskets, van, nosimon and truck. Begum, M. (2016) conducted similar type of survey on orange value chain analysis in Sylhet district where she found Farmer used van (75%) and wholesaler used truck (55%), pickup (45%) respectively. In the present study it was found that, the operations were done in the trader's channel rough unloading, weighing and de handing practices, citrus fruits are heavily liable for impact, compression, bruising, abrasion, puncturing, direct damages. Ahmed (2004) conducted a similar study on postharvest handling and marketing of fruits and mentioned that unconscious loading-unloading practice caused for several loss for fruit in the marketing chain. Rao (1979) stated that proper harvesting is also important. Citrus fruit especially orange should be harvested at proper stage of maturity for transport, handling and storage. It is necessary to delay ripening for distant markets and then enhance ripening for retail sale. Sometimes citrus producers were not aware of dangers of poor sanitation in the fields, and they tend to be reckless in handling the soft fruit leading to physical damage.

In this survey study, for 50000 pieces of citrus fruit (one truck) it was found that the post-harvest loss at trader's level was estimated 30.31% which consisted completely damage citrus fruit (24.39%) and partial damaged citrus fruit (5.92%). Among intermediaries the highest loss was recorded for retailer (18.02%) followed by Arotdar (4.15%) and Bepari(8.14%). This result was supported by the research in Rusitu Vally, Zimbabwe, Musasa (2013). Citrus growers incurred a huge loss (40%) annually because of poor harvest techniques adopted by them. Surveys made by Naqvi and Dass (1994) in several districts in Maharastra 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 post-harvest losses associated with storage and marketing. Such losses were prominent and lie in the range of 20-80%. Another study conducted by 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 highest problem was delayed sale (47.2%) followed by lack of buyers (28.6%) and transportation delay (24.2%) among these three problems. Hasan (2010) reported that postharvest loss of citrus is 20-95% which accounts a big amount in tk for Bangladesh.

In the present study it was found that different level of citrus fruit losses at different points of post-harvest chain that 25 percent of citrus fruits wasted during harvesting process, 29 percent lost during handling process, 30 percent of the fruits lost at storage places and 16 percent lost during transportation from farm to market places. According to Ezekiel, M. Z. (2014), 39.7% of the produced orange fruits wasted per year in Tanzania where 15% orange fruits are during harvesting, 50% lost at storage and 17% lost during transportation. In this study revealed that citrus canker caused by *Xanthomonus axonopodis* pv. *Citri and* citrus scab caused by *Elsinoe fawcettii* affect mostly at farm level. Highest canker incidence (52% in khadimnagar in Elachi lemon, Zara lemon 40%, BARI malta 1(42%). In case of BARI komla highest canker infestation was recorded at Jaintapur (38%). This result is supported by Ahmed. T (2020) who conducted a study revealed that highest canker incidence was recorded in elachilemon (65% followed by Zaralemon(60%) in Sylhet district. In the present study highest citrus scab disease incidence (31%) in BARI malta 1 in jaintapur and lowest scab incidence (16%) in Elachilemon. This results also supported by Ahmed. T *et al.* (2020) and they recorded highest scab susceptibility (55%) in BARI Lemon 1 and lowest scab susceptibility in Jaralemon (15%).

In the present study, disease incidence at traders' level, data was recorded from several market both Sylhet and Dhaka district. Highest blue mold incidence was recorded in retailer shops in Dhaka city (12.3%) and citrus green mold incidence (16.6%) was recorded also in retailer shops in Dhaka city. Lowest Citrus blue

mold incidence (3%) was recorded at kodomtoli wholesale market in Sylhet district and citrus green mold disease incidence (4.1%) was recorded at karwan bazar market. Gardner (1986) reported that Green mould (*P.digitatum* Sacc.) and blue mould (*P.italicum* Wehmer) are important post-harvest pathogens of Nagpur mandarin next to sour rot. However, green and blue mold rots occur in all citrus growing areas and often constitute the predominant type of decay. *Penicillium digitatum* alone is responsible for approximately 90% of total postharvest losses said by Chen, J. (2019) reported that blue mold was 16.6% to 23.3% and green mold was 8.3% to 36% affected at Parlier.

For the marketing margin analysis that was earned by stakeholders, in our study revealed that highest marketing margin gained by retailer level, orange (BARI Komla) (1194.45tk/), BARI malta1 (1254.21tk/quintal), Elachi lebu (tk 87.50/100pieces) and Zara lemon(544.50tk/100pieces). Begum, M. (2016) conducted a study on citrus marketing in Sylhet district. They reported that the profit component the margin for all groups of intermediaries was higher than the cost component. The net margin taken by the retailers was reportedly larger. They also reported that net marketing margin earned by retailer(1980tk/quintal) for orange in year of 2016.

CHAPTER VI

SUMMARY AND CONCLUSION

Citrus is one of the most significant fruit crops in the world, grown in even more than 125 nations. It is also one of the most widely cultivated and consumed fruit crops globally. In terms of productivity, citrus surpasses grape, apple, and banana as the most frequently cultivated fruit crop worldwide. Citrus output in Bangladesh has steadily increased in recent years. Citrus output increased by 2.3% year between 1992 and 2002 in Bangladesh. Before citrus is ready for the market for fresh consumption after storage, they are especially vulnerable to postharvest damage. A survey was conducted to identify the farm practices of citrus production in selected area and to identify the diseases and their causal agent and also to analyze the causes of deterioration in value chain. The survey was conducted during the periods of August 2020 to February 2021 in Sylhet and Dhaka district of Bangladesh. Three Upazillas of Sylhet namely Jaintapur, Khadimnagar and Sylhet Sadar upazilla were selected for collection of information on value chain in citrus production and Kodomtoli wholesale market of Sylhet, Karwarn bazar, Mohammadpur Krishi market and retailer shops at Dhaka city were selected for value chain at marketing levels.Value chain analysis clearly reveal the citrus growing areas are increasing year after year. Most of the orchards had 200-500 plants and the popular citrus varieties grown in Sylhet district were Elachi lemon, Zara lemon, BARI komla, and BARI malta. Farmers regularly used manure, fertilizers and pesticide in citrus production. Van is the most common transport for short distance carrying and truck, nosimon are used for long distance carrying. The common marketing channel is “Grower- Bepari- Aratdar- Retailer- Consumer”. The most common diseases of citrus were found in farm level were citrus canker and scab, Green mold and blue mold. Highest canker incidence (52%) was recorded in khadimnagar in Elachi lemon and highest scab incidence (31%) was recorded in BARI malta 1 in jaintapur. Highest blue mold incidence (12.3%) and green mold incidence (16.6%) was recorded in retailer shops at Dhaka city. In this present study it was revealed that

highest marketing margin was gained by retailer level. In orange (BARI Komla) it was (1194.45tk/quintal), in BARI malta (1254.21tk/quintal), in Elachi lebu (tk 87.50/100pieces) and in Zara lemon (544.50tk/100pieces). Lack of modern storage, transport, processing industries, high margin of traders, high cost of packaging and uncertainty of market price were also notable problem in value chain of citrus.

CHAPTER VII

REFFERENCE

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CHAPTER VIII

APPENDICES

Appendix I. English version questionnaire used for collection of data from citrus farmers.

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

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

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

1. Citrus orchard-
   Own ☐ Contract ☐
2. Area/ farm size-
   a) Increased ☐ b) Decreased ☐ c) No change ☐
3. How many citrus plants in your orchard?
   a) ≤200 ☐ ☐ b)200- ☐ 500 c)≤500
4. Which varieties of citrus plants are in your orchards?
   a. BARI komla ☐ b. BARI Malta ☐
   c. Zara Lebu ☐ d. Elachi Lebu ☐
   e. Shatkora ☐
5. Experience in Citrus 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 citrus?

---------- (days).

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

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

9. How do you pluck the citrus from the plants?

Ans……

10. Which strategy do you follow for packaging Citrus?

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

11. Did you grade the Citrus before selling?

Yes ☐ No ☐

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

Canker ☐ Scab☐

13. What is your opinion about cultivation of citrus?

14. What kind of problems you have faced in post harvest condition for citrus fruit?

Date:…… Name and signature

Researcher

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

Name: - ----------

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

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

1. Which varieties of citrus fruits do you sell?

a. BARI Malta ☐ b. Elachi Lebu ☐

c. BARI komla ☐ d. Zara Lemon ☐

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

3. Write down the availability and price of different Citrus varieties.

Citrus varieties	Times of Availability (Months)	Buying Price (Per 100 pcs)	Selling Price (Per 100 pcs)
BARI Komla			
BARI Malta			
Elachi Lebu			
Zara Lebu			

4. Which factors influencing in Citrus price variation?

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

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

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

a) Trucks ☐

b) Pickup ☐

c) Any other ☐ (specify)----------

6. Did you grade the citrus fruits before sell?

Yes ☐ No ☐

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

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

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

8. Which following diseases have you observed in your citrus business?

i) Citrus Blue Mold ☐ ii) Citrus Green mold ☐ iii) Any others ☐

9. What is your opinion about citrus business?

Good Business ☐ Medium ☐ Not good ☐

10. Who are the key stakeholders in citrus value chain?

a)

b)

c)

Date: …….

Name and signature

Researcher