Original Research Article

~~An Investigation on p~~Post-harvest losses of lemon farmers in Moulvibazar district, Bangladesh: Aspects of Determinants, Practices, and Problems

ABSTRACT

Aims: Lemon is a popular citrus fruit in Bangladesh. Post-harvest management is very important to make lemon production profitable. The current study was carried out to identify the determinants or factors influencing post-harvest losses of lemon at farm levels, and to measure the associated practices and problems of lemon farmers.

Study Design: This article is about investigating the determinants or factors influencing post-harvest losses of lemon farmers and is placed on empirical analysis. It was also conducted to determine the practices and problems incorporated in post-harvest losses of lemon at the farm level.

Place and Duration of Study: The study was conducted in five intensive lemon growing villages of Sreemangal Upazila in Maulvibazar district of Bangladesh~~, were~~ purposively selected as they signify the top lemon producing areas of Moulvibazar district. The study period was the harvesting season of lemons from April to May 2019.

Methodology: The relevant data were collected using structured questionnaires via face-to-face interviews with 160 lemon farmers that were selected using simple random sampling. The socio-economic characteristics of lemon farmers were measured by using descriptive statistics. The farm-level determinants of lemon post-harvest loss in the survey areas were identified using a multiple linear regression model, descriptive statistics (percentage), and the Problem Faced Index (PFI) was generated to assess practices and the severity of the particular problem of lemon farmers.

Results: It is shown from the study that the key determinants of post-harvest loss in the study area were total output or harvested amount, labor, transportation, storage, distance, marketplace, and lemon farmers' farming experience. From descriptive statistics results, it is found that farmers in the study area harvested their lemons under mature green conditions (67.6 percent) to reap the benefits of a longer life span, and 59.5 percent of them use the bamboo cage for packaging and transportation purposes. Lemon farmers were using motor driving rickshaws (48.7 percent) and manual vans (27.8 percent) to carry their product in the market Overproduction, and supply of lemon in the peak season was the greatest severe problem for lemon farmers, after lack of storage facilities, lack of quality seed, high input prices, disease infection, and insect infestation.

Conclusion: Therefore, this study highlights developing suitable storage facilities, convenient transportation, scientific harvesting methods, and a fair price policy to reduce lemon post-harvest losses at the farm level.

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Keywords: *Factors of post-harvest loss, lemon, farmers, practices, problems, Moulvibazar district, Bangladesh.*

1. INTRODUCTION

Post-harvest losses in the agricultural distribution chain are a great problem in both emerging and industrialized nations. The horticulture sector suffers losses greatly after harvest, especially in developing countries. According to Madrid (2011), a considerable percentage of freshly cultivated crops is lost after harvest for a variety of causes around the world. Based on the season of production and the type of the commodities, losses in underdeveloped nations range from 20 to 40 percent, whereas losses in developed nations range from 10 to 15 percent. From manufacturing retail warehouses to food service facilities, post-harvest losses in developed regions are projected to be between 12 and 20% (Madrid, 2011). However, owing to poor storage and food-management technologies, post-harvest losses in emerging countries are significantly higher (Salami *et al*., 2010).

Fruits and vegetables, as horticultural crops, hold a significant role in maintaining food and nutritional security (Parftt *et al.,* 2010). Post-harvest handling and storing environments have an impact on the superiority and nutritional value of fresh food, resulting in post-harvest losses (Alidu *et al.,* 2016). In the case of fruits and vegetables, post-harvest losses relate to the quantitative and qualitative losses that occur along the food chain, from farm to fork (Hodges *et al.,* 2011). Post-harvest losses degrade not just the quality and quantity of the fruit, but also its visual appeal, lowering its market value. Fruit and vegetable losses account for 40 to 50 percent of global losses, with 54 percent occurring during cultivation, handling, storage, and post-harvest, and 46 percent occurring during distribution, processing, and consumption for a complete loss of US$750 billion each year (FAO, 2013). Fruits can suffer post-harvest losses in terms of quantity, economics, nutrition, and quality (aesthetic appeal) (Sudheer & Indira, 2007). Although post-harvest losses may arise at any point along the distribution chain, it is necessary to include the entire distribution chain when calculating losses. Farmers can determine post-harvest losses as a percentage of total produced quantity by quantifying post-harvest losses in absolute terms for produce lost after harvest (Weinberger *et al.,* 2008). Post-harvest losses affect the accessibility of food and the amount of money that might be received by marketing them; hence, in regards to quantity, they are related to food security (FAO, 2010). When compared to creating the same amount of fruit loss, controlling and/or preventing post-harvest losses is less expensive. Post-harvest management has an impact on not just food quality and safety, but also on market competition. In both rich and emerging nations, poor packing, a lack of quantity planning, and excessive handling by producers, merchants, and consumers are all major causes of post-harvest losses (Lebersorger & Schneider, 2014). However, in developing countries like Bangladesh, when compared to key production-related processes, post-harvest preservation and waste prevention strategies are still minimal. Estimates of fruit and vegetable post-harvest losses vary substantially between nations, depending on the season, post-harvest management measures, and the crop used (Ansah *et al.,* 2016). Fruits and vegetables post-harvest losses, for example, are reported to reach 20-40% in emerging nations (FAO, 2012; Ngowi & Selejio, 2019). Post-harvest losses of apples, banana, avocado, citrus, papaya, and grapes in underdeveloped nations were reported to be 14, 20-80, 43, 20-95, 40-100, and 53 percent, respectively (Rajabi *et al.,* 2015; Kughur *et al.,* 2015). The perishable nature of these crops is one of the causes of these substantial losses (FAO, 2011). Thus, such

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So you should review the section following this frame:
First paragraph; analysis on the amount of post harvest losses of horticultural product both in developed and developing countries
Second paragraph: provide the major determinants of the post harvest losses from the global level, regional and national,
Third paragraph: what is the case of lemon in Bangladesh and what are well documented in this case
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perishable commodities necessitate careful handling during and after harvest. As a result, between harvest and consumption, deterioration of produce is reduced through effective handling, storage, and management to fulfill market demand and minimize losses.

Because of the accessibility of inexpensive labor, proximity to the international market, ideal meteorological conditions, and a diverse agro-ecology, Bangladesh has a comparative advantage in the production of numerous fruit and vegetable products, which provide a source of livelihood and income for many people. Fruits covered roughly 1347000 acres in the 2018-2019 cropping season, yielding 4548 metric tons (BBS, 2020). However, due to insufficient post-harvest handling and management techniques, a major amount of the harvested produce never made it to the ultimate user. Every year, due to several factors or determinants, a considerable amount of the harvested crop is lost. Because of the absence of proper storage and marketing opportunities, as well as periodic oversupply, growers were compelled to sell their tireless goods at less and unacceptable rates. Furthermore, because of substantial physical loss, a lack of post-harvest management measures reduces food availability and thus market options, as well as income potential.

Lemon is one of the important fruits growing in Bangladesh, particularly in Moulvibazar (BBS, 2020). Bangladesh, like many other emerging nations, suffers from post-harvest losses of horticultural crops in their distribution networks. A multitude of factors/determinants affect losses, ranging from growth circumstances to consumer handling. Biological, mechanical, chemical, psychological, physical, environmental, and physiological elements are among the considerations (FAO, 2011; Kereth *et al.,* 2013). Furthermore, improper management of fresh horticulture commodities and inadequate marketing methods result in massive losses at the sites of transportation, marketing, and storage following harvest.

Regardless of the fact that these determinants have been well-documented in the literature and that several methodologies to reduce these losses have been developed, they have yet to be successful. This was owing to a lack of focus on the factors that contribute to fruit and vegetable post-harvest losses in Bangladesh and elsewhere. According to Klink (2015), the causes would be the foundation for any improvement approach aimed at increasing rates of achievement in minimizing post-harvest losses in emerging nations. As a result, good harvest management is important for minimizing post-harvest losses and improving nutritional quality, food security, and employment opportunities. It is essential to lessen post-harvest losses and preserve quality in existing supply to meet demand. Huge numbers of fruits, particularly lemons, have decayed and are being lost in our investigation region.

The empirical literature on post-harvest losses of lemon at farm levels is extremely limited. However, the available literature concentrates on other perishable agricultural goods like fish, bananas, and tomatoes. Besides, several surveys investigated socio-demographic factors that influence fruits and vegetables post-harvest losses (Babalola *et al.,* 2010; Molla *et al.,* 2010; Ayandiji & Adeniyi, 2011; Mbuk *et al.,* 2011; Aidoo *et al.,* 2014; Mebratie *et al.,* 2015; Hossain *et al.,* 2017; Kikulwe *et al.,* 2018; Christian *et al.,* 2019; Kulwijila, 2021). Only a few research have used economic models to analyze the impact of various socio-demographic factors on fruit and vegetable post-harvest losses at the farmer and marketing levels in different countries (Mbuk *et al.,* 2011; Addo *et al.,* 2015; Ummar *et al.,* 2015; Mebratie *et al.,* 2015).

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Thus, according to the literature assessment, no study has evaluated the determinants that affect post-harvest losses of lemon at the farm level in the Moulvibazar district of Bangladesh. This study, therefore, determined the socio-economic characteristics of lemon farmers, analyzed determinants that impact post-harvest losses of lemon at farm levels, identified practices, and measure the associated problems of lemon farmers in the Moulvibazar district of Bangladesh. The findings of the study are intended to contribute to our understanding of the determinants that influence post-harvest losses in lemons at the farm level, along with aid in the formulation of suitable policies and approaches for handling post-harvest loss.

2. MATERIAL AND METHODS

2.1 Selection of the study area and sample

The current study was carried out in the Sreemangal Upazila of Moulvibazar district of Bangladesh including five villages namely Sadar, Mohajirabad, Khakiachara, Radhanagar, and Dilbornagar were intensively lemon (local, bilati, china varieties) grown areas compared to other parts of Bangladesh. For the selection of sample farmers, the response was chosen based on simple random sampling. A sample size of 160 was considered for this study, with 32 people chosen from each selected village. In this study, the selection of respondents' was on the basis of two criteria: farmers whose farms are above 6 years old and have at least 1 to 5 years of lemon cultivation experience and marketed their lemons in the local markets.

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2.2 Methods of data collection and analysis

Relevant information on lemon post-harvest losses at the farm level was selected from the above areas through structured questionnaires via face-face interview techniques during the harvesting season of lemon from April to May 2019. Along with primary data, secondary data were also gathered from different publications like government reports, published articles, different organizations, and web searching. Then the collected data were precise, assembled, and analyzed by means of MS Excel and SPSS.

2.3 Analytical Techniques

2.3.1 Determinants of farm farm-level-harvest losses of lemon

The determinants of post-harvest losses of lemon at the farm level were investigated using functional analysis in this study. At the farm level, post-harvest losses were characterized as a function of many socio-demographic parameters such as the farmer's age, educational background, total lemon production, farming experience, selling price, and so on. Khatun *et al.* (2014), Adisa *et al.* (2015), Kaysar *et al.* (2016), Hossain *et al.* (2017), and Tadesse *et al.* (2018) also conducted the same functional analysis to measure the impact of socio-economic factors on post-harvest losses of tomato, yum, brinjal, fruits, and potato. In this investigation, the following multiple linear regression function was used:

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$$Y = \alpha + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \ldots\ldots\ldots\ldots\ldots\ldots + \beta_{12} X_{12} + \mu_i$$

Where,

Y = Post-harvest loss of lemon at farm level in kg per acre

X_1 = Age of the farmers in years

X_2 = Education of the farmers in schooling years
X_3 = Total production of lemon in kg
X_4= Farming experience of farmers in a year
X_5= Selling price in Tk. per kg
X_6= Weather condition dummy which takes the value '1' if the weather during harvesting was favorable and value '0', otherwise
X_7= Labor dummy which takes the value '1' if the labor availability during harvesting was adequate and value '0', otherwise
X_8= Transportation dummy which takes the value '1' if the transportation facility during harvesting was adequate and value '0', otherwise
X_9= Storage dummy which takes the value '1' if the storage facility during harvesting was adequate and value '0', otherwise
X_{10}= Training dummy which takes the value '1' if the farmer received training about lemon production and value '0', otherwise
X_{11}= Distance dummy which takes the value '1' if the distance from farm to market was favorable and value '0', otherwise
X_{12}= Market place dummy which takes the value '1' if the marketplace was favorable and value '0', otherwise
α = Constant term,
β1, β2 . . . . . β12 = co-efficient of the respective independent variables, and
μ_i = Error term.

2.3.2 Problem Face Index (PFI) of Farmers

The problem faced index was designed to assess the importance of each lemon farmer's problem. Respondents were given four options for each of the selected problems: 'severe problem', 'moderate problem', 'little problem', and 'no problem', as Khatun *et al*. had done (2014) in their study. Alternative responses received scores of 3, 2, 1, and 0 accordingly. PFI was calculated using the following formula to determine the score for a certain problem:

$$PFI = (Ps \times 3) + (Pm \times 2) + (Pl \times 1) + (Pn \times 0)$$

Where,
PFI = Problem Faced Index,
Ps = Number of respondents who faced the severe problem,
Pm = Number of respondents who faced the moderate problem,
Pl = Number of respondents who faced the little problem,
Pn = Number of respondents who faced no problem.

3. RESULTS AND DISCUSSION

3.1 Socio-economic characteristics of the respondents

Table 1 shows the socio-demographic characteristics of the respondents who took part in this study. According to the findings, all 160 respondents were men, accounting for 100 percent of the total, and there were no dependent female lemon producers in the study locations. It demonstrates that males account for the majority of lemon output, which could be due to cultural attitudes such as a female's incapacity to participate in cultivation in the research location. 48.75 percent of the respondents were between the ages of 41 and 50, followed by 26.88 percent between the ages of 31 and 40, and 12.5 percent between the

ages of 51 and 60. Meanwhile, only 7.5 percent were between the ages of 20 and 30, with the remaining 4.37 percent being over the age of 61. This indicates that the agricultural sector in the study area has a large labor force. Furthermore, 28.13 percent of the respondents had no formal education, while 52.5 percent had received elementary school, 11.88 percent had obtained secondary education, 5.61 percent had acquired upper secondary education, and 1.88 percent had received a bachelor's degree. The majority of the 160 lemon farmers (42.5 percent) had 11-15 years of farming experience, 36 respondents (22.5 percent) had 6-10 years of farming experience, 35 respondents (21.88 percent) had 16-20 years of farming experience, 18 respondents (11.25 percent) had 1-5 years of farming experience, and the remaining 3 respondents (1.87 percent) had more than 21 years of farming experience. 48 lemon farmers (30.0 percent) had farms that were less than one acre in size, 66.87 percent of the 107 respondents had farms that were between one and five acres in size, and 5 respondents (3.13 percent) had farms that were larger than five acres. With 98 respondents (61.25 percent) producing less than 5000 kg from below 1-acre size farms, 33.75 percent of the 54 respondents have between 5001-10000 kg yield from 1-5 size farms, and the minority of lemon farmers with 8 respondents (5.0 percent) producing more than 10001-above kg yield from above 5 acres of farms.

Table 1. Socio-economic characteristics of the lemon farmers (n = 160)

Socio-demographic characteristics	Explanation	Frequency (n)	Percentage (%)
Gender	**Gender of the respondents**		
	Male	160	100
	Female	0	0
Age	**Age of the respondents (in years)**		
	20-30	12	7.5
	31-40	43	26.88
	41-50	78	48.75
	51-60	20	12.5
	Above 60	7	4.37
Education	**The highest educational level of the respondents**		
	Uneducated (0)	45	28.13
	Primary (Grade 1–5)	84	52.5
	Secondary (Grade 6–10)	19	11.88
	Higher Secondary (Grade 11-12)	9	5.61
	Bachelor (13-16) and above	3	1.88
Experience	**Experience of the respondents (in years)**		
	1-5	18	11.25
	6-10	36	22.5
	11-15	68	42.5
	16-20	35	21.88
	21-above	3	1.87
Farm size	**Farm size of the respondents**		

	(acres)		
	Below 1	48	30
	1-5	107	66.87
	Above 5	5	3.13
Yield	**Yield from the farm of the respondents (kg)**		
	Below 5000	98	61.25
	5001-10000	54	33.75
	10001-above	8	5

Source: Authors estimation, (2020)

3.2 Technologies and practices regarding post-harvest losses of lemon farmers

Lemon growers have their procedures and methods for minimizing post-harvest losses. Table 2 demonstrates the existing post-harvest procedures and technology for lemons among the research area's respondents. Harvesting periods in the research area varied based on the maturation stage of the various cultivars and to a lesser extent, the desire to gain additional benefits depending on market conditions. They discovered that marketing done early and late is more profitable. Lemons were gathered in the majority of cases early in the morning during the day (Table 2). Harvesting may occur late in the afternoon, depending on the need for selling or an agreement with beparies from afar. Concerned growers said that the majority of their lemons are collected in the morning (51%), then in the afternoon (28.5%). This outcome is consistent with the findings of a litchi study conducted by Molla *et al.* (2010) in Bangladesh. On the same day or the next morning, the picked lemons were transported from the orchards to local selling stations. The lemons were then packed and despatched as soon as possible to distant markets. In the research locations, farmers who are active in harvesting were observed to follow some indigenous post-harvest practices. Lemons were gathered at various phases of development. The majority of the fruit was picked in mature green condition (67.6%), followed by half-ripe (19.0%), and fully ripe (13.4%). According to Molla *et al.* (2010), color was the most important parameter for harvesting selection among fruit size, color, and dots on the fruit skin. According to their research, the majority of responders (70-100%) harvested their litchi when the fruit skin had reached 75-100% color. Fruits could also be picked at 50% color attainment on fruit skin for distant marketing in Bangladesh, according to some of the participants (20-30%).

Farmers in the research area used a variety of packaging materials, with the bamboo cage accounting for 59.5% of the total. This outcome is congruent with the results of a litchi study conducted by Molla *et al.* (2010) in Bangladesh, which found that the most common packaging methods were bamboo baskets lined with litchi leaves and covered with gunny sheets. Farmers must keep their lemons in a specific location after harvesting, with 67.8% of farmers keeping their lemons in the morning was the most popular selling time for lemons (49.8%), followed by afternoon (29.5%). Farmers transported lemons in manual vans (27.8%) and motor driving rickshaws (48.7%), as these two vehicles are highly popular and abundant even in these study locations. Molla *et al.* (2010) discovered that litchi growers generally used a manually operated tricycle, locally known as a van, and another locally made tricycle powered by a shallow-engine, locally known as Nosimon, for long-distance marketing in Bangladesh, whereas for large volumes, both growers and intermediaries (bepari) used bus and truck. This contradicts the findings of Dessalegn *et al.* (2016), who

found that fruit is supplied by trucks, often from afar, but that these vehicles lack the essential ventilation to handle perishable items like fruit. Fruit is also transported over short distances using a cart and employees. Regardless of how they are carried, fruits are prone to heat accumulation and mechanical damage. According to Wasala *et al.* (2014), 24% of farmers manually carry complete banana bunches to the sales point in Sri Lanka. Farmers gathered their lemons entirely with their hands (100%). In the survey regions for lemon harvesting, no knives, scissors, or other equipment were detected. Farmers classify lemons based on appearance (43.8%), half-ripe (28.3%), fully ripe (15.7%), and physical damage after harvest (12.2%). 45.6% of farmers in the survey areas sorted their lemons on the basis of half-ripening conditions, whereas 41.7% sorted their lemons by size. These findings contradict those of Molla *et al.* (2010), who found that damaged, pest-infested, disease-infected litchis were the most commonly used foundation for sorting in their Bangladesh research regions.

Bamboo basket field collection (57.8%), plastic crate (28.2%), jute sack (9.6%), and other packing materials were applied in the study locations. These findings are consistent with Molla *et al.* (2010) findings for litchi in Bangladesh, but they are inconsistent with Dessalegn *et al.* (2016) findings in Ethiopia, where they found that 93.5, 16.1, and 3.2% of respondents reported wooden boxes, sack, and plastic box as their fruit packaging materials, respectively. Similarly, Seid *et al.* (2013) reported, sacks are the most frequent fruit packaging material in Ethiopia's South Wollo zone. Mangoes and bananas are likewise transported without being packed, instead of being spread out on the truck. Fruit spoilage is increased when fruits are transported without packaging material because they are more susceptible to mechanical damage during loading and unloading, as well as while traveling on a bumpy road. According to Ekanayake & Bandara (2002), post-harvest losses of bananas in Sri Lanka amounted to 30% and were mostly due to the absence of proper packaging methods for transport from the field gate to the consumer.

Bamboo basket, the most widely used packaging material, has a capacity of 35 to 50 kg and does not require any cushioning to absorb shocks during transit. As a result, it wounds lemons that are packed with it, contributing to the post-harvest loss. Fruit is often packed tightly in packaging material. This method speeds up the ripening process and reduces the shelf life of the fruit. As a result, current packaging materials and practices must be improved to reduce lemon post-harvest losses (Table 2).

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Table 2: Post-harvest practices in lemon cultivation

Items	% of respondents	Items	% of respondents
Time of harvesting from the field		**Means of transportation**	
Morning (6.00 am - 11.00 am)	Headload	Head load	4.4
Afternoon (12.00 pm - 3.00 pm)	28.5	Manual van	48.7
Evening (4.00 pm - 6.00 pm)	27.5	Motor driving van	9.8
Any time of the day	12.8	Motor driving rickshaw	25.3
Point of harvesting		Pick up or truck	11.8
Fully mature	13.4	**Means of harvesting**	
Mature green	67.6	Hand	100

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Half ripe	19.0	**Basis of grading**	
Types of material used for packaging		Looking good	43.8
Plastic crates	11.3	Fully ripen	15.7
Bamboo cage	59.5	Half ripen	28.3
Plastic sack	11.5	Physical damage	12.2
Jute sack	9.5	**Basis of sorting**	
Plastic net bag	8.3	Size	41.7
Place of harvested fruits		Color (Half ripening condition)	45.6
Under the shade of the trees	67.8	Disease/insect	12.7
Placing in a room	28.2	**Packaging materials for marketing**	
Placing in the open sky	4.2	Jute sack	9.6
Time of selling		Plastic sack	4.4
Morning (6.00 am - 11.00 am)	49.8	Bamboo basket	57.8
Afternoon (12.00 pm - 3.00 pm)	29.5	Plastic crate	28.2
Evening (4.00 pm - 6.00 pm)	12.2		
Any time of the day	8.5		
Time of transportation			
Morning (6.00 am - 11.00 am)	41.7		
Afternoon (12.00 pm - 3.00 pm)	37.8		
Evening (4.00 pm - 6.00 pm)	11.3		
Any time of the day	9.2		

Source: Authors estimation, (2020)

3.3 Determining factors of farm-level post-harvest losses of lemon

To investigate the impact of different farmer characteristics on lemon post-harvest losses at the farm level, a multiple linear regression analysis was used. Table 3 presents the determining factors of post-harvest loss of lemon in the study areas. The summary of the overall model suggests that the model is good enough to explain the association between the dependent and the independent variables. The logarithmic regression model's coefficients of multiple determination (R^2) were observed to be 0.76, implying that variations in the 12 independent variables included in the regression model explained 76 percent of the variation in total post-harvest losses at the farmer level. The substantial F-value also means that the coefficients of the independent variables are significantly different from zero, showing that the model is well-fit. The significance of the F value at the 1% level indicates that the explanatory variable included in the model accounts for the majority of the variation in the lemon post-harvest loss at the farm level.

Twelve independent variables (5 continuous and 7 dummies) were inserted into the model to assess their quantitative effect on the proportion of post-harvest loss of lemon out of which seven were found to have a statistically significant impact. It was hypothesized that the factors like age, education, total production, farming experience, training, and transportation have a negative effect on post-harvest losses on lemon which indicate that with the increase in age, education, total production, farming experience, training, and transportation facilities, the post-harvest loss will decrease while factors like adverse weather, inadequate labor,

inadequate storage, distance, market place, and sales price have a positive effect on post-harvest losses indicates with the increase of adverse weather, inadequate labor, inadequate storage, unfavorable distance, market place, and sales price during marketing, the post-harvest loss will be increased.

Total production, labor, transportation, storage, distance, and marketplace are determinants that significantly affect the post-harvest loss of lemon but the farming experience of farmers had a negative significant influence. At the 1% level, the coefficient of total production was a significant and positive link with total post-harvest losses, showing that a 1% increase in the overall production of lemon would result in a 7.141 percent increase in post-harvest loss, assuming all other factors remained equal. These findings are in line with Christian *et al*., (2019) that total production was statistically significant with post-harvest losses in navel fruit in South Africa. Their study showed that the more the production of navel the more the post-harvest losses. The farming experience of farmers was found significant but negative at a 10 percent level, meaning that increasing farming experience by 10% would reduce post-harvest lemon loss by 10.086 percent. As a result, farmers with more years of experience appeared to be better at handling procedures, resulting in lower post-harvest losses. These findings are consistent with conclusions drawn by Kulwijila, (2021), Umar *et al.*, (2015), and Mebratie *et al.*, (2015), who discovered that experience influenced significantly but a negatively post-harvest loss of grape in Tanzania, kinnow fruit in Pakistan, and banana in Ethiopia.

Among the dummy variables, it is surprising to know that labor dummy, storage dummy, distance dummy, and transportation dummy were found negative while the marketplace was found positively significant at a 5 percent level. This implied that with increasingly inadequate labor, transportation facilities, and storage facilities in a unit, post-harvest loss of lemon will decrease by 0.004, 0.035, and 0.039 units. The reason could be that labor is available for production but not always available for handling post-harvest losses or it could be that the labor available did not have the requisite skills in the basic processing of lemon. This result is congruent with the finding stated by Hossain *et al.* (2017) on the post-harvest losses of major fruits in different hill regions of Bangladesh. They found in their study that the labor dummy, market demand dummy, and transportation dummy had a significant but negative effect. Again, if the distance between farm and market is favorable to the farmer by a unit, the post-harvest loss will also decrease by 0.737 units. This finding is also consistent with the result stated by Woldu *et al.*, (2015) on the assessment of post-harvest handling practices and losses of bananas in Ethiopia. They found that in their study that market distance and number of days of storage had a significant and expected relationship with the proportion of post-harvest losses of bananas. The results in Table 3 also show that the increase of marketplace by a unit would increase the post-harvest loss of lemon by 2.401 units. The findings support those of Kulwijila (2021) and Aidoo *et al.*, (2014), who found that unreliable markets influenced grape losses in Tanzania and tomato losses in Ghana, respectively. The unreliable market increased the number of grapes positively way, implying that the better the probabilities of obtaining a market for grapes and tomatoes at the correct period of fruit maturity, the lower the mean percentage losses; all other parameters remained constant. As a result, farmers who have a stable market are more likely to harvest and sell their grapes and tomatoes at the right time, avoiding post-harvest losses.

Table 3: Estimated values of coefficients and related statistics of regression model for post-harvest losses of lemon at farmers' level

Regression variables		Regression coefficient	t-statistic	p-value	Standard error
Intercept	α	11.582***	4.541	0.000	22.142
Age of the farmers (years)	X_1	0.212	5.294	0.920	3.292
Education of the farmers (schooling years)	X_2	0.0835	5.404	0.109	15.631
Total production (kg)	X_3	7.141***	4.684	0.001	4.895
Farming experience of farmers (years)	X_4	-10.086*	2.426	0.078	8.642
Selling price (Tk./kg)	X_5	1.095	1.998	0.614	6.586
Weather dummy	X_6	0.913	1.241	0.741	6.395
Labor dummy	X_7	-0.004**	-1.583	0.047	6.363
Transportation dummy	X_8	-0.035**	-3.851	0.002	5.291
Storage dummy	X_9	-0.039**	-1.738	0.045	4.568
Training dummy	X_{10}	1.557	0.916	0.231	8.693
Distance dummy	X_{11}	-0.737**	-0.874	0.039	7.547
Market place dummy	X_{12}	2.401*	0.958	0.074	5.626
Number of observations			160		
R^2			0.76		
F (160, 12)			22.483***		

Source: Authors' estimation, (2020)
Note: ***, **, and * denote 1%, 5% and 10% level of significance, respectively.

3.4 Problems faced by lemon farmers

Table 4 shows the problems that lemon farmers face. The ten problems identified by the respondents were rated according to their severity. In the case of lemon, the observed PFI ranged from 216 to 445, compared to a possible range of 0 to 480. Based on PFI, The most severe problem for lemon farmers was overproduction and supply during the peak season, followed by a lack of storage facilities, a lack of quality seed, high input prices, disease infection, insect infestation, and so on. Usall *et al.* (2016) emphasized cold storage in their study of physical treatments for post-harvest disease prevention of fresh fruits and vegetables. This type of storage helps to preserve the physical integrity of fruits and vegetables while also lowering the risk of microbial contamination. The main reason for post-harvest losses of lemons, according to 83.13% of respondents, is a lack of sufficient storage facilities. Our findings support the findings of Devkota *et al.* (2014), who argued that the absence of cold storage and insufficient packing facilities had a substantial impact on fruit post-harvest losses in Nepal. Similarly, Zenebe *et al.* (2015) and Dessalegn *et al.* (2016) identified storage conditions and transportation methods are both key factors in the post-harvest loss of bananas and fruits in Ethiopia.

Table 4: Rank of problems faced by lemon farmers

Problems	The extent of problems faced				PFI	Rank
	High problem (3)	Medium problem (2)	Little problem (1)	No problem (0)		
Absence of storage facility	133	19	8	0	445	1
Overproduction and supply in the peak season	118	33	9	0	429	2
Lack of quality seed	122	27	8	3	428	3
High prices of inputs	114	39	7	0	427	4
Infected by diseases	101	56	3	0	418	5
Infested by insect	93	51	16	0	397	6
Lack of technical support	98	35	22	5	386	7
Lower prices of output	74	52	24	10	350	8
Damage due to different reasons	47	53	51	9	298	9
Shortage of labor during harvesting	18	63	36	43	216	10

Source: Authors estimation, (2020)

4. CONCLUSION AND RECOMMENDATIONS

Determining the processes and reasons for lemon post-harvest losses is critical to improving lemon post-harvest management and, as a result, increasing lemon growers' profitability in Bangladesh. Each year, a large amount of harvested lemon damage is documented at the farm level, some of which is because of complete damage and some of which is due to partial damage. The highest prevalence of complete and partial damage occurs during the sorting and grading of lemons from the farm to the rural and urban market, followed by storage and transportation stages. Post-harvest factors that influence the superiority of lemons after harvest include the total production, labor, transportation, storage, distance, marketplace, and farming experience of farmers. To reduce post-harvest losses, farmers can use a variety of post-harvest technologies and techniques, such as modes of transportation, packaging, grading, sorting, and so on. Farmers, on the other hand, must work extremely hard during peak periods to obtain a higher profit margin because the price is considerably lower than the profit margin. In addition, overproduction, and supply of lemon in the peak season, absence of storage facility, lack of quality seeds, high prices of inputs, infection by diseases, infestation by the insect, resulted in a large financial loss in lemon production every year.

Comment [SS6]: Is that a part of your finding?

The following policies/suggestions should be implemented to decrease present post-harvest losses of lemon at the farm level:

- To improve the efficiency and knowledge of farmers and traders, an adequate training program on various post-harvest operations such as handling, grading, packaging, and carrying should be offered.
- Storage facilities should be developed to ensure that their product is sold at a reasonable price. Private entrepreneurs should step up to create storage facilities in key fruit-producing areas as well as other wholesale and retail markets places.

Facilities for storing unsold fruits at the market for one to two days should be established.

- The establishment of various feeder roads should be used to develop the transportation and communication infrastructure. Farmers and intermediaries will be able to move fruits from the farm to a local market or a larger market where they will expect to acquire a higher price for their lemon.
- Proper pre-harvest management to reduce losses due to good plant quality, following a good set of practices, employing trained workers, proper harvesting and packing methods, loadings, and so on.
- A detailed assessment of post-harvest losses must be conducted throughout the whole production and marketing chain in order to identify important gaps and corrective actions.
- Developing a post-harvest infrastructure support base will improve safety, quality maintenance, on-time supply, and reduce handling costs and losses.
- Farmers are increasingly relying on post-harvest information management to stay on top of market demands, as well as labeling and traceability standards.
- For resource-poor farmers to remain competitive in international markets, infrastructure and local skills must be created.

Comment [SS7]: Is that a recommendation?

ETHICAL APPROVAL

This article is original and contains unpublished materials. The corresponding author confirms that both authors have read and approved the manuscript and no ethical issues are involved.

COMPETING INTERESTS DISCLAIMER:

Authors have declared that no competing interests exist. The products used for this research are commonly and predominantly use products in our area of research and country. There is absolutely no conflict of interest between the authors and producers of the products because we do not intend to use these products as an avenue for any litigation but for the advancement of knowledge. Also, the research was not funded by the producing company rather it was funded by personal efforts of the authors.

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ACRONYMS, ABBREVIATIONS

BBS: Bangladesh Bureau of Statistics
FAO: Food and Agriculture Organization
et al.: Et alia (L.) and others
etc. : Etcetera
i.e.: That is
~~Kg~~kg: Kilogram
Tk.: Taka (Bangladeshi Currency)
%: Percentage